Linearity analysis of wake effects induced by complex terrain and wind turbines through CFD wind farm models

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ABSTRACT

Wind turbine wakes have been widely simulated through engineering models for the estimation of wind speed and power deficits inside wind farms. These models were designed initially for wind farms composed by a few wind turbines located in flat terrain. Other models based on the parabolic approximation of Navier Stokes equations have been developed later on, making thus more feasible the operational resolution of big wind farms in flat terrain and offshore sites, where power deficits are mainly induced by the wake effect of upstream wind turbines. These models have demonstrated to be accurate enough when solving wake effects for this type of environments.

Nevertheless, very few analysis exist on how complex terrain topologies can affect the behaviour of wind farm wake flow and its evolution downwind of a wind turbine or even a wind farm. Recent numerical studies [1] have demonstrated that topographical wakes induce a significant effect over the evolution of wind turbines wakes, compared to the flat terrain case. This circumstance has recommended the development of elliptic CFD models which allow the complete simulation of wind turbine wakes in complex terrain.

A fair simplification for the analysis of wind turbine wakes in a wind farm is the so-called actuator disk technique. Coupling this technique with CFD wind models enables the estimation of wind farm wakes preserving the essence of the physical phenomenon present on wind farm wakes. The rotor is modelled as a disk in which a distribution of uniform forces are applied, acting thus like axial momentum sink areas. These forces are prescribed from the upstream wind speed, the thrust coefficient curve of the installed wind turbines and the rotor area.

This paper describes the analysis and validation of an elliptical CFD wake model [2] against experimental wake data from a real operating wind farm located in complex terrain and composed by 43 wind turbines. The analysis reports from experimental evidences whether it is possible to superimpose linearly the effect of terrain and wind turbine wakes or whether it is necessary to resolve the combined effect in one single simulation. It also represents one of the first attempts to observe how engineering models remain valid or not in large complex terrain wind farms in comparison to CFD wind farm models.

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