Fatigue damage assessment and lifetime prediction of a FOWT platform subjected to multiple non-linear stochastic load sources

Project acronym BEL-Float
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Motivation

The development of offshore wind energy is of high importance for the global energy transition. The most common types of offshore wind turbine platforms are bottom-fixed foundations. A limitation of these foundations is that they only make commercial sense to water depths of up to 60m. This considerably restricts the areas suitable for the generation of offshore wind energy. Floating offshore wind turbines (FOWTs), as shown in Figure 1, do not have this depth constraint and are making great progress due to a significant amount of worldwide research. At the time of writing only four operational FOWT farms exist in Europe, but several FOWT types are under development or have reached the prototype stage.

For Belgium to maintain its significance in the global offshore (wind) industry and academic landscape, it is not only necessary to enter this emerging and promising market of floating wind, but also to strive to develop expertise and knowledge to position itself as one of the leading countries in the development of FOWTs. Hereto the BEL-Float project was established, consisting of six research tracks. It aims to develop a competent and long-term academic base, and to kickstart the development of floating wind energy in Belgium. For this project, the universities UGent and VUB will perform research in close collaboration with industry and Norwegian universities (University of Stavanger and the University of Bergen).

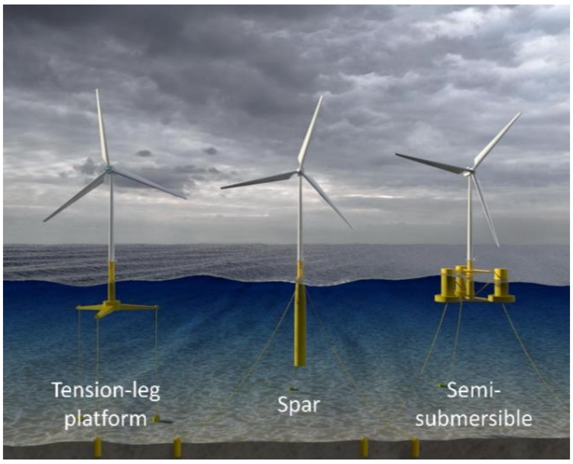

Figure 1: Different FOWT types [1]

One of the many challenges in designing a FOWT is understanding the fatigue behaviour of the floating substructure. The variable hydrodynamic, aerodynamic, and mooring line loads, combined with a non-stationary platform, lead to complex and dynamic stress states. Safe design of a FOWT platform requires **numerical models to assess the fatigue loads, the (local) accumulation of fatigue damage, and ultimately to accurately predict the lifetime of the floater**.

Objectives

In the context of the BEL-Float project, this PhD encompasses the following objectives:

- Develop computationally efficient, multi-dimensional models to identify fatigue critical features of a FOWT platform;

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- Develop algorithms to calculate the local fatigue damage accumulation and its impact on the global lifetime;
- Perform sensitivity studies to gain insight into fatigue dominating mechanisms from a perspective of environmental load conditions and geometrical design choices.

Approach

To attain the previously mentioned objectives, numerical simulations of the dynamic response of a reference FOWT system will be performed under various loading conditions. The results of these simulations will be used to develop fatigue spectra accounting for various site-specific operational conditions and extreme weather events.

Simultaneously, a comprehensive and multi-dimensional strategy is set to be devised for the precise calculation of fatigue-critical stresses, commonly referred to as "hot spot" stresses. This strategy will rely on the utilization of finite element (FE) sub-models (Figure 2), focusing on critical components of the platform. Dynamic loads originating from hydrodynamic, aerodynamic, mooring line, and tower-base loads (Figure 3) will be extracted from simulations of a global model and will be used as boundary conditions for these compliant sub-models.

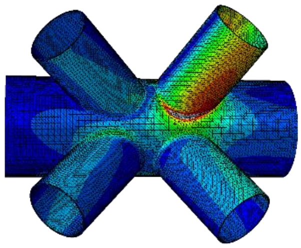

Figure 2: FE sub-model of an offshore lattice structure

The calculated hotspot stresses will then be used for a profound fatigue analysis. For this purpose, open-source algorithms will be developed, utilizing both time domain-based (as a reference) and spectral-based approaches, to accurately capture the nonlinear structural dynamics of a FOWT system. The performance of these tools will be assessed in terms of accuracy of the damage equivalent load and the computational effort.

Note that the fatigue-critical locations of a floater member or feature are load-case dependent and that multi-axial stress conditions will be present at these locations. This means that the validity of using a single stress concentration factor for hotspot stress calculations will be limited and that the development of advanced interpolation and superposition methods will be necessary to assess the fatigue damage over time at different locations.

To this end, stress-based and fatigue damage parameter-based approaches will be developed and critically assessed.

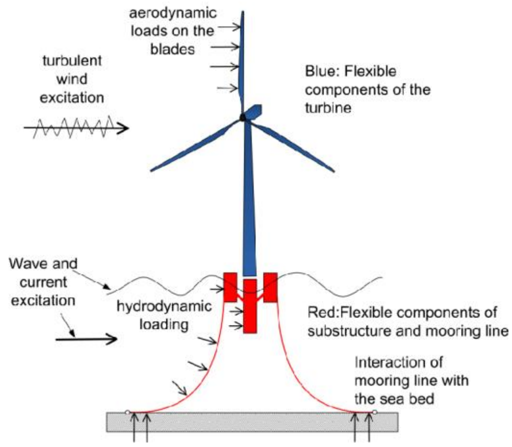

Figure 3: Dynamic loads of a FOWT system [2]

In a final step, surrogate models based on neural networks will be established to reduce the computational costs of a detailed fatigue assessment in the iterative stages of the design process. These models will map the fatigue strength to different environmental and operational conditions. The feasibility and performance of this method will be evaluated on a key feature of a FOWT system.

References

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