Wind plant power optimization and control using multi-fidelity CFD

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Abstract

The development of optimized cooperative wind plant control is an active field of research in the wind industry, where the operation of individual turbines co-located within a wind plant is coordinated to improve the overall power performance. The primary objective of cooperative plant-level control is to improve the net power production by manipulating the trajectory and intensity of wake interactions between nearby turbines, thereby reducing wake losses. However, there are various types of uncertainties involved, such as highly variable microscale and turbine inflow, microscale and turbine model input parameters, as well as the control parameters themselves, such as turbine yaw offsets. The objective of achieving an optimum power production in a wind plant thus becomes a complex problem of design and decision making under uncertainty and some aspects of this problem will be presented.

Keywords: *Wind plant, power optimization, turbine wake, cfd*

Introduction

A recent popular approach towards optimized power performance is yaw-based wake steering, where upstream turbines are yawed to introduce a horizontal deflection of the wake away from the downstream turbines. In a recent NREL-Envision collaboration, a controller that performs wake steering was designed and implemented for the Longyuan Rudong [1] offshore wind plant in Jiangsu, China. The Rudong site contains 25 Envision EN136-4 MW turbines, of which a subset was selected for the field test campaign consisting of the front two rows for the northeasterly wind direction, as shown in Figure 1. In the first row, a turbine was selected as the reference turbine, providing comparison power data, while another was selected as the controlled turbine. This controlled turbine wakes three different turbines in the second row depending on the wind direction. A yaw misalignment strategy was designed using Envision's GWCFD, a multi-fidelity plant-scale CFD tool based on SOWFA [2] with a generalized actuator disc (GAD) turbine model, which, in turn, was used to tune NREL's FLORIS model used for wake steering and yaw control optimization.

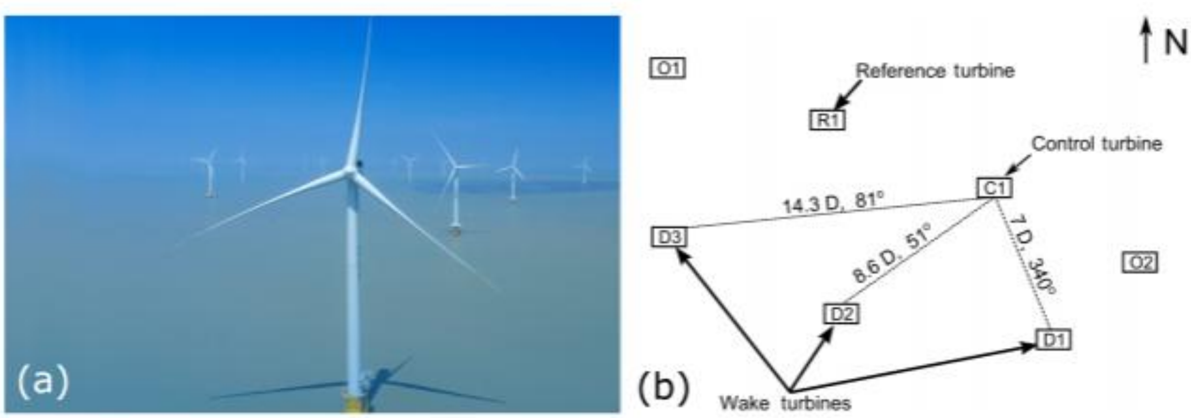

Figure 1: (a) Rudong wind farm used in the field study. (b) Turbine locations. The wake-steering control strategy is implemented to mitigate the wake interactions between C1, on the one hand, and D1, D2, and D3, on the other. As indicated by the diagram, C1 is the control turbine, R1 is the reference

turbine, and D1, D2, and D3 are downstream turbines waked by C1. Turbines O1 and O2 are other turbines not directly used in the study but whose wakes are noticed in certain directions.

Results

The field campaign results indicated a successful improvement in power production. However, the uncertainties associated with the models for CFD simulation and controller design were not considered. In this work, efforts are ongoing for active control of wakes, a formal study to quantify the uncertainties mentioned above, and study their impact on control strategy design. Wind plant flow models involve both aleatoric (irreducible) and epistemic (reducible) uncertainties. For example, the uncertainties associated with the outcome of an atmospheric boundary layer (ABL) model for a given set of governing equations and model inputs are not reducible. However, the uncertainties associated with data extracted from an ABL flow field that serve as input to the turbine model and controller can be reduced by better sampling. The effect of uncertainties in the model input on the output, such as power, are then assessed using low order statistics. This is followed by an inverse problem where the mathematical models for the ABL and turbines are confronted with output data to infer inputs needed to run the model and update control strategies based on the updated predictions. This data-driven uncertainty quantification is expected to yield a more efficient controller design.

References

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