Risk and Reliability based O&M Planning of Offshore Wind Farms

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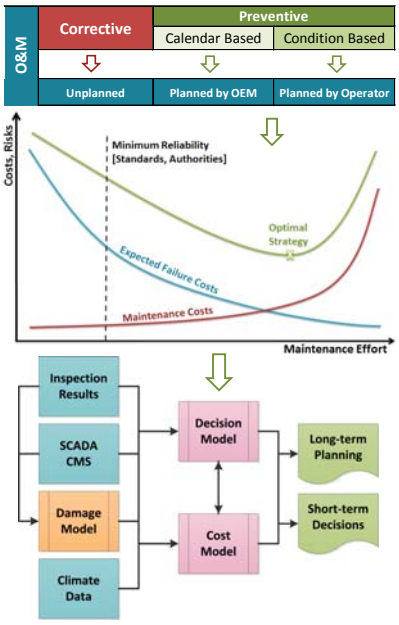
Introduction

Operational costs of offshore wind farms are one of the main contributors to the high cost of energy and can be significantly reduced by using an optimal maintenance strategy to support the wind farm operator in short-term decision making and long-term O&M planning.

During two PhD projects an optimal risk and reliability O&M model is being developed to minimize the total operational costs by balancing the amount of corrective and preventive maintenance efforts, considering all system effects.

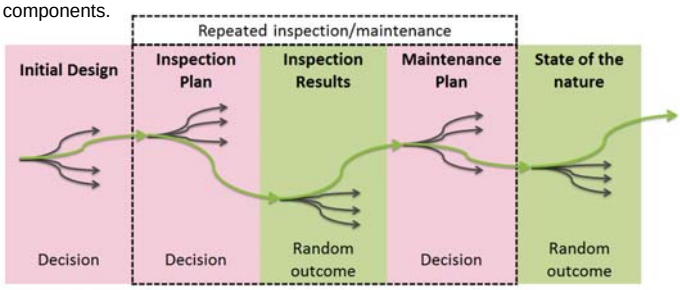
The developed O&M model consists of a risk based decision and cost model, which are using deterioration models, inspection results, SCADA data, condition monitoring data and climate data as inputs.

The model output is the long-term O&M planning of the wind farm and decision support to the wind farm operator in daily wind farm operation.

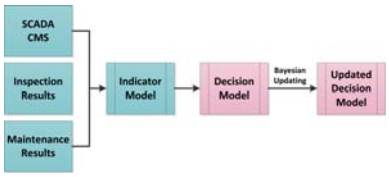


Developing and Updating the Decision Model

By having all the input data and the cost model it's possible to develop a decision model including decision rules and criteria. The following figure shows a life cycle decision tree for optimal O&M planning of a wind turbine or a wind farm with multiple critical components.

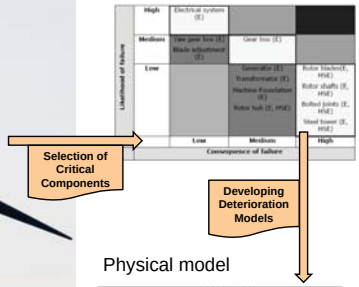


Decision of initial design is made by the designer as it should maximize the total expected benefits minus costs during the whole lifetime such that safety requirement are fulfilled at any time. The 'repeated inspection/maintenance' box includes continuous decisions and observation of uncertain parameters during the whole lifetime.



Risk based O&M planning of offshore wind turbines it's a process where there is continuous feedback of information from the system. Therefore, it's necessary to update the decision rules and criteria whenever new information is being available.

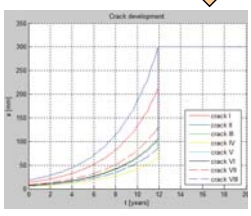
Developing the Deterioration Models



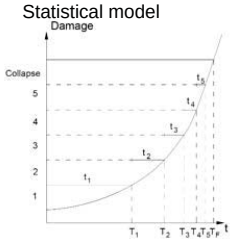
Within this project four deterioration models for selected critical components are being considered:

- Steel welded
- Steel non-welded
- Electrical systems
- Composite materials

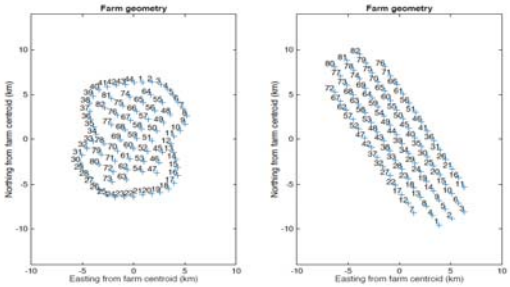
Physical model



Statistical model



Application on NORCOWE wind farm



A baseline O&M strategy is developed and applied to the NORCOWE wind farm. The analysis is made on two different layouts and serves as a reference point for comparison of cost of energy between traditional O&M strategies, and a risk and reliability based approach

Layout	Annual O&M cost	Availability
Curvilinear	1.0564 10^8 [€]	90.01[%]
Rectilinear	1.0553 10^8 [€]	90.21[%]

Demonstration of the risk-based O&M Model

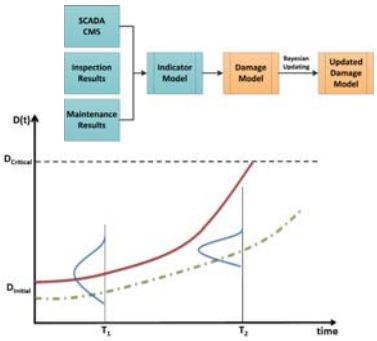
By developing all required data blocks, an optimal risk and reliability based O&M model will be developed. Then, the component based approach will be extended to a system based approach to consider all system effects.

At the end of the project, the developed optimal risk and reliability based O&M approach will be demonstrated using the NORCOWE reference wind farm, which is a 800MW offshore wind farm consisting of 80 NREL 10MW reference wind turbine.

Updating the Deterioration Models

Since deterioration mechanisms such as fatigue, corrosion, wear and erosion are associated with significant uncertainty, the developed deterioration models should be updated using direct and indirect information from indicators and Bayesian statistical techniques.

As illustrated in the following figure, damage model at time T1 has been updated based on the observations from the inspection and associated maintenance actions. Therefore, the expected damage level at time T2 will be smaller in this example.



Acknowledgments

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