Multi-Terminal Power Hardware-in-the-Loop Test Bench for Power System Stability Analyses focused on Distributed Generation

7th International Conference on Real-Time Simulation Technologies

Real-Time 2014

Montreal | 9-12 June, 2014

Authors: Ron Brandl, Fraunhofer IWES

Dominik Geibel, Fraunhofer IWES

Fraunhofer IWES

Multi-Terminal PHIL Test Bench for Power System Stability Analyses

Content

Fraunhofer IWES

1. Introduction

Transformation to inverter-dominated networks

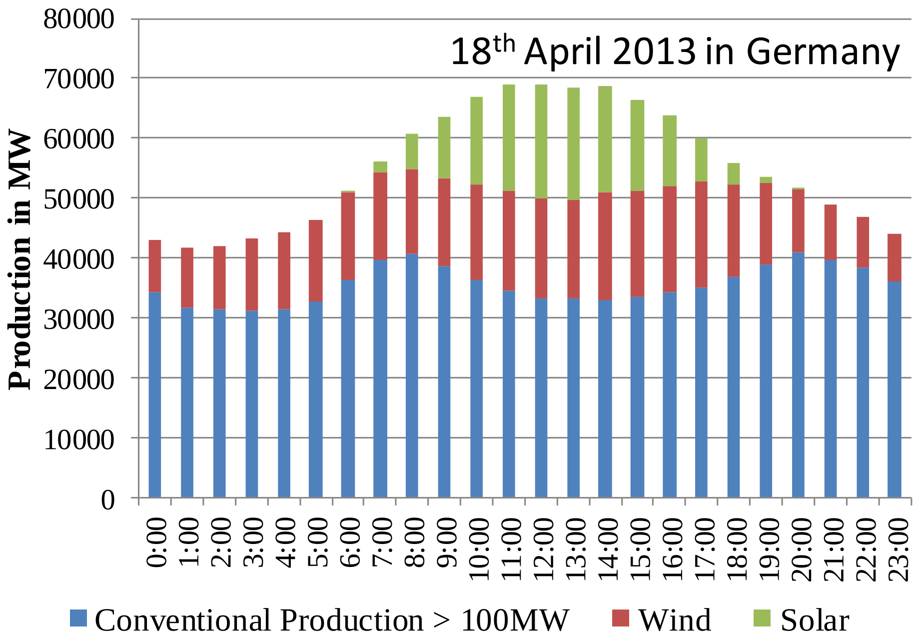
Motivation

- Strong increase of inverter-coupled generating units
- In Germany temporarily over 50% of power generation from PV and Wind

Change of future network

- Loss of flywheel mass
- Decentralization power production
- Future mix pf power plant park will be inverter-dominated

➔ Power system stability (PSS) has to be assured



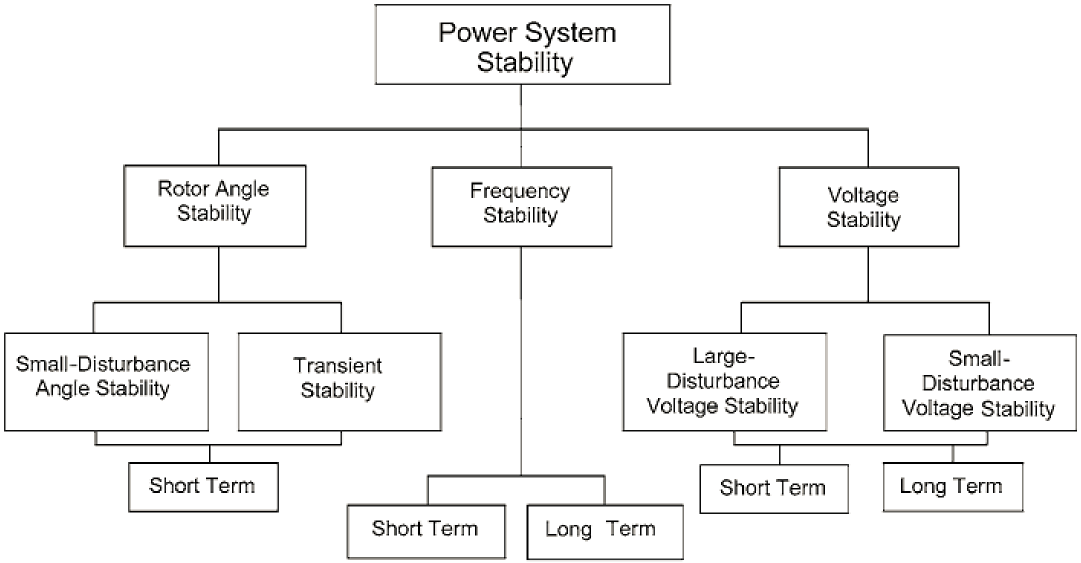
Fraunhofer IWES

2. Power System Stability

Definition of Stability

Conventional PSS

- Focused rotating generators
  - Rotor angle stability
  - Frequency stability
  - Voltage stability



