POAC'23
Glasgow, United Kingdom

Proceedings of the 27th International Conference on
Port and Ocean Engineering under Arctic Conditions
12-16 June 2023, Glasgow, United Kingdom

Challenges with sea ice action on structures for Offshore wind

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ABSTRACT

EU urgently needs to increase the development of secure and green energy, and this includes renewables such as Offshore wind energy. An expansion of Offshore wind will include the Baltic where sea ice is one of the major uncertainties. To ensure that the wind turbines are safe for people and the environment, while keeping them economically competitive better guidelines and regulations should be developed collaboratively by European industry and academia. There are unsolved challenges with respect to ice action on structures for offshore wind. However, in the current draft for Horizon Europe Work Programme 2023-2024 on Climate, Energy and Mobility1, the challenges related to sea ice with regards to Offshore wind energy are not mentioned. In order to meet the crucial green energy goals, it is our statement that it is imperative to include sea ice in the final version.

KEY WORDS: Offshore Wind, Standards, Ice actions, Full-scale data

INTRODUCTION

The EU strives to become the first climate-neutral continent by 2050, as emphasised in the European Green Deal (EU, 2019), and offshore renewables is therefore of key importance. This is vital for Europe both to reduce global warming and ensure the green shift, but also to increase its energy security and reliability. A strong European leadership in renewable energy technologies will pave the way to reach these goals. The EU Offshore Renewable Energy Strategy[3] will shape the development of offshore wind in Europe for the next 30 years and the current goal of at least 60 GW installed offshore wind in 2030 in EU waters calls for a massive effort from industry and authorities (June 2021). The Baltic Sea offers a high potential for harvesting wind energy, and with this comes the challenges related to the significant occurrence of sea ice. Technical solutions for increased offshore wind energy in the Baltic Sea have an impact beyond the goals of the EU and has direct positive effect on at least three of the 13 sustainability goals (#7, #9, #13) of the United Nations in addition to having indirect positive impact on five other goals (#3, #8, #9, #11 and #12).

All structures need to be designed and operated so that they are safe for people and the environment and at the same time economically viable. In a larger framework the industry should comply with Circular Economy principles. The design and operation of bottom fixed offshore wind turbines in the North Sea is well known technology, even if more research may be necessary to optimise the structures so that they become cheaper, but still safe, reliable and efficient. However, sea ice represents one of the major uncertainties for the design of structures for offshore wind in the Baltic Sea. This applies both in the southwestern Baltic Sea and Gotland Sea in Danish, German, Polish, Swedish, Lithuanian waters and even more in the northern and eastern Gulfs (Swedish, Finnish, Estonian and Latvian waters). In the past this has resulted in incidents and accidents when new structures had to be developed without sufficient research and proper guidelines in place. An example is shown in Figure 1 which shows the Swedish lighthouse Björnklacken after it was displaced 17 m along the sea bed by the sea ice and had an inclination of 12 degrees (Bjerkås and Nord, 2016). Furthermore, forecasts from climate models indicate a future increase of the wind energy density in Northern Europe in the winter, when ice is present (e.g. Pryor et al. 2020, Martinez and Iglesias, 2021). Additionally, climate change related modifications of the gulf stream might reduce temperatures in North-European winters (DKK, 2023).

Figure 1. The Swedish lighthouse Björnklacken after being displaced by sea ice in 1985 (photo by Lennart Fransson).

STANDARDS AND SEA ICE

The existing standards with requirements and guidance on how to design robust wind turbine support structure considering sea ice loads such as IEC614000-3-1 (IEC, 2019) and DNV-ST-0437 (DNV, 2021) are predominantly based on experience with Arctic Offshore structures for the petroleum industry contained within ISO19906 (ISO, 2019). There are two important differences between offshore wind turbines and petroleum structures, firstly that the latter are large, stiff and almost quasistatic structures whereas wind turbines are slender and dynamic. The interaction with sea ice is known to be highly dependent on the response of the structure, and the extrapolation from limited experience with lighthouses and platforms cannot always be justified. Secondly, in the Arctic one can assume very large driving forces with almost infinite amounts of heavy ice whereas the Baltic differs as it has lighter ice conditions with typical design ice thickness ranging from 0.3 - 1.2 m.

