Welcome

WIND . ASSURING CONFIDENCE THROUGH COMPETENCE

Torben Jersch

DyNaLab Update: Meeting Industry Needs and Standardization & Hil-Grid-Cop: Generator and Converter Testing

5th Annual International Workshop on Grid Simulator Testing of Energy Systems and Wind Turbine Powertrains,

2018-15-11, Tallahassee FL

Fraunhofer IWES

Short profile of Fraunhofer IWES

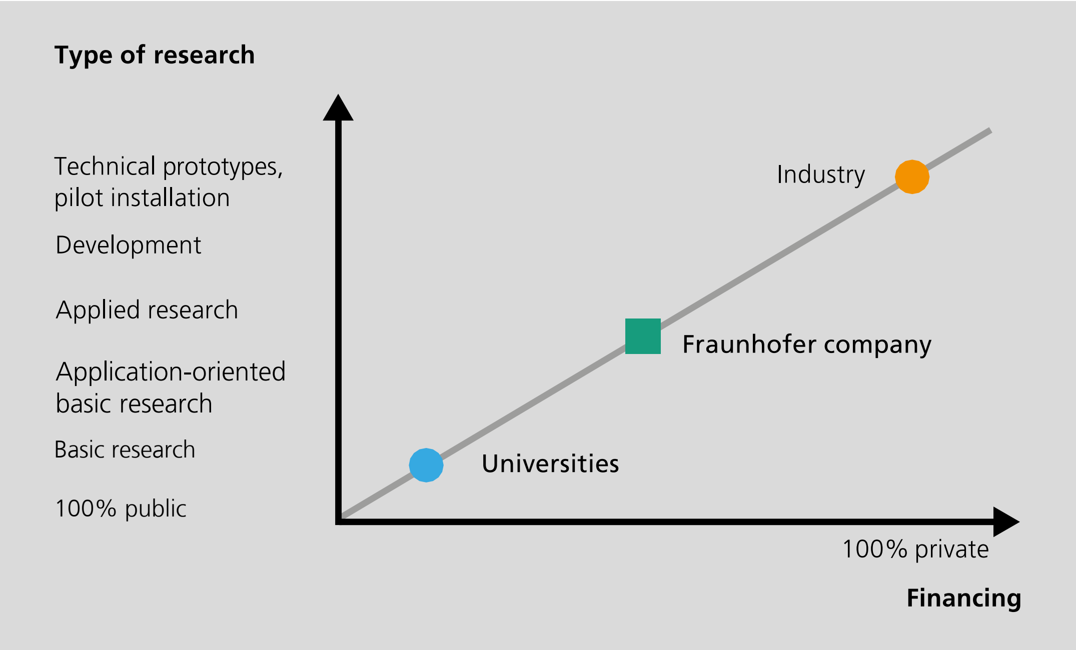
Managing Director	Prof. Dr.-Ing. Andreas Reuter
Research spectrum	Wind energy from material development to grid connection
Operational budget 2016	€ 16.8 million
Staff	170 employees
Located in	Bremerhaven, Oldenburg, Bremen, Hanover
Investments to date in the establishment of infrastructure	€ 80 million
Research Alliance Wind Energy	Strategic Alliance with ForWind and the German Aerospace Center (DLR)

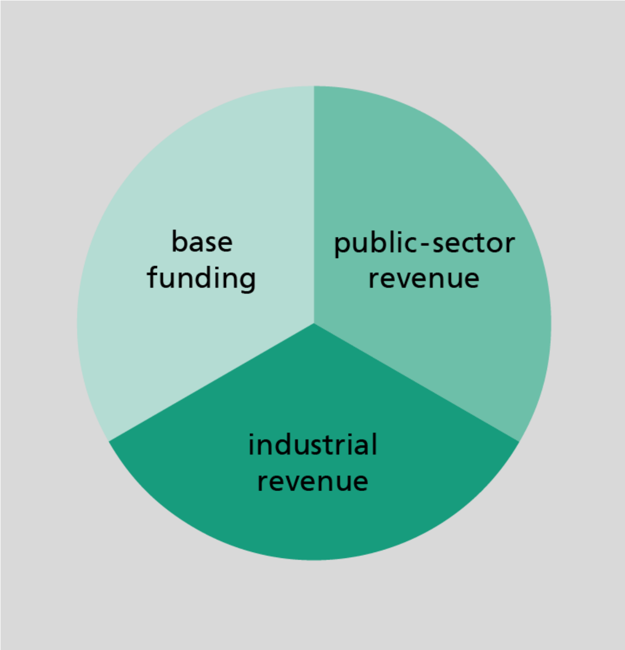
© Fraunhofer

Fraunhofer
IWES

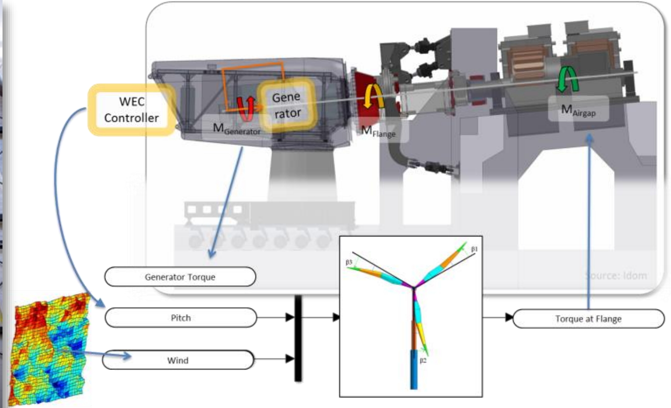
Fraunhofer's business model: Focus on industry as a factor for success

- 67 Fraunhofer institutes in Germany
- More than 24,000 employees, mainly with an academic background in natural or engineering sciences
- € 2.1 billion annual research budget



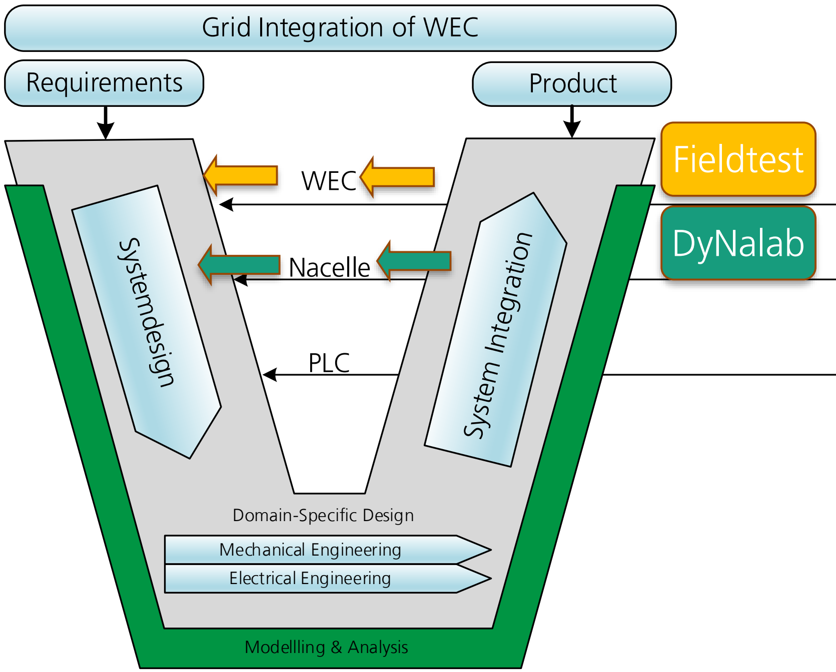


Fraunhofer IWES

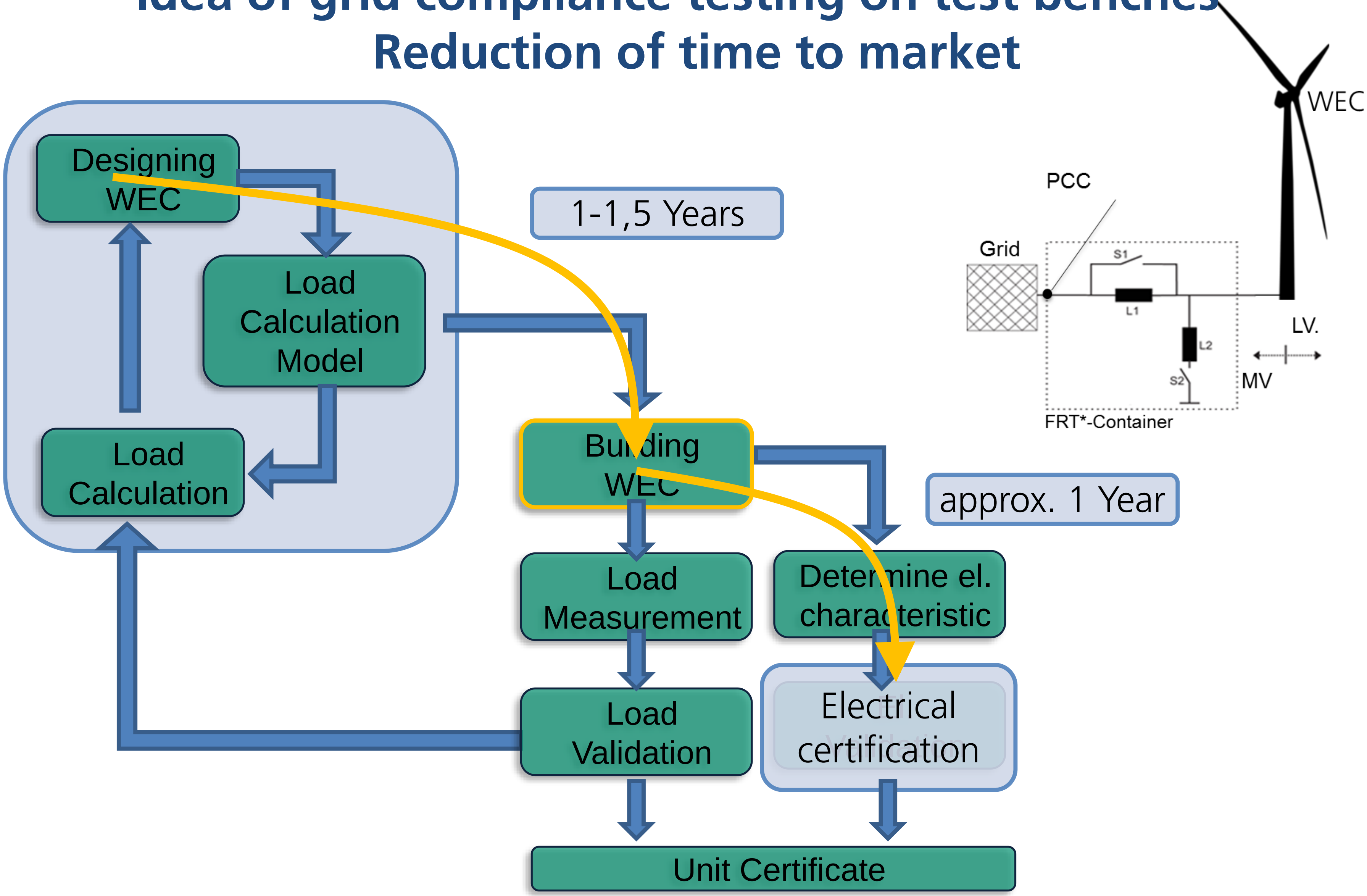


Motivation 2013 – Grid Compliance Testing of WEC on Test benches

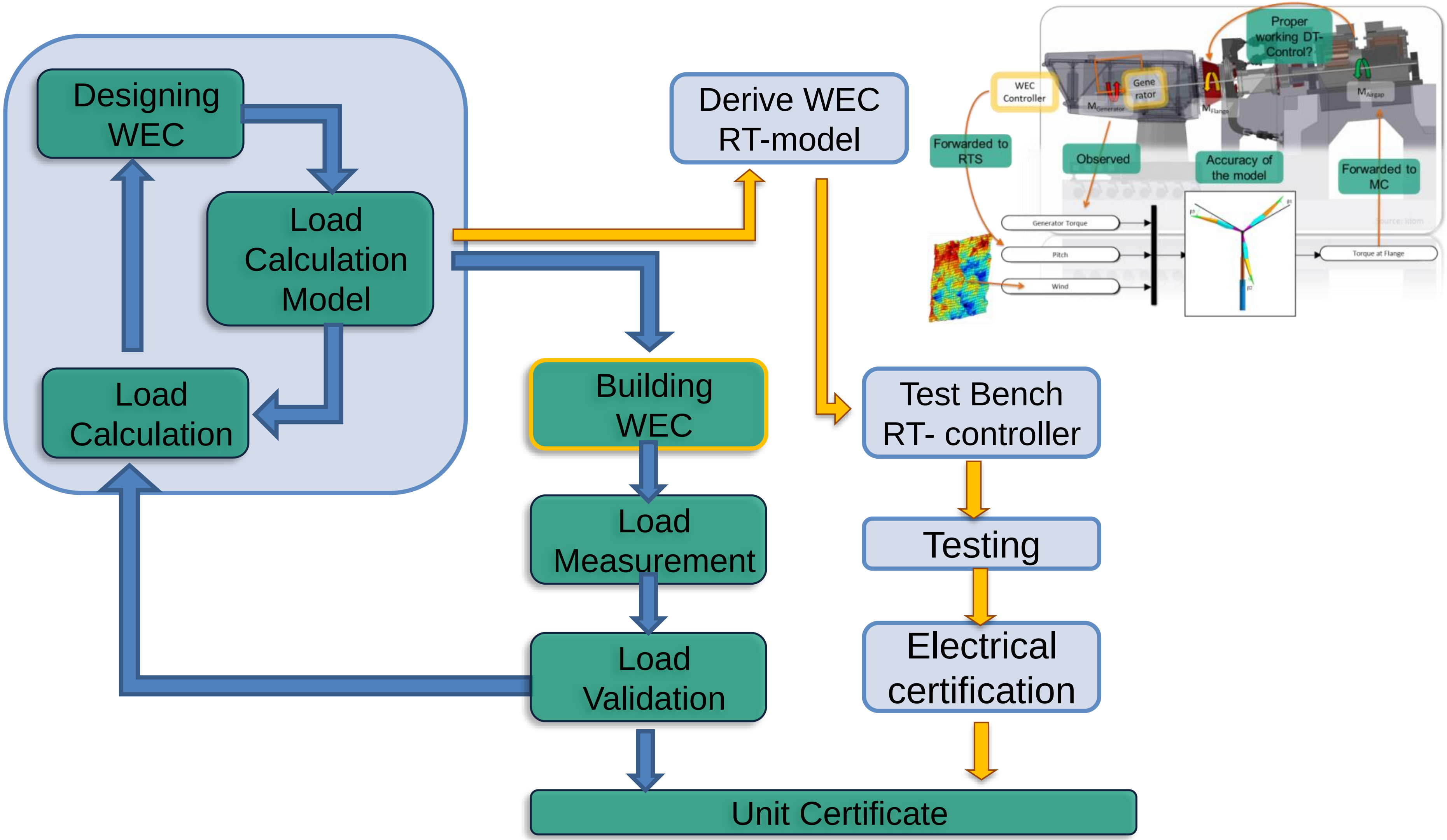
- Creating a genuine added value for wind industries
- Establishing novel development process by creating testing possibilities
- By grid compliance Testing on test benches the design process of WEC can be performed according to V-Modell



