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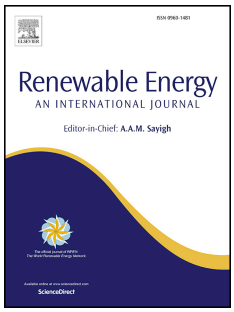

CFD study of Savonius wind turbine: 3D model validation and parametric analysis

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CFD study of Savonius wind turbine: 3D model validation and parametric analysis

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Abstract

A CFD study was conducted in order to characterize the dynamic behavior of a Savonius vertical axis wind turbine. All simulations were executed using the open source code, OpenFOAM. Both two-dimensional and full three-dimensional cases have been investigated in order to provide a suitable tool for geometrical optimization of this rotor. Unsteady simulations are carried out at different tip speed ratio (TSR), varying angular speed of rotor at constant wind speed, using different one and two-equation URANS turbulence models and selecting the $k-\omega$ SST for the final analysis. The two-dimensional model was compared with experimental data available in literature and obtained from tests in wind tunnel. This simplified model shows an over-estimation of experimental data, reporting a maximum efficiency at TSR 1, 20% higher than experimental value. The results of 3D model are in good agreement with experiments with a peak of 0.202 at TSR 0.8 for a rotor with aspect ratio 1.1. The influence of the rotor height has been evaluated on flow dynamics of the turbine and its power coefficient.

Keywords:
Vertical Axis Wind Turbine (VAWT), Savonius, CFD, Turbulence Models, Aspect Ratio, OpenFOAM

1. Introduction

The importance of reducing GHG (greenhouse gases) leads to research more sustainable energy resource and to investigate more efficient technologies. Wind resource is one of the most exploited and in 2014 more than 50 GW have been installed [1]. Wind turbines are generally divided into two main categories: macro aeolian generation and micro aeolian generation. For the first purpose, horizontal axis machines have been developed, composed by a main rotor with air-foil blades and electric generator mounted at the top of a tower (50-150 m tall). While assuring high efficiency and high power, this type produces high noise and requires large space sites for installation. For micro generation, vertical axis devices could represent a valid alternative due to possibility of exploiting wind from variable direction without a complex and expensive control system and easy accessibility and maintenance of power train elements (installed near the ground). Considering this characteristic and low-noise, vertical axial turbines are suitable for urban context such as Savonius [2]. Design is simple and economically competitive and installation requires limited space and it is possible on the top of many buildings. The basic configuration of Savonius turbine is formed by two semicircular blades mounted around a central pole and arranged for creating S-shape. In order to improve the performance, several studies both experimental and numerical have been conducted changing scoop shape (Kamoji et al. [3] and Tian et al. [4]), number (Blackwell et al. [5] and Mahmoud et al. [6] and Damak [7]) and spacing (Blackwell et al. [5]) or adding end-plates (Mahmoud et al. [6] and Ushiyama et al. [8]), leading to relevant modification to original geometry. As this rotor remains a drag driven device, its typical working speed range is low, from 0.6 to 1.1 tip speed ratio (Shigetomi et al. [9]). The consequence is a lower output and a worse performance compared to horizontal axis wind turbines. Several aerodynamics theories have been applied to VAWT composed by aerfoils like Darrenius type (for example, chapter 5, Wilson [10]) but they are not suitable for Savonius configuartion (Ushiyama et al. [8]). Despite the low output characteristics, it doesn't need a system for regulation of pitch or yaw and shows positive torque at every wind incident angle so that it is a self-starting wind turbine (Sivasegaram et al. [11]). The design is very simple and cheap. The installation requires low space and it is possible on the top

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