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Optimising the performance of a small wind farm through wind turbine power modes

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Abstract

Using power modes within the wind turbine controller, this study attempts to optimise the performance of a small onshore wind farm without significant changes of the control system, or any risk of increased loading or significant production losses due to alternative strategies such as wake bending and wind sector management.

The work focuses on a case study project (name and details kept confidential) and proof of concept for a 9 wind turbine project located in the UK. Following an analysis of the operational SCADA data, the tuning of the wake model and an understanding of the power modes already specified within the control system, several different configurations are analysed.

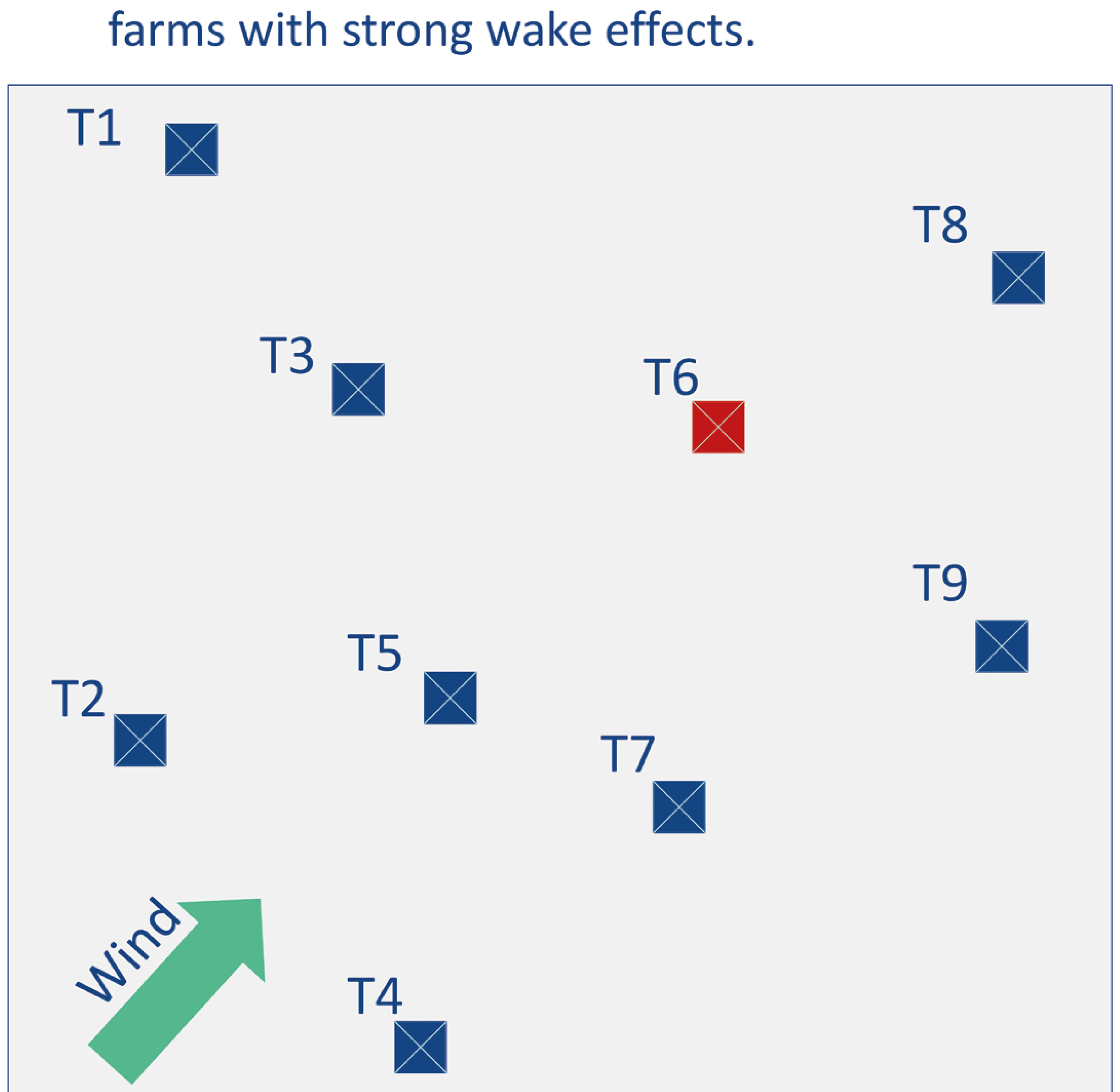
Objectives

A wind farm owner or operator may have different priorities for a project, such as maximum power output or various load scenarios for the turbines. A trade-off between power output and loads may be necessary depending on the case.

In this case study project, the turbine spacing of less than 4.5 rotor diameters in the prevailing wind direction is considered tight. Turbine T6 has been relatively underperforming by over 5%, with the poorest performance and lowest availability among all turbines, which is likely to have been caused by the wake effects.