Idea of grid compliance testing on test benches – Reduction of time to market



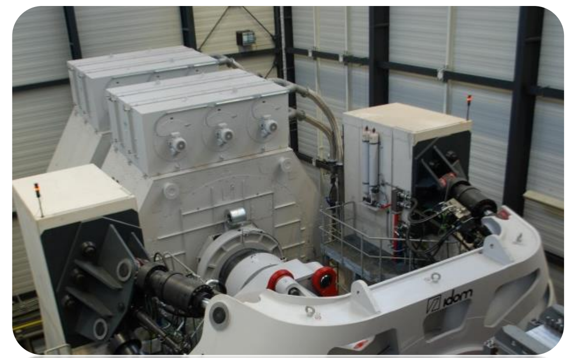
Electrical certification processes – novel approach



Fraunhofer IWES

DyNaLab – 10 MW full nacelle testing

Hydraulic load application unit
- Simulation of mechanical wind loads
- 1.2 MW Hydraulic Power
- Thrust: ± 1900 kN
- Radial loads: ± 2000 kN
- Bending moments: ± 20000 kNm
- Dynamic: 0-2 Hz



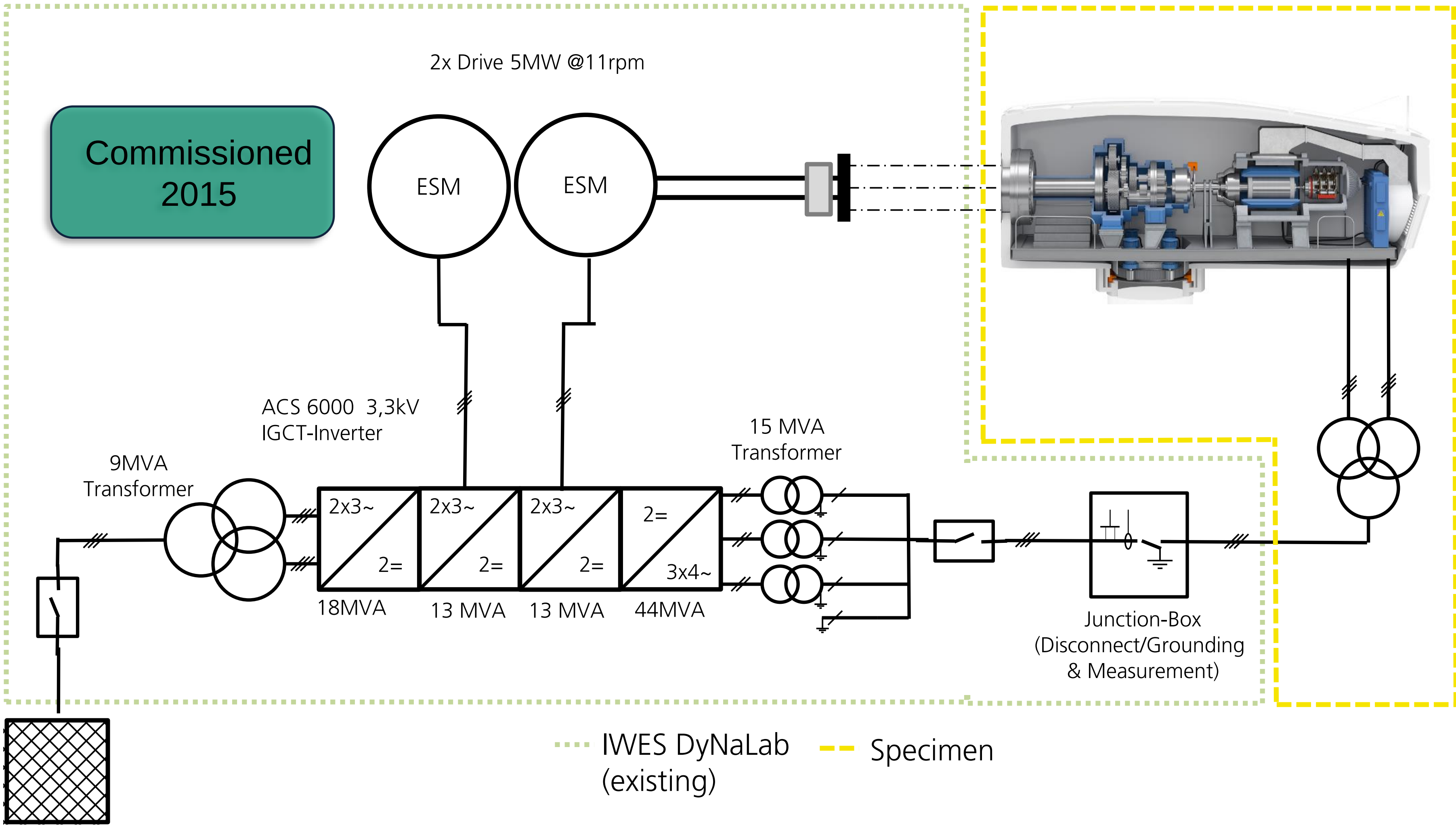
Drive
- 5° inclined Drivetrain
- 10 MW (15 MW Overload) Direct drive
- 8.600 kNm (13.0000 kNm Overload) Torque

Gridsimulator
- 10/20/36 kV nominal voltage levels
- 44 MVA installed converter power
- LVRT & HVRT Simulation
- < 2% THD at 50 Hz

