FRAUNHOFER INSTITUTE FOR WIND ENERGY SYSTEMS IWES

CERTIFICATION OF ELECTRICAL CHARACTERISTICS ON SYSTEM TEST BENCHES

Speeding up Time to Market with Testing for Grid Integration

ACKNOWLEDGEMENTS

Sponsored by

Federal Ministry for Economic Affairs and Energy

European Union
Investing in Bremen's Future
European Regional Development Fund

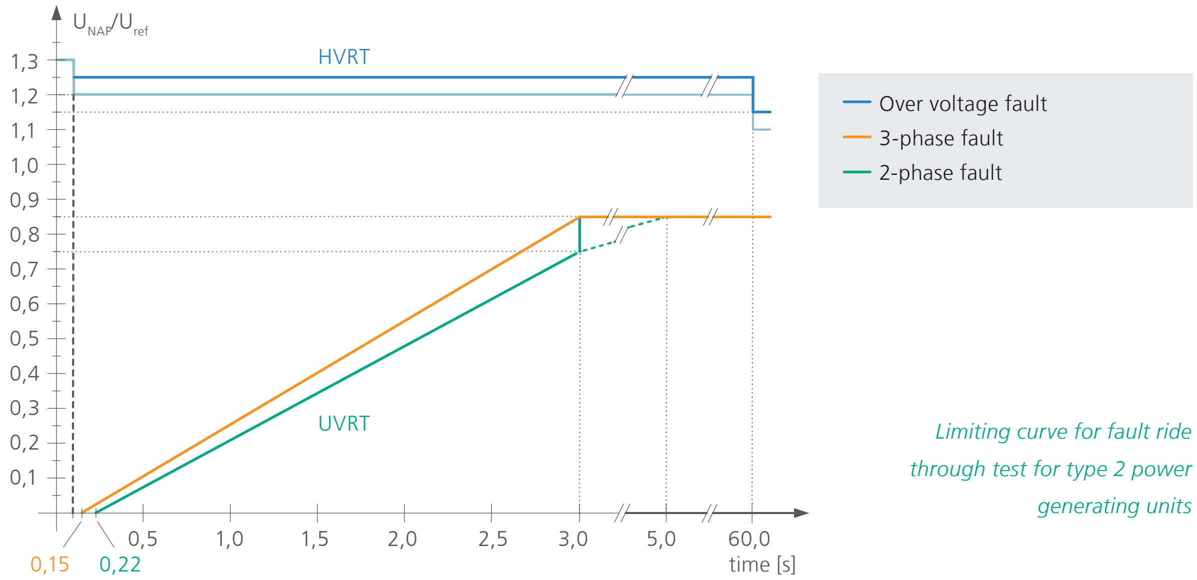
FUNDED BY EFRE

Bremen
Bremerhaven

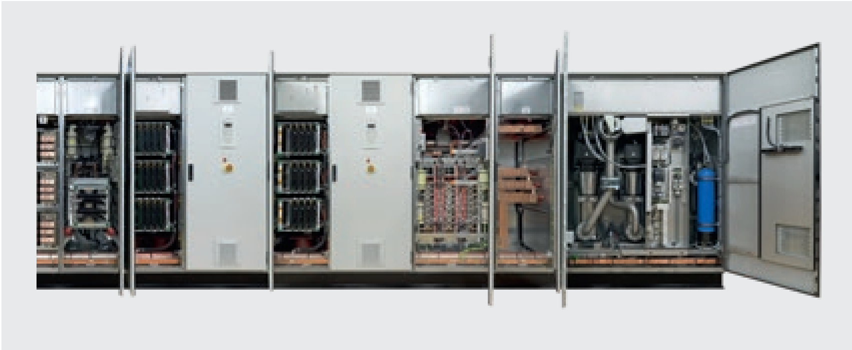
SAFEGUARDING NEW AND MODIFIED TURBINE DESIGNS

The expectations placed on the performance of wind turbines have increased significantly during recent years. The increasing competitive pressure which prevails on the global market and the noticeable professionalization of the industry have increased these expectations: With new turbine designs, the expectation nowadays is that the first turbines of a new type already run with high reliability when they are first delivered. Investors demand proof of comprehensive operational experience before they will commit financing for projects. New developments – even modifications of existing products – therefore represent a significant economic risk as far as the manufacturers are concerned. The experimental validation of prototypes on large test benches reduces this risk, accelerates the certification, and improves the plannability.

