CertBench

Experimental Experience with full-scale Wind Turbine Certification

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Supported by:

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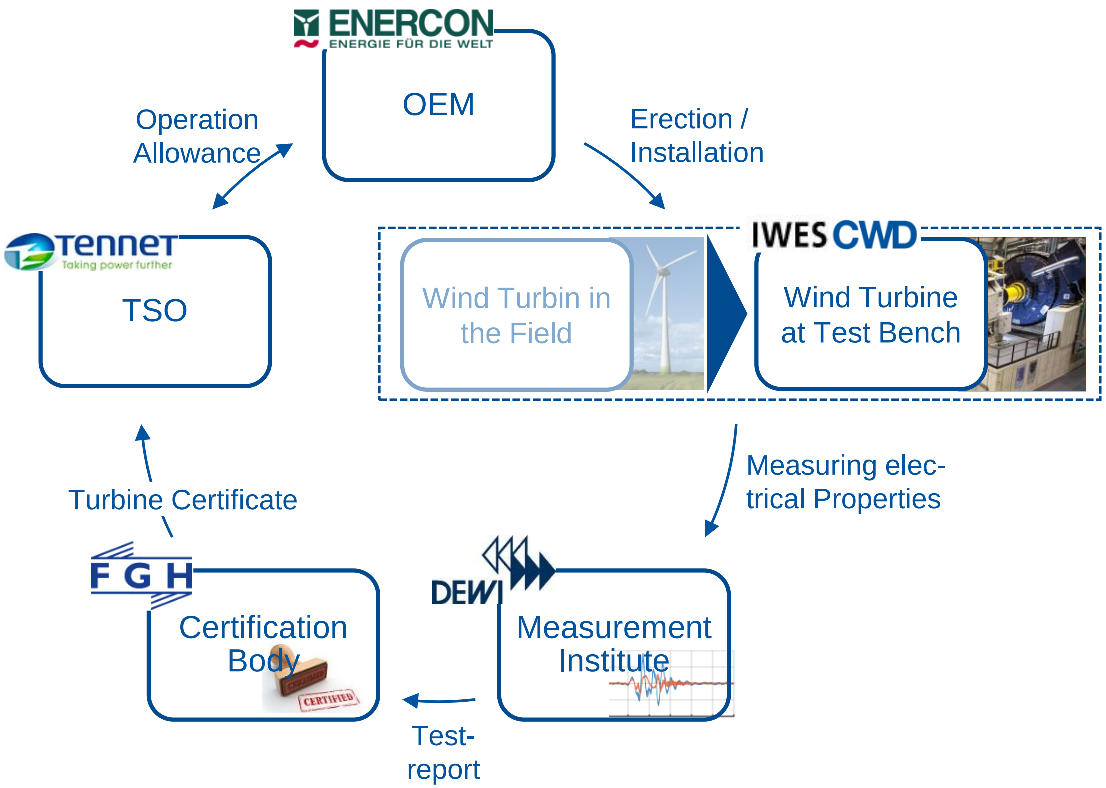
Joint Research Project: CertBench

Certification Process Germany



Goals

- Definition of required modelling detail (rotor)
- Design of mechanical-level HiL-Systems and Control
- **Assessment of the grid simulator's influence**
- Validation of results with the help of commercial ENERCON Turbine and field tests

Test planning

Motivation, Objective & Basis for tests

- Motivation:
  - Compare electrical properties of a wind turbine at
    - Grid simulator
    - Public grid
- Objective:
  - Demonstrate reproducibility of the properties at the PCC of the public grid by means of a converter-based grid simulator
- Basis
  - FGW TR 3 Rev. 24 [TR3] (and draft of rev. 25)
  - Selection of tests with regard to investigations of the sensitivity of electrical quantities (three-phase currents and voltages)

[TR3] FGW, Technische Richtlinie 3: Bestimmung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen am Mittel-, Hoch- und Höchstspannungsnetz

