- WakeBlaster -
Development of a Real Time Wind Farm Simulator

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Abstract

We show the steps undertaken in the development, validation and application of a real-time wind farm simulator. An accurate real-time simulation is an enabling technology for several purposes: Energy production assessment; performance monitoring; wind farm control; short term forecasting.

Improving Wake Model Accuracy

The new model is being validated against a wide range of validation cases. Validation cases from a number of wind farms covering a range of distances, turbulence levels and stability conditions are used. The examples displayed in Fig 1&2 shows the process for moderate wind speed and strong wakes.

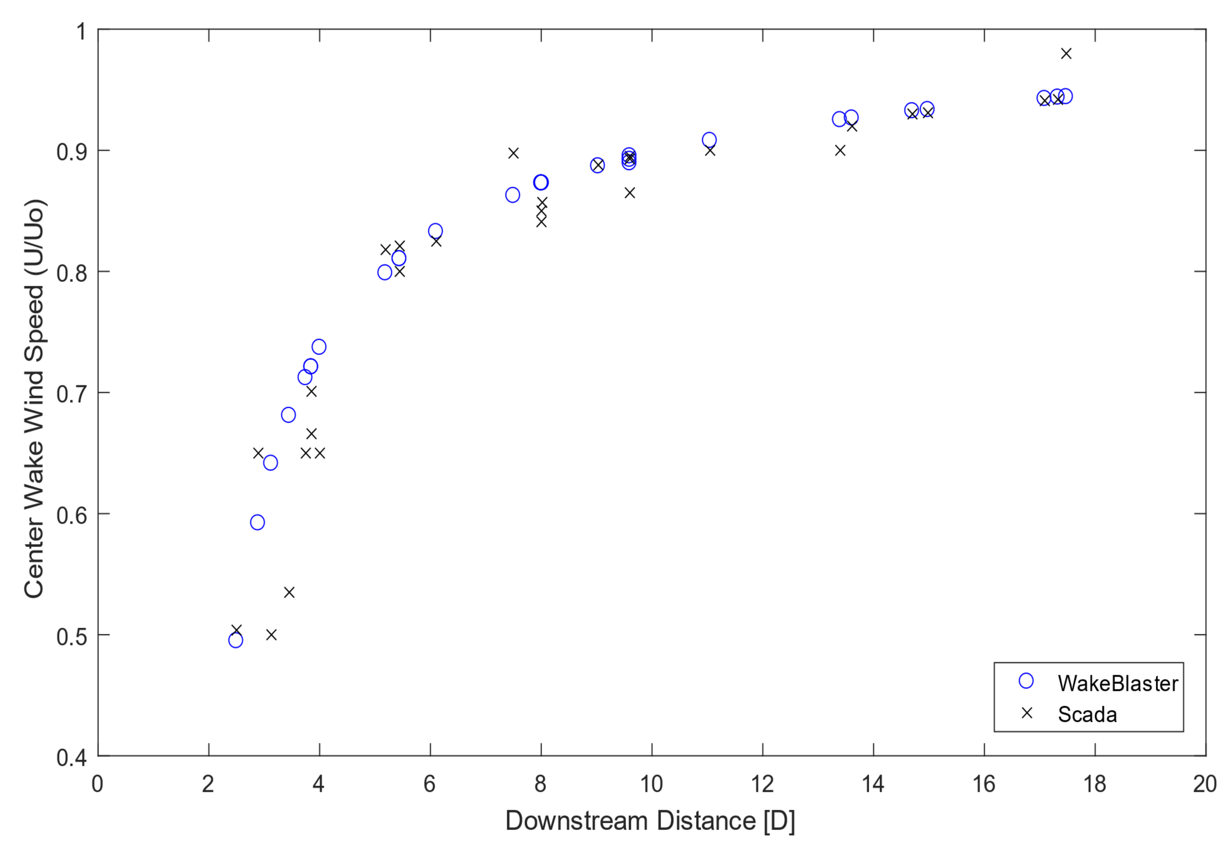

Figure 1: Downstream development of the center-line deficit for strong wakes. Model (o) results and measured (x) data from several wind farms.

