Wake modeling and simulation

We present a consistent, physically based theory for the wake meandering phenomenon, which we consider of crucial importance for the overall description of wind turbine loadings in wind farms. In its present version the model is confined to single wake situations. The model philosophy does, however, have the potential to include also mutual wake interaction phenomena. The basic conjecture behind the dynamic wake meandering (DWM) model is that wake transportation in the atmospheric boundary layer is driven by the large scale lateral- and vertical turbulence components. Based on this conjecture a stochastic model of the downstream wake meandering is formulated. In addition to the kinematic formulation of the dynamics of the “meandering frame of reference”, models characterizing the mean wake deficit as well as the added wake turbulence, described in the meandering frame of reference, are an integrated part the DWM model complex. For design applications, the computational efficiency of wake deficit prediction is a key issue. A computationally low cost model is developed for this purpose. Likewise, the character of the added wake turbulence, generated by the up-stream turbine in the form of shed and trailed vorticity, has been approached by a simple semi-empirical model essentially based on an eddy viscosity philosophy. Contrary to previous attempts to model wake loading, the DWM approach opens for a unifying description in the sense that turbine power- and load aspects can be treated simultaneously. This capability is a direct and attractive consequence of the model being based on the underlying physical process, and it potentially opens for optimization of wind farm topology, of wind farm operation as well as of control strategies for the individual turbine. To establish an integrated modeling tool, the DWM methodology has been implemented in the aeroelastic code HAWC2, and example simulations of wake situations, from the small Tjæreborg wind farm, have been performed showing satisfactory agreement between predictions and measurements.

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