PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP16

MMC Test Bench Demonstrator – Introduction

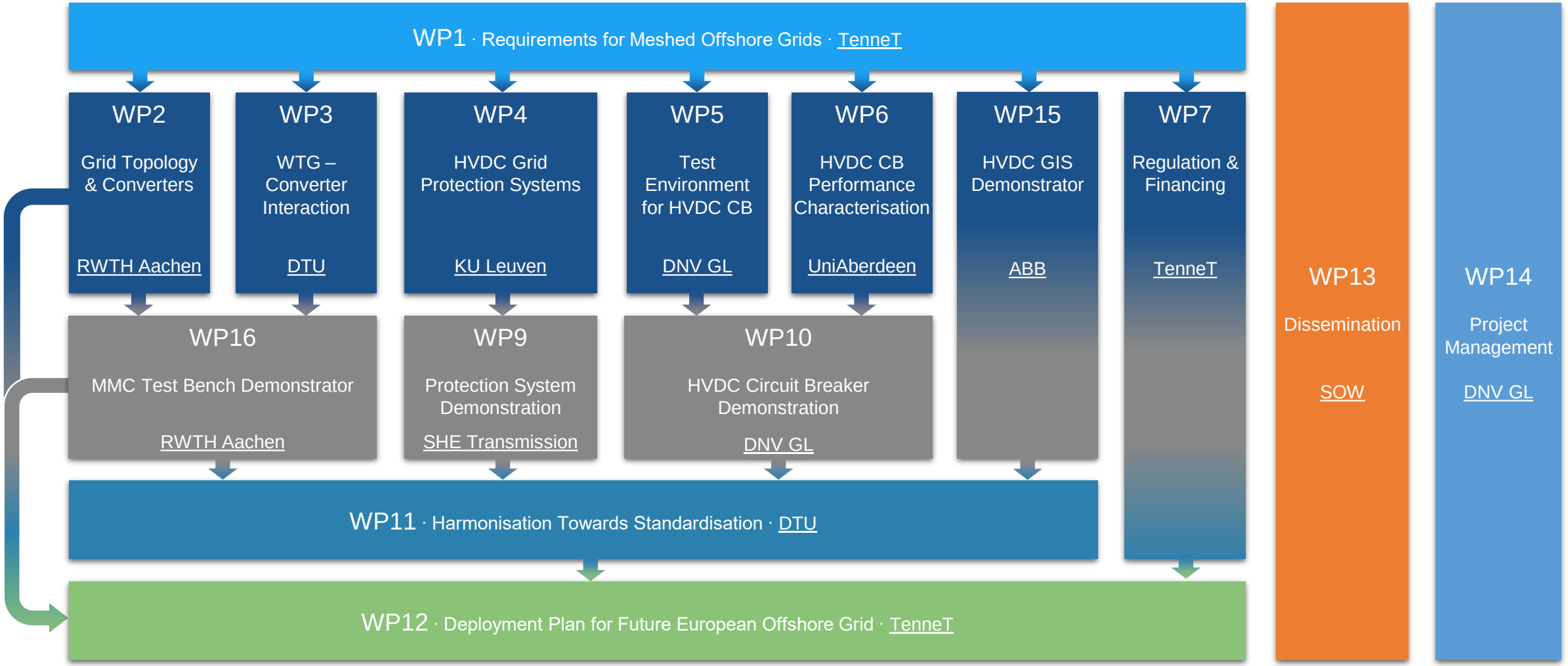
Demonstration of Converter & Controller Model Validation

21.11.2019 – Arnhem

Philipp Ruffing – RWTH Aachen

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Work Packages



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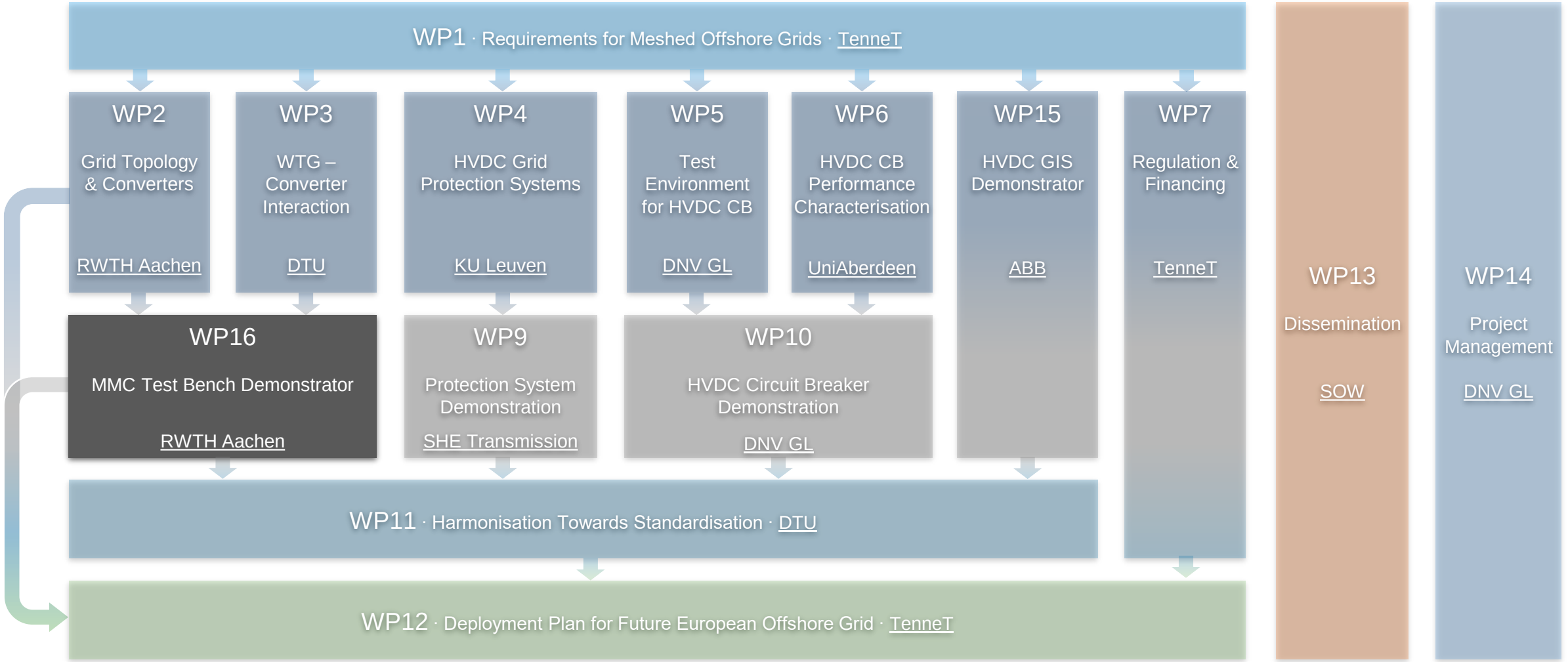

