Aalborg Universitet

AALBORG UNIVERSITY
DENMARK

# Decision Support for Offshore Wind Turbine Installation

*Statistical estimation of Probabilities of Failed Offshore Operations*

Gintautas, Tomas

*Publication date:*
2015

*Document Version*
Publisher's PDF, also known as Version of record



*Citation for published version (APA):*
Gintautas, T. (2015). *Decision Support for Offshore Wind Turbine Installation: Statistical estimation of Probabilities of Failed Offshore Operations*. Poster presented at NORCOWE Science Meets Industry 2015, Stavanger, Norway.

# Decision Support for Offshore Wind Turbine Installation

## Statistical estimation of Probabilities of Failed Offshore Operations

Tomas Gintautas (P)[1] John Dalsgaard Sørensen[1], Sigrid Ringdalen Vatne [2], Yngve Heggelund [3] - Project manager

(1) Aalborg University, (2) MARINTEK, (3) Christian Michelsen Research

Christian Michelsen Research

norcowe Norwegian Centre for Offshore Wind Energy

AALBORG UNIVERSITY

## Abstract

The costs of operation & maintenance (O&M), assembly, transport and installation of offshore wind turbines (OWT) contribute significantly to the total cost of offshore wind farm. The O&M access and installation operations are mostly carried out by specific ships, that have to be hired for the operational phase and for duration of the installation process, respectively. The duration, and therefore the ship hiring costs, is among others driven by waiting time for weather windows for weather-sensitive operations.

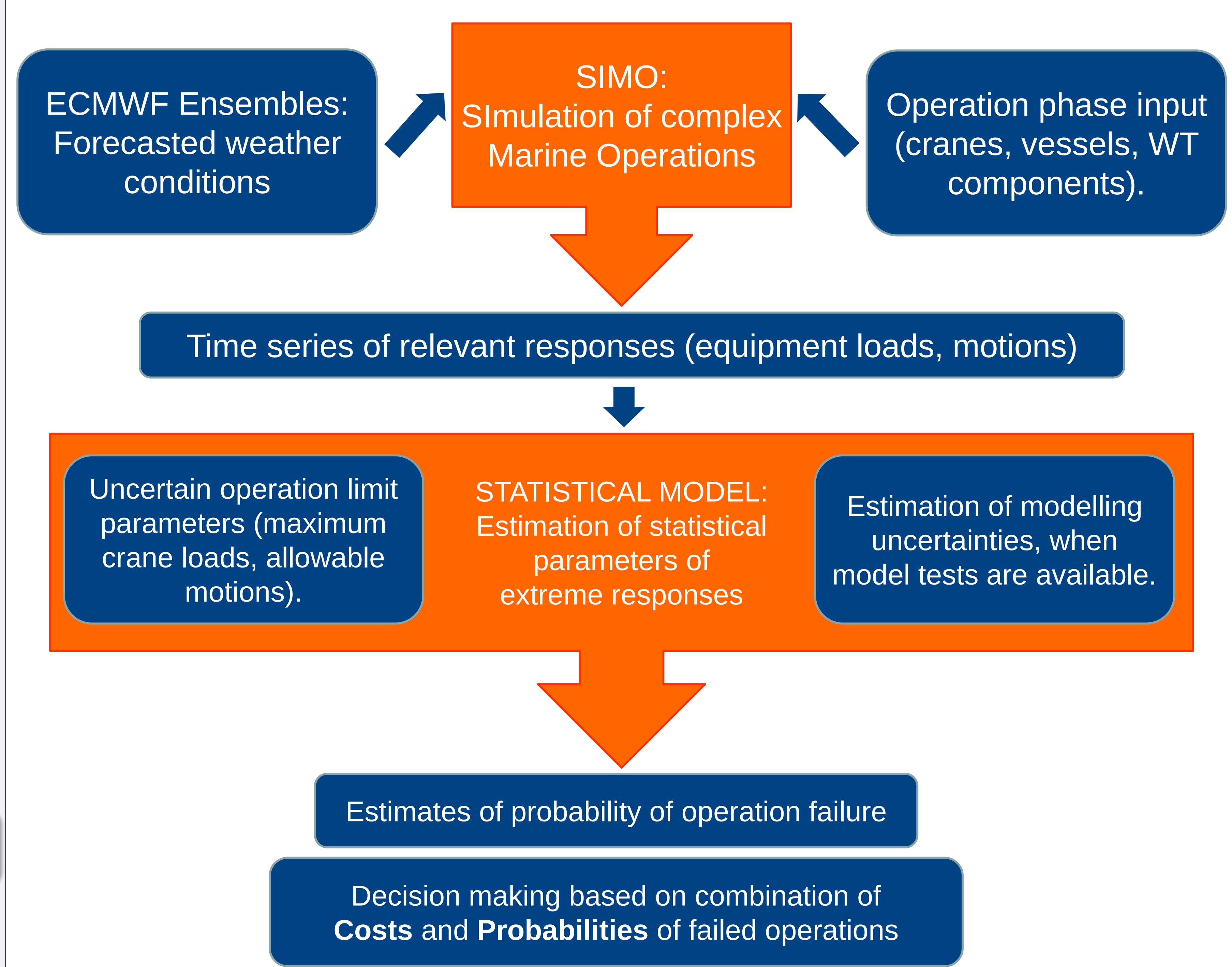
Today the state of the art decision making criteria for weather-sensitive operations are the significant wave height and the average wind velocity at reference height, however the actual limitations are physical and related to the response of equipment that is used e.g. crane wire tension, air gap between rotor assembly and nacelle, etc. Transition from weather windows to physical response criteria in decision making would improve the cost predictions and, furthermore, potentially reduce the cost of energy.