Testing schedule

Overview of tests according to FGW TR 3

No	Test
1	Active power peaks
2	Power limited operation
3	Power limitation at overfrequency
4	P-gradient after loss of power
5	Restart time after loss of power
6	Q-behavior in normal operation
7	PQ-diagram
8	Votlage-dependent PQ-diagram
9	Q control
10	QU control (optional)
11	cosϕ(P) control (optional)
12	Power Quality (NR) – general procedures
13	Power Quality – Switching
14	Power Quality – Flicker
15	Power Quality – Harmonics
16	Power Quality – Asymmetry
17	Disconnection of WT from grid
18	Confirmation of connection conditions
19	LVRT
20	HVRT

Normal operation

Reactive power output

Switching of WT

Active power setpoints

Reactive power output for voltage variations

Fault ride through behaviour

Omitted

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Performing the tests on the system test bench

No	Test
1	Active power peaks
2	Power limited operation
3	Power limitation at overfrequency
4	P-gradient after loss of power
5	Restart time after loss of power
6	Q-behavior in normal operation
7	PQ-diagram
8	Votlage-dependent PQ-diagram
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20	HVRT

Behaviour during faults

- Objective:
  - Investigation of wind turbine behaviour during under- and overvoltage events
- Execution:
  - By means of grid simulator and FRT container (at public grid), different voltage drops or overshoots are generated
- Expected result:
  - Converter of grid simulator can emulate the fault

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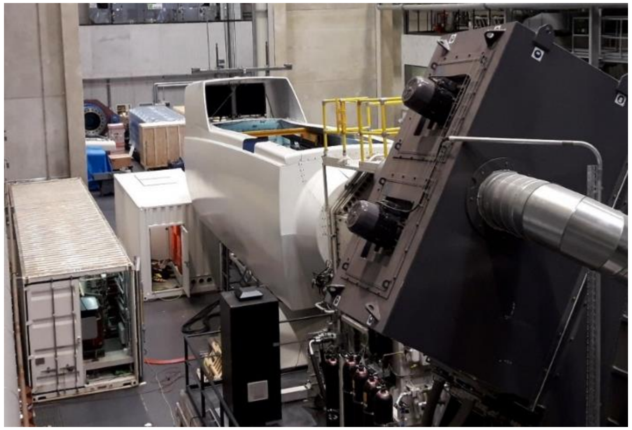
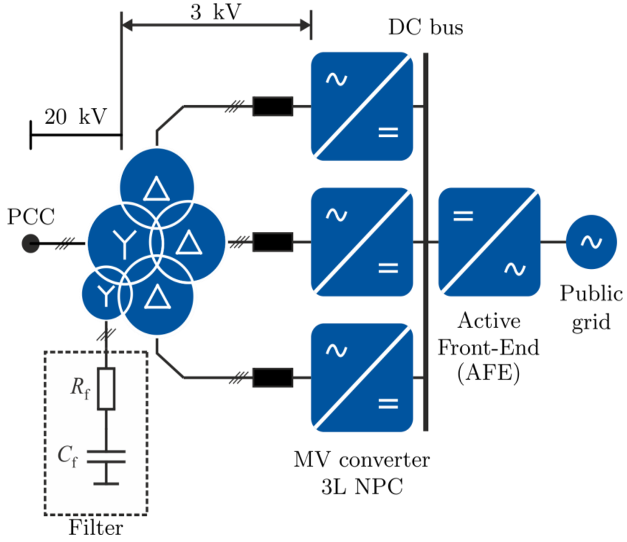
Electrical Integration of the FRT-Container

Objective

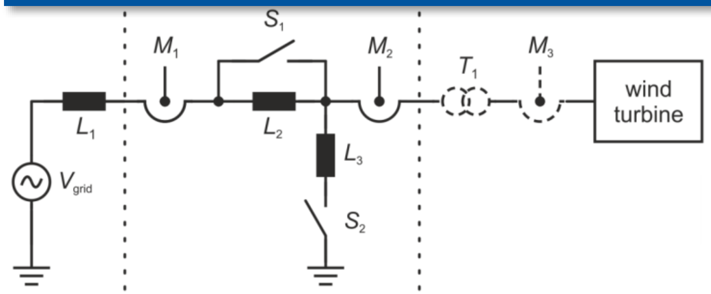
- Comparison of FRT-Container and grid simulator
  - Switch connection between direct connection to public grid and grid simulator
- HVRT-Capability
  - +30 % Overvoltage



