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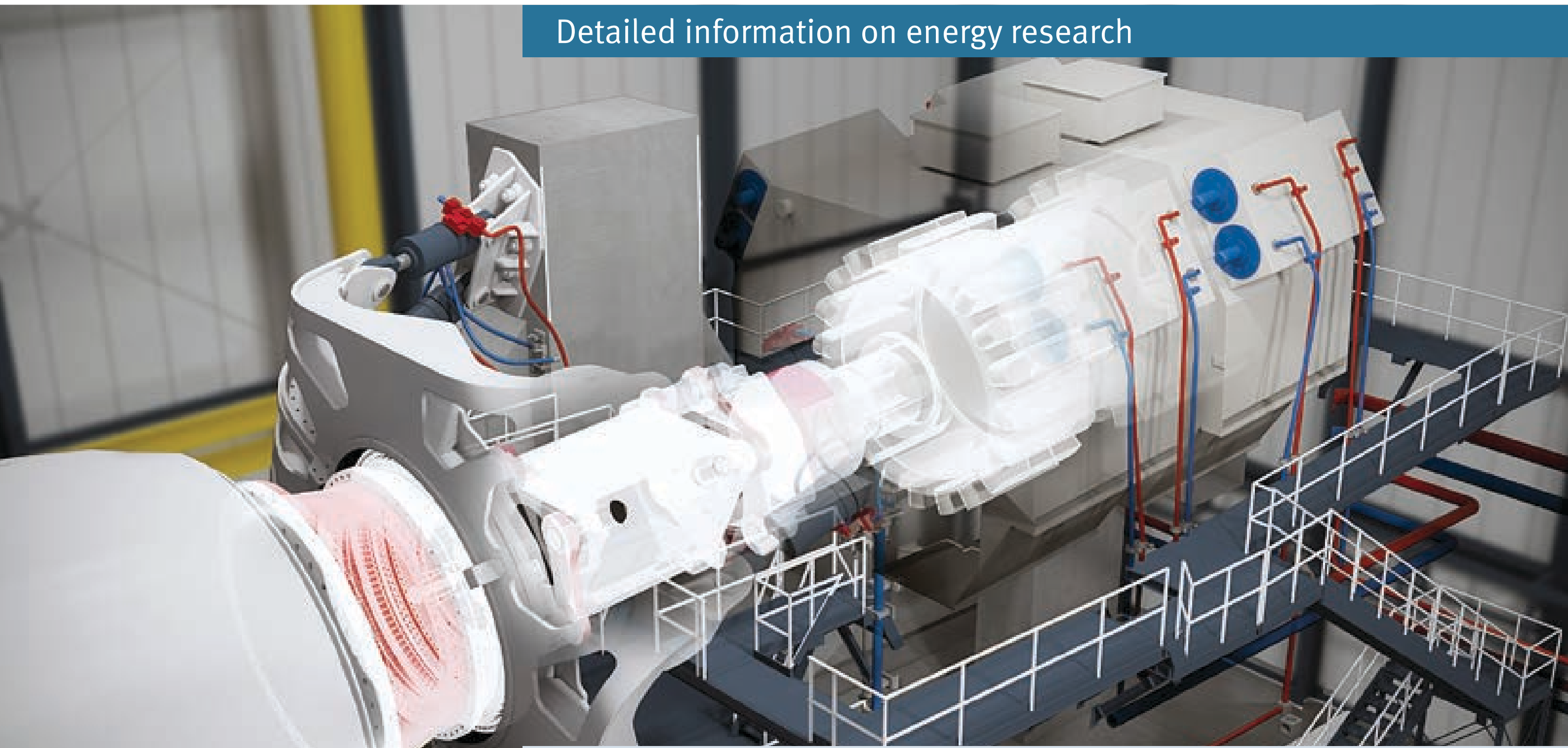
Detailed information on energy research



Fast-track testing of nacelles

From 2015, wind turbine nacelles will be tested in Germany's first test rig

BINE Information Service

In Bremerhaven, a test rig is being developed that can test complete wind turbine nacelles in the multi-megawatt class. Unprecedented: a load transmission system mechanically simulates the wind loads occurring in the field. The researchers are investigating the electrical components using a simulated electricity grid. Laboratory tests are also providing information on how wind turbine concepts can be improved. With these properties, the test rig has the world's most powerful grid simulation system.

The increasingly large wind turbines and new turbine designs need to prove their reliability and efficiency – even under challenging operating conditions. In particular, lightning strikes, extreme loads but also fatigue and wear of the components are ubiquitous risks. At higher altitudes, greater wind speeds are an additional burden on the ever-larger towers.

