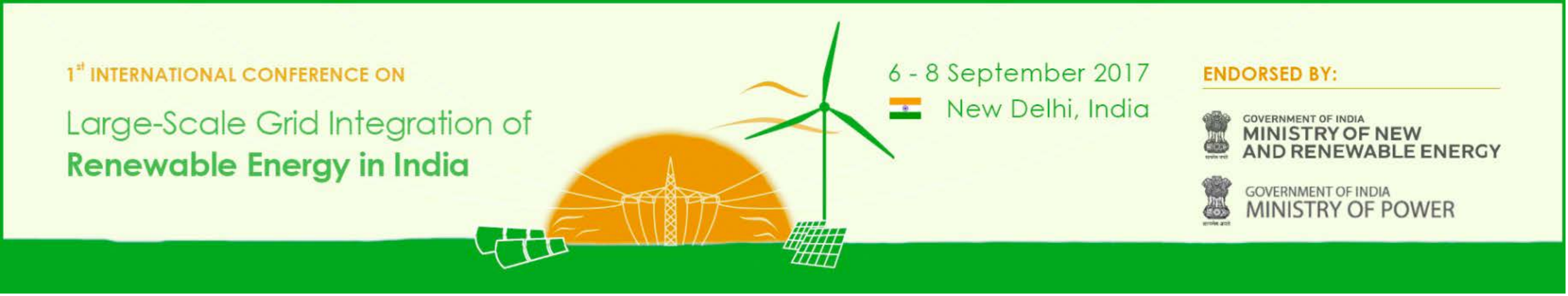


GRID CODE COMPLIANCE TESTING OF RENEWABLES – NEW REQUIREMENTS AND TESTING EXPERIENCES

Nils Schäfer, Dr. Gunter Arnold, Wolfram Heckmann

Fraunhofer Institute for Wind Energy and Energy System Technology
Kassel, Germany

