ICE-INFESTED WATERS:

CHALLENGES AND POSSIBILITIES FOR WIND POWER

The waters off the Swedish east coast provide with shallow depths and high winds excellent conditions for a large-scale deployment of offshore wind power. However, land-fast ice and drift ice cause different challenges. The structures might be subjected to significant ice forces, and the ice conditions might also affect the ability to carry out different work operations. In order to meet these challenges and identify possible solutions, a study is planned. For further information, represents from universities, industry and others interested are welcome to contact Daniel Bergström.

A pilot study commissioned by The Swedish Wind Power Association has been carried out during 2013. This study is a compilation of some of the priority conditions for offshore wind power in Swedish and nearby waters. One of the topics is a description of how land-fast ice and drift ice are affecting the conditions for offshore wind power. Reference material has mainly been provided by Lennart Fransson, ice researcher at Luleå University of Technology. An important base for this material is empirical studies of ice forces against offshore lighthouses and inshore bridge foundations.

Daniel Bergström

MSC Engineering Physics, Certified Offshore Diver, Competency as Builder and Installer of Wind Power

Contact: msc@danielbergstrom.com, +46 702 83 71 88

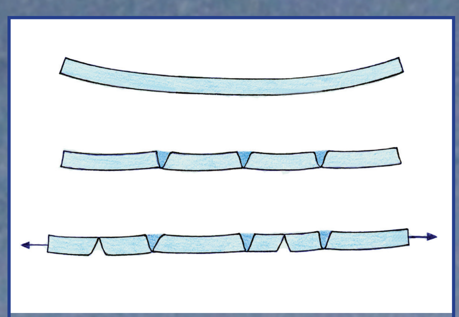
ICE EXTENT AND ICE LOADS

Sea ice may be present in the entire Baltic region. Along the east coast one can expect annual icing north of Gävle. The loading mechanisms can be divided into:

* Horizontal load from land-fast ice due to temperature fluctuations, or thermal ice load.
* Horizontal load from land-fast ice due to water level variations and vault effects.
* Horizontal load from drift ice.
* Vertical load from land-fast ice.
* Load from pack ice.

Thermal ice loads and loads from drift ice sometimes reach extreme levels. Because the resulting forces are mainly horizontal, bottom fixed (or floating) structures are likely to be damaged if installed in these waters in transitional depths (30 – 50 meters). A complication is the slender nature of a complete turbine structure, and also its high centre of gravity.

Thermal ice loads may reach significant levels in freshwaters, that is Bothnian Bay, Gulf of Bothnia and Stockholm Archipelago. This is due to the positive coefficient of thermal expansion for freshwater ice. This means that when the temperature is rising, the thermal load from a land-fast ice cover will be greater if a structure is located far from land, and especially if the ice cover can expand towards free waters a short distance outside the structure. Possible thermal ice loads have been estimated for the north of Sweden to 500 kN/m and for the south of Sweden to 250 kN/m. If a structure would have a diameter of 4 meters, this would correspond to a load of 200 tonnes and 100 tonnes respectively.

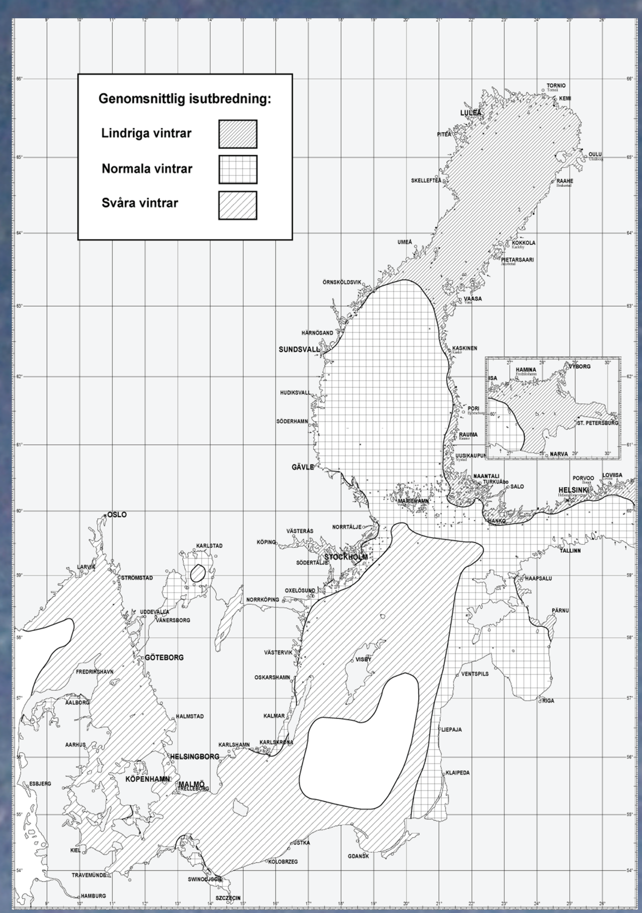


Thermal ice load. The upper surface of the ice shrinks as temperature drops. The fractures formed are filled with water, which then freezes. As temperature rises, the ice needs more space than before. Fractures are then formed in the lower surface.

