Requirements for PV plants connected to German MV Distribution System

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OUTLINE

- Introduction to Fraunhofer IWES
- Introduction / background to DER grid supporting requirements
- Requirements for DER plants connected to the German MV distribution system
- Approval of grid behaviour of DER plants and PV-inverters according to (new) German MV GridCode
- Summary / Outlook

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Fraunhofer Society - Facts and Figures

- Fraunhofer is the largest organization for applied research all over Europe
- More than 80 research subsidiaries with 60 Fraunhofer institutes located all over Germany
- 17 000 employees, most of them with education in science or engineering
- 1,5 billion Euros research budget annually

Fraunhofer Institute for Wind Energy and Energy System Technology (IWES)

- **Foundation:** 1.1. 2009
- **Personal:** ≈ 240 scientists (170 full-time equiv.)
- **Directors:** Prof. Dr. Jürgen Schmid (KS),
  Prof. Dr. Andreas Reuter (Bhv)
- **Formerly:**
  - Institute for Solar Energy Supply Technology - ISET in Kassel
  - Fraunhofer Center for Wind Energy and Offshore Technology (CWMT) in Bremerhaven
- **Research Spectrum:**
  - Wind energy from material development to grid optimization
  - Energy system technology for all renewables

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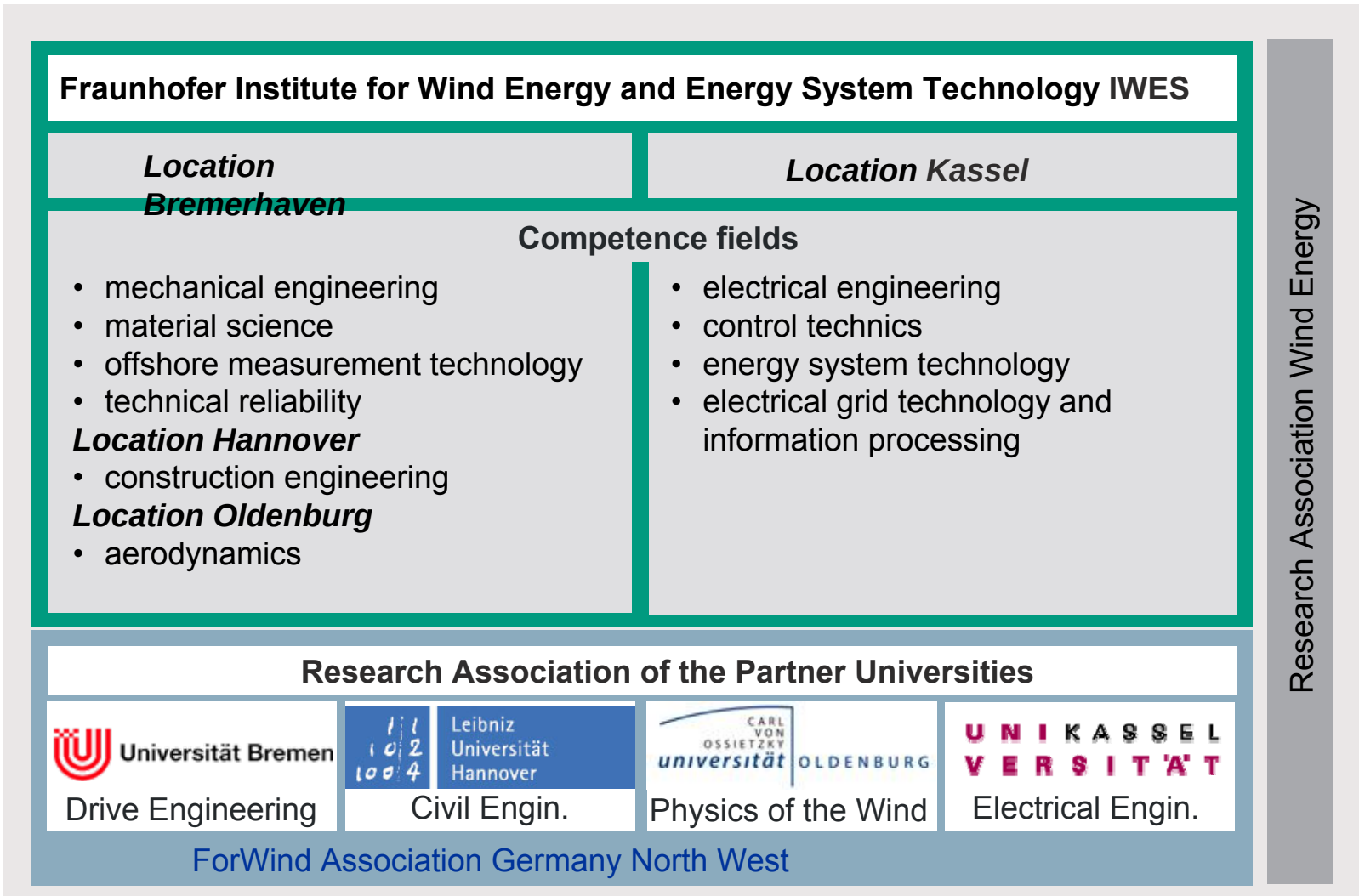
Fraunhofer IWES and associated partner universities



