MSc. Thesis Proposal

Title: Quantifying Uncertainties in Flows Over Wind Turbines

Supervisors
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Introduction

Motivation

In the energy transition from fossil fuel to renewable energy sources, wind power is playing a major role. Due to limited space on land, offshore wind energy will become increasingly more important. 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 the structural effects that need to be taken into account due to the long slender turbine blades. Additionally, floating wind turbines operate in a complex environment and require simultaneous prediction of unsteady hydrodynamic 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. This project aims to investigate the uncertainties by utilizing Uncertainty Quantification (UQ) techniques to assess the most important inputs to a typical simulation set up on predicted motion and performance, with a particular focus on validation using uncertain experimental measurements.

Most of the attention will be given to accounting for uncertainties in the wind conditions measured in MARIN's Offshore Basin, Fig.1. In this facility, wind fields may be generated using a dedicated wind fan setup. Fig. 2 shows the spatial wind velocity and wind turbulence; the nozzle is indicated by the dotted ellipse and the rotor is indicated by the solid circle.

In the UQ analysis we intend to investigate two types of uncertainties: input and numerical, as well as their correlation. For the input uncertainties the study of the experimental facilities and setup and their associated imperfections and uncertainties is need. This might also culminate in an analysis of the experimental data uncertainty. For the numerical uncertainties, the CFD calculations will have to be scrutinized in terms of round-off, iterative, statistical and spatio-temporal discretization, as performed in [2] for a propeller case.

This work is of leading-edge scientific and industrial level and almost unique. Therefore, upon good performance of the student and supervising team, this should culminate in a Journal paper.

Existing work

Previously, uncertainty quantification analysis of flat plate and model-scale propeller using laminar-turbulent transition model in CFD was carried out [1,2]. In that work, experience was gained on how to build a surrogate model in CFD in a computationally efficient manner. A particularly challenging aspect of the work was to design a framework to study the combined effect of input and discretization uncertainties. The previously developed approach will be here used, improved and modified if needed. Experimental data by MARIN, see Fig.1-2, will be available during the validation phase.

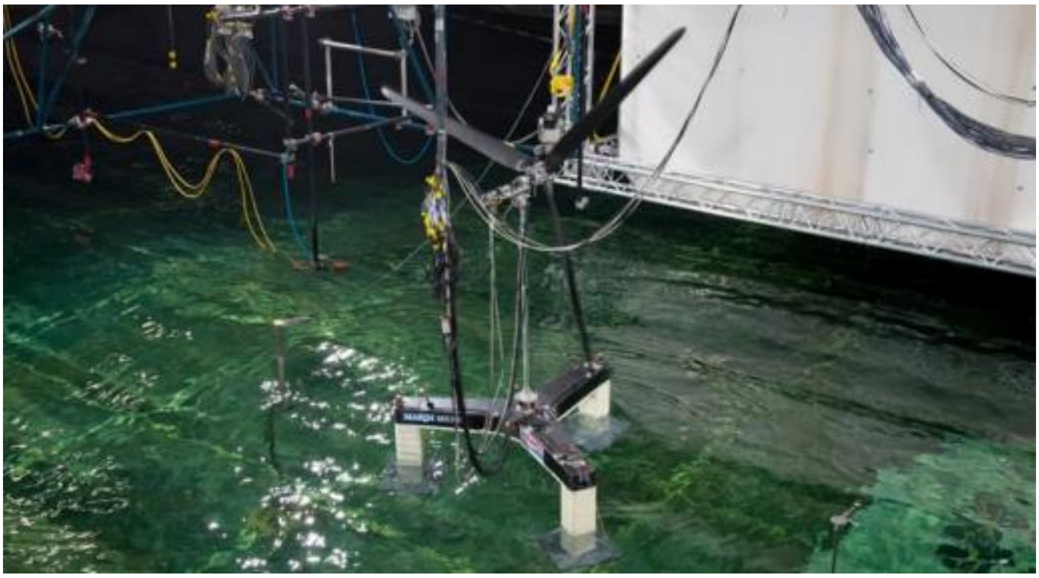

Figure 1: Floating wind turbine tested in waves and wind in the MARIN offshore basin..

