WakeBlaster – Understanding Wind Farm Performance

A simulator to dynamically and accurately predict wind farm power output

PO.151

Wolfgang Schlez, Philip Bradstock, Michael Tinning, Staffan Lindahl
ProPlanEn

ProPlanEn
Wind Energy Advisory

Introduction

In an operating wind farm, the 10-minute mean power produced depends on the atmospheric conditions and turbine operating states.

Traditional wind farm design packages, when used as simulators of wind farm performance, calculate the power of a wind farm in a statistical approach by binning wind speed and direction for average values of parameters such as stability, turbulence, air density and full availability. The WakeBlaster tool avoids errors associated with such simplification and accurately calculates the performance of a wind farm over any 10-minute period given any atmospheric and operational conditions.

The factors influencing the power output of an operating wind farm come in two main groups: atmospheric conditions and wind farm operating state.

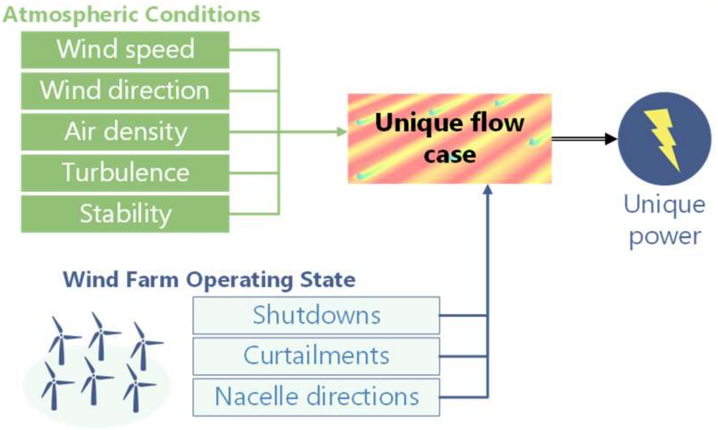


Figure 1: The factors that WakeBlaster considers in the simulation of 10-minute mean power

New Generation Wake Model - 3D RANS

Most wind farm performance simulators use either the Jensen (Park) or 2D Ainslie families of models. For the WakeBlaster simulator, a specialized 3D Reynolds Averaged Navier-Stokes (RANS) wake model was developed in order to give higher accuracy in complex flow cases. One of the key advantages is that it allows an implicit modelling of **superposition of wakes**.

Most onshore wind farms have irregular layouts, which need accurate modelling of superposition. In order to validate the superposition in the **3D RANS** model, power matrices were calculated for a series of wind farms and compared to observational data as well as to the Jensen and Ainslie models in WindFarmer. Figure 2 shows one particular example of the power output of a single turbine at 8m/s in a sector where it is under the influence of multiple wakes. The results show that the shape of the power matrix is better predicted by the 3D RANS model with implicit superposition.

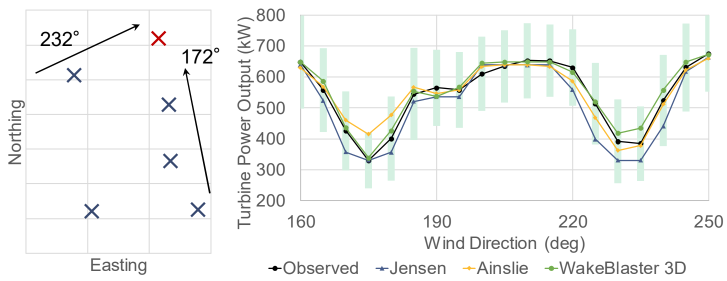


Figure 2: (left) The layout of wind turbines with the study turbine marked in red; (right) the power output of the study turbine in three different wake models compared to the observational medians (observational standard deviations are marked as grey bars).

Atmospheric conditions affecting performance

Amongst atmospheric conditions, diurnal and seasonal changes in air density affect the power curve and can affect power capture up to 10%. Stability and shear also have considerable impact.

However, the strongest atmospheric impact on power is due to turbulence. Turbulence intensity alters power output both by increasing wake dissipation and by changing the shape of the 10-minute power curve. Both effects can be seen in the WakeBlaster simulation in Figure 3.

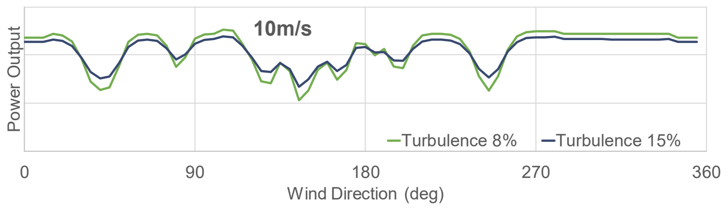


Figure 3: WakeBlaster simulated power of a heavily waked turbine. Higher turbulence intensity decreases the strength of the wakes but also decreases output at the knee of the power curve.

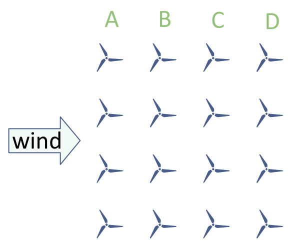
Shutdown Scheduling Optimisation

In the wind farm operating state, shutdowns and curtailments of individual turbines not only reduce the power of that turbine but also influence other turbines via wake interaction. Furthermore, differing nacelle directions modify power capture due to yaw misalignment and the steering of wakes.

In order to study the effect of independent turbine shutdowns, WakeBlaster was run on a hypothetical wind farm maintenance case study. Results were run on a farm of a 4-by-4 grid of turbines with a 5 diameter spacing in both directions aligned West to East and North to South.

In the hypothetical case, all turbines need to be switched off for maintenance for one hour, and **four turbines are shut down simultaneously** at any one time – leading to a total of four hours of partial outage. The wind direction is constantly from the **West** but the wind speed is expected to increase linearly from **6m/s to 10m/s** during the same period.

WakeBlaster results show that shutting down turbines by North-South columns rather than by West-East rows will provide more energy yield due to decreased wake effects. WakeBlaster analysis also shows that shutting down the middle columns last (when the wind speed is higher) produces more energy yield than shutting down the middle columns first.



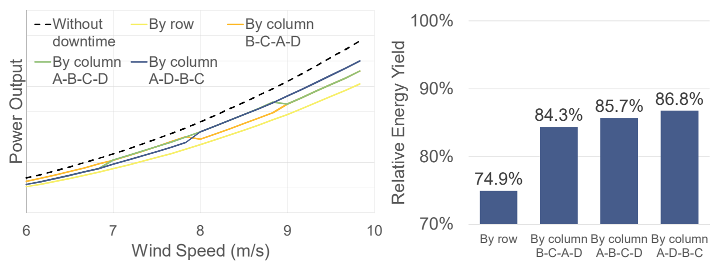


Figure 4: (left) Power produced in different maintenance schedules against a wind speed linearly increasing over time; (right) energy yield produced by various maintenance schedules compared to energy yield without downtime. Order of shutdown by column is indicated where "A-B-C-D" is in order from West to East.

Acknowledgements

The WakeBlaster development was co-funded by the UK's innovation agency, Innovate UK. A number of companies contributed operational wind farm data to this research, their support is greatly appreciated.

Meet us at 1A30