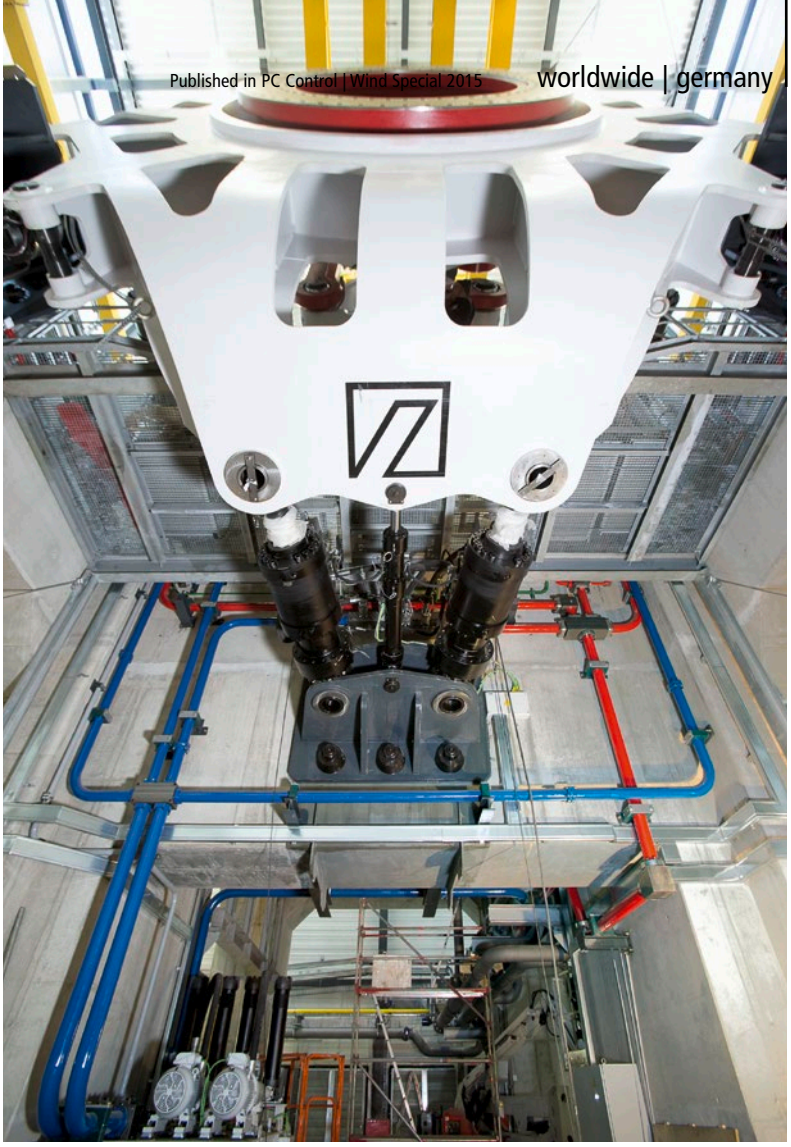
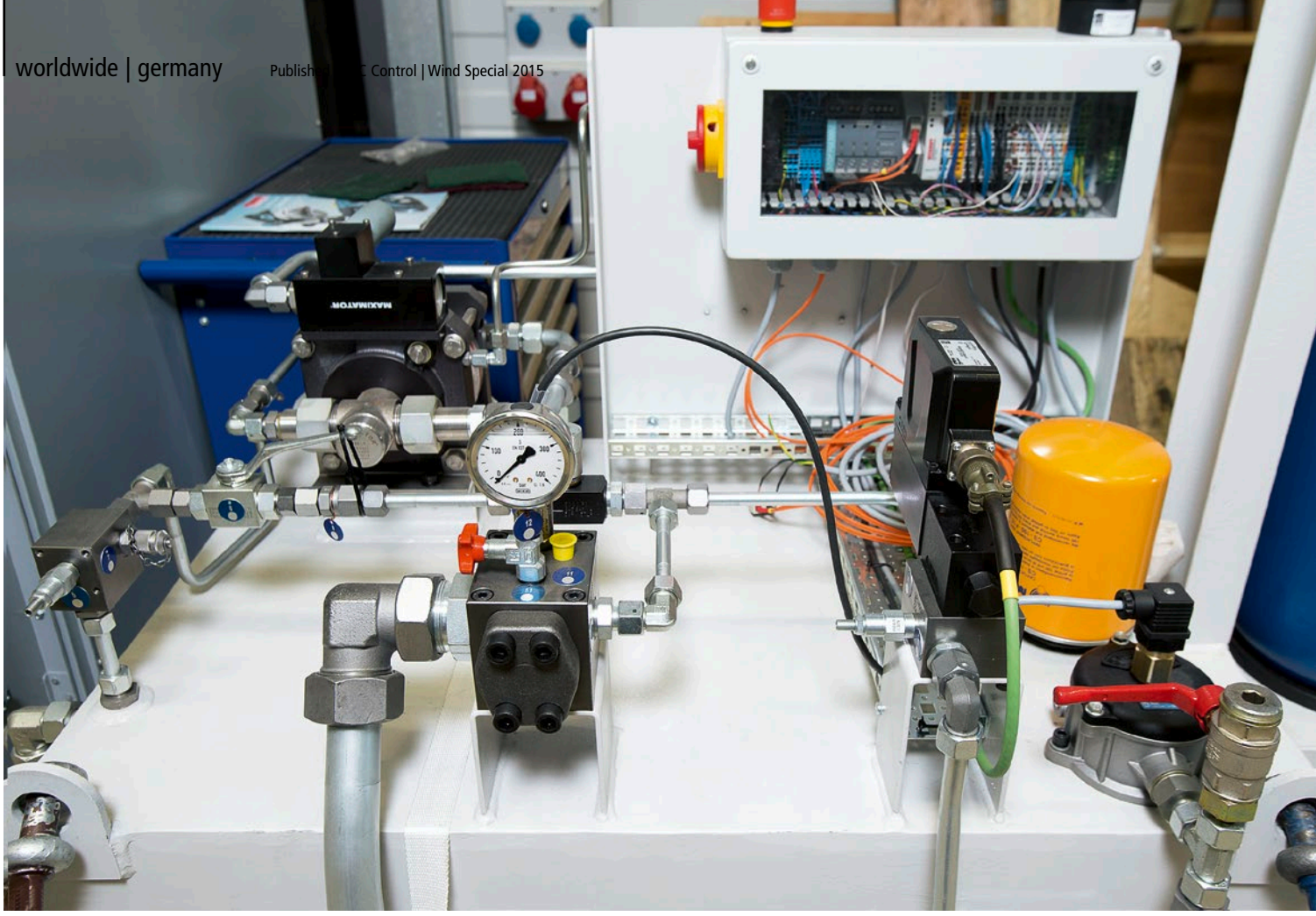


