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Development of a New Wake Model using Large-Eddy Simulations and Wind Tunnel Data

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The aerodynamic research for wind turbines has contributed significantly to the success of modern wind energy. Wind turbine wakes in particular have been a topic of intensive research from the early start of wind energy utilization in the late 1970s. Models describing wind turbine wakes were developed mainly in the 1980s, such as the simple N.O. Jensen model for a single generator. Wind resource software like WAsP utilizes such models to estimate the power loss in wind farms due to the wind speed reduction in wakes from upstream wind turbines. Such models have advantages in the viewpoint of designing a wind farm due to its simplicity and computational speed in comparison to Computational Fluid Dynamic based models. Jensen model is obtained by using conservation of momentum theory and assuming a top-hat shape of the wake velocity deficit as well as a linear expansion with downwind distance. However, several studies have shown that the wake deficit does not follow a top-hat shape, but it is near Gaussian.

A simple wake model is proposed here which is also based on conservation of momentum and assumes a linear expansion of the wake. However, unlike Jensen model, the new model assumes a Gaussian axi-symmetric shape of the velocity deficit in the wake. The volume below the Gaussian surface is constant and depends on the rotor diameter and the thrust coefficient of the wind turbine. Therefore, the model only requires one parameter: the rate of expansion of the Gaussian distribution. Wind-tunnel data and Large-Eddy Simulation (LES) results support the assumptions of Gaussian distribution, axi-symmetry and linear expansion of the wake. Moreover, the new model yields substantially improved predictions of the velocity distribution in the wake, compared with the Jensen model. Further comparisons of the new wake model with field measurements and LESs will be carried out in the future. Emphasis will be placed on understanding the dependence of the wake growth rate on effects such as turbulence intensity and mean shear of the ambient flow.