E.ON Energy Research Center

Development of a 4 MW Full-Scale Wind Turbine Test Bench

PEDG 2015, Aachen, Germany

23.06.2015

Nurhan Rizqy Averous, M.Sc.

RWTH AACHEN UNIVERSITY

Outline

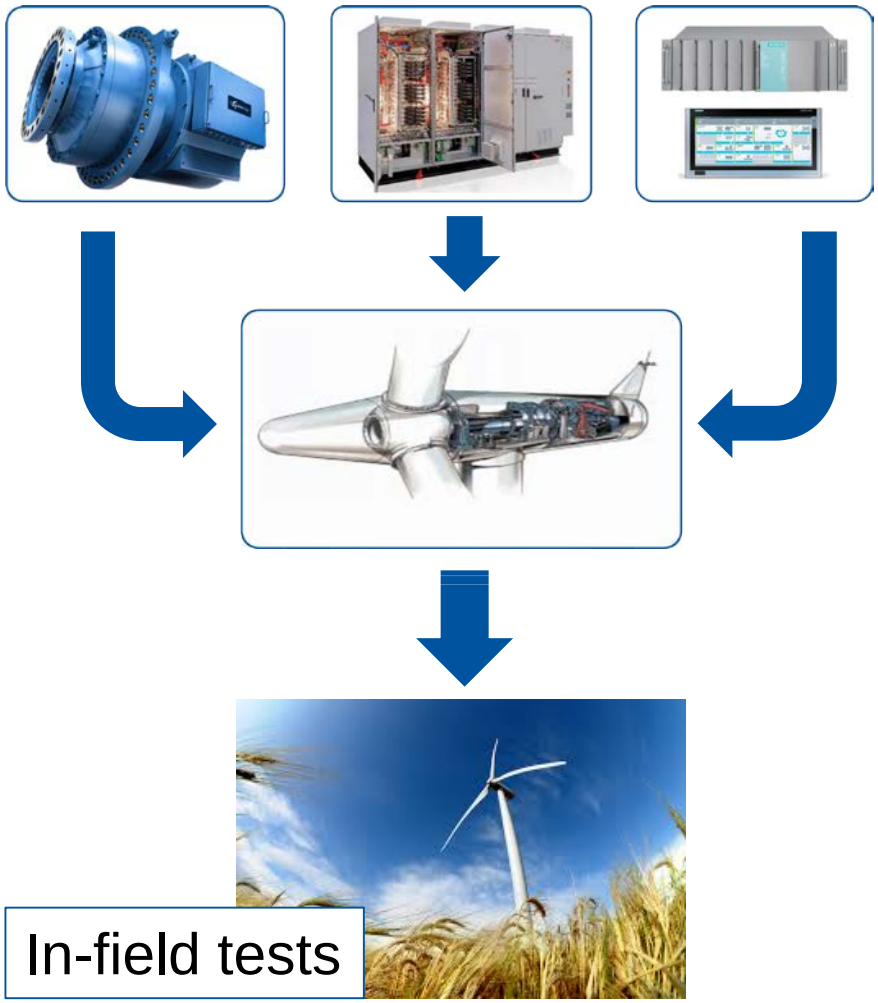
- Background
- Test Bench Concept
- Device Under Test
- Measurement Results
- Summary

Outline

- Background
- Test Bench Concept
- Device Under Test
- Measurement Results
- Summary

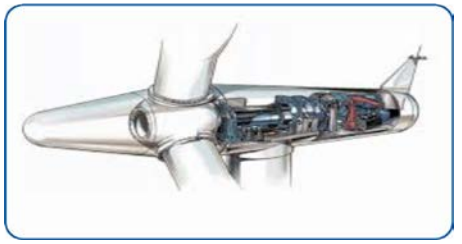
Background

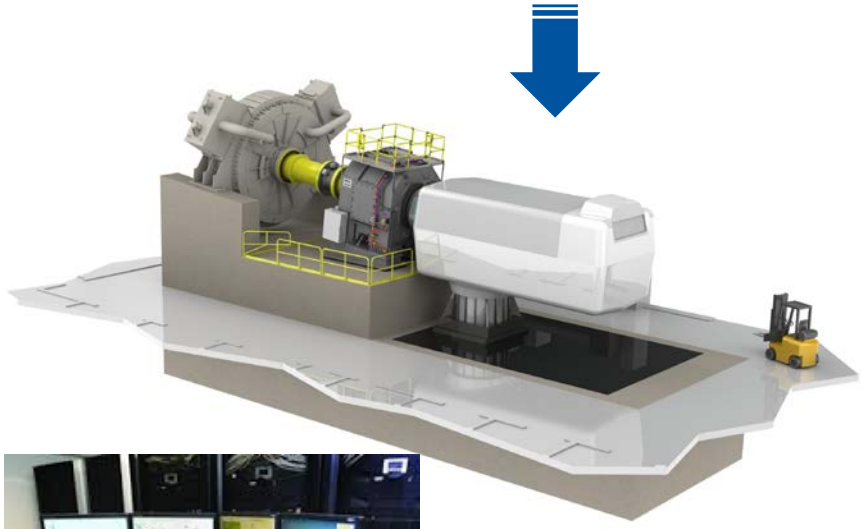
- System level tests to investigate the interactions between components
- Inefficiency shown by the classical in-field validation



Background

- System level tests to investigate the interactions between components
- Inefficiency shown by the classical in-field validation
- A full-scale system test bench offers a potential solution
- Emulation of realistic operation conditions in a laboratory setup





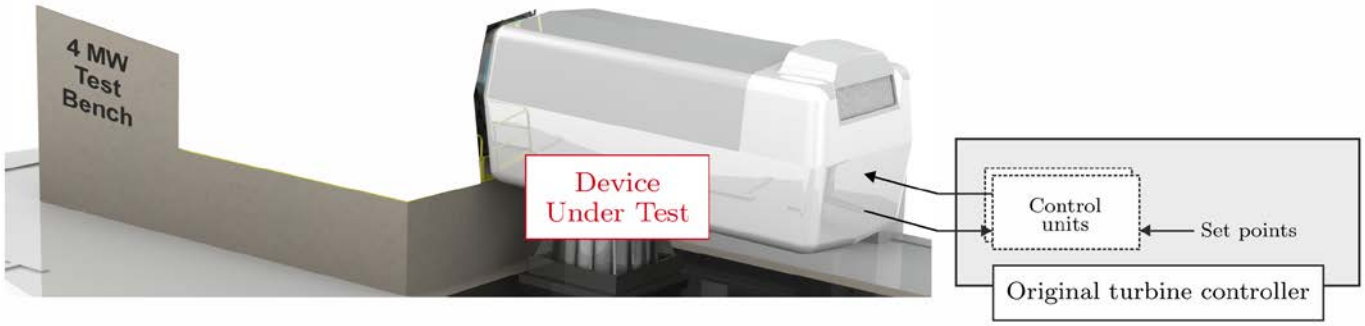
Outline

- Background
- Test Bench Concept
- Device Under Test
- Measurement Results
- Summary

