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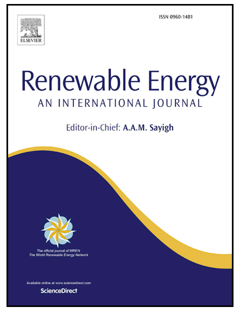

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Application of Extended Vortex Theory for Blade Element Analysis of Horizontal-axis Wind Turbines

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Abstract

Vortex theory is used in blade element analysis (BEA) of wind turbines to account for the finite number of blades, N, usually in terms of Prandtl's "tip loss function", F. Wood et al. [1] calculated alternative "trailing vorticity functions" using helical vortex theory. F was found to be inaccurate over the entire blade at low tip speed ratio and in error near the hub at any tip speed ratio. Further, the trailing vorticity function is not constrained to be less than unity as is F. Wood & Okulov [2] analyzed the nonlinear terms in the streamtube equations for angular and axial momentum and found an accurate way of including these in BEA. This paper describes the use of the trailing vorticity functions, which can be different in the axial and azimuthal directions, in an otherwise standard blade element analyses. Comparison is made to wind tunnel tests of model rotors and to calculations using F. There is only a small difference in the calculated power and thrust coefficients. The present calculations show higher induced axial velocities in the tip and hub regions and it is suggested that the trailing vorticity functions can be used in situations where F cannot.

Key words: wind turbine, tip loss, blade element analysis, trailing vorticity function

1. Introduction

Blade element analysis (BEA) is, and will remain, an important part of wind turbine aerodynamics. van Kuik et al. [1] make the following statement