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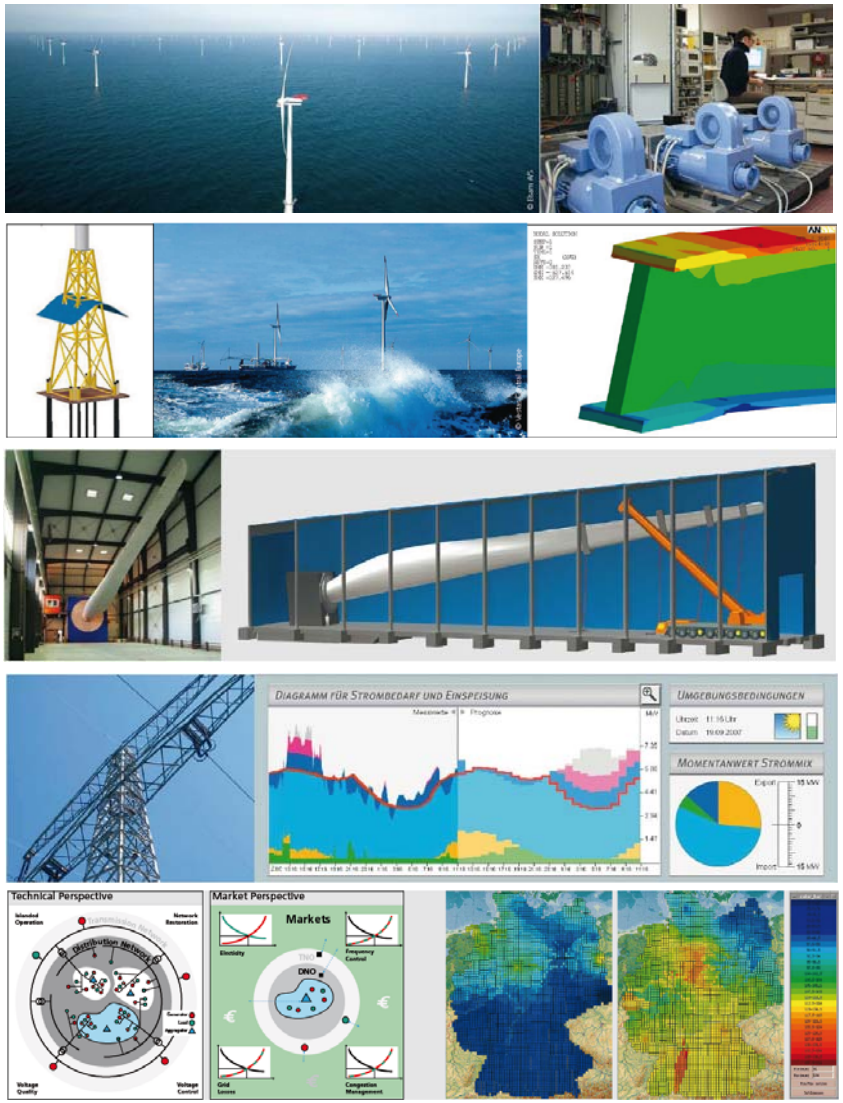
Main Business fields of IWES



- Wind energy technology and operating control
- Elasticity and dynamics of turbines and components
- Competence center for rotor blades
- Development of rotors, drive trains and foundations
- Environmental analysis for wind and ocean energy
- Control and grid integration of decentralized converters
- Energy management and grid operation
- Energy supply structures and systems analysis

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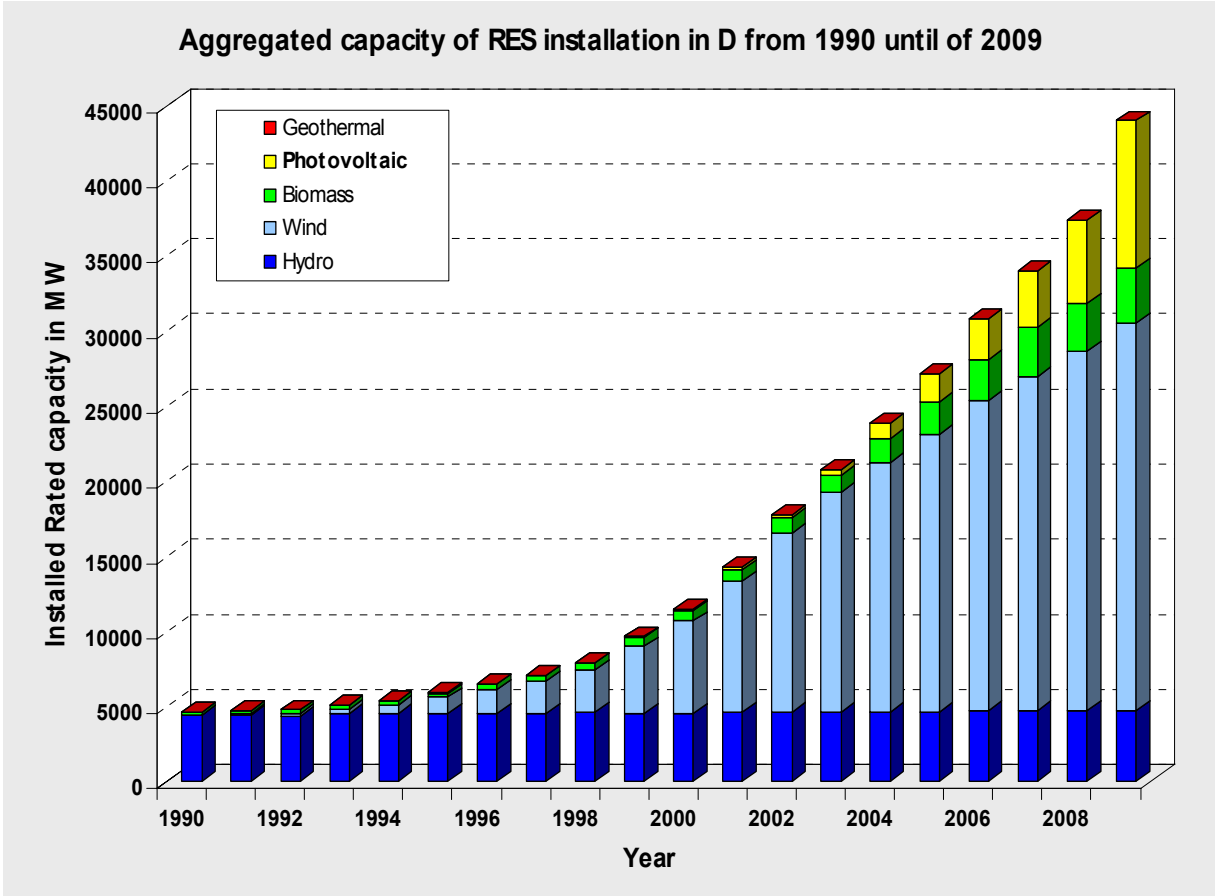
Background for DER grid supporting requirements in DE

