Karlsruhe Institute of Technology

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A standardized and modular power electronics platform for academic research on advanced grid-connected converter control and microgrids

Frank S.R., Schulz D., Stefanski L., Schwendemann R. and Hiller M.

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Motivation

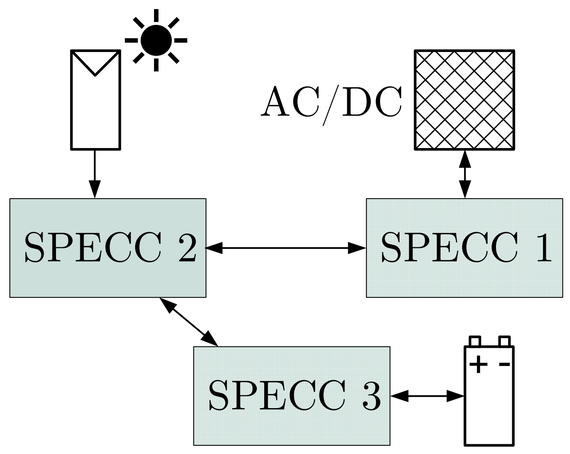
Standardized **P**ower **E**lectronics **C**onverter **C**abinet (**SPECC**)

Properties

- Highly modular design
- From scratch self-developed hard- and software
- Simple reconfiguration and extension
- Cost-effective

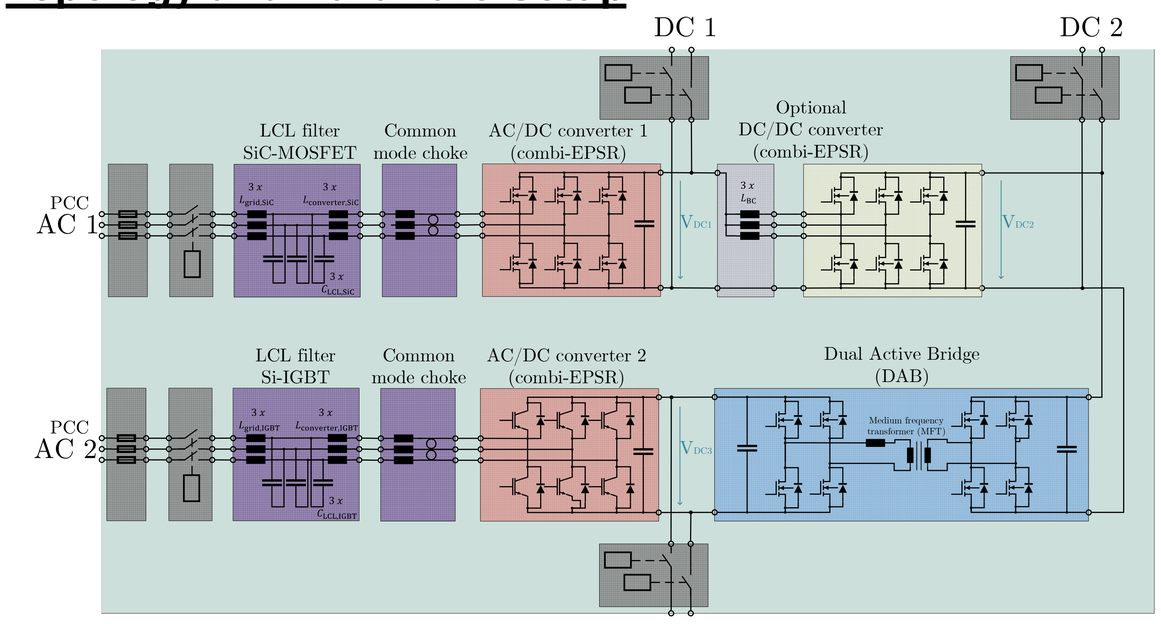
Applications

- Design and control of grid-connected converters
- Coordinated operation of multiple converters
- Emulation of arbitrary grid conditions
- DC grid investigations