The higher proportion of electricity from regenerative sources in the distribution and transmission grid structures at various voltage levels increases the demands being placed on the grid integration of wind turbines as power generating units (PGU) even further. These requirements are laid down in standards and guidelines which have to be taken into account in future developments. Turbine certificates are mandatory for new and modified turbine designs. They ensure that the PGU operation is compliant with the grid code and thus guarantee the grid connection in the long term and the continuation of the feed-in tariff. Fraunhofer IWES assists turbine manufacturers by offering efficient test methods for the accelerated validation of the electrical properties of PGUs on test benches to meet the increasing requirements.

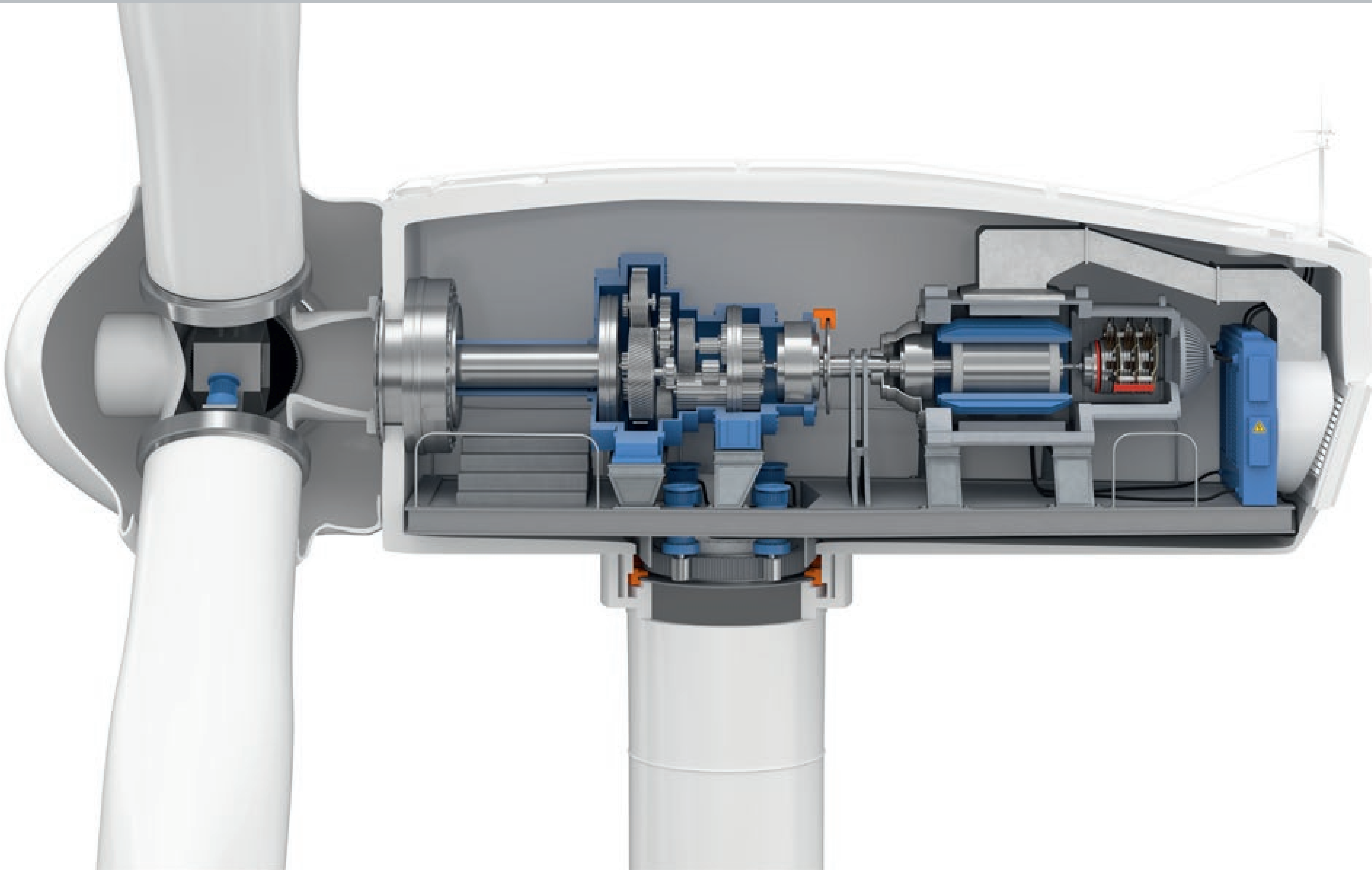


Limiting curve for fault ride through test for type 2 power generating units



IGCT modules of ABB's grid emulator in operation at Fraunhofer IWES

MEASUREMENT OF A WIND TURBINE IN THE FIELD



The testing of grid compatibility for the certification of the electrical characteristics of new wind turbines – or recertification when existing types of turbines are modified or improved – is currently undertaken almost exclusively with the aid of mobile test installations in the field. To determine the electrical characteristics, these field tests always include the following measurements, which are taken with the aid of the test installation, Fault-Ride-Through (FRT) containers and measuring systems:

