A Comparative Study of Wind Farm Control Strategies using Surrogate Models based on High Fidelity Simulations

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Introduction
From 2010 to 2018, the global energy production of wind energy has nearly tripled. This increasing trend, shown in Figure 1, is mainly driven by the increasing number and size of individual wind turbines. However, the power production could be even further increased by taking a more holistic approach and maximizing the power production of wind farms as a whole.

![Figure 1: Global energy production of onshore and offshore wind. Credits: ©IRENA](https://www.irena.org/)

Wind farm control (WFC) can be used to reduce the aerodynamic interactions between wind turbines and thus increase the power production of existing wind farms or allow for more compact construction of upcoming wind farms.

Wind farm control concepts
Different control concepts can be applied to control the wakes of wind turbines in order to limit the aerodynamic interactions. One popular option is axial induction control, shown in Figure 2, where an upstream wind turbine is derated such that the downstream turbine can operate in more optimal conditions and increase its production.

![Figure 2: Axial induction control](https://www.irena.org/)

A second option is yaw-based wake redirection control, shown in Figure 3, where the upstream turbine is yawed such that the wake is deflected away from the downstream turbine.

![Figure 3: Yaw-based wake redirection](https://www.irena.org/)

Surrogate models
In order for these control concepts to be effective, it is essential that the downstream turbine(s) make up for the power loss of the upstream turbine(s). Therefore, fast and reliable surrogate models based upon high fidelity large eddy simulations are constructed in order to be able to estimate the power production and fatigue loads of the turbines based on their thrust and yaw settings. The surrogate models will allow for rapid optimization of the wind farm operational settings in order to maximize the power of the wind farm as a whole, opposed to maximizing the power of each individual turbine. Further analysis will also be conducted on the fatigue loads occurring within the wind farm and how these can be optimized by the WFC techniques. Two surrogate modelling approaches are taken for the purposes of this study. The first type of surrogates makes use of the Chaospy Python library to take a polynomial chaos expansion approach to construct the model. Due to the growing interest in the applications of machine learning within the field of wind energy, a second approach is taken using artificial neural networks with the TensorFlow Python library.

Conclusion
WFC techniques are promising approaches to reduced the fatigue loads and power losses occurring within wind farms. A successful optimization of wind farm operations will result in a decreased levelized cost of energy, further encouraging the growth and development of wind energy on a global level.

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2. https://www.irena.org/