According to a reliability study on variable-speed wind turbines as part of the EU's RELIAWIND project, the most common faults occur in the electrical system and the mechanical drive train. The technical reliability of the large-volume and extremely heavy nacelles for wind turbines – to which the components mostly belong – largely determines the overall availability in the grid. This is why accelerated and realistic testing procedures are becoming increasingly important. Manufacturers previously had to build a prototype for each new turbine – which is a very time-consuming and expensive procedure. Using accelerated test procedures on a nacelle test rig enables the prototype testing phase to be considerably shortened.

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Federal Ministry for Economic Affairs and Energy (BMWi)

For this purpose, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES in Bremerhaven has developed a test centre, the Dynamic Nacelle Testing Laboratory (DyNaLab). The heart of the DyNaLab is a nacelle test rig where, from spring 2015, primarily gearless nacelles with up to 8 megawatts of electrical capacity, including both prototypes and serial production nacelles, can be tested for onshore and offshore applications. In the laboratory, field tests can be mimicked under realistic conditions. The nacelle test rig is supplemented with other testing facilities for the main components of wind turbines such as converters, generators, bearings and main shafts. “The tests on the test rig help to increase the reliability of the wind turbines – especially offshore. In addition, the loads acting on the drive train can be reduced by new control strategies,” says DyNaLab project manager Martin Pilas in explaining the benefits for manufacturers and operators of wind turbines. The tests enable a reduction of the tower head mass, improved operational management and control, an increase in the grid availability and shorter production lead times thanks to the accelerated certification.

Eliminating weak points early on

The investigations using the nacelle test rig contribute to a better understanding of the wind turbines. The simulation of specific operating cases enables weaknesses to be identified and countermeasures to be developed, which makes them more reliable. Potential flaws can already be corrected during the construction before the first prototype is erected in the field. This shortens the commissioning phase, which in turn leads to a quicker market introduction.
Before a nacelle can be tested, a detailed testing campaign is drawn up, which also includes the safety concept. Here, for example, load limits or abortion criteria are set and the respective adapters are designed. A nacelle test can take between three and twelve months in accordance with customer wishes. This means that a maximum of two to four nacelles a year can be tested on the test rig.

Testing the nacelle at a stretch

Hydraulic force transmission enables all the moments and forces acting on the rotor and nacelle to be depicted. The torque generated by the wind is modelled using two synchronous generators in tandem, which each have a drive output of 5 MW. A nominal torque of 8.6 MNm is therefore possible on the test piece. 13 MNm is also possible for short periods. This maximum torque is 20,000 times the force produced by a sports car with 404 kW (550 PS). It depicts the loads acting on the wind turbine via the rotor.
When gusts, turbulence or obliquely inflowing wind act on the rotor, this causes additional bending moments and shear forces that can also be simulated by the test rig, whereby the hydraulic force transmission system transfers the wind loads (Fig. 1). Via a load disk and a double-row tapered roller bearing, six hydraulic cylinders transfer the moments and forces onto the rotating main shaft. The test piece is connected to the rotating shaft via a flange adapter. The bending moments are applied around two axes with ca. 20 MNm and a thrust force of about 2 MN.
The wind load simulation works with either simulated static and dynamic operating conditions or with data from real-time simulations. The depiction of these impacts requires a highly dynamic drive train. This is only possible by using a very stiff drive train construction. “That sets us apart from the other test rigs,” says Martin Pilas and adds: “The force transmission can be used in diverse ways but is limited with respect to the transmittable forces. Normal operation can, however, be simulated realistically.”
Although the focus is on gearless nacelles, the test rig is also generally suitable for wind turbines with other drive train concepts, such as medium- and high-speed turbines with gears. In particular when investigating perturbations by the electricity grid, the testing of gearless wind turbines requires a particularly high dynamic test rig, as there is direct coupling between the grid and the wind side. However, the system also covers lower dynamic requirements, such as with other turbine concepts.

