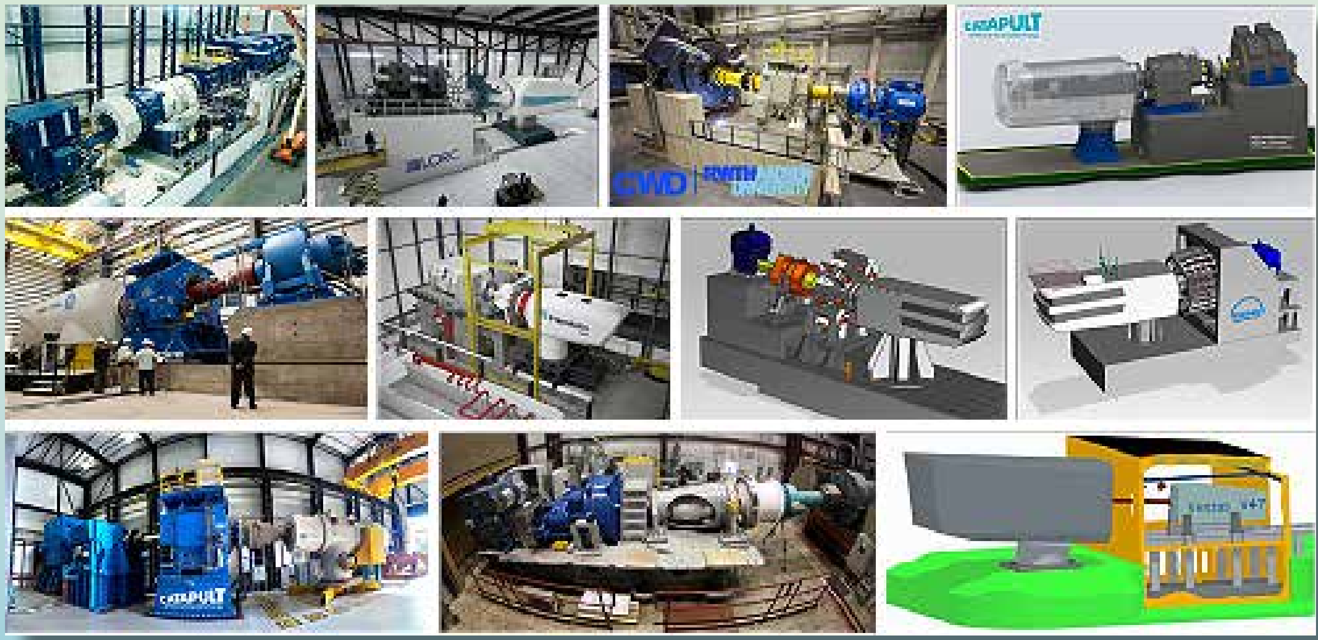
15 Task 35 Full-Size, Ground Testing for Wind Turbines and Their Components



1.0 Introduction

As wind turbine generators (WTGs) 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 the technology. These standards need to reflect the requirement of improving reliability at low costs. Reducing the downtime and development costs of WTGs ensures that wind energy remains competitive in the global electricity marketplace. 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 the predictability of site-specific load cases. As an alternative, ground-based test benches offer the opportunity to evaluate WTG components under reproducible, accelerated life conditions and may become an important tool for development and certification of new WTGs.

The following table shows the participants of Task 35. In late 2014, China, the Netherlands, and Spain expressed their interest and intention to join Task 35.