The Stewart platform for the load transmission to the wind turbine nacelle offers six degrees of freedom and uses six 3000 kN servo cylinders.

PC- and EtherCAT-based control technology in a feature-filled test bench system for wind turbines

Fast EtherCAT communication for distributed real-time controllers in a 10 MW test bench

The Dynamic Nacelle Testing Laboratory (DyNaLab) is the first test environment for complete wind turbine nacelles ever built in Germany. It features a test bench drive with a rated output of 10 MW, designed for testing wind turbine systems with a rated output of 4 to 8 MW. PC-based control from Beckhoff is used to control the complex system, and a high-speed EtherCAT communication ensures a consistent real-time solution as well as optimum consideration of the distributed subsystems from a control perspective.



DyNaLab is located in Bremerhaven, Germany, at the "Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) Northwest". The research activities at the IWES cover the whole spectrum of wind energy technology, from wind physics to grid feed-in. The focus is on understanding wind turbines as systems with dynamic interaction between the individual components and environmental factors, which – according to Torben Jersch, group leader for plant and system technology – creates potential synergies in comprehensive approaches to these solutions. This is especially true in view of the fact that the Fraunhofer IWES in Bremerhaven already operates two continuously utilized rotor blade test rigs, and therefore offers a unique overall testing infrastructure.

Testing wind turbines comprehensively and under realistic conditions

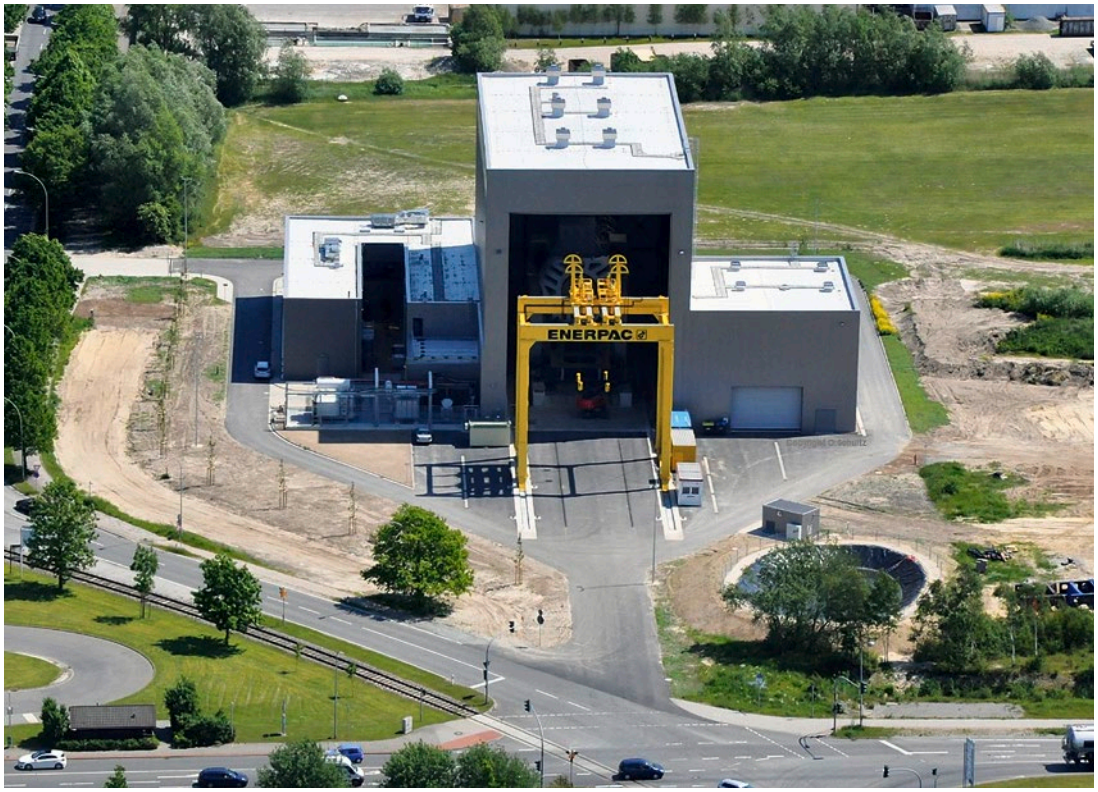
DyNaLab offers wind system manufacturers a realistic test environment in the multiple-megawatt range, enabling meaningful laboratory tests that can contribute to the assessment and optimization of existing and future system concepts. The first tests were conducted in August 2015, in cooperation with a Spanish system supplier. The wind turbine nacelle from Jacobs Power Tec GmbH to be tested was connected via a hydraulic load application system in the form of a Stewart platform, and consisted of a hexapod with six 3,000 kN servo cylinders. One of DyNaLab's key features will be electrical certification of wind turbines on the test bench.