Consequently, the objectives of this study are:

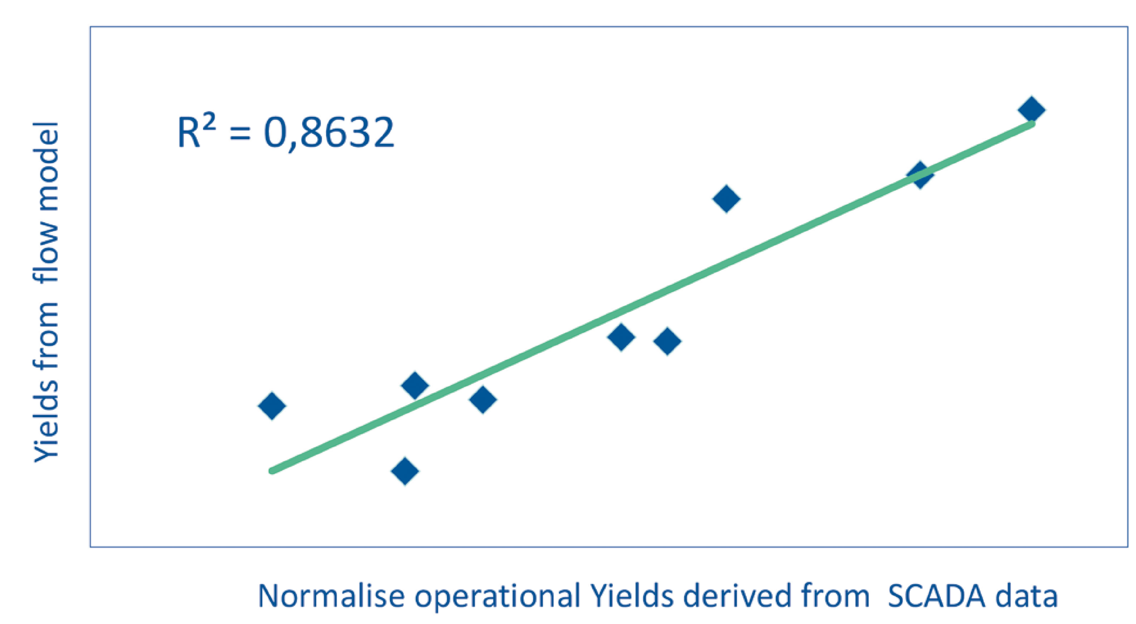
1. Reducing loads on T6 using power modes in order to improve its long-term prospects in terms of losses due to unavailability and maintenance costs; and if possible,
2. Maintaining the energy yield of the wind farm through reduced wake losses;
3. Selecting / design of the power mode to achieve the objectives above;
4. Proving the effectiveness of this optimisation concept for use in larger and offshore wind farms with strong wake effects.



Methods

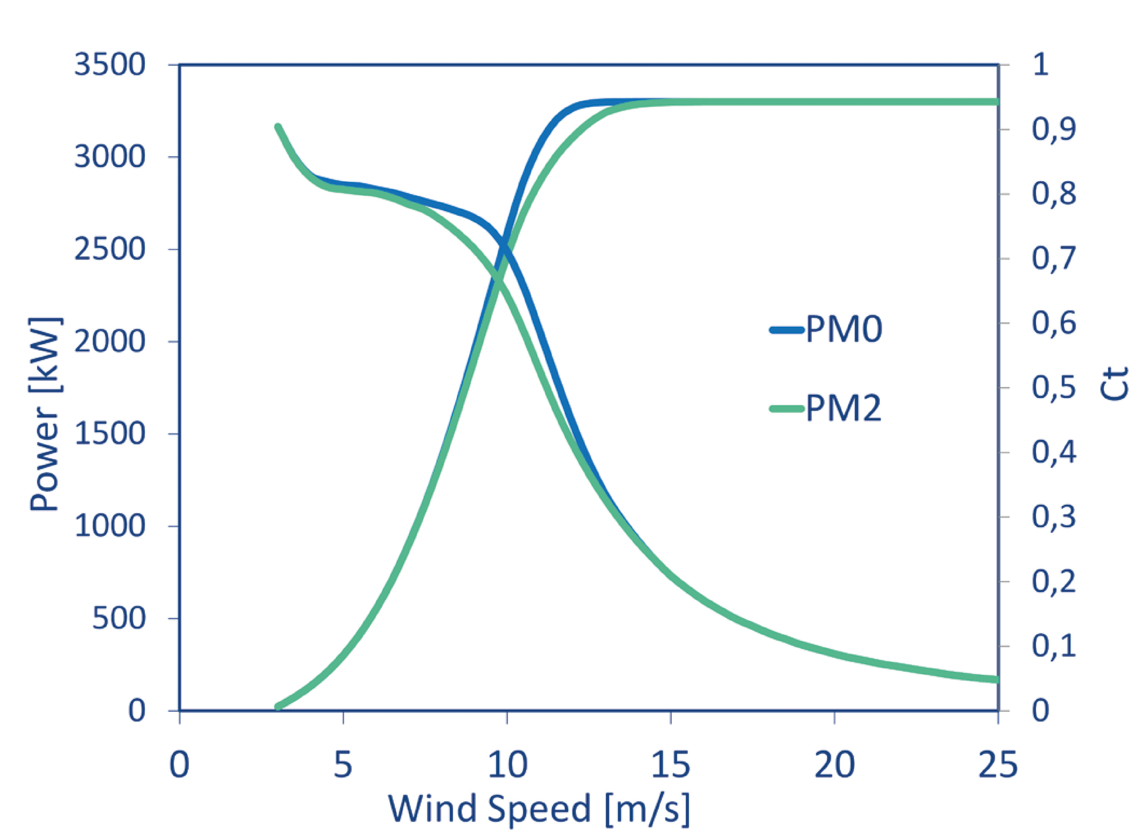
The operational yields derived from the SCADA data were normalised in order to take out the variations due to windiness of the operational period, energy-based availability, data recovery and major sub-optimal performance issues.