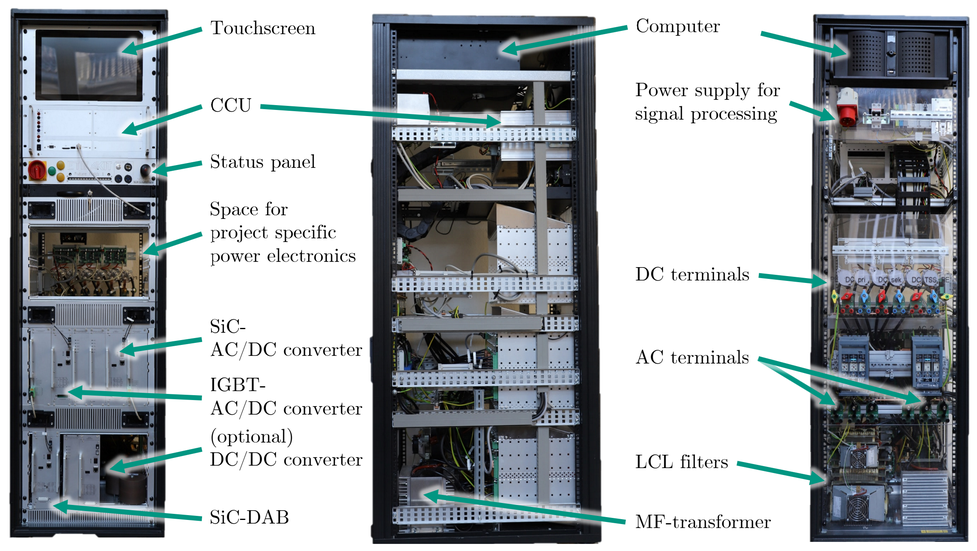
Example interconnection of multiple SPECCs

Topology and Hardware Setup



Topology of one SPECC

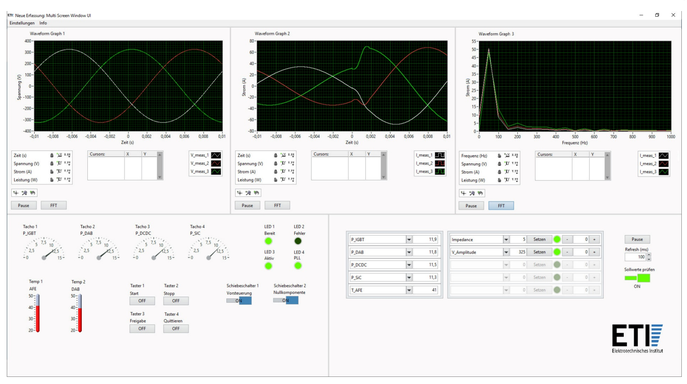
- 2x AC/DC 2L-VSC (SiC-MOSFET and Si-IGBT type) with LCL-filters equipped
- SiC-MOSFET Dual Active Bridge (DAB) to ensure galvanic isolation
- Optional SiC-MOSFET DC/DC converter
- All DC-links accessible via DC connectors



Hardware setup of one SPECC

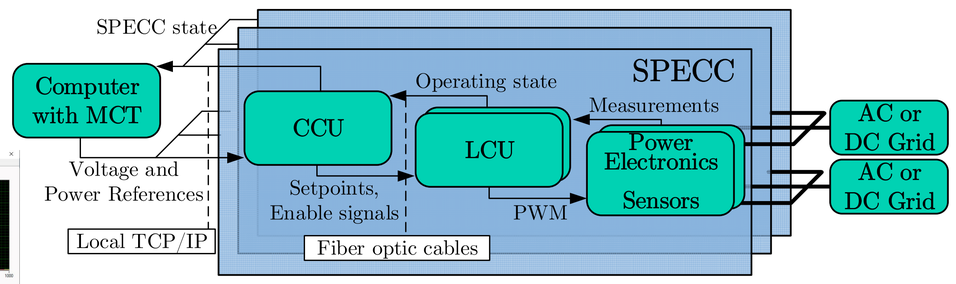
- 30 kW bidirectional power transmission
- DC voltages up to 800 V
- All power electronics units in 19“ racks, spatially separated from signal processing, quick exchange of modules

Signal Processing



Supervising control with monitor control tool (MCT)