Inverter-based grid simulator



FRT-Container



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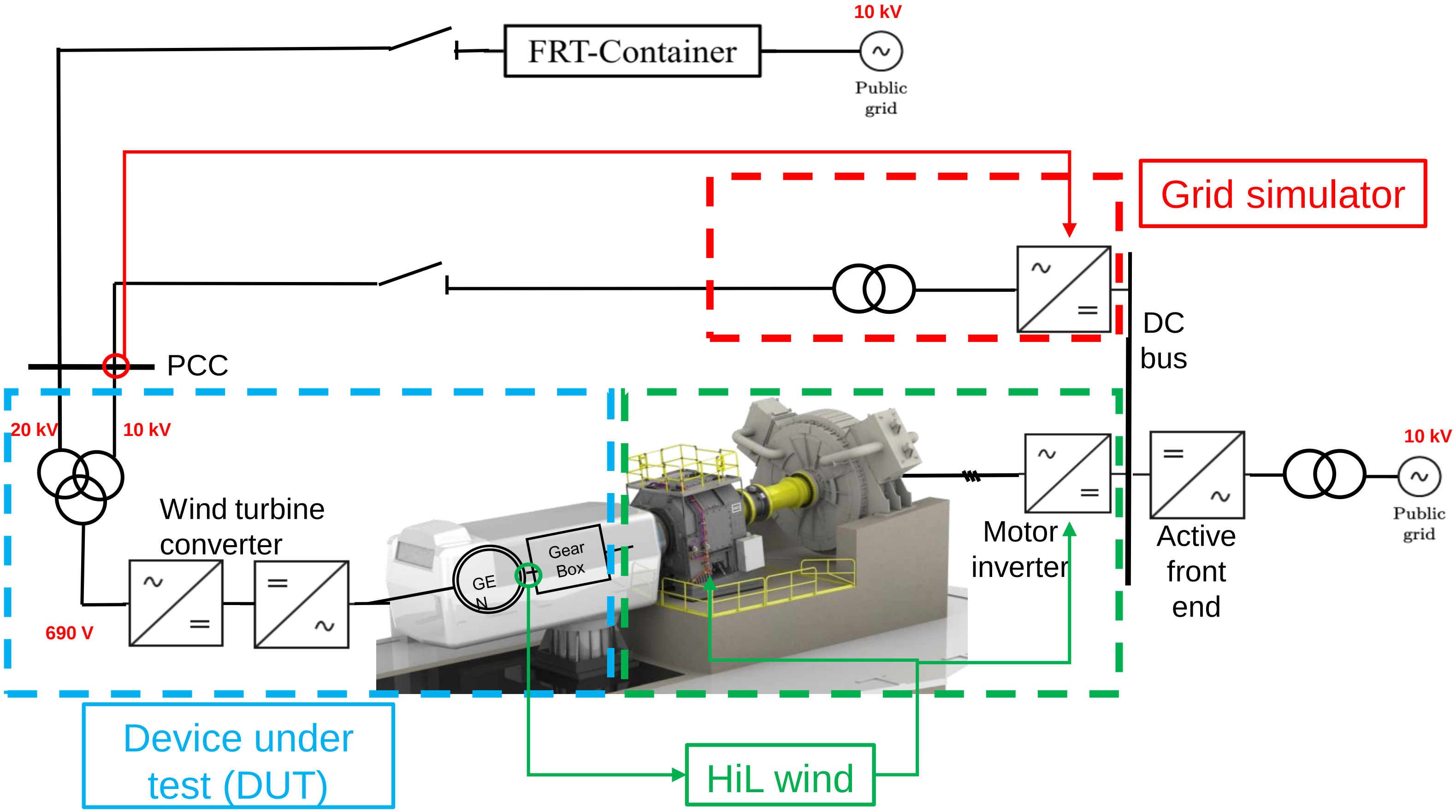
Comparison of grid simulator to FRT container

Conducting FRT tests with a connection of wind turbine to:

- The public grid via the FRT-container (in black at the top)
- The grid simulator (in red)