Fraunhofer
IWES

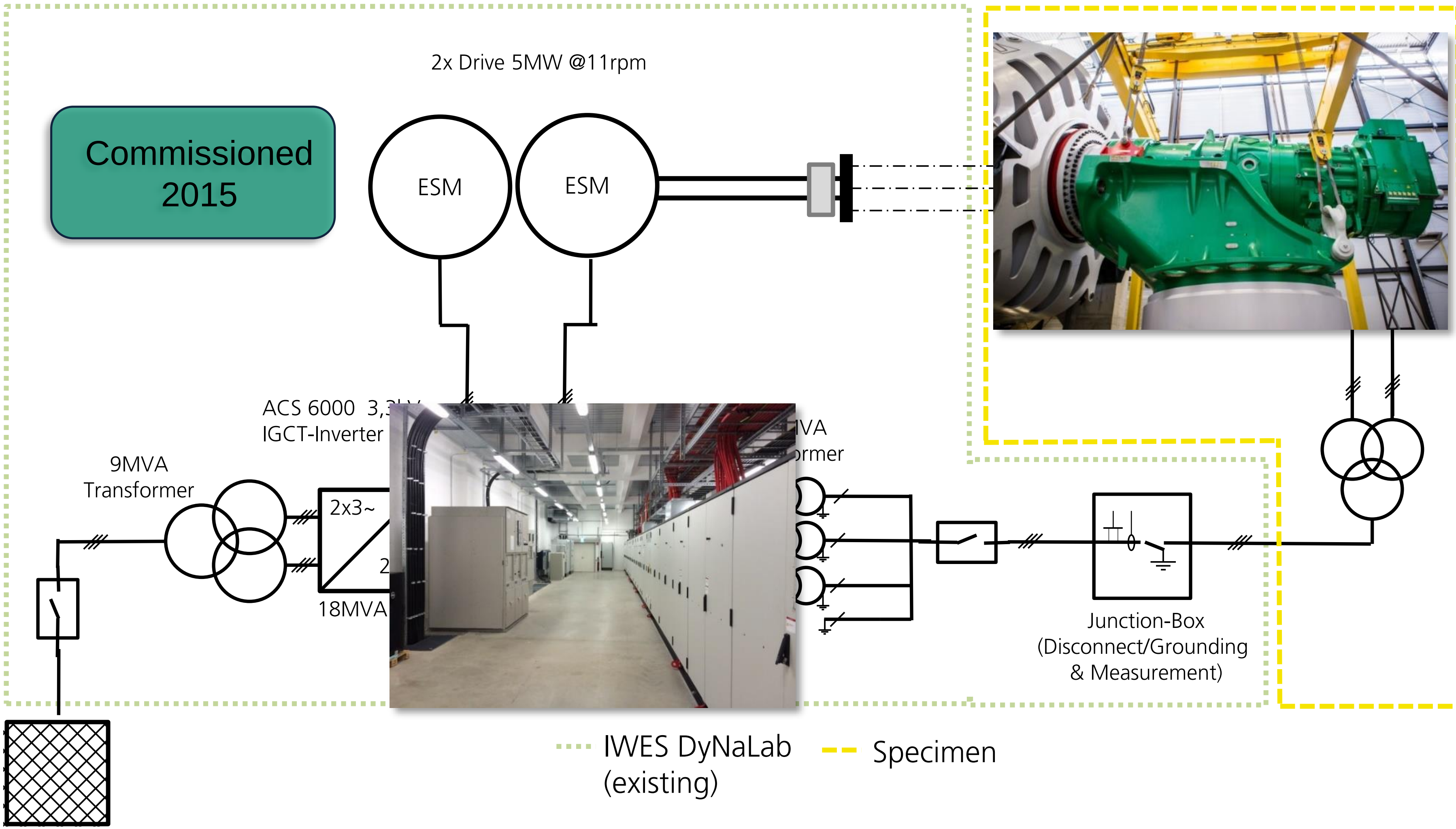
DyNaLab – 10 MW full nacelle testing

Commissioned 2015



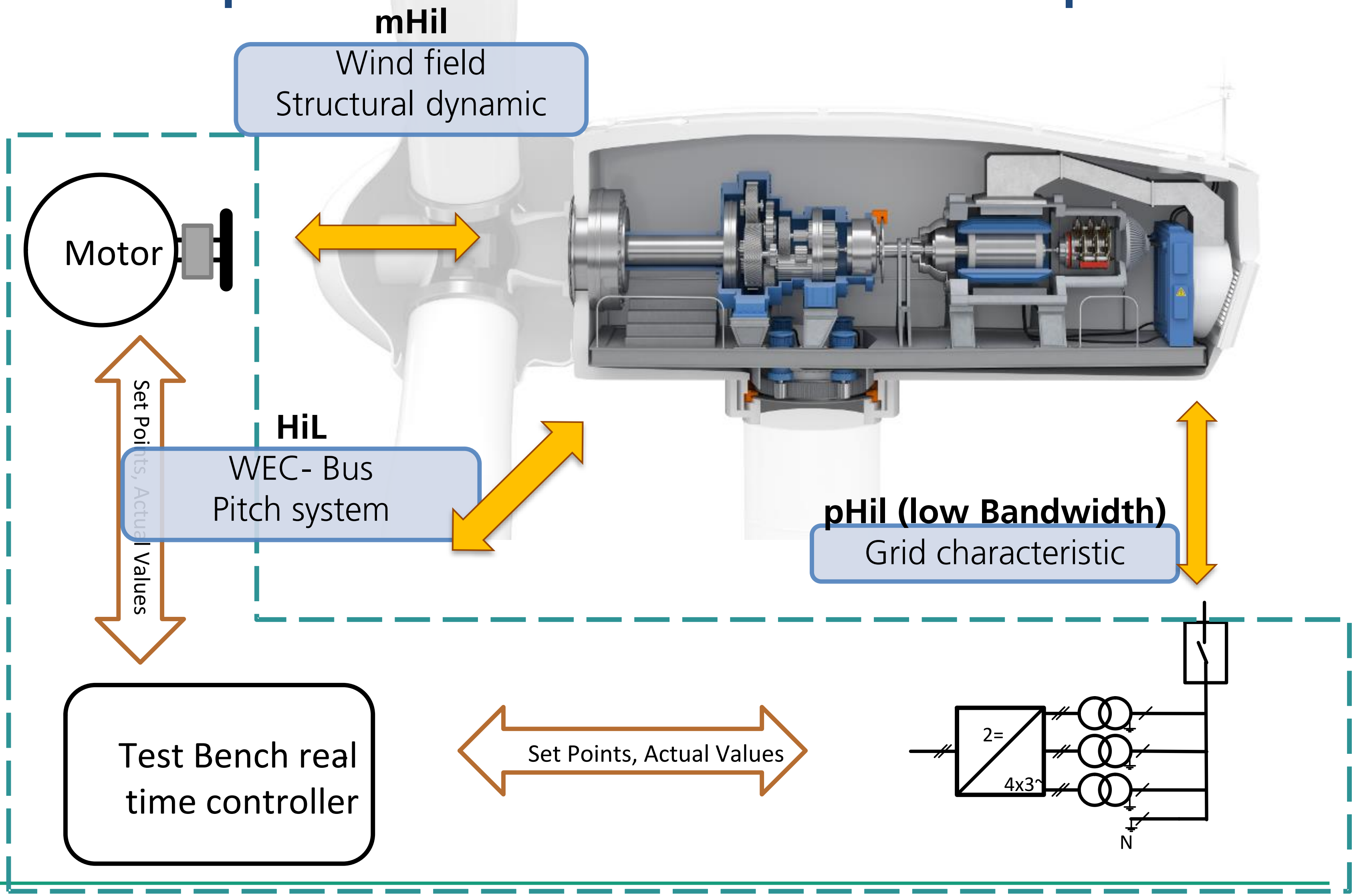
Fraunhofer IWES

DyNaLab – 10 MW full nacelle testing

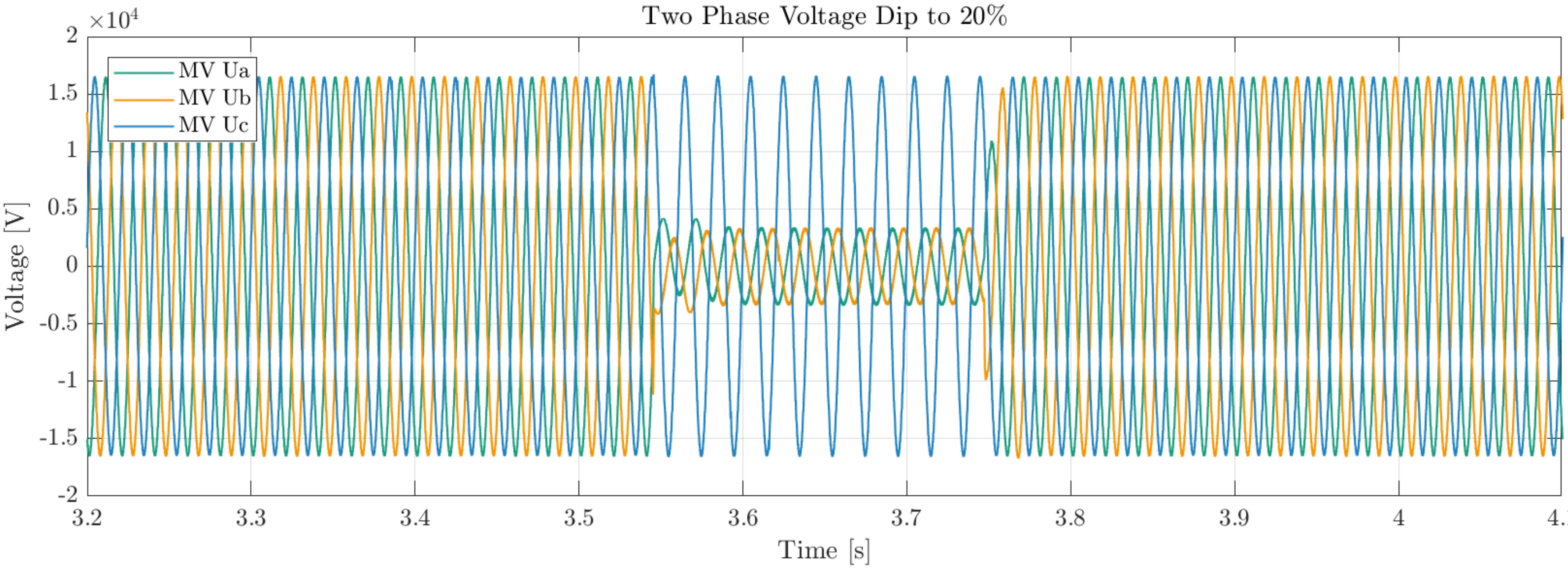


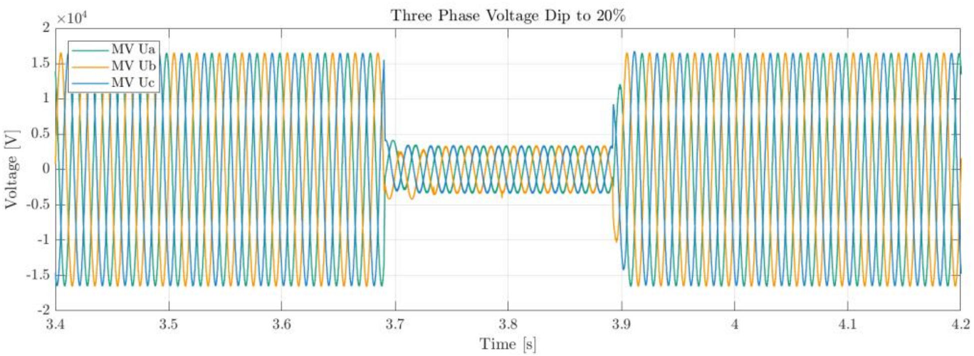
Fraunhofer
IWES

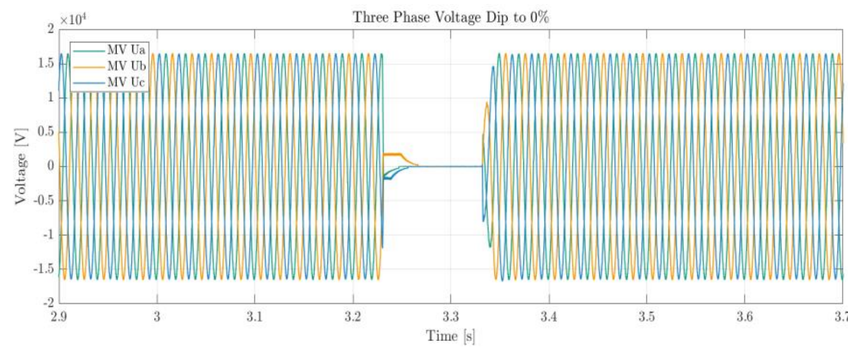
HIL-Setup – Emulation of non existent components



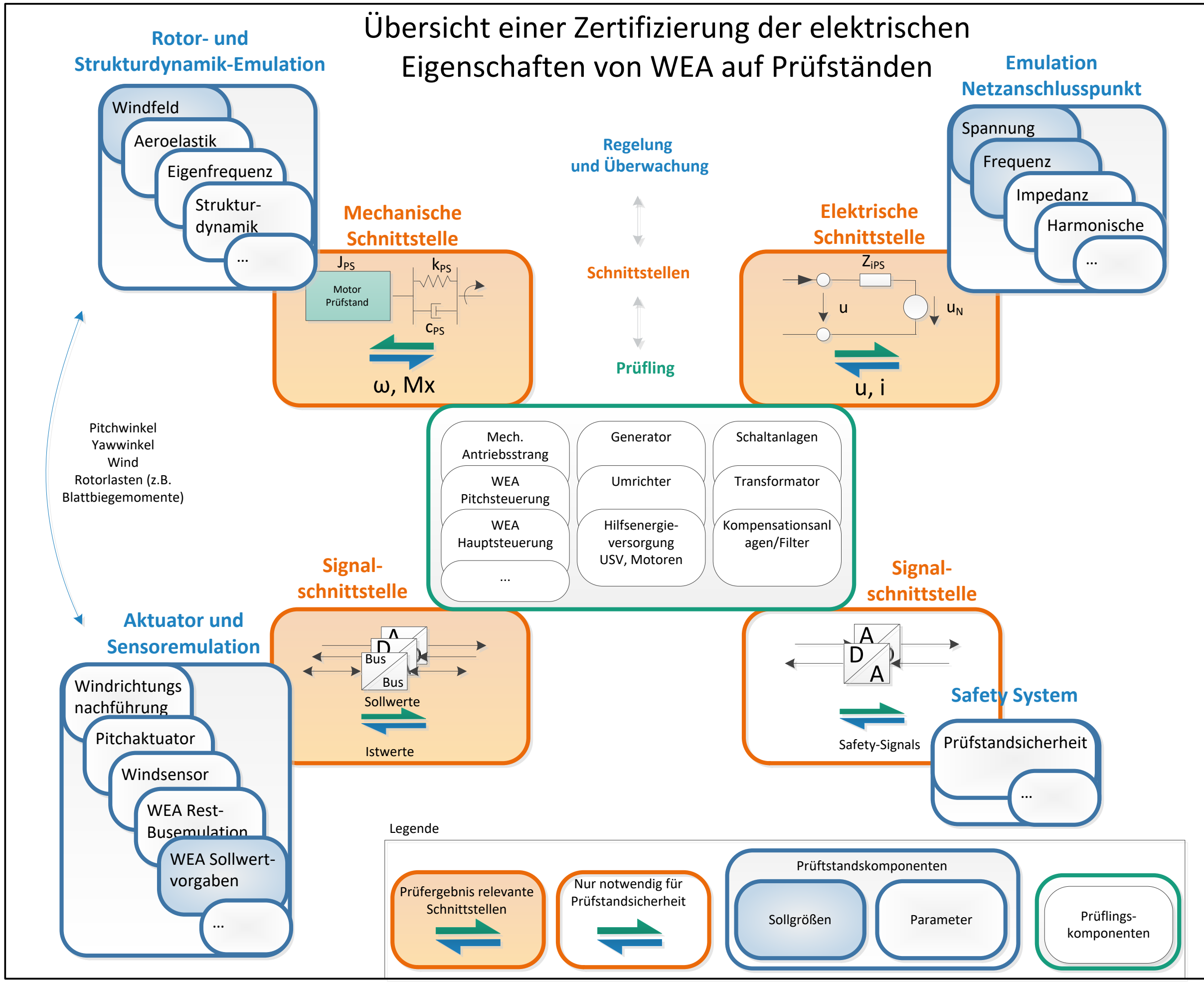
Exemplary Voltage Dips – filtered Voltages







Accompanying Standardisation works – according to FGW TR3 rev. 25



Participants

- Certification entities
- Measurement organization
- Test bench operators
- WEC Manufactures

Since 2015

Daily Challenges running Nacelle Test benches

- HSE Requirements
- IGCT Fails
- Reproducibility of tests
- Complexity
- Voltage Sags in Public Networks
- DC-Link Over Voltage of Cooling Inverters
- Loose Bolts
- EMC Disturbance on Safety
- Broken Sensors
- Over Temperature of measurement Equipment
- Defect Bolt Pretention Tool
- Maintenance

Industry Requirements

- Increased number of Tests
  - Full load, partial load, partial load curtailed
- Different Testing According to:
  - IEC 61400.21.1
  - FGW TR3
- Grid Codes
  - UK, Germany, Denmark, US, Japan, …
- Testing with different controller Settings
- Repeating tests test twice, three time, ….
- Request for few thousand tests

Test automation
for semi automated testing

Minimizing Time-to-Market
And lowering cost

- Why can't we accelerate the Testing?
- Long preparation, Adapter, defining sensors, cooling, Data handling etc
- Why should we Test gearboxes for WEC with fast running generator

Fraunhofer IWES

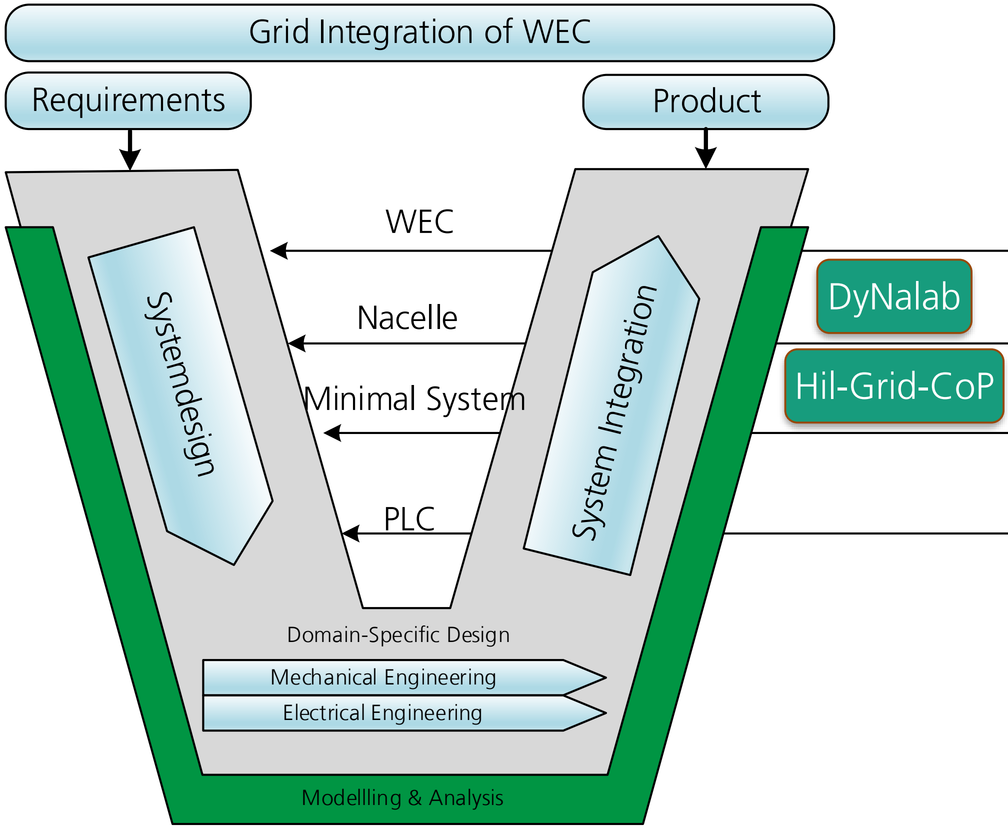
Motivation – Hil-Grid-CoP

Project Objectives:

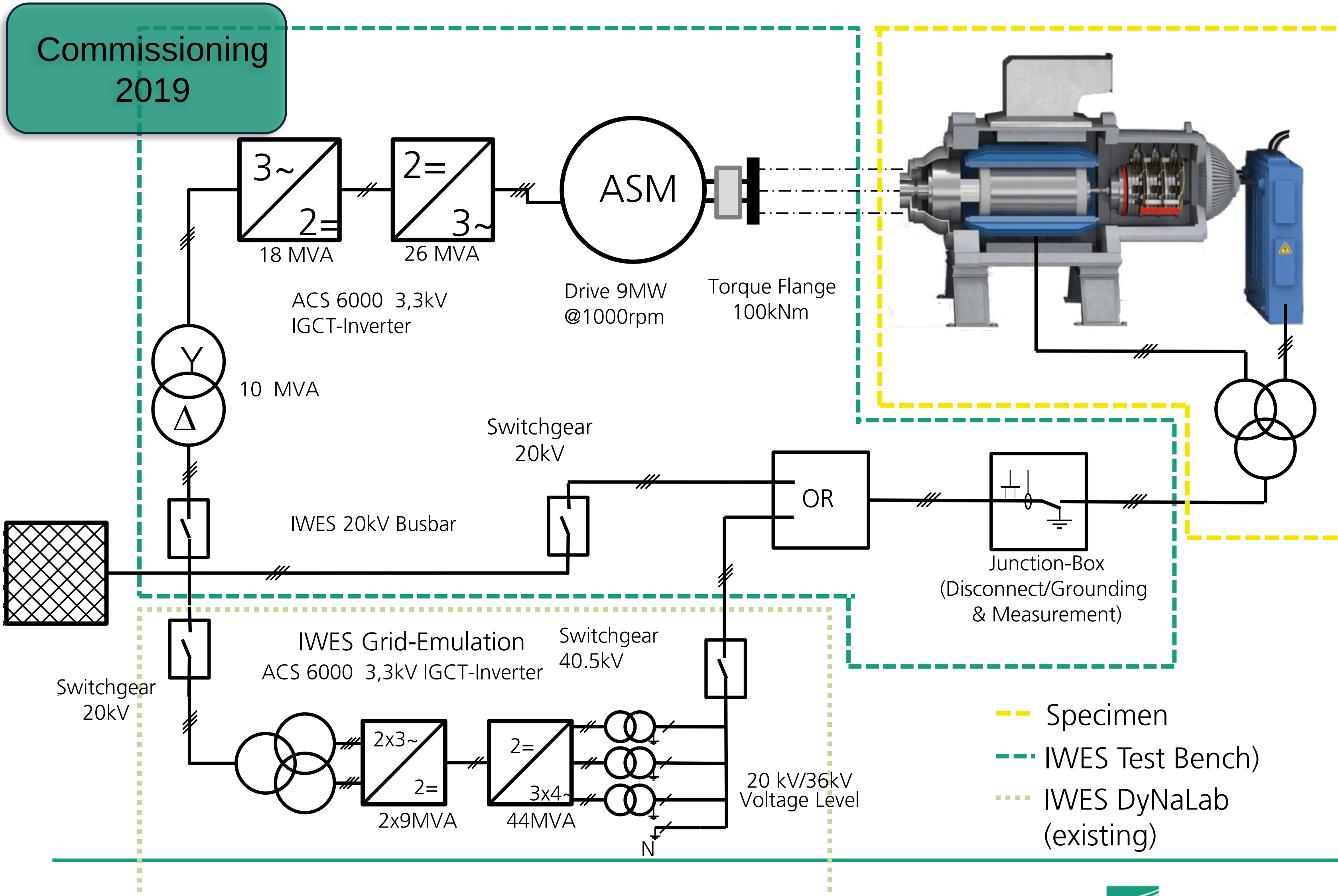
- Testing Minimal Systems - Fast running generator, Inverter system, Transformer and WEC Main Control
- Advanced logistic concept
- Fast switching between specimen

- Developing test methodology for minimal systems

- Mutual standardization works



Hil-Grid-Cop Test Bench: Testing el. Energy systems



Fraunhofer IWES

Hil-Grid-Cop Test Bench: Fact Sheet

Test Bench Objectives:

- Testing Minimal Systems, Fast running generator, Inverter system, Transformer and WEC Main Control
- Testing of 6.5 MW Generators-Inverter systems
- Overload Capability up to 200%
- Grid emulation for FRT-Testing
- Harmonic characteristic Analysis*

- Automated test bench operation

- Optimized Logistics

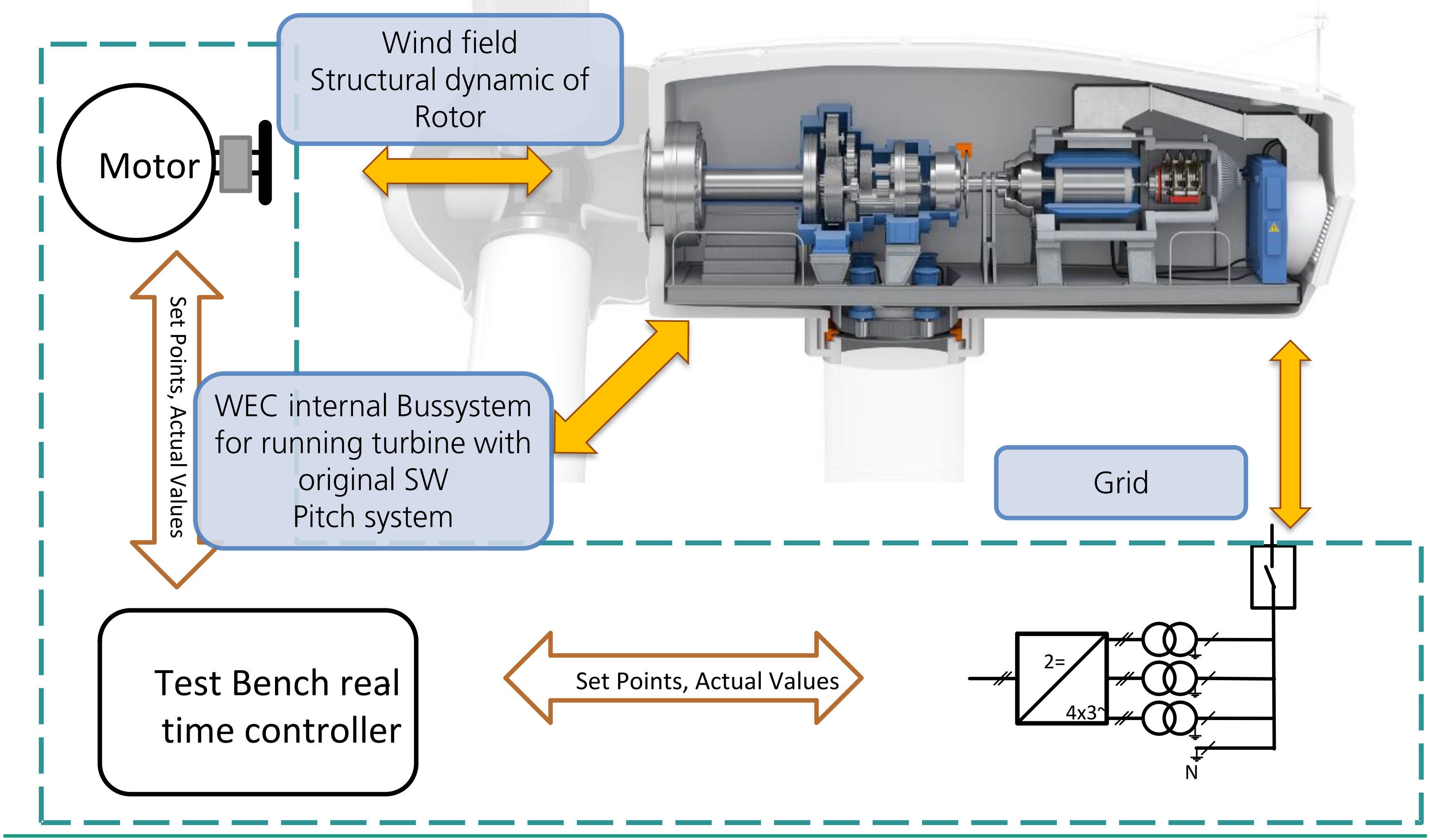
Operational Q3 2019

- **Test bed** 650 t
- **Induction machine** 9/13 MW @ 1000-1800 min^{-1}
- **Inverter Power** 26 MW

- **Grid Connection** 20 kV
- **Grid simulator**
  - **Nominal Voltage** 20/36 kV by tappings
  - **Low THD**
  - **Symmetrical and unsymmetrical FRT**
  - 3-ph 2-ph and 1-ph dips with phase angle jumps
  - **Frequency Range** 45 Hz…65Hz ROCOF 20 [Hz/s]
  - **Impedance Variation**

- **Test automation**
- Fully integrated WEC-Control Testing for HIL
- **Real-time Control System** with synchronized electrical and mechanical measurements

What we are doing? – Emulation of non existent components on the test bench



Fraunhofer IWES

Accompanying international standardization Advertising Participation

IEC

88/685/NP

NEW WORK ITEM PROPOSAL (NP)

PROPOSER: Denmark	DATE OF PROPOSAL: 2018-05-31
DATE OF CIRCULATION: 2018-06-01	CLOSING DATE FOR VOTING: 2018-08-24

IEC TC 88 : WIND ENERGY GENERATION SYSTEMS

SECRETARIAT: Denmark	SECRETARY: Mrs Christine Weibøl Bertelsen
NEED FOR IEC COORDINATION:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this NP to the TC/SC secretary

FUNCTIONS CONCERNED:

☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY

TITLE OF PROPOSAL:

Wind energy generation systems – Part 21-4: Measurement and assessment of electrical characteristics - Wind turbine components and subsystems (proposed IEC TS 61400-21-4)

☐ STANDARD ☒ TECHNICAL SPECIFICATION

PROPOSED PROJECT NUMBER: 61400-21-4

SCOPE
(AS DEFINED IN ISO/IEC DIRECTIVES, PART 2, 14):

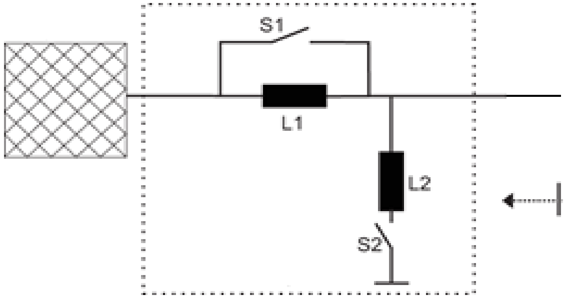
The proposed work for the NWIP of Measurement and assessment of electrical characteristics - Wind Turbine components & subsystems is to define a uniform methodology that will define measurement, testing and assessment procedures of electrical characteristics of Wind Turbine components & subsystems, as basis for the verification of the electrical capabilities of Wind Turbines and WT families.

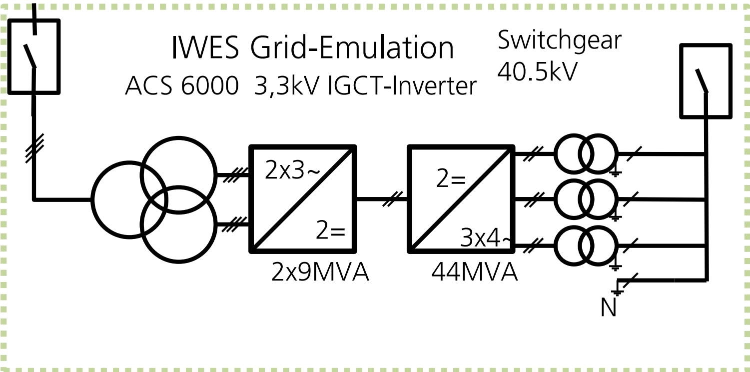
- Defining test methodologies for testing nacelles, subsystems and components
- Kick-Off Meeting in 10-2018
- Next Meeting January 2019 at DTU, Denmark

- **Appreciate non European participants to help on defining new standards, too**

- Emulating existing testing methodologies, Inductance divider for creating voltage dips

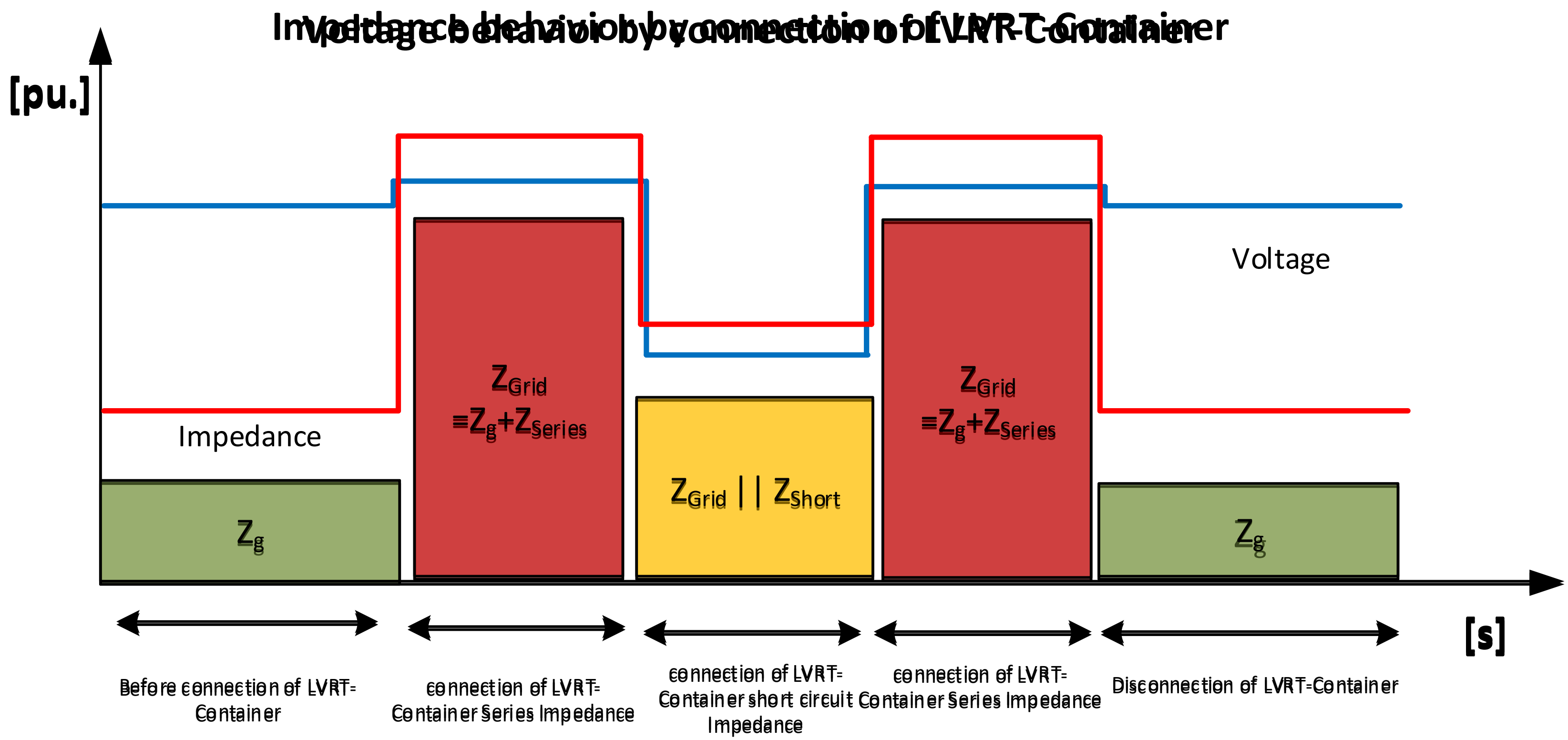
Tasks - Verification of programmable UVRT Test