➔ Reconsideration of conventional stability assessment

Source: Definition and Classification of Power System Stability, IEEE/CIGRE Joint Task Force, P. Kundur et. al.

2. Power System Stability

Scenarios of different PSS Disturbance

Factors for network imbalance

- Failure/blackout of
  - central power plants
  - large loads
  - transmission line
- HVDC terminals
- Switching operations on transmission network
- Weather influence
- Change of active coupling points of the interconnection to boundary networks

Fraunhofer IWES

2. Power System Stability

Network Support Today – In Future

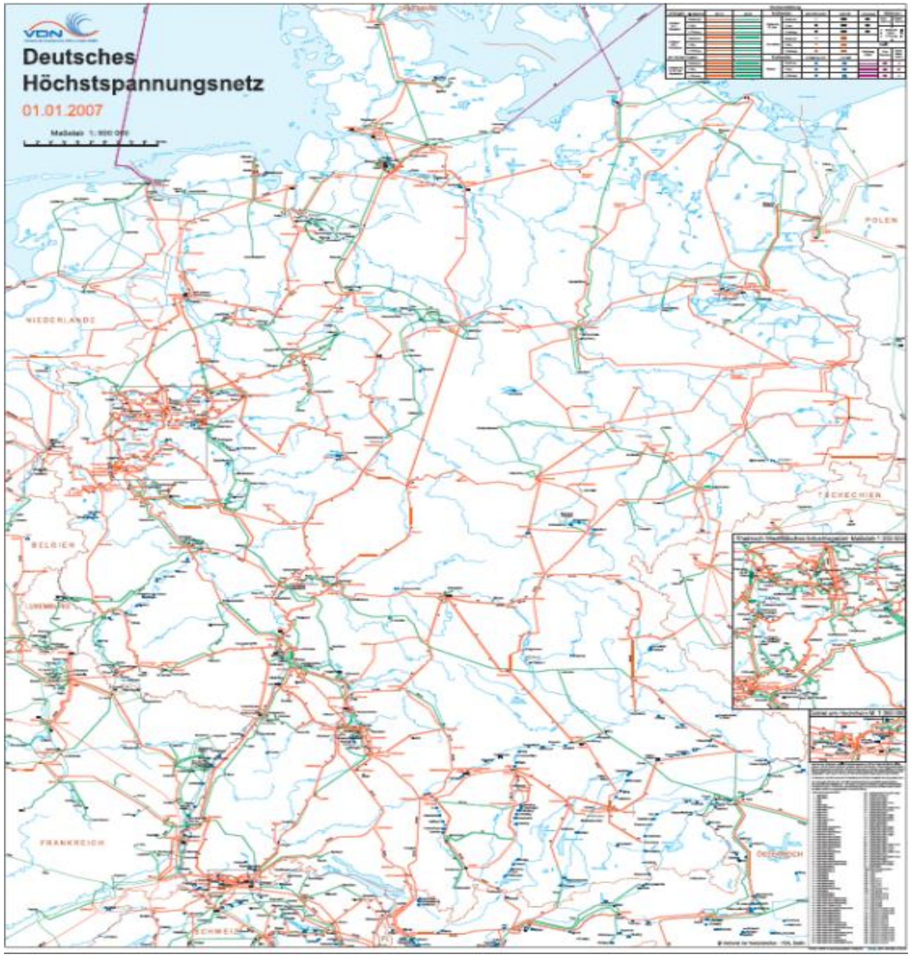
Movie

3. Simulation Environment

Motivation

Intention of new simulation platform

- Holistic simulation of transmission and distribution network in terms of stability studies
- Include properties of decentralized generators in the distribution network
- Availability for real-time simulations, esp. PHIL simulations
- Derivation of the needs of the power system, while increasing inverter-based generators on a scientific basis