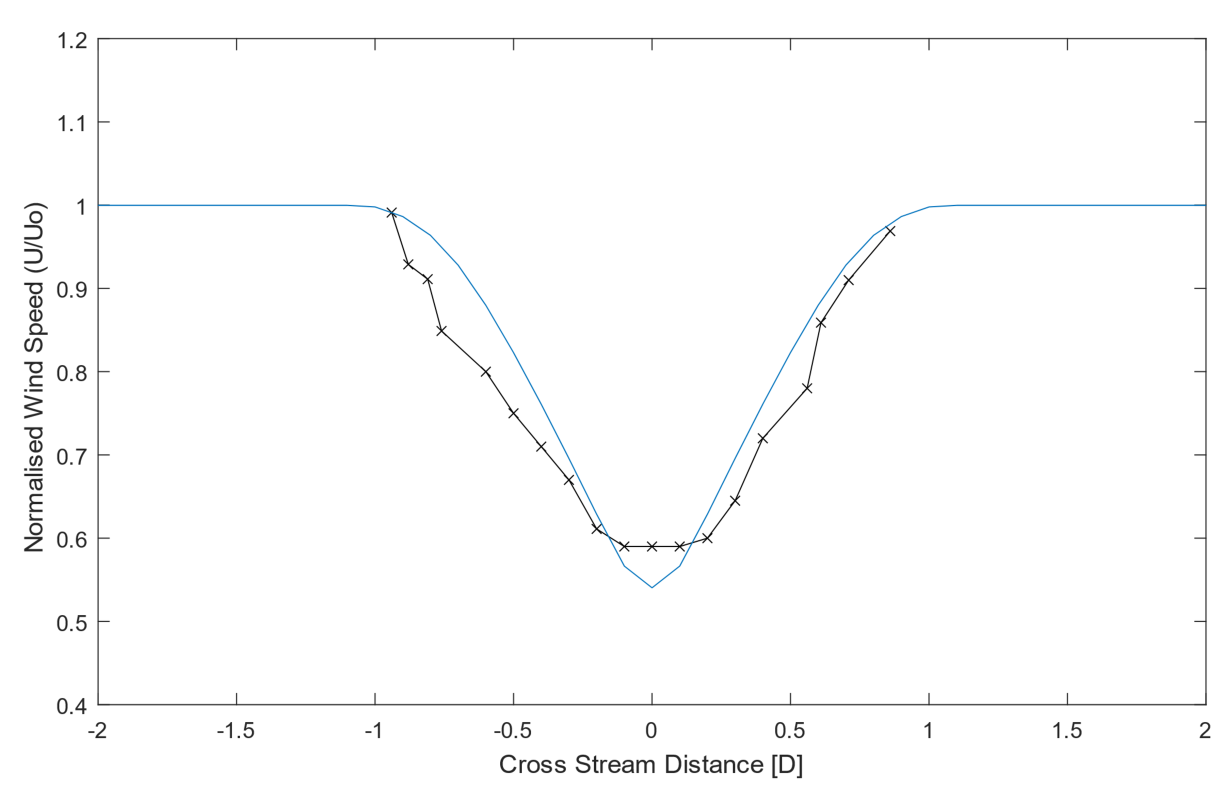

Figure 2: Example of a wake profile at a distance of 2.5D downstream.

3D RANS Solver with Eddy Viscosity Turbulence Closure

Both 2D and 3D Reynolds-averaged Navier-Stokes (RANS) models have been developed for use in a real time wind farm model, taking account of local and temporal environmental conditions. The 3D model allows modelling of significant 3D effects, such as the interaction between multiple wakes or between a wake and the boundary layer.

