Application of Wind Farm Control and Wind Farm Layout for the Optimisation of Wind Farm Power and Loads

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Research Motivation

For many years wind turbines have typically been operated as single entities, regardless of whether they are part of a larger wind farm (WF) or not, a strategy that often does not lead to the most optimum performance of the wind farm.

Wind farm control can offer a highly effective way of optimising the wind farm. A wind farm controller designed to reduce the loads on the most at risk turbines in a wind farm could help reduce O&M costs. With knowledge of wind turbine interaction, the aim is to create a wind farm controller that distributes power changes throughout the wind farm to optimise the cost of energy.

Research Methodology

Key to the methodology of this research is development of a wind farm model that will:

- Allow a full range of wind conditions and wind farm layouts to be easily simulated;
- Allow structural loads on the wind turbines assessed;
- Be suitable for WF control design and assessment;
- Simulate a realistic flow field and provide a good estimate of wake interactions within a WF.

Given that the wind turbine and wind farm models are developed and validated to indicate their efficacy (ideally using data from existing wind farms), it is then through a wide range of simulations that data can be produced, which will be statistically analysed for relative Damage Equivalent Loads of turbine components to assess fatigue.

The methodology is then to develop wind farm layouts and wind farm control strategies via optimisation routines, to reduce the loads on wind turbines, whilst minimising any power reduction.

"StrathFarm" – The University of Strathclyde Wind Farm Model

The requirement was for an analysis and design wind farm model and simulation tool that:

- Models the wind field and wake interactions.
- Models the turbines in sufficient detail that tower, blade and drive-train loads were sufficiently accurate to estimate the impact of turbine and farm controllers on loads.
- Includes commercial standard turbine controllers.
- Includes a wind farm controller.
- Provides very fast simulation of large wind farms; run in real time with 100 turbines on a standard PC.
- Flexibility of choice of farm layout, choice of turbines & controllers and wind conditions, direction, mean wind speed and turbulence intensity.

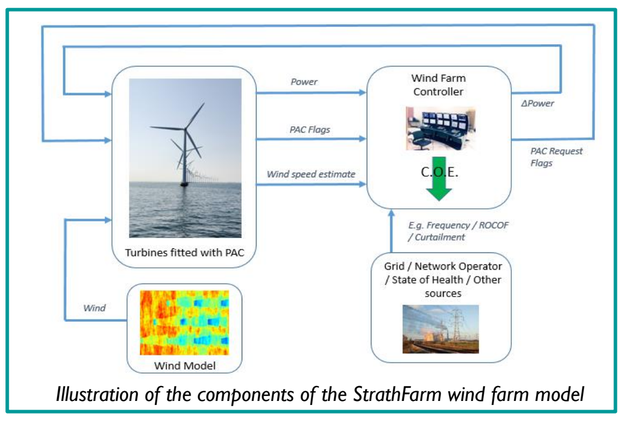
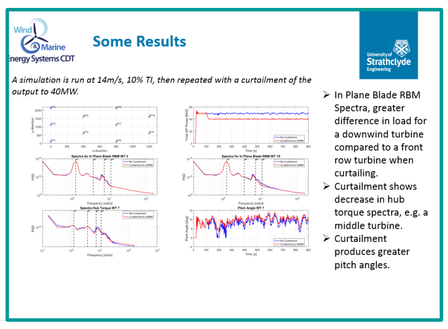
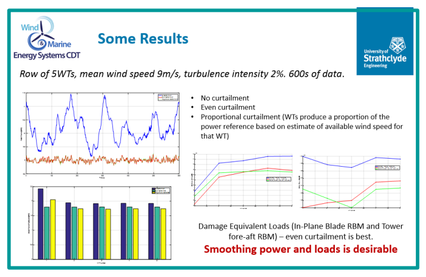
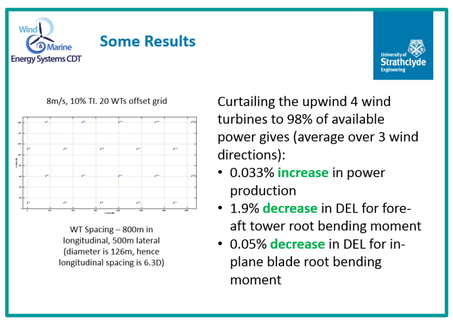
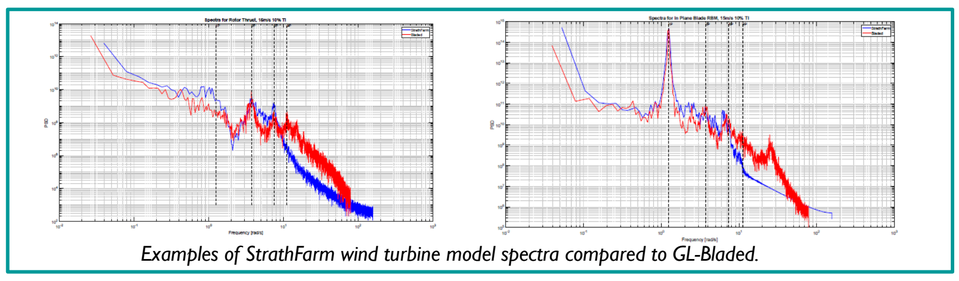


