Decision support

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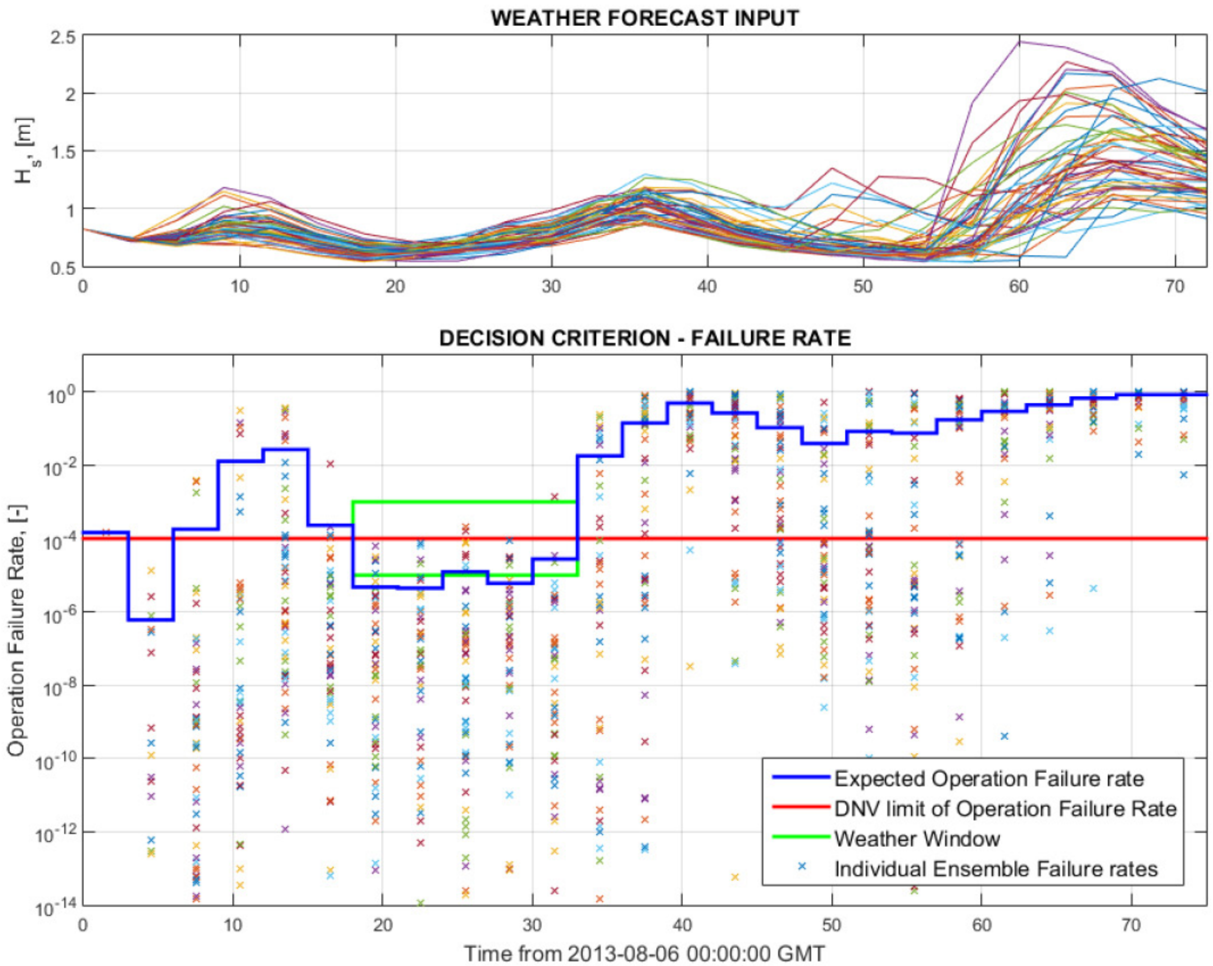
Background
Offshore operations like the installation of equipment, maintenance and repairs are complex and to a high degree weather sensitive. The cost of such operations is largely caused by waiting for suitable weather windows for weather-sensitive phases (transportation, mooring, crane operations, etc.). For installation of offshore wind turbines, the cost of transport and installation contributes to 15-20% of the total capital expenditure (CAPEX) [1].