Exemplary results of FRT tests

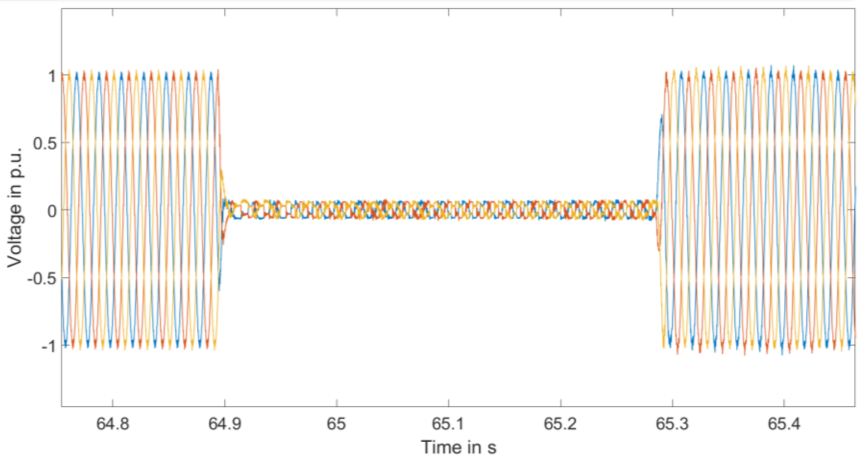
Different degrees of freedom for tests

- Residual voltage level
- Type of fault (2 phase / 3 phase)
- Load condition (None / Partial / Full)
- Wind turbine parameters, e.g. droop for reactive power injection

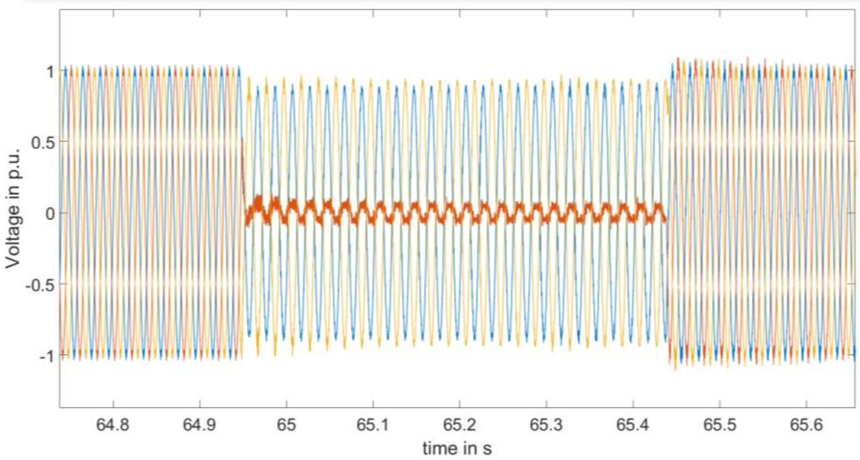
Indices for evaluation

- Voltage level
- Fault time
- Settling time

Balanced voltage dip (0.05 p.u.)



Unbalanced voltage dip (0.05 p.u.)



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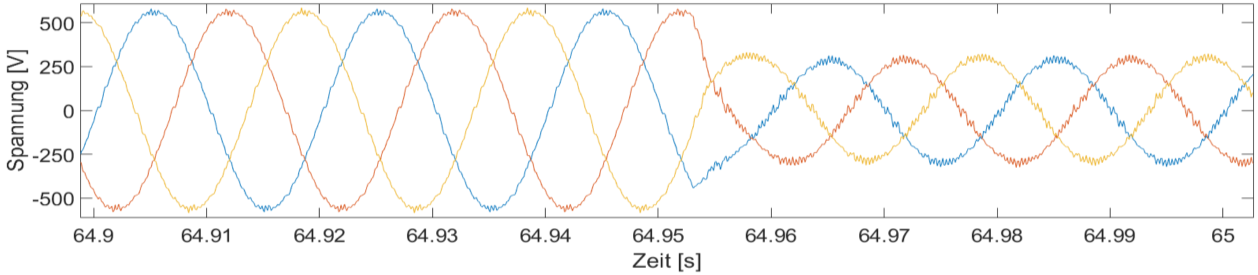
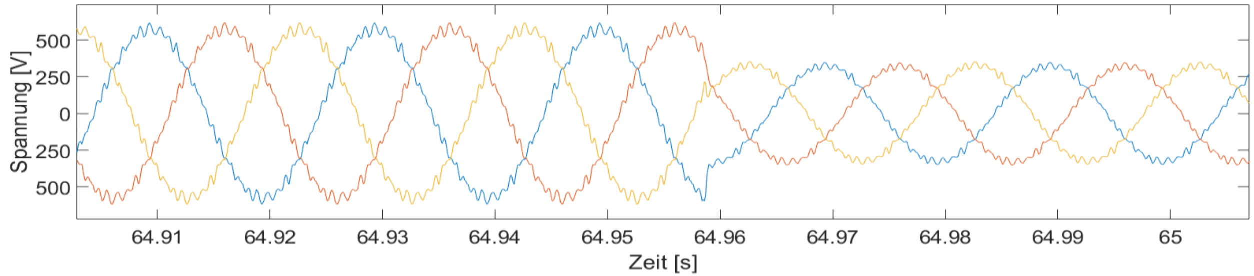
Exemplary results: Dynamics of FRT tests (1)