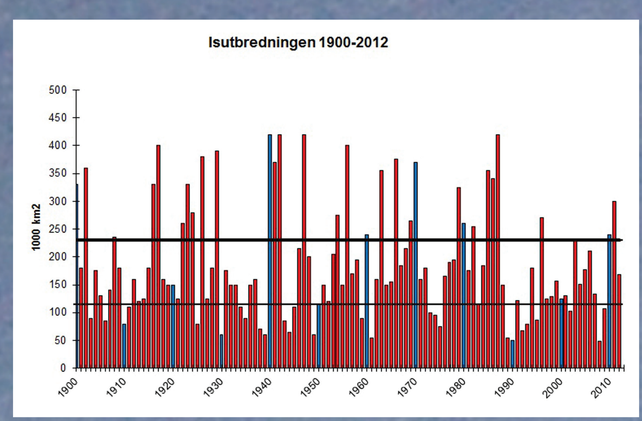
Horizontal load from drift ice is determined by velocity, thickness and strength of the ice cover, and also by the ice structure failure mode near the structure. The different modes are crushing, cracking, bending and buckling. The ice can also be broken periodically. If the frequency corresponds to one of the natural frequencies of the structure, mechanical resonance may occur. This is also referred to as "lock-in".

POSSIBILITIES

* Improved forecasts of local sea ice conditions.
* Modelling of extreme and combined events.
* Detailed and customized resource planning.
* Improved knowledge of different cone shaped foundations and their interaction with different ice situations.
* Dimensioning of foundations to withstand extreme ice loads but at the same time minimize contact surface.
* Anti-resonance systems.



Average ice extent in the Baltic Sea.

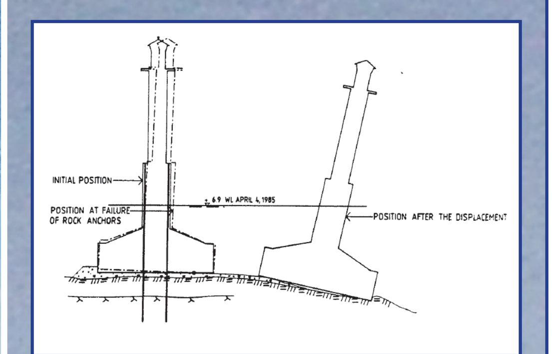


Maximum ice extent between 1900 – 2012.

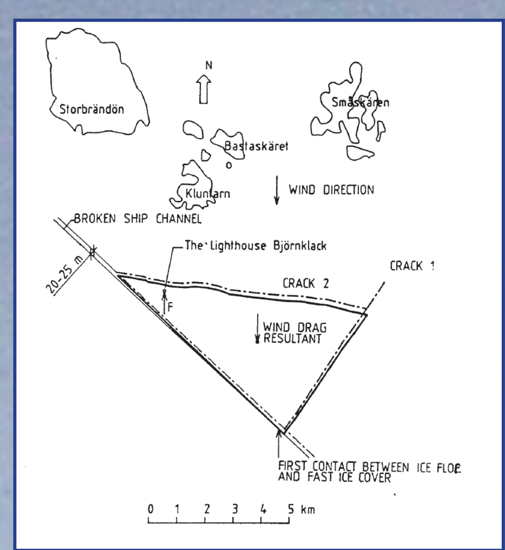
Low ice load from drifting ice against a lighthouse.

Track from a lighthouse.

Björnklack, April 1985. The lighthouse in the Bothnian Bay was subjected to extreme ice forces. It was displaced 17 meters and tilted 12 degrees. The ice load was estimated accurately to 1090 tonnes!

