MSc. Thesis Proposal

Title: Uncertainty Quantification of power generation in floating wind turbines

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Introduction

Motivation

During the development phase of a floating wind turbine, the design is often optimized based on a set of physical measurements and/or numerical simulations. This engineering approach can never include all the possible wind conditions in terms of wind speed, angle of attack, turbulence intensity, etc, that the turbine will encounter during its exploitation life. It is therefore crucial to quantify the uncertainties of the measurements and the simulations to understand the impact of each parameter on the turbine performance and to mitigate shortcomings of the design. Two examples of applications where Uncertainty Quantification (UQ) is crucial are detailed hereafter.

Wind generation in a basin.

The prediction of wind turbine performance at model-scale is a challenging task due to the operation in low-Reynolds regimes, where laminar to turbulent flow transition is important, and due to the structural effects, that need to be taken into account due to the long slender turbine blades and tower. Additionally, floating wind turbines operate in a complex environment and require simultaneous prediction of unsteady hydrodynamic and aerodynamic loads, floater motions, and structural response of moorings. Identifying the associated uncertainties of operating in these complex conditions, is a key element in improving the overall performance prediction of floating wind turbines.

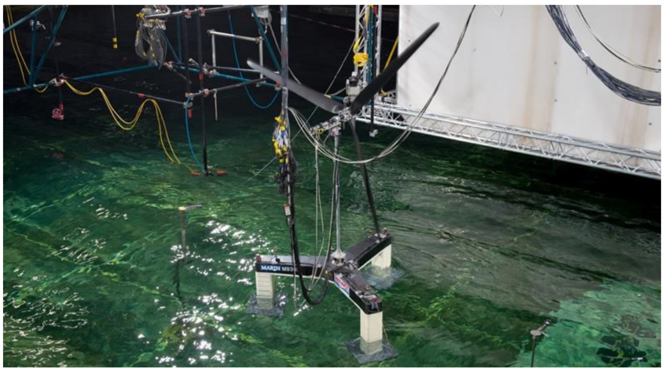

Figure 2: Floating wind turbine tested in waves and wind in the MARIN offshore basin.

Turbine-turbine interaction in an offshore wind farm

In offshore wind farms, turbines are deliberately spaced close together to achieve economic benefits related to area use and to infrastructure. This proximity means that turbines are often strongly affected by the turbulent wakes produced by others that are upwind from them. This spatially varying incoming wind field and turbulent flow have a significant effect on the performance of the turbine, but they are difficult to quantify through measurements. Quantifying the uncertainty of the power output of the turbine given the uncertainty in the incoming

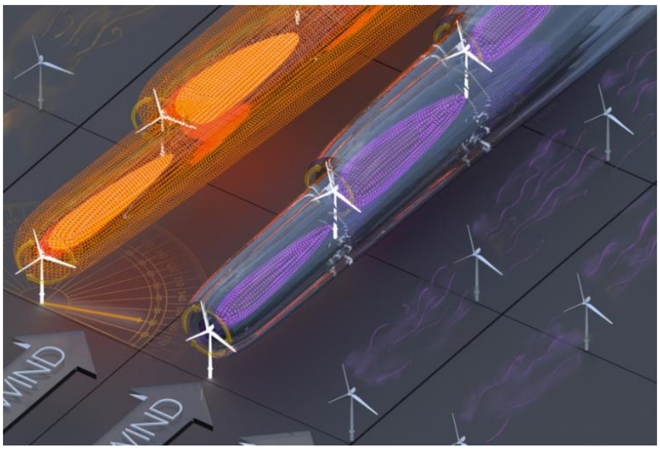

Figure 1: Turbine-Turbine interaction (https://news.mit.edu/2022/wind-farm-optimization-energy-flow-0811)

varying wind field would provide valuable information for the farm operator.

Existing work

blueOASIS recently supervised a Master thesis focusing on the UQ related to the DTU 10MW turbine[1]. The UQ of the thrust and power coefficients was performed considering the inlet velocity and the inlet turbulence intensity to evaluate the combined uncertainty caused by the inputs, the mesh discretization and the associated Sobol indices. The UQ analysis was performed in two steps: (i) Uncertainty Characterization, where the source of input uncertainty (physical or purely numerical) and its nature (aleatory, epistemic) were investigated; (ii) Uncertainty Propagation, where input uncertainties are propagated through models, obtaining parameter uncertainties that affect the outputs. The propagation can be performed either by intrusive methods, requiring modifications in the model equations, or by non-intrusive spectral methods that addresses the model as a "blackbox", not requiring any alteration of the model and being based on a sampling approach [2]. This was done using the code developed by Katsuno et al. [3].

Objectives

The main objective of this work is to carry out a UQ analysis of a floating wind turbine using a low-to-medium fidelity simulation model such as QBlade [4]. We will consider the full geometry of a floating wind turbine or a set of wind turbines in a wind farm, and focus on how the various features of the simulation model affect the performance of the turbine.

The work will be divided into the following tasks:

- Problem configuration in the simulation model:
    - Setup of the set of the wind turbines
    - Setup of the UQ problem; the inputs and their distribution characteristics and the outputs
    - Selection of the features of the simulation model to include in the UQ analysis
- Application of the currently developed UQ method to the results
- Analysis of the results and revisiting the first task if needed
- Reporting and Presentation

Requisites

- Applicants must have: good Python skills, and experience with numerical tools.
- Good to have: Git experience, Linux experience, Knowledge/Experience in Aerodynamics and/or Hydrodynamics of wind turbines, basic knowledge in Statistics and Probability

Location

The student must be present at least 3 days per week at the MARIN office in Wageningen, the Netherlands.

Companies Involved

blueOASIS: www.blueoasis.pt
MARIN: https://www.marin.nl/en

References

[1] M. Andrade, T. Gomes, G. Vaz, and F. Lau, "Uncertainty Quantification for Model-Scale Wind Turbines," in *Numerical Towing Tank Symposium (NuTTS2023)*, Ericeira, Portugal, Oct. 2023.

[2] T. J. Sullivan. Introduction to Uncertainty Quantification, volume 63. Springer International Publishing, 2015. doi: 10.1007/978-3319-23395-6. ISBN: 9783319233949.

[3] E. T. Katsuno, A. K. Lidtke, B. D¨ uz, D. Rijpkema, J. L. D. Dantas, and G. Vaz. Estimating parameter and discretization uncertainties using a laminar-turbulent transition model. Computers and Fluids, 230, November 2021. doi: 10.1016/j.compfluid.2021.105129. ISSN: 00457930.

[4] https://qblade.org