- **Todays situation:** Very strong increase of DER plants connected to the distribution system PV: > 16 GWp with 15 - 20% at MV-grid, 80 - 85 % at LV-level
- **Targets:** Further massive installation of DER together with long term assurance of network stability
- **Action needed:** DER units and plants connected to German distribution system must be equipped with grid supporting features



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Background for DER grid supporting requirements

- **Regulations in the German renewable energies act (EEG 2009)**
  http://www.eeg-aktuell.de/
  - Pre-condition for connection: Fulfilling of technical minimum standards concerning grid behaviour (§6)
  - Link to GridCodes
  - Approval of Conformity by certificates (§64)
- **DistributionCode „DER plants connected MV distribution grid“ (2008)**
  - Techn. requirements for DER plants (steady state / transient) at PCC
  - Basic procedure for approval of conformity
  - Link to Technical Guidelines of FGW for verification of requested grid behaviour
- **Technical Guidelines of FGW**

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Overview of BDEW DistributionCode

- **Steady state requirements:**
  - Limitation of power-quality characteristic parameters (voltage change, harmonics, flicker)
  - Active power control (reduction)
  - Reactive power control
  - Protection functions (U<<, <U, U> ,f<, f>)
- **Transient behaviour:**
  - Fault-ride-through (FRT) capability during voltage dips
  - No change of active power generation
  - Feed-in of reactive power during the fault
  - Limitation of short-circuit current contribution

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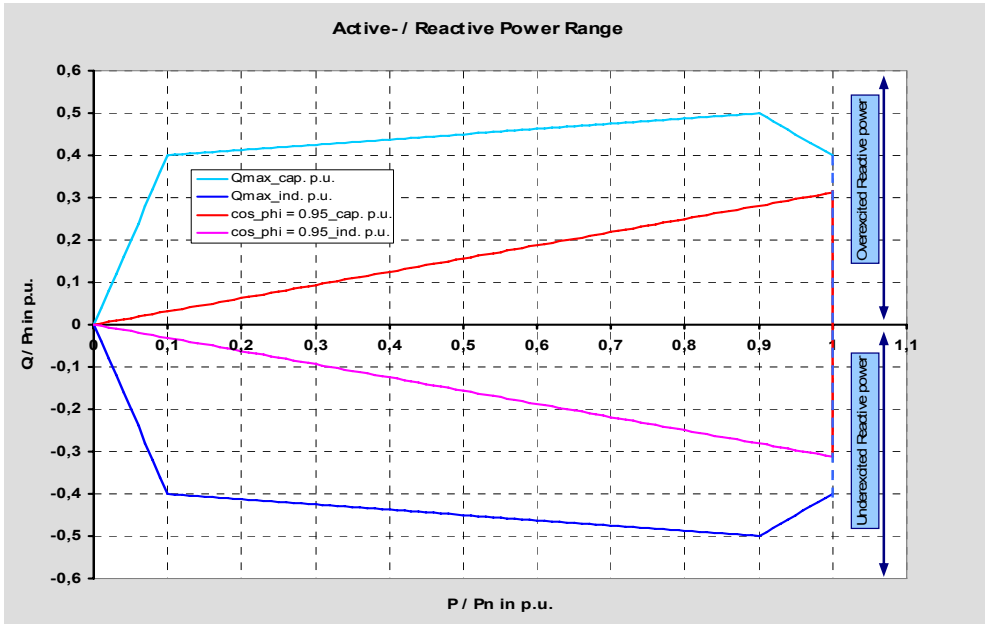
Reactive power control / provision

- Main limiting factor for grid integration of DER plants is the violation of the voltage change (rise) of 2%U_n due to feed-in of active power.
- DER units / plants should be able to provide at least reactive power with a displacement factor cos φ between 1 and 0.95 leading or lagging for grid voltage stabilization under normal operating conditions.
  - Minimal requirement (area between red and magenta lines)
  - Typical for inverter based DER units: (area between blue lines)



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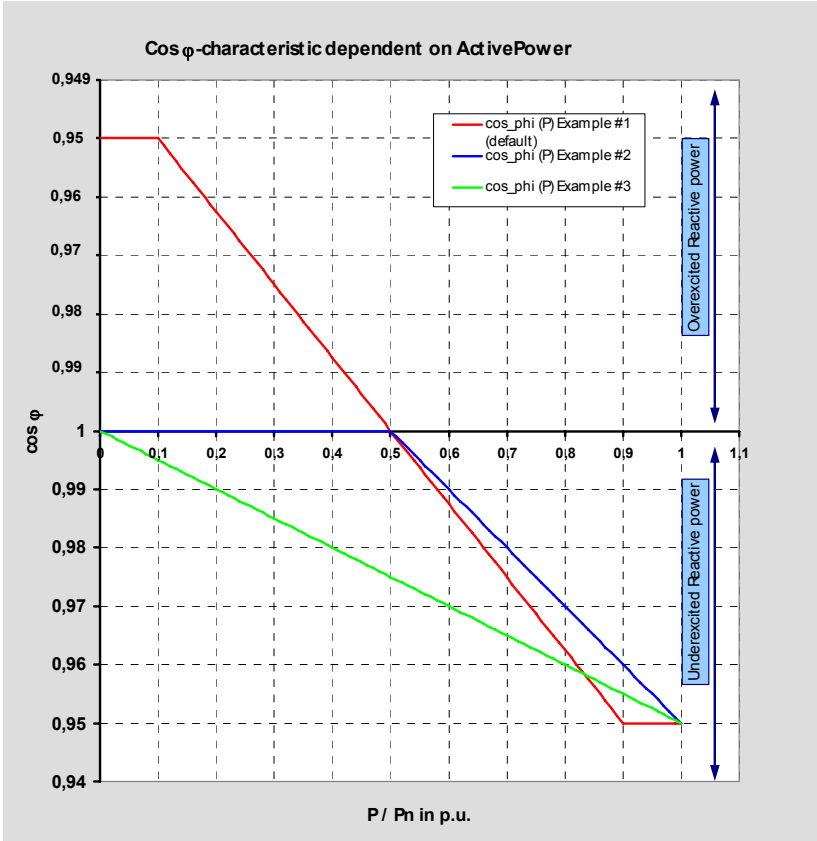
Reactive power control / provision