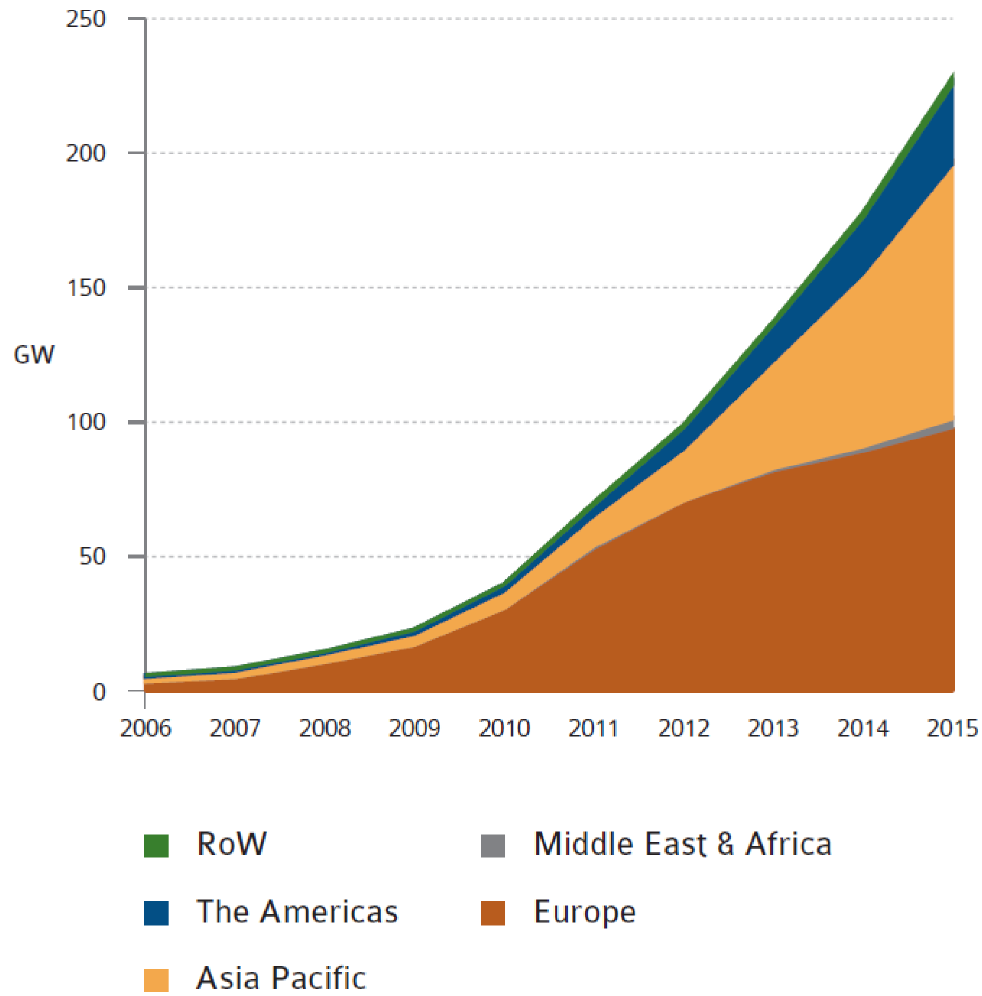
Fraunhofer IWES

OUTLINE

- Trends in photovoltaic installations and inverter technology
- Grid Connection of Renewables
  - Application process for interconnection in Germany
  - Unit and Plant Certification according to German grid codes
  - New grid code requirements in India
- Grid code compliance testing
  - What is essential to compliance test procedures?
  - Examples: Fault-Ride-Through, Interface protection
- Test infrastructure
- Specific challenges for testing utility-scale PV inverters

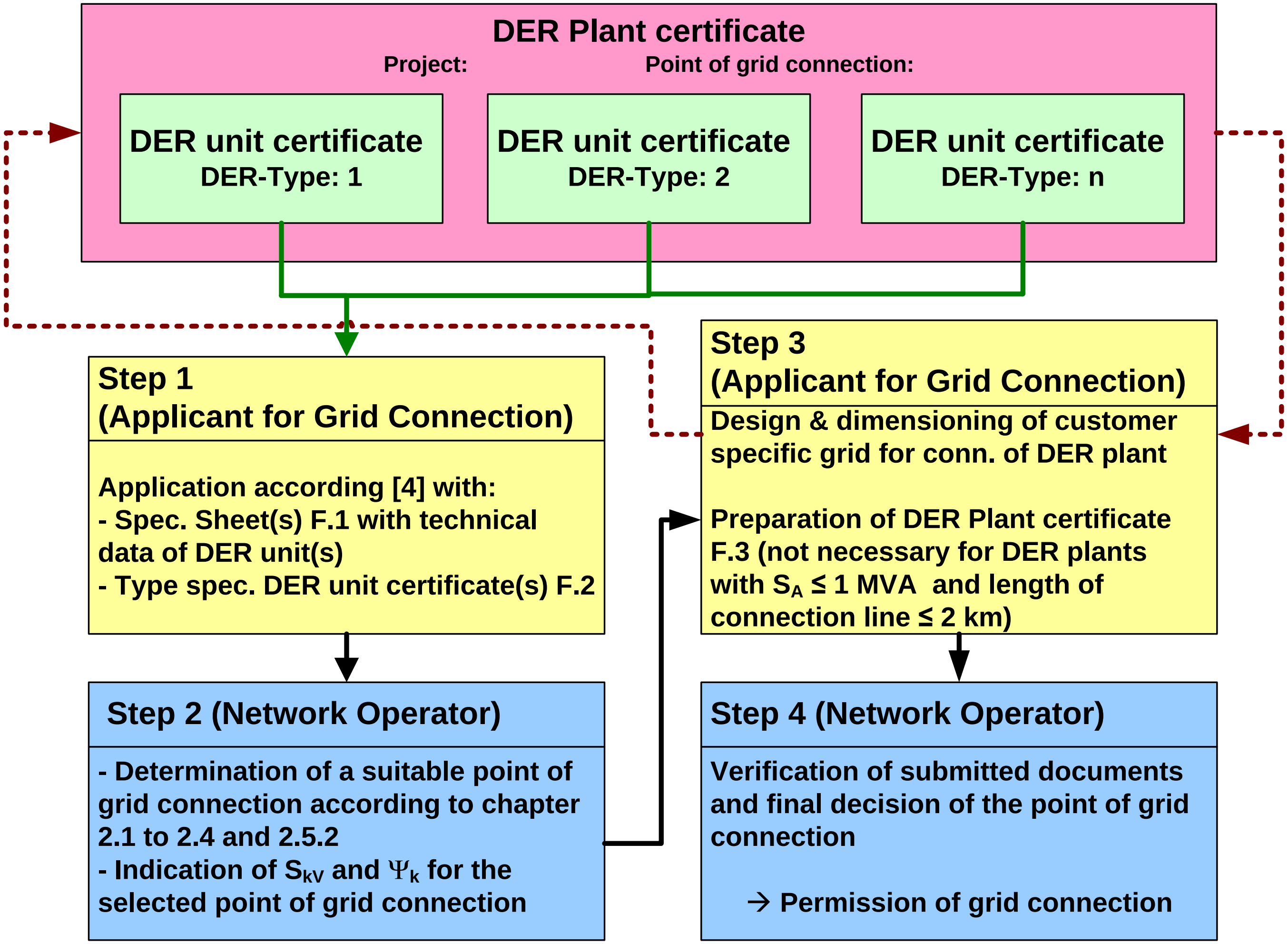
Trends in photovoltaic installations / inverter technology