Test Bench Concept
Device Under Test (DUT)

E.ON Energy Research Center

- Nacelle without rotor blades and tower section
- Original turbine controller is included
- Indenpendent on the drive-train concept



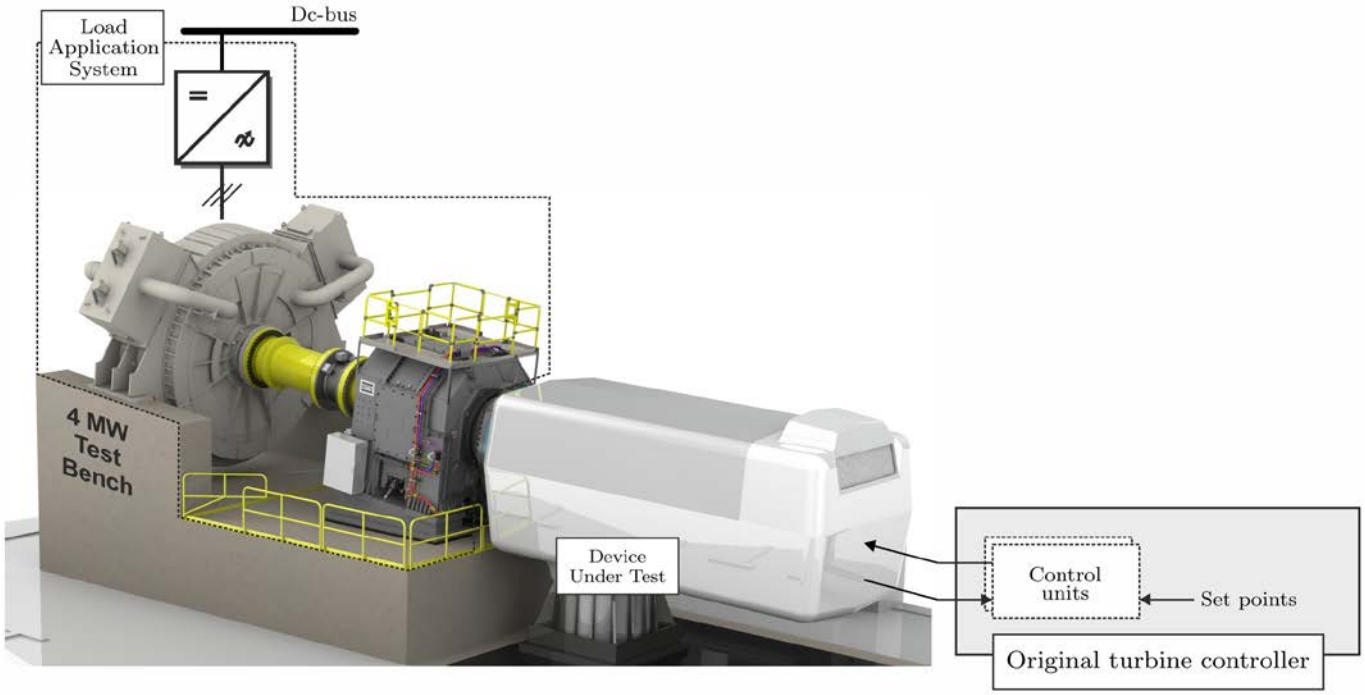
Nurhan Rizqy Averous, M.Sc.

RWTH AACHEN UNIVERSITY

Test Bench Concept
Load Application System (LAS)

E.ON Energy Research Center

- Applying the mechanical loads at the rotor flange



Nurhan Rizqy Averous, M.Sc.