Uncertainty in design methods leads to either over-conservative design with higher LCOE and CO_2/MW ratio than necessary or, more dangerous, unconservative designs. The uncertainty with respect to sea ice is currently significantly higher than uncertainties involved in estimation of wind, wave and current loads. Specifically, there are five points which require attention for the Baltic Sea:

- The system risk associated with critical offshore energy infrastructure being exposed to winter conditions exceeding current design limits.

- Standardization of methods to determine ice design parameters such as thickness, exposure time and strength. Limited full-scale data forces the use of empirical methods which yield a large range of results. This is particularly the case in areas where the occurrence of sea ice is so rare that systematic local measurements are unfeasible. It is yet unclear if and how climate change can be included in determining these parameters.

- Further development of existing numerical ice load models to become open-source. Industry competence with respect to ice loading differs significantly from company to company. A common and open availability of tools and knowledge can create a more level playing field ultimately resulting in increased optimization of designs.

- Development of standards for floating wind in ice. The transition depth between bottom-fixed and floating structures depends on a range of factors, and history has shown us that the most economical solution per water depth evolves over time. This increases the likelihood of floating wind installations being deployed in seas with seasonal ice. Research on this topic is still in its infancy and requires notable advances to assure that the required knowledge is available in time.

- Many locations are infrequently visited by ice, but structural design of specific wind farm components requires consideration of events with a probability of occurrence as low as once every 10 000 years (DNV-ST-0145). If ice is seldom present for example only once per 50 years, and thus never quantified, then there is no industry practice or guidance at all on how to define the appropriate design load conditions.

An essential ingredient in addressing these topics is to ensure more full-scale data on combined ice conditions and ice-structure interaction. The full-scale measurements that the ISO19906 equation for global pressure is based on are the Molikpaq data from the 1980s (see e.g. Frederking and Sudom, 2006) and the Nordströmsgrund in the 2000s (see e.g. Schwarz and Jochmann, 2009). It is now 20 years since the LOLEIF/STRICE campaign and the digital revolution has created new possibilities for both local and remote measurements of needed parameters that could not be quantified 20 years ago. For example observation on local ice drift (100 m – 1 km) around the lighthouse and structural response data with sufficient frequency and spatial coverage. Because of the lack of full-scale ice load measurements on offshore wind turbines, the industry and academia need a full-scale test platform to achieve more knowledge on ice loads precisely on the wind turbines, to validate and further develop the ice load models for the structural design purposes. The test platform should be located in a sea area where the structure is interacting with harsh ice conditions. The size of foundation structure at the water line and the dynamic properties of the structure should be comparable with real wind turbine foundations. Such an effort cannot be addressed by individual actors.

They require a joint European action involving efforts from both academia and industry as well as cooperation across sectors, so that the experience and knowledge from both maritime and oil & gas is used.

The Copernicus products provide good historical data, but with a low spatial and temporal resolution. Reliable and rational methods for downscaling are needed for practical application for design and operation of structures.

Over the past five years significant developments have already been made through several projects focusing on monopile foundations in ice that have involved European partnerships between industry and academia. However, it is urgent to continue developing the competence and enable the European industry to keep this position while advancing their world leading expertise and exporting competence that benefits on a global level. This needs to be done in collaboration with academic institutions, industrial partners and public funding agencies.

Unlocking the vital potential of offshore wind energy in areas of sea ice is in line with the Horizon Europe Strategic Plan 2021-20244 and relates to the expected impacts #23 and #21. The current (April 2022) draft for Horizon Europe Work Programme 2023-2024 on Climate, Energy and Mobility that deals with R&D needs for Offshore wind lacks the aspect and challenges of sea ice. If European industry is going to strongly contribute to the fullfilment the EU goals related to Offshore Wind Energy, then and accelerate progress we need to develop better and more accurate rules and guidelines for the design and operation of Offshore wind structures exposed to drifting sea ice. Success necessitates joint efforts between European universities, research institutes, and offshore wind industry.

CONCLUSIONS

The development of rational and applicable standards and guidelines require joint efforts from academic institutions, industrial actors and governmental funding agencies. It is necessary to develop data analysis techniques, numerical and data-driven models, physical understanding of the relevant processes, but most of all a new set of full-scale data on ice-structure interaction with up-to-date measurements techniques is needed.

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