ABSTRACT

On-site fatigue monitoring of offshore wind turbines using mechanical strain measurements adds maintenance effort. Instead, estimating loads is more cost effective. Load estimation can be done with data driven models requiring only a short period of mechanical strain measurements. This paper elaborates on the amount and type of sample data needed to establish a reliable fatigue estimator for the entire operational life of the turbine. It is shown that the diversity of loading situations needs to be reflected within the model and a systematic approach for sample data selection and categorization is suggested. The study reveals direct implications for load measurement campaigns conducted for this purpose.

KEYWORDS: fatigue life; load monitoring; neural network; alpha-ventus; measurement campaign

INTRODUCTION

Measuring the loads on offshore wind turbines with conventional mechanical strain gauges adds maintenance effort and a risk of reduced availability. Considered over the entire lifetime and current technology this direct approach is uneconomic for large scale application. However, without the site and turbine specific fatigue an optimized maintenance schedule, wind farm load control and potential life-time extension is not possible.

In order to make use of fatigue information collected during the operating life of a wind turbine, a monitoring system suitable for wide scale implementation is necessary. In (Cosack and Kühn, 2009) it is stated that these requirements are well addressed by a load estimation scheme based on a data driven neural network model. A measurement campaign, that involves strain gauge installations, needs to be conducted initially - but once sufficient sample data is collected a system that indirectly estimates the fatigue load cycles can take over. Robust load monitoring is achieved by relying on standard data such as wind speed, generator speed and pitch angle - all readily available signals from the operational control system. This saves extra costs for maintenance of strain sensors and downtimes that might sum up to a multitude of the installation costs, as described in the report of Gamesa (2010).

Following conceptual studies with simulation data, the successful implementation of fatigue load estimation based on standard data was first reported in (Cosack and Kühn, 2007) and in (Cosack, 2011) for a 2.5 MW commercial onshore wind turbine and a 5 MW onshore prototype, both on a ~ 150 h total measurement time basis. The investigations included tower and blade fatigue loading under free-stream conditions. Further application of the method to offshore wind farm data of ~ 250 days including various operational and inflow conditions has been tested by (Obdam et al., 2010). Additional studies on the fatigue loads of tripod type support structures by Smolka et al. (2011, 2012) revealed that appropriate signal selection allows satisfactory estimates even under conditions where hydrodynamic loads are dominant.

The research results preceding this work allow the conclusion that data driven models established with neural networks algorithms serve very well as estimators of ten minute fatigue loading events with a mean error below 5% and a standard deviation of around 10%. However systematic conclusion for the set-up of a measurement campaign that is done to collect sample data which is representative for a lifetime-operation cannot be drawn. Table 1 shows basic parameters that drive the measurement campaign design.

Table 1: Parameters to be considered when designing a measurement campaign for load monitoring.

<table>
<thead>
<tr>
<th>Objective</th>
<th>collect representative data samples to be used for a neural network training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumentation</td>
<td>definition of signals to be measured definition of resolution and accuracy</td>
</tr>
<tr>
<td>Duration</td>
<td>define which loading situations need to be recorded</td>
</tr>
</tbody>
</table>

This paper addresses two questions:

- What is the optimal neural network input configuration of standard data statistics for fatigue estimation?
- How long does the measurement campaign need to be run in order to collect sufficient data that is representative for the entire operational life?