Illustration of the components of the StrathFarm wind farm model









Examples of StrathFarm wind turbine model spectra compared to GL-Bladed.

"StrathFarm" has been developed to this end, as a Simulink model with some compiled C++ elements. Fully flexible WF generator script with user interface for simulations. The above requirements have been met, although the following developments will be made:

- Discretised wind turbine model in C++ to replace continuous, Simulink model: provides large execution speed up and opens up possibility for model predictive WFC.
- Wake interaction model to be revised and replaced.
- Novel WFC algorithms to be developed.

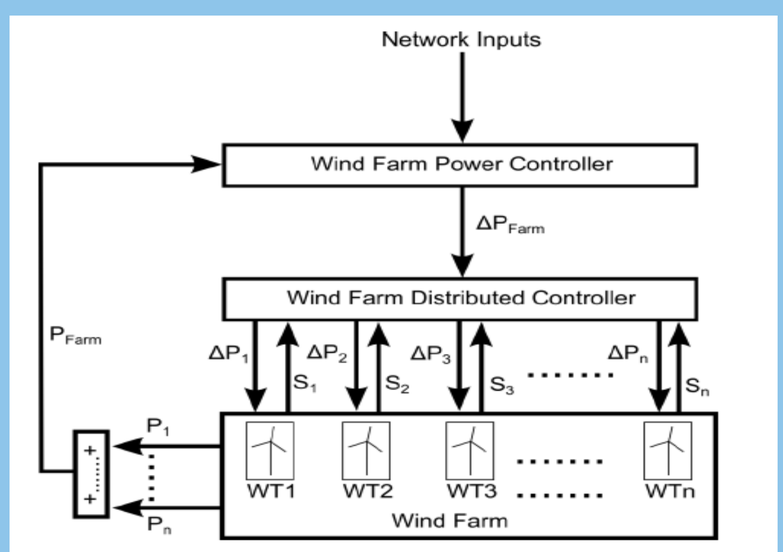
Future Work

Wake Model & Wind Farm Controller

Wind farm control can offer a highly effective way of optimising the wind farm. A wind farm controller designed to reduce the loads on the most at risk turbines in a wind farm could help reduce O&M costs. With knowledge of wind turbine interaction, the aim is to create a wind farm controller that distributes power changes throughout the wind farm to optimise the cost of energy. Development of a novel wake interaction model that can run efficiently within the wind farm control algorithm is required.

Wind Farm Layout

Having developed a sound knowledge of the key aspects of wind turbine interaction that drive the loadings and power capture of wind farms in this PhD, design of more optimal farm layouts can be undertaken. The aim is to derive a more informed approach to turbine positioning based on wind interactions.



Layout of a wind farm controller with hierarchical structure [1].
Wind farm controller split into two parts – a power controller and a distributed controller. For optimisation of the wind farm the aim of the distributed controller will be to change power in such a manner as to reduce loads on the turbines.

[1] "Augmented Control for Flexible Operation of Wind Turbines", Adam Stock, PhD Thesis, University of Strathclyde, 2015