Numerical Comparison of Drifting Sea Ice and Wave Loads on Different Offshore Wind Turbine Support Structures

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Introduction

The Baltic Sea features a potential for large capacity wind farms because of relatively high and constant wind velocities. Mostly shallow coastal areas enable cost-efficient foundation and grid connection. However, in the northern sea area - Gulf of Bothnia - the sea freezes annually. Sea ice loads and ice-induced vibrations due to drifting ice field introduce major uncertainties in the support structure design for offshore wind turbines.

The magnitude and time variation of ice load depends on various factors, like the thickness and velocity of the ice as well as the size and shape of the structure. The ice load magnitude and time variation depends on the failure mechanism of ice, which is strongly governed by the shape of the structure at the water level.

Approach

FAST (Fatigue, Aerodynamics, Structures and Turbulence) aeroelastic simulation code was used to investigate structural performance of offshore wind turbines. The structural model was based on the NREL offshore 5-MW baseline wind turbine. Two different ice models were used in this study: Määttänen-Blenkarn model to describe the ice crushing for a monopile and ISO flexural failure model for a cone. Special attention was paid for studying combined load from the ice and wind. Wind and ice crushing model are coupled to the motion of the structure. ISO flexural ice model is an independent precalculated input. The JONSWAP spectrum was used for modelling wave loads.

Main Body of Abstract

Various failure modes of ice have been observed in ice-structure interaction. Typically, for the level ice, one of the following failure modes takes place: bending, buckling, cracking/splitting or crushing. For the load design, ice crushing is usually the most important because it induces a dynamic excitation on the structure. Also, the loads related to crushing are usually higher than in the other failure modes. A conical shape at the waterline can be used to change failure mode from crushing to bending, which decreases the ice loads on support structures. However, larger cross-section area will increase wave loads.

The aim of this study was to compare the ice loads to monopile foundation and coned structures. Loads and displacements were compared with different ice thicknesses and velocities. Ice-induced tower vibrations depend strongly on the water depth as the height of the structure plays an important role in the dynamics. Therefore, two different water depths were studied.

Conclusions

Optimizing wind turbine support structures in areas where the sea freezes during the winter is balancing between the wave and sea ice loads. The study showed that the cone reduces the ice loads significantly, but on the contrary, increases wave loads. Both of these loads are dynamic excitations. An optimal solution depends on the turbine dimensions, water depth and local wave and ice conditions.

Learning objectives

Although ice loads on offshore structures (for example lighthouses) have been studied in the past, comprehensive understanding of ice-induced loads and vibrations is still missing. It is important to understand how the wind turbine with flexible and rotating blades interacts with dynamic sea ice and wave loads.