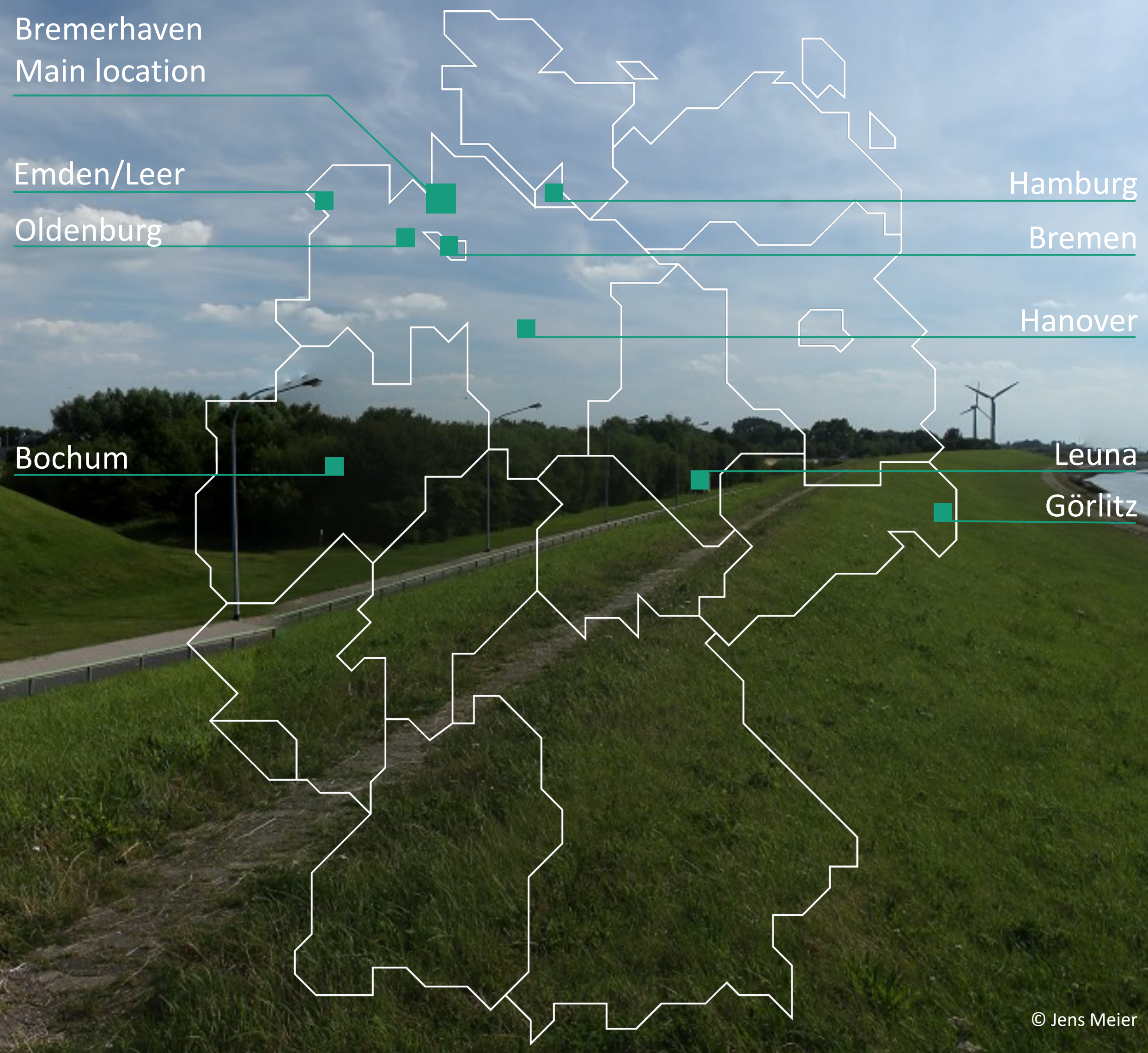
11/09/2022 – 6th International Workshop on Grid Simulator Testing

Grid Integration Research and Projects at Fraunhofer IWES – Results of Hil-GridCoP Project

Gesa Quistorf

Agenda

- Overview about Fraunhofer IWES
- Grid integration testing at Fraunhofer IWES
- HiL-GridCoP project
- Mobil-Grid-CoP project



- **300** staff
- 90 publicly funded research projects
- € 38 m **operating budget / year 2021**
- € 96 m investment in test infrastructure

