Integration of Degradation Processes

in a Strategic Offshore Wind Farm O&M Simulation Model

Thomas M. Welte, Espen Høegh Sørum, Iver Bakken Sperstad, Magne L. Kolstad

SINTEF Energy Research (Contact: thomas.welte@sintef.no)

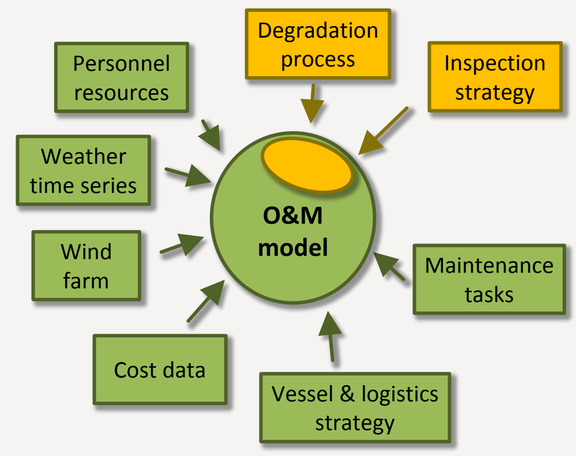
Abstract

Strategic decision support tools for offshore wind O&M need to represent the failure behaviour of components. This work discusses two different alternatives for integrating component degradation processes in a strategic offshore wind farm O&M simulation model:

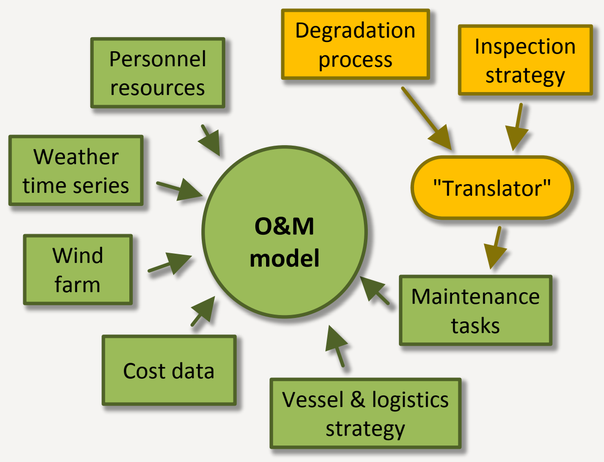
- *Full integration* of a degradation process in the O&M simulation model
- *Loose integration* of a degradation process, using a simpler representation

Although loose integration models some effects less accurately than full integration, the accuracy is for most purposes sufficient for such O&M models.

Full integration of degradation process:



Loose integration of degradation process:



Background

- Typical application of offshore wind farm O&M simulation models: Strategic decision support, e.g. for wind farm investment decisions, selection of vessel and logistics strategy, etc.
- Most such models use only a high-level representation of the failure behaviour, such as failure rates, but using more detailed models representing components' failure behaviour may improve the models and the results.
- Evaluating the value of more detailed modelling and discussing alternatives for integration of degradation processes is the aim of this work.

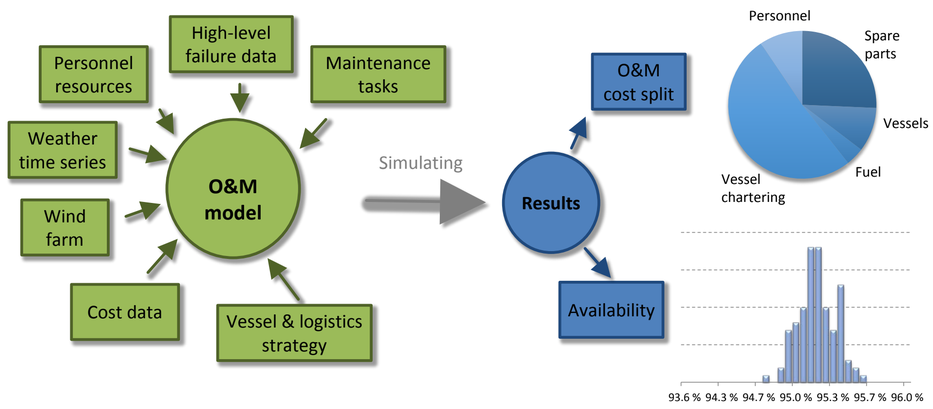


Figure: Typical inputs and outputs of a strategic O&M simulation model.

Full integration of degradation model

- The NOWIcob O&M simulation tool is used for this work.
- Full integration means that existing NOWIcob tool must be extended.
  → Additional computational work.
  → Each type of model that can be applied for modelling degradation (Markov process, Gamma process, Paris law, ...) requires the full implementation of the model in NOWIcob with corresponding changes to the user interface.
- <u>Case study:</u>
  As a simple but practical example, a Markov chain model for blade degradation with discrete condition states as presented by Florian and Sørensen (2017), has been considered in our case study.

