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Studies on Vertical Axis Wind Turbine - A Review

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Abstract

A VAWT is the one turbine which rotor and shaft are kept in transverse direction to the direction of the wind. Due to this the motor or generator is kept on the ground. There are Darrieus, Savonius and Giromill types of VAWT are there. This type of turbine has many problems like the effect of turbulence, flow separation to eddies, and stress generation in the blade. All these things have been discussed in this review paper and conclusions are given. Different methods like FEM and CFD are used to find the performance of VAWT.

Keywords: *VAWT, Power coefficient, CFD, FEM, Turbulence.*

1. INTRODUCTION

Wind turbine is the device that came in to the picture in the 1970s and was developed to their full potential to generate electricity as they have the aerofoil blades and utilize wind energy as it is one energy that cannot be controlled by political people. The further development leads to Darrieus VAWT. But this was not the first wind turbine; there was already a HAWT in 1891. The variable pitch Darrieus VAWT which is also called Giromill was seen to be efficient like HAWT and the COP for this was 0.5. The cost incurred for VAWT was less than HAWT however using or application of VAWT was not easy. A few problems were: first, the HAWT had a stable AOA while for VWAT the AOA was very inconsistent and changes rapidly. Second, VAWT faces the turbulent wind at that height which are basically created by wind passing through the windward side. However, due to these two problems, there was a thorough investigation done all over the world. The recent innovation has improved the performance of the turbine. The aerofoil curved and straight blades have been changed in recent times. The curved blades are called Eggbeater or phi-rotor and the straight ones are evolved as Diamond, V/Y, and delta. One more variation which came later was H-rotor which came as a replacement to the Musgrove rotor which was earlier called Variable-geometry VAWT.

2. EARLIER STUDY OF VERTICAL AXIS WIND TURBINE

Tjiu et al. [1] here covers the VAWT configuration and also discussed the limitation of these configurations. There were various parameters which were assessed like performance, components and reliability. The two configurations viz. the curve and straight blade was patented. The curve blades have changed to cantilever version from the traditional guy-wires support. Various types of straight blades viz. diamond, delta etc are now not used due to high specific COE. Mus groove rotor has been changed to H-rotor which has further evolved to Articulating, Tilted and Helical H-rotors.

Tjiu et al. [2] in his second paper explained the problem of HAWT and the advantage of multi-megawatt Darrieus VAWT over it. A few challenges in HAWT were: first, the weight of the blade was a problem, and the blade acts a cantilever beam and the rotation causes large bending stress but now composite material is used which is light. Second, were the transportation, installation and maintenance. Third, offshore HAWT has advantages like string winds etc but also challenges due to the cyclone, and corrosion due to sea water. All these challenges gave the opportunity to Darrieus but the further advancement in the HAWT led to challenges for VAWT like changes in blade material, direct-drive generator (DDG) system. However, currently, Darrieus is developed for deep water and provide lower specific COE and the advantages are less blade material, and less cost.

Sridhar et al. [3] gave the aerodynamic perspective for VAWT by using CFD for implementing tubercles on the leading edge on the blade which generated vortices and delayed flow separation. It was also seen that there was an increase power coefficient by 28%, maximum lift was increased by 14% and noise emissions were reduced. Hence it was concluded that using tubercles in VAWT reduces noise and increases power.

Santamaria et al. [4] tried to reduce some issues with VAWT by using Active Driving Mode (ADM) as there are self-starting issues, reduced aerodynamic torques, and high rotational speeds. ADM introduces an external motor. There are two losses namely mechanical and aerodynamics for which two approaches were suggested of which the first one suggests rotor without a blade such that no aerodynamic power is generated. The second approach suggests running a turbine without wind. The CFD analysis was done for H-type VAWT which shows that the investigation is reliable.

Celik et al. [5] studied the consequences of J-shaped aerofoil for distinct value of opening ration on the overall aerodynamic performance of H-type Vertical Axis wind turbine.

The study led us to the result of dynamic startup model required to study self-starting potential of J-shaped aerofoil and the ability of self-starting increases as the opening ratio increases. Also, the slight positive pitch angle (B=0) was found to have a better self-starting potential.

