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

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Background

- For many years wind turbines have typically been operated as single entities, regardless of whether they are part of a larger wind farm or not, a strategy that often does not lead to the most optimum performance of the wind farm. Typically, the variable that operators would like to optimise is the cost of energy.
- One method of decreasing cost of energy is to maximise the power output of the wind farm. Given a series of turbines, each one in the wake of the next, the optimum solution for maximising the total power output is typically to reduce the power output of one or more upwind turbines.
- Another consideration is minimising the expense of maintenance, requiring an understanding of how winds affect the loadings on wind turbines, how the operational strategy of wind turbines can be altered to reduce loadings, and how the wind propagates through the wind farm.
- Hence, through design of the wind farm layout and active dynamic control of the wind turbine operational strategies, it is possible to bring about a more optimum farm output than the usual method of simply controlling each turbine in the farm individually.

PhD Aims and Objectives

- Gain a thorough and deep understanding of the current state of the art for modelling of wind turbine wakes and the interactions of wind turbines in a wind farm;
- Develop existing wind turbine and wind farm models to allow a full range of wind conditions and wind farm layouts to be easily simulated and the structural loads on the wind turbines assessed;
- Through simulation of a wide range of wind conditions, produce data that can be statistically analysed for the likelihood of failure of components and damage to structural components;
- Develop wind farm layouts and wind farm control strategies to minimise the loads on wind turbines, whilst minimising any power reduction in order to reduce the cost of energy;
- If available, validate the model using data from existing wind farms.

Wind Farm Model

- Supergen wind turbine model implemented with Power Adjusting Controller (PAC) [1]. This allows a dynamic adjustment in power set-point (within limits) without interference with the full envelope controller.
- Wind field model [2] that generates longitudinal and lateral turbulence time series with the required characteristics. The wind-field time series is generated off-line and is used on-line within a wake deficit calculation to output an effective rotor speed for each turbine at each time step.
- Existing wind farm controller deals with droop control and synthetic inertia [2].

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.

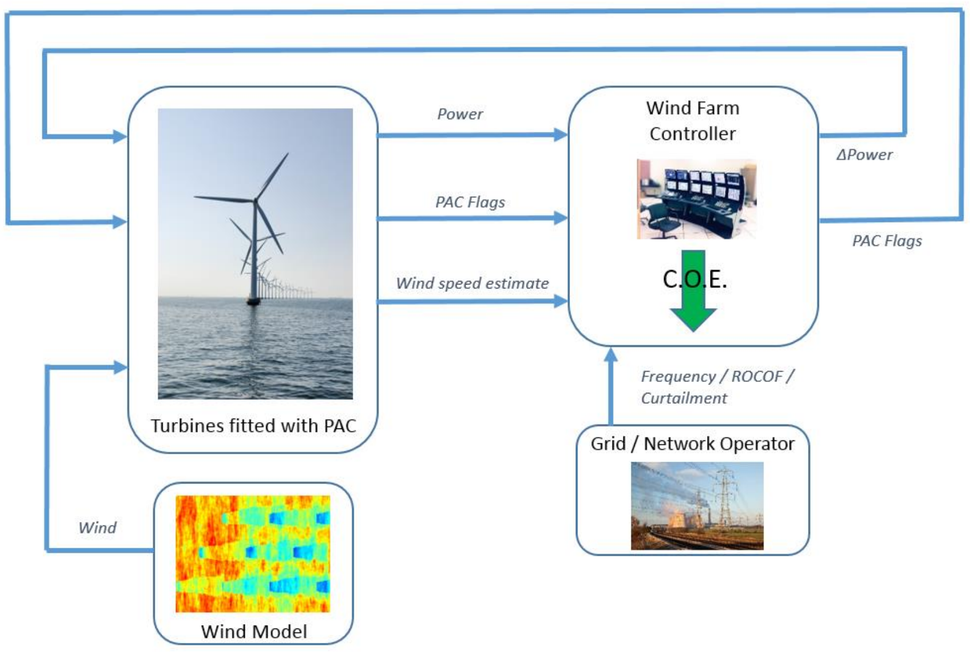

Figure 1: Overview of the components of the wind farm model

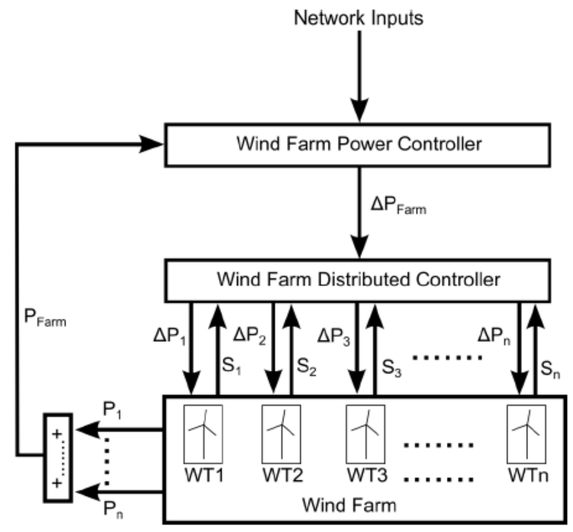

Figure 2: Layout of a wind farm controller with hierarchical structure [1]. Wind farm controller split into two parts – a power controller and a distributed controller. For optimisation of the wind farm the aim of the distributed controller will be to change power in such a manner as to reduce loads on the turbines.

References

[1] "Augmented Control for Flexible Operation of Wind Turbines", Adam Stock, PhD Thesis, University of Strathclyde, 2015
[2] "Wind Farm Simulation Modelling and Control", Saman Poushpas, PhD Thesis, Univeristy of Strathclyde, 2016

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