- Reactive power provision according to
  - Setpoint by DSO via remote control or
  - Specified characteristic at PCC
- The following characteristics for Q provision have to be implemented
  - Fixed displacement factor cos φ or
  - Fixed reactive power value or
  - Displacement factor / active power characteristic or
  - Reactive power / voltage characteristic



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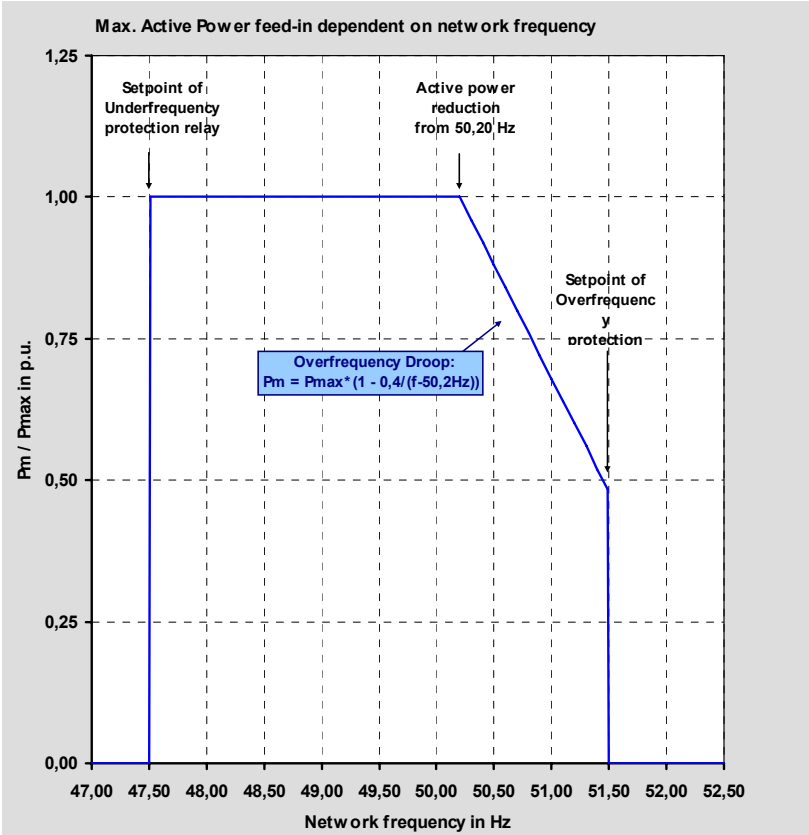
Active power control

- Active power control (limitation / reduction)
  - Remote active power setpoint control in steps of ≤ 10 % by the DSO in case of network congestions or danger of power system collapse.
  - Automatic reduction of active power generation according to a droop characteristic if $f_{grid} > 50.20$ Hz with:

    $P_m = P_{max}*(1 – 0.4/(f_{grid} – 50.2Hz))$

- Default setpoints for protection functions
  - Underfrequency trip: $f_{grid} < 47.5$ Hz
  - Overfrequency trip: $f_{grid} > 51.5$ Hz



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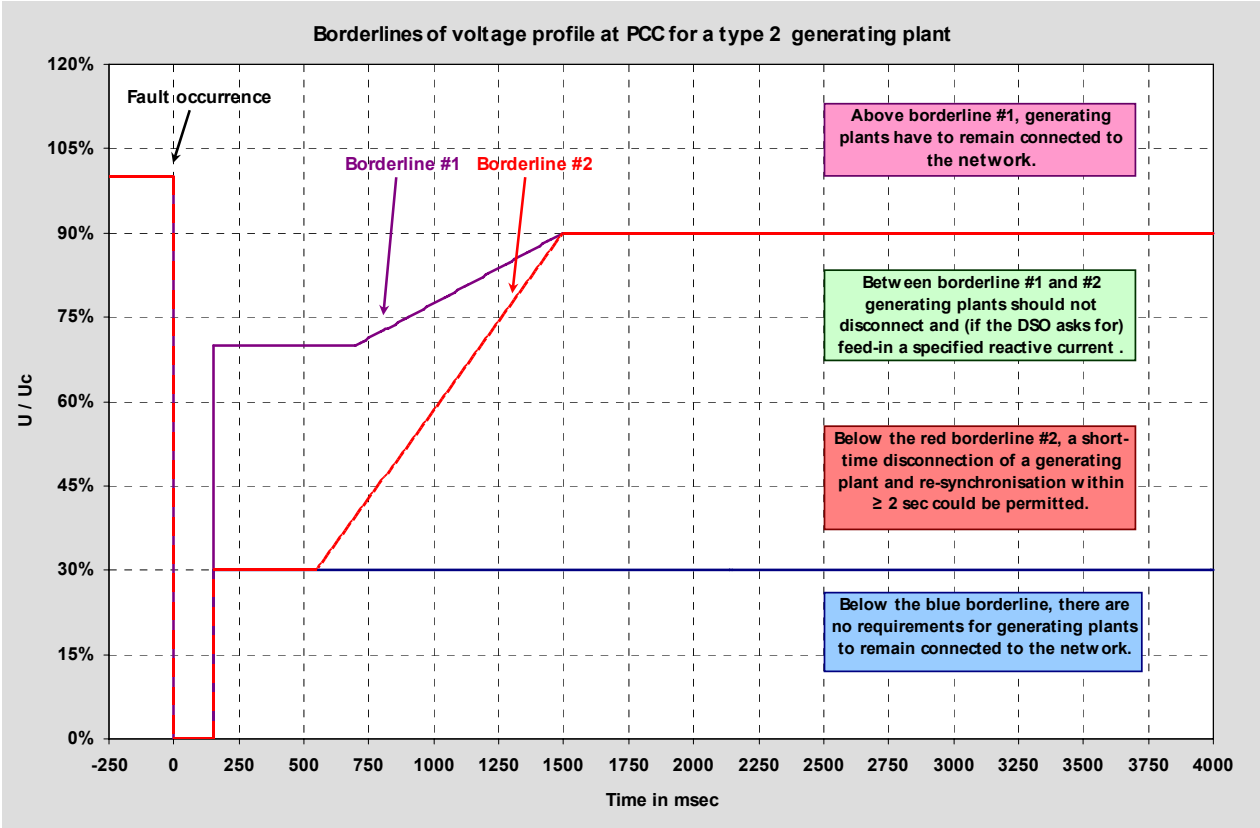
Behaviour of DER plants during voltage dips