- Highest rates of additionally installed PV capacity in the Asia Pacific region
- Large PV plants: Average costs of 8 €ct/kWh (Germany) and around 4.5 €ct/kWh (India)
- India's PV target by 2022: 100 GW with 60% utility-scale
- Worldwide market share of central inverters in 2016: 54%
- Increasing rated power of central inverters (2.5 MVA and above) and DC voltages of up to 1.5 kV



Evolution of regional PV installations (GW)
Source: International Energy Agency (IEA), Report IEA PVPS T1-30:2016

Grid Connection of Renewables
Application process for interconnection in Germany



Approval procedure acc. to German MV-Grid Code (with DER = Distributed Energy Resource)

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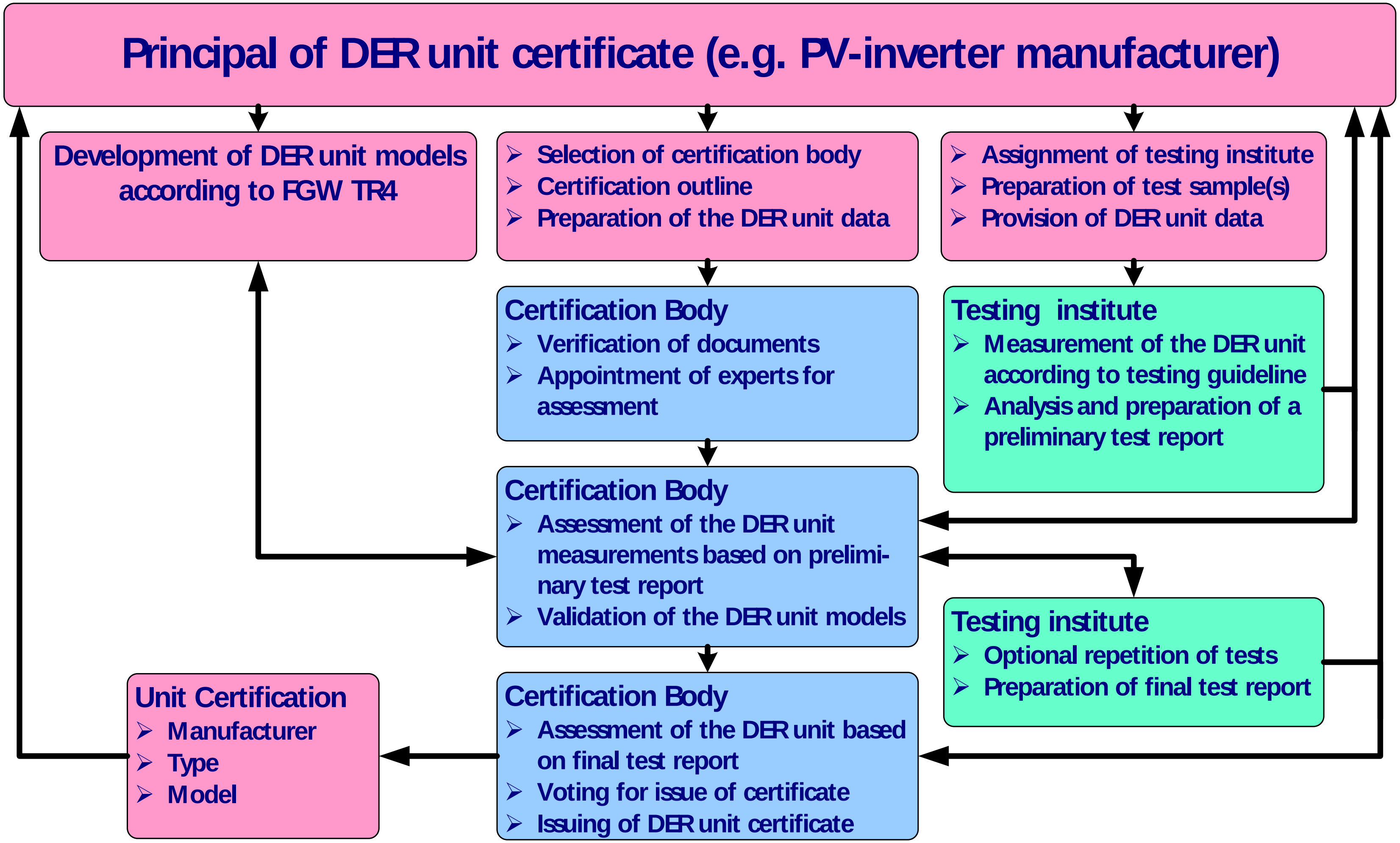
Grid Connection of Renewables

