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Comparison of numerical response predictions for a bottom-fixed offshore wind turbine

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Abstract

Numerical simulations are widely used for response calculations on offshore wind turbines. Code-to-code comparisons are frequently used for verification of the codes, as full-scale measurements can be difficult to obtain. However, most code comparisons performed focus on documenting the responses predicted by the different codes, or on the effect of specific differences between the codes. Little insight is provided to how these differences would affect design calculations, such as the fatigue utilization. In this paper, the response predictions of the programs SIMA, vpOne and FAST are compared using the DTU 10 MW reference wind turbine on a monopile foundation. While differences in the models are first highlighted through a number of simplified load cases, a lifetime fatigue evaluation of the model is then performed for the monopile at mudline. In the deterministic load cases the response of all models are quite similar, while some differences become apparent in the stochastic analysis. For the fatigue calculations, a difference of 14 % is found in the damage equivalent bending moment at mudline. This demonstrates how sensitive the fatigue utilization is to small differences is code capabilities and modelling.

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Keywords: Bottom-fixed wind turbine; code comparison; stochastic wind and waves; fatigue

1. Introduction

The most widely-used method for analysis of offshore wind turbines (OWTs) is numerical time-domain simulations. However, limited access to full-scale measurements makes it difficult to validate the computer codes against real-life measurements. Software-to-software comparisons have therefore been used extensively in verification of developed codes. Here, the OC3, OC4 and OC5 projects [1–4] stand as the greatest efforts, with a large number of institutions and codes contributing to large-scale comparisons. Other code comparisons have also been performed; either with the introduction of new code features or as more ad-hoc investigations to explain differences between the codes [5–10].

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In addition to verifying the theory implementations, code-to-code comparisons are suitable for investigating how different solution methods affect the calculation results. A large number of different calculation and solution methods are available and implemented in the different codes. Aerodynamic loads are typically calculated using the blade element momentum theory (BEM), while CFD analyses and generalized dynamic wake are examples of alternative calculation methods[11]. The BEM theory can also include a number of engineering corrections. Wave kinematics can be calculated using linear or higher order wave theory, and integrated to the mean or instantaneous free surface. Furthermore, a number of options are available for modelling of soil-structure interactions. Kühn [12] presents three options for a monopile structure: the use of nonlinear springs along the length of the pile, implementation of a translational and rotational spring at the mudline, or the use of an equivalent cantilever beam. Finally, the structural dynamics can be analysed using either the finite element method, modal analysis, multibody dynamics or a combination of these.

This paper aims at investigating how the calculated fatigue utilization will vary between different computer codes. To do this, the DTU 10 MW reference wind turbine [13] is modelled in SIMA v3.3.2 from SINTEF Ocean, FAST v8 from NREL and vpOne from Virtual Prototyping. The paper will first present the model, before an overview of the theory implementations and modelling capabilities of the codes will be given. Following this, the response to deterministic load cases are presented to easier identify the differences between the codes. Finally, a number of stochastic load cases are analysed before a simplified fatigue analysis is performed.

2. Model Description

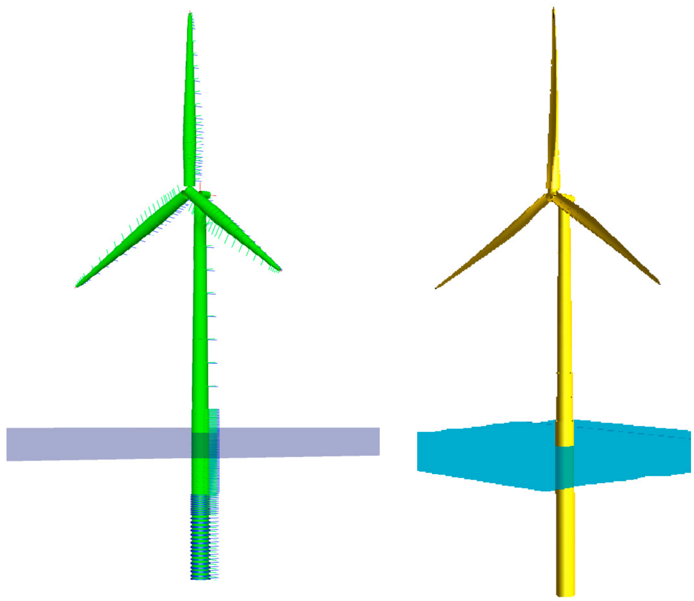

Fig. 1. Model in SIMA (left) and vpOne (right)

The turbine used in the analyses is the DTU 10 MW reference turbine, as described in [13], with the basic DTU 10 MW controller [14]. In order to reduce the natural period, the wall thickness of the tower has been increased by 20 %. Furthermore, the inner foils of the turbine have been modified, both following [15]. The turbine is placed on a monopile foundation in 30 m water depth, which extends to 42 m below the mudline. The transition piece is modelled from 10 m below the mean water level (MWL) to 11.5 m above MWL. Both the transition piece and monopile have an outer diameter of 9 m, while the thickness is set to an equivalent thickness of 0.15 m for the transition piece and 0.11 m for the monopile. Soil properties are taken from Dogger Bank, and the soil is modelled as non-linear springs using the p-y curves in accordance with [16] in SIMA and vpOne. In FAST, an equivalent cantilever beam is used to represent the soil stiffness. Structural damping was modelled as mass and stiffness proportional damping in SIMA