Table 1. Countries and Organizations Participating in Task 35 During 2014

	Country	Institution(s)
1	Denmark	Technical University of Denmark (DTU) Wind Energy DTU Mechanical Engineering Lindoe Offshore Renewables Center (LORC) Vestas Wind Systems A/S LM Wind Power A/S R&D A/S
2	Germany	Center for Wind Power Drives (CWD) Rhine-Westphalia Institute of Technology (RWTH) Aachen University GE Energy Power Conversion GmbH Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) MTS Systems GmbH Senvion SE Technical University of Berlin TÜV Rheinland AG Windtest Grevenbroich GmbH Siemens AG (Winergy)
3	United Kingdom	Offshore Renewable Energy (ORE) Catapult Lloyd's Register Group Services Limited
4	United States	Clemson University Wind Drivetrain Test Facility McNiff Light Industry MTS Systems Corporation National Renewable Energy Laboratory (NREL) National Wind Technology Center and Wind Technology Testing Center Sandia National Laboratories

2.0 Objectives and Strategy

IEA Wind Task 35 intends to address the emerging demand for reliable and cost-effective ground testing. Because the use of full-scale ground test facilities for validating WTG designs has become an attractive option to the component manufactures, WTG original equipment manufacturers (OEMs), and WTG owner/operators [1], [2], the challenge is to exploit the potential of each facility and combine all specific capabilities.

Therefore Task 35 aims to:

- Improve the quality and reliability of ground-based component testing of WTG nacelles and blades in order to evaluate the in-field performance and possible failure modes under accelerated life test conditions.
- Specify the requirements and boundary conditions of test bench configurations.
- Refine the standardization and certification procedures of the entire WTG and its components.
- Emphasize the use of test facilities as a reliable alternative or complement to field tests for design validation and demonstration of functionality, service life, and safety response.
- Reduce design and development time, as well as the overall costs.

Through this investigation, the expert teams of Task 35 will formulate recommendations to incorporate new and emerging test methods and standardize them across multiple laboratories with various capabilities. Depending on the recommended configuration, most test benches will be capable of performing the same standardized test with equivalent results at the same confidence level. As a long-term goal, the expected results can be used for the advancement of the present certification processes and to improve extant basis test procedures for WTGs and their components.

3.0 Progress in 2014

3.1 Subtask nacelle

3.1.1 Scope definition

In December 2013, the participants of Task 35 decided to agree to the scope of the Task, including relevant types of testing for both nacelle and blade subsystems, and to estimate their future prospects. Table 2 shows the relevant test category type certification, design and model validation subdivided into several test clusters. The long-term prospect of type certification testing is to substitute type certification field tests with full-size ground tests. Laboratory testing with system test benches can be a cost-effective alternative with several advantages like independent wind and grid states and reproducible conditions. In addition to this goal, the design and model validation testing aims to reduce costs of WTG product development and to increase WTG reliability. These two categories of type tests allow for verification of design assumptions and model qualities within a flexible and controlled environment. So far, 62 single tests have been agreed upon and assembled in these test clusters. Table 2 summarizes the achieved outcome (functionality matrix and system test cluster description) and future outcome (abstraction, interfaces, and load cases) of Subtask Nacelle.

In addition to the testing scope, the capabilities of the test facilities have been compared to get an overview of the testing performance and compatibility. Table 3 shows the test facility comparison.

3.1.2 Functionality matrix

According to the relevant system tests, a so-called functionality matrix was set up to determine all test-bench functions for each test that is necessary. With this matrix, the potential customer will know which tests can be performed at a particular test facility. Figure 1 shows the plan for the functionality matrix and the consensus that has been reached on the test procedures and the functionality aspects.

The 19 functionality aspects are divided into the groups' wind loads, grid loads, control structure, and environment. All these aspects represent the minimal requirements and capabilities of a system test bench to perform a certain test. About 80% of the type certification tests and 60% of the design and model validation tests are already defined. Some aspects, like the dynamic requirements, require that further information be gathered during the task progress. As an example, table 4 shows the requirements of the electrical robustness testing with electrical failures (design validation test).