In 2012, NORCOWE partners initiated a project proposal combining the joint competencies in the centre to look into reducing the cost of installing wind turbines offshore. After a successful application process, the recently finished project "Decision support for installation of offshore wind turbines" (DECOFF) started in 2013 as a 3 year knowledge building project supported by Statoil and the Research Council of Norway. A main idea in the project has been to base the decisions on the equipment responses caused by the weather



rather than on conservative weather parameter limits, and thereby potentially improve the weather windows. Project partners were Christian Michelsen Research (project owner), MET Norway, Aalborg University, Uni Research, Marintek, University of Bergen and Statoil. Statoil took an active part in the project and served as work package manager for one of the work packages.

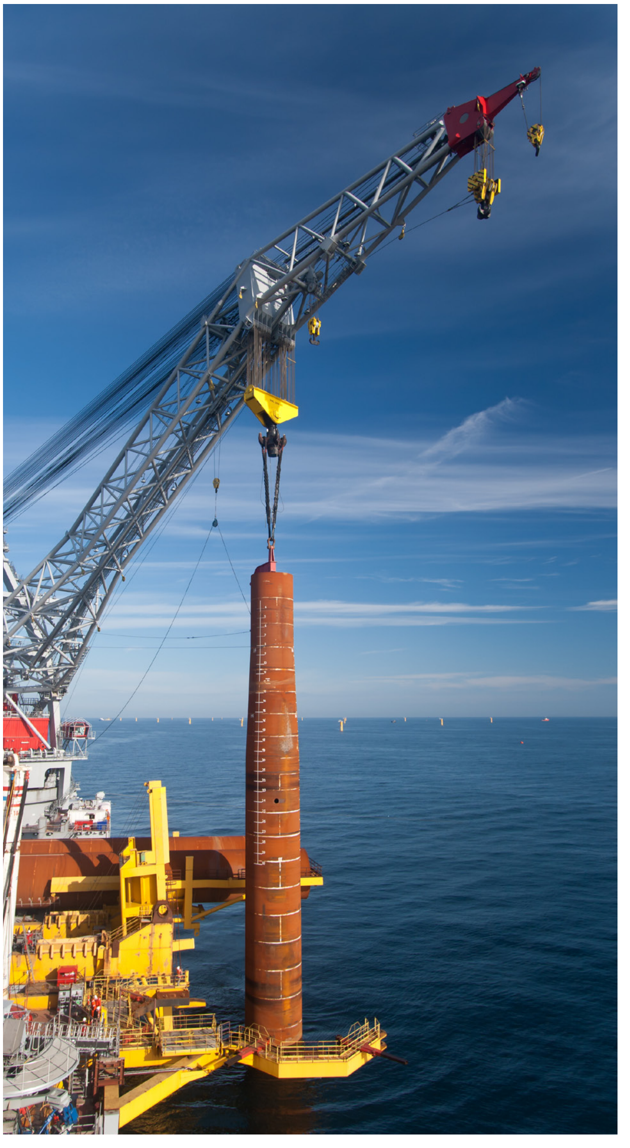
The standard method for calculating weather windows
Before discussing the project and the results, let us explain the standard method for calculating weather windows. Before the operation, one must identify the critical limits for the responses of the equipment (for example maximal allowable crane load). Then one needs to find corresponding limits for significant wave height and wind speed that can cause the critical limits to be exceeded. This is done either through numerical equipment simulators, wave tank models or by experience. This process can lead to rather conservative limits for the weather parameters.

For day-to-day marine operations, planners use these limits together with weather forecasts to compute weather windows. As we all know, weather forecasts come with uncertainties, which varies from forecast to forecast. The standard method of incorporating uncertainties is to scale the weather limits with bulk factors called alpha-factors [2], i.e. make the limits even more conservative. DNV GL recommends alpha-factors based on analysis of weather forecasts and observed weather.

Results of the DECOFF method
The DECOFF method is more direct than the standard (alpha-factor) method in that it uses an equipment response simulator for each weather forecast to compute the corresponding equipment responses. We have used SIMO, which is a non-linear time domain simulator developed by Marintek. The equipment responses come as time series, which are then analysed statistically to give an estimate of the probability of exceeding critical limits within the operation period. The expertise at Aalborg University has been vital for the statistical modelling [3].