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Overview and Objectives of WP16

Motivation:

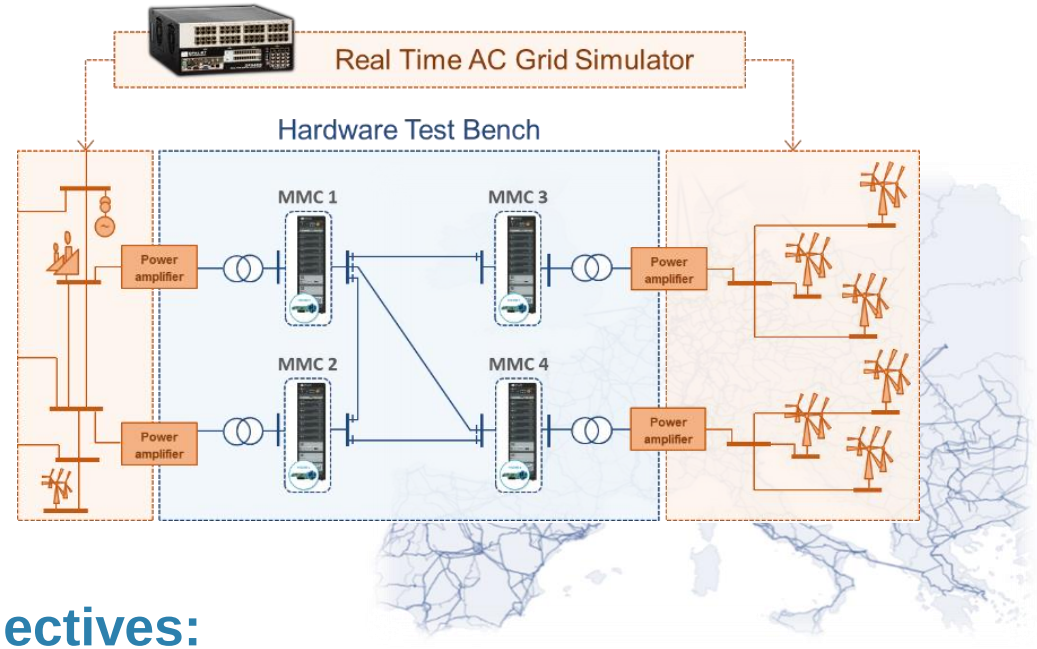
- Meshed offshore DC systems lead to novel challenges for TSOs, manufacturers and grid planners
- Experience missing concerning
  - Multi-terminal operation
  - Interaction with the large AC transmission systems
  - Interaction with offshore wind farms

Work Package 16: Investigation regarding the operation and control of meshed HVDC system

✓ Power Hardware in the Loop (PHiL)

✓ Control Hardware in the Loop (CHiL)

✓ Real-Time Simulation (RTS)



Objectives:

- Derive appropriate principles and policies to ensure interoperability between different components and technologies in meshed HVDC offshore grids
- Analysis of harmonic resonance phenomena in offshore grids (analysis of the freq. dependent impedance of MMC and WT-VSC)
- Demonstrate the operation of DRU

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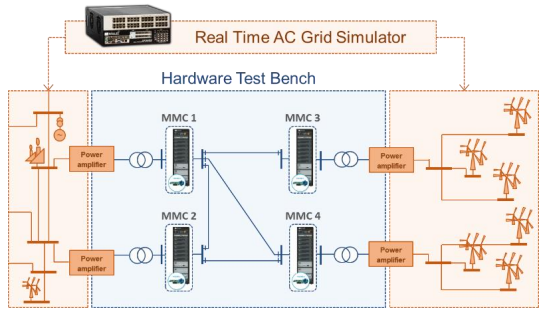
WP16 – Internal Structure

MTDC Test Bench - PHiL

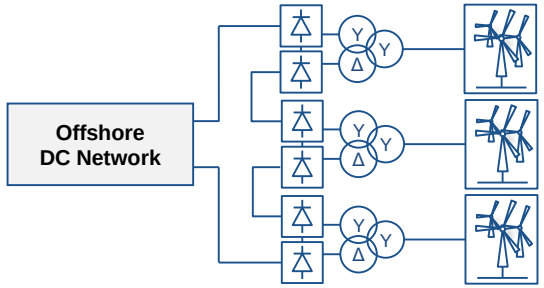


Test Cases

Demonstration of the controllability and interoperability offshore MTDC networks

- Grid & converter configurations
- Interaction MTDC network and OWP
- MTDC and OWP fault handling
- AC grid support with meshed offshore grids