- Distinction between two DER types:
  - Direct connected synchron. generators (type 1)
  - All other generators (type 2)
- DER behaviour depends mainly on two quantities:
  - Depths of voltage dip
  - Fault duration

→ Four different requirements



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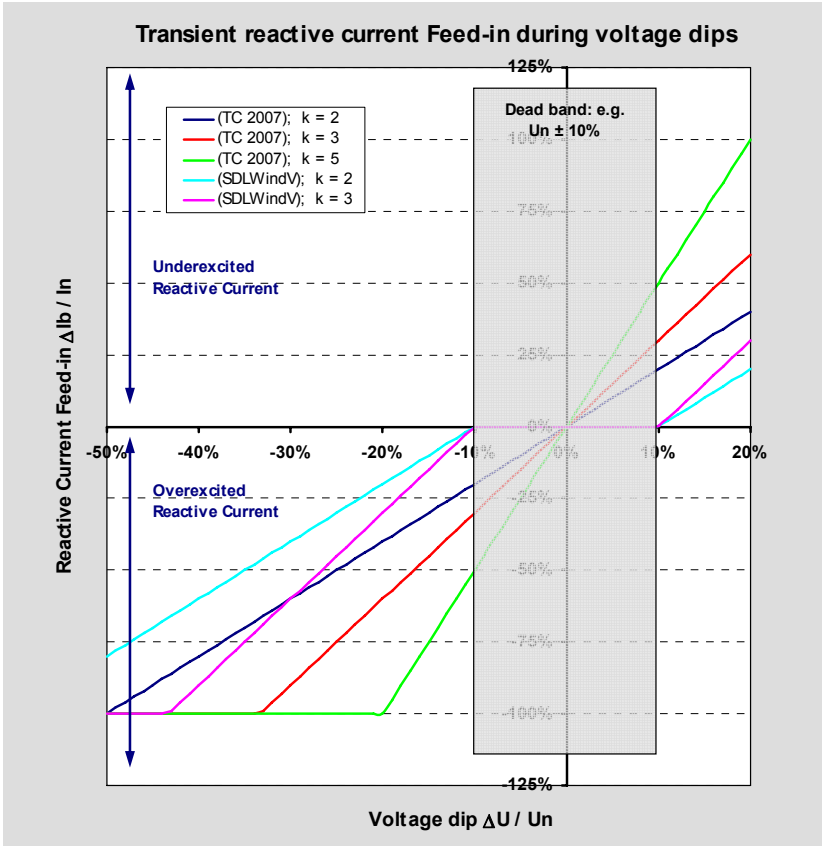
Reactive current feed-in during voltage dips

- DER plants have to feed-in additional reactive current according to a specified characteristic:
  - Value depends on depths of voltage dip and reactive power setpoint prior to fault
  - k-Factor (k = ΔIb/In / ΔU/Un) > 2.0 p.u.
  - Definition of characteristic (ΔU) is different according to GridCode
    - TransmissionCode 2007 (TC 2007)
    - System Service Ordinance for Wind Energy plants (SDLWindV)
- Control response time: ≤ 20 msec
- Max. reactive current: $I_b \leq 1.0\ I_n$
- Max. duration of reactive current feed-in: Fault clearance + 500msec
- Tripping of overvoltage protection must be avoided (unsymmetrical voltage dips)



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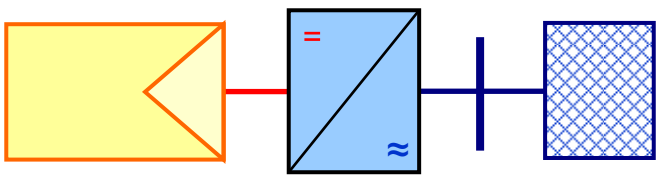
Distinction between DER unit ↔ DER plant

DER unit (EZE)

Single device for generation of electricity

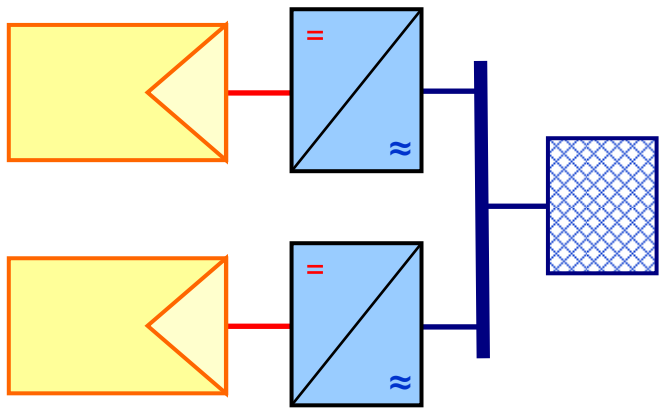
- e.g. one WTG or
- Part of a PV-plant, which is connected to one inverter!
- $S_A \leq 1$ MVA (only unit certificate necess.)
- $\ell_{PCC} \leq 2$ km (only unit certificate)



DER plant (EZA)

Farm / cluster with at least one but normally more DER units (EZE) and

- All equipment, necessary for grid connected operation of the DER plant
  - Farm cabling, substation, trafo, farm controller & other power cond. devices such as filters etc.



