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Importance of Traceability for Determining the Efficiency of wind turbine drive trains on test benches

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Summary:
In this paper, the efficiency of a 2.75 MW nacelle is compared using calibrated and uncalibrated measurement devices. The results show that especially calibration of mechanical input is important, as the torque measurement is off by about 5 % and results in significantly lower system efficiencies.

Keywords: Calibration, efficiency determination, nacelle system test bench, mechanical input power, electrical output power

Introduction

In order to optimise the efficiency of wind turbine drive trains during the development process, measurements are carried out on nacelle system test benches (NTBs). A standardised method based on traceable mechanical and electrical power measurements is required for reliable and comparable efficiency measurements. Traceable measurements are possible either by installing additional calibrated high-precision measuring devices or by calibrating the existing measuring devices. In the given set-up, the calibration of the mechanical power measurement strongly influenced the resulting efficiency.

Measurement set-up

On the 4 MW NTB (see Fig. 1) at the Center for Wind Power Drives (CWD) of RWTH Aachen University in Aachen, Germany, onshore wind turbine drive trains can be tested. The low-speed prime mover operates the device under test (DUT) with up to 3.4 MN m and 30 rpm depending on the DUT. The DUT used for the measurements is a research nacelle of FVA (Forschungsvereinigung Antriebstechnik e. V.) with a nominal output of 2.75 MW and a rated torque of 1.55 MN m.

In the NTB, a non-torque loading unit (NTL) simulates wind loads by applying forces in three and bending moments in two degrees of freedom. The test bench's torque transducer is located between the prime mover and the NTL unit. In addition, a 5 MN m torque transducer from PTB, which is traced to national standards, was installed in the drive train directly on the rotor hub of the DUT. The mechanical input power was measured separately by these two torque transducers and a magnetic encoder for rotational speed measurement.

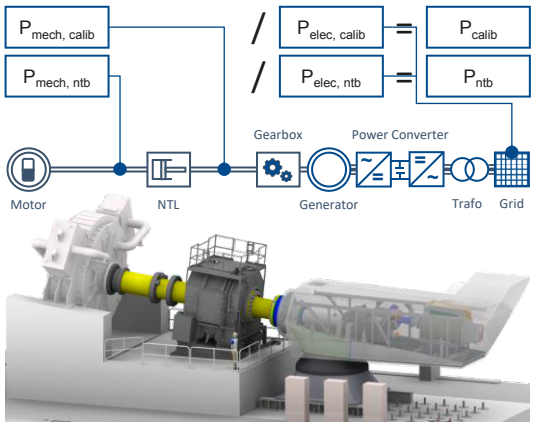

Fig. 1. 4 MW NTB at CWD of RWTH Aachen University including four measurement points for mechanical and electrical power measurement.

The electrical output power was measured by the test bench's current sensors and a voltage divider between the transformer and the middle voltage grid. For a traceable measurement of the electrical output power, three calibrated, high-precision current sensors and a high voltage divider traced to national standards were installed at the same point. All signals are gathered by separate data acquisition systems

(DAQs) which were synchronised via network time protocol (NTP). [1]

Measurement methodology

In general, the efficiency η of rotating electrical machines is the ratio of generated electrical power to total mechanical power in:

$$\eta = \frac{P_{\mathrm{el}}}{2\pi \cdot n \cdot M.} \qquad (1)$$

For torque measurement, signals are tared by the zero offset and averaged over six full rotations of the drive train. Detailed descriptions for measurement methodology and uncertainty analysis can be found in [2].

Results and analysis

The torque measured by the test bench's torque transducer before and after the calibration to the PTB torque reference is presented in Fig. 2.

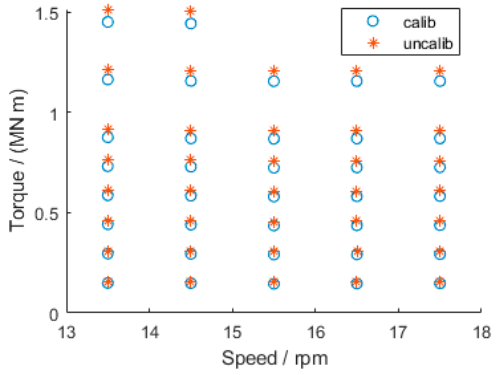

Fig. 2. Torque measurement before and after the calibration to the PTB torque transfer standard.

Without calibration, the test bench's torque measurement is off by about 5 %, as shown in Fig. 3.

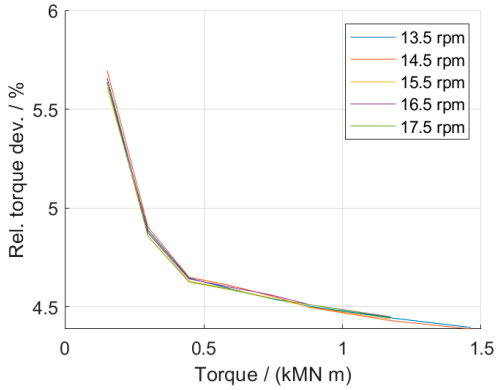

Fig. 3. The relative deviation of uncalibrated torque measurement.

For efficiency determination of the DUT, the efficiency results using uncalibrated and calibrated measurement devices are shown in Fig. 4. Without the calibrations, the efficiency of the DUT is measured significantly lower compared to the calibrated results. This is mainly due to the higher torque measured incorrectly.

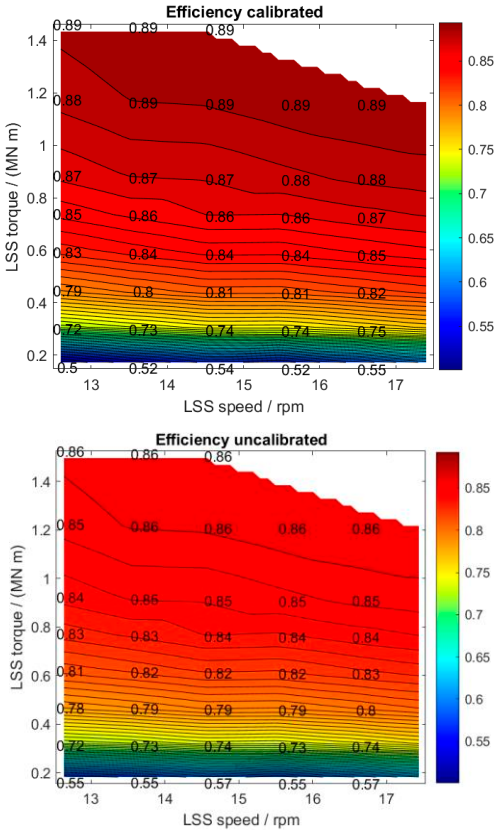

Fig. 4. Efficiency determination using calibrated and uncalibrated measurement devices.

Conclusion and outlook

In this paper, the efficiency of a 2.75 MW nacelle is compared using calibrated and uncalibrated measurement devices. The results show that especially calibration of mechanical input is important, as the torque measurement is off by about 5 % and results in significantly lower system efficiencies.

Acknowledgements

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References

[1] P. Weidinger *et al.*, "Summary report describing the schedules for the three measurement campaigns to determine the efficiency of nacelles and their components on test benches with a target uncertainty of 1 % including pre-tests, measuring devices, and transfer standard specifi." Zenodo, 2022. doi: 10.5281/zenodo.7043161.

[2] Z. Song *et al.*, "Traceable efficiency determination of a 2.75 MW nacelle on a test bench". Manuscript submitted for publication.