MSc. Thesis Proposal

Hadi-Gabriel Hammoud
H.G.Hammoud@student.tudelft.nl

Topic: Wind Turbine Structures
Title: Load response model for site suitability and support structure design based on different wind models.
Company Supervisor: Dr. Kai Irschik. Lead Expert WTG Loading, Turbine Systems Engineering. RWE Offshore Wind GmbH, Hamburg, Germany. Kai.irschik@rwe.com.
Academic Supervisor: Prof.Dr. Simon Watson. Professor of Wind Energy Systems and Director of the TU Delft Wind Energy Institute. TU Delft, Delft, Netherlands. S.J.Watson@tudelft.nl.
Expected Completion Date: July 2024.

Motivation

Load calculation is a central service for the site-specific design of wind farms and their sub-structures. With interfaces to almost all disciplines, load calculation feeds into the design of all WTG components. Moreover, site suitability assessment for potential wind farm projects is impossible without a precise estimate of the expected loads. In addition, an improved load calculation work flow can help accelerate wind power project timelines. Consequently, optimizing the load calculation process results in better designs both on the WTG and the wind farm levels. Ultimately, for wind energy, this translates into a lower LCOE, accelerated project timelines and a reduced environmental footprint from a life-cycle perspective.

Problem Statement

Current state-of-the-art load calculation practices in the wind power industry rely on sophisticated aero-elastic software that implement multi-physics models of the WTG and solve the corresponding differential equations in a step-by-step process. This approach, although reliable, is costly and time-consuming. Also, it requires expert knowledge, which introduces a risk of human error. Not only that, but at the early stages of wind farm projects, developers may not have access to the exact aero-elastic models of the considered commercial turbines (since these are manufacturer property). All these considerations call for the development of a simplified, yet robust approach for load calculation that does not requires the performance of numerous aero-elastic simulations.

Objective

The aim of this thesis is to develop a so-called Load Response Model (LRM) for wind turbine load calculation. This LRM takes the form of a set of analytical formulae that map site-specific wind climate parameters (e.g. mean wind speed distribution, turbulence intensity, wind shear, etc...) to a set of IEC-compliant load metrics that characterize the ultimate and fatigue limit states of the considered turbine class (see Figure 1). The LRM can thus be used by wind farm developers to guide sub-structure design and to evaluate site suitability for different commercial turbine classes at early project stages.

The starting point is to compile an extensive load catalogue by running a large number of aero-elastic simulations for a variety of wind climate combinations and using different wind models. Then, the load catalogue shall be converted into an LRM by applying relevant mathematical techniques, such as Taylor series approximation or statistical regression (see [6]) or even artificial neural networks (see [3]).

Multiple LRMs for wind turbine loads have been developed for both commercial (see [2] and [5]) and academic purposes (see [1], [3], [4] and [6]). However, most of them have been derived based on a single turbulence model, namely the Kaimal model. Nowadays, more elaborate models, such as the Mann model and the DWM model, have been introduced into the IEC standards. Hence, it is expected that the incorporation of these models into the LRMs would yield more accurate results, especially in a wind farm setting.

This thesis aims to address these issues by applying various wind models in the derivation of the load catalogue. Furthermore, different wind-wave scatter distributions will be considered, leading to a more comprehensive coverage of the offshore wind climate conditions. Finally, the intention is to benchmark the obtained LRM against the commercial model implemented in the WindPro software (see [2]). This will be done with the assistance of RWE lead experts based on actual project data from the RWE fleet.