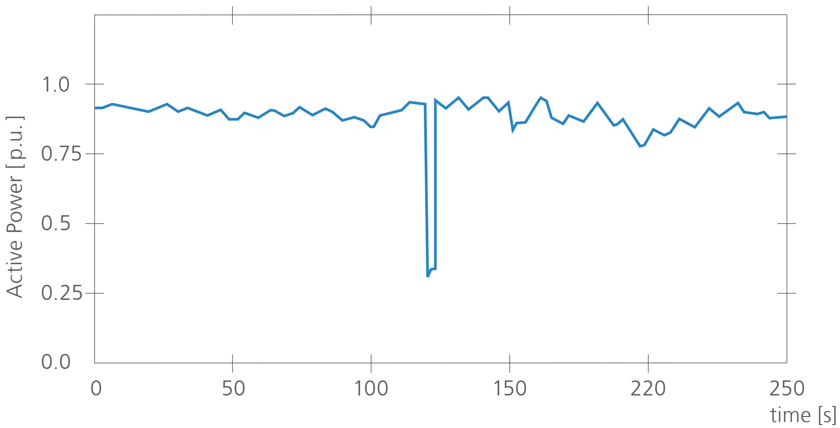
- Control response of the power generating units (PGU): active and reactive power
- Grid perturbation: Switching operations, flicker, harmonics, imbalances
- Grid protection (PGU disconnection from the grid)
- Fault-Ride-Through (overvoltage and undervoltage tests)

The complete certification campaign usually covers a period of up to two years; this amount of time is a significant cost factor in turbine development and decisively determines the point in time at which the turbine is launched commercially.

The demand for suitable locations for the prototype certification is high, as is the number of turbines to be certified. The site conditions largely determine the realizability of a certification campaign: alongside the need for good wind conditions, increasing turbine size means that higher demands are placed on the grid connection. Test for the certification of the electrical characteristics of power generating units affect the downstream supply network and therefore require close coordination in advance with the local network operator.

