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Risk-Based Operation and Maintenance of Offshore Wind Turbines

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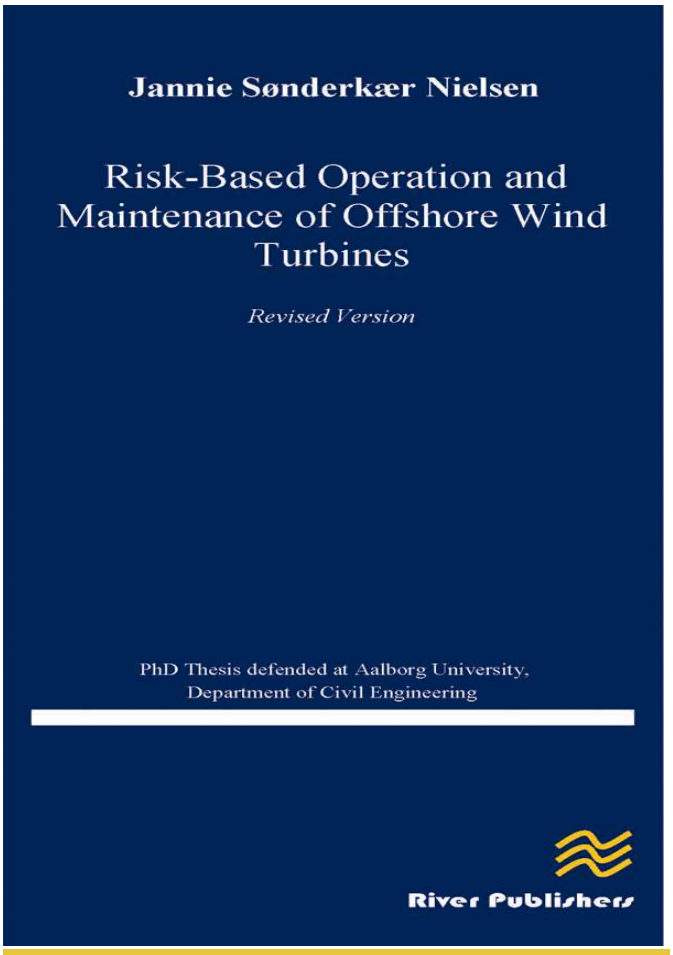
For offshore wind turbines, maintenance costs are substantial due to a large number of component failures. In addition to the repair costs, equipment costs and lost production costs are large due to limited accessibility to the turbines. In order to reduce the costs, preventive methods can be used, but presently maintenance is not planned using advanced methods taking all available information into account in a consistent manner.

Maintenance decisions can be made based on risk-based methods, where the total expected life cycle costs are minimized. Methods have been developed for assessing the corrective maintenance costs, and many studies have also been published for preventive maintenance. However, an important part is the modeling of the relationship between maintenance and reliability, which is typically not modeled in a consistent way. Therefore, the methods cannot be used directly for optimal maintenance planning, taking into account monitoring, inspections, preventive repairs and corrective repairs. This can be done using methods developed from a Bayesian perspective. Such methods have been developed for use in the oil and gas industry under the name Risk-Based Inspection (RBI), and are based on the Bayesian pre-posterior decision analysis. In order to make the problem computationally feasible, approximations are necessary. The approach typically used for RBI cannot directly be transferred to wind turbines as the conditions are different. For wind turbine components, the reliability is lower compared to oil and gas structures. In addition, condition monitoring systems are often available, and the information should be taken into account when making decisions.

In this thesis, methods for risk-based maintenance planning using Bayesian methods are investigated, with the aim of making optimal decisions considering all available information. First, a theoretical damage model is formulated, the model is then updated using condition monitoring data, and the updated model is used as basis for risk-based decision making. Several approaches for solving the decision problems have been considered: various types of stationary decision rules, limited memory in?uence diagrams, and Markov decision processes. Several of the approaches are used together with Bayesian networks.

The approaches have been tested for theoretical decision problems, and the expected costs were compared for different strategies. It was possible to achieve big savings, but the results of course largely depend on the input. With real decision problems, it can be difficult to formulate the model if the design assumptions are not ful?lled in real life. The potential of the method is large, but further development is necessary, especially concerning the modeling of speci?c examples.



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