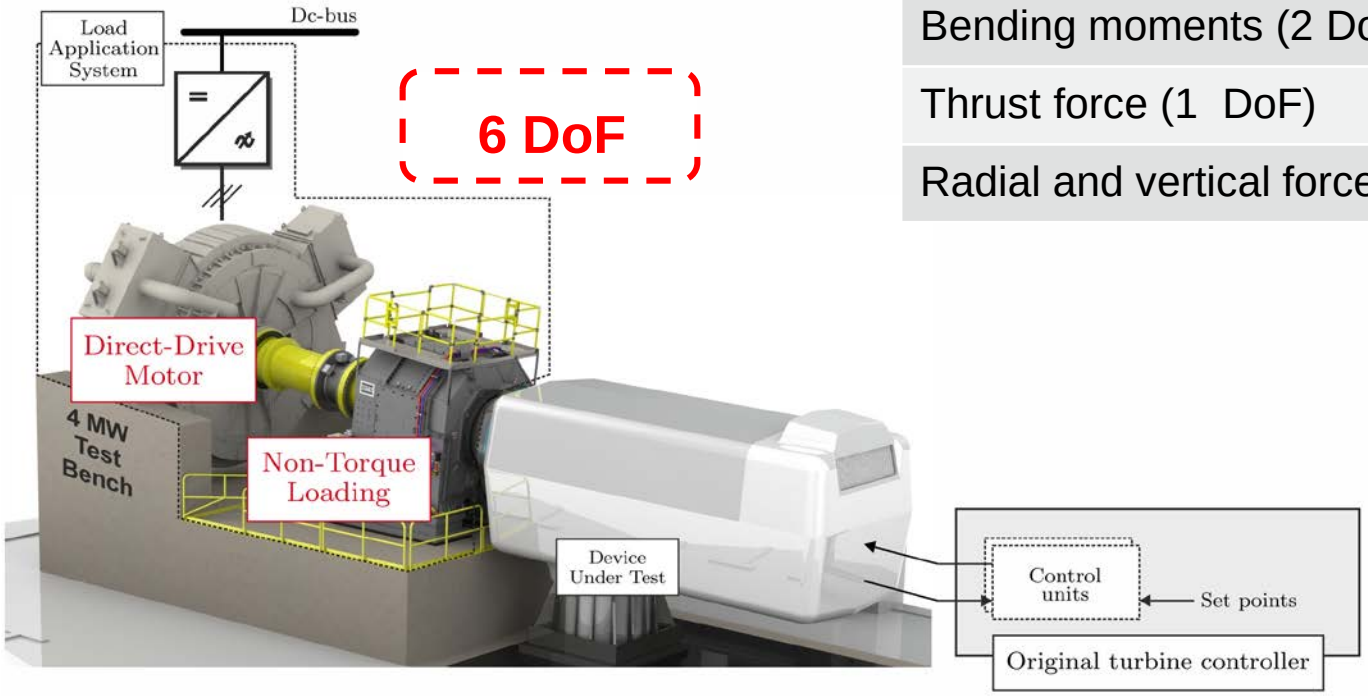
RWTH AACHEN UNIVERSITY

Test Bench Concept
Load Application System (LAS)

E.ON Energy Research Center

- Applying the mechanical loads at the rotor flange

LAS Specification	Value
Shaft speed	14 rpm
Shaft torque (1 DoF)	2.7 MNm
Bending moments (2 DoF)	7.2 MNm
Thrust force (1 DoF)	4 MN
Radial and vertical forces (2 DoF)	3.25 MN

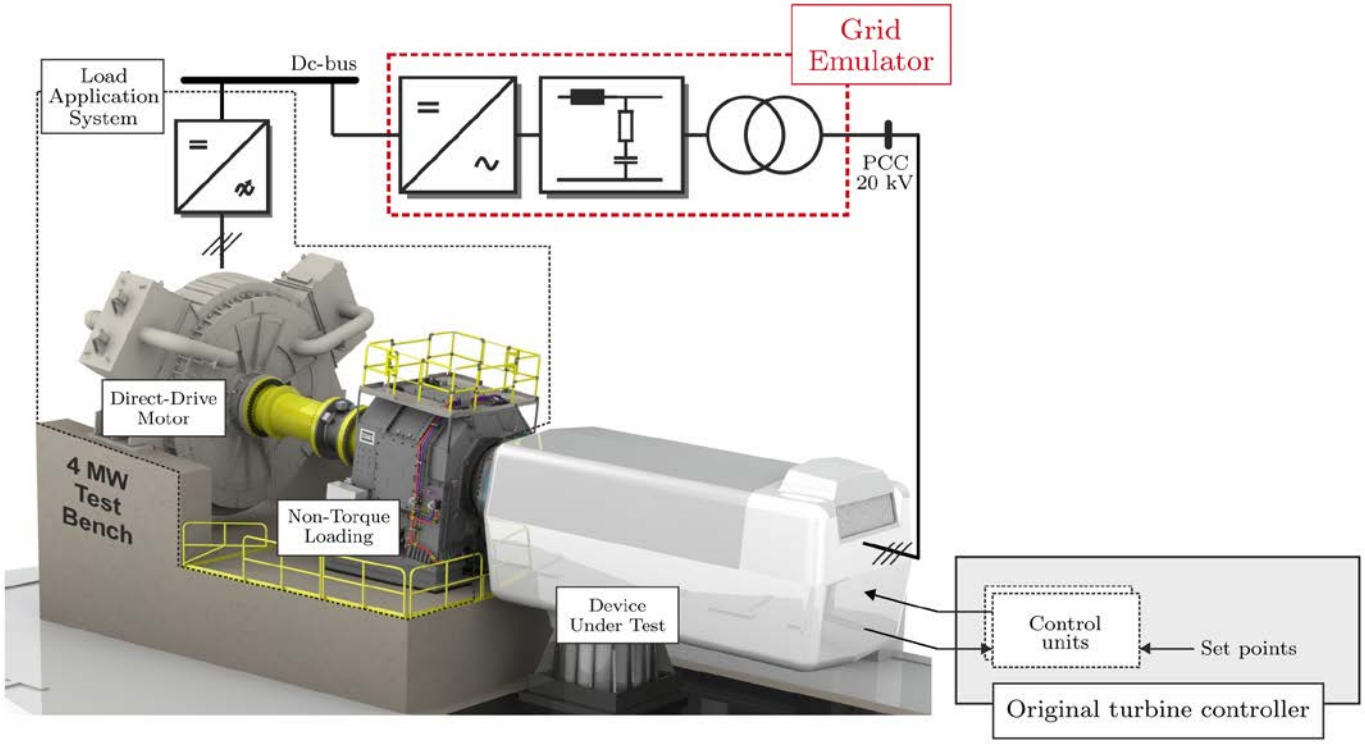


DoF : Degree of Freedom

Test Bench Concept
Grid Emulator

E.ON Energy Research Center

- Artificial electrical grid at the point of common coupling (PCC)