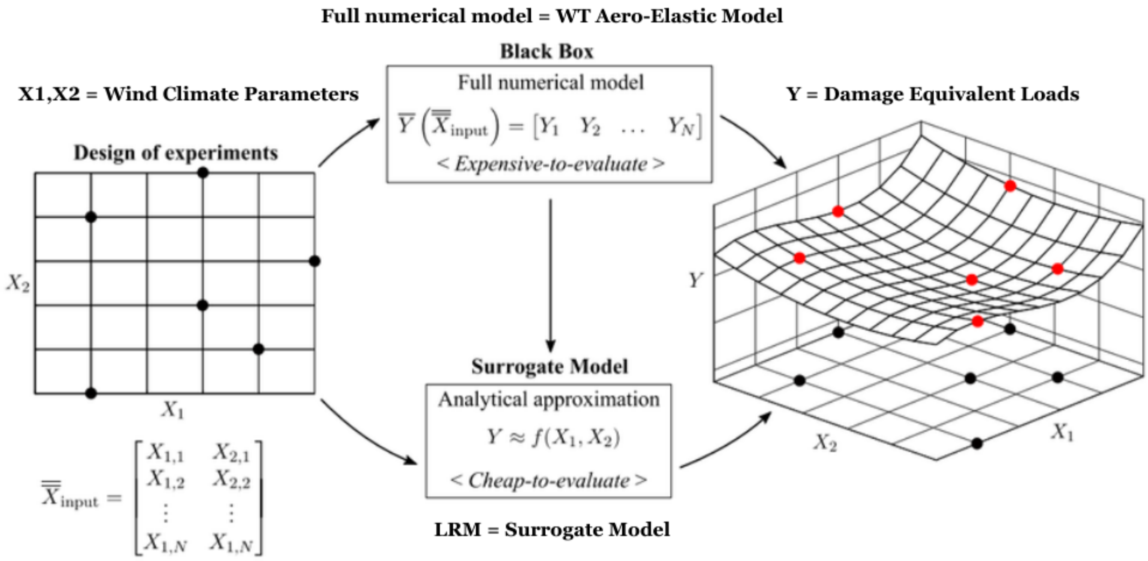

Figure 1: Illustration of the LRM concept in the context of load calculation (adapted from [5])

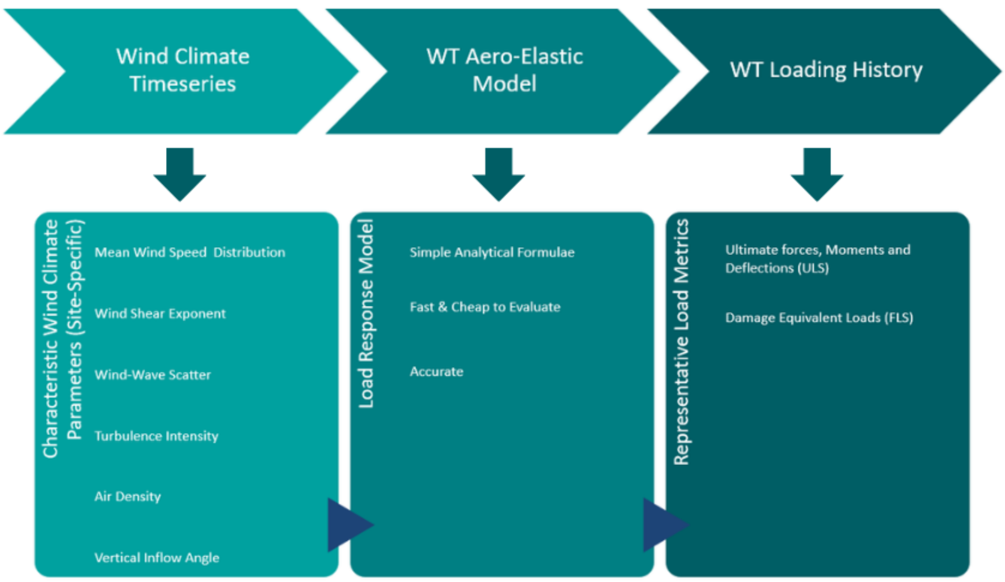

Figure 2: Illustration of the intended outcome of the thesis

References

[1] Dimitrov, N., Kelly, M., Vignaroli, A., & Berg, J. (2018). From wind to loads: wind turbine site-specific load estimation using databases with high-fidelity load simulations. Wind Energ. Sci. Discuss, 375, 767-790. DOI: https://doi.org/10.5194/wes-2018-18

[2] EMD International. Description of the LOAD RESPONSE module of the wind farm modelling software windPRO. DOI: https://www.emd-international.com/windpro/windpro-modules/load-modules/load-response/.

[3] Müller, K., Dazer, M., & Cheng, P. W. (2017). Damage assessment of floating offshore wind turbines using response surface modeling. Energy Procedia, 137, 119-133. DOI: https://doi.org/10.1016/j.egypro.2017.10.339.

[4] Mouzakis, F., Morfiadakis, E., & Dellaportas, P. (1999). Fatigue loading parameter identification of a wind turbine operating in complex terrain. Journal of Wind Engineering and Industrial Aerodynamics, 82(1-3), 69-88. DOI: https://doi.org/10.1016/S0167-6105(98)00211-6.

[5] Slot, R. M. M. (2019). From Wind Climate to Wind Turbine Loads: efficient and accurate decision support and reliability analysis. PhD thesis submitted to Aalborg University, Denmark. DOI: https://vbn.aau.dk/en/publications/c60ab64e-df05-4442-9fed-5bcd9c1bc132.

[6] Toft, H. S., Svenningsen, L., Moser, W., Sørensen, J. D., & Thøgersen, M. L. (2016). Assessment of wind turbine structural integrity using response surface methodology. Engineering Structures, 106, 471-483. DOI: https://doi.org/10.1016/j.engstruct.2015.10.043.