

Challenges and potential solutions for determining the efficiency of wind turbines

Although wind is an almost unlimited source of renewable energy, the availability of wind turbine sites that are both suitable for energy production and acceptable to the local population is limited. It is therefore essential that the available wind energy be converted into electrical energy as efficiently as possible at these locations. This means using wind turbines with the highest possible degree of efficiency, with this efficiency determined in such a way that it has the smallest possible measurement uncertainty and is traceable to national standards.

The factors that make up the overall efficiency are the aerodynamic properties of the blades (i.e., the generated mechanical power) and the conversion of mechanical power into electrical energy in the nacelle of the wind turbine. In the following we will be looking at the second of these two efficiency factors. Conversion efficiency can be determined independently of wind on a special system test bench for wind turbines. Figure 1 is a block diagram showing the basic setup of such a wind turbine test bench. Here, an electric drive is used in place of turbine blades to supply mechanical power to the system. In wind turbines with direct-drive generators, there is no gearbox upstream of the generator [1].

Determining efficiency on wind turbine test benches is a major technical challenge not only because of the large dimensions of these systems but also because of the often adverse environmental conditions to which the measuring equipment is subjected, such as electromagnetic interference fields and converter-related non-sinusoidal electrical quantities. Another important point involves the synchronization of the electrical and mechanical measurements taken at the various and often widely spaced measuring points [2].

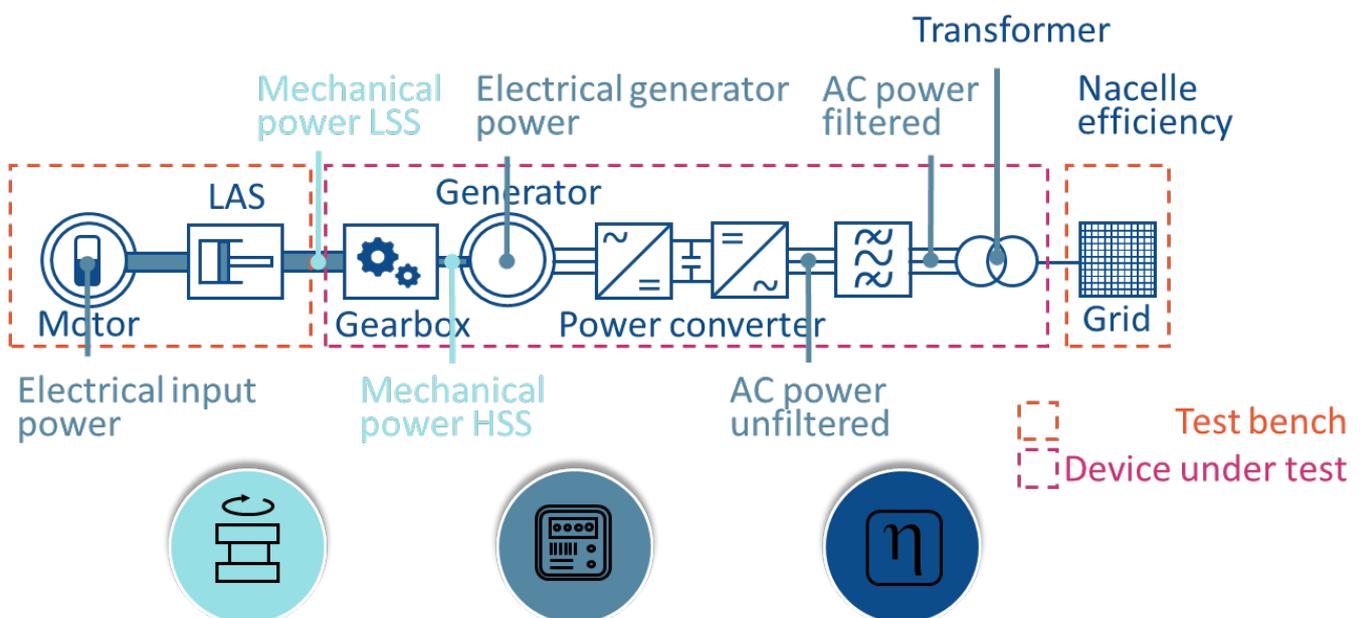


Figure 1: Block diagram of a test bench for complete nacelles from wind turbines based on [1]