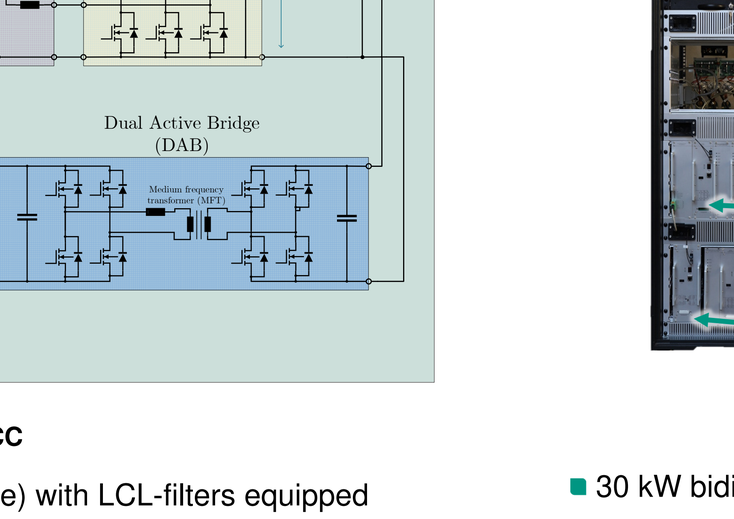
- User configurable GUI
- Central MCT instance enables coordination of multiple SPECCs



Hierarchy and interconnections of the signal processing structure

- Standardized LCU based on Artix®-7 FPGA for each power electronics PCB

→ Applications: Fault detection, high-bandwidth control loops, modulation



Central Control Unit (CCU) with basic SPECC configuration

- Modular CCU with multiple extension cards (ADC, GPIO, fiber-wire..), based on ZYNQ®-7030 SoC

Local Control Unit (LCU)

AC/DC converter (EPSR)

Dual Active Bridge (DAB)

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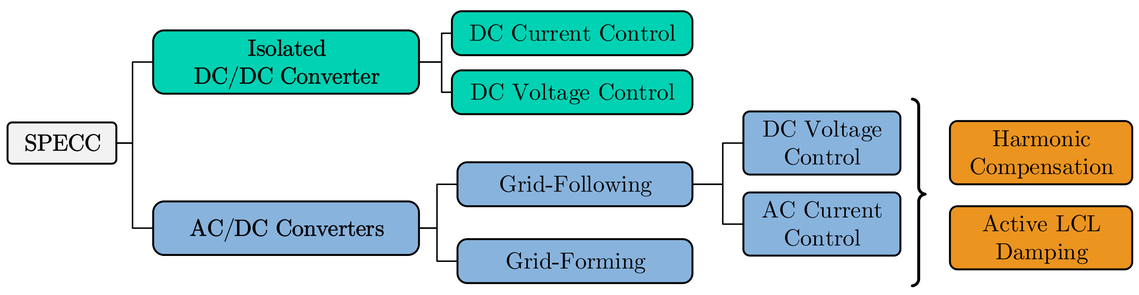
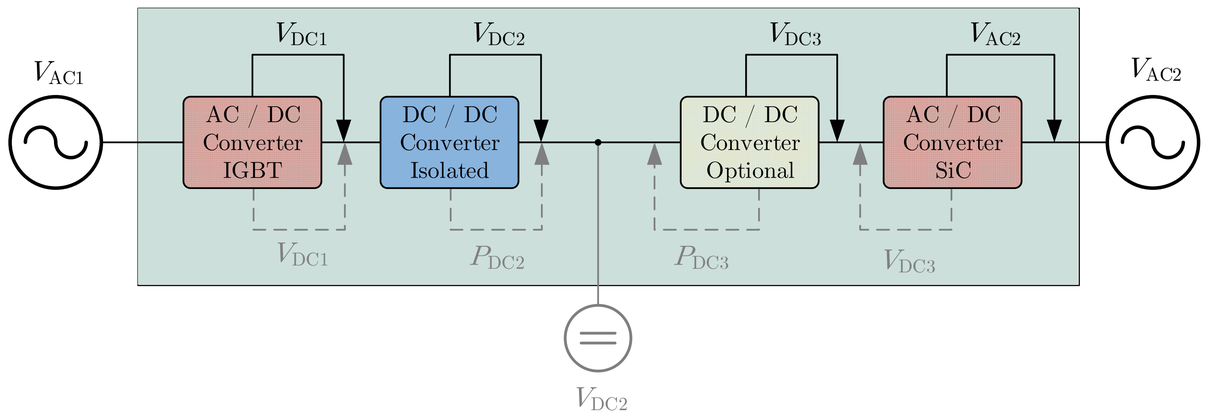
Distributed Control Architecture



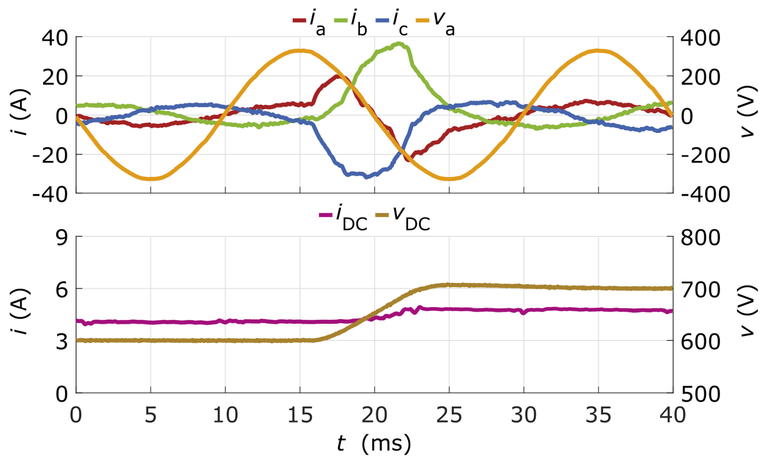
Overview of control methods used within one SPECC



Example control setup for grid-forming operation (black) and constant power load in a DC grid (grey)

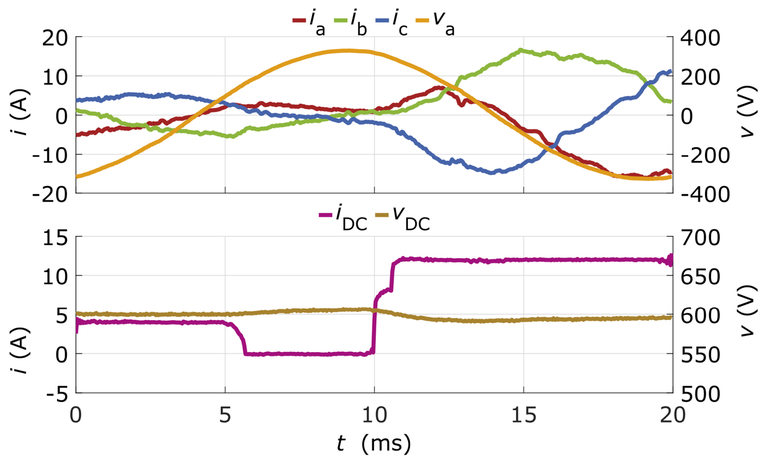
Measurements

Grid following operation



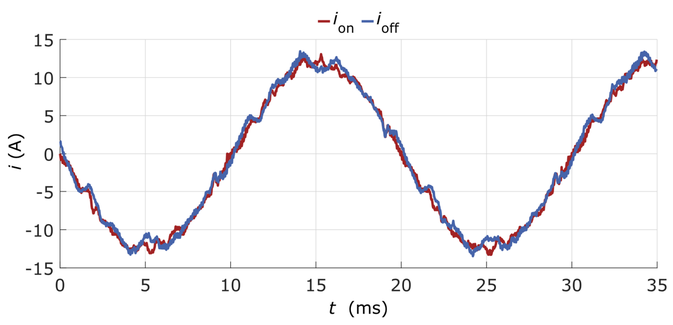
DC voltage setpoint step

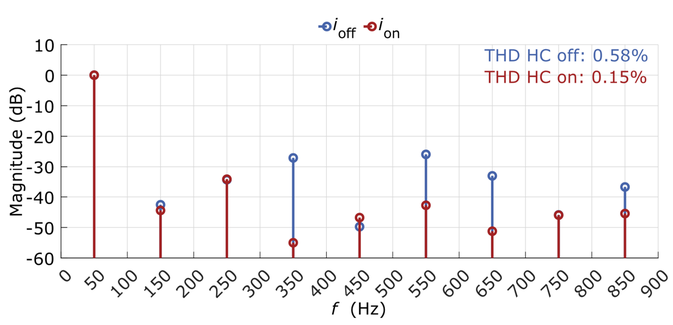
- DC link voltage controlled
- Setpoint change from 600 V to 700 V at $t \approx 16$ ms
- Ohmic load $R = 146\ \Omega$



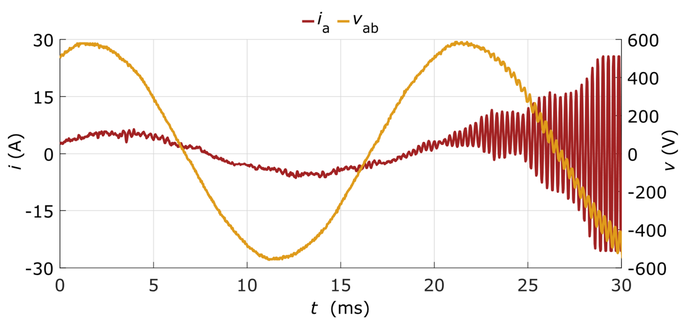
Load step ohmic load

- DC link voltage controlled
- First load step from 146 Ω to high-impedance at $t \approx 5$ ms
- Second load step from high-impedance to 49 Ω at $t \approx 10$ ms



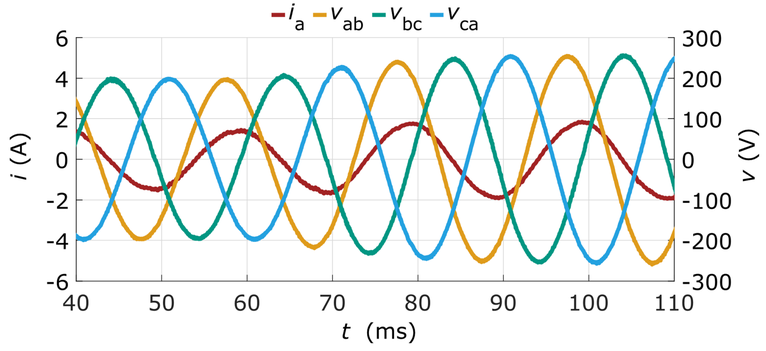


Effect of harmonic compensator on grid current waveform



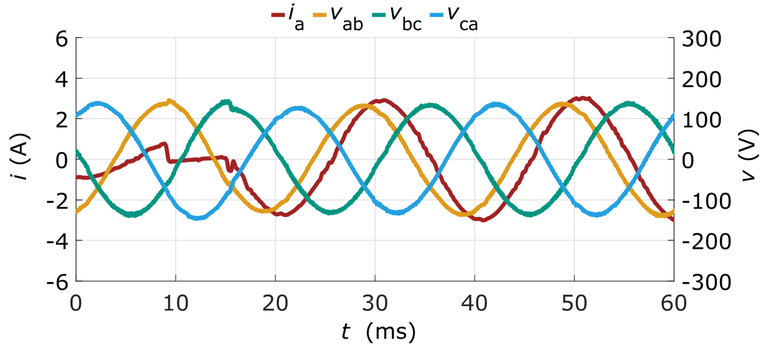
Active damping effect (disabled at $t \approx 17$ ms)

Grid forming operation



AC voltage setpoint step

- Setpoint change V_{LL} from 200 V to 250 V
- Ohmic-inductive behavior of load resistor, $R = 146\ \Omega$



Load step ohmic load

- Ohmic-inductive behavior of load resistor
- First load step from 146 Ω to high-impedance at $t \approx 9$ ms
- Second load step from high-impedance to 49 Ω at $t \approx 15$ ms

Summary

- **Highly modular, standardized power electronics platform with development access from the highest to the lowest level**
- First measurements demonstrate harmonic compensation, active damping and grid forming control with ohmic load

Future work

- Studies on the active filter (capacitor voltage feedback, state-space control with estimators)
- Investigations of control stabilities under typical grid disturbances (voltage dips, unbalances, changes of grid impedance)
- Coupling of several SPECCs for AC and DC microgrid investigations