Master thesis offer (6 month)

Wind inflow customization at the wind turbine blade scale using wind tunnel measurements and CFD simulations

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Salary: ~660 euros/month

Key-words: wind inflow, wind energy, wind tunnel measurements, CFD

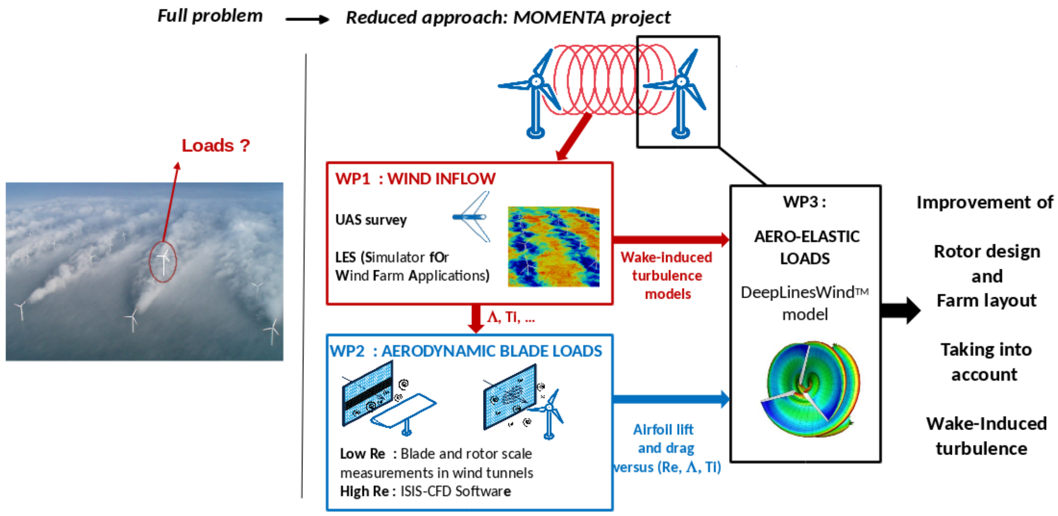
Context:
Wind energy is a clean and renewable energy source. Increasing the share of wind energy is therefore one of the solutions to decrease carbon emissions and thus curb global warming. However, for wind energy to be cost-effective, one key issue that has to be addressed is the increase of the wind turbine lifetime and in particular the lifetime of the rotor. To achieve this, it is important to reduce the loads and the load fluctuations that are acting on the rotor and that cause significant fatigue damages. On the rotor blades, the origin of rotor in-plane load fluctuations comes mainly from the atmospheric, turbulent wind in which wind turbines operate (Rezaeiha et al, 2017). However, while the turbulent fluctuations in the wind play an important role in the generation of high loads, most of the available aerodynamic load datasets used in aero-elastic solvers come from wind tunnel experiments at low turbulent intensities (Ti~0.3%). To close this gap, field measurements would be an option. However, these field measurements of aerodynamic loads would have to be combined with measurements of the incoming atmospheric conditions. This is a rather complex and expensive task due to the difficulty to install sensors on the rotor blades and to isolate and statistically analyze the impact of specific events (Snel and Scheppers, 1991 & 1993; Troldborg et al, 2013). Therefore, wind tunnel measurements on 2D airfoils in turbulent inflow conditions pose a good alternative. However, applying the desirable inflow perturbations is not straighforward due to the complexity of the turbulent wind in the atmospheric boundary layer and the turbine's rotation. Mean wind shear effects that cause sinusoidal load fluctuations due to the turbine's rotation can be modeled using an active rotation of the wing (see e.g. Melius et al, 2016 ; Jaunet et al, 2018) or a sinusoidal inflow (e.g. Wei et al. 2019a and Wei et al. 2019b). Moreover, grids added at the inlet of the test section can be used to increase the turbulence and thus simulate the impact of atmospheric turbulence on aerodynamic loads acting on the rotor blade (e.g. Sicot et al, 2006). Active grids can also be used to reproduce mean and spectral features similar to those found in the atmospheric boundary layer (Reinke et al, 2017) or to generate gusts (Traphan et al. 2018, Wester et al. 2018). While some turbulent inflow conditions have been reproduced in wind tunnel setups, nothing is yet implemented to reproduce a realistic inflow at the blade scale when the wind turbines are arranged in wind farms and thus possibly subjected to the wakes of upstream turbines that can have high mean shears and turbulence levels.
The objective of this master thesis is to work with an existing new perturbation system that was especially built to induce strong, rapid, turbulent gusts. A first characterization has already been performed by Neunaber & Braud (2020). The succesfull candidate will further customize and characterize this system to create realistic inflow conditions. The work will be performed within the framework of the national project ANR MOMENTA (WP2, blade scale).
We are looking for a candidate who is interested in continuing on the topic after the Master thesis during a PhD thesis funded by the ANR MOMENTA project. Whithin this PhD thesis, the impact of the previously customized inflows on different blade sections will be investigated, from low

Reynolds numbers (wind tunnel) to full scale Reynolds numbers (simulations). The different blade sections will be chosen from the existing blade scanning of a 2MW wind turbine in operation. Different inflows characteristics (turbulent Inflow, turbulent length scales …) will be provided by the WP1 of the ANR project using field measurements (meteorologic mast, drone and scanning LIDAR).

Working plan:
- The Master candidate will first perform and analyze PIV measurements of the inflow to complete the work of Neunaber & Braud (2020).
- Finally, depending on the candidate and the remaing time, the chopper blade configuration can be investigated numerically using the in-house ISIS-CFD solver under the suppervision of E. Guilmineau.

Applicant profile:
Master candidate in fluid mechanics willing to work in the field of wind energy, predilection for both experiments and numerics

ANR MOMENTA:
The objective of the MOMENTA project is to improve the estimation of aero-elastic loads in a configuration which appears more and more frequently with the current wind farm layouts, namely the specific case of a wind turbine exposed to the turbulent features of the wake of an upstream wind turbine (called later Wake-Induced Turbulence). The project proposes thus to provide an accurate description of two necessary aspects:
- the Wake-Induced Turbulence using original drone measurements (WP1, WIND INFLOW)
- the impact of this Wake-Induced Turbulence on aerodynamic loads using both wind tunnel measurements and CFD computations (WP2, AERODYNAMIC BLADE LOADS).
Then, these improved descriptions will be implemented in the aero-elastic wind turbine design solvers (WP3, AERO-ELASTIC SOLVERS) for a better estimation of aero-elastic loads. Due to the improvement of the Wake-induced Turbulence description (WP1), this project will also provide a first step towards optimized wind farm layouts in dense configurations, in terms of both energy yield and load reduction.



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