Fraunhofer IWES

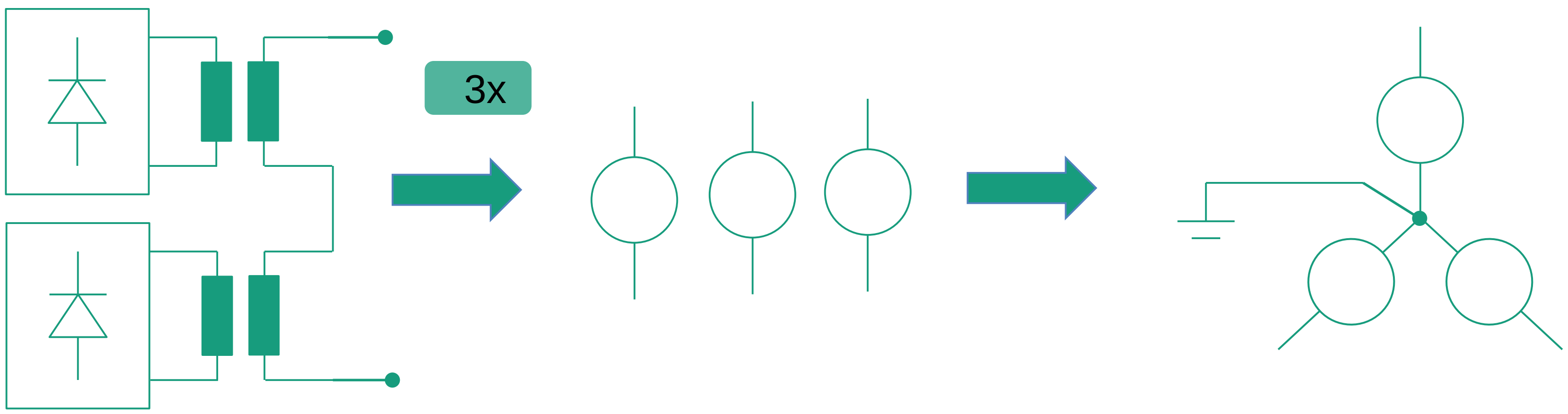
Tasks - Verification of programmable UVRT Test



Voltage sag by UVRT-Container shows inherent impedance change

Fraunhofer IWES

Design of the 44MVA Grid Emulator – HW Setup



- 3 separate transformer with H-Bridge on lower MV site
- Windings connected in series

→

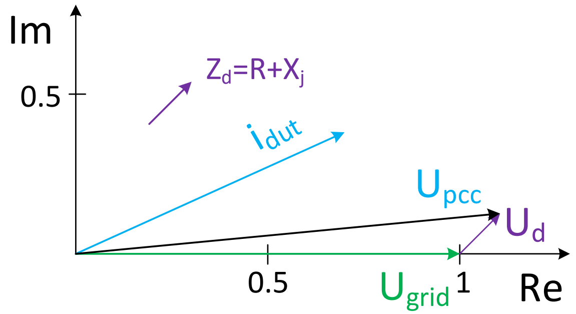
- Multi-level architecture
- Elimination of harmonics
- Separate control of each phase

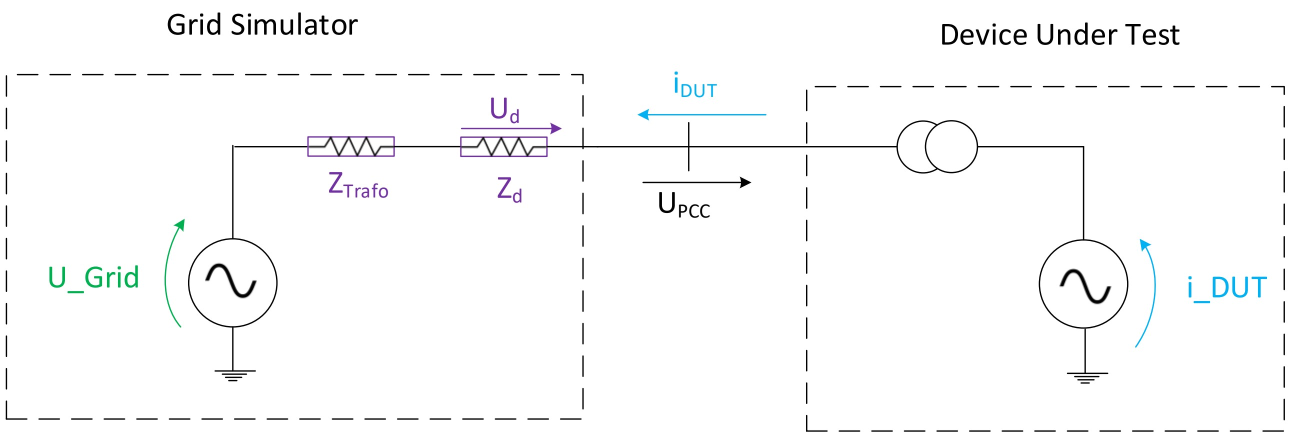
- Impedance change is no inherent system characteristic
- Fully programmable for amplitude, phase angle, impedance, Frequency

Fraunhofer IWES

Design of the 44MVA Grid Emulator – Impedance Emulation

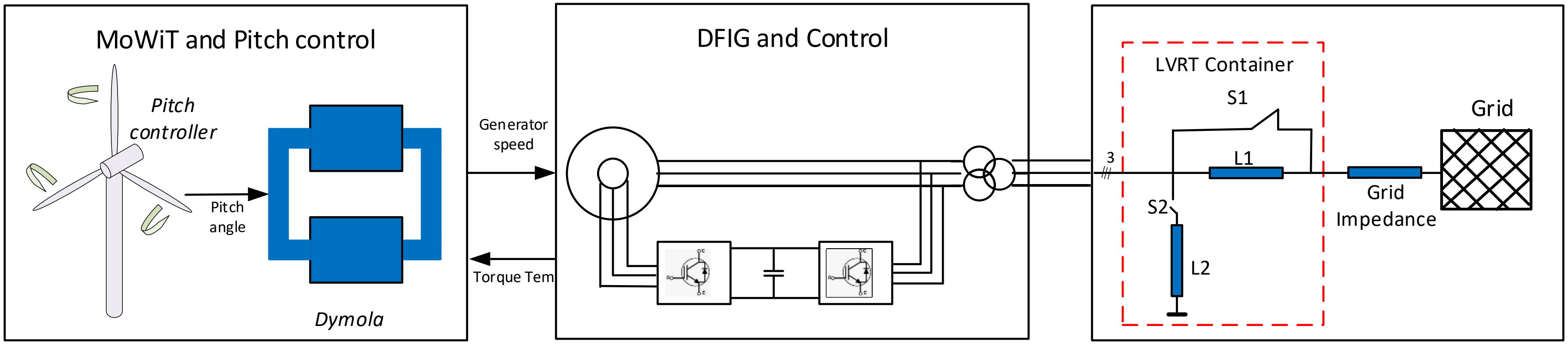
- Impedance emulation
- Limited Bandwidth approx. 100 Hz
- Limited bandwidth due to slow switching frequencies





Fraunhofer IWES

Simulation Setup



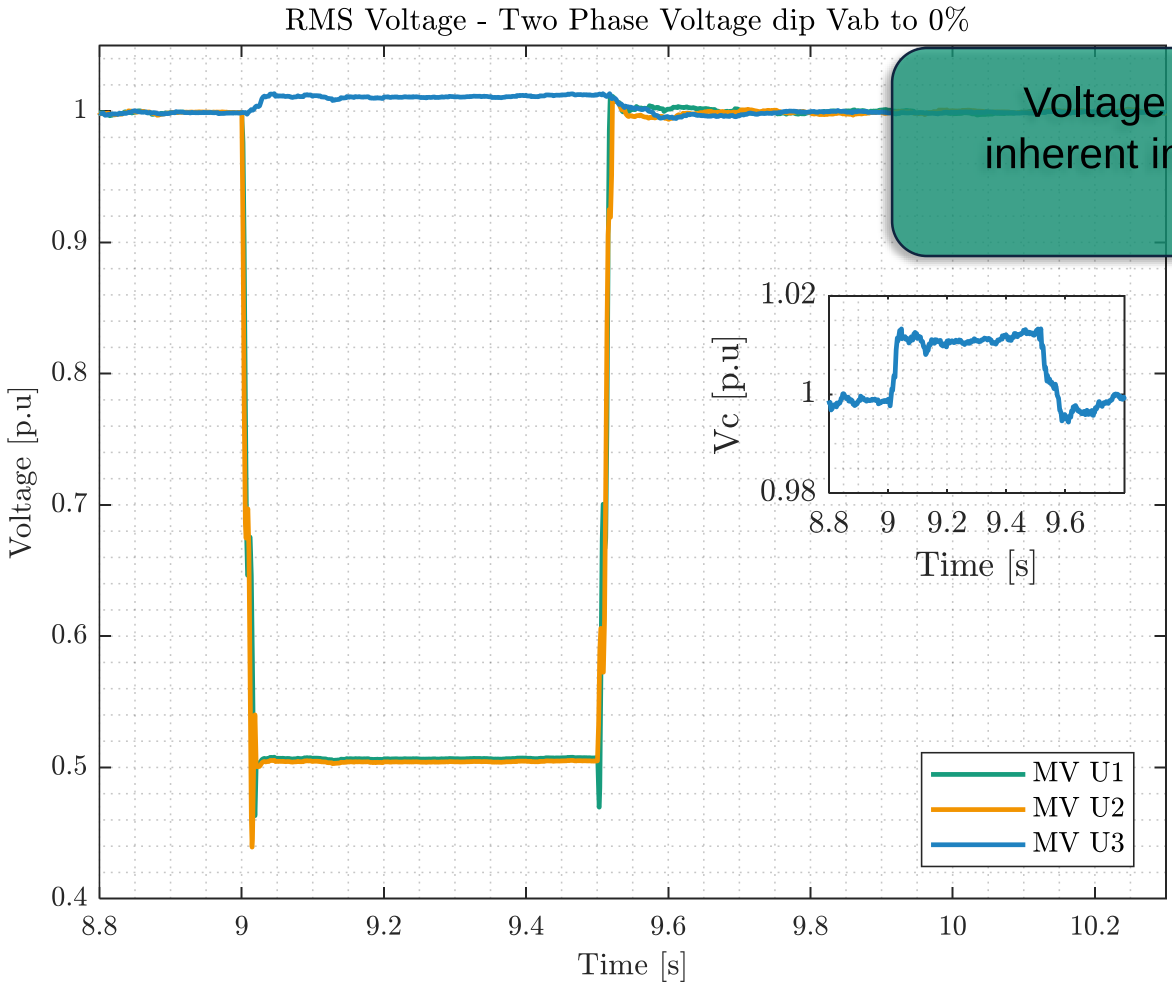
- Fully coupled aero-elastic-simulation
- MoWiT running in Matlab
- 2.5 MW WEC

- DFIG
- Full model PE
- Grid Compliant control according to VDE AR 4110/4120
- E.g. K-Factor of 2