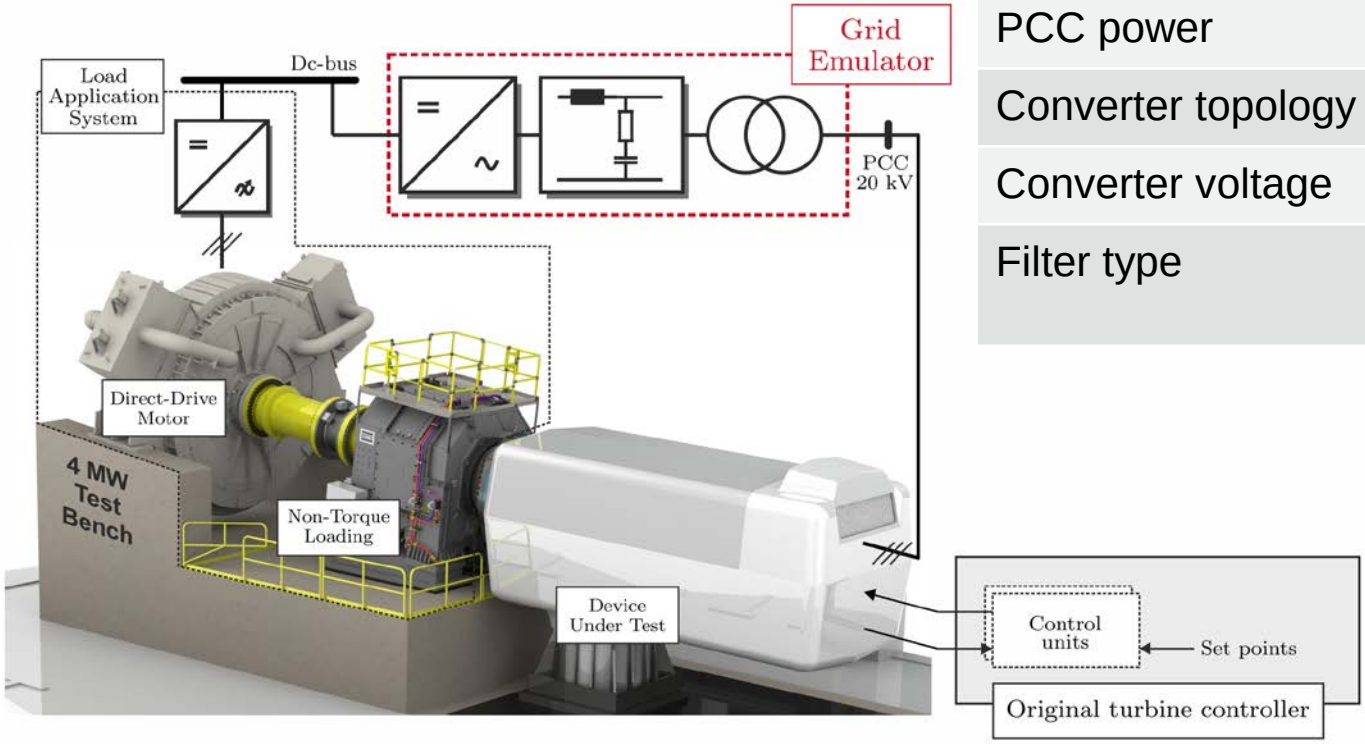


Test Bench Concept
Grid Emulator

E.ON Energy Research Center

- Artificial electrical grid at the point of common coupling (PCC)

Grid Emulator Specification	Value
PCC voltage	20 kV
PCC power	3.5 MVA
Converter topology	3L-NPC
Converter voltage	3.1 kV
Filter type	*LC*-Filter with passive damping

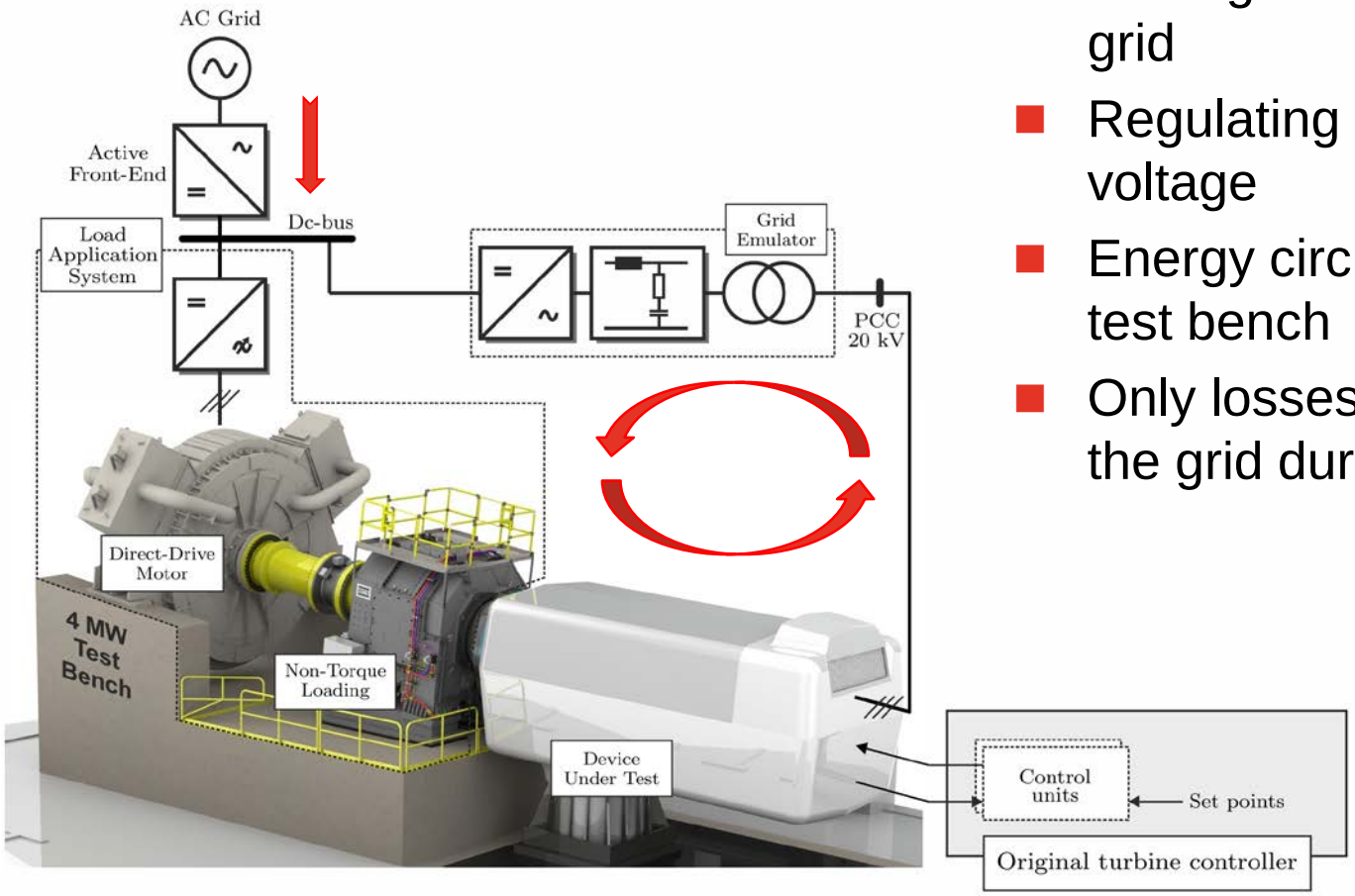


Nurhan Rizqy Averous, M.Sc.