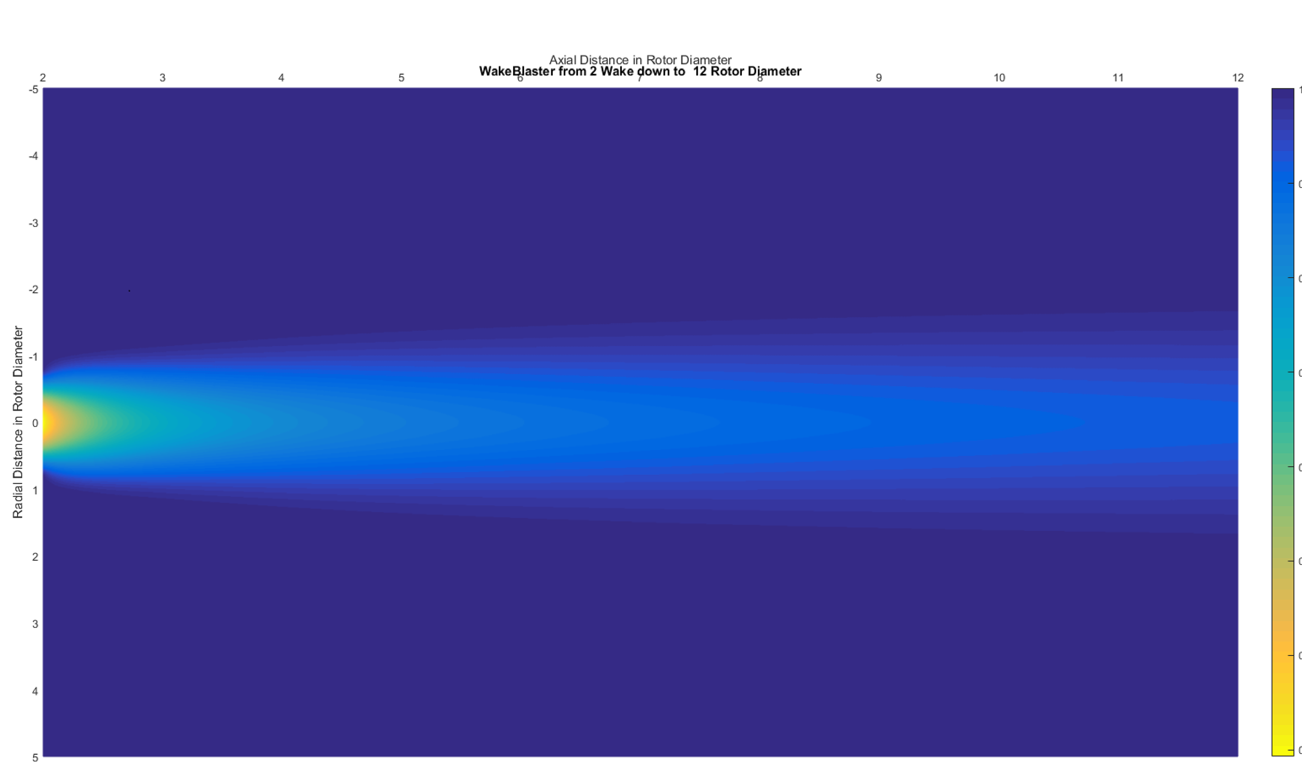

Figure 3: Simulation with a 2D RANS model with EV turbulence closure.

Real Time Wind Farm Simulator

The 3D RANS model of the waked flow is then integrated in WakeBlaster, a real-time wind farm simulator software. The tool models for each step the state of the wind farm and reports simulation results such as power and rotor equivalent wind speed due to wakes. In Fig. 4 the output is compared to SCADA data.