DRU - WPP

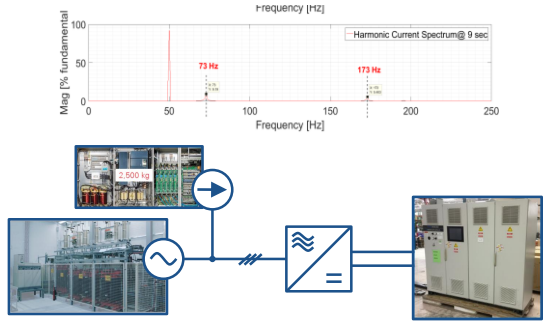


Test Cases

Demonstration of the operation of DRU-enabled wind turbine control systems

- in multi-terminal HVDC systems
- with actual wind turbine controls
- with commercial protection hardware
- black and brown start operation for wind farms in islanded control

Harmonic Resonance Studies



Test Cases

- Development and validation of impedance models of wind turbine and HVDC converters
- Analysis of harmonic stability and potential interactions of active components and the AC grid

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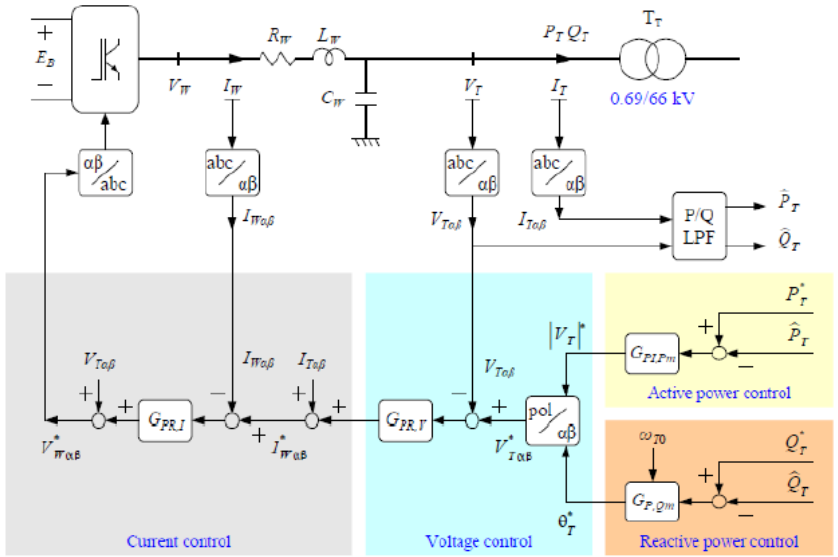
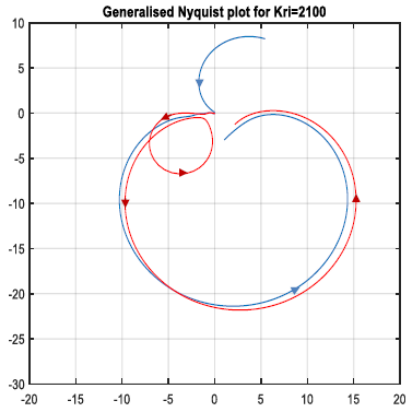
Deliverable 16.5

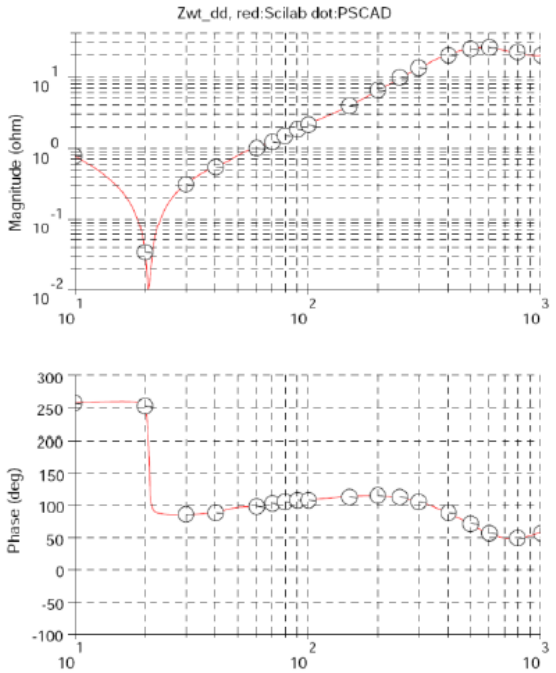
Documentation of analytical approach

Implementation of an Analytical Method for Analysis of Harmonic Resonance Phenomena

- Wind Turbine Converters
- MMC-HVDC Converters
- DRU-connected Wind Turbines







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MMC Test Bench – Status Update