Fraunhofer IWES

3. Simulation Environment

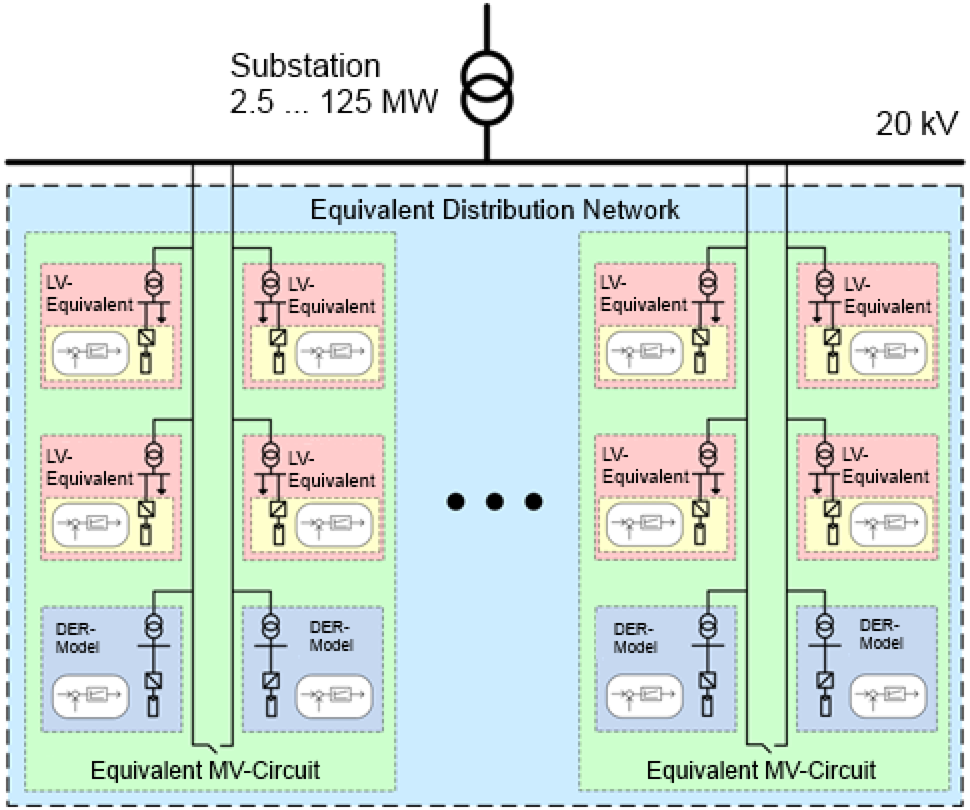
Dynamic Model of Distribution Networks

German interconnection network

- Holistic stability analyses required
- >> 100.000 nodes and machines from high voltage down to low voltage level

Handling

- Aggregated models of distribution networks with dynamic behaviors
- Development of models ≤ 110 kV which are scalable and containing the influence of distribution generators
- Verification of network models based on available data of real network disturbance



Fraunhofer IWES

3. Simulation Environment

Benefits/Summary

Advantage

- Use of self-made simulation models
- Access of calculation equations and simulation routine

Challenges

- Development of a holistic interconnection network simulation
- Real-time capability and compatibility with real-time products
- Parallel simulation on different cores is necessary, due to high numbers of nodes