3.1.3 System test cluster description (model/design validation)

After determining the link between the test procedures and the test bench functionality the subtask nacelle focuses on the description of the system test cluster (see Table 2). The objective of this step is to agree about the general test procedure definition for system tests (full nacelle). In particular, the design and model validation tests are poorly defined. Every test facility participating in Task 35 has different conceptions of these relatively new test procedures. The first step of the test procedure standardization is to define the following aspects:

1. Test description
2. Objectives
3. Purpose/rationale
4. Value to customer
5. Limitations
6. Methodology
7. Risks

The agreed description of the test cluster is an important step towards uniform testing standards across test facilities around the world. Moreover, the OEM and other potential customers have trustworthy documentation and can easily incorporate and adapt their testing objectives.

3.2 Subtask blade

In 2014, the rotor subtask group convened meetings to identify and outline subtasks to be performed. Work in the rotor subtask concentrates on topic areas where a greater

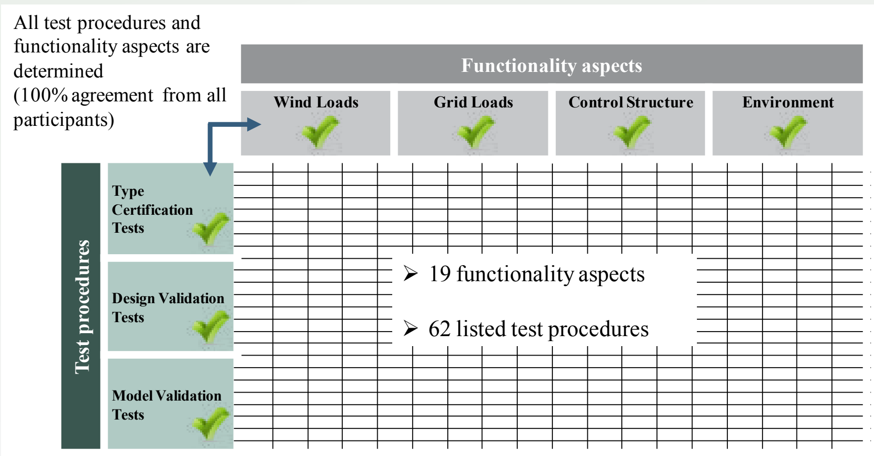


Figure 1. Plan for the functionality matrix

Table 2. Status of Nacelle Test Descriptions

	Outcome Scope of Subtask Nacelle ✓ Already done ⌚ In progress – Not available IEC Described in standards like the IEC 61400	Test Description	Objectives	Purpose/ Rationale	Value to Customer	Limitations	Methodology	Risks	Test Bench Functionality	Influence of Abstraction	Interfaces communication	Load Cases
	Test Cluster											
Type Certification	Load Measurements	IEC	IEC	IEC	–	IEC	IEC	–	✓	⌚	⌚	IEC
	Power Performance Measurements	IEC	IEC	IEC	–	IEC	IEC	–	✓	⌚	⌚	IEC
	Gearbox Tests	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	IEC
	Grid Code Compliance	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	IEC
	Acoustic Noise Measurement	IEC	IEC	IEC	–	IEC	IEC	–	✓	⌚	⌚	IEC
	Behavior	IEC	IEC	IEC	–	IEC	IEC	–	✓	⌚	⌚	IEC
Design Validation	Robustness Tests with Forced Failure (mechanical)	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
	Robustness Tests with Forced Failure (electrical)	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
	Accelerated Life Tests	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
	System Efficiency	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
	Load Distribution Measurement	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚
	WT Controller Operation and Optimization (mechanical)	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
	WT Controller Operation and Optimization (electrical)	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚
	Overspeed Protection	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚	⌚
	Alternative Concepts	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
Model Validation	Mechanical Model Validation	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚
	Electrical Model Validation	✓	✓	✓	✓	✓	✓	✓	✓	⌚	⌚	⌚