- Unsymmetrical Voltage Sag

Comparison UVRT with Impedance emulation Voltage Drop

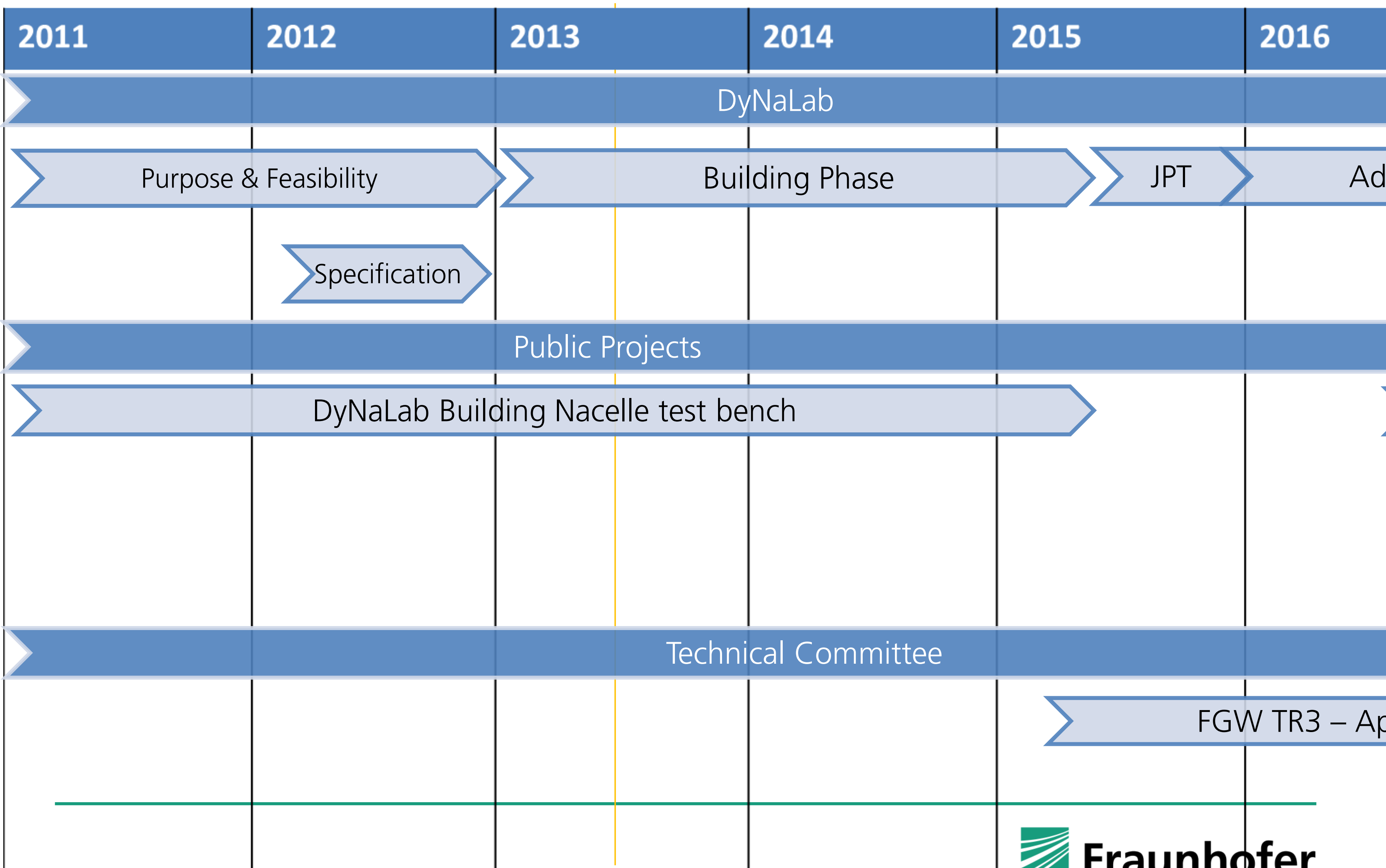
Simulation of voltage sag by Voltage divider



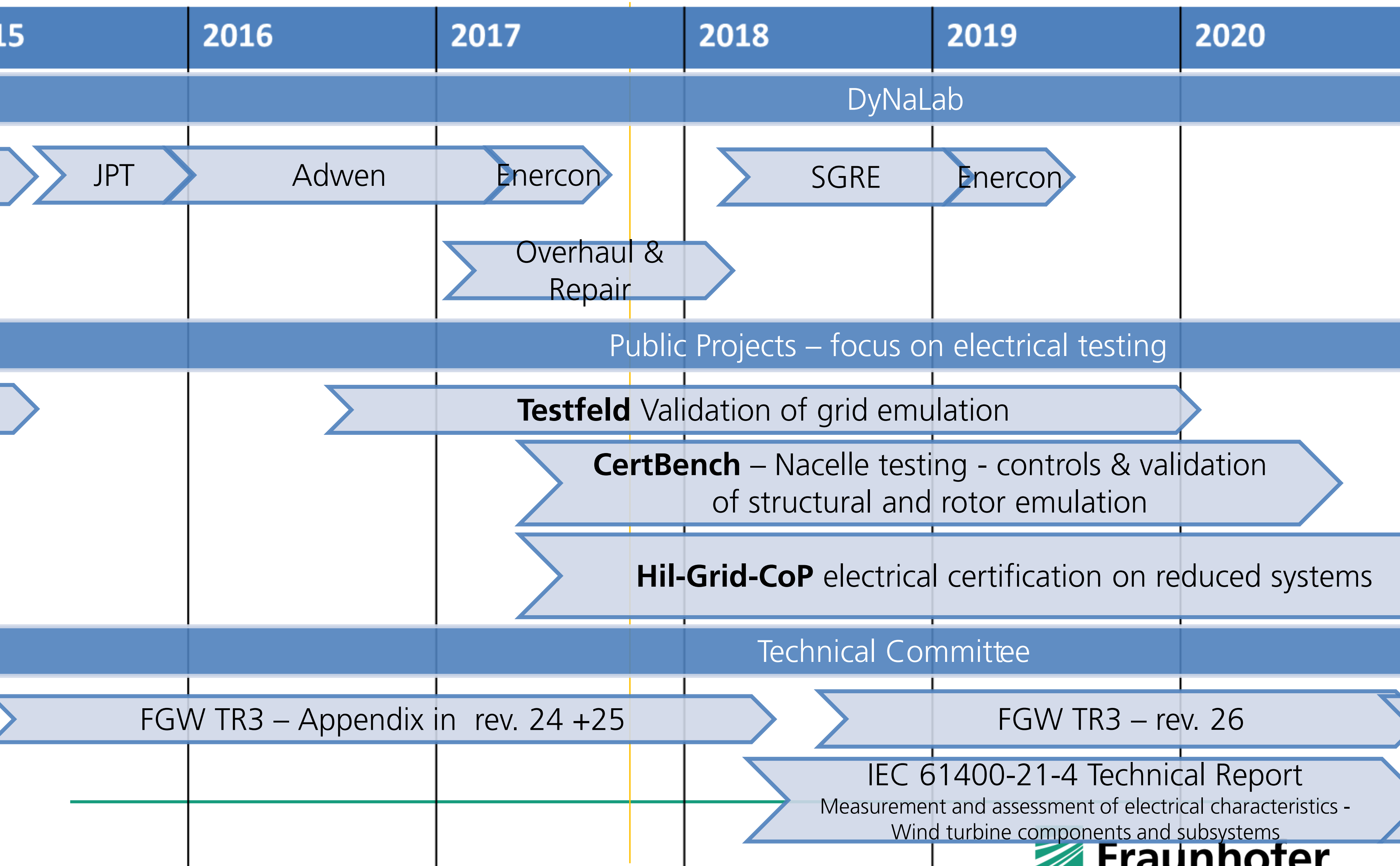
Voltage sags by UVRT-Container inherent impedance and phase angle change

Fraunhofer IWES

Review and Outline - Electrical Testing @ Fraunhofer IWES



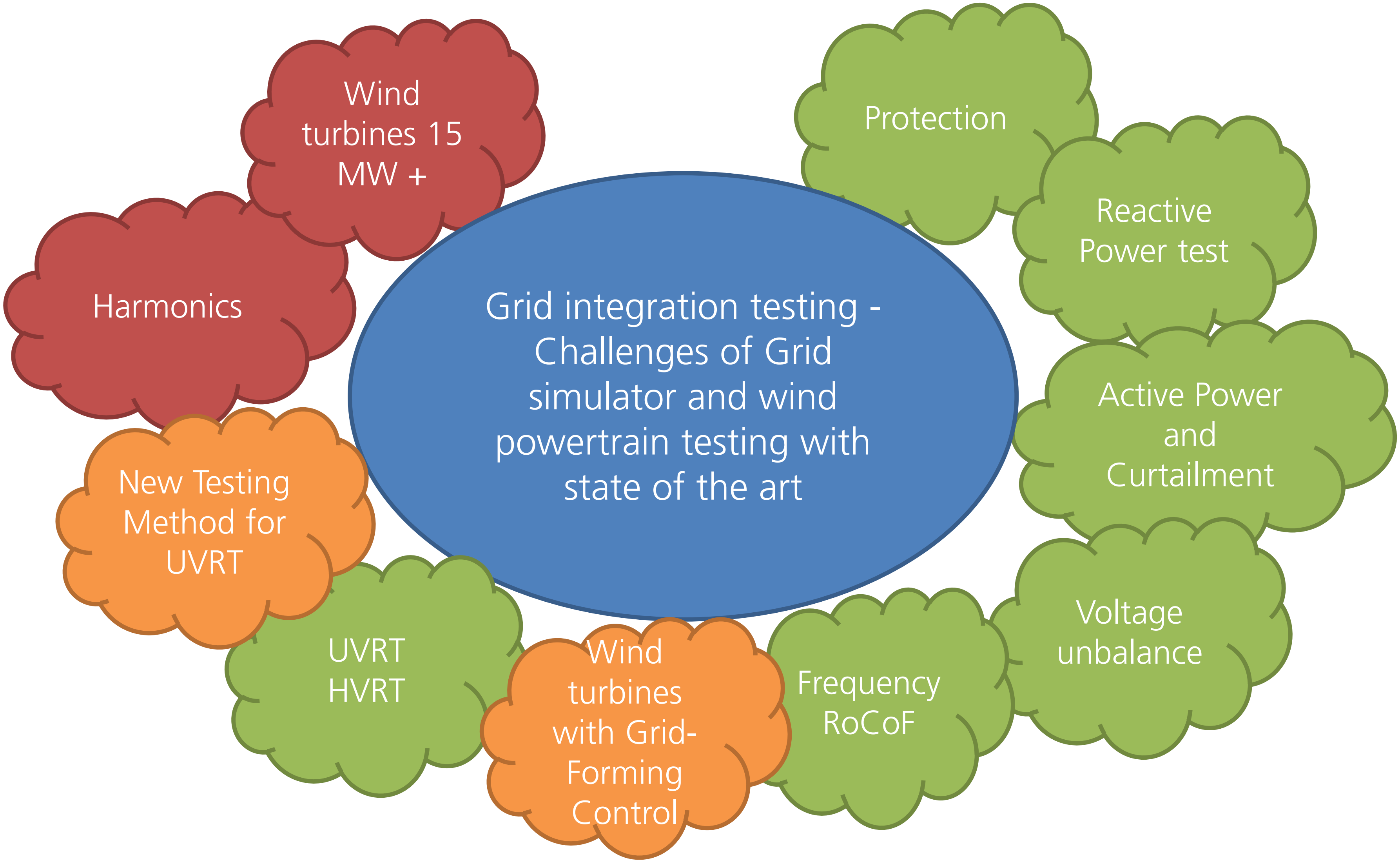
Review and Outline - Electrical Testing @ Fraunhofer IWES