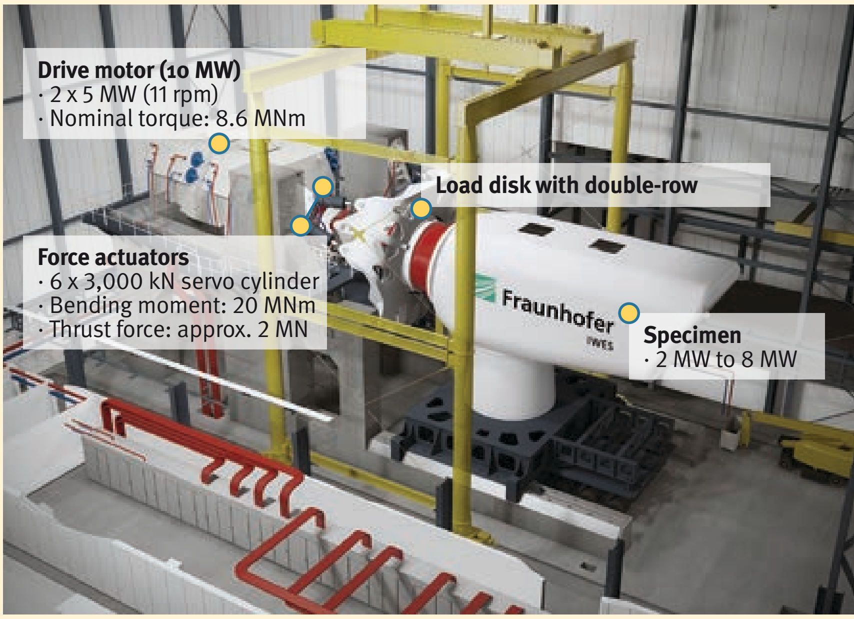

Fig. 1 *Load transmission: six hydraulic cylinders transfer the forces and moments to the nacelle. The electricity grid is modelled in the converter room behind.*

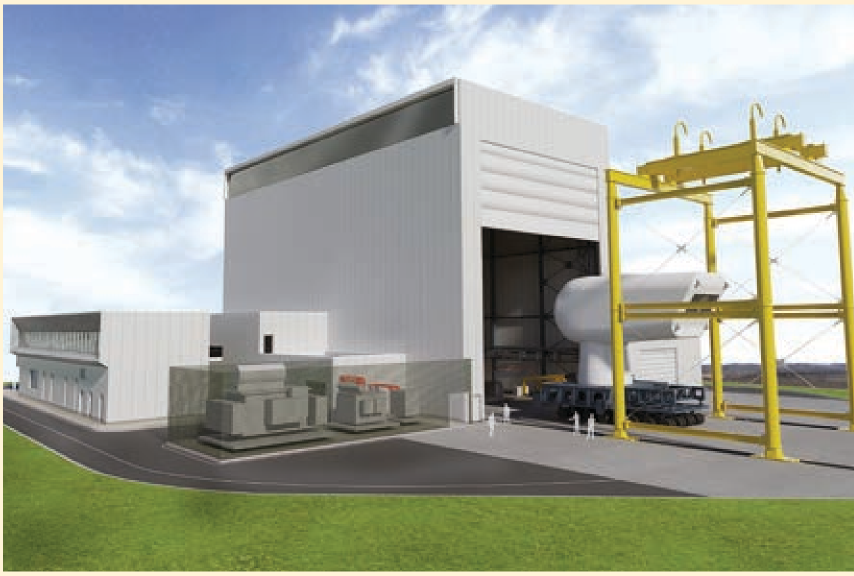

Fig. 2 *Simulation: a nacelle is driven on a heavy load transporter into the 30-metre-high testing hall. The yellow gantry crane can raise loads of up to 420 tonnes.*

Force transmission	*Dynamic application of 20 MNm bending moment, 2 MN thrust forces*
Nominal / peak output of the test rig drive	*10 MW / 15 MW*
Nominal torque	*8.6 MNm (transient also 13 MNm overload torque)*
Grid simulation	*Artificial grid with 44 MVA of installed converter capacity*
Apparent power	*40 MVA*
Voltage level AC	*10/20/36 kV*
Current at 36 kV	*650 A*
Frequency	*45 – 65 Hz*
Phase angle of the grid impedance	*0° – 90°*
Measurements	*More than 600 synchronous, high-resolution measurement channels*
Specimen	*2 bis 8 MW*

Fig. 3 *Characteristic values for the nacelle test rig in the DyNaLab*

Causes for the faults in wind turbines

As the components increase in size, so do the loads. Since both small and large structures invariably behave elastically, vibrations occur that can generate high dynamic load shares. Loads acting on the rotor of a wind turbine are passed to the other components and largely determine their individual load levels.
The most common faults include early failures (teething problems), incorrect commissioning (run-in phase) and installation errors. Failures can also be caused by random external events such as lightning strikes, extreme loads and combined loads. If early fatigue and component wear occur, this is sometimes due to a lack of knowledge of the system or faulty construction. However, they are also caused by environmental factors such as humidity and temperature changes.