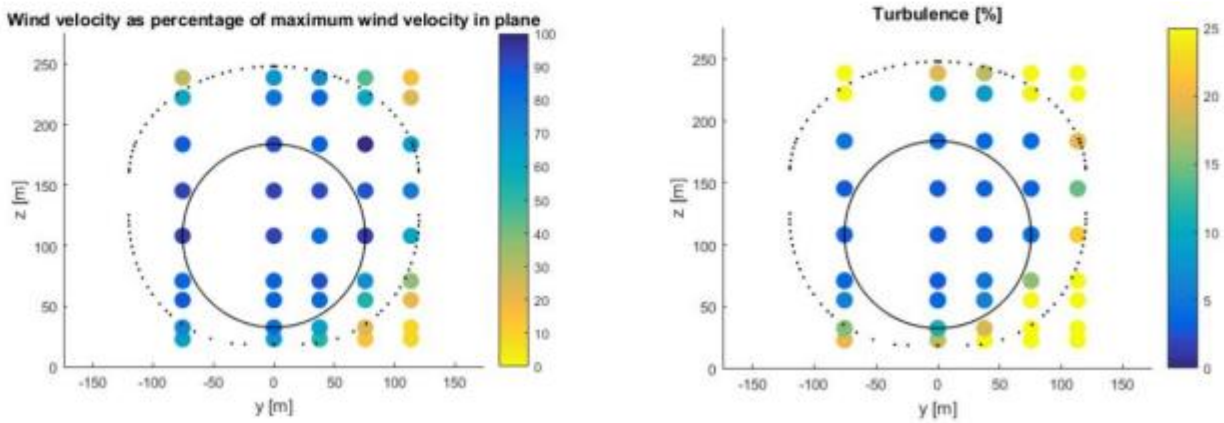

Figure 2: Measurements of spatial wind field. Left: Wind velocity in rotor plane. Right: Wind turbulence in rotor plane.

Objectives

UQ methods will be used for the flow over a wind turbine. The CFD simulations will be carried out with the blueOASIS-MARIN CFD code ReFRESCO. Building upon the experience and knowledge from the previous work [1-4], the scope of the work is as follows:

- Get familiar with the current UQ approach written in Python [1,2].
- Get familiar with using ReFRESCO in the problem of flow over wind turbine [3,4].
- Identify the uncertain input parameters such as wind velocity and turbulence intensity. Characterize their limits and distribution types.
- Generate the meshes to be used in the CFD simulations building on an existing set up.
- Apply the UQ technique to quantify the output uncertainties, with particular attention dedicated to the effects of transition and experimental validation.
- Reporting and presentation. A publication in a conference and a journal is planned, depending on the outcome of the work.

Requisites

Applicants must have:

- General knowledge on CFD.

- Coding experience with python or similar.

Good to have:

- Linux experience.
- Latex experience.
- Git experience.

Added value to have:

- Knowledge on UQ.

Location

blueOASIS (www.blueoasis.pt) Edificio D.Pedro, Quinta da Fonte, R. Malhões, 2770-071 Lisboa The student is invited to join the team in the office when the supervisor is present (at least three days per week).

During the MSc project the student will relate to the R&D department of MARIN (www.marin.nl) in the Netherlands. The people that might be involved at MARIN are Bulent Duz, Artur Lidtke, Douwe Rijpkema and Arjen Koop, as researchers at the R&D department.

Companies Involved

blueOASIS is a young team with more than 45 years of combined knowledge and experience on Aerospace, Mechanical, Naval and Maritime engineering. The multicultural and multidisciplinary team is committed to make our oceans safer and greener, using state of the art numerical and data science tools. BlueOASIS focuses on renewable energies, ocean cleaning, decarbonization, sustainable offshore structures and green ships optimization.

MARIN is the biggest Maritime Research Institute in the World, existing since 1935. It is located in Wageningen, the Netehrlands. MARIN has top-world quality experimental facilities, simulators, HPC resources and around 380 people working on making ships and offshore constructions better, cleaner and safer.

References:

[1] Katsuno, E., Lidtke, A., Düz, B, Rijpkema, D. and Vaz, G., "Parameter uncertainty quantification applied to the Duisburg Propeller Test Case", NuTTS 2019, Tomar, Portugal.

[2] Katsuno, E., Lidtke, A., Düz, B, Rijpkema, D., Dantas, J. and Vaz, G., "Estimating Parameter and Discretization Uncertainties using a Laminar-Turbulent Transition Model", in Computer & Fluids, Aug 2021 (https://doi.org/10.1016/j.compfluid.2021.105129)

[3] Make, M. and Vaz, G., "Analysing Scale Effects on Offshore Wind Turbines using CFD", In Journal of Renewable Energy, Volume 83 pages 1326-1340, November 2015 (http://doi.org/10.1016/j.renene.2015.05.048).

[4] Garrido, A., "CFD Analysis of NREL 5MW Wind Turbine at Model and Full-Scale", Msc, Aerospace Eng, IST, 2021