IEA Wind Task 35

Full Size Ground Testing of Wind Turbine Nacelles

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Dipl.-Ing. Dennis Bosse studied mechanical engineering with a specialization in construction and development at the RWTH Aachen University until 2007.

Since 2007, he has been working as a scientific assistant at the IME. In 2011, Mr. Bosse became team leader of the group “Test Methods” in the field wind. There he coordinates research activities in the joint project “Improvement of operational behaviors of On-Shore wind power plants by means of a new type of system test rig” and the setting up of the “Center for Wind Power Drives” at the RWTH Aachen University as well as the construction of a 4 MW system test rig for wind power plants. Since July 2013, Mr. Bosse is responsible for the topic test as business unit manager at the Chair for Wind Power

Introduction

As wind turbine generators (WTG) continue to contribute an increasing portion of the electricity supply, it is crucial for design and testing standards to keep pace with the development of technology. Although full-scale prototype turbine field testing is a common technique employed in the development of new products, it is expensive, time-consuming, and suffers from unpredictability of site-specific load conditions. Ground-based test rigs for WTG nacelles have the potential to substitute field tests for type certification and to evaluate WTG components under reproducible conditions. The wind technology collaboration programme of the international energy agency (IEA Wind) established Task 35 to address the demand for reliable and cost-effective ground testing of WTG. The experts from research testing facilities, WTG and test rig manufacturers as well as certification bodies work together in Task 35 to develop recommendations for standardized test methods. The recently established nacelle test laboratories in the USA, Denmark, United Kingdom, Germany, Spain and China collaborate to develop novel tests for design and model validation as well as to facilitate and enhance the type certification process.

Approach to standardized nacelle test procedures

The goal of Task 35 is to formulate recommendations for ground based test procedures of nacelles and to standardize them across the test facilities around the world. Depending on the recommended configuration, test rigs shall be capable of performing the same standardized test with equivalent results at the same confidence level. As a long-term goal, the standardized test procedures support the

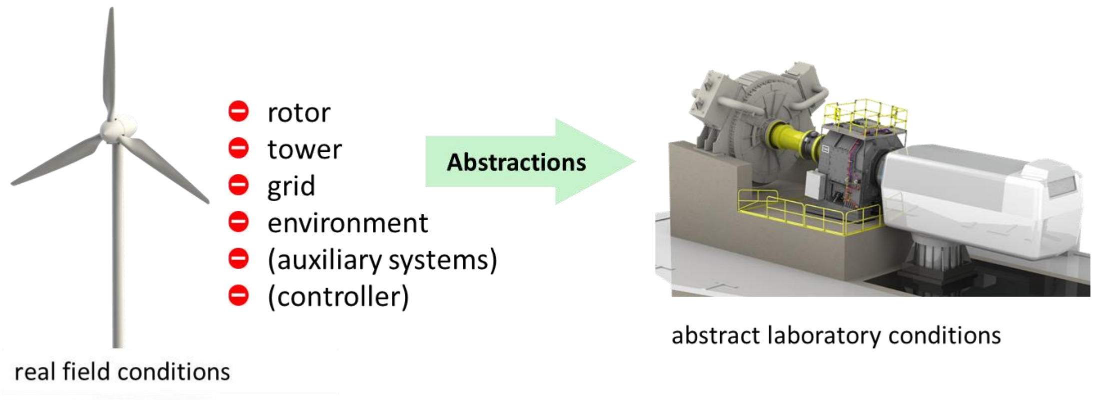
- Enhancement of the certification processes
- Improvement of the quality and reliability of WTG nacelles and blades
- Reduction of WTG design and development time
- Evaluation of in-field performance and possible failure modes of blade and drivetrain components

Realistic emulation of wind and grid conditions

Test facilities with WTG nacelle test rigs offer two particular benefits. The first major benefit is the reduction of certification effort by performing type certification tests under reproducible and reliable laboratory conditions in a significantly shorter period than in the field. The test rigs contain several mechanical and electrical load application systems that reproduce and emulate site specific grid and wind conditions as realistic as possible. Aside from certification tests, the second benefit is, that these test rigs can also be used to validate WTG designs and simulation models. The possibilities are manigfold, both customer specific tests and standardized design and model validation tests are possible.