A strength of this method is that it uses all aspects of the weather forecasts. Wave period (and wave spectra if available) is for example taken into account, which is not explicitly possible with the standard method.

Ensemble forecasts provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) have a low resolution, on the scale of tens of kilometres. This is suitable for large-scale regular forecasts, but not for companies planning marine operations at a specific site, where effects of coastal or seabed terrain may be important. Uni Research has therefore worked on downscaling the forecasts to 3 km resolution for the atmosphere and 300 m for the waves. For the site selected in this project (see the fact box), downscaling gives significant changes for the wind, but for waves



the differences were rather small. MET Norway has in parallel worked on site calibration of forecasts. They show that the continued rank probability score improves by 40 % for wave height and 60 % for the mean wave period. The bias was also strongly reduced [4].

Christian Michelsen Research has in addition to managing the project, worked on combining the above tools, methods and forecasts into an online decision support tool. There are many simulations to run, and the tool was therefore designed to be highly scalable. All system states are stored in a database so that adding more web-servers and simulation servers is straightforward. The database is also scalable, making it possible to add more database servers for increased performance, redundancy and availability. The results of the simulations are presented to the user with the most important information at the top level (the computed probability of failure), while allowing the user to drill-down into the underlying data (e.g. the time-series of the critical response parameters).

The project has shown in a virtual test case that the method performs better, or at least as good as the standard method. We are now in a position to do validation of the method in a real installation case, and we hope to do that in a potential follow-up project.

References

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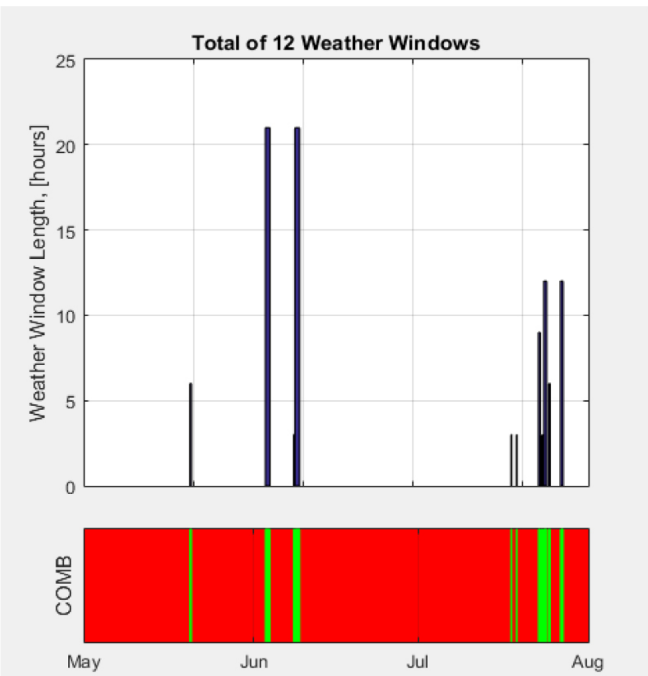
2. DNV, "DNV-OS-H101. Marine Operations, General," DNV, 2011.
3. Gintautas T, Sørensen JD, Vatne SR, "Towards a risk-based decision support for offshore wind turbine installation and operation & maintenance", DeepWind'2016, 20-22 January 2016, Trondheim, Norway.
4. Furevik B, Bremnes JB, Restad M, "Evaluation of ensemble prediction forecasts for estimating weather windows", DeepWind'2016, 20-22 January 2016, Trondheim, Norway.

Measurements from the FINO 3 platform (http://www.fino3.de/en/), located in the North Sea about 80 km west of the border between Germany and Denmark, were selected as the offshore met-ocean data source for the project.

The online accessible database from the German BSH (Bundesamt für Seeschifffahrt und Hydrographie) provides 10-minute averages of more than 70 meteorological and oceanographic parameters from the site.

Three years of selected data with relevance for offshore wind energy applications (wind speed and direction, temperature for stability estimations, ocean currents and wave parameters) have been quality controlled, both by a series of plausibility tests and visual inspection of the time series.

Alpha-Factor method



DECOFF method with FINO3 measurements