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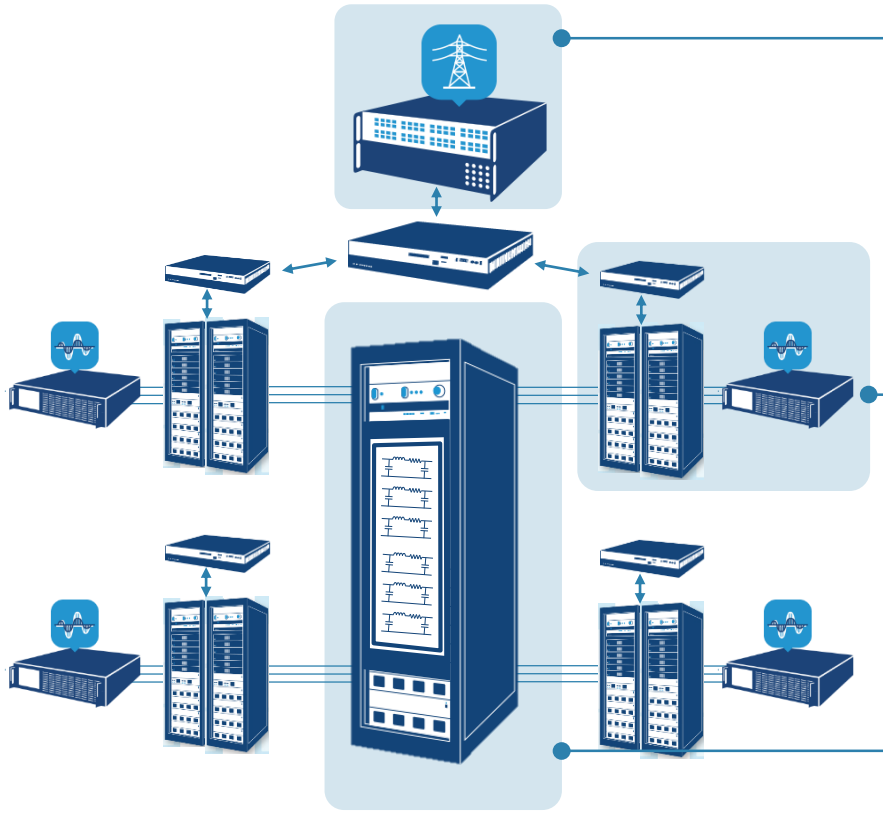
MMC Test Bench - Overview

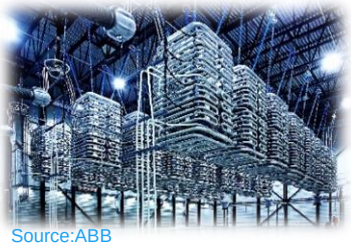


AC system and component modelling

Source: www.windpoweroffshore.com

- OP5707 real-time simulator for AC grids (up to 3000 nodes) and wind farms
- OP4510 real-time simulator as DC grid controller
- 4x Puissance Plus power amplifiers (21 kVA, 4-Q operation, -3 dB at 50 kHz)

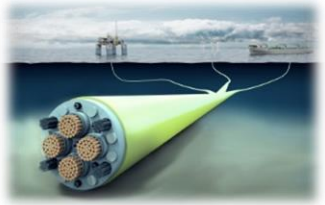
MMC converter stations



Source:ABB

- Hardware representation of Modular Multilevel Converters with half-/full-bridge submodules (10 levels per converter arm) at laboratory scale: $V_{dc,r}$ = 400 V, $I_{dc,r}$ = 15 A
- Possibility to investigate DC grids with up to 8 converter stations in sym. monopole or up to 4 converter stations in bipolar configuration

DC-line models



Source: www.offshore-technology.com

- 32x Pi-Line models
- Up to 800 km in bipolar grid configuration
- Up to 1,600 km in monopolar grid configuration

➢ Different DC topologies can be represented with hardware components at laboratory scale

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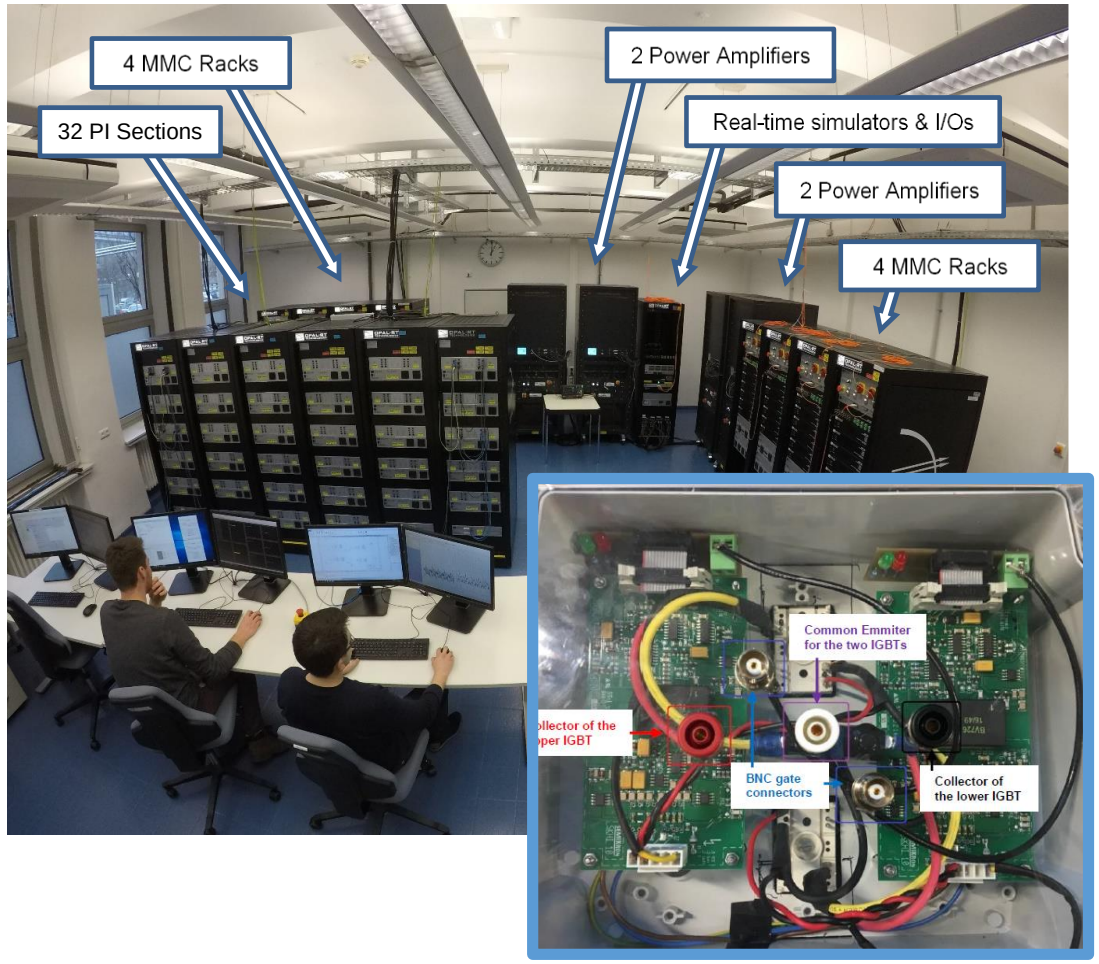
MMC Test Bench – Status Update