Table 3. Test facility comparison

DD = Direct drive Gear = Geared drive		Prime Mover			Wind Load Application			Load Emulation				
Organization	Country	Drive	Power [MW]	T_{max} [MNm]	Mb_{max} [MNm]	$F_{max\ rad}$ [MN]	$F_{max\ ax}$ [MN]	Real-Time Wind	Real-Time Grid	FRT-Scenarios	Industrial available	Operating
Catapult ORE	UK	DD	15	14.3	43	8	4	?	×	×	✓	✓
		Gear	3	5	15	4	4	×	×	×	✓	✓
Clemson	US	Gear	15.7	15	50	8	4	?	✓	✓	✓	2015
		Gear	7.5	6	10	2	2	?	✓	✓	✓	✓
NREL	US	Gear	5	4.6	7.2	3.2	4	✓	✓	✓	✓	✓
		Gear	2.5	1.4	1	0.44	0.16	✓	✓	✓	✓	✓
LORC	DK	DD	7.2	~7.2	~35	~2	~2	×	✓	✓	✓	2016
		DD	13.8	12	N/A	N/A	N/A	(✓)	✓	✓	✓	✓
RWTH	DE	Gear	1	0.33	0.22	0.2	0.48	✓	✓	✓	✓	✓
		DD	4	3.4	7	3.3	4	✓	✓	✓	✓	✓
IWES	DE	DD	10	13	28	4.5	2.2	✓	✓	✓	✓	2015
AREVA	DE	?	5	?	?	?	?	?	?	?	×	✓
Vestas	DK	DD	18	18	18	4	5	?	?	×	×	✓
Siemens	DK	?	>6	?	?	?	?	?	?	?	×	?
DTU	DK	Gear	1	?	?	?	?	?	?	?	?	?
Cener	ES	Gear	8	?	?	?	?	×	✓	✓	?	✓
CWEA/CGC	CN	Gear	6	?	?	?	?	?	?	?	?	?
		Gear	3	?	?	?	?	?	?	?	?	?
		Gear	1	?	?	?	?	?	?	?	?	?

Table 4. Test Bench Requirements for Electrical Robustness Testing with Electrical Failures

Wind Loads	Torque dynamic excitation frequency Steady torque according to nominal torque Peak torque according to nominal torque Speed dynamic excitation frequency Non-torque wind load application Load dynamic excitation frequency Turbulence category	<5 Hz <110% <110% <2 Hz not necessary not necessary A (high)
Grid Loads	Grid model simulation (weak/micro grid, wind plant) Grid short circuit capacity Positive sequence voltage magnitude Grid's frequency according to nominal frequency Voltage unbalance factor Voltage harmonic emission (up to 2.5 kHz)	not necessary 10 pu 1.0 pu 94–106% 2% not necessary
Control Structure	Hardware in the loop wind loads Hardware in the loop grid loads Original WTG control strategy Wind farm control strategy	necessary necessary necessary not necessary
Environment	Temperature emulation Humidity emulation	not necessary not necessary