Fig. 4 *The test rig drive is mounted on a concrete foundation. The nacelle is fixed to this foundation via a pallet system.*

Test rig facilitates optimisation process

New control strategies are helping to reduce the loads acting on the drive train. For this purpose, the scientists are investigating new drive train concepts, which in an optimal case will enable a reduction in the tower head mass. An accurate measurement of the loads acting on different components provides information on whether it is possible to revise downwards the safety factors when designing the components, which would also save weight in the structure.
Because there is no rotor or tower in the test rig, the nacelle has other system characteristics as in the field. Therefore in order to calculate the real loads as closely as possible, the researchers are developing real-time models and control algorithms. For this purpose they are calculating the occurring loads and the interactions between the nacelle and rotor in the laboratory. The interaction of the hardware components and simulation models makes it possible to operate the test rig and test piece using the hardware-in-the-loop (HIL) process.

Simulating the grid

The electricity grid into which the wind turbine feeds its generated electricity can also be modelled in the DyNaLab. The artificial, 36-kV medium voltage network with a 44-MVA converter rating allows the simulation of short circuits and other short-term events in the grid with a high repetition frequency. This therefore spares the general supply grid and the duration of these test runs can be adapted in accordance with manufacturer requirements. The various loading situations include among others the behaviour in storms, incorrect pitch control, grid outages and emergency stops. This means that different operating scenarios can be simulated as often as required in the nacelle test rig.
The harmonic behaviour of nacelles and their impact on the grid can also be determined in the DyNaLab. For this purpose the world's largest artificial grid is being installed. Here, nacelles will undergo static tests to investigate, for example, the active and reactive power outputs with different grid conditions or the thermal behaviour of electronic components. The scientists are simulating transient events in the grid that impact on the entire nacelle system.

Tests shorten certification process

"Although the nacelle test cannot replace a comprehensive field test, it can support the development and certification process," explains the project manager. Since different operating situations can be modelled as much as required in the nacelle test rig, this enables, for example, the operational management and control to be optimised and the model to be validated. That saves money, reduces the project risk and shortens the time to market launch.

Monitoring wind turbines and identifying faults

Entire wind turbine nacelles can be tested in the DyNaLab testing rig. However, all the components still have to prove themselves in operation even after such testing processes. Early fault detection systems then monitor the turbine condition. Until now, wind turbines have been serviced either reactively or preventively. With the latter method, the respective wind turbine is shut down within specified time intervals so that the components can be checked or replaced. The result: intact components are also replaced and the remaining service life is wasted. The permanent, condition-based monitoring of components, on the other hand, has the advantage that the wind turbine can also be monitored remotely.

Early fault detection and wind field measurements

Condition monitoring systems (CMS), which are based on the regular or continuous recording of the wind turbine condition, measure and analyse physical parameters such as vibrations, temperatures and positions. Here the condition monitoring pursues two objectives: safety and turbine efficiency. It is comparable with the structural health monitoring of structural components, which is used to continuously obtain indications about the functioning of building components and structures. The intention is to identify damage, such as cracks or deformations, at an early stage so that countermeasures can be taken swiftly.

The condition of wind turbines can also be checked remotely using the laser-based LiDAR system. LiDAR is a method very closely related to radar that is used for making optical distance and speed measurements as well as for the remote measurement of atmospheric parameters. LiDAR stands for Light Detection And Ranging. However, instead of radio waves – as is the case with radar – the system uses laser beams. The system has already been deployed offshore in meteorological buoys.

In addition, measurement sensors on wind measurement masts record the wind layers at heights between 100 and 200 metres. This makes it possible to investigate the influence of forest areas and terrain slopes on the wind profile and the emergence of turbulence. Sensors on the mast record the measurement values that also help to validate and further develop the LiDAR method.

Project participants

- **Project management:** Fraunhofer Institute for Wind Energy and Energy System Technology IWES, Bremerhaven, Germany, Martin Pilas, martin.pilas@iwes.fraunhofer.de

Links and literature (in German)

- Video on the nacelle testing in the DyNaLab: www.windenergie.iwes.fraunhofer.de/content/dam/windenergie/de/video/IWES_DyNaLab_IDOM_DE_small.avi
- Final report on the EU's RELIAWIND project: http://cordis.europa.eu/publication/rcn/14854_de.html

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