Computer tools can be applied to simulate motions of floating vessels (barges and cranes) representing the access and installation of offshore wind turbines. Since weather predictions have a certain degree of uncertainty the response of the installation equipment is expected to be uncertain also. Assessment and appropriate incorporation of response uncertainties into the decision making processes is essential in order to make accurate decisions.

## Objectives

- Present a general framework for Risk Based Decision Making for OWT installation process.
- Present the current status of the development of the Decision Support Tool.
- Discuss limitations of current knowlege on Operation limits.

## Graphical representation of the model



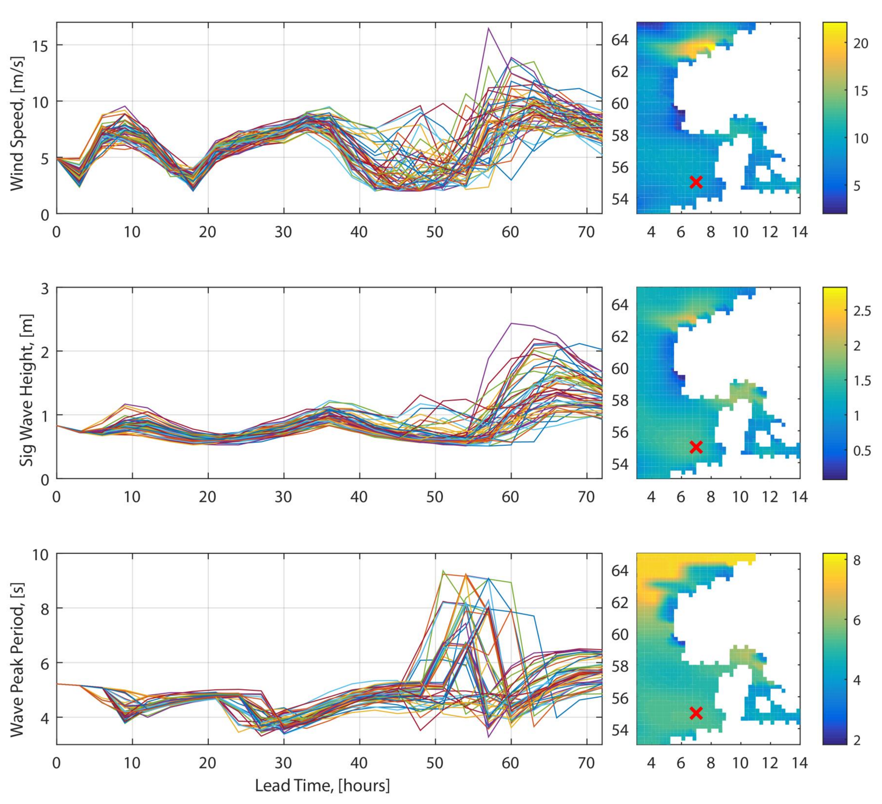

$$C_{total} = C_{waiting} + C_{equipment} + \sum_{i=1}^{N_{phases}} \left( \sum_{j=1}^{N_{LS}} P_{LS,i,j} C_{LS,i,j} \right)$$

## Methods

# Weather Input to SIMO

**ECMWF weather forecasts with 3 days lead time:**

- Multiple weather parameters (wind speed and direction, wind-sea and swell parameters and directions).