Dynamics for voltage dip (occurence of fault)



Grid simulator



FRT container

- Large impact of series impedance of FRT container on ripple
- Smooth transition for grid simulator vs hard switching of container
- The tolerance limits according to IEC 61400-21 are complied with

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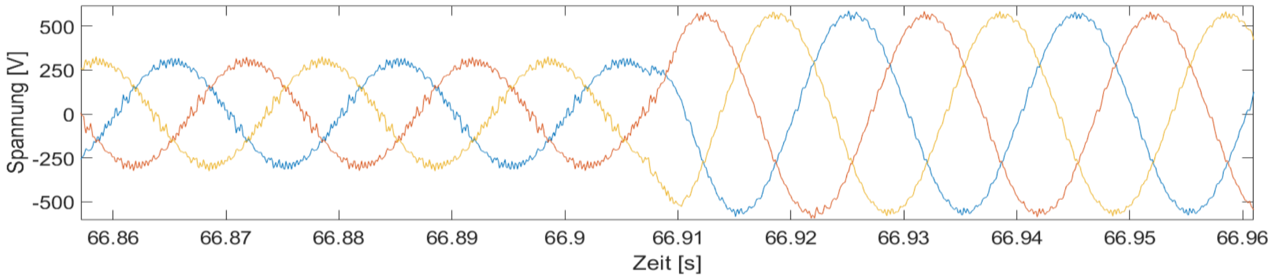
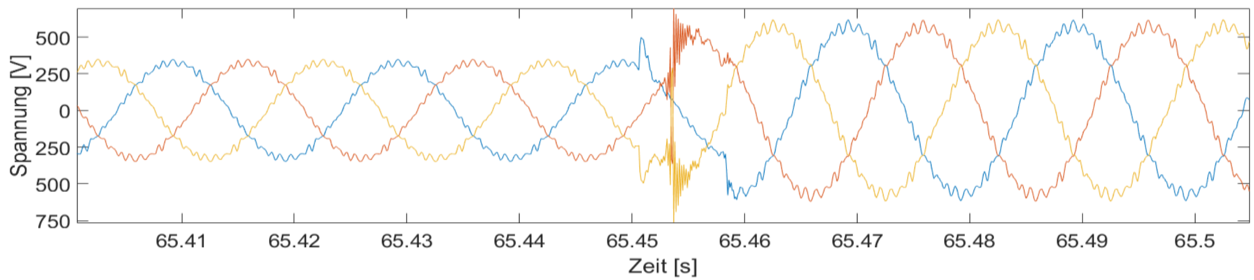
Exemplary results: Dynamics of FRT tests (2)

Dynamics for voltage dip (clearence of fault)



Grid simulator



FRT container

- Smooth transition for grid simulator vs overshoot with container
- The tolerance limits according to IEC 61400-21 are complied with

Summary and Conclusion

Summary of preliminary results

- Sufficient capability of grid simulator for FRT tests
- Large impact of grid stiffness on results
- TR3 norm not sufficiently adapted for test benches

Future work

- Revision of fault definition in TR3 norm
- Closer mapping of FRT-container and grid simulator
- PHIL with grid simulator for adaptive grids to enable virtual placement of wind turbines for certification process
- Comparison with real faults?
- Analysis of harmonics possible with grid simulator?

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Thank you for your attention

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