Unit Certification (→ basis for Plant Certification) according to German grid codes



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Grid Connection of Renewables

New grid code requirements in India

- Draft 2nd amendment to the "Technical Standards for Connectivity to the Grid" (Indian Central Electricity Authority, Nov. 2016)
- Major changes and new requirements:
  - Under-voltage-ride-through (UVRT) capabilities introduced for solar and adapted for wind power systems
  - Introduction of frequency response, Over-voltage-ride-through (OVRT) capability, voltage control and short circuit ratio (SCR)
  - Specification of ramp rates
  - Changed reactive power capabilities and harmonic emission limits

Grid code compliance testing
What is essential to compliance test procedures?

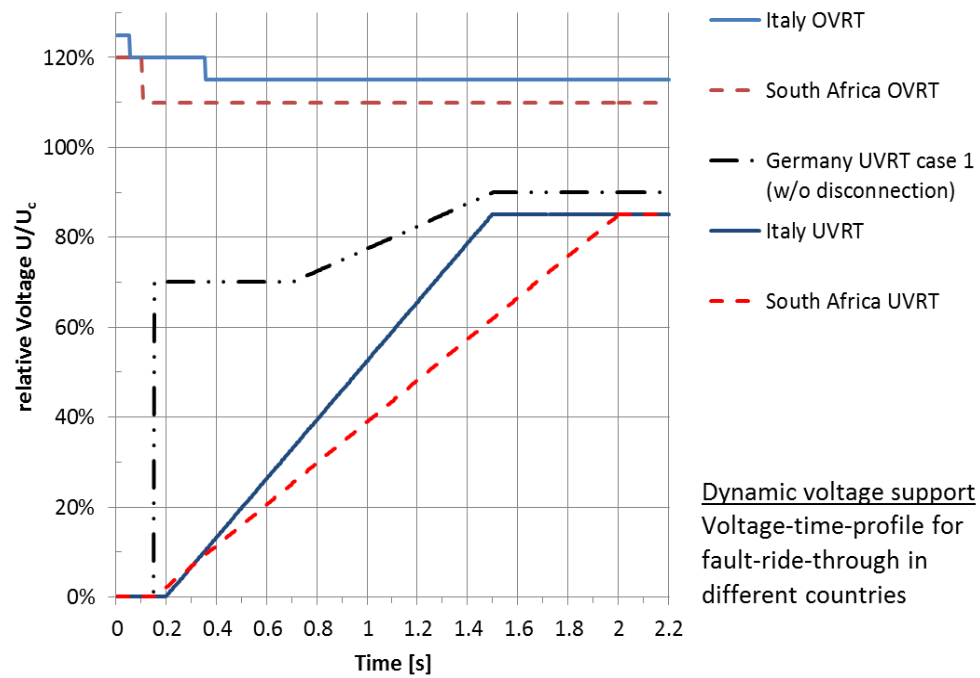
- Clear definition of requirements on:
  - Test setup (e.g. field measurement vs. test lab, measurement quantities)
  - Measurement system & conditions (e.g. sampling rates, m. uncertainties)
  - Method of testing and test plan
    - Operating conditions of the Equipment Under Test (EUT)
    - Set point values and/or characteristics
    - Test sequences and necessary repetitions
  - Evaluation process (e.g. processing of measurement data, definition of tolerances for reaching set point values etc.)
  - Test report (incl. information like calibration certificates)

