

Experimental measurement of wind turbine performance through Blade Element Theory

Ahmed Abdelrahman and David Johnson

*Department of Mechanical and Mechatronics Engineering, University of Waterloo,
Waterloo, Canada*

A control volume approach to unobtrusively measure the performance of a three bladed 3.3 m diameter turbine in a large scale, controlled wind facility has been presented. The turbine blades utilized NREL S83X airfoils appropriate for the flow conditions and Reynolds number present. Airfoils were blended along the radial direction in a varying chord, varying twist blade design with a design coefficient of power (C_p) peak at $\lambda = 5:4$. Simultaneous three component velocity measurements were obtained at specific radial locations (segments) upstream and immediately downstream of the rotor plane. These velocities were utilized to determine blade element momentum (BEM) parameters and to predict the performance of the rotor. Measured radial velocities upstream of the rotor were near zero and uniform in the radial direction and were uniform and slightly larger downstream of the rotor indicating the BEM assumption of limited radial interaction between segments was acceptable and that the wake was expanding. Axial induction was most uniform in the radial direction at the design and peak C_p condition. Tangential measured velocities, tangential induction and circulation show the impact of the nacelle and blade root location and the tip. An evaluation of the local angle of attack and two dimensional airfoil data at one radial location gave a reasonable comparison with other measured torque values. Rotor performance determined with this method was compared with electrical power measurements and previous BEM model predictions. The power derived from the BEM method outlined here closely followed electrical turbine power measurements although the method over-predicted the power likely due to the segment discretization in the tip region. The detail of these results should be useful to further understand the flow immediately downstream of a rotor in controlled conditions and provide detailed data for BEM model enhancement and future model development.