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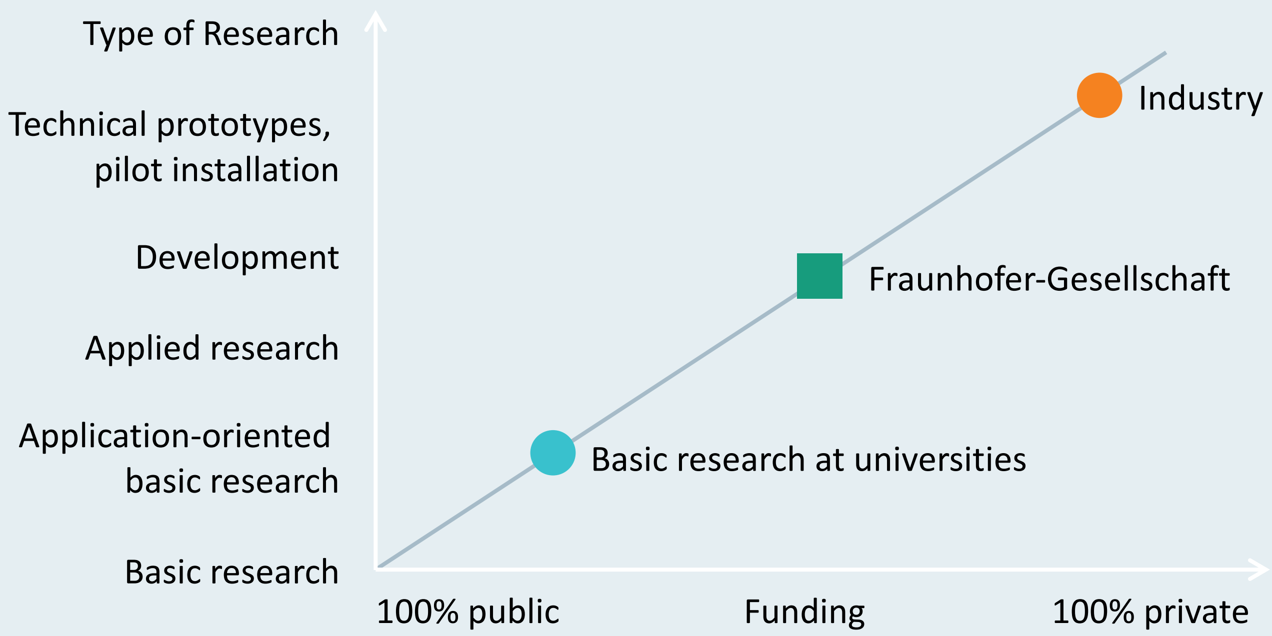
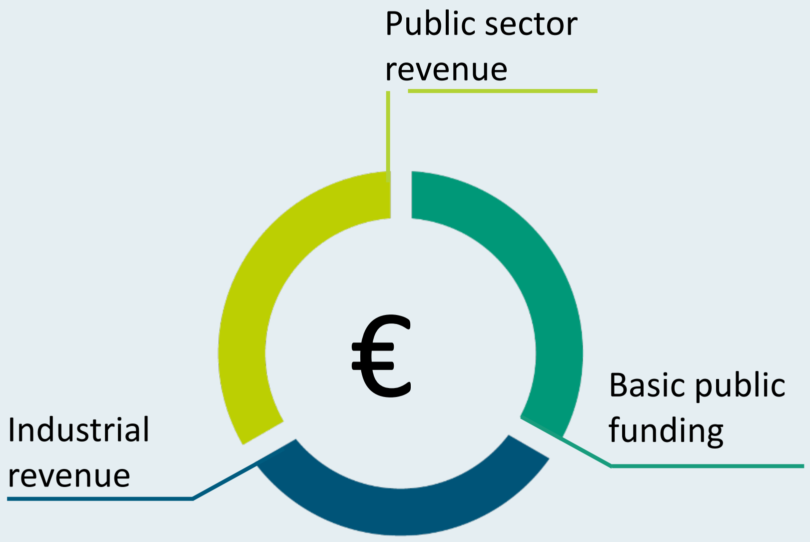
Research with added value for the industry

Fraunhofer-Gesellschaft´s business model





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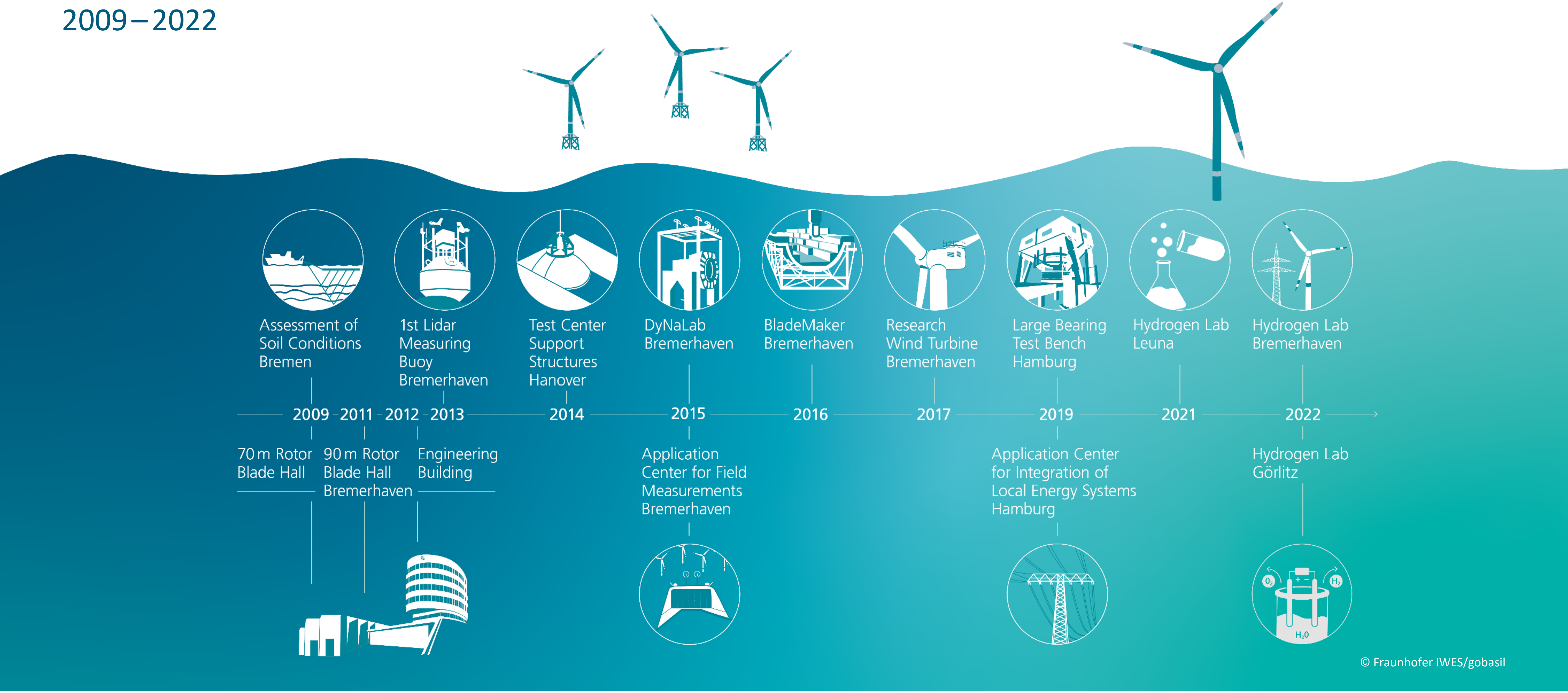
Our testing infrastructure