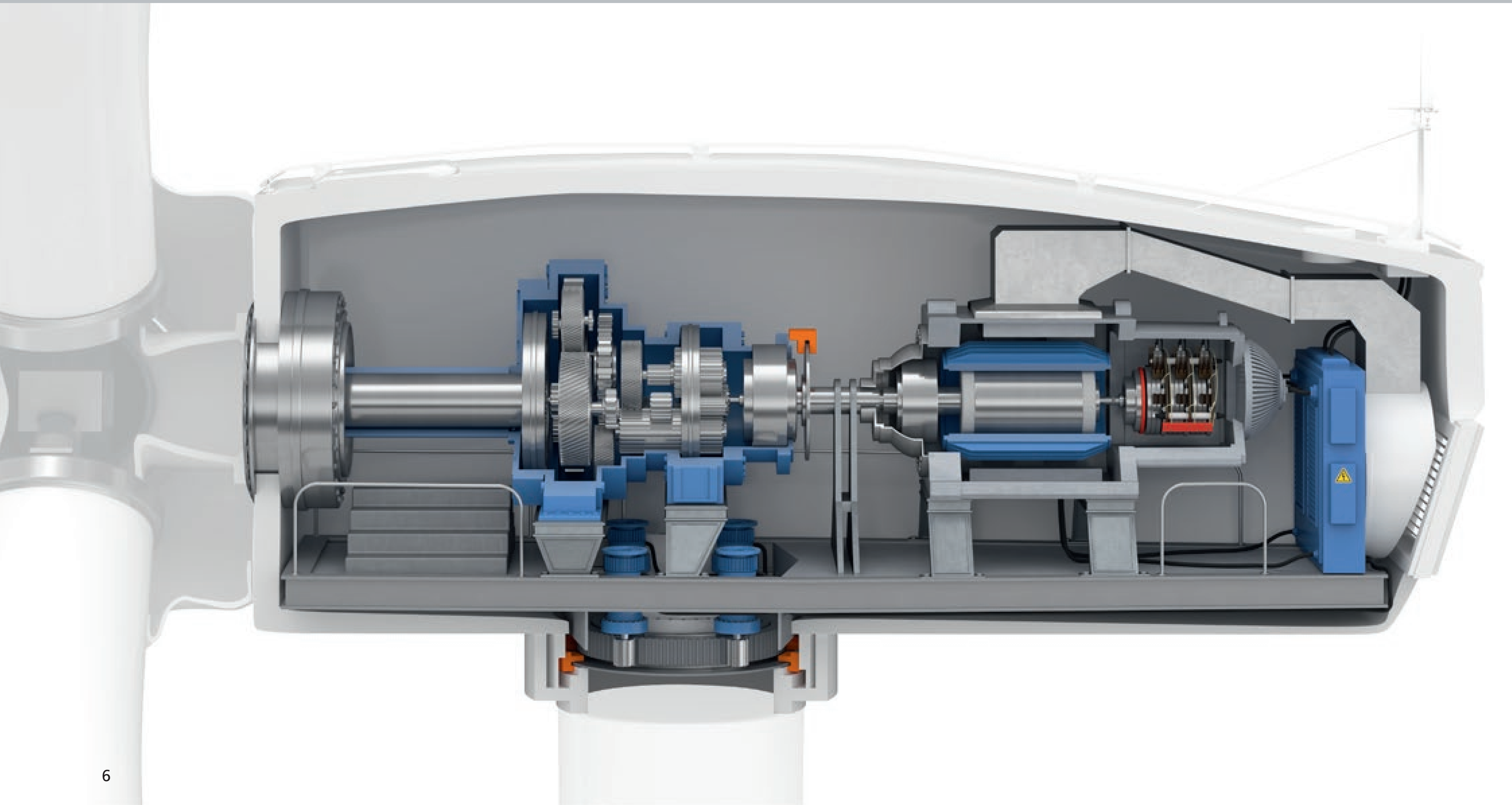
In addition, field tests are practically irreproducible; it is extremely unlikely that two tests can be performed under precisely the same wind and grid conditions. The comparability of the results for verification is therefore limited. Moreover, there can sometimes be long delays before the requisite test conditions can be met. This therefore makes it much more difficult to plan the series production for the commercial launch.

Insight of a measurement container for a certification campaign in the field



Active power supply at PCC during voltage sags

TEST VARIATION 1:
HIL TESTING ON THE NACELLE TEST BENCH IN THE DYNALAB



The Dynamic Nacelle Testing Laboratory (DyNaLab) at Fraunhofer IWES provides turbine manufacturers with a realistic testing environment in the multi-megawatt range to carry out tests under reproducible conditions within a specified time period. Existing and future concepts for wind turbines can thus be validated and optimized where necessary. By using an artificial network with 44 MVA installed converter power, it is possible to reproduce typical grid faults such as voltage dips with a high repetition rate.

This combination of mechanical tests and a grid emulator to test wind turbines up to 10 MW is currently the only one anywhere in the world. Since it was commissioned in 2015, the prototype of AD 8-180 was tested, and Enercon and Siemens Gamesa Renewable Energy have used the nacelle test bench for their campaigns. Moreover, a superconducting generator was tested at the facility as part of the EcoSwing research project.

The high-performance grid emulator allows static tests to be carried out to determine the effective and reactive power output for different grid conditions, for example. In addition, transient grid events which affect the whole nacelle system can be simulated: Tests of dynamic Under-Voltage-Ride-Through (UVRT) and High-Voltage-Ride-Through (HVRT) events, as are demanded by various grid codes, and dynamic changes to the grid frequency can be specifically reproduced and their effects on the turbine analyzed.