➡ Comparability and Reproducibility of the test results!

Grid code compliance testing

Example: Fault-Ride-Through

- Test of the generator's capability to continue operation (and inject a reactive current) during transient events like voltage sags (UVRT) or swells (OVRT)
  - Under-Voltage-Ride-Through
  - Over-Voltage-Ride-Through
- UVRT tests acc. to FGW TR3:
  - 5 different voltage depths
  - 3-ph and 2-ph faults
  - Evaluation of build-up and settling time for provision of reactive current
  - After fault clearance: Return to pre-fault values of P and Q within 5 s



Selected UVRT / OVRT requirements at MV level

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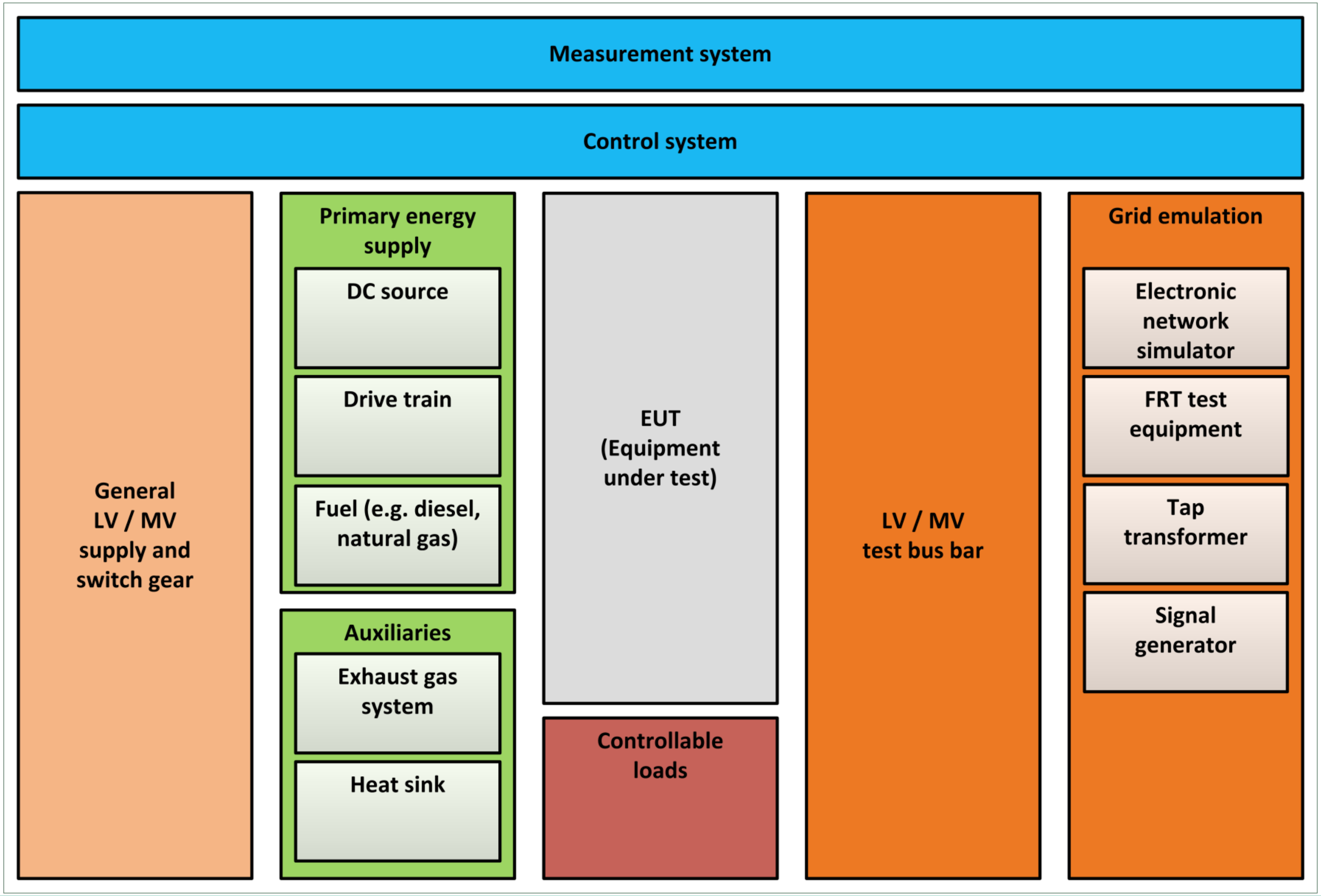
Grid code compliance testing
Example: Interface protection