One of the aims of EMPIR project 19ENG08, WinDEFY "Traceable mechanical and electrical power measurements for efficiency determination of wind turbines", which started in September 2020, is to develop methods for the traceable measurement of wind turbine efficiency that also minimize measurement uncertainty. Before being applied on the wind turbine test bench, these newly developed measuring methods will be tested in PTB's motor test field on a reduced scale (small scale test). One further focus of the project is to develop transfer standards, e.g., for mechanical performance measurement, and to trace them to national standards.

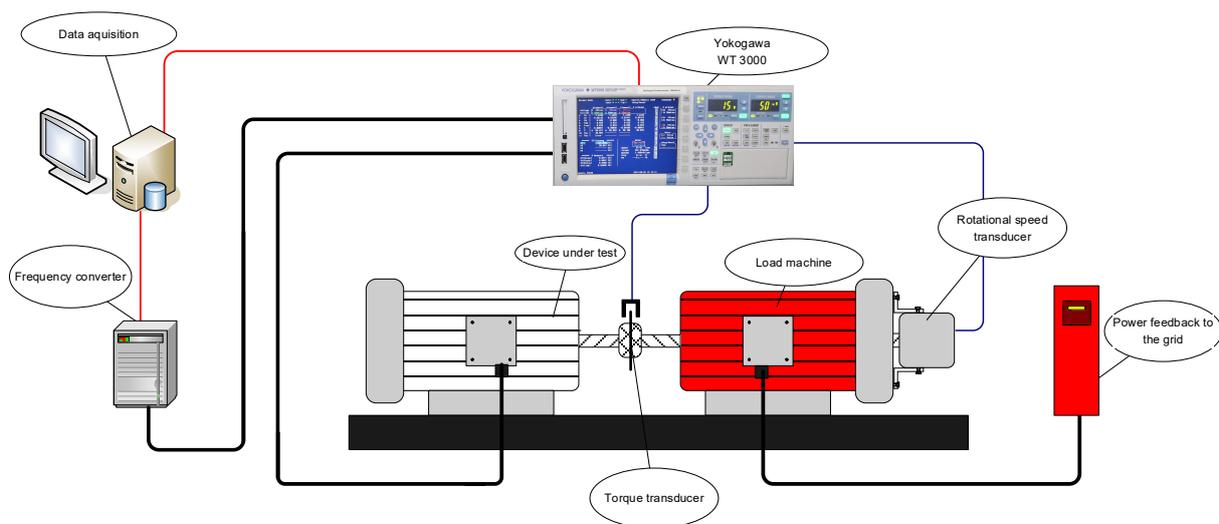


Figure 2: Basic experimental setup for direct measurement of the efficiency of electrical machines

The motor test bench used is set up analogously to the illustration in Figure 2: The load machine can be operated in all four quadrants, which allows the machine coupled via the torque measurement flange, the "device under test", to be operated both as a motor and as a generator. The machine can be powered either directly from a mains supply at 50 Hz (1st step) or via a frequency converter with regenerative feedback capability (2nd step).

The motor test bench was modified to accommodate a second measuring flange (HBK T12HP), intended as a transfer standard, in addition to the torque measuring flange already in the test bench. A special power analyzer was used for the synchronous acquisition of data from the two torque transducers. Figure 3 shows the modifications made. In addition to the speed sensor on the test bench, the speed signal of the HBK T12HP will also be evaluated.

