Linearised CFD Models for Wakes

This report describes the development of a fast and reasonably accurate model for the prediction of energy production in offshore wind farms taking wake effects into account. The model has been implemented as a windows application called Fuga which can run in batch mode or as a graphical user interface. Fuga is briefly described. The model is based on a linearization technique which is described in some detail, and linearized, governing equations are derived and written in a standard form based on a mixed-spectral formulation. A new solution method is used to solve the equations which involves intensive use of look-up tables for storage of intermediate results. Due to the linearity of the model, multiple wakes from many turbines can be constructed from the wake of a single, solitary turbine. These are in turn constructed from Fourier components by a fast Fourier integral transform of results derived from generic look-up tables. Three different models, based on these different closures, are examined:

- the ‘simple closure’ using an unperturbed eddy viscosity $u_z$
- the mixing length closure
- the $E-\varepsilon$ closure

Model results are evaluated against offshore wind farm production data from Horns Rev I and the Nysted wind farm, and a comparison with direct wake measurements in an onshore turbine (Nibe B) is also made. A very satisfactory agreement with data is found for the simple closure. The exception is the near wake, just behind the rotor, where all three linearized models fail. The mixing length closure underestimates wake effects in all cases. The $E-\varepsilon$ closure overestimates wake losses in the offshore farms while it predicts a too shallow and too wide the wake in the onshore case. The simple closure performs distinctly better than the other two. Wind speed data from the the Horns rev met masts are used to further validate Fuga results with the ‘simple’ closure. Finally, Rdsand 1 and 2 are used as an example to illustrate the interaction between wind farms.