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Lifetime extension for large offshore wind farms: Is it enough to reassess fatigue for selected design positions?

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Abstract

Fatigue reassessment within the decision process of lifetime extension might be uneconomical when individually performed for each turbine of a large offshore wind farm. This paper analyses the possibilities to extrapolate results from fatigue reassessment of wind turbines at selected design positions to other wind turbines of the wind farm. Five monopile-based turbines placed in a generic offshore wind farm were assessed with integrated aero-hydro-elastic simulations. A fatigue assessment was performed for each out of the five selected turbines using site specific environmental data commonly available during the design process. The results were compared to a fatigue reassessment where environmental data were modified in order to account for changes in environmental conditions during the service lifetime of the wind turbines. Results indicate that an extrapolation is feasible for selected parameters when changes in environmental conditions are small. This is an important step towards an effective and efficient assessment methodology for lifetime extension of offshore wind turbines.

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Keywords: Offshore wind turbine; lifetime extension; fatigue reassessment; design position; extrapolation

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1. Introduction

The discussion in the wind industry on lifetime extension of turbines is receiving increasingly more attention. This is naturally driven by the onshore wind industry as more wind turbines are close to the end of their design lifetime already today. Wind turbines are typically designed for 20-25 years and must be decommissioned afterwards. Once lifetime extension becomes important for offshore wind turbines (OWTs) in five to ten years, several issues will differentiate the analysis from onshore. For instance, OWTs are designed site-specifically and turbine downtime may increase loading as pointed out by Ziegler & Muskulus [1]. In addition, offshore wind farms are typically larger, easily inheriting more than 100 turbines. For lifetime extension of onshore wind turbines, every turbine is assessed individually if it has enough structural reserves according to [2]. In large offshore wind farms, however, an individual assessment of every turbine is potentially uneconomic.

Water depth and soil conditions may vary significantly in large offshore wind farms. Ziegler et al [3] presented the influence of site variations on the load level and design process of monopile substructures for OWTs. After several years of turbine operation, measurement data may show that environmental and operational conditions differ from assumptions in the design phase. It is then necessary to reassess fatigue in order to decide if structural reserves are present which potentially allow an extension of the operational life.

Ziegler & Muskulus [1] recently presented fatigue reassessment for monopile-based offshore wind turbines and concluded on the importance to monitor specific parameters during the operational phase of offshore wind parks. Furthermore, it was shown in [4] that wave fatigue loads are sensitive to site conditions. Studies suggested a concept to extrapolate loads from one turbine to the entire wind farm based on in-situ load measurements [5],[6]. However, to the knowledge of the authors, there is no study on the relation between design and numerical fatigue reassessment for different positions within an offshore wind farm.

The purpose of this study is to assess whether it is possible to extrapolate results from fatigue reassessment of selected design positions to the entire wind farm. The study uses a generic wind farm consisting of 100 wind turbines placed in the North Sea. Five turbines of the wind farm with differences in water depth, soil conditions and neighbouring turbines are randomly selected for this study. The numerical models and environmental conditions used for the study are presented in Section 2. Fatigue reassessment is individually performed for each out of the five turbines of the wind farm. Section 3 explains the approach used for the fatigue reassessment and how it is compared with the fatigue assessment in the design process. Results are shown and discussed in Section 4 and a conclusion is drawn in Section 5.

2. Numerical models and environmental conditions

Subject of this study is an offshore wind farm consisting of generic monopile-based offshore wind turbines. The monopile support structure used in Phase II of the OC3 project [7] with the NREL 5MW reference wind turbine atop [8] serves as a reference model. Load simulations were performed for five turbine positions within the generic wind farm. The positions differ in terms of water depth, soil conditions, and wake effects, whereas wave conditions are assumed to be identical for all positions within the wind farm.

2.1. Support structure model

The five OWTs under study with their soil and water depth's conditions at each position in the wind farm are shown in Fig. 1. The height of the rotor and tower bottom with respect to the mean sea level is identical for all turbines. This requires an adjustment of the length of the monopile according to the water depth. A soil penetration depth of 36m is kept constant for all positions.

Table 1. Water depth and first natural frequency of each position.

Parameter	Unit	Pos. 1	Pos. 2	Pos. 3	Pos. 4	Pos. 5
Water depth	[m]	15	20	22	26	30
First natural frequency	[Hz]	0.246	0.237	0.232	0.226	0.217

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