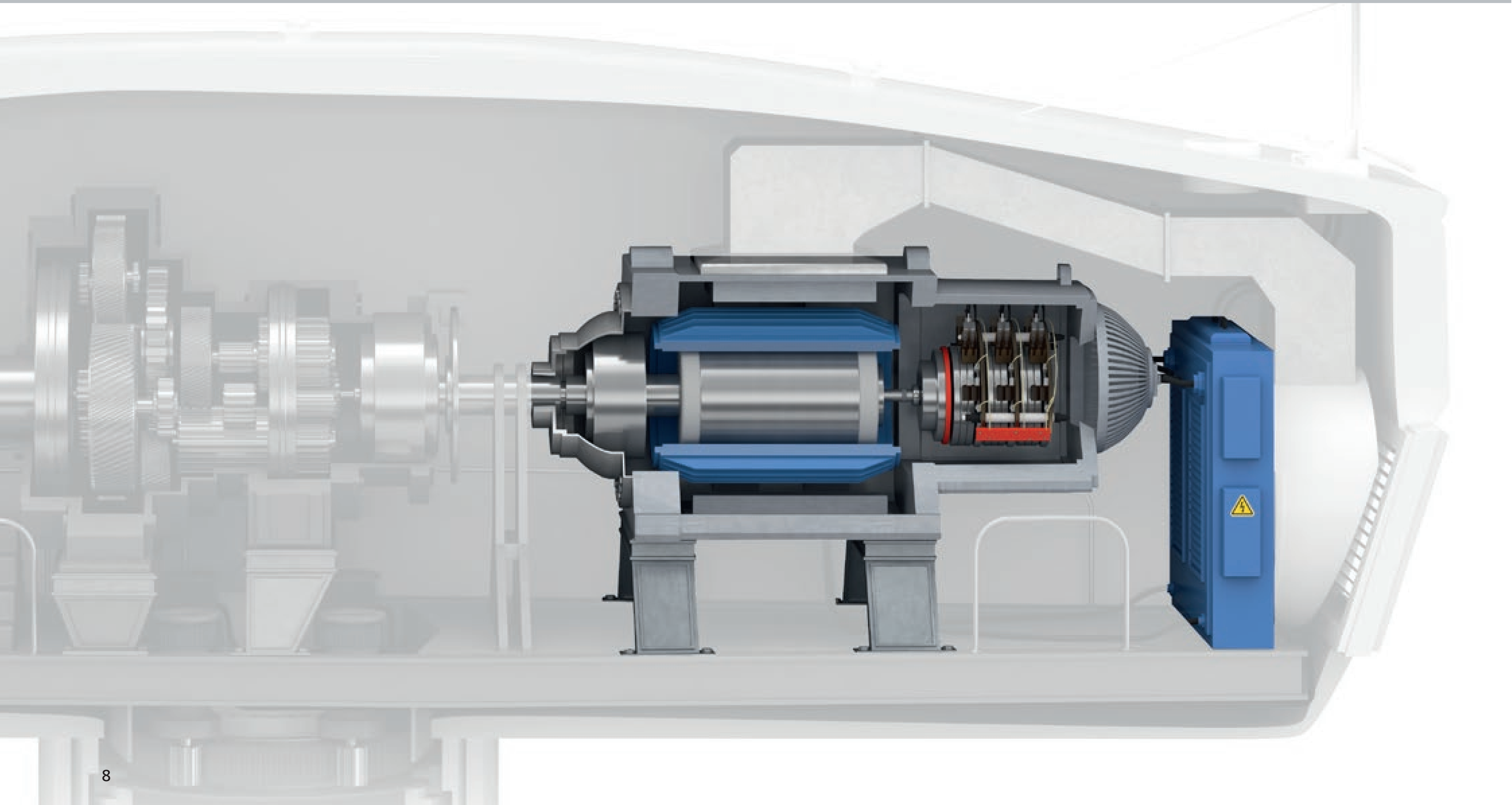
Since the nacelle is tested on the test bench without rotor and tower, it has different system characteristics than it has in the field. To replicate the actual conditions, the loads and interactions which occur between nacelle and rotor are calculated and imposed on the nacelle on the test bench. In the Hardware-in-the-Loop (HiL) method, high-performance, real-time models and corresponding control algorithms are used to operate the test bench including the unit under test. A testing campaign for certification on the test bench can be scheduled precisely and defined so as to be manufacturer specific.

Technical data DyNaLab:

- *Force application: dynamic application of 20 MNm bending moment, approx. 2 MN thrust forces*
- *Nominal torque: 8,6 MNm*
- *Overload torque: 13 MNm*
- *Drive Performance: 10 (15) MW*
- *Artificial network with 44 MVA installed converter power*
- *Measurements: more than 600 synchronous, high resolution measuring channels*