- Protective disconnection functions for grid and system protection
  - Over- / Undervoltage protection (ANSI code 59, 27)
  - Over- / Underfrequency protection (ANSI code 81)
- Requirements acc. to FGW TR3 testing guideline:
  - Separate tests for threshold values and release times
  - Test of full setting ranges (max. / min. values of thresholds and times)
  - V>>, V>, V<, V<< → individual tests for each of the measured voltages
  - f>, f< → only symmetrical tests required
  - Test of resetting / disengaging ratio required for voltage protection

Test infrastructure

Laboratory building blocks / conceptual arrangement



Test infrastructure of Fraunhofer IWES "SysTec"
Test centre for Smart Grids and Electromobility

- AC grid simulator, 1 MVA
  100...900 V, 45...65 Hz
- DC source (PV emulator), 3 MW
  100...1000 VDC @ 3000 ADC
  (or ±1000 VDC @ 1300 ADC)
- MV/LV tap transformer, 1.25 MVA
  254…690 V ± 5 x 1%
- programmable RLC loads, 600 kVA
- mobile 20 kV UVRT test container up to 6 MVA (OVRT container under development)
- outdoor: MV/LV test grid and hybrid system test bench

Source: Fraunhofer IWES / Volker Beushausen

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Specific challenges for testing utility-scale PV inverters

- Large variety of PV inverters (differing rated power and operating ranges)
  - AC voltages ranging from typically 300 V to 690 V

    ➡ wide operating range of grid simulators and tap transformers required
  - MPP voltages typically ranging from 600 V to 1000 V, but also >1000V

    ➡ wide operating range of DC sources required
- High phase-to-ground voltages may occur. Additional equipment like isolating transformers may be required.
- As intended, Q(V) control feeds back on the AC voltage. This effect has to be compensated by the grid simulator.
- Highly dynamic requirements for FRT testing (transition periods of ≤20 ms)

  ➡ For high power ratings suitable dynamic grid simulators are very expensive, here MV FRT test equipment is an alternative.

Thank you for your attention!
Questions?

Contact:

Nils Schäfer
Dr. Gunter Arnold
Wolfram Heckmann

Fraunhofer IWES
Königstor 59
34119 Kassel, Germany

nils.schaefer@iwes.fraunhofer.de
gunter.arnold@iwes.fraunhofer.de
wolfram.heckmann@iwes.fraunhofer.de