2009 – 2022



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Motivation at Fraunhofer IWES

Grid compliance testing at test benches

General purpose of grid integration testing

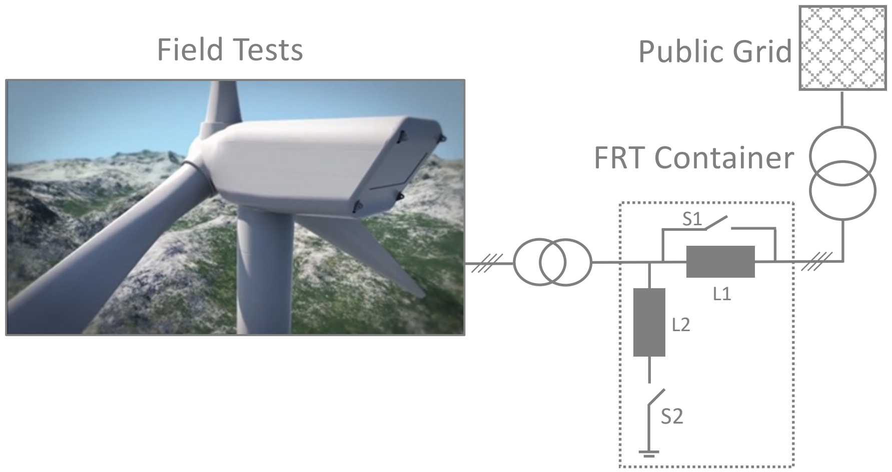
- Performance evaluation of turbine
- Generation of measurement data for model validation

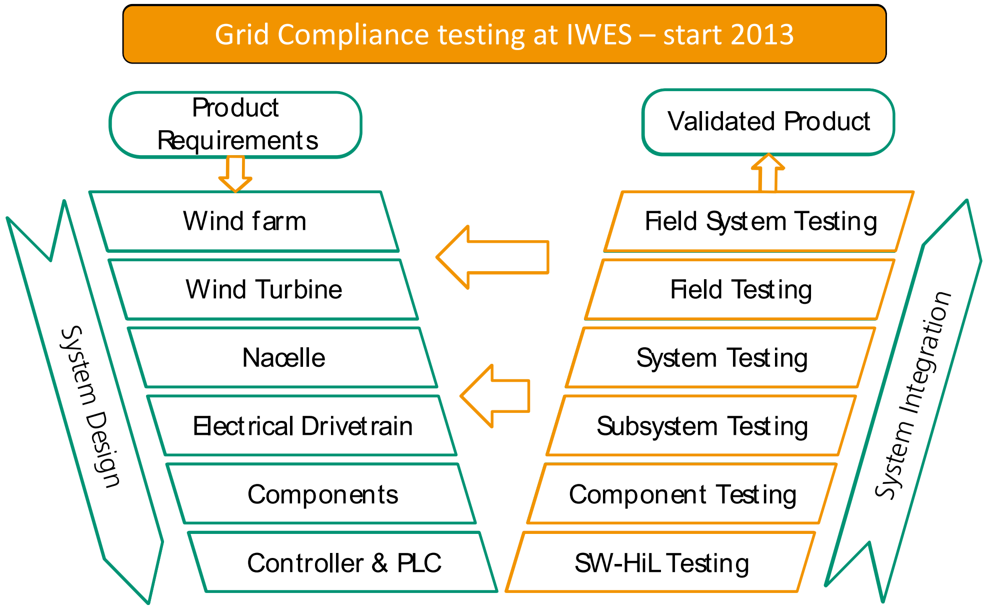
Current status: Wind turbine testing on prototype in field

- Time-intensive
- Cost-intensive
- No reproducible tests
- No orientation to the development process according to V-model

Development process according to V-model

- Performance test in field
- Functional & engineering test of component
- SIL & CHIL- Testing during the development process