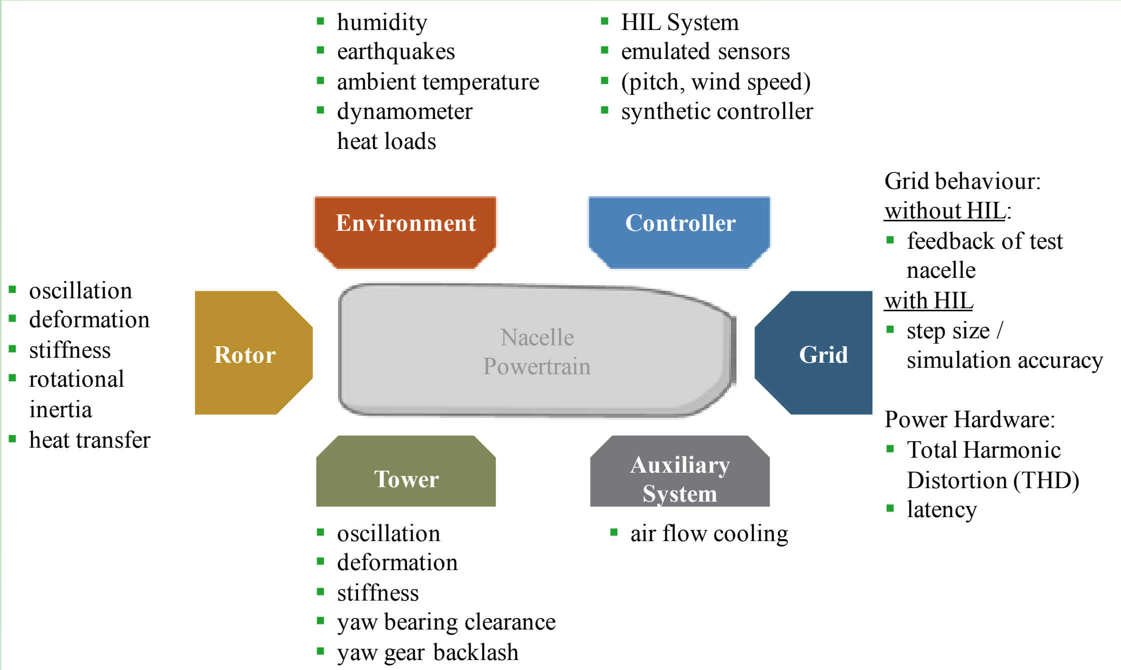


Figure 2. Sources of abstractions

body of knowledge and information on existing and emerging practices can be used to inform development of blade testing standards. Four general topic areas are considered: 1) fatigue test methods, 2) rotor subcomponent testing, 3) non-destructive test methods, and 4) uncertainty analysis of wind turbine blade testing. The Technical University of Denmark will lead the discussion on wind turbine blade test methods, evaluating and comparing current practices. Fraunhofer will lead the subcomponent testing topic, in part using recent advancements of subcomponent test methods, including beam subelement tests. Sandia National Laboratories will be taking the lead on non-destructive test methods for rotor blades. The National Renewable Energy Laboratory will lead the discussion on implementation of uncertainty estimation for blade tests. Subtask work in 2014 also included canvasing and comparing static and fatigue wind turbine test methods and capabilities of worldwide laboratories.

4.0 Plans for 2015 and Beyond

4.1 Subtask nacelle

In 2015, the test cluster descriptions will be revised and expanded to single test procedures. The next step to determining further test bench requirements is to estimate the benefits and losses of the abstraction due to the laboratory testing environment.

Figure 2 shows the sources of abstraction due to the interfaces to the rotor, tower, auxiliary system, grid, controller, and environment. The influences on specific testing results have to be evaluated. The rotational inertia of the rotor, for example, has to be considered when applying dynamic torque on the drivetrain. It is crucial for the fidelity and development of ground test procedures to consider the influence of abstraction and to find compensation strategies.

In late 2015, the current system test repertory will be expanded by additional component test procedures. Therefore, the Subtask Nacelle group will agree on reasonable component tests and suitable test-bench configurations. Similar to the system test procedures, the component test procedure will be described and standardized.

4.2 Subtask blade

In 2015, each working group of the rotor subtask will develop framework documents covering the respective topic areas. Framework documents will outline existing practices, identify new approaches and new technologies, and identify areas of opportunity for improved practices. These documents are intended to promote a robust discussion within each group and provide the framework for developing recommended practice documentation. Documentation of best practices and areas for continued improvement will be conducted in 2016. While each topic has a defined lead, all groups will be active participants in reviewing and providing content for the framework documents.

References:

Opening photo: A collage of test centers participating in Task 35.

[1] Areva; www.areva.com/EN/news-9108/offshore-wind-turbines-arevas-5-megawatt-full-load-test-benchin-operationsinceoctober2011.html, 23.11.2011

[2] Vestas; worldofwind.vestas.com/en/verification-testing; 17.01.2013

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