- 51 forecast ensembles to ensure low statistical uncertainty (51 weather predictions per lead time).



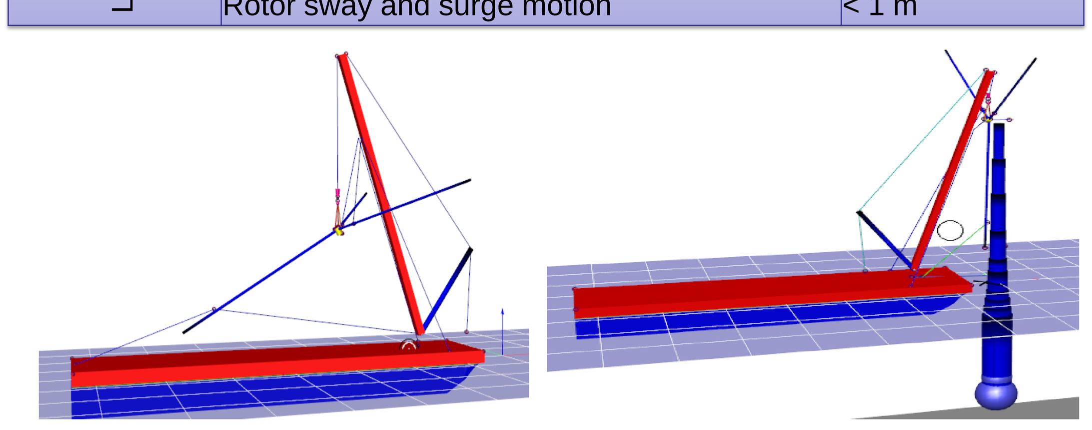

Weather forecast for FINO3 site

For each forecasted weather situation (emsemble) 16 realisations are simulated with different seeds within SIMO to ensure stability of the results (according to IEC 61400-1). This sums up to 816 simulations per lead time.

# Simulation model, output and postprocessing

SIMO software is used to simulate the installation sequence using systems of barges, cranes, control wires/tugs and wind turbine components. The installation process is split into different phases (transportation, positioning, lifting of the rotor, etc.). Each phase has multiple failure criteria, example:

| | | |
|---|---|---|
| Phase 5. Lift rotor up close to nacelle | Crane loads | < 4250 kN |
| | Lift wire tension | > 0 kN |
| | Air gap blade 3 and tower | > 0 m |
| | Rotational and absolute rotor acceleration | < 1 and 4 rad/s$^2$ |
| | Yaw and tilt angle | < 5 degrees |
| | Rotor sway and surge motion | < 1 m |