Achievements:

- ✓ Comparison between MMC Test Bench and Simulations
- ✓ Controller optimisation for similar dynamics of the demonstrator and full-scale simulations
- ✓ PHiL with (strong) transmission grids and wind power plant
- ✓ Impedance Measurements in grid following operation
- ✓ KTH Breaker tested

Next Steps:

- Integration of KTH small-scall HVDC Breaker
- Investigation of PHiL methods for OWP in grid forming control
- Impedance measurement of the MMCs in grid forming control
- Protection of MTDC grids with full-bridge MMCs
- Upgrading PI-sections



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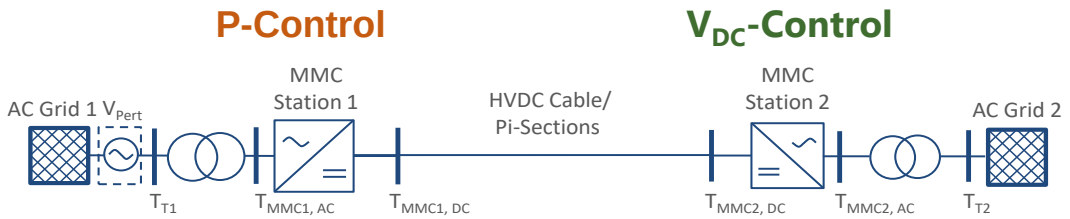
Impedance Measurement

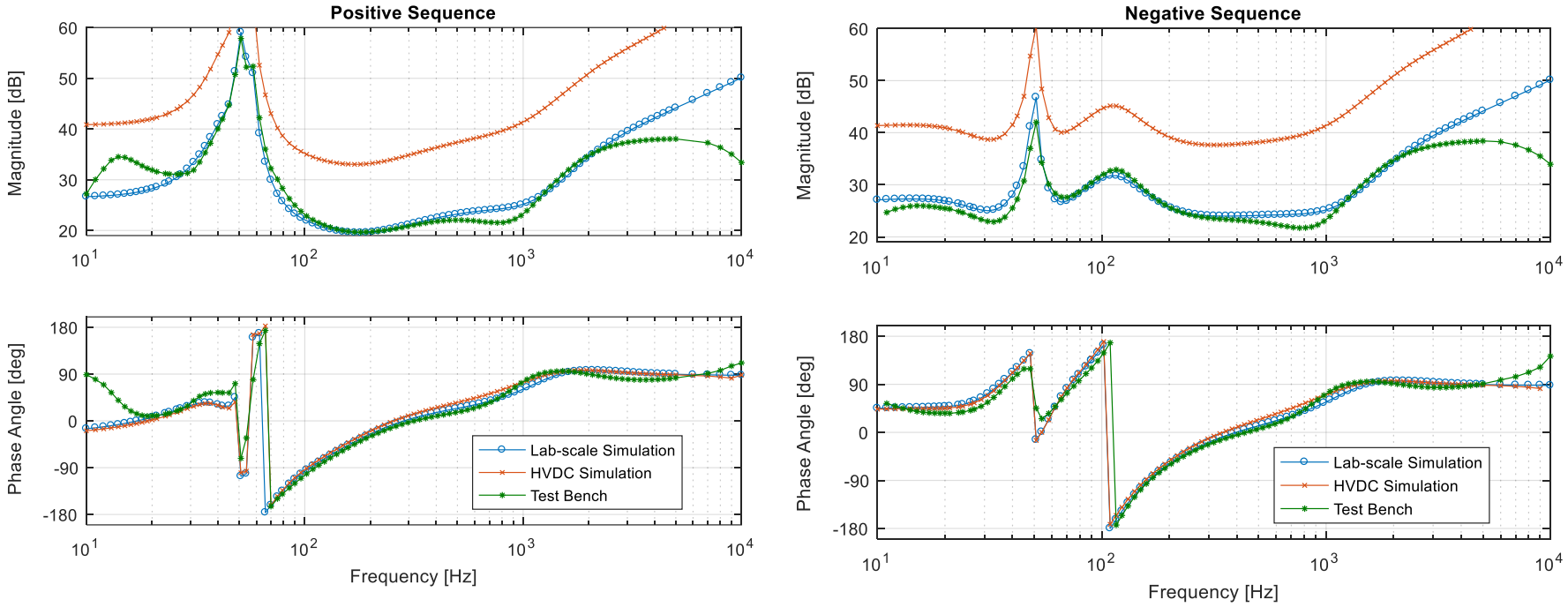
MMC Test Bench



- Logarithmic intervals ranging from 10 Hz to 1 kHz
- Comparison between simulation and the MMC Test Bench
- Scaling between full-scale and small-scale is not yet integrated in the figure

Set-point

- P-control mode
- P_{ac}^{*} = 0.5 p.u.
- Q_{ac}^{*} = 0.0 p.u.