Nacelle of an 8 MW wind turbine arriving at the DyNaLab for testing

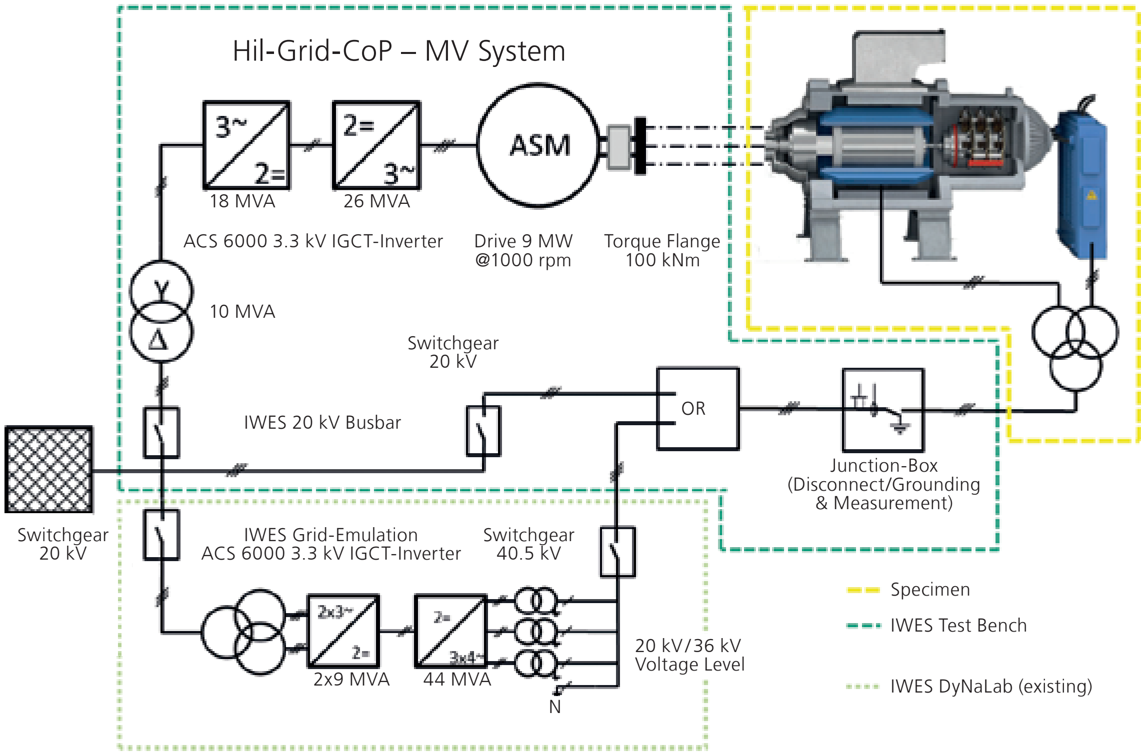
TEST VARIATION 2: HIL TESTING OF HIGH-SPEED GENERATOR-CONVERTER SYSTEMS



Fraunhofer IWES is satisfying the sustained demand from the industry for accelerated testing possibilities for the electrical system of a wind turbine by building a new test bench which will go into operation in 2019. Unlike the nacelle test bench, this one will be designed to test minimal systems. They consist of high-speed generators and converter systems, as well as components for grid integration on the medium voltage level. Therefore, the test bench is appropriate for systems with high generator numbers of rotation (1200-1800 1/min) up to 6-7 MW nominal power with two- to three-stage gearboxes.

The aim is for test methods being developed as part of HiL-GridCoP, a BMWi-supported project, to facilitate the partial automation of the processes necessary for the certification of the electrical characteristics. Turbine manufacturers thus save time and money on the testing process and also because the logistics are simpler. The first companies to use the test bench will be the HiL-GridCoP project partners Senvion, Nordex, and Vestas.

To test all the characteristics of a wind turbine in the laboratory, development tests with several different runs are necessary and their execution is to be partly automated. The software-assisted test management utilizes approaches from the automobile industry to provide the client with standardized interfaces, generate test profiles from the test specification, and allow the tests to be carried out with only partial manual control.