RWTH AACHEN UNIVERSITY

Test Bench Concept
Active Front-End (AFE)

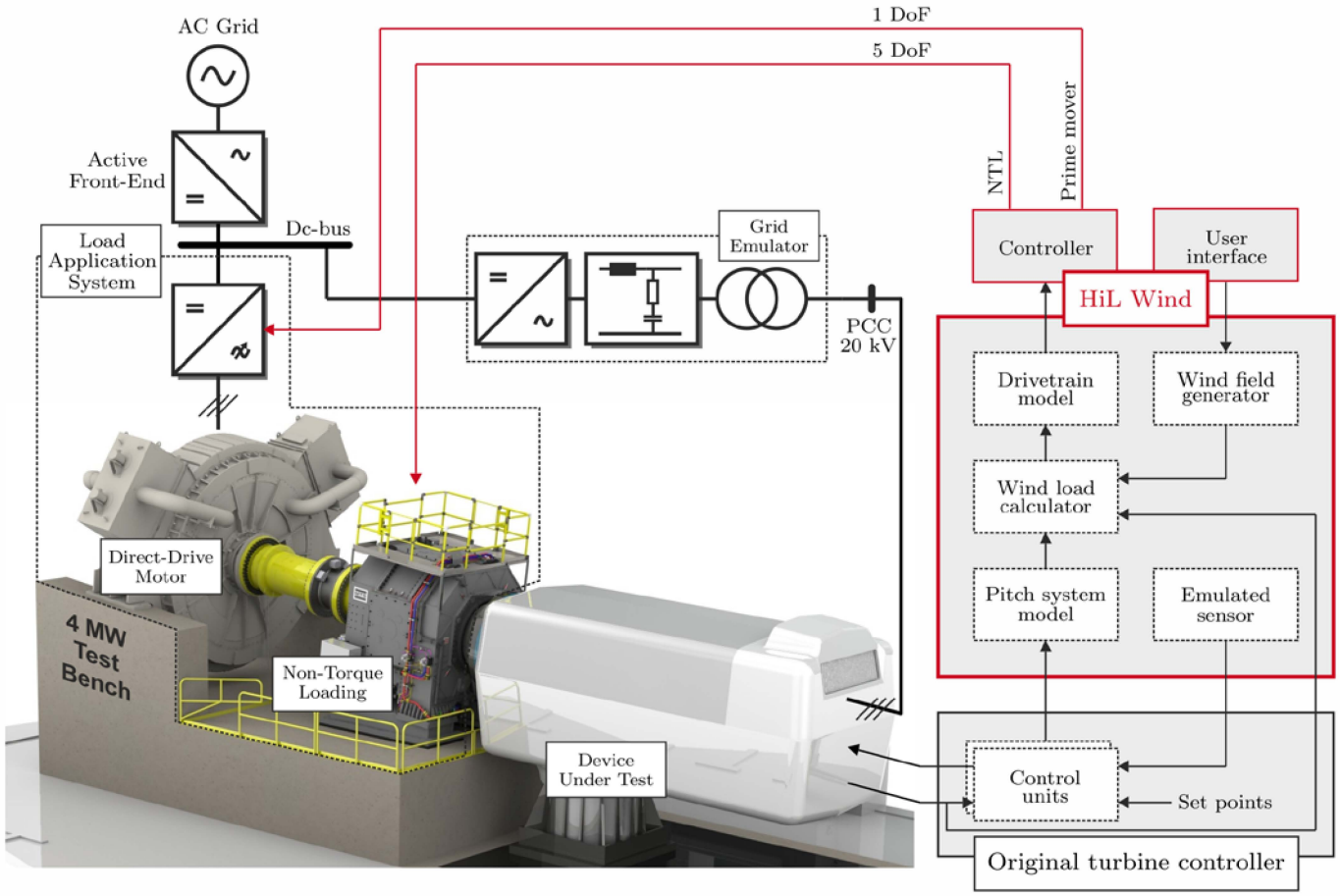
E.ON Energy Research Center



- Linking the dc-bus to an ac-grid
- Regulating the 5 kV dc-bus voltage
- Energy circulates inside the test bench
- Only losses absorbed from the grid during operation

