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GEOMETRICALLY NONLINEAR AEROELASTIC RESPONSE OF HORIZONTAL AXIS WIND TURBINES UNDER ROTATIONALLY SAMPLED TURBULENCE

Aditya K. Sabale[1] and K. V. Nagendra Gopal*[2]

[1] Indian Institute of Technology Madras, Chennai, India, aditya_aero@smail.iitm.ac.in
[2] Indian Institute of Technology Madras, Chennai, India, gopal@iitm.ac.in

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The nonlinear aeroelastic response of a very large horizontal axis wind turbine rotor operating at the rated speed in a turbulent wind is investigated using accurate and computationally efficient aerodynamic and structural descriptions. The geometrically nonlinear deformation of the rotor blades is modelled using the geometrically exact beam theory which includes the large displacements of the beam reference axis and cross-sectional rotations while the blade element momentum theory equipped with several important corrections is used for aerodynamic load computations. The model includes aeroelastic coupling between the blade deformations and the aerodynamic loads. Aeroelastic computations are carried out with the aid of a shadow frame of reference that rotates rigidly with the moving/deforming blades at the rated tip-speed ratio. The spatially varying turbulent wind field is obtained using the assumptions of the Mann uniform shear turbulence model. Rotationally sampled inflow velocities at the centers of the blade elements are then computed by interpolation between the grid-points at each time-step, in accordance with Taylor's frozen turbulence hypothesis. Fully-coupled dynamic aeroelastic response of the NREL 5MW reference wind turbine at the rated speed is obtained in the form of the time-history responses of all the six degrees of freedom at the tip along with the six root stress resultants in both the inertial and the blade-attached frames. The uncertainty in power-production and hub-loads due to the stochastic nature of turbulence is quantified and the implications of the same on rotor design are discussed.

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