General Benefits

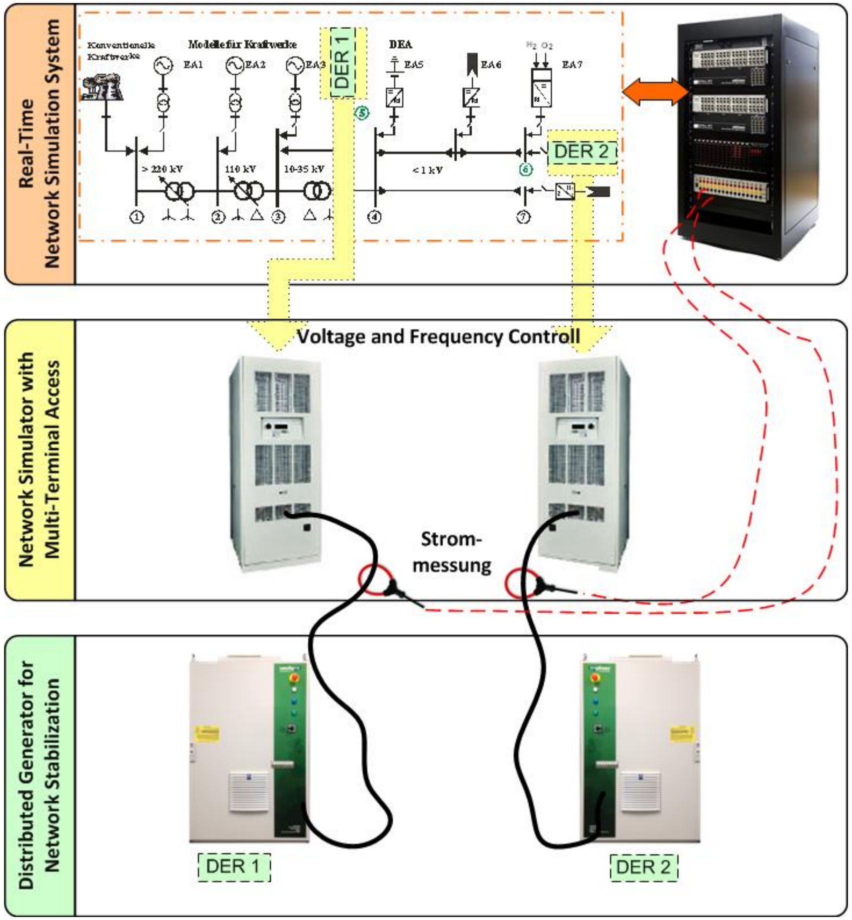
- Flexibility → total access for developer possible
- Scalability → Level of detail user defined
- Expansion to new research fields

4. Hardware Environment

Laboratory Test bench

Power Hardware-in-the-Loop test bench

- Development, construction and operation of PHIL test Bench
- Demonstration of the contribution of distributed generators (DER) to power system stability in a laboratory environment
- Verification of the influence of power-stabilizing control method from inverter-based generators by coupling real-time simulations with larger transmission and distribution networks



4. Hardware Environment

Laboratory (under preparation)

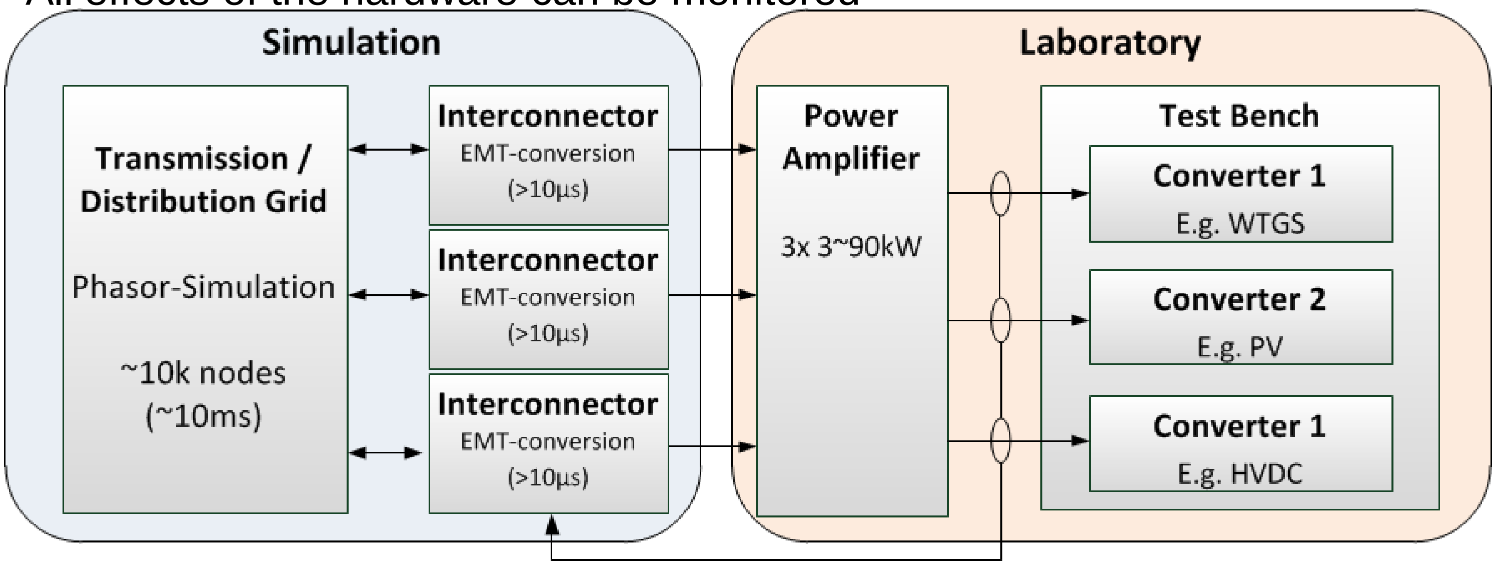
- Systec Laboratory, Fraunhofer IWES
- Power Hardware-in-the-Loop test bench
  - Ametek, Power amplifier, 3x 3phase 90 kVA (single/parallel operation)
  - Scienlab, DC-source (battery emulator), 290 kW
  - TriPhase, DC-DC-AC inverter, 2x 15 kVA