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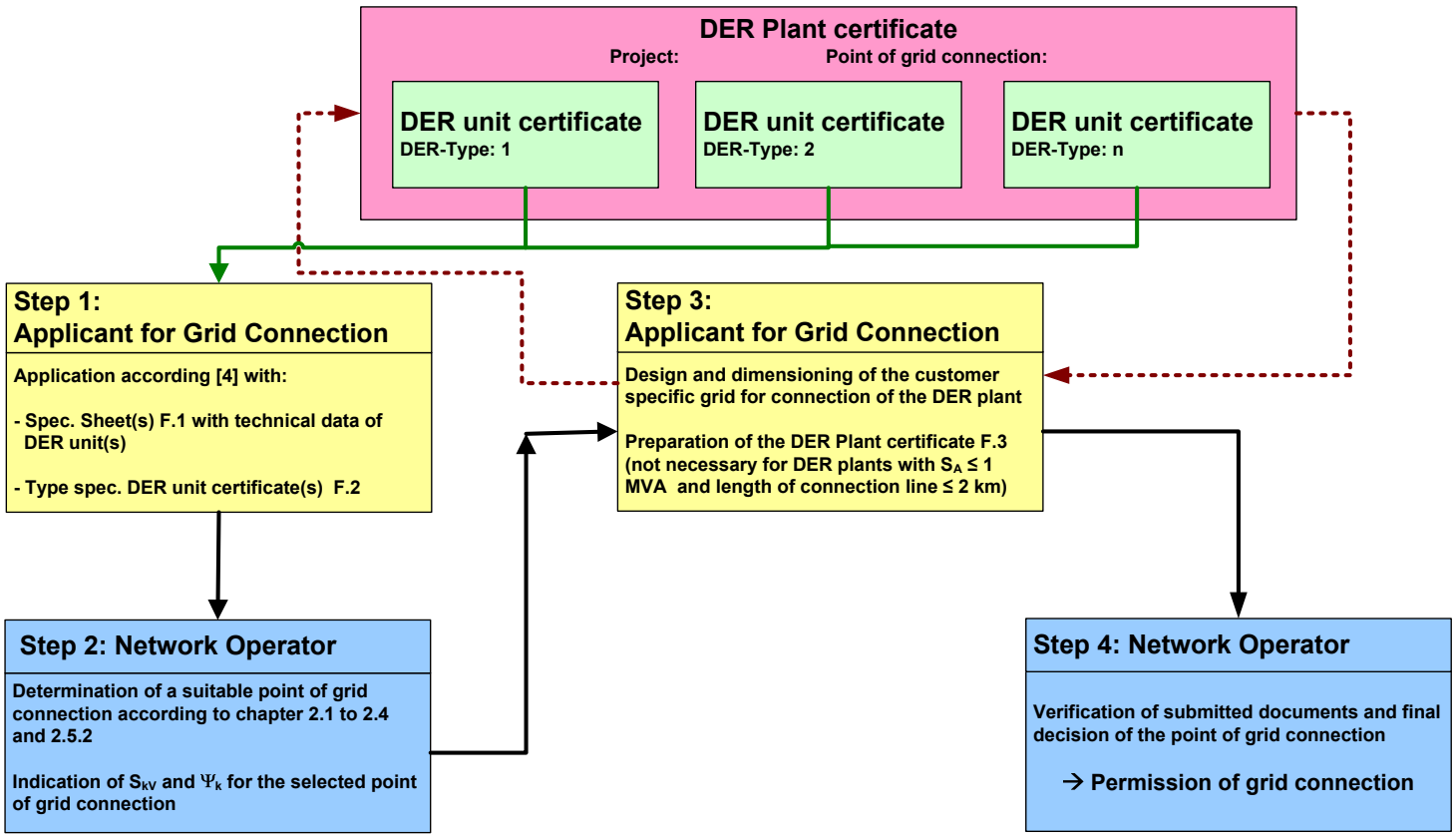
Approval procedure for grid connection



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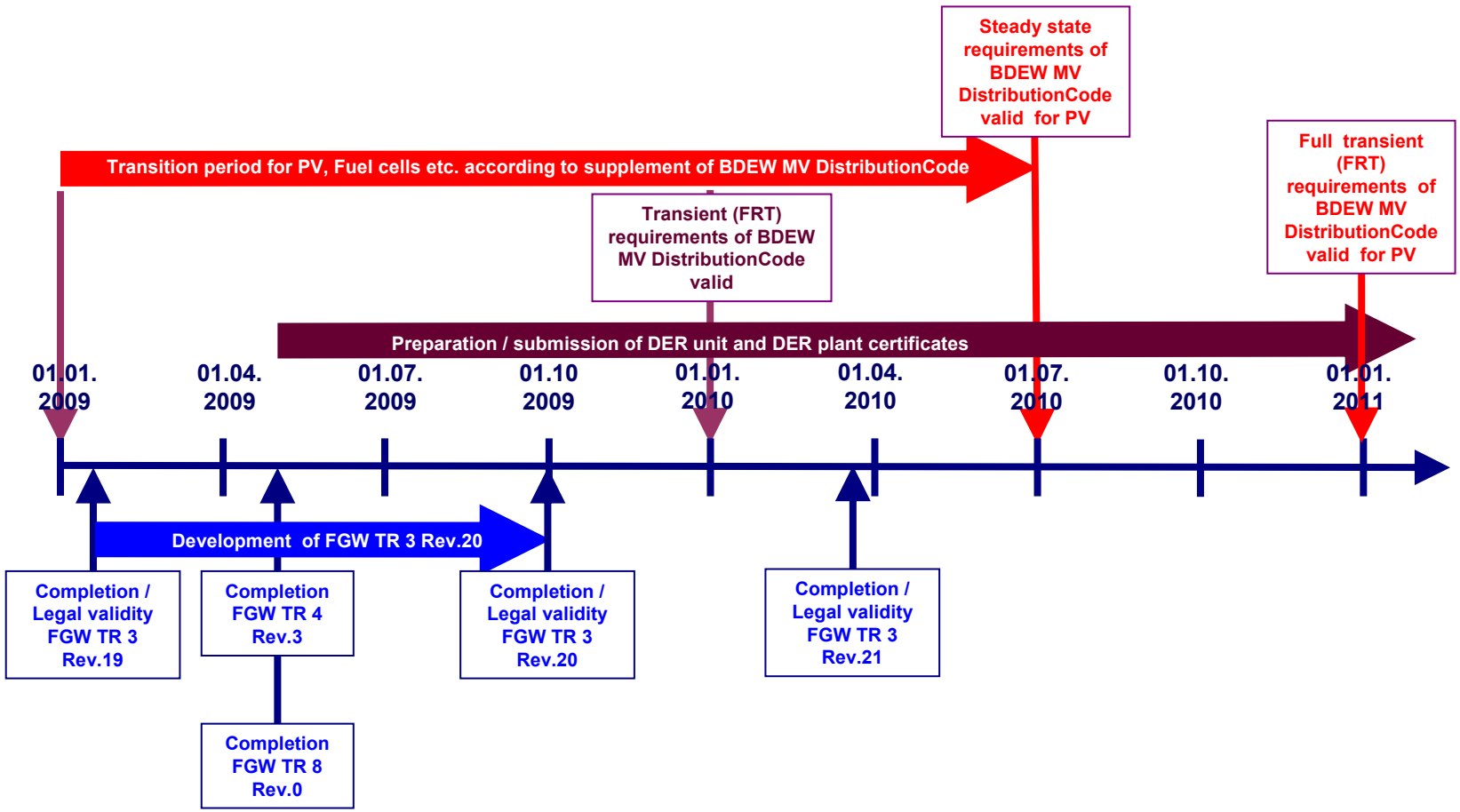
Time schedule for approval of grid behaviour



