Saint-Nazaire wind farm offshore wind resource assessment considering boundary layer interactions and non-stationary processes

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The construction of a new offshore wind farm has been awarded off the coast of Saint Nazaire in France within the country's first offshore wind tendering process. With 78 km² surface and 80 wind turbines, the whole wind farm totals 480 MW which should cover the power demand of 700 000 inhabitants. The objective of this work is to perform wind resource assessment for the area using numerical modeling which includes the effects of turbulent wind flows validated with data from coastal onshore meteorological masts.

WRF (Weather Research and Forecasting Model, Michalakes et al.1998) simulations are carried out in order to consider global wind conditions over a mesoscale area of the future wind farm.
The WRF results are then downscaled to a microscale wind simulation model based on CFD package. The flow around a small group of turbines is finally investigated more in detail by running non-stationary simulations with a Large-eddy Simulation (LES) tool based on OpenFOAM®. The latter is developed by the National Renewables Energy Laboratory (NREL) and named SOWFA (Simulator for Offshore Wind Farm Application). Non-stationary LES modeling also provides power production and fatigue outputs when run with an aero-elastic turbine model.

A statistical analysis of the global wind data over several years is carried out to initiate the work for the Saint Nazaire site. A focus is made on two wind regimes: the most common wind typical of the site's location and the extreme winds over the period. For the micro-scale side, a wind farm design CFD software is used to determine the stationary flow over the area. The flow is computed by solving the Reynolds-averaged Navier-Stokes equations (RANS) for steady motion of an incompressible Newtonian fluid using Boussinesq eddy-viscosity assumption. For the present work a k-epsilon turbulence model is used. A SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) algorithm is used to couple the Navier-Stokes equations with an iterative procedure. The model automatically takes into account both elevation and roughness variations of the ground coastal surface. The output of the micro-scale simulation is a stationary flow field for the selected periods used for continuing the refinement to the non-stationary level.

SOWFA (Simulator for Offshore Wind Farms Application) is a recent simulation tool combining an ABLS (Atmospheric Boundary-Layer Solver), with the aero-servo-elastic wind turbine model FAST (Fatigue, Aerodynamics, Structures and Turbulence), both developed by the NREL (Cordle and Jonkman, 2011). The ABLS uses a LES formulation and is also based on OpenFOAM®. It considers incompressible flow and the momentum equation includes a modeled buoyancy force. The Coriolis force is also taken into account. The use of LES allows to simulate flow fields instantaneously and to resolve small turbulent scales by means of a Smagorinsky model. This allows a very realistic representation of the flow in an Atmospheric Boundary-Layer.

The grid nesting from WRF to SOWFA is able to simulate very fine wind fields taking into account the ABL interactions. The validation work is carried out by comparing coastal masts measurements to the whole model outputs. The differences between the wind and turbulence characteristics for both wind regimes are analyzed and discussed. Conclusions based on the wind field analysis are given for the Saint Nazaire wind farm.

Michalakes J, Dudhia J, Gill D, Klemp J and Skamarock W, (1998), *Design of a next-generation regional weather research and forecast model : Towards Teracomputing*, World Scientific, River Edge, New Jersey, 1998, pp. 117-124.
Cordle A, and Jonkman J (2011), *State of the Art in Floating Wind Turbine Design Tools*. GL Garrad Hassan, ISOPE 2011.