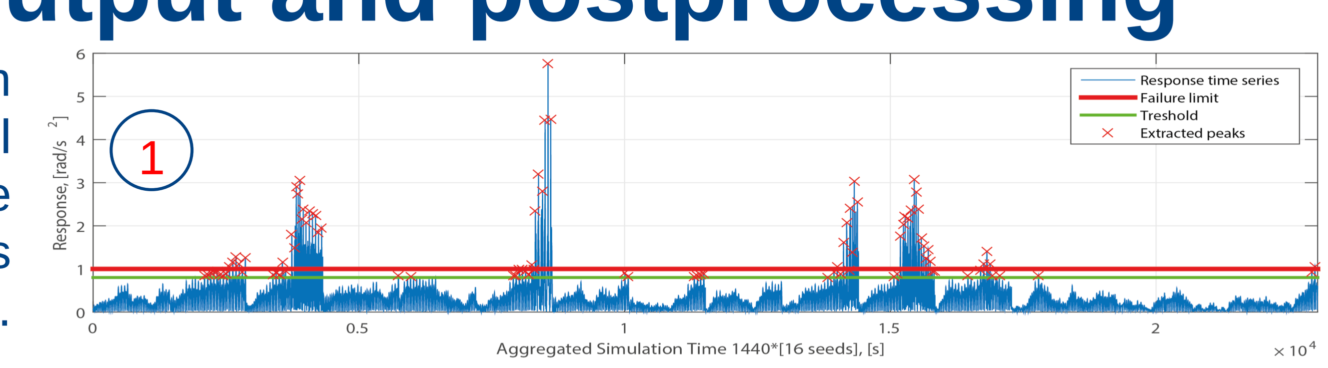
Rotor lift-up from barge and bolting to the nacelle.

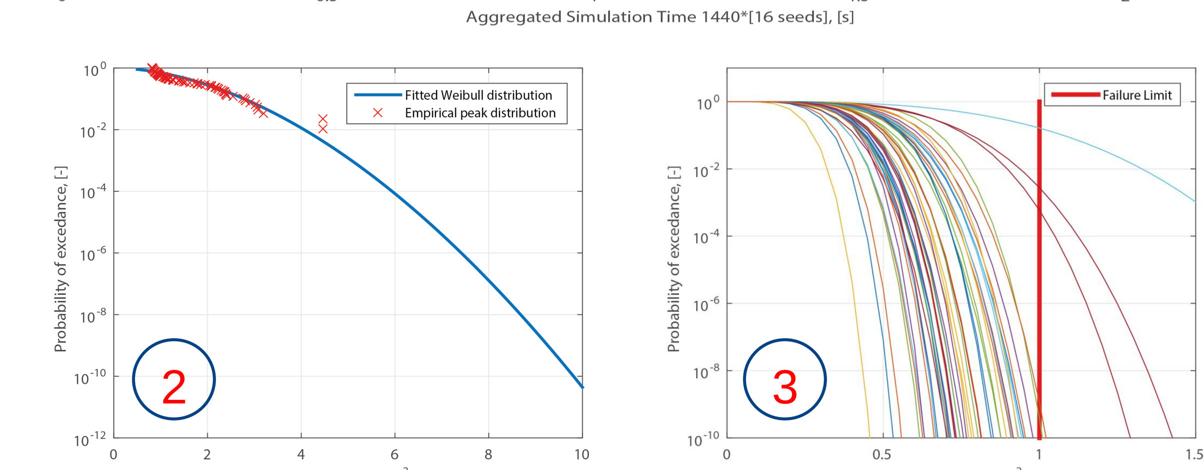
Weather forecasts are passed through SIMO and response time series are analysed statistically in order to obtain Probabilities of Failed operations:

1. Peak Over Threshold method is applied to extract extreme values of relevant responses.

2. Weibull or Gumbel distribution is fitted to the extremes using Maximum Likelihood parameter estimation.

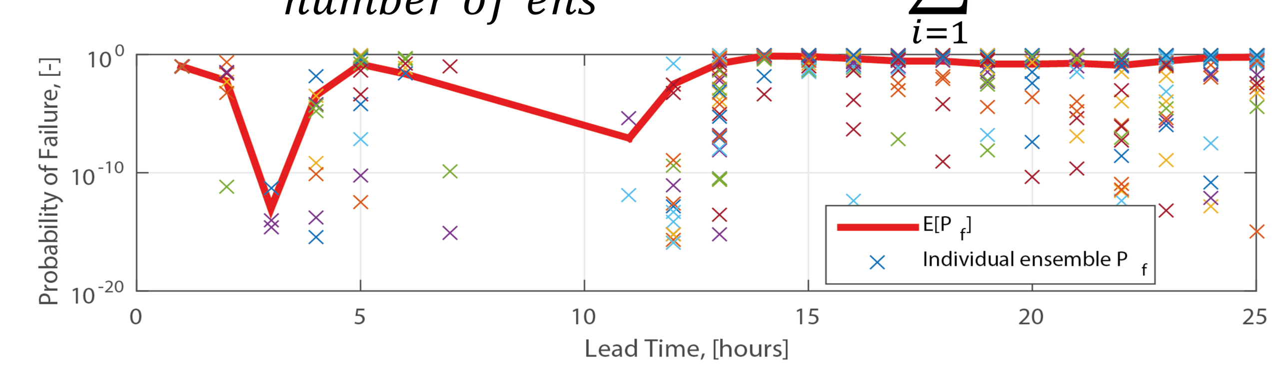
3. Steps 1-2 are repeated for 51 forecast ensembles individually (example lead time 36 hours).

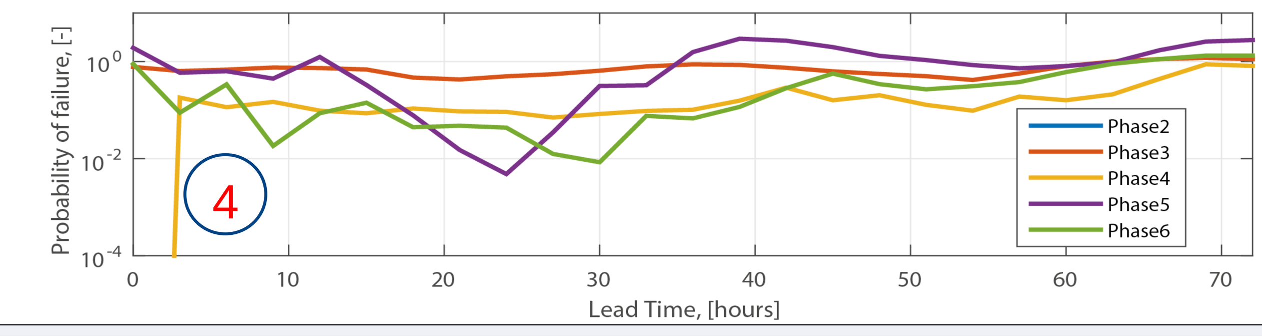



4. The Probability of Failure for one limit state in one phase is estimated using the 51 ensembles. Summing up all the limits states in one phase gives Probability of failure within an operation phase.

$$P_{F,Lim\ State} = \frac{\sum_{i=1}^{N} P_{F,Ensemble}}{number\ of\ ens} \qquad P_{F,Phase} = \sum_{i=1}^{N_{Lim\ States}} P_{F,Lim\ State,i}$$




## Acknowledgments

The research is funded by The Research Council of Norway, project No. 225231/070 - Decision support for offshore wind turbine installation. The authors also acknowledge Christian Michelsen Research, Meteorologisk Institut (Norway), MARINTEK, Uni Research, University of Bergen (UiB) and STATOIL for their valuable inputs and support.

## Conclusions and future work

After extensive testing it can be concluded that the procedure for estimation of Probability of Failed Operations produces consistent results and could be used to assist in decision making for Offshore Wind Turbine installation. Although, due to lack of available information about the actual physical operational limits, it has to be noted that the example case only acts as a proof of concept. By combining probabilities with expected costs of failed operations, the procedure can be also used for Risk Based decision making. Future work would include expanding the tool to include Costs of Failure, more clear definition of actual physical operational limits (with related uncertainties), tests with scaled installation models for estimating model uncertainties, implementation of Bayesian statistical framework to update the model with on site measurements of equipment responses and/or weather conditions