5. Power Hardware-in-the-Loop Simulation

Benefits/Summary

Intention of Power Hardware-in-the-Loop simulation

- Integration of „black box“ devices for stability support (e.g. converters)
- Level of detail increased due to use of the real hardware in comparison to software models
- All effects of the hardware can be monitored

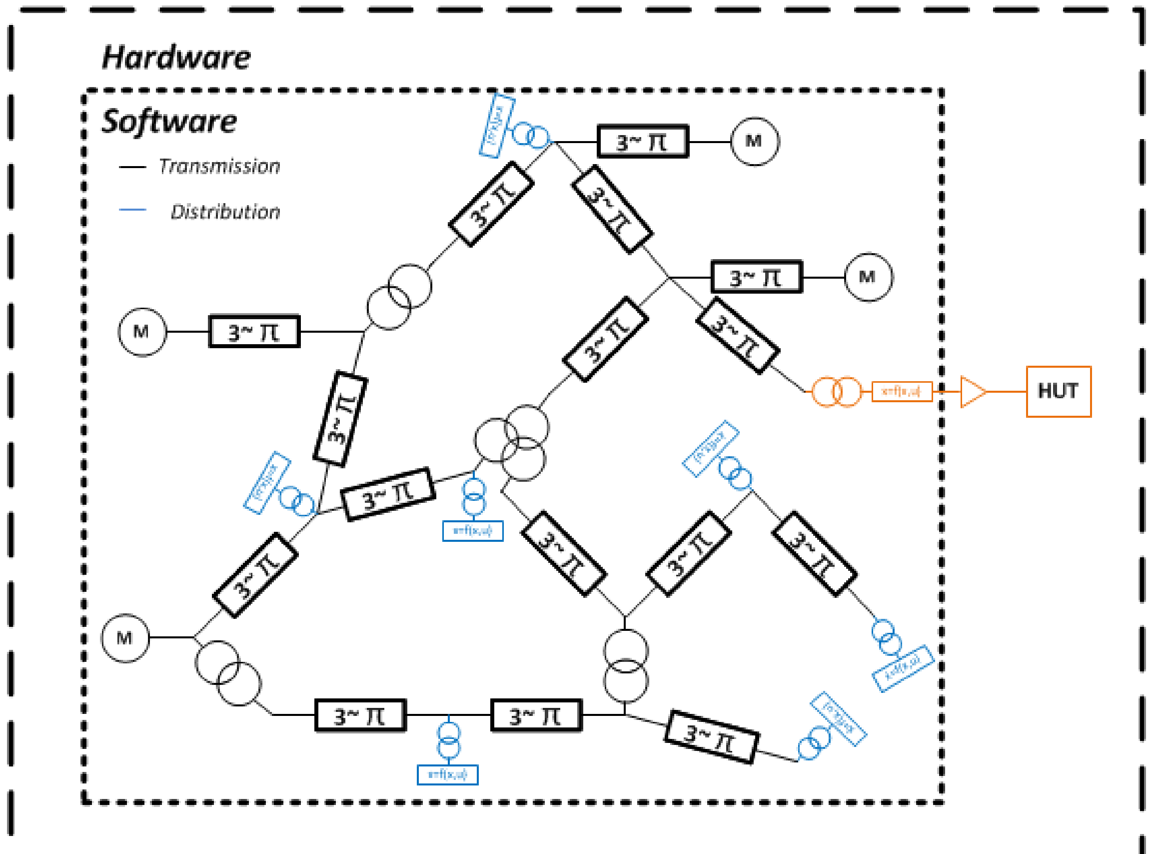


5. Power Hardware-in-the-Loop Simulation

Network Simulation Scheme

German interconnection network

- Transmission level
  - 2.000 nodes
  - 1.000 machine
- Distribution level
  - Aggregated models
  - 4.500 active nodes
  - 4.000 machines
- Connection point HUT
  - Current feedback circuit