The load transmission structure for simulating mechanical wind loads, such as shear or bending moments, is linked to the flange adapter via a moment bearing. Moments and forces can thus be transferred from the non-rotating load disc to the rotating shaft. With this special configuration, it is possible to apply bending moments of approximately 20,000 kNm or shear forces up to 1,900 kN, and, moreover, it enables the dynamic simulation of radial loads. The wind torque is modelled via two externally excited synchronous machines in a tandem arrangement with a drive power of 5 MW each. For test operation, this enables a total drive power of 10 MW and the introduction of a rated torque of 8,600 kNm to the equipment under test.

The whole drive train of the test bench is tilted by 5°, which corresponds to the actual orientation of a wind turbine in the field, therefore simulating a real load situation. The wind load simulation can either mimic different static and dynamic operating conditions, or it can be run as a real-time simulation, as well. To test wind turbines as comprehensively as possible, pitch and yaw systems are integrated in the system test. For this purpose, the control values of the individual systems are implemented via actuators in the real-time simulation. A 36,000 V medium voltage grid simulation enables simulation of network faults and voltage dips during the nacelle test with a high repetition rate.

Real-time capable control system for the test bench

Torben Jersch explains the requirements for the control technology of the test bench: "Because we wanted to perform distributed real-time calculations and control simulations, a very fast and deterministic communication system was a must-have. EtherCAT has proven to be ideal for this purpose. Due to profound



PC-based control is modular and finely scalable, which means it can be used in all areas of the test bench as required.

The large hall of the test complex contains the actual test bench as well as the hydraulic and cooling systems; whereas the bulk of the electrical installation is housed in the building to the left.

EtherCAT expertise and the wide range of EtherCAT components available from Beckhoff, it made sense to completely rely on PC-based control."

In the meantime, this approach has been tried and tested in practice, as Torben Jersch explains: "The eXtreme Fast Control (XFC) characteristics of EtherCAT, such as Distributed Clocks and Timestamping, ensure time synchronicity across the whole test bench. As a result, we could easily configure the required distributed discrete control loops, consistently adhere to the real-time concept, and consider all sub-components from a control perspective. EtherCAT is therefore the main communication bus for controlling the key components of the test bench, such as inverters, motors, hexapod, simulation computers, set value specification and additional monitoring for the test object. Standard Ethernet is used for the non-real-time monitoring and control of auxiliary systems, such as cooling pumps."

The Beckhoff control technology includes TwinSAFE to ensure the system safety of the test bench. In addition, the Hexapod controller directs the six hydraulic cylinders in parallel, as well as the tasks performed by the central DyNaLab control computer and the real-time calculation of the wind turbine rotor model. Three Industrial PCs (IPCs) perform these tasks, specifically two 19-inch C5102 slide-in IPCs and a CX5010 Embedded PC. Torben Jersch explains the reasons for this configuration: "The physical separation into three computing devices was part of our specification, in order to provide a clear structure for the control system, with unambiguous interfaces. In addition, this architecture facilitates subsequent extensions or optimizations for various subsystems."

Simplified engineering through TwinCAT 3

DyNaLab uses the TwinCAT 3 automation software, which offers particular benefits because of the seamless interfacing with MATLAB®/Simulink® software, as Torben Jersch explains: "The integration of MATLAB® code enables the majority of our staff to program controllers themselves and therefore to focus on application development, without having to delve deeper into microcontroller or PLC programming." Other components used in the test bench include the base TwinCAT 3 software environment and additional functions such as TC3 PLC, TC3 Scope View Professional and Scope Server, and TC3 XML Server and Database Server.

Further information:

www.windenergie.iwes.fraunhofer.de/en
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