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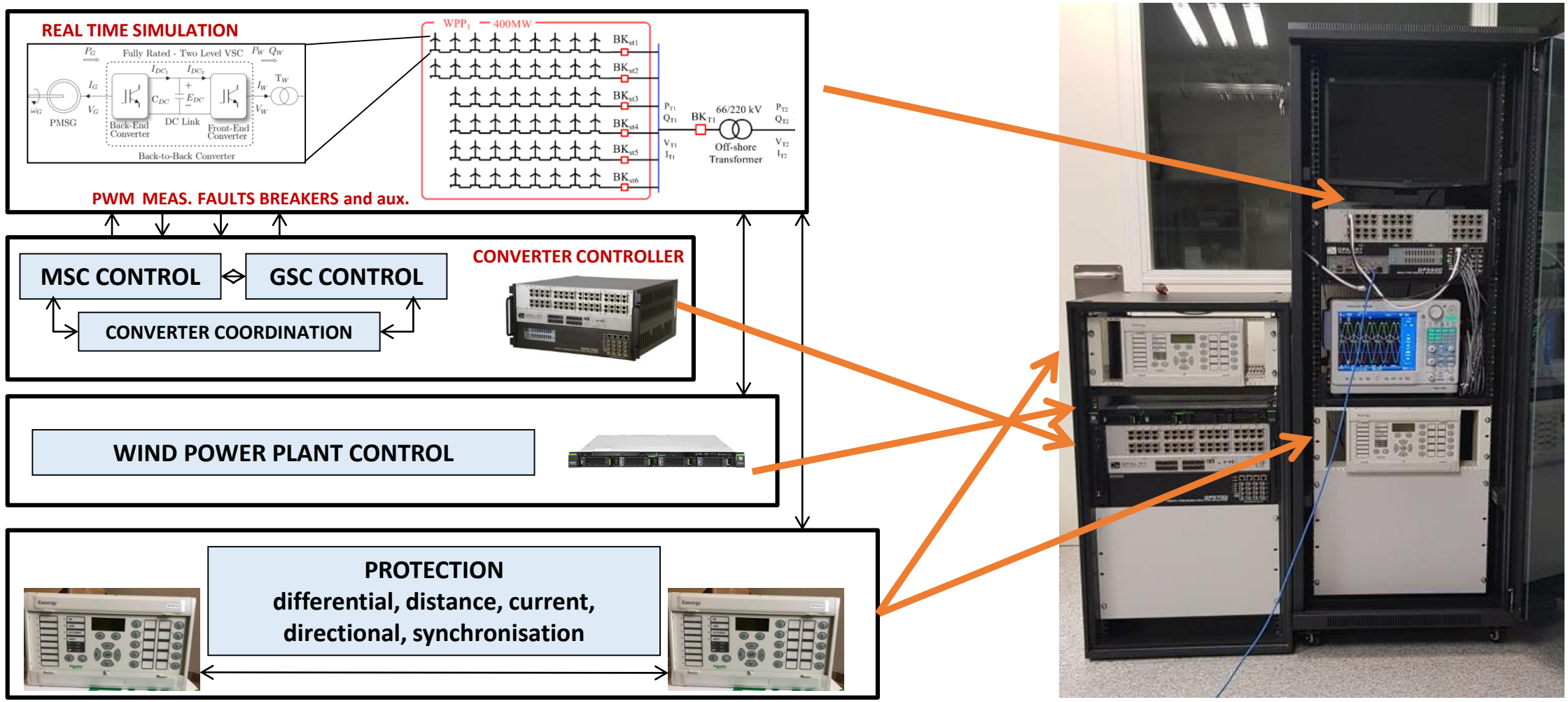
DRU/OWP - CHiL



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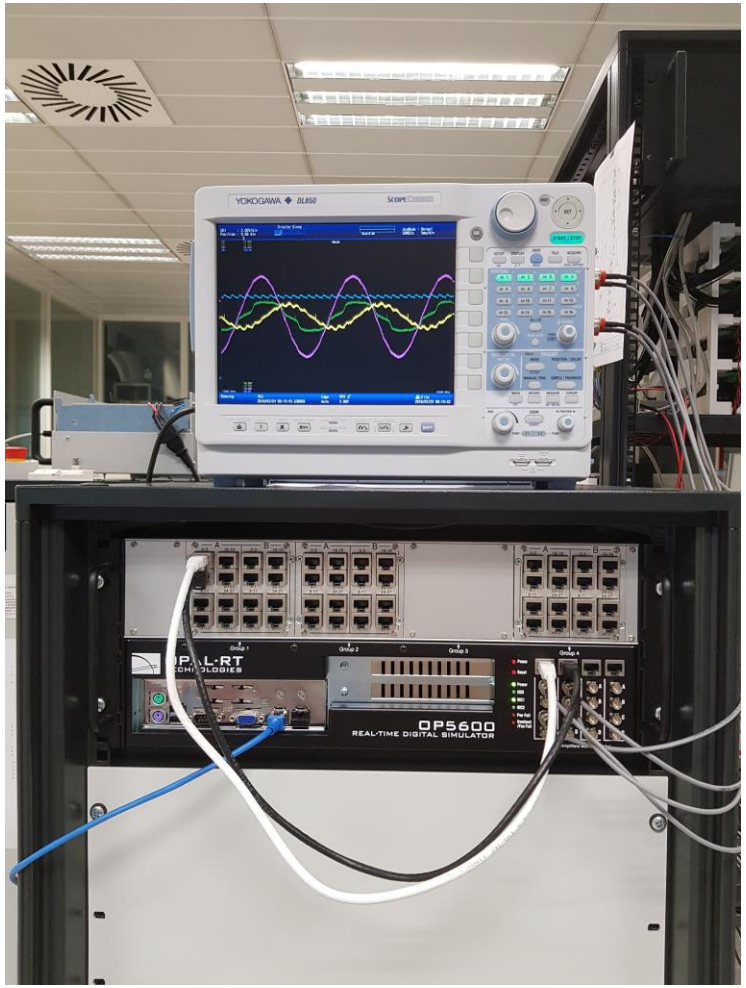
DRU/OWP - CHiL