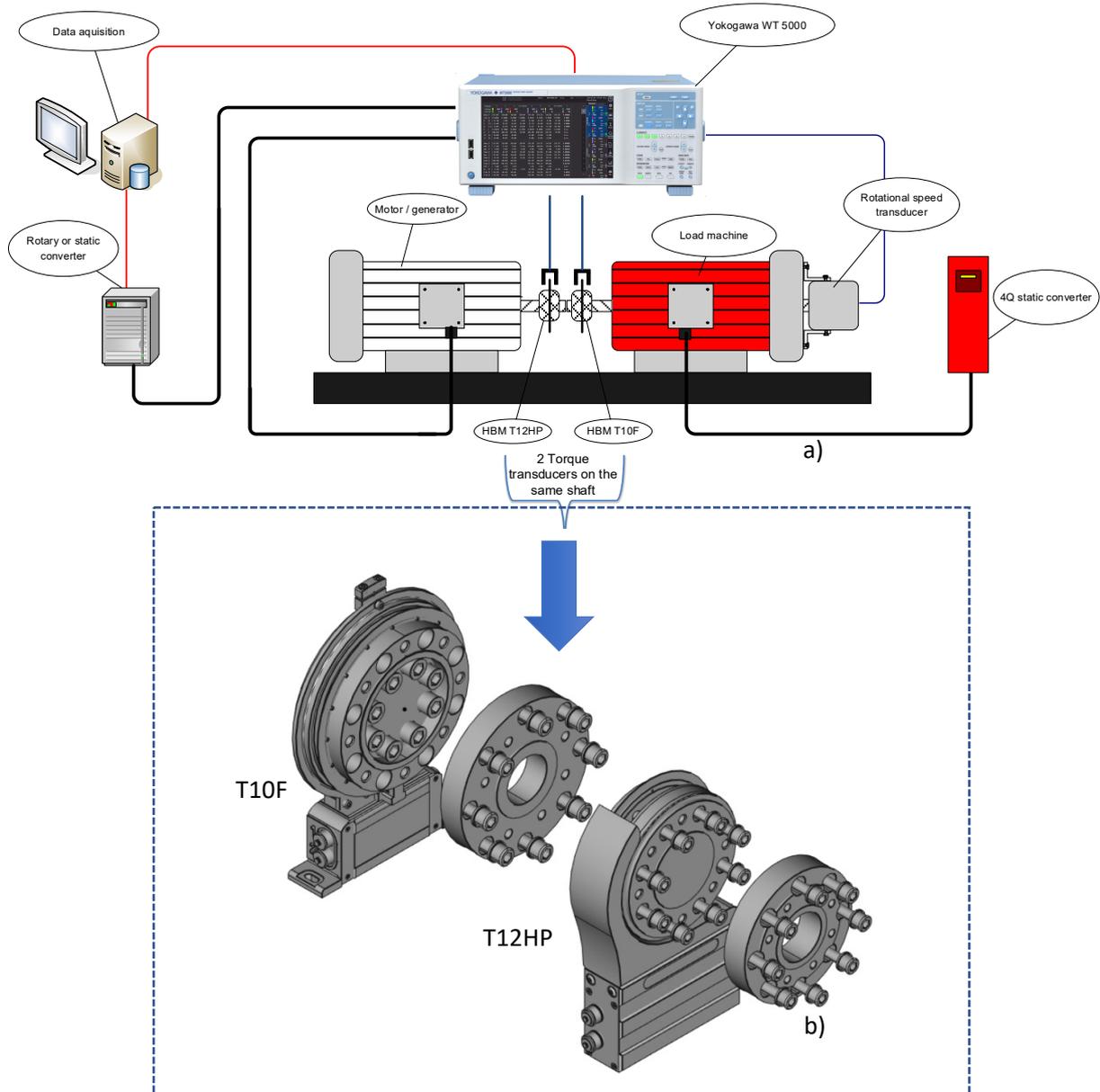


Figure 3: Modified motor test bench for the small scale test

a) Block diagram of the test bench

b) CAD drawing of the two torque transducers with mechanical connectors

This talk will elaborate on the EMPIR project and its goals and present the initial results of the investigations conducted at PTB's motor test field. One focus here will be on the testing of various efficiency determination methods to see which are most suitable for use on wind turbine test benches.

We will further look at the current status of the calibration of the mechanical performance transfer standard and examine the solutions that have been developed for synchronizing the acquisition of measured data on a real wind turbine test bench.

Literature

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Acknowledgments

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