Test Bench Concept
Hardware-in-the-Loop (HiL) Configuration

E.ON Energy Research Center

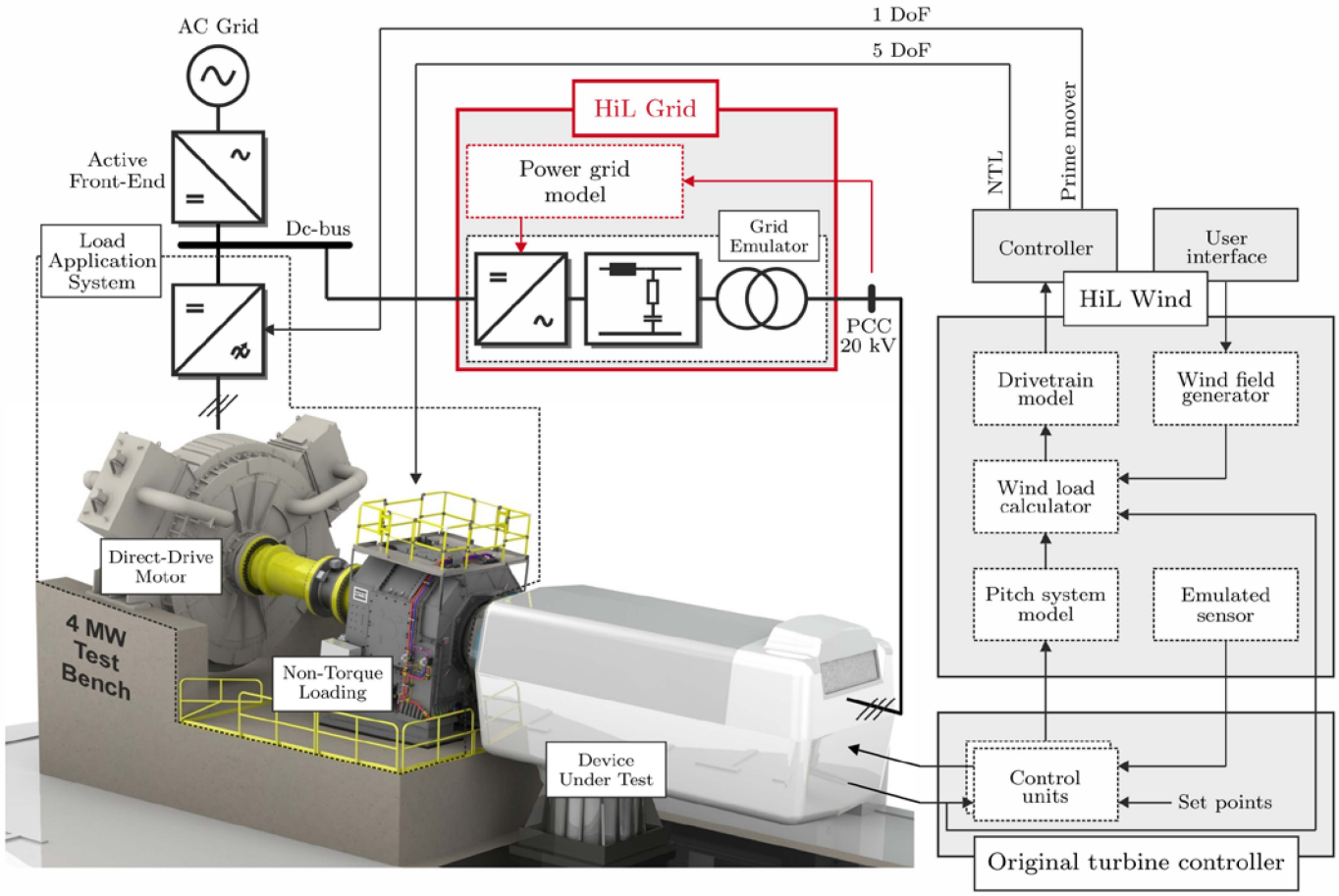


Nurhan Rizqy Averous, M.Sc.

RWTH AACHEN UNIVERSITY

Test Bench Concept
Hardware-in-the-Loop (HiL) Configuration

E.ON Energy Research Center



Nurhan Rizqy Averous, M.Sc.

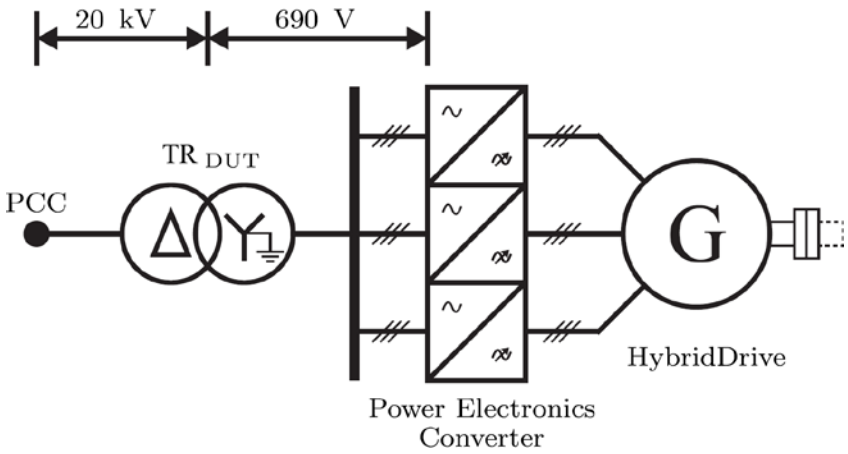
RWTH AACHEN UNIVERSITY

Outline

- Background
- Test Bench Concept
- Device Under Test
- Measurement Results
- Summary

Device-Under-Test
Current Configuration

E.ON Energy Research Center



- Combination of gearbox and generator in one housing

Parameter	Specification
Max. input torque	2.55 MNm
Rated speed	431 rpm
El. output power	3.12 MW
Rated voltage	720 V
Generator type	PMSG

- Power electronics converters
  - Low voltage 2L-VSC
  - Interleaved switchings

Parameter	Specification
Grid side voltage	690 V
El. output power	3 x 1.12 MVA
Grid code	SDLWindV 2009

Outline

- Background
- Test Bench Concept
- Device Under Test
- Measurement Results
- Summary

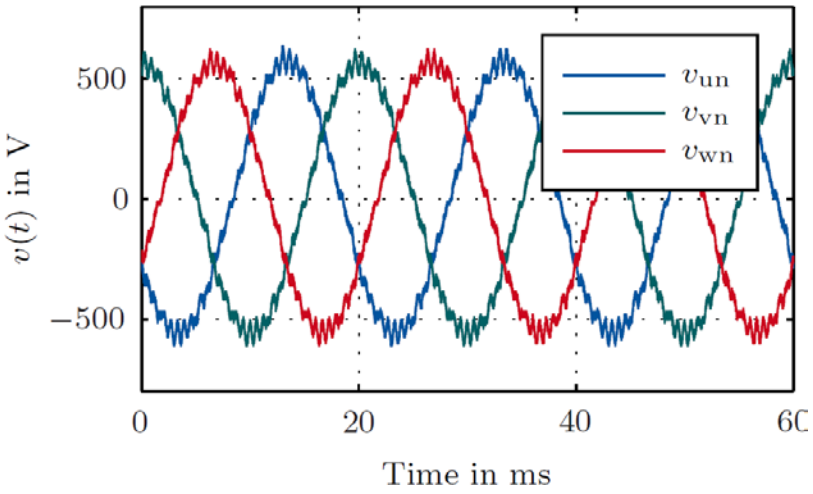
Measurement Results
Emulated Grid Properties

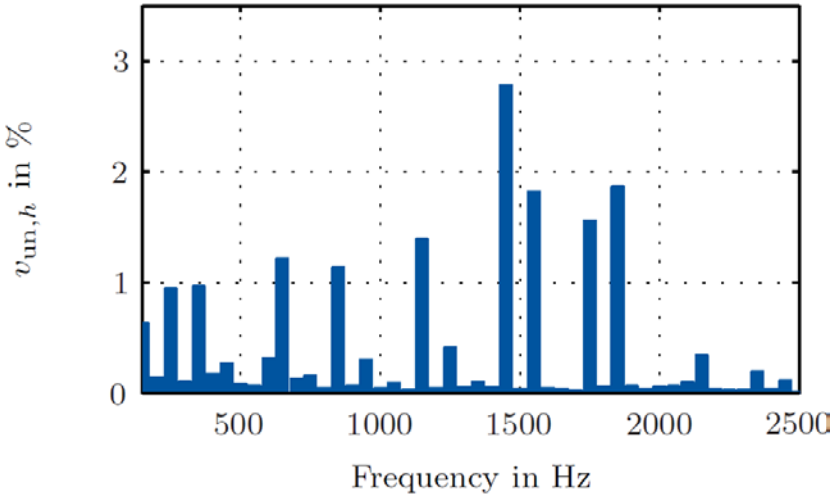
E.ON Energy Research Center

- Voltage properties at no-load

Parameter	Measurement	Reference
RMS Voltage	687. 4 V	690 V ± 10 %
Frequency	49.99 Hz	50 Hz ± 0.5 Hz
THD	4.92 %	< 5 %
Unbalance factor	0.3 %	< 2 %