The analytical wake model, PARK2 [1, 2] was then tuned in order to achieve the best correlation between the modelled yields and the normalised operational yields. This tuning was possible because of the simple/rolling terrain surrounding the site [2], therefore any resultant divergence should be dominated by the uncertainty in wake model, assuming that the performance of the turbines is consistent and the turbines are without major sub-optimal performance issues.



A strong correlation of 86.3% was achieved after tuning, bringing confidence to the wake model for this study.

The Power Mode, PM2, was selected for this study because PM2 does not require the turbine to be de-rated, preserving the yield at higher wind speeds. By smoothing the 'knee' of the power curve, where the loading of the turbine peaks, PM2 can considerably reduce the loading for the turbine in question. The wake loss and turbulence for the turbines downwind is also reduced due to less momentum being extracted from the wind, as shown in the thrust coefficient (Ct) curves below.



PM2 was applied to various turbines, with the emphasis on reducing loads on turbine T6, and for T5 to reduce wake turbulence on T6. This has the effect of a reduction in loads experienced by the turbines [4] because turbulence is one of the key drivers of loading on major components including blades, gearbox and tower.

The energy yields were calculated for each scenario and compared to the baseline scenario where all turbines were set at PM0.

Results

The application of PM2 results in a ~ 2.6 % energy loss for the turbine in question, however with the energy gain from other turbines due to wake reduction, the overall energy loss is approximately only 0.1 – 0.2 % per each turbine operating under PM2. This is without accounting for the potential improvement of the performance of T6 due to reduced downtime and maintenance costs.

Turbine with PM2	Normalised yields
None	100.0%
T6	99.8%
T5	99.8%
T4	99.8%
T5,T6	99.7%
T5,T7	99.7%
T2,T4	99.6%
All	98.2%

The energy loss due to the power mode on a per turbine basis is therefore found to be negligible.

Effective Turbulence Intensity (TI) was also estimated for T6 assuming a Wöhler curve exponent of 10 [3]. It was found that the Effective TI on downwind turbines dropped by 2 – 3% due to the application of PM2, reducing loads by approximately 5 – 10% and therefore lowering the risk of turbine failures.

Following this study, we suggest that PM2 is applied on T6 or T5 for this project.

Conclusions

The wake model, PARK2, was successfully tuned to better represent the actual operational data from a detailed performance assessment.

With careful selection/ design of power mode, it is possible to achieve a significant reduction in wind turbine loading through the smoothed 'knee' of the power curve and/or reduced wake effects with only a very small impact on overall wind farm yield. This is especially true when wake effects are prominent, such as in this case where turbine spacing is tight, and for offshore scenarios.

Further study is ongoing for larger/ offshore projects and also quantification of the reduction in loads and the monetary benefit. Computational algorithms can be designed to automate this process and allow the iteration of a great number of scenarios or the creation of custom power curves.

References

1. M.H. Zhang, D. Pullinger, N. Hill, T. Crutchley, "The impact of upgrades to the latest WAsP model (v12.0) on wind resource assessments", Lloyd's Register, United Kingdom, Jan 2018.
2. O. S. Rathmann, B. O. Hansen, J. M. Leon, K. S. Hansen and N. G. Mortensen, "Validation of the Revised WAsP Park Model," in WindEurope, Amsterdam, Netherlands, 2017.
3. International Electrotechnical Commission, 2005. IEC 61400-1 Wind turbines – Part 1: Design requirements Ed. 3.
4. A Bustamante et al 2015 J. Phys.: Conf. Ser. 625 012020