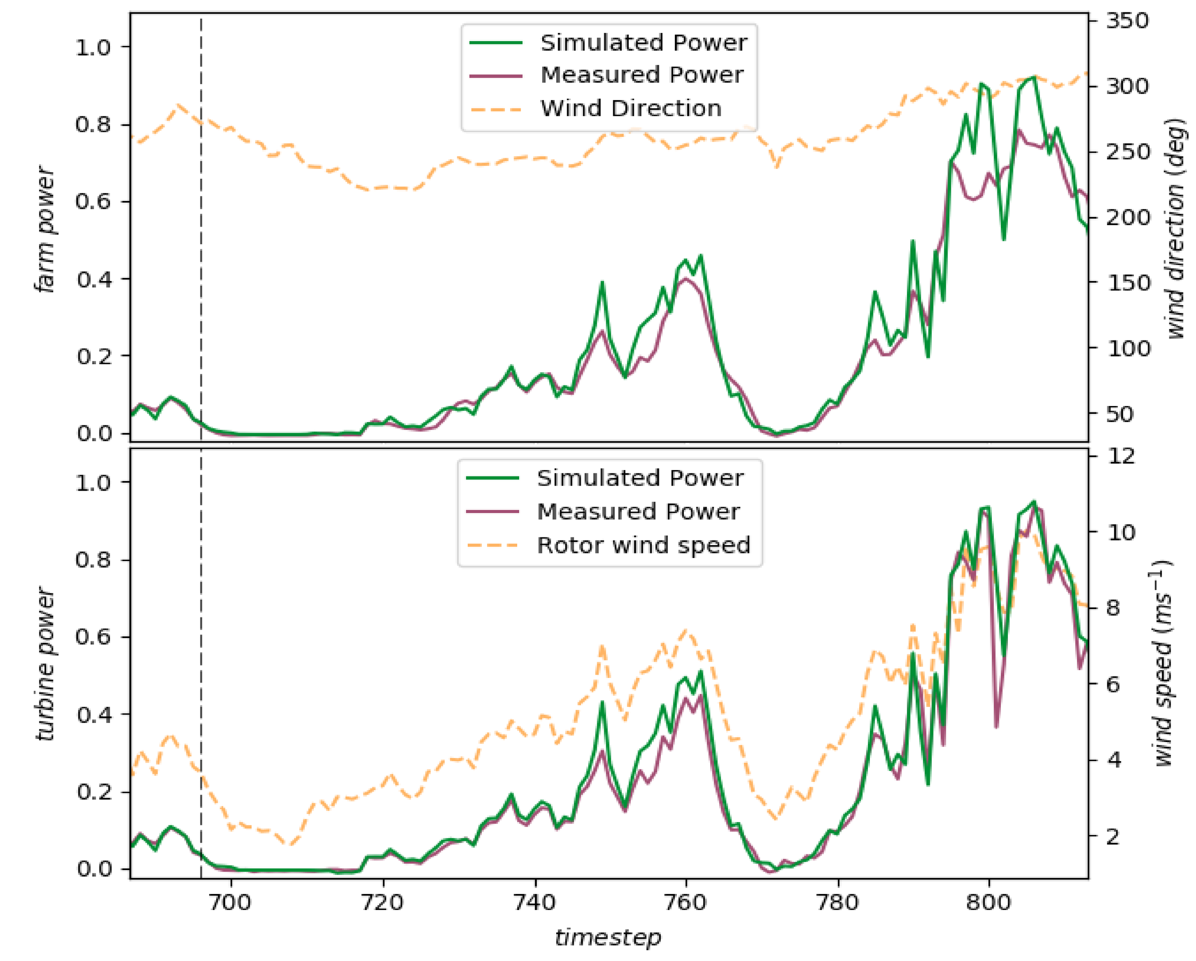

Figure 4: Real-time wind farm simulator and wind farm SCADA data (top: power of entire wind farm; bottom: power of a single turbine and its local wind speed).

The time domain approach allows for short-term temporal variations to be accounted for based on SCADA data. The model contemporaneously adjusts for: turbulence; air density (due to temperature variation); yaw misalignment; local rotor equivalent wind speed due to shear and waked flow. Furthermore, this time domain approach models startup/shutdown hysteresis and manual stoppages of specific turbines; both of which cannot be modelled by statistical methods