Note: Measurement performed on the low voltage side



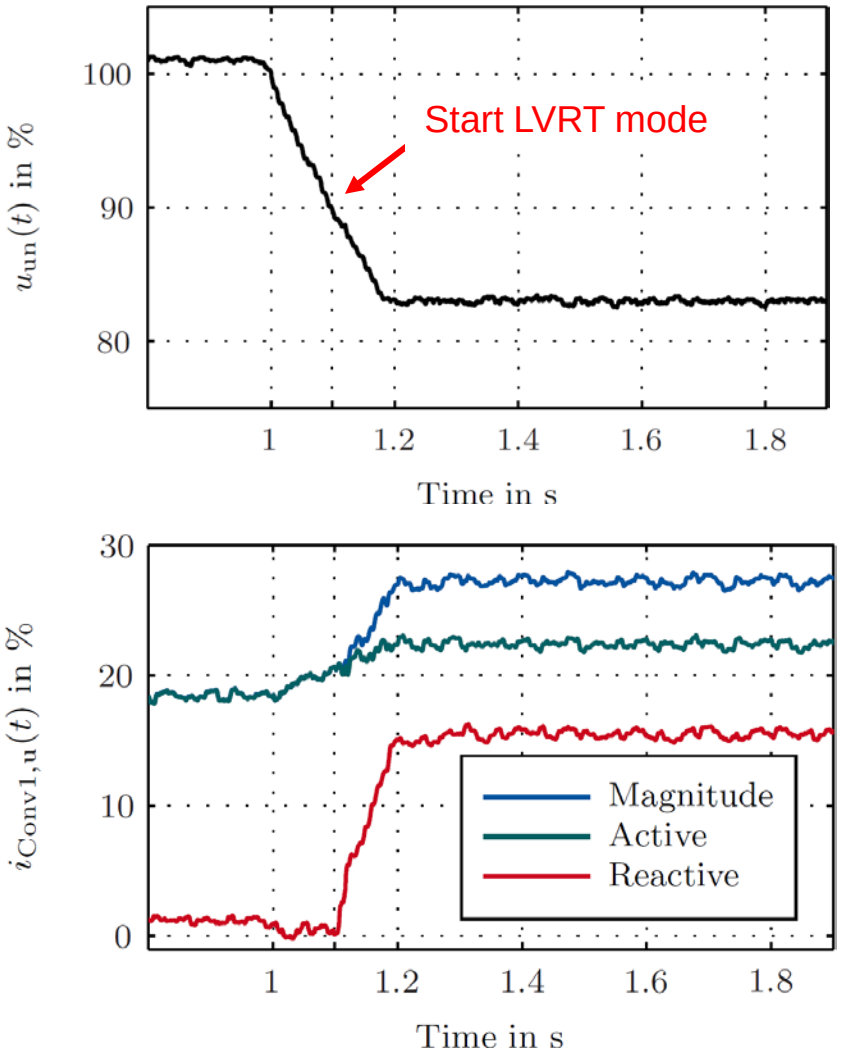


- Emulated grid satisfies the requirement according to IEC 61400-21
- Synchronization possible

Measurement Results
Low-Voltage Ride Through (LVRT) Test

E.ON Energy Research Center

- Possible voltage dips:
  - Symmetrical
  - Unsymmetrical without zero sequence component
- Example of an LVRT test with 19% load for each converter
- DUT behavior during grid fault
  - DUT remains synchronized
  - Reactive current support
  - Further active power infeed

