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A Comparative Study of Design between Overhang and Simple Supported Straight-Bladed Vertical Axis Wind Turbine

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Abstract

A comparative study of design between overhang and simple supported 1kw straight-bladed vertical-axis Darrieus Wind Turbine is done with the cascade theory. In the work the effect of dynamic stall and flow curvature is taken into consideration. Design is performed with mean wind velocity for the coastal regions of Bangladesh which is taken as 5 m/s and cutout wind speed as 15 m/s. Finally, comparisons are made between two types of support.

Nomenclature

AR	aspect ratio = H/C
C	blade chord
C_P	turbine overall power coefficient = $P_o/½\rho A V_\infty^3$
D	diameter of turbine
H	height of turbine
N	number of blade
P_o	overall power
Q_s	starting torque
Rpm	turbine speed in revolutions per minute
S_a	allowable stress in N/mm^2
V_{cut}	cutout speed
V_∞	wind velocity
λ	tip speed ratio = $R\omega/V_\infty$
σ	solidity = NC/R
D	design point

Introduction

There are three theories such as momentum, vortex and cascade currently available for designing Vertical Axis Wind Turbines. Of them, the Cascade theory, proposed by Hirsch & Mandal [Hirsch & Mandal, 1987], gives reasonable correlation with the experimental data available. The problem of convergence associated with the momentum and vortex theories can be eliminated mostly by using the cascade theory. In 1989, Muniruzzaman [Muniruzzaman and Mandal, 1993] included the effect of Dynamic Stall with Cascade theory that gives improved correlation. Finally in 1994, Mandal & Burton [Mandal & Burton, 1994] carried out further work with the effect of dynamic stall including flow curvature that gives better prediction.

Design feature

In the present design, the effect of dynamic stall and flow curvature is taken into consideration. For dynamic stall consideration, Boeing-Vertol stall model with modification is taken into account. For the flow curvature effect the lift values are corrected only by a factor that is determined using the thin airfoil theory.

For the design with variable turbine speed there appear many variable parameters. Few of them are considered to be fixed before conducting the design analysis. These are airfoil, number of blades, mean wind speed, cutout speed, blade supporting type, the blade material (aluminum alloy) and blade pitching.

Airfoil: The turbine blade section is chosen as the profile of NACA 0018.

Number of Blade: In this design, the number of blade is chosen as three. A turbine with three blades is better due to smooth running because of lower fluctuations of energy in each revolution.

Mean Wind Speed: The mean wind speed is chosen as 5 m/s.

Cutout Speed: The cutout speed is chosen as 15 m/s.

Blade Material: In this design blade material is chosen as aluminum alloy where allowable stress is chosen as 100 N/mm^2.

Blade Support: Both the overhang and simple supported blades are considered in this analysis. These two types of supports are shown in the Fig. 1.

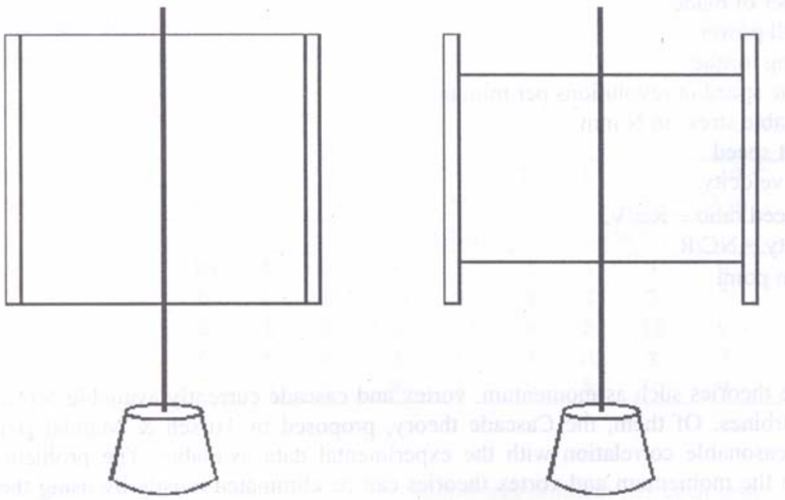

Fig. 1. Straight-bladed vertical-axis darrieus wind turbine

Result and discussion

Design configurations of variable speed turbines at various wind speeds for simple and overhang supports are shown in the Fig. 2 and 3. The solidity is chosen as 0.5 while the design power is 1 kW.

It is observed from the Figure 2 that with the increase of wind speed, the height, diameter and chord of the turbine decreases in general. It is further observed that for the overhang type support the diameter of the turbine drops significantly while the height increases remarkably in comparison to those of the simple support type. On the other hand variation of chord is negligible for both types of support.

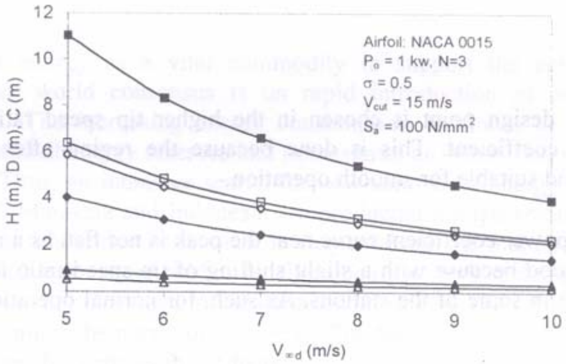

Fig. 2. Comparison of design configurations of 1 kW variable speed straight-bladed VAWT at various wind velocities

Symbol	:	■	▲	♦	(simple support)
		□	Δ	◇	(overhang support)
Parameters	:	D	C	H	

In the Fig. 3, variations of starting torque, aspect ratio, design rpm, design tip speed ratio and overall design power coefficients with respect to different wind speeds are shown. From this figure, it is found that the starting torque and design tip speed ratio of simple supported turbines are slightly higher than those of overhang supported turbines. Whereas the design rpm and aspect ratio of overhang supported turbine are remarkably higher than those of simple supported turbines. However, the overall power coefficient is almost same for both kind of turbines.

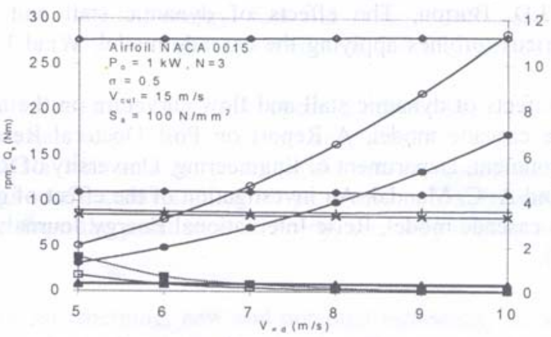

Fig. 3. Comparison of design configurations of 1kW variable speed straight-bladed VAWT at various wind velocities

Symbol:	■	▲	●	◆	+	(simple support)
	□	Δ	○	◇	×	(overhang support)
Parameters:	Q_s	C_p	rpm_d	AR	$_d$	

Conclusions

- In the present design method, design point is chosen in the higher tip speed ratio side from that corresponding to peak power coefficient. This is done because the region after the peak power coefficient is relatively stable and suitable for smooth operation.

- For a high solidity turbine, the power coefficient curve near the peak is not flat, as a result design with peak power coefficient is not good because with a slight shifting of tip speed ratio towards the lower value, there may appear stalling in some of the stations. As such, for normal operation of turbine it is avoided.

- The overhang type support reduces the overall dimensions of the turbines reasonably in comparison to those of the simple supported turbines.

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