SMALL-SCALE STRAIGHT-BLADED DARRIEUS VERTICAL AXIS WIND TURBINE

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ABSTRACT

The subject of this work is the research and development of small-scale straight-bladed Darrieus vertical axis wind turbine (VAWT) with distributed energy generation integrated into residential power system. First, this study discusses the advantages of small-scale straight-bladed Darrieus vertical axis wind turbines; reviews the main design parameters, such as, swept area (A), tip speed ratio (TSR), number of blades (N), angle of attack (\(\alpha\)) and analyzes their impact on power coefficient (\(C_P\)). In the end, wind tunnel simulations will be performed applying the theory discussed before. The results obtained with the model simulation will be used to choose the prototype design parameters and predict power coefficient (\(C_P\)).

Keywords: vertical axis wind turbine, vawt, Darrieus, wind tunnel, power coefficient.

INTRODUCTION

The use of wind energy as renewable power source has grown significantly over the past years. A recent report made by Global Wind Energy shows a growth rate of more than 163\% in installed wind capacity in the last 5 years (GWEC, 2014).

Small-scale wind turbines can achieve important status in this scenario. They can produce energy in a decentralized way with small environmental impact and release the load flow in the transmission lines and distribution by the electric utilities, postponing expansions.

Vertical axis wind turbines (VAWTs), Figure 1, offer an advantage over the horizontal axis wind turbines (HAWTs) for small applications in industrial, urban environment and in remote areas because of the structural simplicity due to the independence with respect to the wind direction (Fujisawa, 2011). Thus, the VAWTs field was surveyed and the main design parameters reviewed, such as, swept area (A), tip speed ratio (TSR), number of blades (N), angle of attack (\(\alpha\)) and their impact on power coefficient (CP) was analyzed. After this study, wind tunnel tests will be made to predict torque (T), angular velocity (\(\omega\)) and power coefficient (\(C_P\)) for specifics design parameters of the prototype.

RESULTS AND CONCLUSIONS

Straight-bladed Darrieus rotors are wise choice for small-scale wind turbines in urban environment; they are cost effective and show good relation between power efficiency and blade design complexity if well dimensioned.
A well designed turbine can achieve a 30% or better power coefficient ($C_P$) value. However, there is a theoretical limit for $C_P$ of a wind turbine determined by the deceleration the wind suffers when going across the turbine. For HAWTs, the limit is $19/27$ (59.3%), and for VAWTs, the limit is $16/25$ (64%) (Castillo, 2011). $C_P$ is the most important design parameter in a wind turbine design and represents the part of the total available power that is actually captured by wind turbine blades (Castillo, 2011).

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C_P = \frac{P_{\text{Turbine}}}{\frac{1}{2} \rho A V_0^3}
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The power coefficient is strongly dependent on tip speed ratio (TSR), defined as the ratio between the tangential speed ($R \omega$) at blade tip and the actual wind speed ($V_0$) (Castillo, 2011). Thus, wind tunnel simulations are going to be made to study the behaviour of $C_P$ and TSR for different design parameters.

Figure 2 shows the wind turbine model structure. The next step, before wind tunnel tests, will be the design of carbon fiber NACAxx series blades.

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