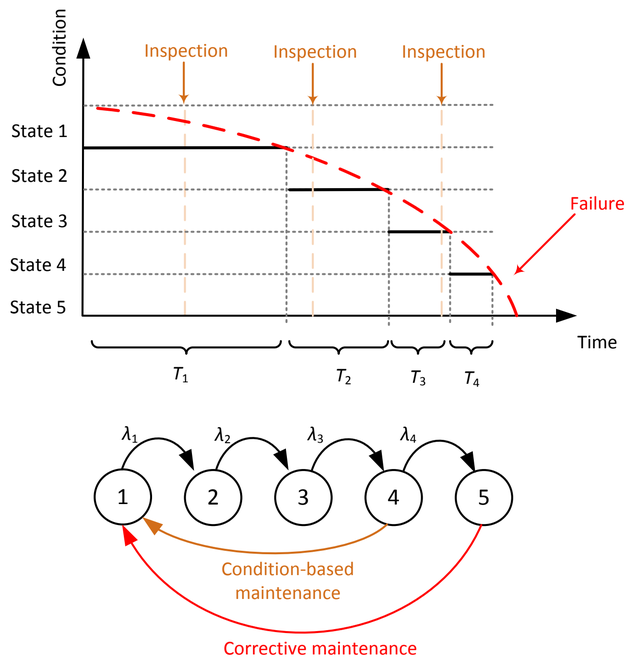


Figure: Simple example of Markov process for degradation (below) and conceptual illustration of underlying degradation pattern (above).

Methodology for loose integration

- The link between the degradation model and NOWIcob is established by means of an integration tool ("translator") that "translates" the inputs of the degradation process and the inspection strategy to the high-level inputs required by NOWIcob's existing condition-based maintenance module:
  - p_{det} : The overall probability that a potential failure is detected and a warning is given (given a specific inspection strategy)
  - T_{det} : The number of days between the warning and when the failure would have occurred if the warning had not been given
- That is, the degradation and inspection processes are simulated outside NOWIcob, neglecting effects such as weather and logistics.

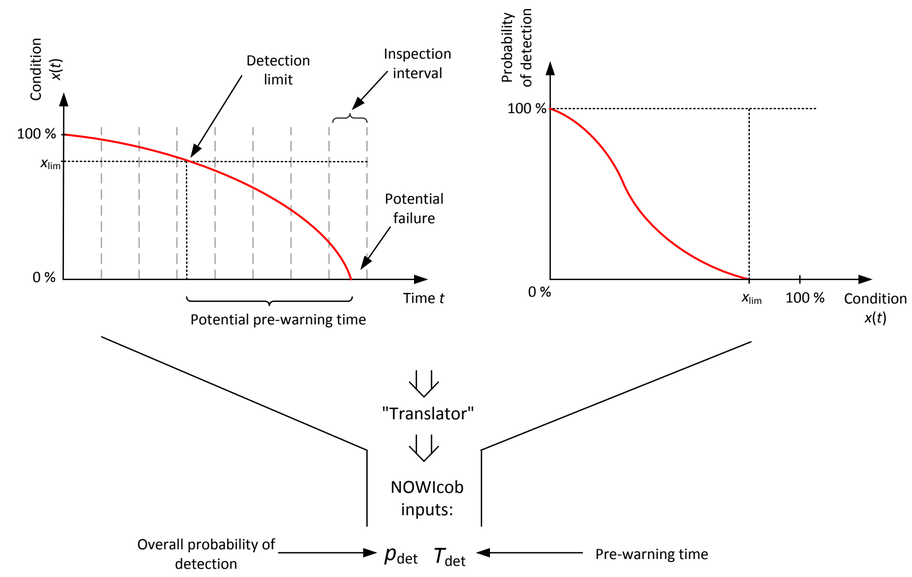
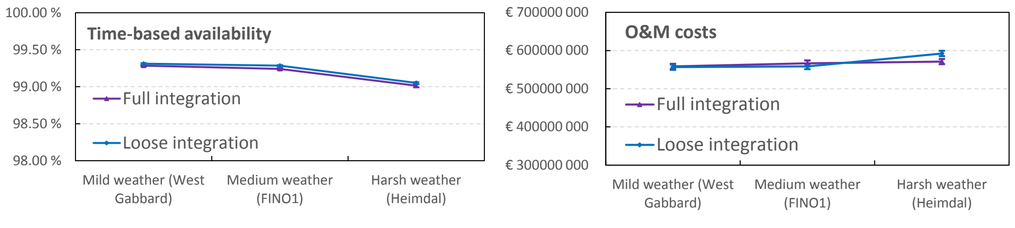


Figure: Conceptual illustration of the "translation" from a degradation process and inspection strategy to a simplified representation in a strategic O&M simulation model.

Results and conclusions

The difference between full and loose integration in aggregated result parameters such as availability and O&M cost are very small in the case study.



Advantages of full integration	Advantages of loose integration
Higher accuracy (given detailed and accurate input data) for more detailed result parameters	**Easier to implement** (not necessary to implement and integrate one model for each component and failure mode)
Detailed representation of inspection strategy (allows for better optimization of strategies)	**More flexible** (generic model can represent different degradation patterns)

References

Hofmann, M.; Sperstad, I. B. (2013). "NOWIcob – A tool for reducing the maintenance costs of offshore wind farms". *Energy Procedia*, vol. 35, 2013, pp. 177–186.

Florian, M.; Sørensen, J. D. (2017). "Case study for impact of D-strings on levelised cost of energy for offshore wind turbine blades". *International Journal of Offshore and Polar Engineering* (accepted).

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