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Reliability requirements for life extension of wind turbines

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Thousands of wind turbines across Europe are reaching the end of the design life within the next few years. For many of these, the business case for continued operation beyond the original design life could be economically feasible. For structural components, fatigue is often the design driver, and if designed to the limit, the design fatigue life would be consumed at the end of the original lifetime. However, as many uncertainties are accounted for in the design, the time to fatigue failure would for the vast majority be much longer. Data from operation and inspections contains information that can be utilized to estimate variables more accurately, and in many cases could prolong the design fatigue life. In these cases, the turbines could continue to operate while still fulfilling the original reliability requirements. In other cases, available data will not be sufficient to verify acceptable fatigue life. Still, life extension could be acceptable from the view of the society: "*Economic, social and sustainability considerations, however, result in a greater differentiation in structural reliability for the assessment of existing structures than for design of new structures.*"[1]

The general principles for reliability of structures are given in ISO2394[2]. Here three levels of decision making are given:

- Risk-informed decision making
- Reliability-based decision making
- Semi-probabilistic method

The semi-probabilistic method is typically used for design of wind turbines and other structures and use characteristic values and partial safety factors. The safety factors in design codes are calibrated using reliability-based methods to obtain the desired target reliability level. Risk-informed decision making provides a rational approach for setting the reliability level that should be required by the society. Risk-informed decision making requires a full analysis including all direct and indirect consequences of failure such as loss of human lives, monetary loss, loss of reputation, societal impact and pollution[3]. For existing structures this approach will typically lead to a lower acceptable reliability level, as the costs of improving the safety is higher for existing structures than at the design stage. For decisions related to life extension of wind turbines, and the consequence of failure will often be smaller, as the asset value is less, and life safety is often not an issue for wind turbines. The work presented is conducted under the Lifewind project[4].

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[1] ISO 13822:2010.

[2] ISO2394:2015

[3] Nielsen et al., *Proc. of ICASP13* (2019)

[4] Lifewind, supported by EUDP. http://www.lifewind.dk/