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Technical Guidelines of FGW

- FGW working committees developed Technical Guidelines for WTG since 1992
- FGW Guidelines are ground-breaking for international standardization of WTG
  → e.g. IEC 61400 - 21
- Following FGW-TR documents are relevant for approval of grid behaviour:
  - Part 3: Testing and measurement of DER units
  - Part 4: Modeling and validation of DER units and DER plants
  - Part 8: Certification of DER units and DER plants

FGW Technical Guidelines Part 3 (FGW-TR3)

- FGW-TR3 describes measurement methods and test procedures for approval of the grid behaviour of DER units according to the MV-DistributionCode (valid: Rev.19, 14.1.2009)
- FGW-TR3 was developed in the past only for WTG → Measurements and tests according to IEC 61400-21
- Latest Rev. 19 should also be suitable for other DER technologies (PV, Biomass, Hydro)
  → Determination of PV specific test procedures was a very important task!
- FGW working group FGW AK-PV (chaired by IWES) is in charge of this!

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FGW Technical Guidelines Part 8 (FGW-TR8)

- Accredited (IEC 45011) certification body evaluates the conformity of DER units / DER plants with the requirements of MV DistributionCode based on:
  - Manufacturer‘s certificate,
  - Test reports accord. to FGW-TR3
  - Validated models accord. to FGW TR4
  - Simulation results of DER plant
- FGW TR8 includes:
  - General regulations (application, approval, validity, withdrawal of certificates etc.)
  - Evaluation contents and -criteria accord. to the MV DistributionCode

F.2 Einheiten-Zertifikat

LOGO Zertifizierungsstelle Akkreditiert nach EN 45011 – ISO / IEC Guide 65		LOGO
Einheiten-Zertifikat		Nr: 2009-n Unterzeichnete Kopie No. 1
Hersteller		
Typ Erzeugungseinheit		
Technische Daten	Nennleistung:	
	Bemessungsspannung:	
	Nennfrequenz:	
Netzanschlussregel	**BDEW-Richtlinie „Erzeugungsanlagen am Mittelspannungsnetz** Richtlinie für Anschluss und Parallelbetrieb von Erzeugungsanlagen am Mittelspannungsnetz, Ausgabe Juni 2008	
Mitgeltende Normen/ Richtlinien	DIN EN 61400-21; FGW-Richtlinie TR 3	

Die oben bezeichnete Erzeugungseinheit erfüllt die Anforderungen der BDEW-Richtlinie „Erzeugungsanlagen am Mittelspannungsnetz", Ausgabe Juni 2008.

Der Hersteller hat die Zertifizierung seines Qualitätsmanagementsystems nach ISO 9001 nachgewiesen.

Das Zertifikat beinhaltet folgende Angaben:

- technische Daten der Erzeugungseinheit, der eingesetzten Hilfseinrichtungen und der verwendeten Softwareversion;
- den schematischen Aufbau der Erzeugungseinheit;
- zusammen gefasste Angaben zu den Eigenschaften der Erzeugungseinheit.

Ort, Datum (TT.MM.JJJJ)

Deutscher Akkreditierungs Rat DAR

Dieses Zertifikat darf nicht in Ausschnitten verwendet werden.

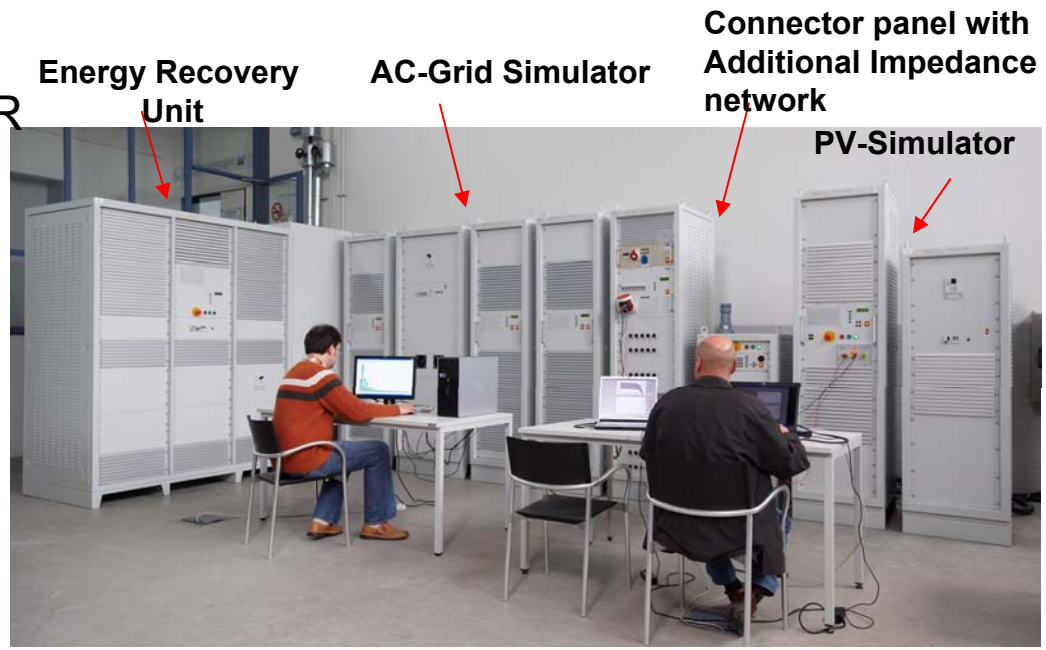
LOGO Zertifizierungsstelle, Adresse, e-mail