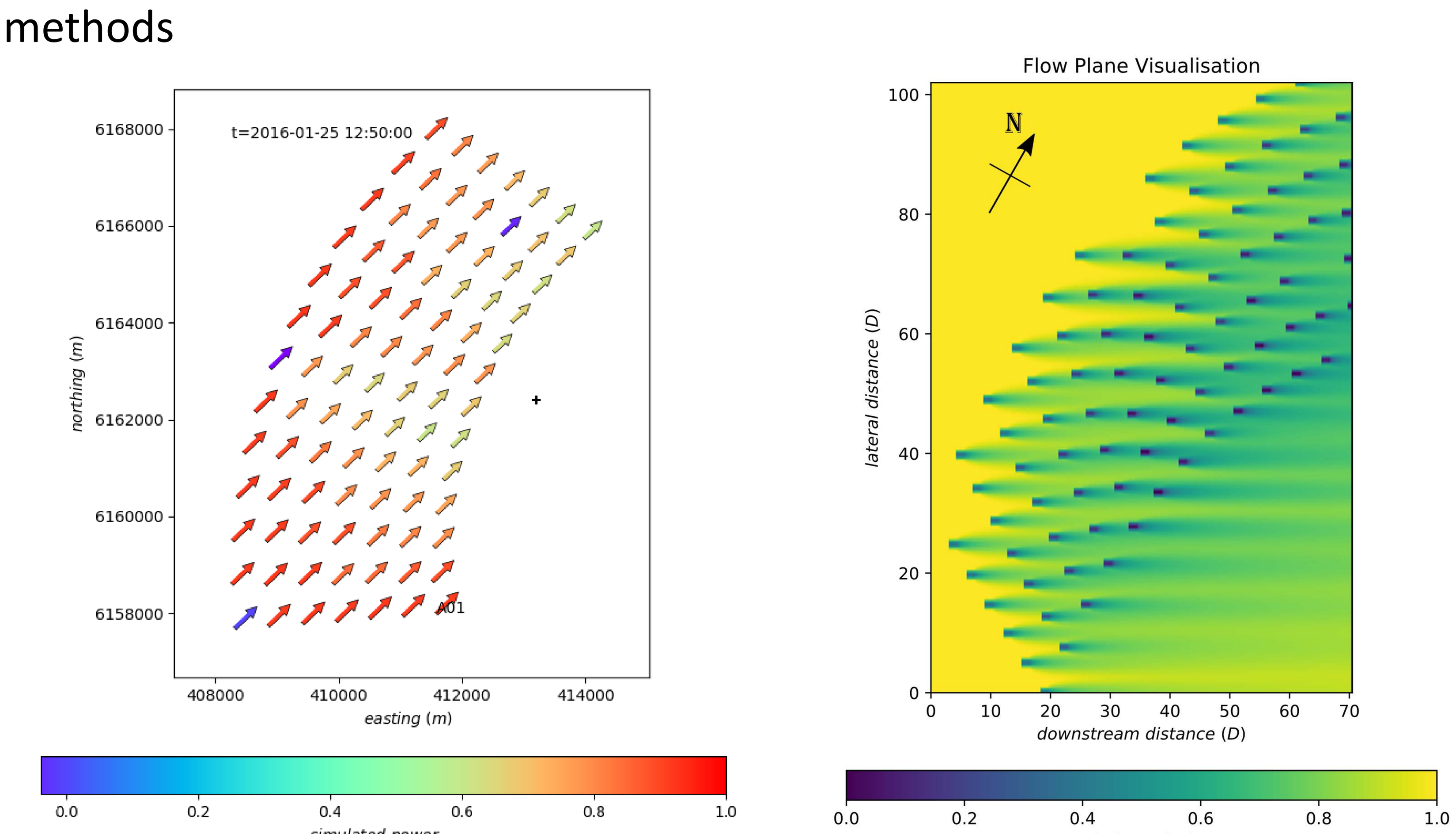

Figure 5: Simulation of the waked wind in Horns Rev 2 wind farm (left: simulated power and local wind vectors at each turbine; right: Full waked flow field for the same case)

Fig. 5 demonstrates a particular benefit of using time series SCADA data in a simulation of Horns Rev 2 wind farm where three of the turbines are stopped and the turbine flow field is calculated based on the concurrent operating state.

Conclusions

We have developed a new wind farm simulation software component that features improved accuracy and higher level of detail compared to statistical models. Analytical approximations for 3D flow effects are replaced by numerical modelling. The wind farm simulation allows detailed modelling of time variant and hysteresis effects.

Acknowledgements

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