Fraunhofer IWES

Time for Questions

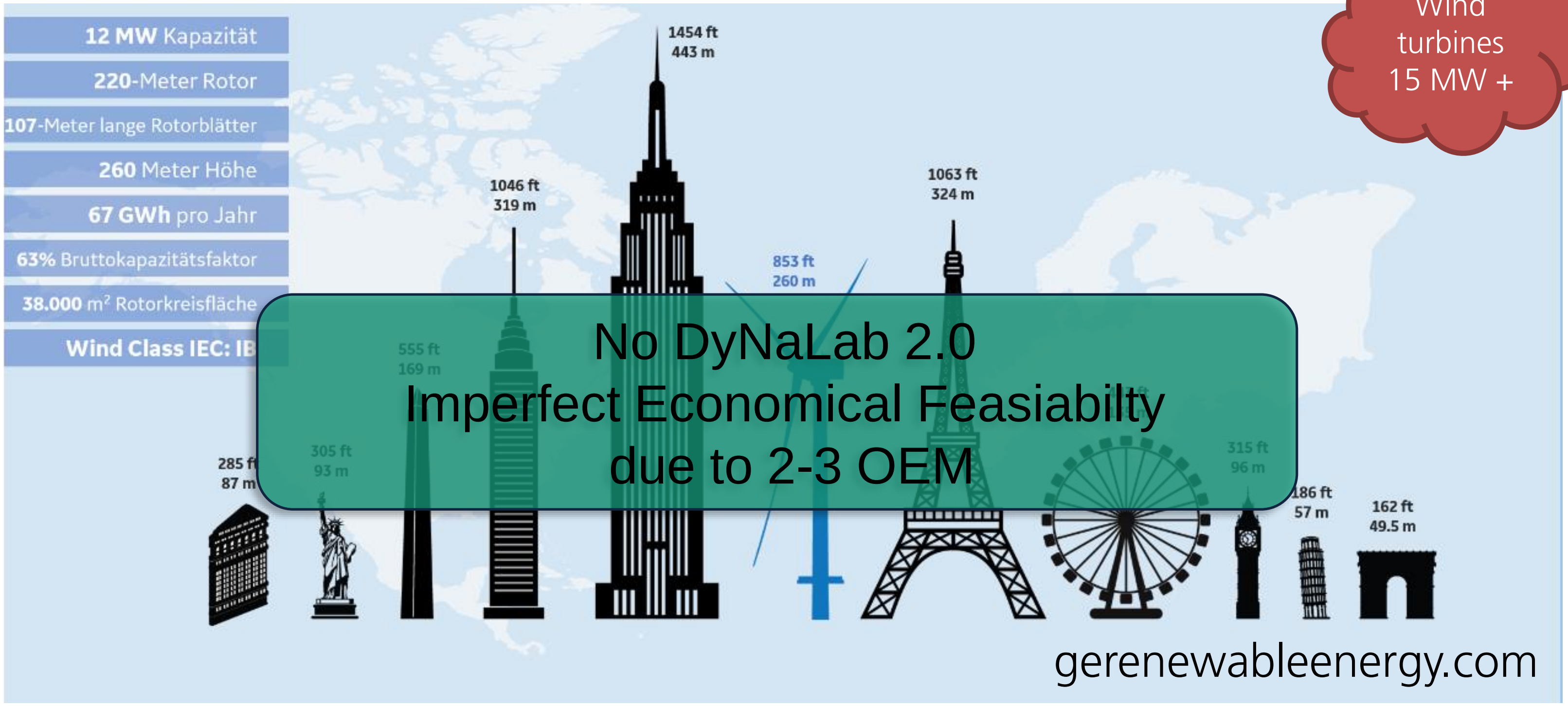
Challenges of grid integration testing



Fraunhofer IWES

How to test Wind Turbines 15 MW+

Wind turbines 15 MW +



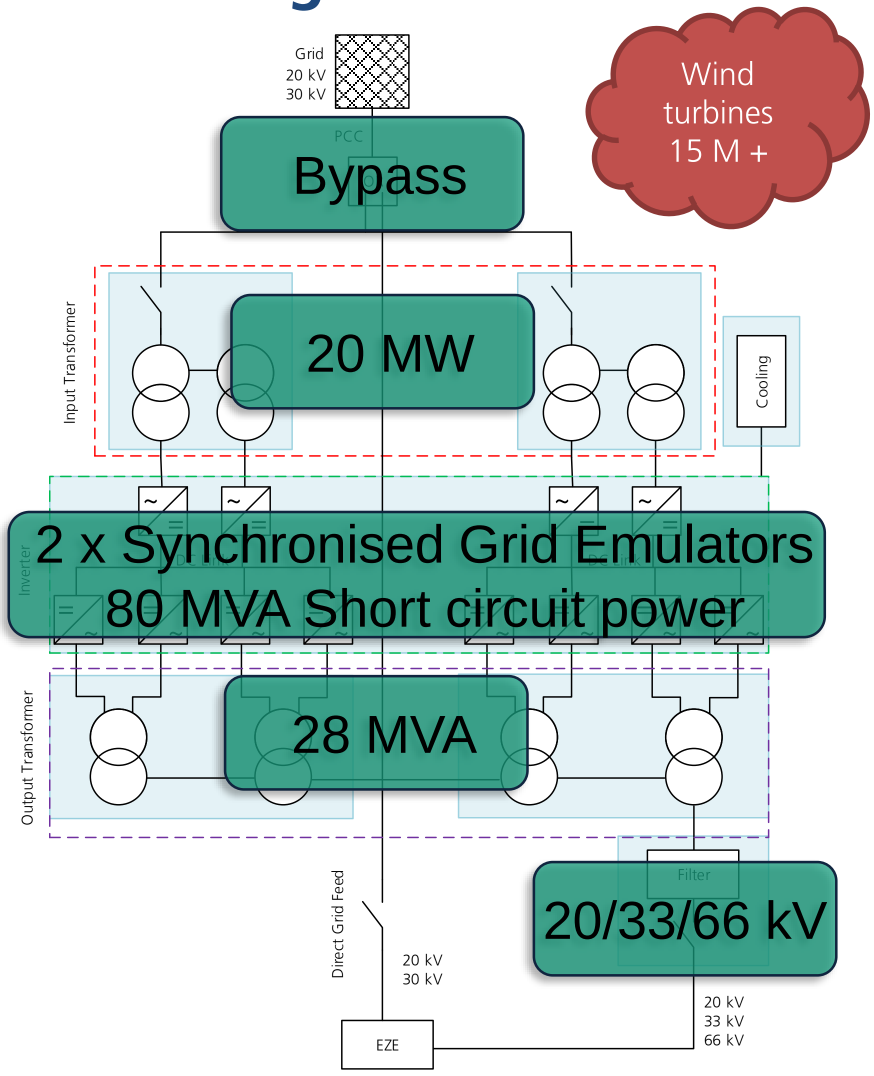
No DyNaLab 2.0
Imperfect Economical Feasiabilty
due to 2-3 OEM

- Nowadays 12 MW > mid term 15 MW > long term 20 MW
- Actual Test benches 10 MW to 15 MW
- Building new system test benches 15 MW will result in approx. 80 Mio investment

Mobile-Grid-CoP – 28 MVA mobile grid simulator

Project Objectives:

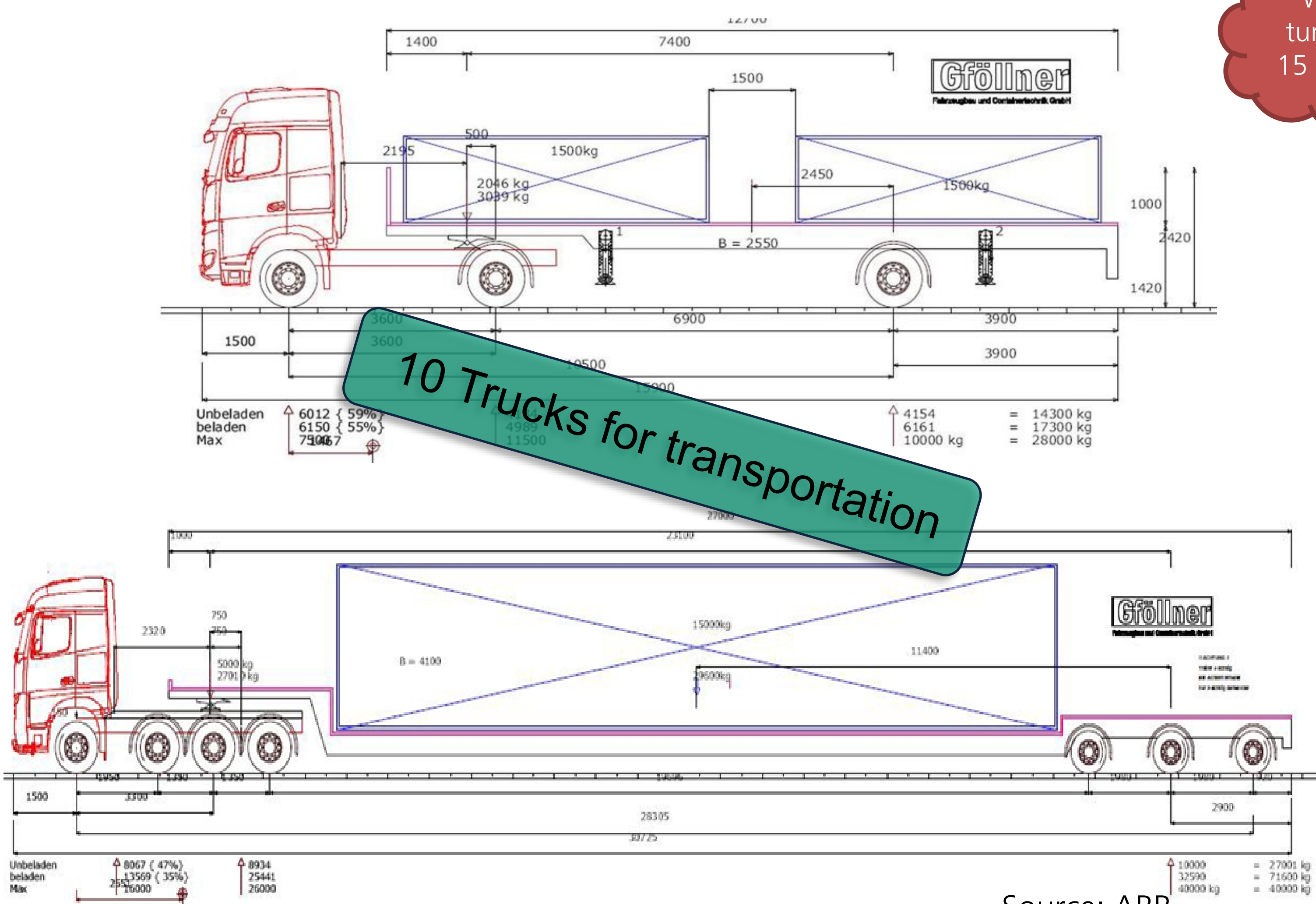
- Providing advanced grid Simulator testing to wind turbines in Fields
- harsh RoCoF requirement for grids with highly penetrated Renewable Energy
- Optimization of RoCoF Capability
- Investigation of grid excited loads of wind turbines
- Investigating wind farm interaction
- No Grid interference due to inverter technology
- Testing grid compliance of
    - Special energy supply units
    - Industrial Systems with highest availability
    - Large charging stations



Fraunhofer IWES

Mobile Grid Simulator – Logistics

Wind turbines 15 MW +

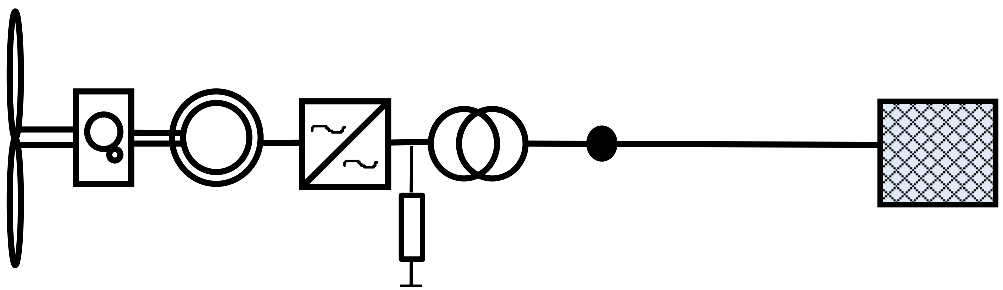


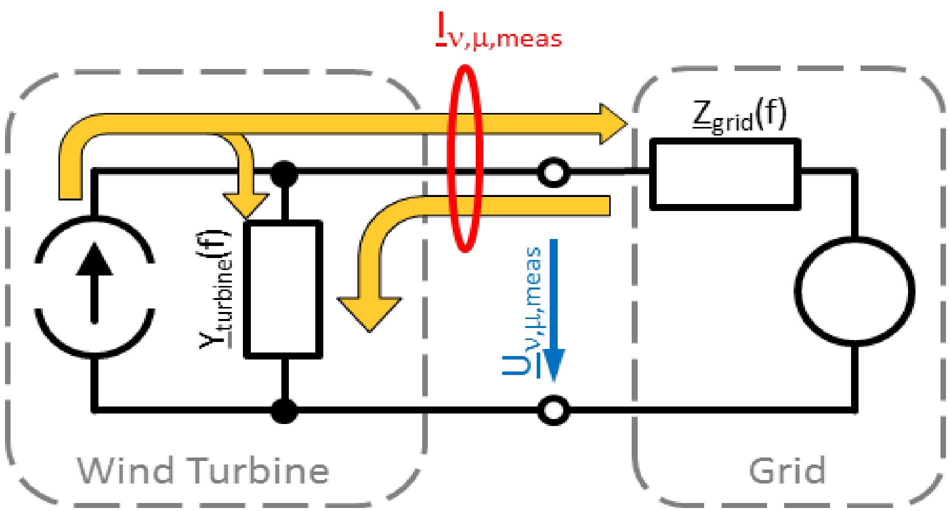
10 Trucks for transportation

Source: ABB

Main problem of measuring harmonic emission

Harmonics

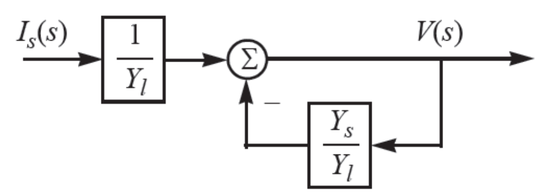




Source: UL-DEWI

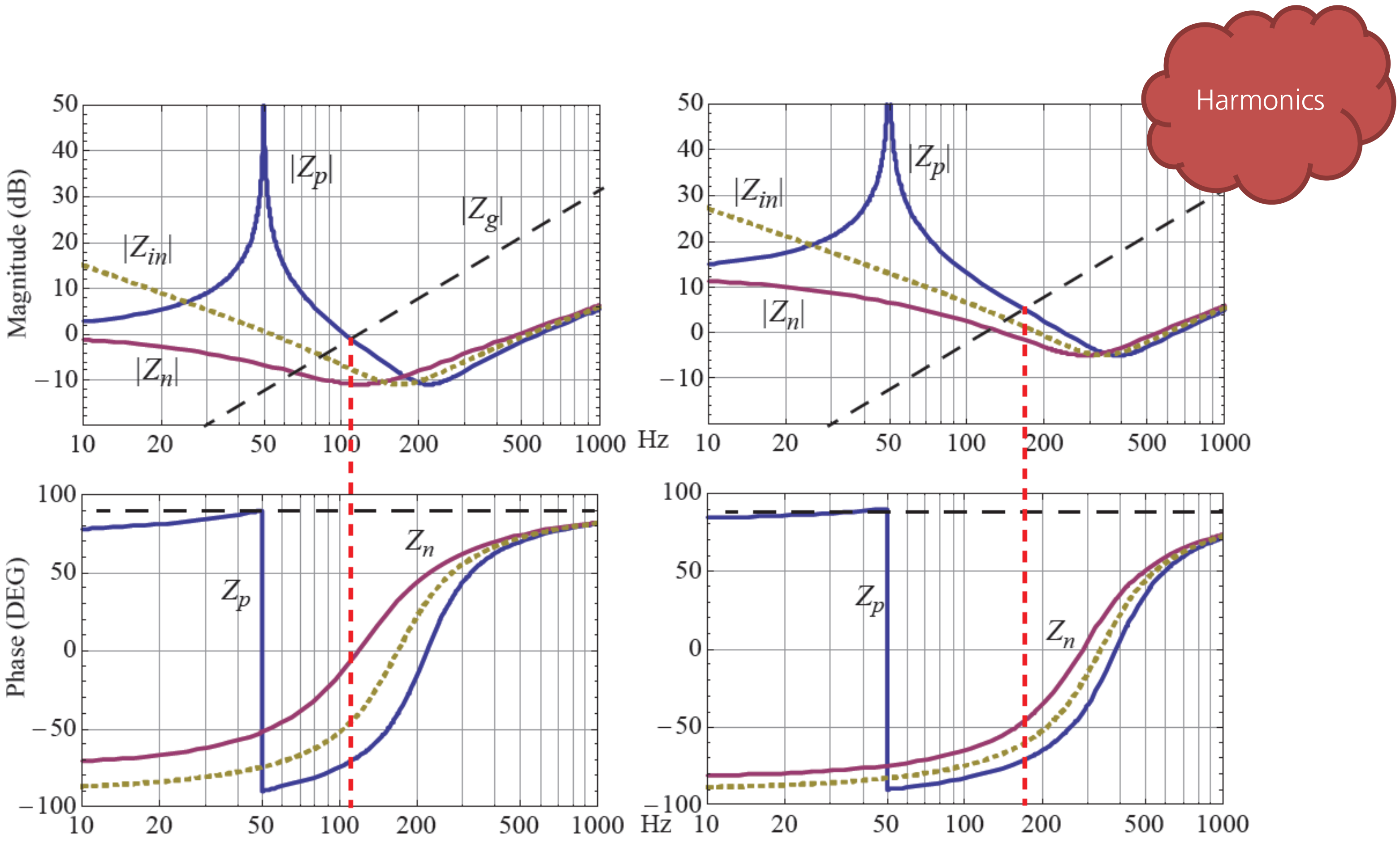
Root-Cause of Harmonics

- Harmonics produced by WT
- Background Harmonics in the Grid
- Harmonic currents are dependent on impedances
- Grid infrastructure resonances
- Impedance induced resonances
- Inherent system interaction