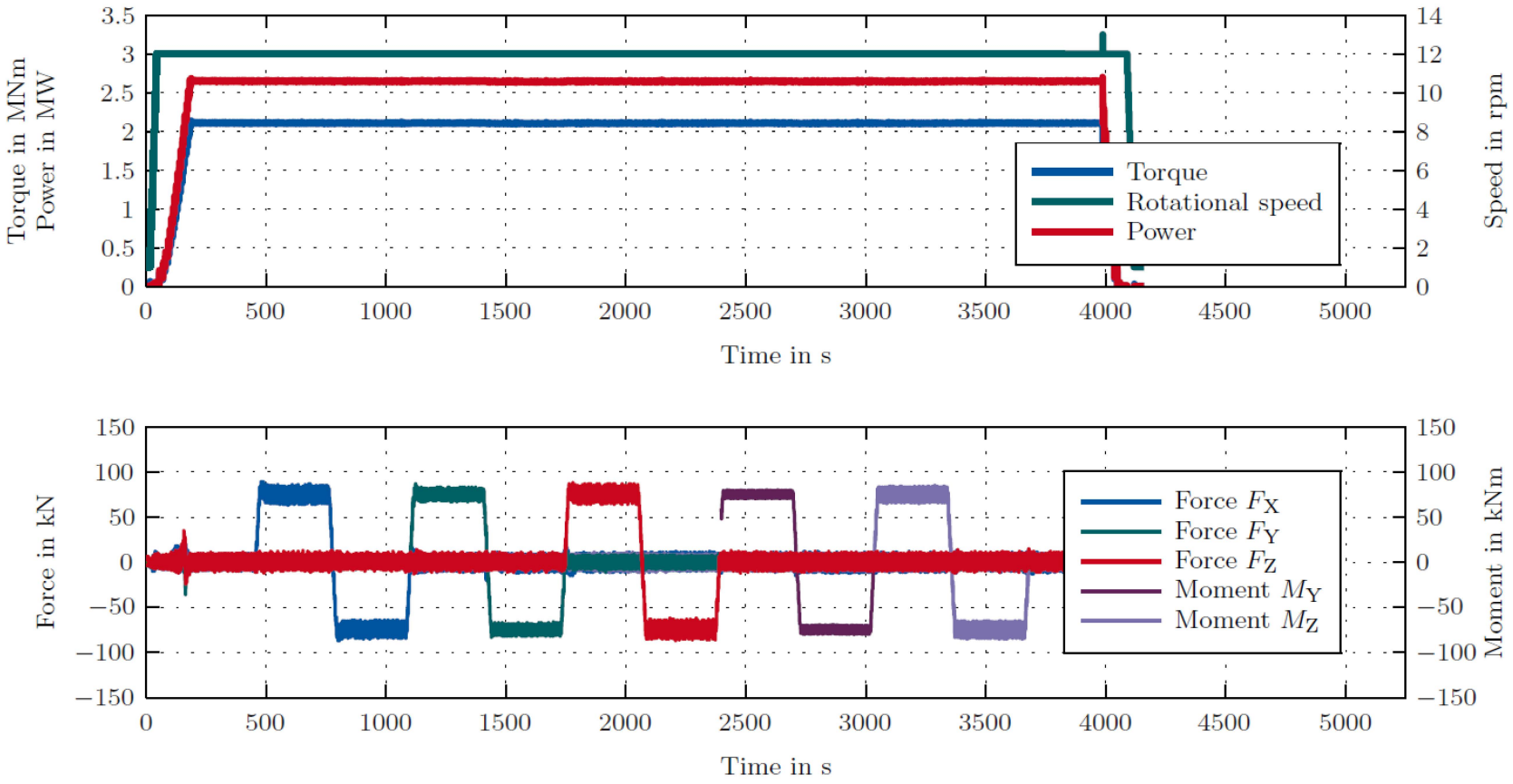


Nurhan Rizqy Averous, M.Sc.

RWTH AACHEN UNIVERSITY

Measurement Results
Application of the 6 DoF Loads

E.ON Energy Research Center



Nurhan Rizqy Averous, M.Sc.

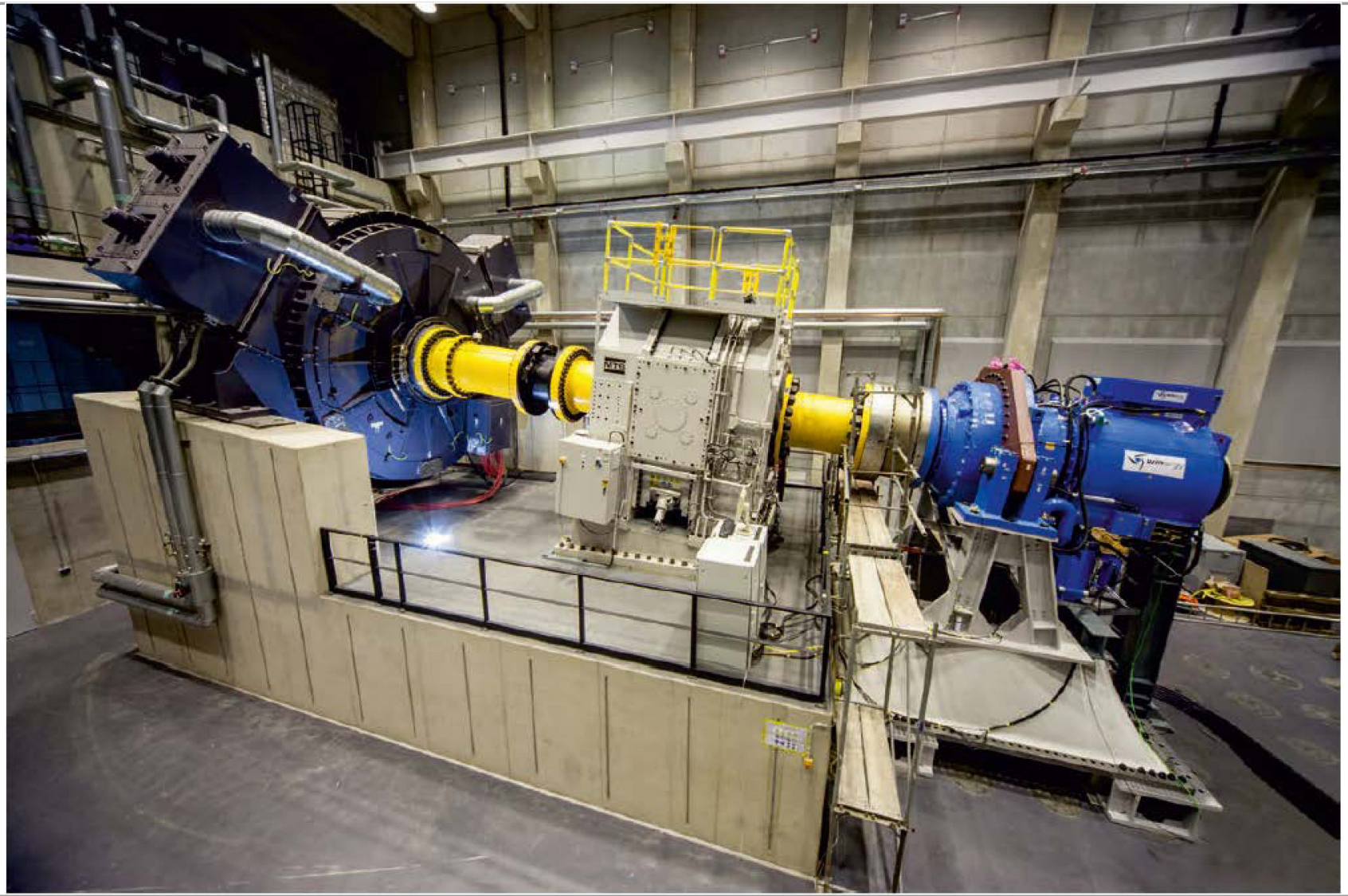
RWTH AACHEN UNIVERSITY

Outline

- Background
- Test Bench Concept
- Device Under Test
- Measurement Results
- Summary

Summary

- A 4 MW full-scale wind turbine test bench has been developed
- Emulator systems are the key enabling components for the reproduction of the realistic loads
- Power electronic converter based grid emulator enables the application of a wide variety of grid conditions
- Load application system with 6 DoF is required to realize realistic stresses to the mechanical components



E.ON Energy Research Center

Thank you for your attention

PEDG 2015, Aachen, Germany

23.06.2015

Nurhan Rizqy Averous, Marco Stieneker, Stefan Kock, Cristian Andrei, Alexander Helmedag, Rik W. De Doncker, Kay Hameyer, Georg Jacobs, Antonello Monti

RWTH AACHEN UNIVERSITY