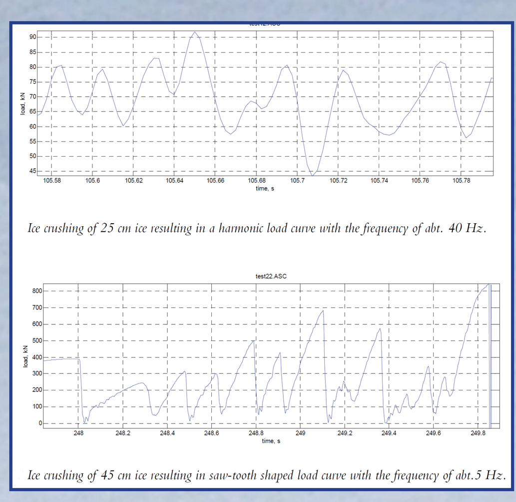


Reconstruction of the overloading event. The structure was stabilized by gravity foundation, partly by iron fill. It was provided with prestressed rock anchors, increasing the ultimate ice load capability with about 60 per cent.

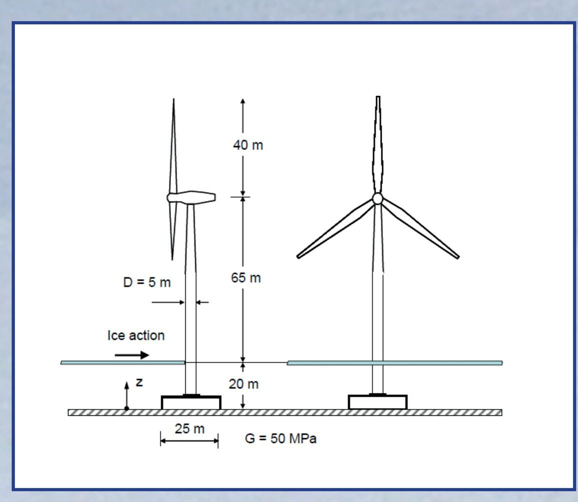


Ice situation at the Björnklack site at the instant of overloading. (Channel width and ice floe displacements enlarged.)

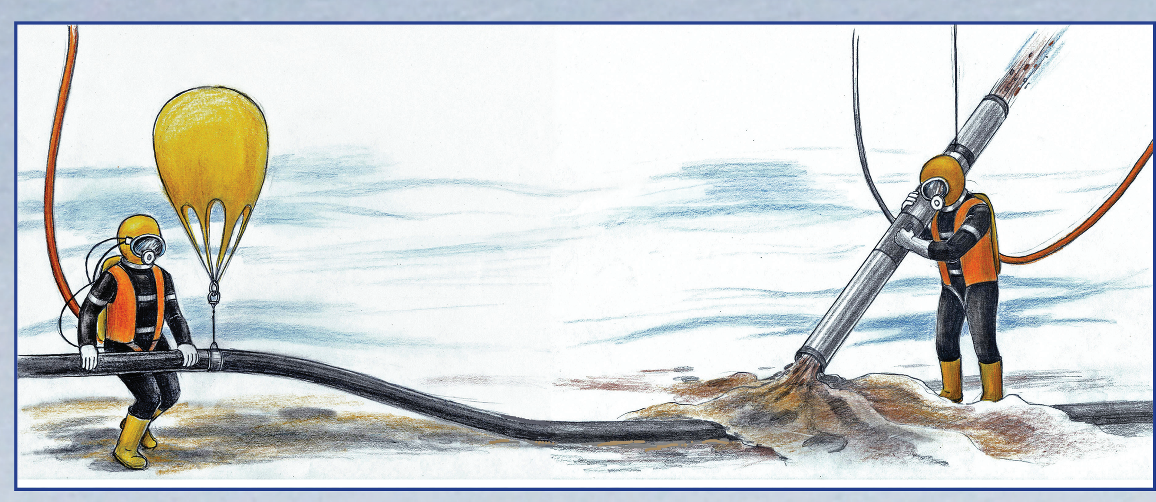
Arctic Ant is a hydrocopter (airboat) suitable for difficult ice conditions with ice ridges and a mix of ice and open water. It has a transport capacity of 4 – 6 persons, baggage and tools and if necessary a stretcher. This will probably be a preferred transport solution for a wind power service team if the ice conditions are difficult and varying.



Measurement of loads against icebreakers. A vertical pipe was assembled in front of the ship and connected to a pressure sensor. This was a scaled simulation of the loads from ice drifting against offshore structures, such as lighthouse or wind turbine foundations. These graphs show how the ice load variation sometimes have a frequency.



A fictive offshore wind turbine structure subjected to ice actions. Main structural and soil characteristics are selected, and then a FEM model is used to obtain eigenmodes and eigenfrequencies.



Divers working on a submarine power cable. The subsea environment is complex and structures are exposed to different stresses. Power cables are sensitive and sometimes damaged. Surface supplied operations must be carried out from a stable platform, and diver umbilicals, wires, crane chains etcetera must be sheltered from drift ice and have free passage.