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Use of a nacelle LiDAR to assess nacelle transfer functions following maintenance operations

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1. Introduction

Nacelle transfer functions (NTF) [1] are used to assess the performance of operating wind turbines. Nacelle anemometers are known to be sensitive to their position on the wind turbine, to operating conditions such as inflow or turbulence and to significant changes in the turbine aerodynamics or controls. In this context, it is likely during wind farm operation over several years that specific events, maintenances, or upgrades could lead to a change in the NTF. This change is difficult to notice unless free-wind measurements are used, and this could lead to incorrect performance monitoring.

The present case study focuses on the analysis of the NTF after maintenance operations were performed. The use of a validated nacelle LiDAR [2] is investigated for this application. The NTFs obtained for both systems are compared. The nacelle LiDAR is used to assess the fine evolution of the nacelle transfer function through the maintenance operations. Finally, the sensitivity of the function to turbulence intensity is assessed.

2. Experimental set-up

A measurement campaign was organized on the ECN test site from June 2013 until April 2014. The site is a near shore site consisting of flat, agricultural terrain.

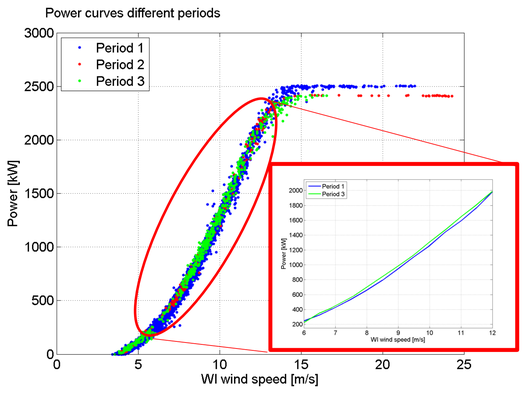
The North part of the site consists of 5 ECN research turbines in a row from East to West with a rated power of 2.5MW, a rotor diameter of 80m and a hub height of 80m. The second turbine from the East is the turbine under test. Directly South-West of this turbine at 2.5D a fully IEC compliant, 108m high meteorological mast (MM3) is located with boom measurements at hub height.

The Wind Iris (WI) of Avent Lidar Technology was installed on the second ECN research turbine. The Wind Iris is a two beam, pulsed LiDAR with a beam separation of 30 degrees. It takes measurements from 80m until 440m in ten ranges. The measurements at 200m (2.5D) are considered in this study. The LiDAR was previously validated against the meteorological mast [2].

3. Impact of Maintenance Operation on Power Curve

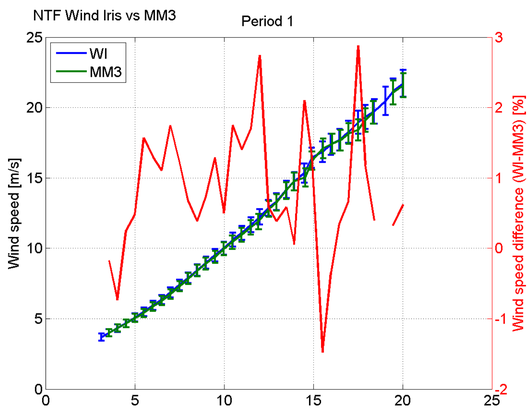
In the considered period two major maintenance operations have been performed: converter maintenance in January 2014 and main shaft bearing change in March 2014. For the latter the rotor and the shaft needed to come down. With respect to these events 3 periods are defined (before, in between and after). For these periods power curves have been constructed with the Wind Iris similar to [2].

	Period 1	Period 2	Period 3
Number of data	5692	199	536
Rated Power	2.5 MW	2.4 MW	2.4 MW
Power Curve analysis	Reference	Insufficient data	About 4% increase in 6 to 12 m/s wind speed range



- The converter maintenance had an unexpected impact on the rated power of the turbine (2.5 MW to 2.4MW).
- It is useful to check power curves after a major maintenance operation.

