Development and validation of a wake model fed by blade loads estimated wind conditions

Wind turbine wake physics is by nature unsteady and highly sensitive to the local wind characteristics. While modern Computational Fluid Dynamic methods (eg: Large Eddy Simulation) allow to accurately capture the flow at the wind farm scale, they still come at a prohibitive computational cost, preventing their use for online control or Machine Learning schemes.

This work aims at developing a computationally affordable yet robust wake meandering model. The latter is based on the commonly used passive tracer hypothesis which states that the wake is advected by the downstream background flow.

Providing a robust wake characterization requires the knowledge of the upstream wind conditions, i.e. velocity and turbulence intensity. Following previous work of Bottasso et al.[1], an Extended Kalman Filter was developed to estimate the wind profile upstream the wind turbine based on the blade loads. The flow characteristics as estimated by the filter are then fed to the wake model as input parameters.

The present study assesses the performances of both the wind estimator and the wake model on the NREL 5MW wind turbine thanks to data recovered from high fidelity numerical simulations [2]. An Immersed Lifting Line-enabled Vortex Particle-Mesh method is used for simulations at the scale of a single wind turbine, while windfarm simulations are performed by a fourth-order finite difference Large Eddy Simulation code.

[1] Bottasso et al., Renewable Energy, 116, 155 (2006)
[2] Moens, PhD Thesis, UCLouvain (2018)