Predicting Offshore Wind Farm Cluster Performance Using RaNS-based Actuator Disc Wind Turbine Model

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ABSTRACT

The EU offshore wind energy sector is rapidly growing, with a significant capacity already installed and large amount of offshore wind farms to be built in the next years. Naturally, these wind farms will cluster around favourable locations, where shallow waters facilitate deployment and onshore grid connection points are available. As distances between Wind Turbines (WTs) inside wind farms and distance between wind farms decrease, minimization of production losses from wakes takes a significant role in making these projects economically viable. The EU project EERA-DTOC [1] seeks to create a tool that facilitates the planning and design of these clusters, and for that purpose it gives great importance to improving estimation of inter-WT and inter-wind-farm wakes and overall wake losses. It is under this project to this subject that this work attempts give a contribution.

By modelling each individual WTs wake and their combined effect using a RaNS atmospheric flow solver we are able to model an entire wind farm and its internal wake effects, estimating the wind farm's performance for a given inflow. The RaNS solver [2] used is specifically tailored for atmospheric flow, and has been used for wind resource estimation purposes for many years. A wake model was developed and integrated into the RaNS solver, based on Froude's Actuator Disc concept [3]. By using an iterative method developed from Froude's one-dimensional theory, feeding on the iterating solution from the RaNS solver, the model [4] is able to predict a WTs performance and wake effect, using only the WTs general dimensions and thrust curve. The perturbed inflow from an upwind wind farm can be considered by previously simulating that wind farm, and using it as source for inlet conditions. This solution keeps individual cases smaller, making the solver runs more robust and overall calculation times smaller, while little loss in the quality of the estimations.

The Rødsand II wind farm, in Denmark was selected as a test case. It has curved WT rows, giving it variable spacing, a good test of a wake model, and while it operates in clean inflow from westerly winds, under easterly winds it operates in the wake of another closely spaced wind farm, Nysted. This allowed the testing of the cluster-scale wake effects in play. Wind farm performance was simulated for different inflows, and model results were compared with operational data from the Rødsand II wind farm. For the Westerly flows the Rødsand II wind farm was simulated, showing overall good agreement with SCADA data. When modelling Easterly wind both Nysted and Rødsand II wind farms were simulated, sequentially, to produce improved inflow data for the Rødsand II wind farm. This precursor solution to modelling wind farm clusters allowed the model results to replicate the large deficit area in Rødsand II, initiated by the Nysted wind farm, visible in the SCADA data.

On some inflow directions, where flow is most aligned with the rows, there is an increasing disagreement between SCADA data and model results as one progresses down the rows. We expect this to be due to a difficulty already identified previously: the inability to simulate the wind directions width filter applied in the filtering of the SCADA data, something the model can only replicate by averaging an ensemble of runs slowly varying inflow direction.

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