4. Nacelle Transfer Function: Mast vs nacelle LiDAR

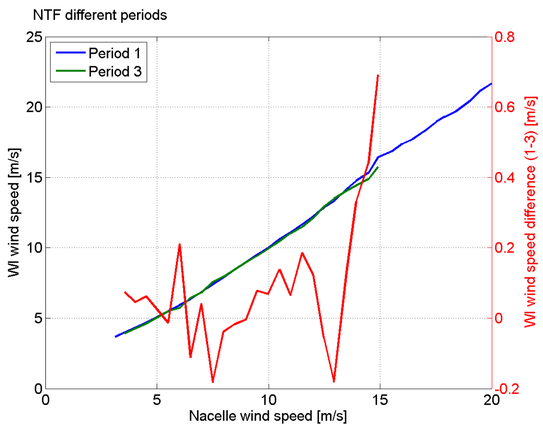


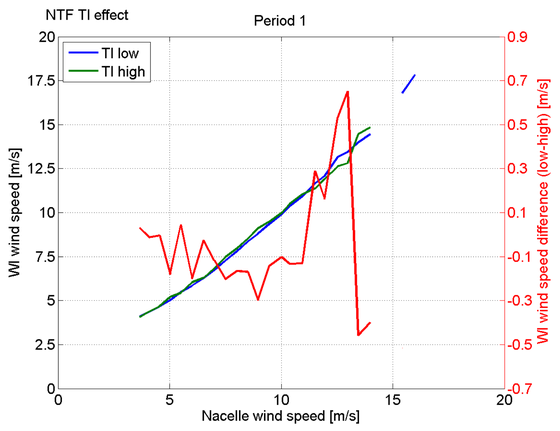
The NTF for the research turbine has been determined for period 1 using both the mast and the Wind Iris. Below rated, the WI NTF is slightly higher than the mast NTF (0.5% to 2.5%).
Uncertainties were computed in accordance with [1]. As the nacelle wind speed switches between sonic and cup measurements, the largest uncertainty contribution is considered. The Wind Iris uncertainty of [2] is also considered. While the WI uncertainty is slightly larger due to the calibration step, the two uncertainties compare well and represent a difference of 1.5% at 12m/s.

- The WI and the meteorological mast yield similar results for NTF, the former slightly higher, but well within their respective uncertainties.
- The NTF is non-linear. Therefore, this nacelle anemometer 'calibration' is a significant step in determining the power curve using nacelle anemometers.

5. NTF: Maintenance and Turbulence effects

In this part, the effect of maintenance operations and of TI on the NTF is studied using the Wind Iris. NTF is analyzed before and after maintenance operation (Period 1 vs Period 3), and for low and high TI during Period 1.





	Period 1 vs Period 3	High TI vs Low TI
Changes in operating conditions	- Rated power reduced from 2.5 to 2.4MW - Main shaft bearing is replaced	- Low TI is defined as <10% - High TI is defined as >10%
Effects on the NTF	- Below rated wind speed the difference between the two periods is negligible (within 0.2m/s) - Near and above rated wind speed, the NTF for period 3 becomes lower	- On average and below rated wind speed the NTF for high TI is higher as compared to the NTF for low TI. - Similar effects have been observed in power curves [3]
Analysis	- A lower rated power setting may modify the rotor induction near and above rated wind speed, thereby affecting the nacelle anemometer	- When rated wind speed is reached, the NTF for high TI becomes lower, probably because at higher TI the turbines pitches earlier [3].

- The effect of the converter maintenance causing a change in rated power is reflected in the NTFs.
- The effect of the main shaft bearing change is not clearly reflected in the NTFs, whereas this is the case for the power curves.
- The effect of turbulence is reflected in the NTF both below and beyond rated wind speed, similar to its effect on power curves.

6. Conclusions

- Nacelle Transfer Functions comprise non-linear effects, which may lead to incorrect performance monitoring.
- The Wind Iris of Avent is a valid alternative to determine the NTF.
- Maintenance operations can have unpredicted effects on the NTF, supporting the need to regularly verify these functions.

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References

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