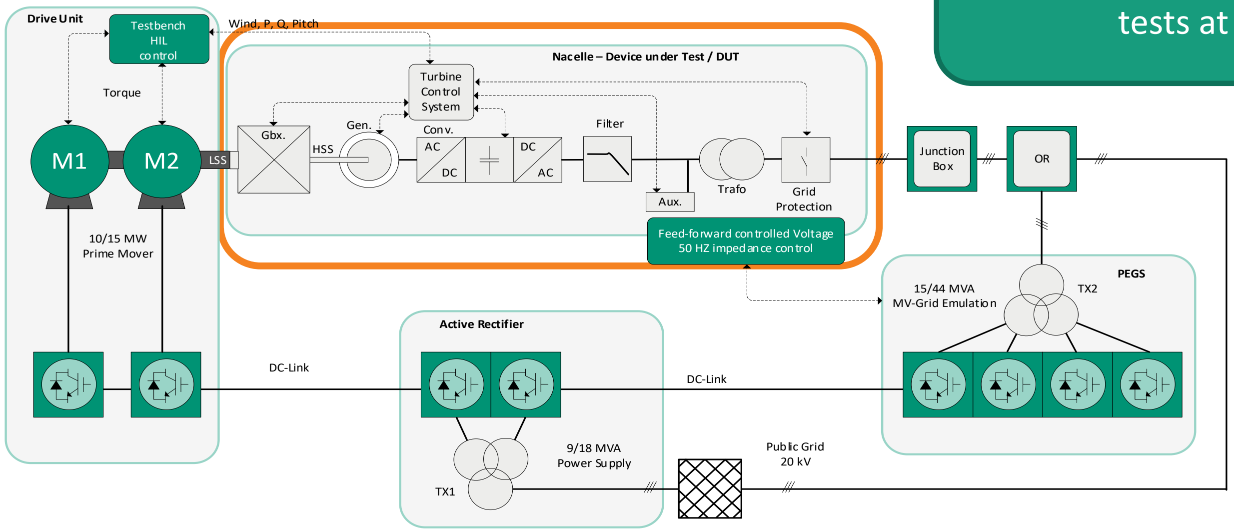
Dynamic Nacelle Testing Laboratory

Grid compliance testing at test benches

- Motor continuous power: 10 MW
- Motor overload capacity: 15 MW
- Grid simulator continuous power: 15 MVA
- Grid simulator installed inverter power: 44 MVA

- Virtual emulation of wind turbine
- Testing nacelles with original field controller
- Testing of 8 different customers since 2015 (combination test campaigns, electrical & mechanical)

Acceleration of logistics & set-up as well as cost reduction are needed for electrical tests at test benches!



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Hil-GridCoP Project

Hardware-**i**n-the-**L**oop **Grid Co**mpliance **P**rüfstand (Test Bench)

Motivation:

- Reducing testing efforts by testing generator-inverter systems
- Existing test benches require the installation of all components of a wind turbine
- Specially designed for high-speed generators, such as DFIGs

Project key points:

- Supported by the German Federal Ministry for Economic Affairs and Climate Action
- Project partner: Vestas, Nordex
- Project duration: January 2017 – March 2022
- Project phases:
  - Complete design, built and programming of the test bench by IWES
  - Field measurement campaigns by Nordex and Vestas
  - Test bench measurement campaigns

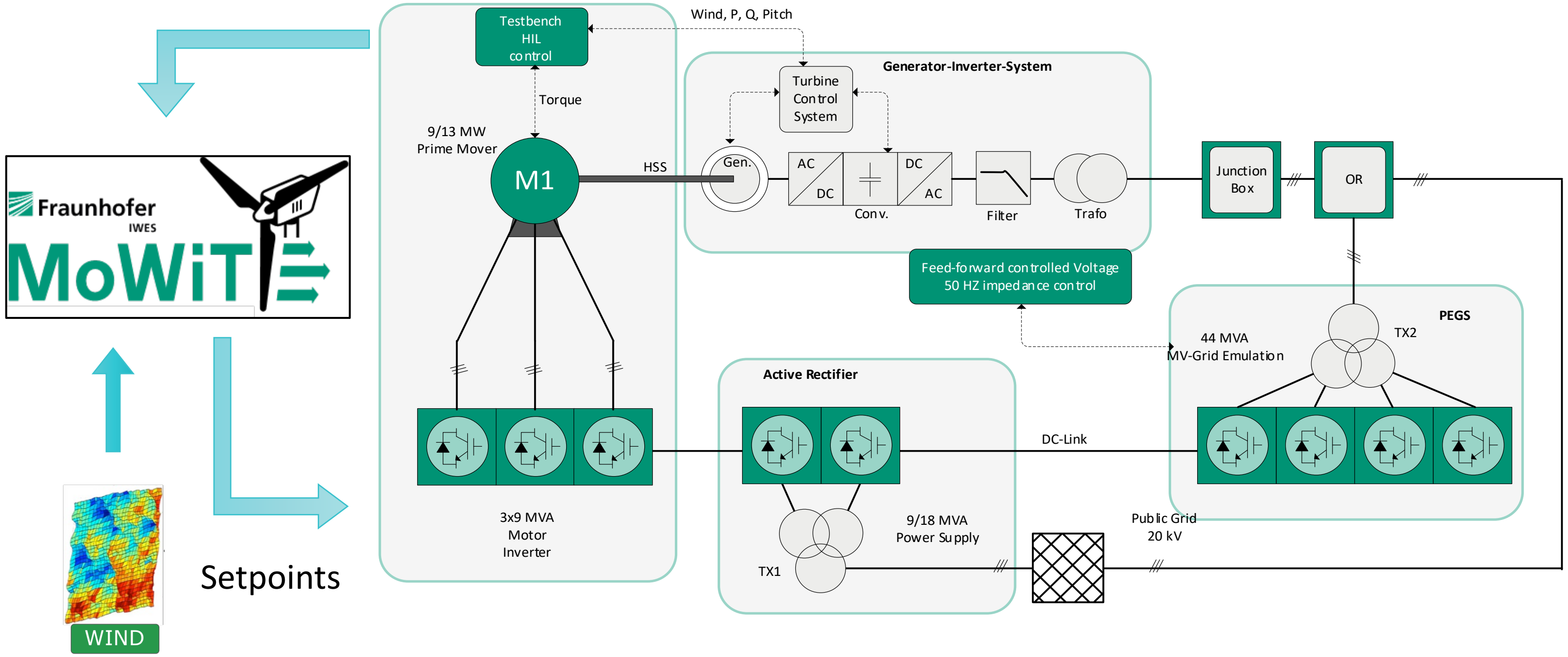
Target: Reproduction of field tests!