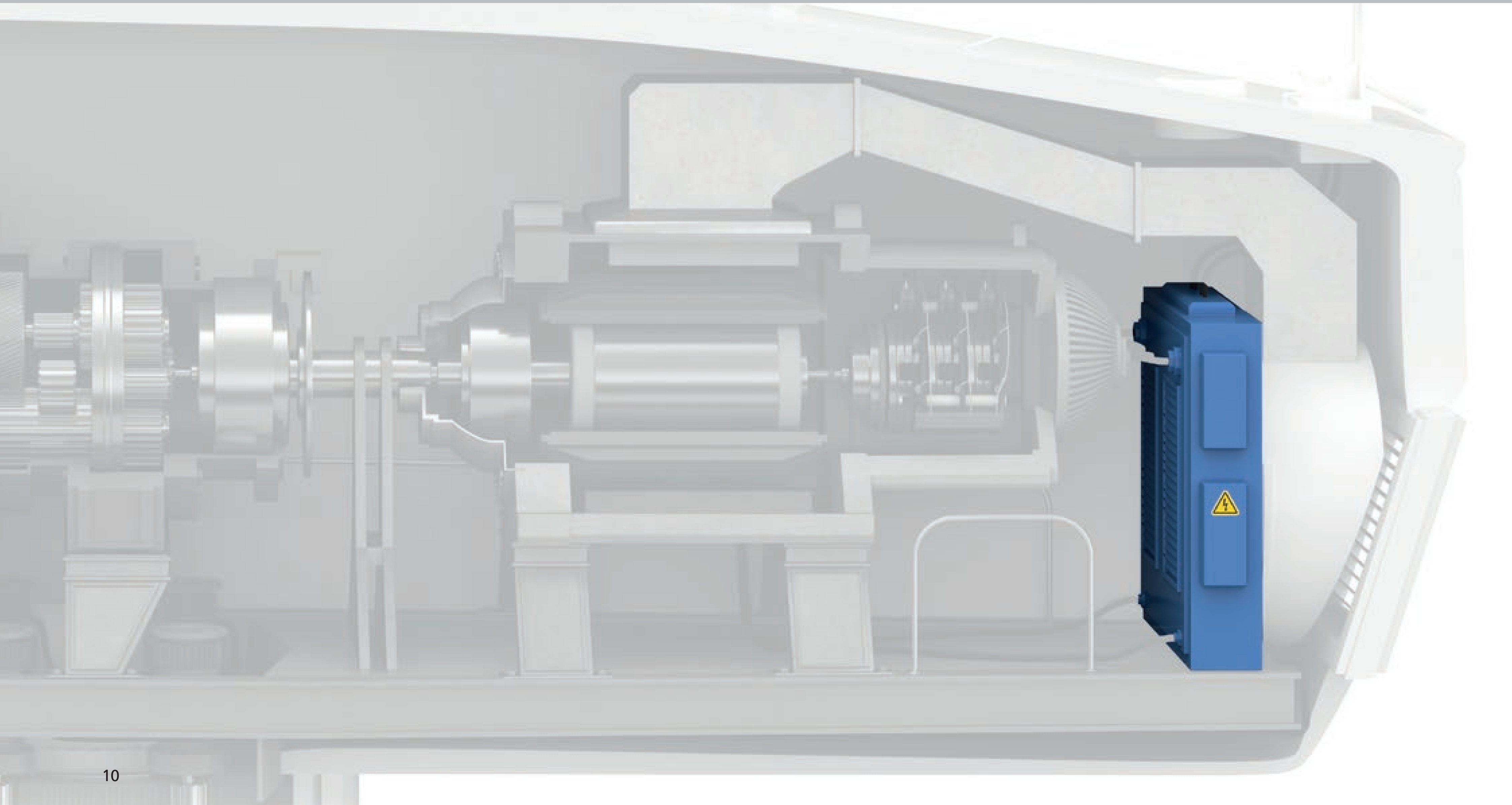


Medium voltage system and test bench for testing a high-speed generator/converter system

The test bench will have a 9 MW drive unit (up to 13 MW in overload) to replicate realistic generator moments with the aid of Hardware-in-the-Loop (HiL) techniques. The demands being placed on the HiL methods of testing are increasing – apart from replicating the rotor on the nacelle test bench, they must also be able to emulate the drive train. This particular demand is met by using detailed, real-time models on high-performance target hardware which allows optimum data exchange with the test bench control.

The test bench uses the existing grid emulation of the nacelle test bench to replicate various grid conditions. IWES also plans to expand the functionalities of the existing grid emulators significantly so as to meet the demands for the grid integration of future wind turbines as well. The aim is to be able to replicate systems from extremely weak grids up to special harmonic interference spectra.

TEST VARIATION 3:
TESTING OF CONVERTER SYSTEMS



Ever-increasing requirements are being placed on the grid integration to ensure the distribution and transmission network operates with high stability on the different voltage levels as the proportion of fluctuating feed-ins increases. This is evident, for example, in the increasing requirements being placed on the main converters of wind turbines in respect of the electrical characteristics of their power quality (PQ) - regardless of their drive train topology. A logical next step is to reduce the system being tested further to the (main) component: the converter.

Analyses relating to power quality and the certification of the electrical characteristics of the converter are already state of the art for generation and consumer units in the low voltage category (several kW). It is against this background that Fraunhofer IWES is planning to develop concepts for testing and validating converter systems further and thus provide this branch of industry with new ideas. These activities furthermore aim to strengthen and expand the competitiveness of the converter manufacturers as important component suppliers for the wind power industry.

