Keywords: wind sensing, load measurements, turbulence.

Local estimation of wind speed and turbulence using wind turbine blades as sensors

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Knowledge of the velocity field upstream of a wind turbine is needed in order to maximize power production as well as alleviate blade loads. This work is in line with the current trend consisting in using wind turbines as sensors and presents a method to estimate wind speed and turbulence based on blade load measurements. The long-term goal of this research is to leverage local information estimated this way to allow the control of individual turbines.

Bottasso et al.[1] present a method dedicated to estimating the Rotor-Effective Wind Speed by a Blade-Load-based Estimator. The latter is an Extended Kalman Filter (EKF) and models the system by means of a so-called cone coefficient, which is an image of the out-of-plane root bending moment (M_{oop}, see Fig.1(b)).

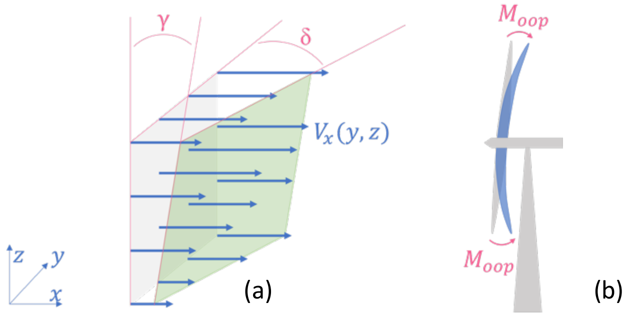
For the present work, we made the choice to use a Blade Element Momentum theory (BEM) to represent the physics of the system. This BEM can take non-uniform velocity profiles into account on each blade of the turbine. The M_{oop} comes as an output of the EKF. The synthetic M_{oop} measurements provided to the EKF are extracted from high fidelity numerical simulations performed on the NREL 5MW wind turbine[2]. Data were computed with an Immersed Lifting Line-enabled Vortex Particle-Mesh method as well as a fourth-order finite difference Large Eddy Simulation code. The wind speed and turbulence level estimated by the EKF are compared with those given by the numerical simulations.

Currently, the method allows to determine at each time step a linear approximation of the instantaneous velocity field upstream of the rotor (see Fig.1(a)). The linear interpolation coefficients are consistent with the expected values given by the simulations. The method also allows to determine the overall turbulence level of the upstream wind, which is well correlated with the turbulence level extracted from the simulations.

By the time of the conference, we will have extended the current method to capture turbulent characteristics of the incoming wind at a local scale. Part of the upcoming work will focus on recovering turbulence spectra from the EKF estimates. We eventually intend to use these local characteristics of the upstream flow to perform load alleviation.

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement no. 725627).

Figure 1:
(a) Linear approximation of the velocity field
(b) Out-of-plane root bending moment



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[1] Bottasso et al., *Renewable Energy,* **116**, 155 (2017)
[2] Moens, *PhD Thesis,* UCLouvain (2018)