Results of working committee AK-PV for FGW-TR3

- **Solar module independent testing:**
  - Measurements/tests of a PV unit (inverter) should be performed either on-site but also inside a lab with „appropriate“ simulators
  - Using Simulators for testing leads to major simplifications
  - TR3 „Annex E“ describes the requested characteristics of the DC-Source (PV-simulator)
  - Revised Manufacturer's certificate on specific data of PV-units in Annex A
  - Important Task: Improvement of PV specific tests for testing of transient behaviour (Chapter 4.7.) Rev. 20 and Rev. 21

Testing of DER units grid behaviour at IWES

- IWES established in 2008 in DeMoTec a Test-lab for Testing accord. to MV DistributionCode and FGW-TR 3
- Accreditation of the Test-lab accord. to IEC 17025
- IWES is performing such grid compatibility tests accord. to German MV DistributionCode since Q3/2009
- Test equipment in DeMoTec: (Limited to DER units with appr. ≤ 100 kVA rated power)



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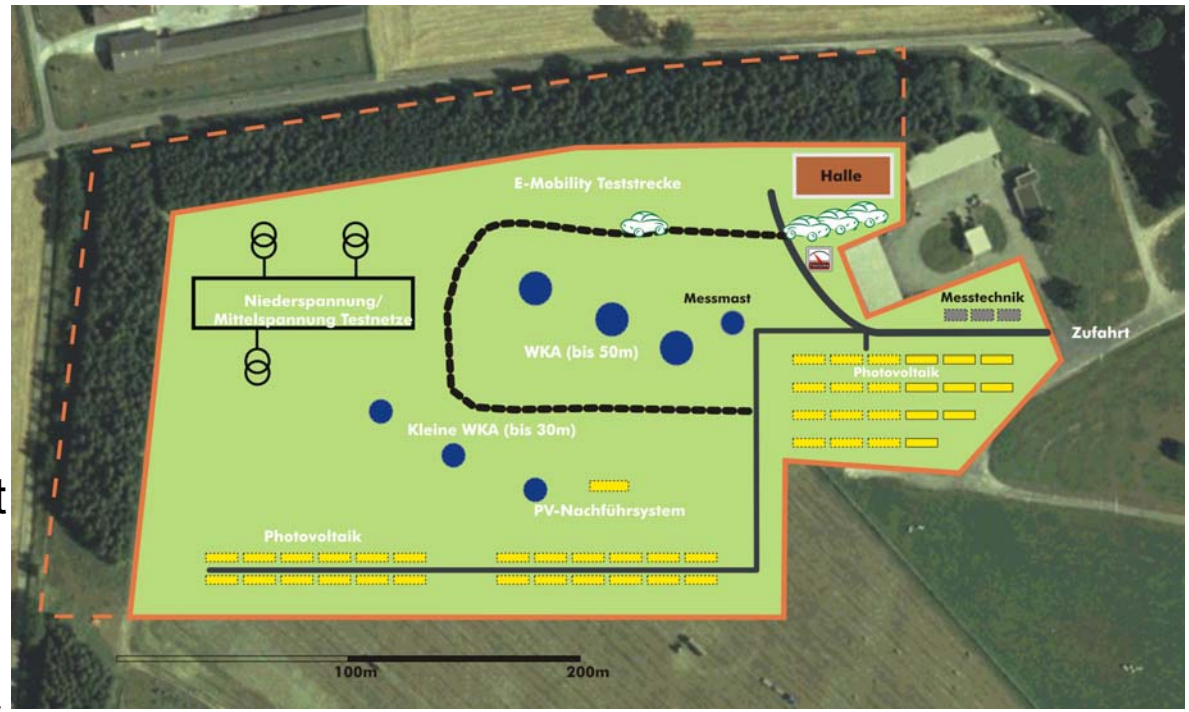
IWES - Test Field for Smart Grids und E-Mobility

SysTec – Outdoor Test Field and Lab for Smart Grids and E-Mobility located in Fuldatal near Kassel

- Real electricity grids (MV-, LV-level)
- Real PV units, small WTGs, hybrid systems and typ. customer loads
- E-Mobility: Charging stations, roller type test bench and test road
- Tests of large inverters
- 6 MVA FRT test facility



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Summary / Outlook

Performed Tasks:

- Manufacturer of DER units: Additional effort (financial & human resources) for adaptation / further development of Inverter
- Test-Labs: Development of new PV-specific Test procedures
- Significant investments concerning new powerful test facilities (MW range)

Outstanding Issues:

- Certification bodies: Increasing the capacities for DER plant certification
- Release of the new German LV GridCode
- Harmonisation (European / Global) of GridCodes and testing standards

Outcomes:

- Important innovations for PV Inverter and other DER plant technologies (similar to the development of WTG approx. 7-8 years ago)
- Stable network operation with significant higher share of power generation by DER and PV plants in distribution networks is achievable

Thank’s a lot for your Attention!

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