Converter system for grid emulation at the DyNaLab

CERTIFICATION ACTIVITIES

To safeguard the power supply and the network stability, statutory stipulations are in place in Germany in respect of the technical system services for wind turbines – primarily in relation to voltage stability and load control – with binding deadlines. This is reflected in the technical connection conditions, among other things, which have crucial impacts on the operating demands placed on wind turbines and wind parks connected to the interconnected supply grid, and also affects the certification process.

Fraunhofer IWES has set itself the goal of accompanying all activities relating to the certification of the electrical characteristics of power generating units, thereby putting the emphasis on wind turbines on system test benches, to the extent that all partners involved are guaranteed a very high level of transparency and reliability through correspondingly standardized testing procedures which are described in the relevant standards and guidelines.

In 2015, Fraunhofer IWES initiated the 'WEA Prüfstände' (Wind turbine test benches) research group within the 'Arbeitskreis Messvorschrift AK TR 3` (Measurement specification working group) of the technical committee 'Electrical Characteristics' of the 'Fördergesellschaft Windenergie und andere Dezentrale Energien FGW e.V.' (Association for the promotion of wind power and other forms of decentralized power). This group has worked in close coordination with manufacturers, certification authorities, meteorology institutes, and test bench operators under the direction of Fraunhofer IWES to revise the description of test bench tests and testing equipment thoroughly. This work was published as part of the latest revision 25 of the TR3 ('Determination of electrical characteristics of power generating units and systems in medium, high and extra-high voltage grids') in summer 2018.

There is great global interest in standardized testing procedures – this is an incentive for Fraunhofer IWES to contribute current findings to international standards (IEC) actively in the future as well. Across Europe, the increasing harmonization of the EU regulations requires all EU member states to adapt to EU directives, which will be reflected in national test specifications. Experts at Fraunhofer IWES make key contributions on this level and introduce their know-how, which has accrued over the years as a result of operating the test bench and testing a variety of systems.

NETWORKING IS THE FACTOR FOR SUCCESS

The continuous process of certifying the electrical characteristics of wind turbines as PGU on a globally unique test infrastructure is one example of how the risks associated with development are being systematically identified and minimized. The certification and launch of innovative products is thus accelerated and the quality level safeguarded – precisely what the manufacturers want. Certification authorities and metrology institutes are closely involved in the testing process: in collaboration with the client, a highly individual solution is being developed to integrate the customer systems on the level of the control system and also to reproduce the operation of the HiL methods of testing.

The intensive exchanges with the numerous partners involved in the certification process, and the activities undertaken in national and international bodies mean that Fraunhofer IWES succeeds in testing the electrical characteristics in accordance with the latest findings and current specifications. Our experience with different systems and test designs made crucial contributions to our know how expansion.

Moreover, the fact that we are expanding our networking with the universities in Bochum and Bremen plays its part in optimizing the networking of the skills required to meet the complex demands of grid integration and power mechatronics, and in developing them further. Experimental platforms such as the 'Smart Wind Park Laboratory' or the setting up of a scaled demonstrator for the electrical connection of several offshore wind farms to the transmission grid on land make an important contribution here.

'Wind turbines, especially those for offshore sites, have reached a power rating that requires technologically demanding, cost-intensive testing – but there are rarely proper test sites available. The aspirational standardization of electrical testing of wind turbine sub-systems and components on test benches provides the opportunity of accelerated testing under controllable conditions for OEMs and suppliers.'
Prof. Björn Andresen,
Aarhus University and Convener of IEC 61400-21

'We consider testing for the purpose of electrical certification as a possibility to run reducible tests for measuring the electrical characteristics of power generating units and therefore improve their system behaviours.'
Jochen Möller,
Managing Director, Moeller Operating Engineering GmbH

'Responding to diverse market requirements within rapidly paced development cycles are seen as joint aims for the equipment qualification on a test bench.'
Uwe Helmke,
Head of Division System Test and Optimization at Enercon´s WRD

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Publisher

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The Fraunhofer Institute for Wind Energy Systems IWES is a constituent entity of the Fraunhofer-Gesellschaft and as such has no seperate legal status.

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80686 Munich, Germany
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VAT Identification Number in accordance with §27 a VAT Tax Act:
DE 129515865

Court of jurisdiction
Amtsgericht München (district court)
Registered nonprofit association
Registration no. VR 4461

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S. 11: Pascal Hancz /
S. 14: Martina Buchholz

Print: Druckerei Schmidt GmbH & Co. KG, Lünen

State: July 2018

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