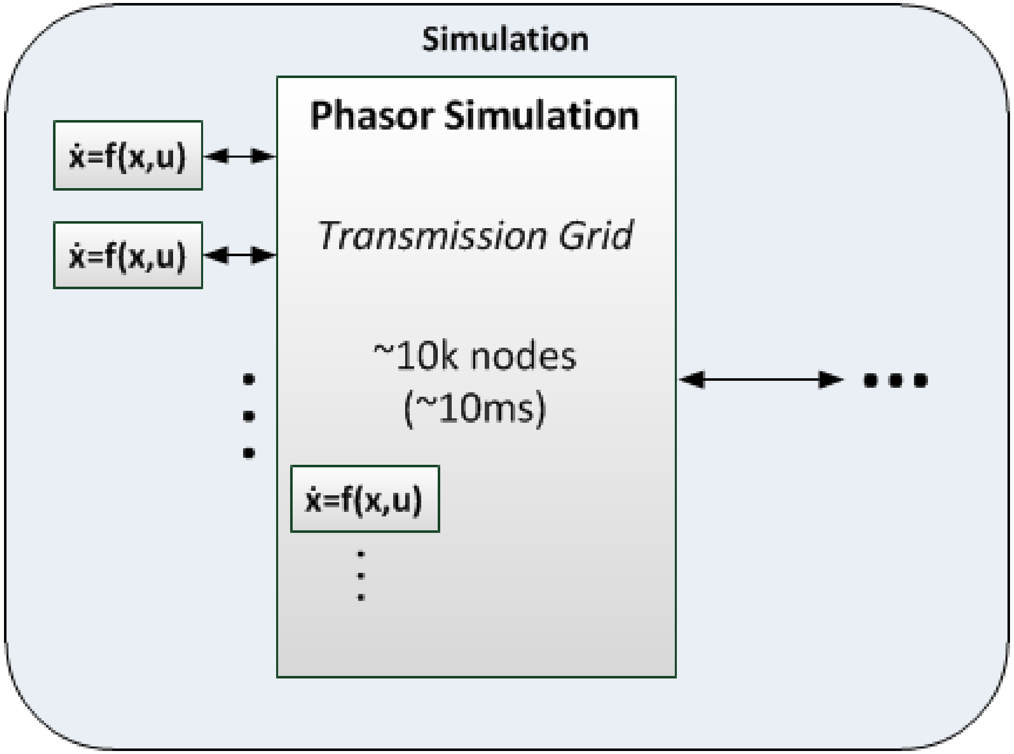
Fraunhofer IWES

5. Power Hardware-in-the-Loop Simulation

Simulation platform

Controlled execution

- Higher-ranked phasor simulation
  - Transmission network simulation
- Adaption/Integration of self-made models
  - Classified aggregated distribution network
  - Distributed generator
    - Wind park
    - Photovoltaic system
    - CHPs
    - HVDC link
    - …



Fraunhofer IWES

6. Conclusion

Summary

Summary

- Reconsideration of power system stability
  - Focusing of inverter-dominated generators in future
- Creating of holistic network simulation for stability analyses
  - Scenarios of conventional PSS
  - Research of new/upcoming PSS
- Power Hardware-in-the-Loop
  - Laboratory Test – “Black Box” or self-programmed inverter testing

Outlook

- Network simulation for stability studies
- Development of new control strategy for DER
- Advanced test platform for DER

Thanks for your attention

Ron Brandl

Fraunhofer Intitute of Wind Energy and Energy System Technologie
Koenigstor 59
34119 Kassel/Germany

Ron.Brandl@iwes.fraunhofer.de

Acknowledgement
We acknowledge the support of our work by the German Ministry for the Environment, Nature and Nuclear Safety and the Projekträger Jülich within the project “DEA-Stabil: Beitrag der Windenergie und Photovoltaik im Verteilungsnetz zur Stabilität des deutschen Verbundnetzes” (FKZ 0325585).

Fraunhofer IWES