A coupled near and far wake model for wind turbine aerodynamics

In this paper, an aerodynamic model consisting of a lifting line-based trailed vorticity model and a blade element momentum (BEM) model is described. The focus is on the trailed vorticity model, which is based on the near wake model (NWM) by Beddoes and has been extended to include the effects of downwind convection and to enable a faster and more accurate computation of the induction, especially close to the blade root and tip. The NWM is introduced to model the detailed steady and unsteady induction from the first part of the trailed vorticity behind the individual rotor blades. The model adds a radial coupling between the blade sections and provides a computation of tip loss effects that depends on the actual blade geometry and the respective operating point. Moreover, the coupling of the NWM with a BEM theory-based far wake model is presented. To avoid accounting for the near wake induction twice, the induction from the BEM model is reduced by a coupling factor, which is continuously updated during the computation to ensure a good behavior of the model in varying operating conditions. The coupled near and far wake model is compared with a simple prescribed wake lifting line model, a BEM model and full rotor computational fluid dynamics (CFD) to evaluate the steady-state results in different cases. The model is shown to deliver good results across the whole operation range of the NREL 5-MW reference wind turbine.

General information
Publication status: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Aerodynamic design
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Pages: 2053–2069
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Wind Energy
Volume: 19
Issue number: 11
ISSN (Print): 1095-4244
Ratings:
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.079 SNIP 2.367
Web of Science (2016): Impact factor 2.725
Web of Science (2016): Indexed yes
Original language: English
Keywords: Blade element momentum, Lifting line, Near wake model, Rotor aerodynamics
Electronic versions:
A_coupled_near_and_far.pdf
DOIs:
10.1002/we.1969

Bibliographical note
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Source: FindIt
Source ID: 2292505640
Research output: Contribution to journal › Journal article – Annual report year: 2016 › Research › peer-review