Time domain flutter analysis of wind turbine rotor blades

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Abstract

Over the past years, wind turbines grew considerably in size in order to reduce the levelized costs of wind energy. The rotor blades became increasingly slender and flexible since manufacturers try to reduce the weight of the blades coincidently. One of the main aspects in wind turbine design has been fatigue life. However, experience in aircraft design has shown that aeroelastic instabilities became an issue as aircraft wings grew longer and flexible. It can therefore be expected that today's rotor blades for multi-MW-sized wind turbines are more susceptible for aeroelastic instabilities. Hence, the need for aeroelastic stability analyses in wind turbine design processes is apparent.

Flutter limits of wind turbines are typically predicted via an aeroelastic eigenvalue analysis in the frequency domain, or an aeroelastic analysis in the time domain. An eigenvalue analysis linearizes the model of the wind turbine around a steady-state operation point and determines the modes which contribute to the turbine state. A time domain analysis simulates the response of the wind turbine over time. Non-linearities are easier to incorporate in a time-domain analysis since an *a priori* linearization is not needed. Furthermore, the rotor blades' deflections and rotations, and the corresponding forces and moments, are visualized more easily.

The current research focuses on time domain analysis computed with the OpenFAST aero-servo-elastic code from NREL. The blade element momentum theory is used to determine the aerodynamic forces that are coupled with a geometrically nonlinear finite beam element formulation describing the blade's structural dynamics. The aeroelastic behavior of the IWT-7.5-164 reference rotor blade is analysed. The OpenFAST model of the reference rotor blade is verified with comparison to other codes. The wind turbine is then operated in a run-away scenario, i.e. the turbine is disconnected from the grid and the blade pitch is set to zero, and the wind speed is continuously increased. By doing so, the turbine is allowed to spin freely and can accelerate towards the flutter limit. The results of the reference rotor blade are compared with a swept configuration, highlighting the impact of a blade sweep on the flutter limits of wind turbines, though the results are highly turbine-dependent.

Keywords: flutter, aeroelasticity, instability

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