Achievements:

- ✓ Implementation of DRU models and wind turbine controls from WP3 on real-time simulators (RTS)
- ✓ commercial protection relay integrated into CHiL system

Next Steps

- Programming of the commercial protection relay
- Investigation of the Black Start Capability of HVAC and DRU-Connected OWP



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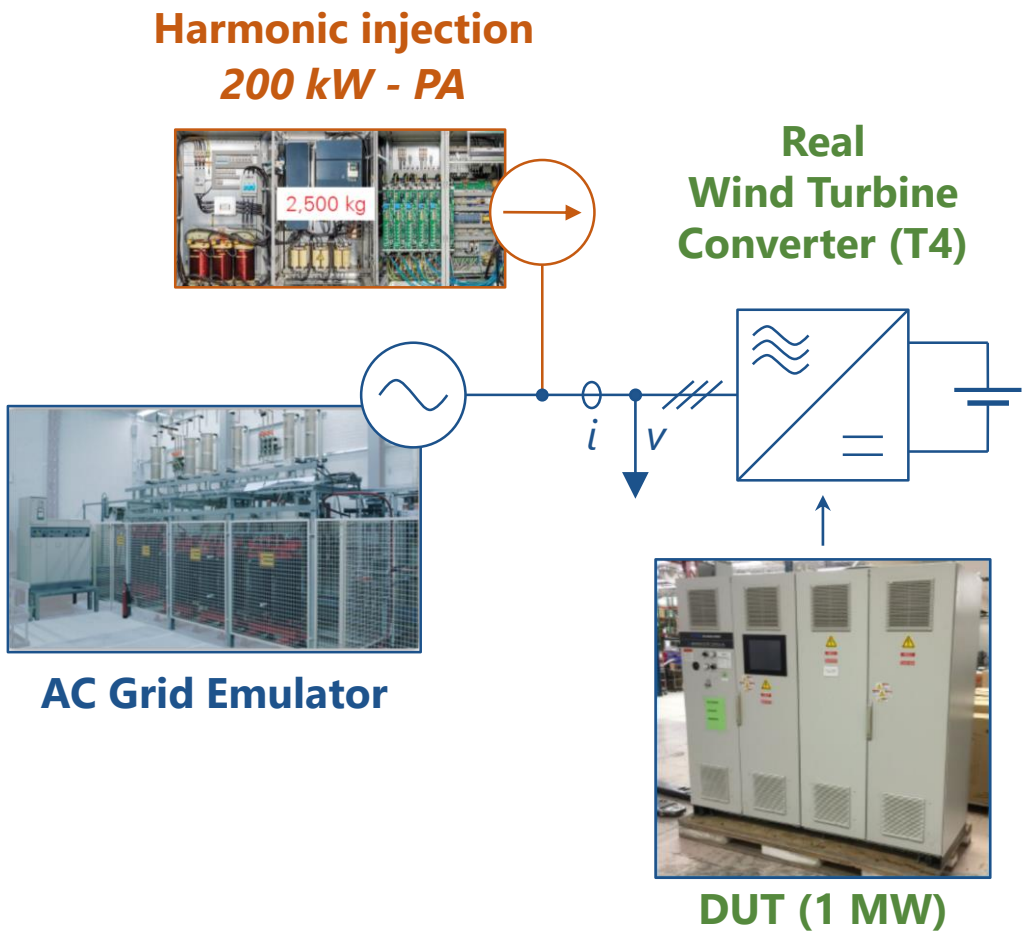
Harmonic Resonance Studies

Achievements:

- ✓ CHIL Wind Turbine Setup
- ✓ WT - CHIL Input Admittance Measurement and Validation Methodology Development
- ✓ Commissioning of WT CHIL test system
- ✓ “Online” Impedance Measurement Method
- ✓ MMC - CHIL Input Admittance Measurement and Validation Methodology Development of
- ✓ WT - PHIL Input Admittance Measurement and Validation Methodology Development of