The HiL-GridCoP test bench

Physical and virtual test bench topology

Electrical properties:

- Asynchronous 9 MW motor; 1000 – 2200 rpm
- 20 kV Public grid connection or
- Connection to 44 MVA grid simulator
  - ACS 6000 Multi-level inverter
  - Interconnection of inverter units via three single-phase step-up transformers
  - Three individually controllable output voltages
  - 10 kV, 20 kV, 36 kV nominal voltage levels
  - < 3% THD at 50 Hz
  - Frequency changes with a ramp up to 20 Hz/s
  - Phase jumps

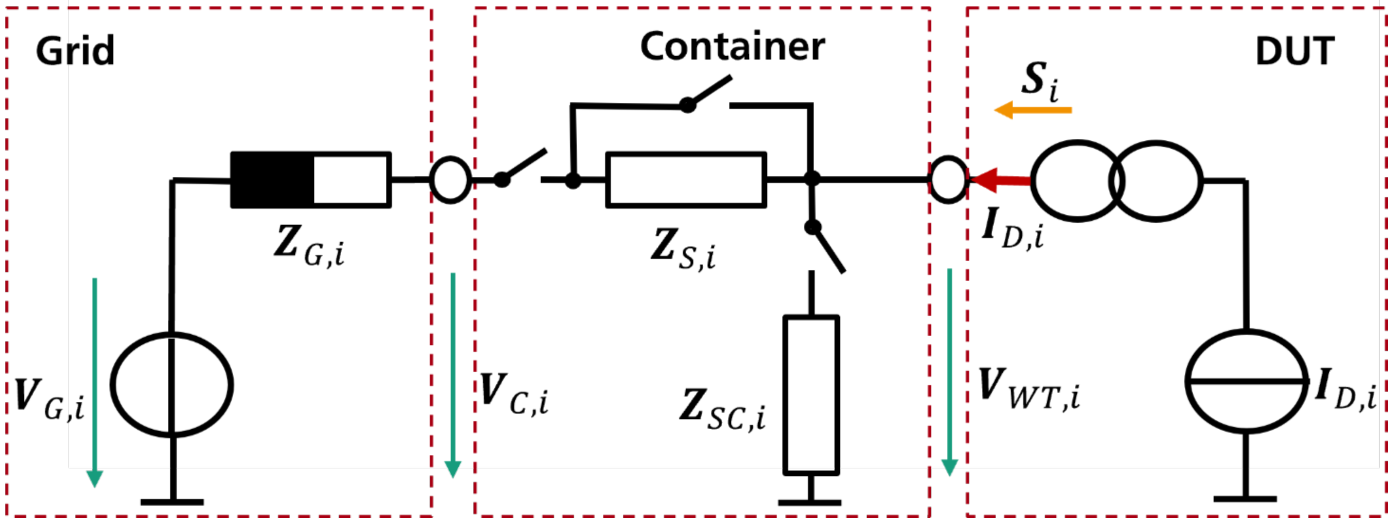


Reproduction of field tests

Simulation of a FRT container

Challenges:

- FRT-Container
  - Manufacturer tolerances, heating of components, and simplified component modeling
  - Validation of the FRT container parameters
- Step-up Transformer
  - Influencing the DUT transformer by the flux control of the step-up transformer
  - Accurate steady-state compensation of transformer impedance
- Characteristic of DFIG-Turbine
  - Due to the direct coupling of the stator to the grid, the mechanical eigenfrequencies of the turbine must be seen at the PCC



