The effect of sea ice on offshore wind farm operations and maintenance

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Determining Operability

- For operations, the two important characteristics of sea ice are concentration and thickness.
- International Maritime Organisation provides guidelines for safe levels of operation for vessels in sea ice [1] . A Risk Value, RV, is determined based on thickness of the ice and the vessel class. If concentration, C, is known, the risk index outcome, RIO, can be determined using the following equation:

$$\text{RIO}=\sum_{i=1}^{n} C_i RV_i$$

Modelling Sea Ice for O&M

- The offshore wind operations model is updated to include ice-breaking vessel functionality.
- The model simulates wind farm operations over its lifetime, factoring in weather, turbine failures, and maintenance schedules based on resource availability [2].
- Users input key data such as climate, failure rates, transport, costs, resources, and wind farm specifics.

Sea ice can reduce offshore wind farm availability by up to 10% in Nova Scotia, driven by inaccessibility and non-icebreaking vessels.

Methodology

- The model simulates wind farm failures using Monte Carlo simulations, triggering assigned transport vessels for maintenance.
- If weather exceeds a vessel's limits during the repair window, deployment is delayed until conditions improve.
- With the new functionality, the ice class of the vessel can be selected.
- The vessel's winter risk value is determined hourly by referencing the current ice thickness along with vessel classification. Using the corresponding ice concentration in that hour, the RIO can be determined. If the RIO is negative then that indicates the vessel cannot travel. Table 1 outlines the guidance given by the IMO regarding risk index outcome values.
- Simulation outputs cost breakdowns, resource allocation, availability and power production.

Table 1: IMO's Risk Index Outcome Guidance [1]

Risk Index Outcome	Ice Class ≥ PC7	Ice Class < PC7
0 ≤ RIO	Normal Operation	Normal Operation
-10 ≤ RIO < 0	Elevated Operation Risk	Do not operate
RIO < -10	Do not operate	Do not operate

Nova Scotia, Canada Case Study

- Average ice thickness up to 0.4 m during January to April.
- Over 50 inaccessible days resulted from a wind farm with no ice breaking vessels.
- Wind farm is located 25 km from shore.
- Operating strategy utilises CTV, SOV and Jack Up vessels. SOV assumed increase cost for ice breaking capabilities is 15% based on construction costs of new ice breaking vessel designed for offshore wind with vessel class PC6 [3].

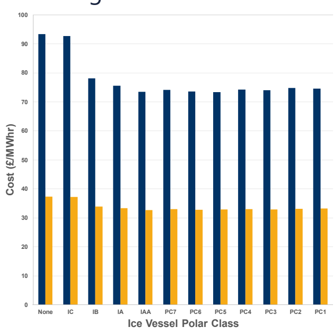

Fig 1: Operational costs including transport costs for Nova Scotia using different ice breaking capabilities for SOVs.

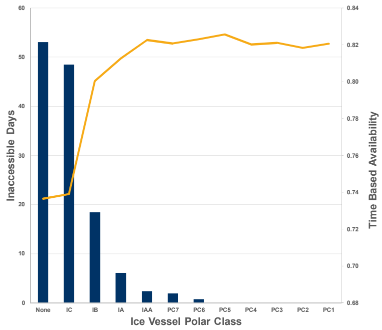

Fig 2: Inaccessible Days in Nova Scotia and the associated time based availability of the wind farm over it's lifetime

Impact on future offshore wind farms

- Sea ice may cause inaccessibility to wind farms, resulting in lost productions costs.
- A case study carried out on Tahkoluoto wind farm in Finland revealed a reduction in availability by 2.5 % from icy conditions to no ice.
- Similarly, a wind farm in the Bohai Sea, China had a 1.2 % decrease in availability without the use of ice breaking vessels.
- Location, wind farm size and climate all will impact the severity of the reduction in availability.
- The research finds there could be significant lost production cost dependant on accessibility of the site.
- Ice breaking vessels would improve operation in sea ice areas in terms of availability but their costs are largely unknown.

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References

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