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A new approach to modelling mean flow and turbulence in wind turbine wakes and wind farm environments

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A new fast and efficient approach to the problem of modelling the development of wind turbine wakes is proposed, which has been developed as part of the EU FP6 TOPFARM project. The similarities between the dispersion of a plume of gaseous material in the atmospheric boundary layer and the breakdown of a wind turbine wake have been exploited.

New developments have been made to CERC's ADMS model that is used worldwide for modelling the dispersion of atmospheric pollutants for regulatory purposes. In these new developments, the fully-expanded turbine wake is characterised as a thin volume source, with source strength and dimensions calculated to give a maximum wind speed deficit 2aU. Here a is the Axial Induction Factor calculated either from an iterative solution of Blade Element Momentum (BEM) theory, or, from the input values of thrust coefficient as a function of the hub height wind speed U, according to the user's choice. Meandering-induced turbulence is modelled using ADMS's well-validated model of concentration fluctuations, here used as a surrogate for velocity fluctuations. The changes to ADMS include consideration of the special dispersion characteristics of wind turbine wakes: the downstream delay before the wake vortex begins to entrain ambient air, the additional shear-induced turbulence at the edge of the wake and the lack of large-scale wind direction meandering in wind farm environments.

Wind farms can be modelled easily in the new model, with the individual sources being modelled in downstream order, so that wakes from upstream turbines affect the vertical wind and turbulence profiles used both to characterise the turbine effective sources and to disperse their wakes. Special treatment is included for the wakes of turbines that are inside the wakes of upstream turbines: increased turbulence and no entrainment delay. Output from the model is in the form of hourly values of ambient wind and power, wake-affected wind and power, wind and power deficits and meandering-induced turbulence on a user-defined grid of output points and/or at the turbine locations. These data can be given either individually for each meteorological condition modelled, or, as an average wind speed and total power over the full set of meteorological data modelled. The new model has been validated against measured data from Tjæreborg Enge, Nysted wind farm and Noordzee wind farm. The model has been used to demonstrate the differences in potential annual power output for different configurations of wind turbines for the existing wind farm at Stags Holt and Coldham Farm in the UK.