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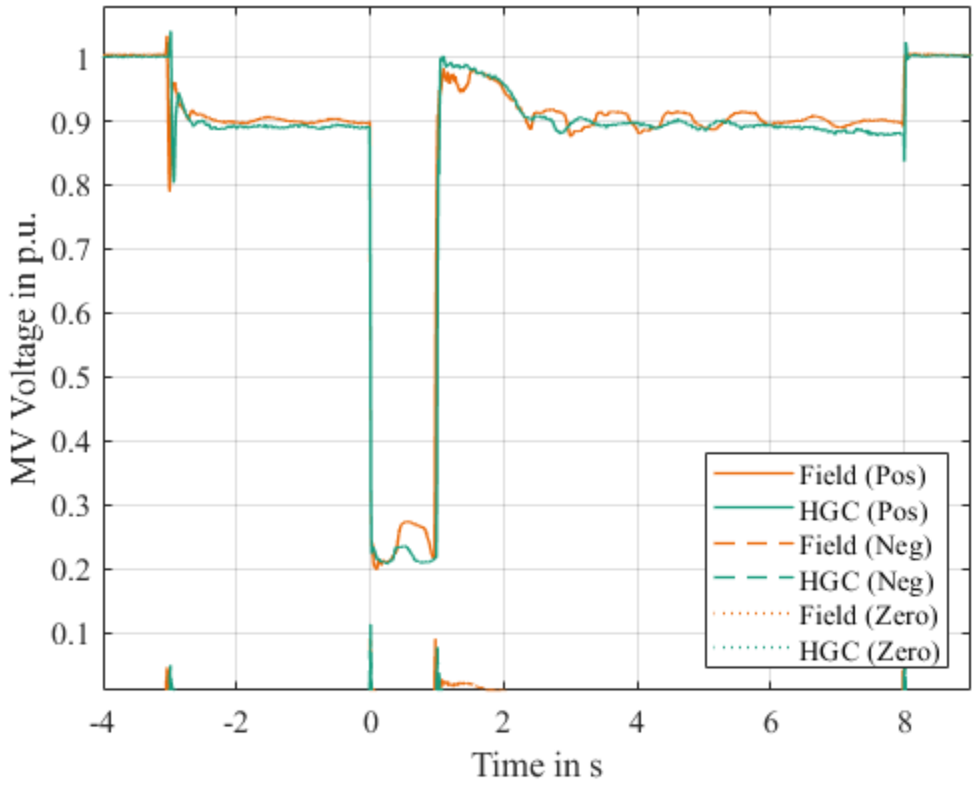
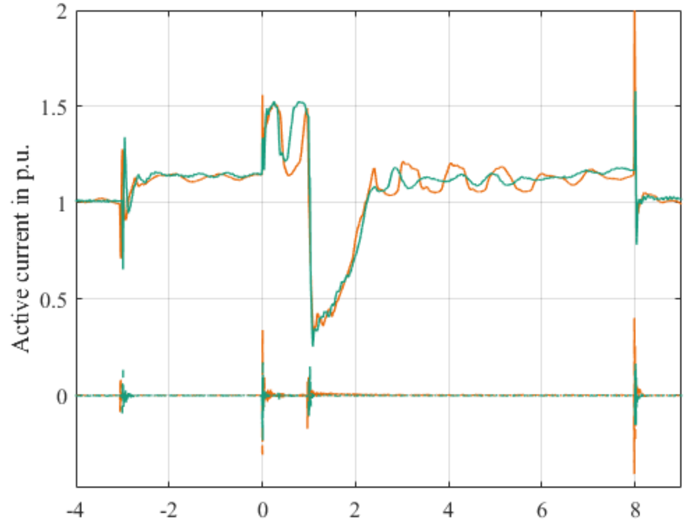
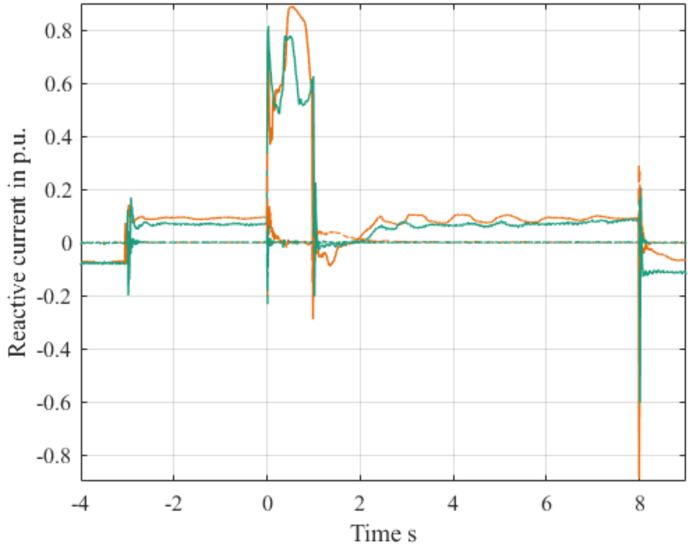
Measurement results of a DFIG