- However: Only one mutual measurement

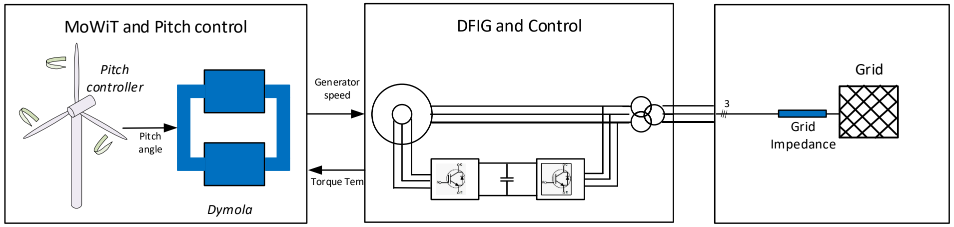
Unknown and time variant impedance characteristic



Source: Tennet
[Impedance Modeling and Analysis Methods for Offshore Wind and HVDC Systems]

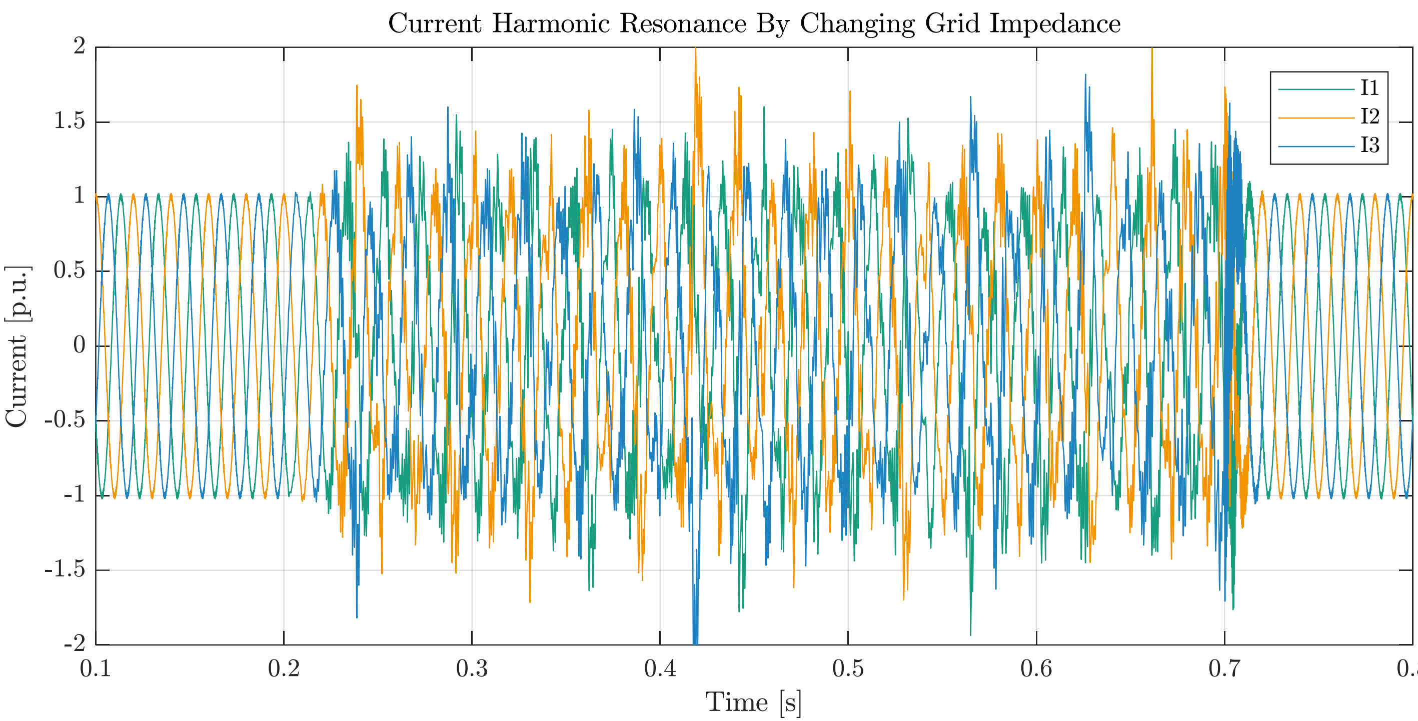
Fraunhofer IWES

Impedance Induced Harmonics due to Weak Grid



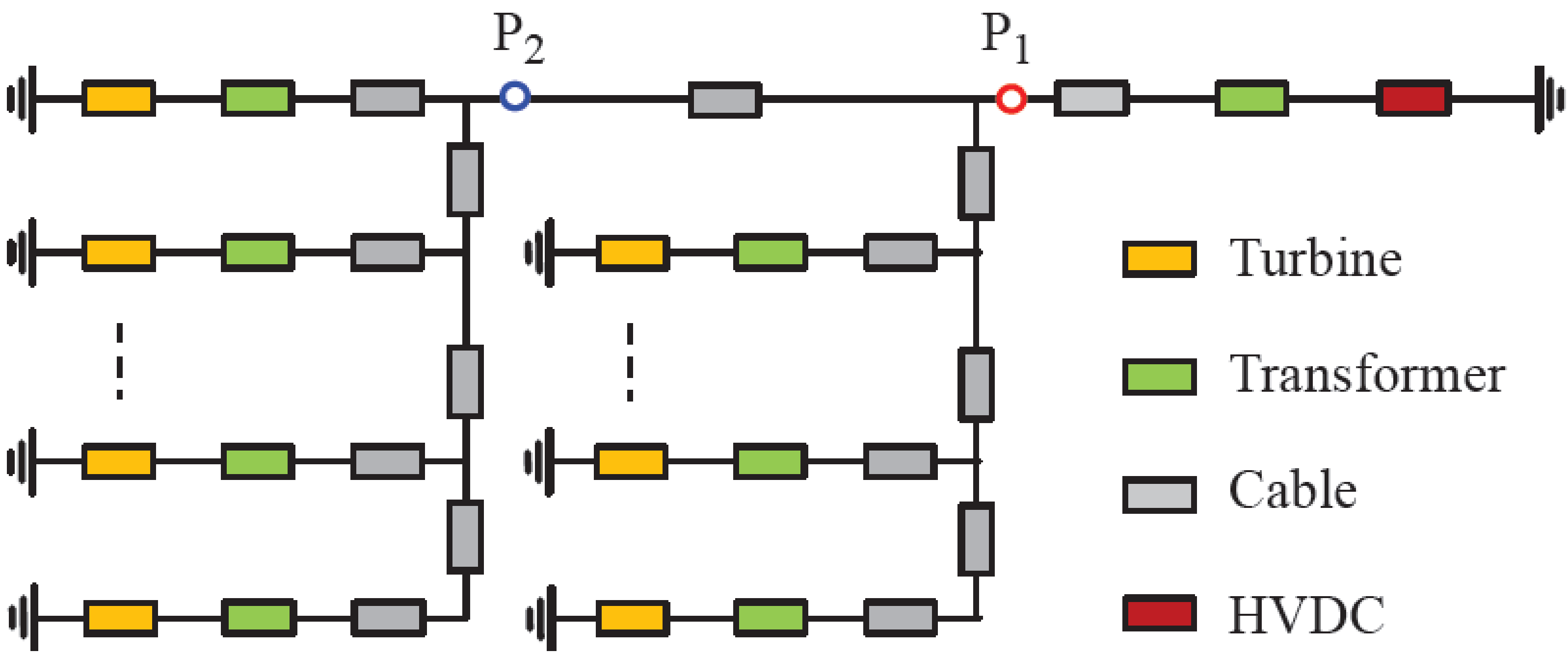
Harmonics

Impedance change at 0.22s



Fraunhofer IWES

Complex impedance characteristic in wind farms



Source: Tennet
[Impedance Modeling and Analysis Methods for Offshore Wind and HVDC Systems]

PQ-4Wind

Harmonics

Project Objectives:

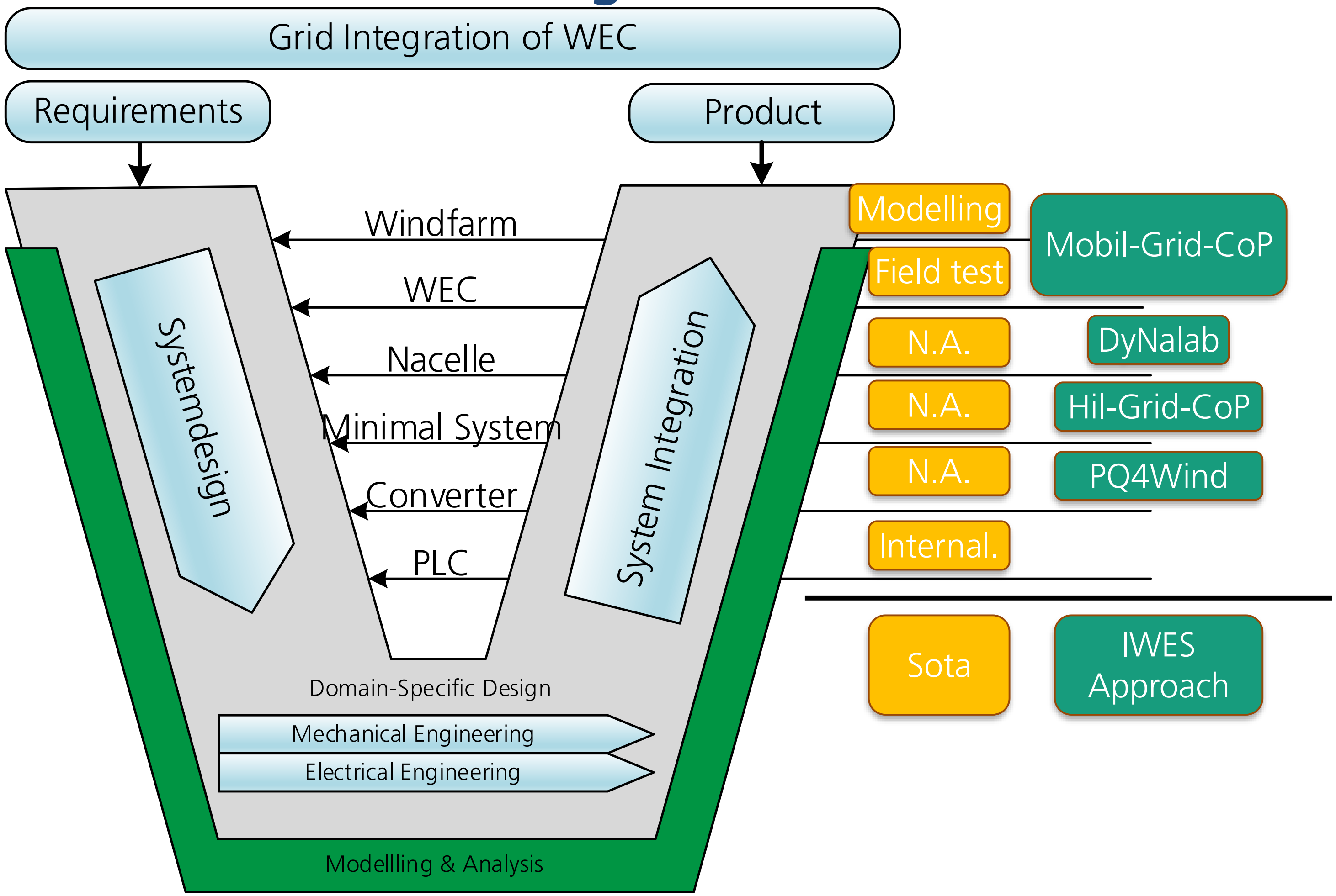
- Test bench for testing inverters of 5 MVA
- Focus on Harmonics and impedance measurement
- Decoupling the inherent coupled systems by controlling impedance und harmonics
- Emulating generator characteristic
  - Emulating different types of generators
  - Nonlinearities due to saturation
- Emulating grid characteristic
  - Precise Harmonic-Injection in amplitude and phase angle
  - Impedance emulation
  - Nonlinearities of wind farms
  - HVRT Capability

Test bench fact sheets:

- 8 MVA Generator pHIL Generator emulation
- 8 MVA Grid pHil emulation
- 25 kHz IGBT - real Switching frequency
  - 50 kHz by interleaved switching
- FPGA Control board with optimized delay times
- Simulation of PE-Models on FPGA
- Emulating complete mechanical Wind turbine behavior
- 4 MVA Grid supply

Applied for funding

Fraunhofer IWES – Overview of holistic grid compliance testing



Acknowledgements
Fraunhofer IWES is funded by the:

Federal Republic of Germany

Federal Ministry for Economic Affairs and Energy

Federal Ministry of Education and Research

European Regional Development Fund (ERDF):

Federal State of Bremen

- Senator of Civil Engineering, Environment and Transportation
- Senator of Economy, Labor and Ports
- Senator of Science, Health and Consumer Protection
- Bremerhavener Gesellschaft für Investitions-Förderung und Stadtentwicklung GmbH

Federal State of Lower Saxony

Free and Hanseatic City of Hamburg

Thank You For Your Attention

Any questions?

Torben.Jersch@iwes.fraunhofer.de