Towards accurate performance prediction of a vertical axis wind turbine operating at different tip speed ratios

Towards accurate performance prediction of a vertical axis wind turbine operating at different tip speed ratios

A. Rezaeiha [(a)]*, I. Kalkman [(a)], B. Blocken [(a,b)]

(a) Building Physics and Services, Department of the Built Environment, Eindhoven University of Technology, P.O. box 513, 5600 MB Eindhoven, The Netherlands

(b) Building Physics Section, Department of Civil Engineering, KU Leuven, Kasteelpark Arenberg 40 – bus 2447, 3001 Leuven, Belgium

Abstract

Accurate prediction of the performance of a vertical-axis wind turbine (VAWT) using CFD simulation requires the employment of a sufficiently fine azimuthal increment (dθ) at which the flow characteristics on the smallest time scales can be accurately resolved. Furthermore, the domain size needs to be sufficiently large to minimize the influence of flow blockage and the uncertainties regarding the boundary conditions at the domain inlet and outlet on the results. The current study systematically investigates the effect of the domain size and azimuthal increment on the power coefficient (C_P) and thrust coefficient (C_T) of a 2-bladed vertical axis wind turbine (VAWT) operating at a wide range of tip speed ratios (λ) from 1.5 to 5.5 using 2D and 2.5D unsteady Reynolds-averaged Navier-Stokes (URANS) calculations with 4-equation transition SST turbulence modeling. Results reveal a strong dependency of the minimum requirement for azimuthal increment and distance to the outlet (d_o) on λ. While an azimuthal increment of 0.5° can give accurate results for λ = 4.5, it can overpredict the turbine C_P for λ = 1.5 by more than 100% compared to a dθ of 0.1°. The minimum d_o increases from 10 to 30 when λ decreases from 4.5 to 1.5. The cause for this is that at lower the tip speed ratios the flow becomes more complex and the wake length of the turbine increases. The findings of the current study can be used as guidelines for accurate CFD simulation of VAWTs.

Keywords: Vertical axis wind turbine; CFD; guideline; domain size; azimuthal increment; tip speed ratio.

* **Corresponding author**: Abdolrahim Rezaeiha, Building Physics and Services, Eindhoven University of Technology, P.O.Box 513, 5600 MB Eindhoven, the Netherlands. Tel.: +31 (0)40 247 8577
E-mail address: a.rezaeiha@tue.nl