Symmetrical 20% UVRT in the field and on the test bench



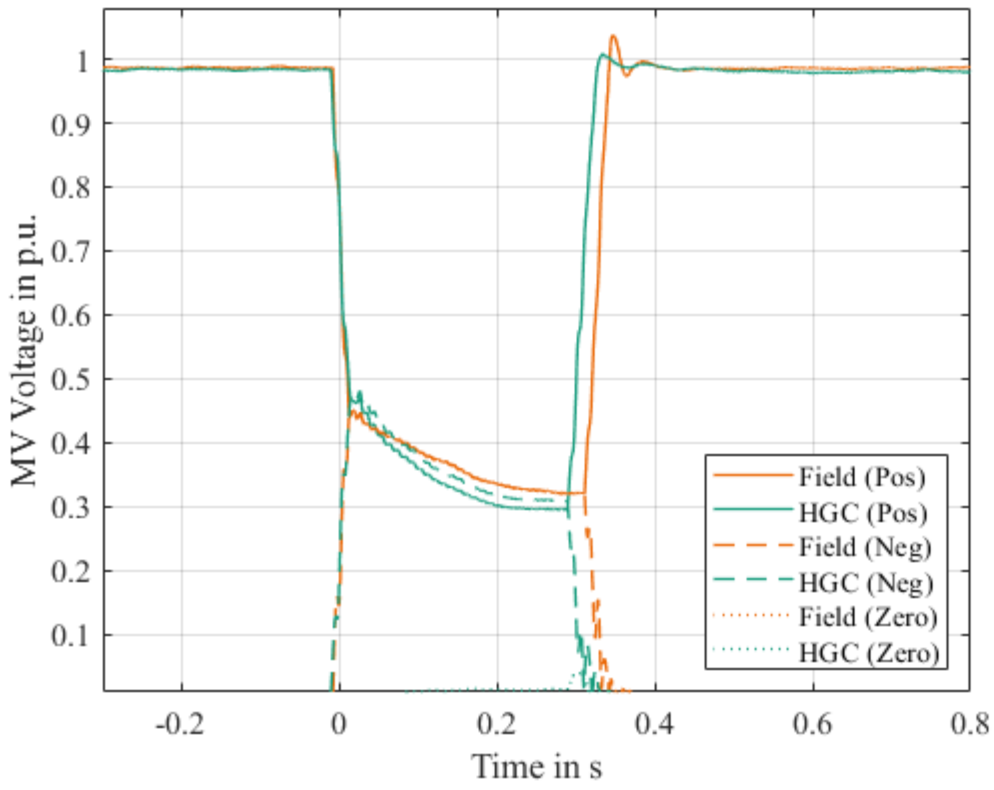


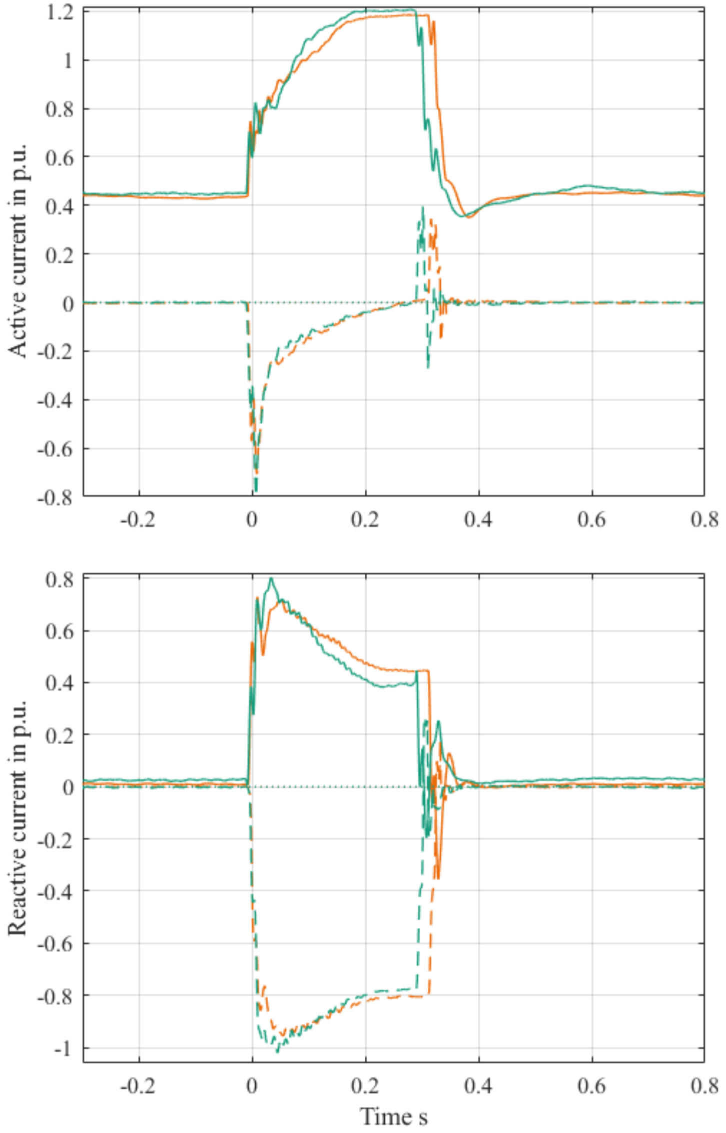


Less than 5% voltage deviations

Measurement results of a DFIG

Asymmetrical 0% UVRT in the field and on the test bench





Good compliance of field tests and HGC measurements

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Measurement results of a DFIG

Validation of control and mHiL

Test bench validation process:

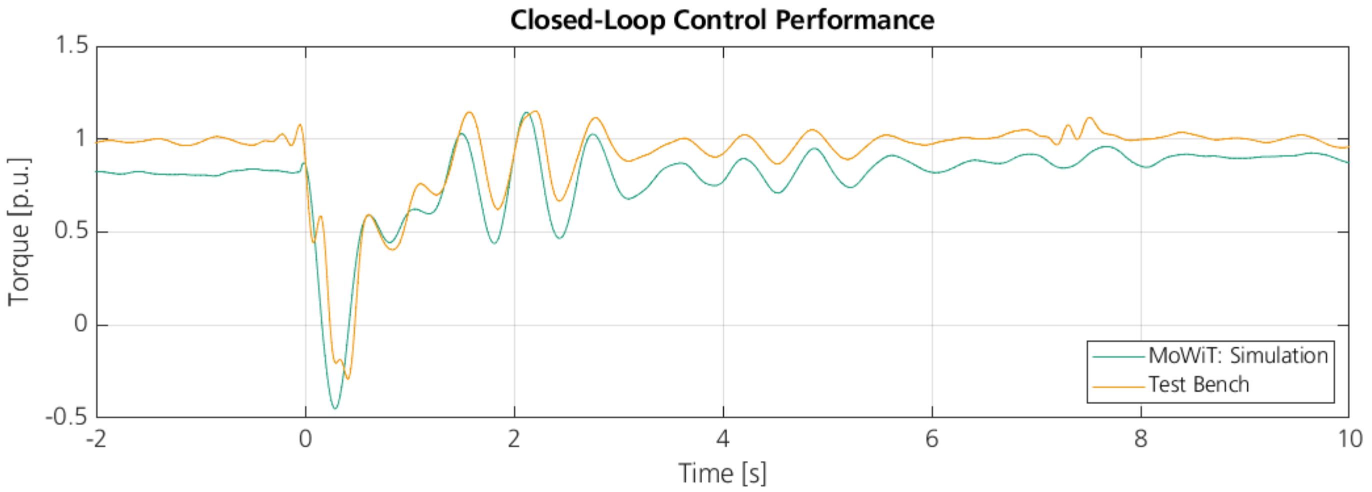
- Static validation
- Dynamic validation
- FRT validation

Example - Test conditions for FRT validation:

- Symmetrical 0% UVRT
- Full-load condition

Result:

- The first coupled eigenfrequency is around 1 Hz and the second coupled eigenfrequency is in the range of 2 Hz



Motivation Mobil-GridCoP

Mobile Test Bench for **Grid Co**mpliance **P**rüfungen (Testing)