It is crucial for the credibility and development of ground test procedures to consider the influence of abstractions that are made when emulating realistic in-field conditions for wind turbine nacelles mounted on a test rig (see figure 1). The main challenges are to realistically emulate all missing subsystems like rotor, tower, real grid and environment when performing nacelle test procedures.

Figure 1: Abstractions made from field to laboratory conditions



The magnitude and significance of abstraction effects for test results may vary between test facilities due to specific test nacelle configurations and test rig setups. For example, the impact of test rig heat loads or humidity can be relevant or not, depending on the individual test purpose. However, although test rig capabilities across the world are different, there are a few general effects that are common and require particular consideration. The experts of Task 35 elaborated an overview of 29 major and minor abstractions including the description of these effects, their influence on test result, their relevance for testing as well as compensation possibilities, either physical or calculative. The following superordinate abstractions have significant influence on common test procedures.

Without consideration and compensation, the rotational inertia and the stiffness of the coupled drivetrains of test rig and nacelle have significant effects on local loads and the dynamic torsional behavior due to the missing rotor. Each individual property of the device under test (DUT) including the drivetrain stiffness, the rotor inertia and aerodynamic response behavior needs to be implemented into the torque load simulation. Furthermore, a specific test controller adjustment is necessary to ensure adequate damping of false eigenfrequencies. Independent form the DUT, a rigid drivetrain and sufficient dynamic of the test rig prime mover is recommended.

Aside from the torque related effects, the missing tower is another relevant abstraction. Nacelles on top of a 100 m tower can move 2 m back and forth with up to 0.2 Hz. Moreover, at realistic in-field conditions the tower bends and twists which damps the wind loads. In the test facility the DUT is fixed on a stiff foundation. For higher accuracy requirements of sensitive measurements (e.g. torque sensitive measurements at gear wheels), an individual adjustment of the wind load calculation model can be useful to compensate tower stiffness and movement. The group concluded that a fixation of the DUT should be as stiff as possible due to the limited displacement of the load application actuators. Reaction forces of inertia in the system components due to the tower movement cannot be emulated on the test rig. These forces, however, are minor compared to the main loads.

On the electrical side the grid connection and emulation is limited to the performance (dynamic, accuracy and power level) of the grid emulation hardware and power electronics. Depending on the test purpose, the emulation of a wind farm power level (e.g. 100 MW wind farm transformer) and strong grids (20 times nominal power required) for example require adequate performance capabilities of the grid emulator. Aside from the power level, harmonics emission of up to 1 kHz as well as deviant response time due to signal delays from the emulation hardware result in accuracy losses of the grid emulation. The grid emulation controller needs to react 2-3 times faster than the cycle of operation of power electronic hardware. With transient effects of 1 ms expected, the requirements for the reaction time can be up to 0,3 – 0,5 ms. Although the requirements from the national grid codes increase, it is estimated that up to 80 % of the electrical certification can be done at ground test facilities.

Conclusion of abstraction influences

After evaluating the above mentioned influences, the consortium of Task 35 concluded that for current test purposes the influences of the mentioned abstractions can be compensated, either physical (via adequate hardware) or calculative (via simulation models). The test results are expected to be comparable and transferable to in-field conditions. Moreover, the controlled environment of the test rig offers the potential to increase the credibility and understanding of the nacelle behavior under realistic conditions with the unique capability of reproducible loading.

Learning objective

The evaluation of all relevant abstraction influences and its compensation strategies are crucial for developing novel nacelle test prodcedures and for configuring the test rig setup. According to the IEC 61400 standard, Task 35 elaborates recommendations for test load cases in which the operating mode as well as the wind and grid conditions are determined, including combined transients events like faults of the mechanical, the electrical and the control system. This way, the robustness of WTG can be validated by testing extreme events (e.g. gust and simultaneous grid loss). The test load cases will be applicable to most common types of WTG and test rig configurations. Moreover, these recommendations guide the WTG manufacturers and other customers through the design and certification process.

Acknowledgement

This abstract highlights results of the ongoing collaborative research project Task 35 “Full Size Ground Testing of Wind Turbines and their Components” of the wind technology collaboration programme of the international energy agency (IEA Wind). See http://www.ieawind.org/.

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The International Energy Agency
Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems