THE RELEVANCE OF GRID-FORMING CONVERTERS AND HOW TO TEST THEM

Tech Talk and Digital Lab Tour

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The Smarter E Industry Days

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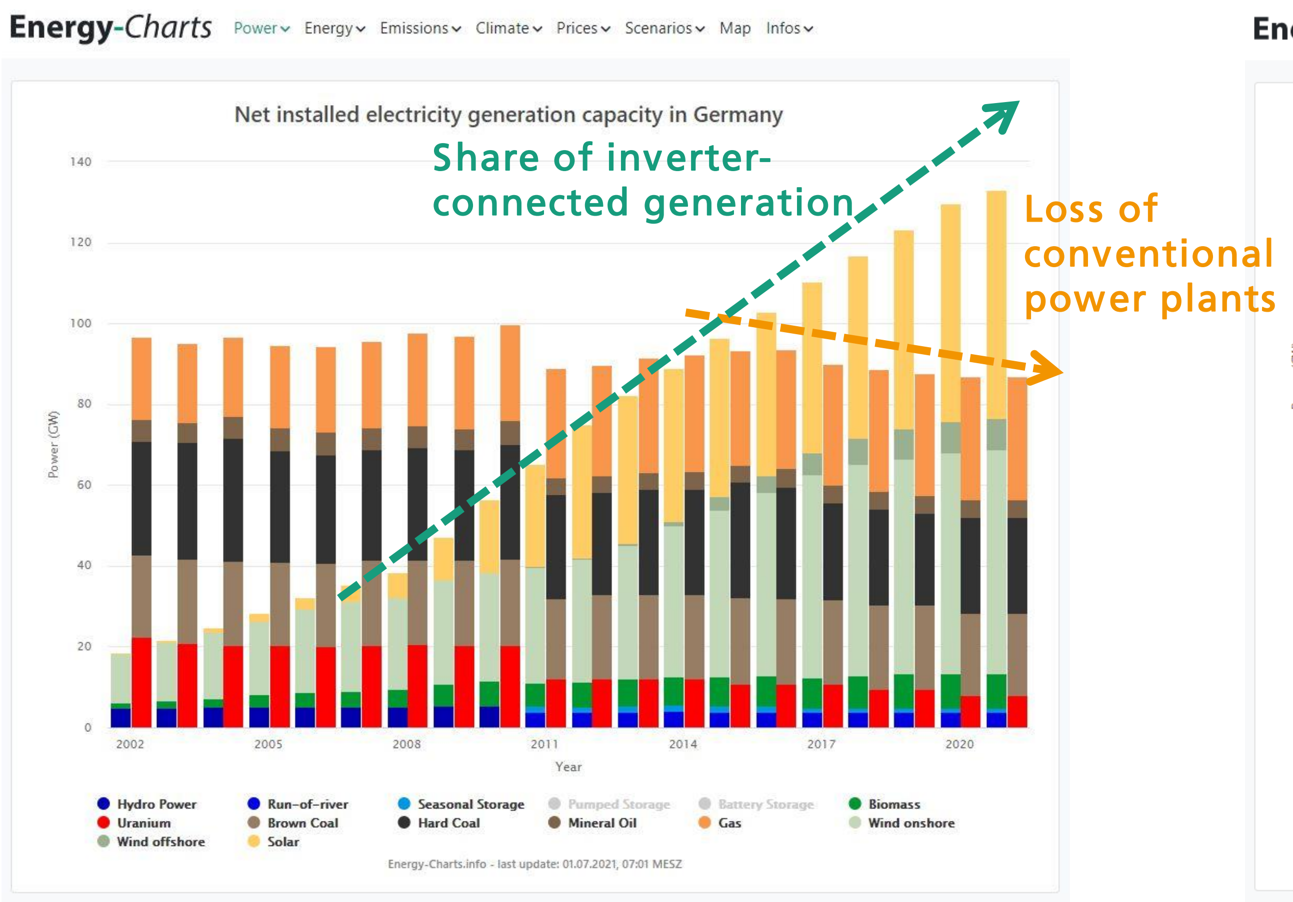
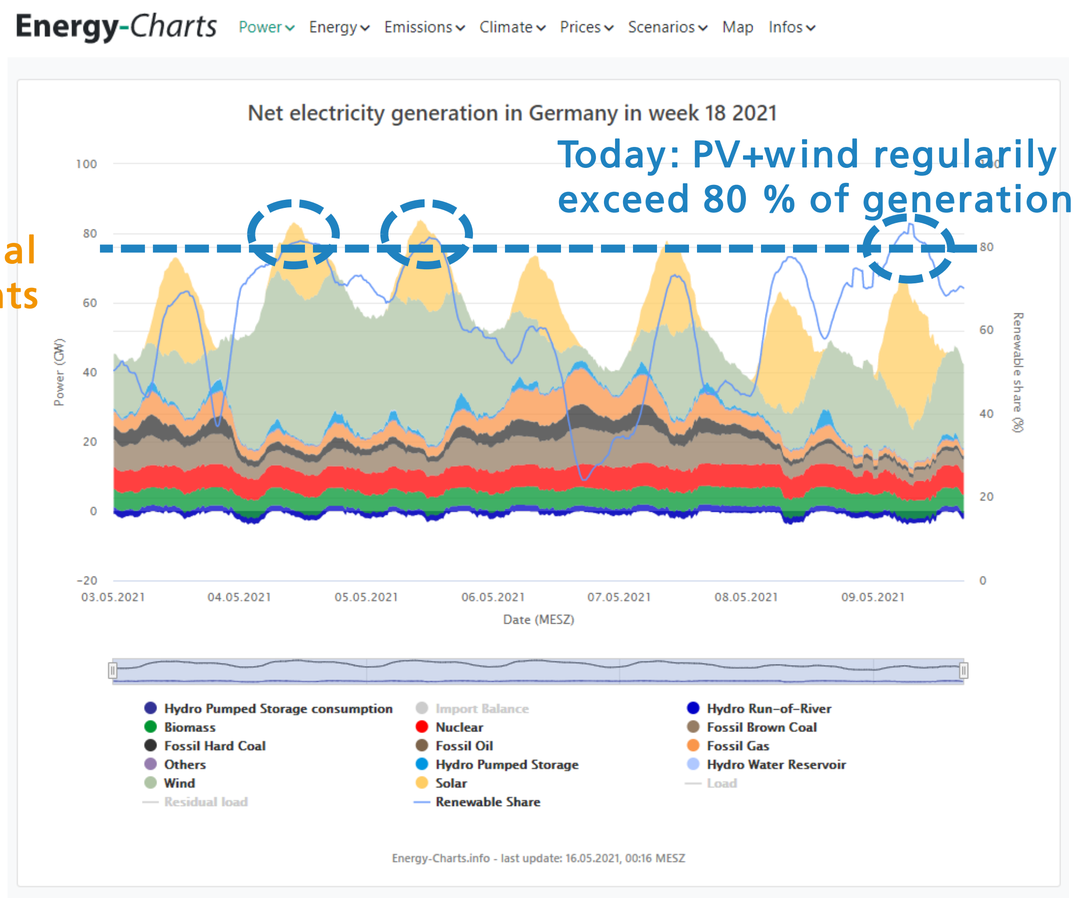
www.ise.fraunhofer.de

Motivation

Why Do We Need Grid-Forming Converters?

Motivation
Towards 100% Renewable Energy Generation





Source: Energy Charts (www.energy-charts.info)

"Electronification" of the Power Grids

Estimated installed inverter capacity for generation and storage in the German power grid

Plant type	2020*	2030**	2050***
Photovoltaics	54 GW	200 GW	415 GW
Wind onshore	54.8 GW	144 GW	260 GW
Wind offshore	7.7 GW		
Large battery storage	0.5 GW	84 GW	170 GW
Home storage	0.7 GW		
Electrolyzers	0.0 GW	5 GW	75 GW
Total	**106 GW**	**433 GW**	**970 GW**

Inverter capacities will increase
4x in the next 10 years /
10x in the next 30 years

Inverters are the technological backbone of the future energy grid!

*) Energy Charts - Installed net capacity for electricity generation in Germany in 2020; Transmission system operators' data on prequalified battery storage for primary control power; Derived from 2018 Annual Report on Storage Monitoring Program & 2019 Update; BSW fact sheet on the German solar power industry 2020;
**) Derived from the targets of the German government's Climate Protection Act 2021, National Hydrogen Strategy;
***) Fraunhofer ISE study "Pathways to a Climate Neutral Energy System"; 2020.

Replacement of Synchronous Generators by Inverters

source: Siemens

source: GE Power Conversion

Synchronous Generator:

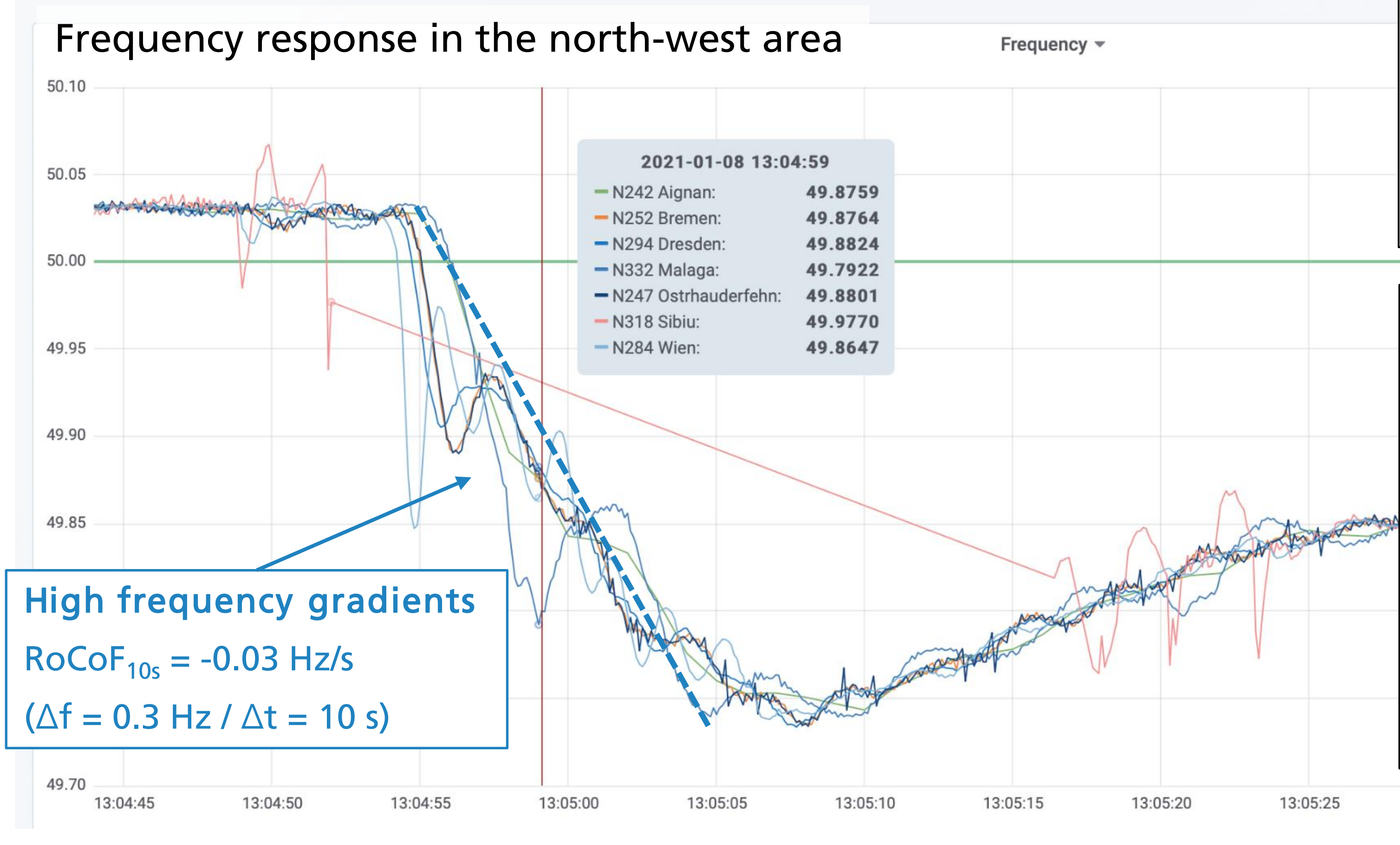
- Inherent voltage source behavior
- Inertia for rotating masses
- High overload capability

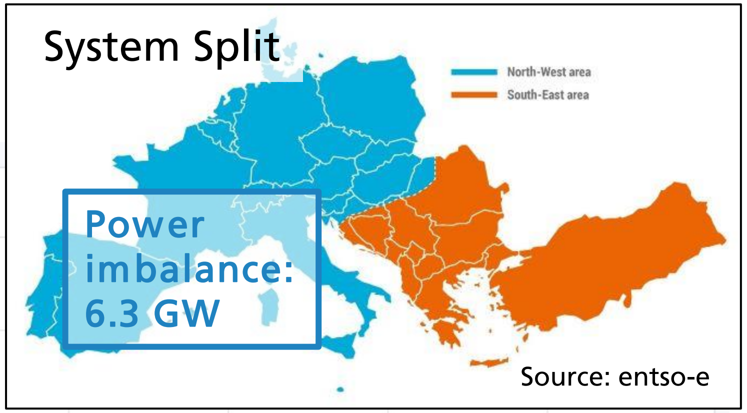
Inverter:

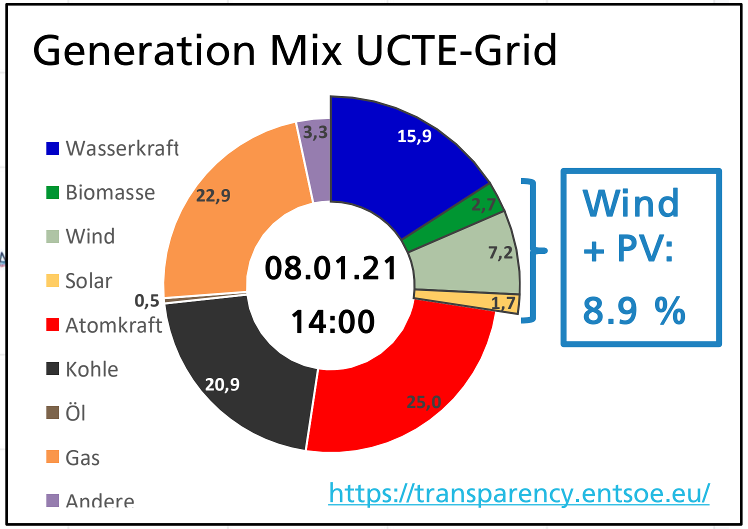
- Freely programmable electrical behavior
- High dynamic controllable
- Hardy overloadable

System Split of the UCTE Grid on 08.01.2021, 14:05h

Frequency Reaction







Sources: http://gridradar.net/ , www.energy-charts.info, https://www.entsoe.eu/news/2021/01/15/system-separation-in-the-continental-europe-synchronous-area-on-8-january-2021-update)

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Definition

What Are Grid-Forming Converters?

Control Types of Grid-Coupled Inverters

	Current Controlled		Voltage Controlled	
	Grid Following	**Grid Supporting**	**Grid Leading**	**Grid Forming**
Type of Source	Constant current source	Controlled current source	Fixed voltages source	Controlled voltage source behind an impedance
Application	Power feed-in	Power feed-in and provison ancillary grid services	Island grids with single voltage source	Interconnected systems with multiple sources

State of the art

Required for future grids

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Motivation
What are grid forming inverters (GFC)?

GFC should enable stable grid operation without synchronous generators.

- *"Grid Forming Converters shall be capable of supporting the operation of the AC power system (from EHV to LV) under normal, disturbed and emergency states without having to rely on capabilities from Synchronous Generators (SGs). This shall include the capabilities for stable operation for the extreme operating case of supplying the complete demand from 100% converter based power sources. "*[1] [HPoPEIPS Report.]

Required feature of GFC according to HPoPEIPS report:

- *Creating system voltage*
- *Contributing to fault level*
- *Sink for harmonics*
- *Sink for unbalance*
- *Contribution to inertia*
- *Preventing adverse control interactions*

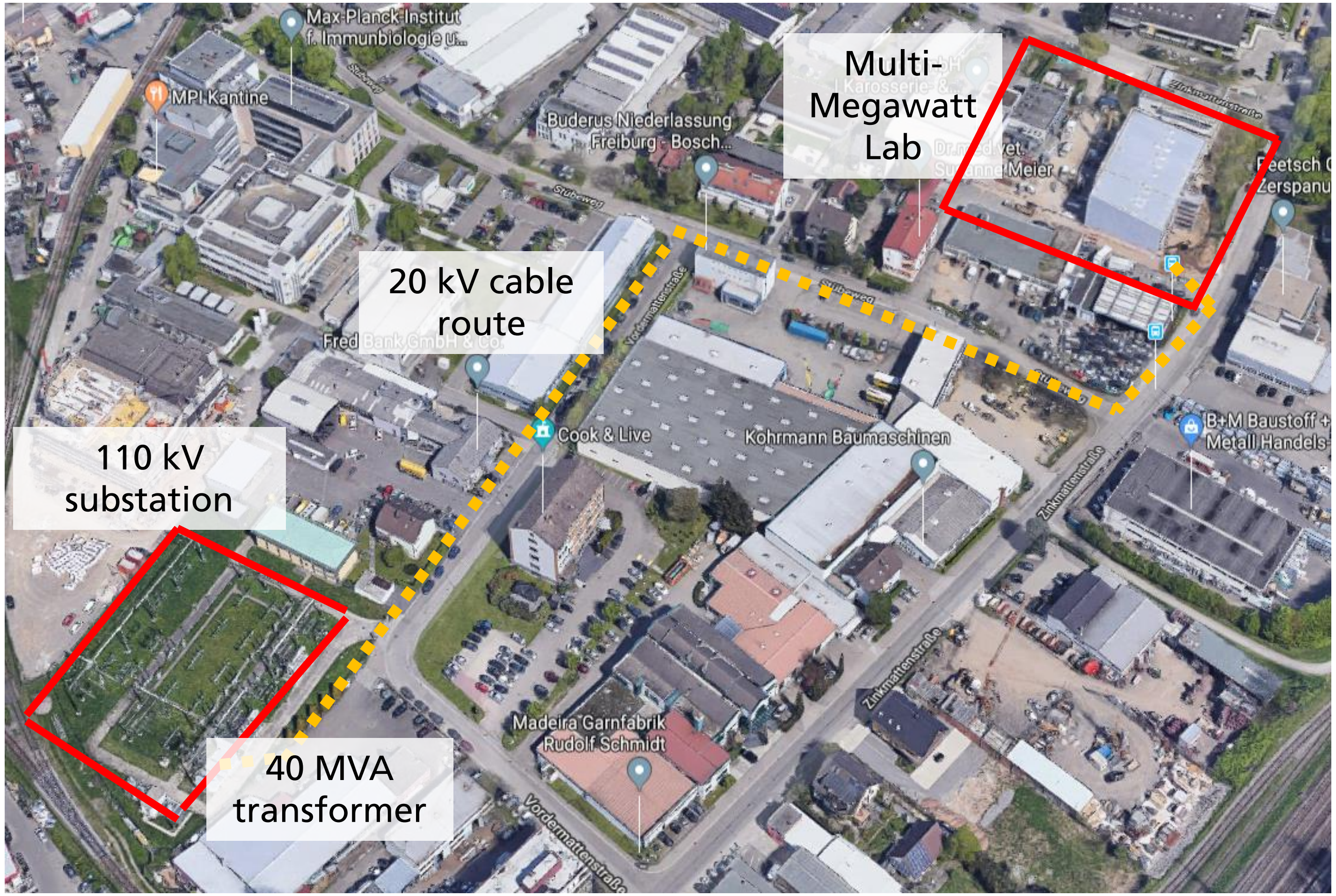
[1]Source:
ENTSO-E, "*Technical Report: High Penetration of Power Electronic Interfaced Power Sources and the Potential Contribution of Grid forming Converters,*" Jan. 2020.

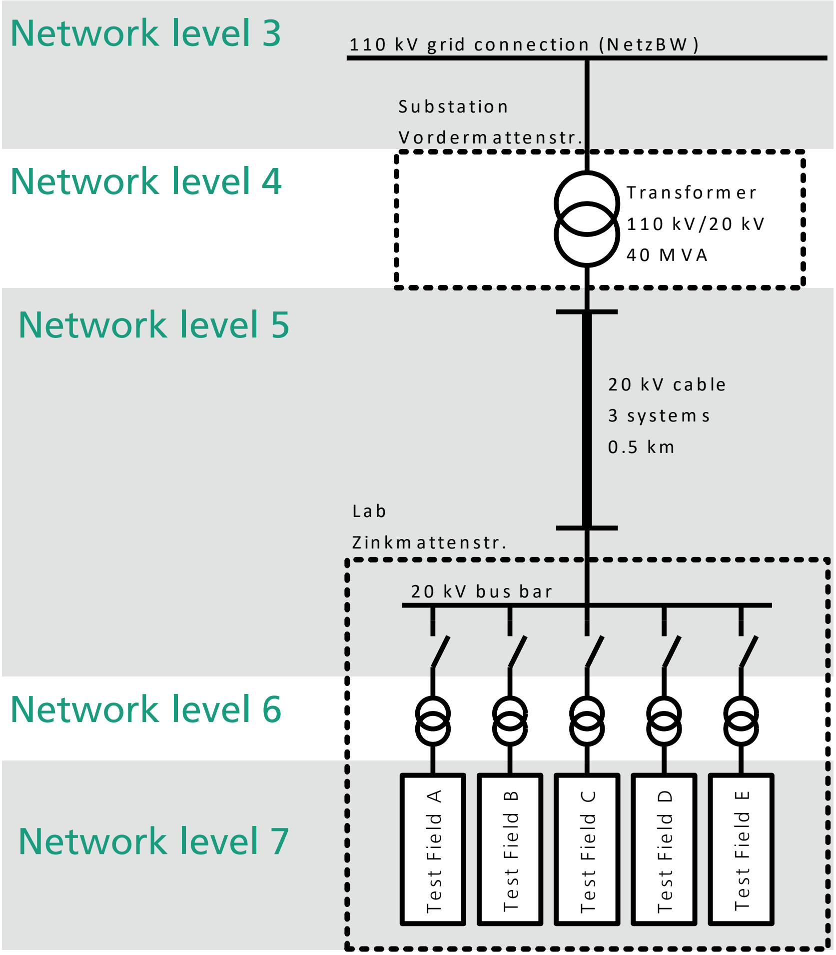
Conformity Assessment

How Can We Test Grid-Forming Convertes?

Testing Inverters at Fraunhofer ISE's Multi-MegawattLab

Infrastructure: 110 kV/40 MVA Grid Connection



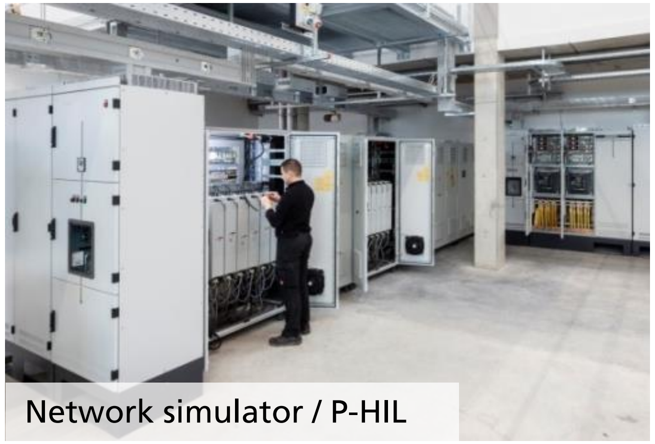


Testing Inverters at Fraunhofer ISE's Multi-MegawattLab

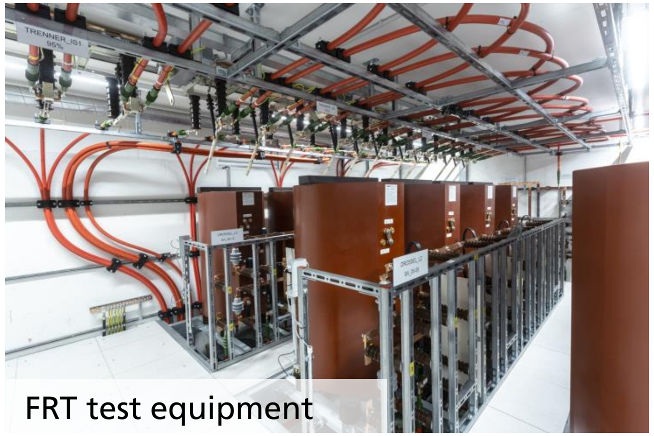
Laboratory equipment

- High-precision, broadband power measurement
- PV generator simulator (up to 2,000 V / 1.4 MW)
- Bidirectional DC sources (up to 1,000 V / 600 A)
- Highly dynamic network simulator with P-HIL functionality (up to 1 MVA)
- Climatic chamber (-30 … +80 °C)
- Mobile and stationary FRT test equipment (4.5 MVA / 10 MVA)
- R, L and C loads (1.2 MW / 7 MVAr)
- Anti-islanding test stand (400 kVA)


PV generator simulator


Network simulator / P-HIL


Climate chamber


FRT test equipment

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Multi-MegawattLab

Now Join Us On Our Virtual Lab Tour…

Properties of GFC to Be Tested

Behavior of GRID FORMING CONVERTER

Voltage source behavior

- Stability of the voltage source
- Effective internal impedance

Voltage quality

- Sink for asym-metries
- Sink for harmonics

Inertia

- Inertia constant H
- Damping D

Overload and fault behavior

- Voltage fault
- Phase fault
- Frequency fault (RoCoF)
- System split

Active/Reactive power control

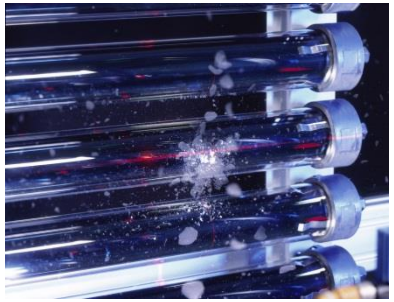
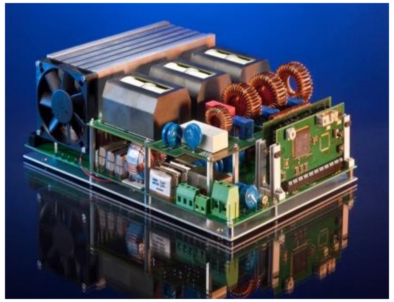
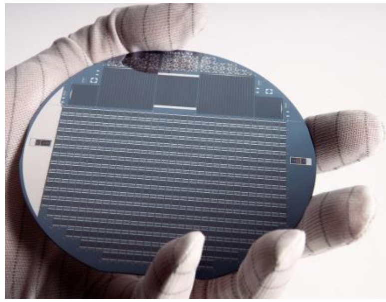
- Control accuracy
- Settling time
- Frequency control (e.g. LFSM-O/-U)
- Voltage control (e.g. Q(U))

Grid interaction

- Impedance spectro-scopy

Thank you for your attention!

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