Future challenges

- Electrical interaction
- Weak grid
- Harmonics
- Grid forming
- Black start & Islanding
- Wind Turbines 15 MW+
- Voltage level: 66 kV (or higher)

- New Grid Codes requirements
- New testing methods for validation
- Complex grid scenarios for pHiL
- Detailed validated models
- Turbine design: Mechanical & electrical interaction

Example: TAR HVDC, (VDE-AR-N 4131, German Grid Code)

Technical requirements for grid connection of high voltage direct current systems and direct current connected power park modules (PPMs)

- Published March 2019
- Requirements models:
  - Valid EMT-models of the PPMs up to 2500 Hz
  - Harmonic models of the PPMs up to 9000 Hz
  - Valid models for the grid connection point
- Requirements for black start and islanding operation

FNN-Guideline: Grid forming behaviour of HVDC systems and DC-connected PPMs

- Published June 2020
- Describes a method for the verification of grid forming behaviour
- Includes complex grid scenarios, which can be set-up in pHiL

Mobil-Grid-CoP

Technical facts and current project status

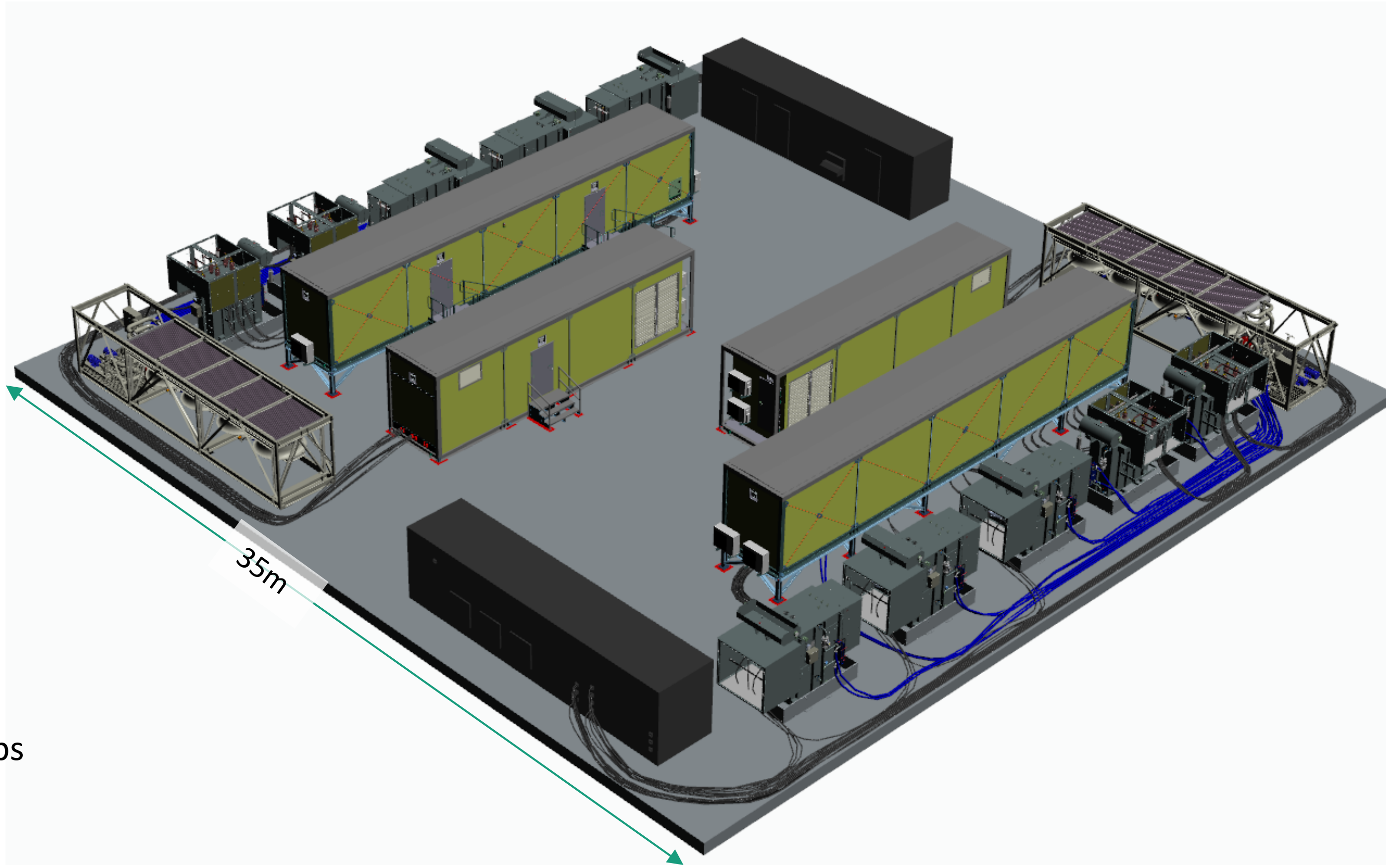
Commissioning summer 2022

Project key points:

- Supported by the German Federal Ministry for Economic Affairs and Climate Action
- Project duration: January 2020 – March 2024 (March 2023)
- Project tasks:
  - Complete design, built & set-up of the Mobil-Grid
  - pHiL set-up for future grid scenarios

Technical key points:

- Two strings – complete moveable
- 18 components (8 containers, 10 transformers)
- continuous power: 20 MW / 28 MVA
- 80 MVA installed inverter power
- 20 kV, 33 kV, 66 kV nominal voltage levels
- UVRT & OVRT capability (0% Un up to 150% Un); RoCoF; phase jumps
- Harmonic injection up to 2500 Hz
- Capabilities for grid forming testing



Thanks a lot for your attention!

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