The turbulence scales of a wind turbine wake: A revisit of extended k-epsilon models

The turbulence time and length scales of a single wind turbine wake subjected to atmospheric turbulence are calculated from two large eddy simulations that differ in ambient turbulence intensity. The smallest turbulence length scale in the wake is about half the rotor radius and it increases for higher ambient turbulence levels. The large eddy simulations are compared with Reynolds-averaged Navier-Stokes simulations employing the standard and three extended k-ε models: the k-ε-fP model of van der Laan, the k-ε model of Shih and k-ε model of Durbin. It is shown that all three extended k-ε models can be written in a similar form. All Reynolds-averaged Navier-Stokes based turbulence models predict turbulence time scales that are comparable to the turbulence time scales of the large eddy simulations. The standard k-ε model underpredicts the velocity deficit because the turbulence length scale is overpredicted compared to the large eddy simulations. The performance of the k-ε model of Durbin shows to be very dependent on the ambient turbulence level and it is therefore less suited for wind turbine wake simulations. The k-ε model of Shih and the k-ε-fP model of van der Laan are recommended to be used for wind turbine wake simulations because their results are similar and compare well with results of large eddy simulations for both a low and high ambient turbulence intensity due to a limitation of the turbulence length scale in the near wake.

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