Chen et al. [6] used CFD and performs Two-stage optimization in multiple VAWT. In the first stage, the Taguchi method was used for evaluating and optimizing. In the second stage, the analysis for specific factor was done using the Taguchi method. Finally, results show that power output is increased by 3%, power coefficient is also increased. Also the third turbine direction was changed which further led to a decrease in power output this is due to Magnus affect from the first and second turbine.

Hao and Li [7] studied the ramifications of flow separation on performance of VAWT like it reduces power efficiency. So, he used a device called Adaptive Flap to reduce flow separation. The static flap whose flap angle is adjustable was installed, to further improve the performance, a linear torque was used. The study shows that the two torque composites performed better.

Carvajal et al. [8] studies show the consequences of geometrical parameter on performance of traditional Savonius Vertical Axis Wind Turbine. It was seen that an aspect ratio of 4-6 is good to get a maximum C_p ad C_t. also the value of a= 45 gives the optimal value for Cp and Ct.

Naseem et al. [9] studies and focuses on the numerical investigation on the performance of bluff bodies and also studies consequences of vortices on the performances. The Multiple Stream Tube Model is used to design wind turbines, with parameters such as power, no of blades, aspect ratio, and wind speed. The Reynolds averaged Navier-Stokes equation is used in the simulations. In addition, VAWT The aircraft is fitted with three NACA 0018 airfoils. A single and two upstream bluff bodies is used in this investigation, distance of VAWT from a bluff body is altered to 1X, 2X, 3X (where X is length and width of the bluff body)such that length and width is parallel and normal to direction of flow in order to determine the best place for maximum flow power. The wind which got deflected from the bluff body has12 percent greater velocity than for a single bluff body and has 25% more wind velocity for two bluff body, according to this study. Additionally, Vertical axis wind turbine was installed downstream of high rise structure to increase power generation.

Liu et al. [10] studies the trailing edge movable flap and associated parameters like flap angle, flap length, and position. The results show that it reduced the flow separation and noise at large AOA. Hameed et al. [11] did an investigation using FEM of composite VAWT blade. The result shows that the bending stress is affected by both centrifugal and aerodynamic forces. In FEM analysis, SHELL elements are more compatible with complex geometries. Glass epoxy reduces the effect of centrifugal forces as it has a lower density and high strength-to-weight ratio as compared to Aluminum. Also keeping more layers in 90-degree orientation increases the stress but reduces deflection. So, a low-density material with high strength should be chosen.

Barnes et al. [12] investigates the impacts of VAWT farm configuration on power output. Different configurations were used to get the highest power coefficients. On the farm scale, the configuration with the highest power coefficient was proposed to get the maximum efficiency and increases power up to 80%. Premkumar et al. [13] did the test of the Savonius Vertical axis wind turbine for finding out the performance with and without endplates. The results showed the plot of angle vs torque. The highest torque was seen at 51 degrees which are 0.310 without endplates and with end plates, it was seen to be 0.314 at 43 degrees. Initially, the torque is high, but it decreases gradually. Molina et al. [14] conducted an investigational study on the performance of Vertical axis wind turbine due to turbulence. A wind tunnel was used to test the model of turbine. The result shows that the power coefficients have increased by 20% but it fade as Reynolds no surpasses 400000. Solomin [15] studies a method for finding cost effective dynamic baking controller based on centrifugal mechanical activation. The experiment shows that the right spring with good stiffness can reduce the speed of rotor or when electricity is suddenly reduced

3. CONCLUSION

As a result, from the literature review discussed above the different areas that will be covered in this study are as follows.

- Using CFD it was seen that the power coefficient increases and noise decrease by using tubercles to avoid flow separation.
- ADM used helps in reducing some issues like self-starting, aerodynamic torques, and high rotational speed.
- Slight positive pitch angle for J shaped aerofoil have the better self-starting capability
- Farm configuration helps VAWT to increase power output by 80%

- The torque vs angle graph plotted shows maximum torque for two different conditions viz. with end plates and without endplates.
- Using FEM, it was found out that bending stress are affected by both aerodynamic and mechanical losses which can be further reduced by using glass epoxy material which is of light weight.
- Taguchi method opted to increase the power coefficient and also moving flap at the trailing reduces the noise and flow separation.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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