Flexible Power Grid Lab @ DNV GL



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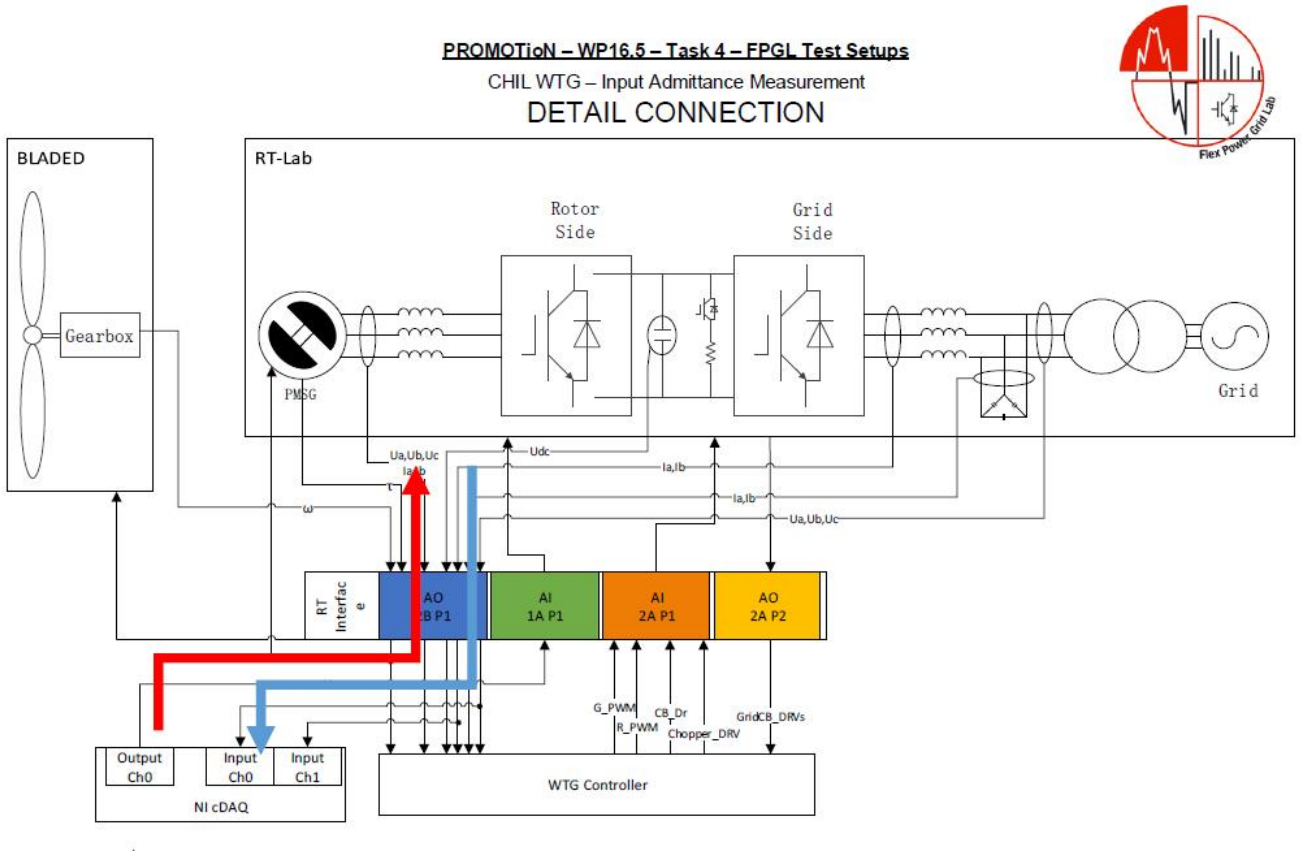
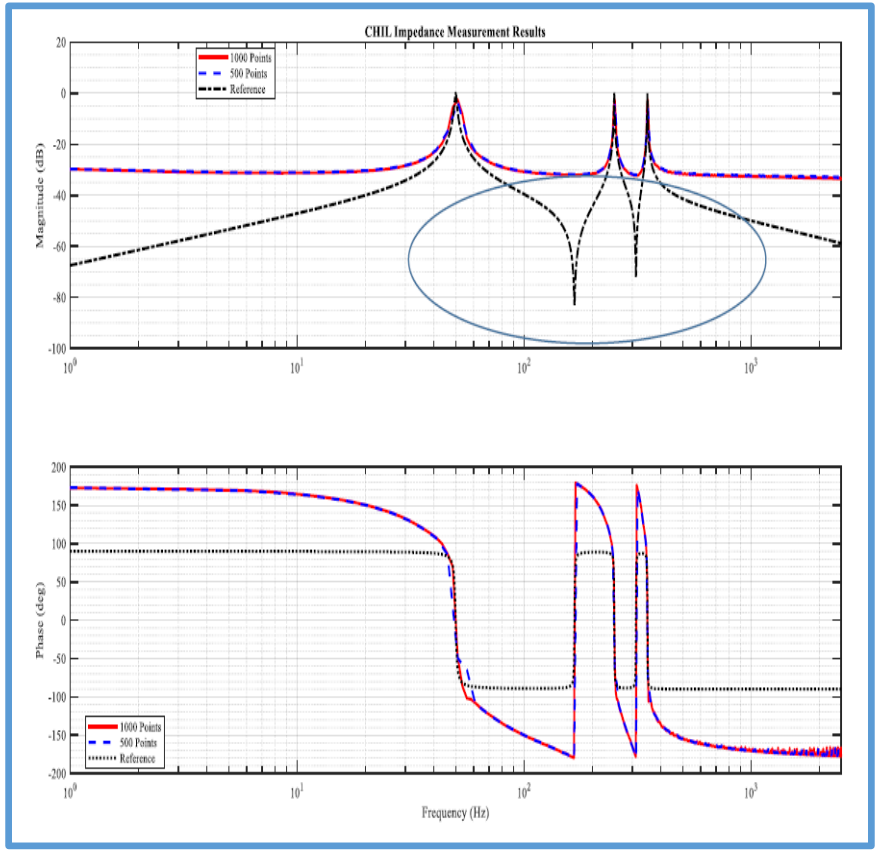
Harmonic Resonance Studies

CHiL Wind Turbine Setup and First Studies





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Any Questions?

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APPENDIX

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