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ReaLCoE

Developing the Next Generation 12+ MW Offshore Wind Turbine for Clean and Competitive Electricity

Continuous lifetime monitoring technique for structural components and main bearings in wind turbines based on measured strain and virtual load sensors

Motivation and methodology

A holistic condition monitoring system of a wind turbine can be defined as a combination of individual component condition monitor systems that are combined in order to determine the global health state of the turbine. Two examples investigated in the REALCoE project, were to use load sensors at both the blade root as well as the tower bottom of the DTU V52 research turbine at the DTU Risø Campus, to obtain the turbine load of the blades, tower and the main bearing in order to estimate the damage accumulation of these components during 9 years of operating the turbine. This approach is challenging, since the load sensor might degrade and fail, and Figure 1 shows a proposal of first auto-calibrating the sensors as well as creating virtual sensors that can replace the real sensors if they fail and are not operational until they are repaired [1].

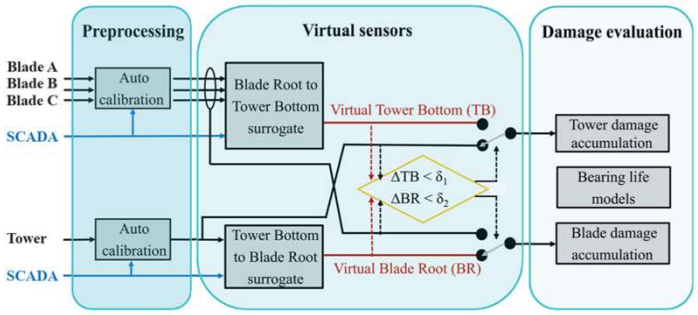

Figure 1. Holistic condition monitoring combining load measurements from the blade roots and tower bottom with the SCADA data of a wind turbine [1].

Results

Figure 2a shows virtual sensors replicating the tower bottom Fore – Aft bending moments from the blade root load sensor as well as the SCADA data for the DTU V52 turbine[1]. It was found that the Long-Short Term Memory (LSTM) neural network is providing the best prediction of the tower bottom bending moments and Figure 2b illustrates how a 6 month gap of missing data due to an imagined failed tower bottom strain gauge from March to August in 2023 can be filled using the virtual sensor. The accumulated tower bottom damage after gap filling with the virtual sensor is only 5 % lower than the real accumulated damage[1]. Figure 2c shows the damage accumulation of the main bearings of the DTU V52 turbine estimated from the load measurements and the ISO281 standard for bearing lifetime [2]. A model mitigating the turbine loads to the axial and radial bearing loads , as well as estimating the bearing temperatures from the ambient temperature, has been formulated, and a main bearing lifetime of 562 years was found and reflecting very low wind at Risø[2].

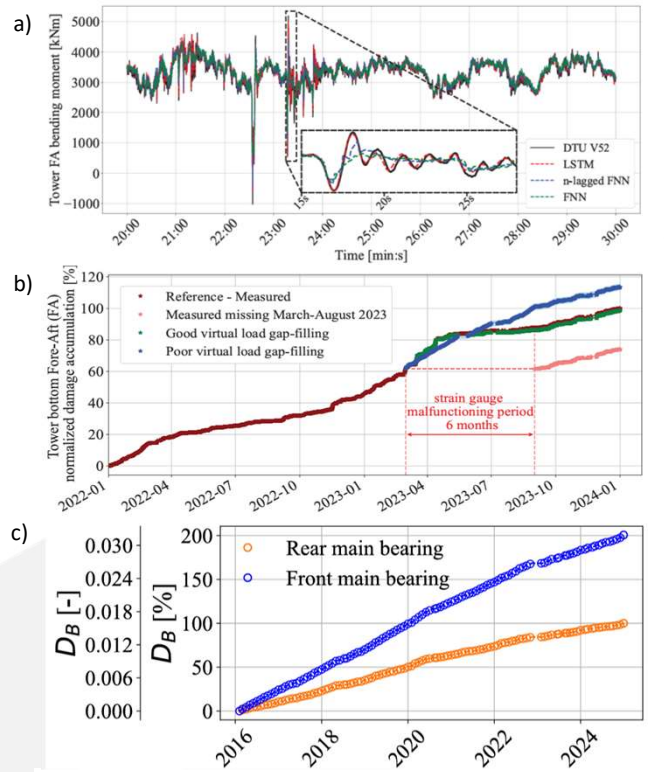

Figure 2. a) Virtual load sensor replication of V52 tower bottom bending moment[1]. b) Tower bottom damage accumulation over 9 years[1]. Good virtual load gap filling refer to training the virtual sensor after the auto calibration of the strain gauges and poor without. c) V52 main bearing damage accumulation demonstration by assuming one of the two bearings as positioning [2].

Conclusion

The concept of a robust holistic condition monitoring system has been demonstrated using the DTU V52 research turbine to estimate the damage accumulation of the tower and main bearings by adding a virtual sensor for replacing a failed sensor.

Source

1. Bruno R. Faria, Nikolay Dimitrov, Victor Perez, Athanasios Kolios, Asger B. Abrahamsen, „Virtual load sensors based on calibrated wind turbine strain sensors for damage accumulation estimation: a gap-filling technique “, 2025 J. Phys.: Conf. Ser. 3025 012011, https://DOI.org/10.1088/1742-6596/3025/1/012011
2. Bruno R. Faria, Nikolay Dimitrov, Nikhil Sudhakaran, Matthias Stammler, Athanasios Kolios, W.Dheelibun Remigius, Xiaodong Zhang and Asger Bech Abrahamsen, “Continuous lifetime monitoring technique for structural components and main bearings in wind turbines based on measured strain and virtual load sensors”, Wind Energy Science, Pre-print wes-2025-233, https://doi.org/10.5194/wes-2025-233

ReaLCoE's vision is to unleash the full potential of offshore wind energy
€35/MWh LCoE Goal, +12MW WEC Capacity, ~32 mio € Total Budget, 42 month project duration

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