Mittelspannungsprüffeld

… nur eine Betonhalle mit großer Steckdose?

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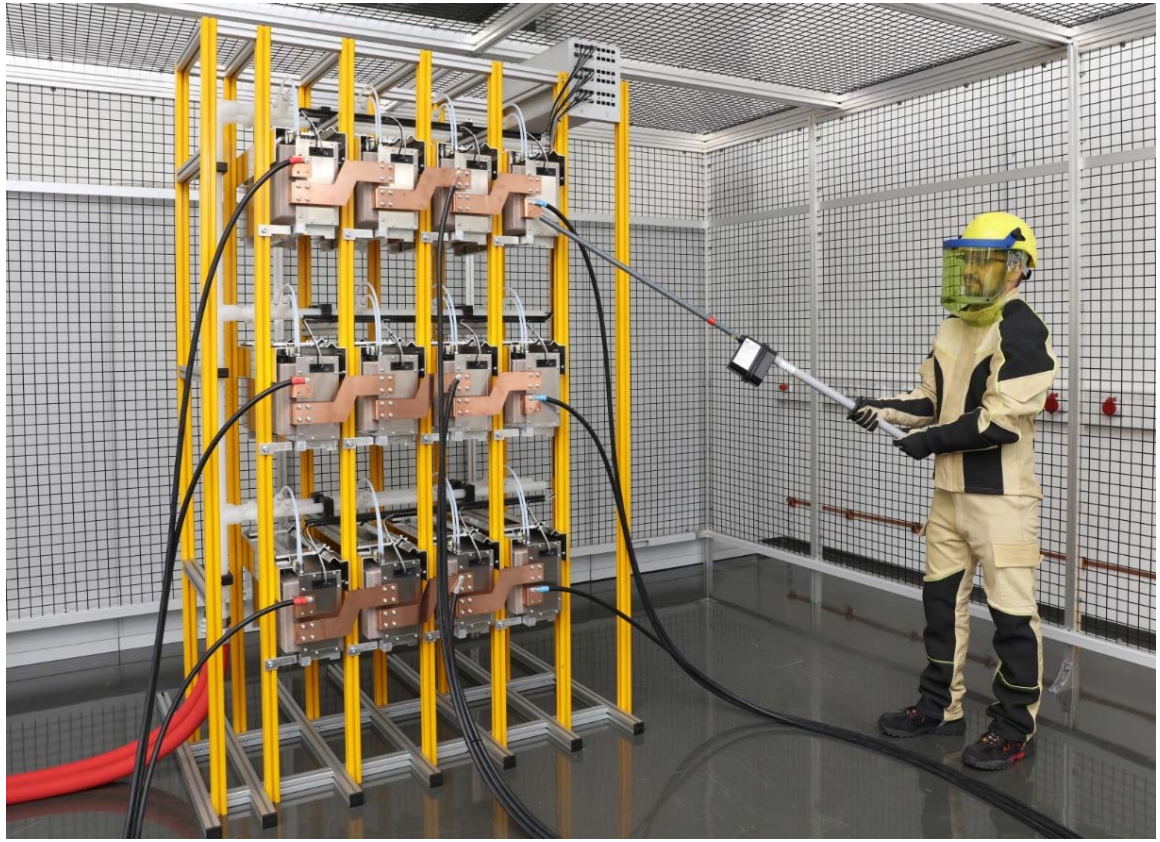


Motivation

Fraunhofer IISB

Status Quo

- Increase of electric consumers
- Increase of electric producers
- Increase of power semiconductor development → Solid state transformers

Challenge

- No lab infrastructure for application relevant tests at medium voltage levels

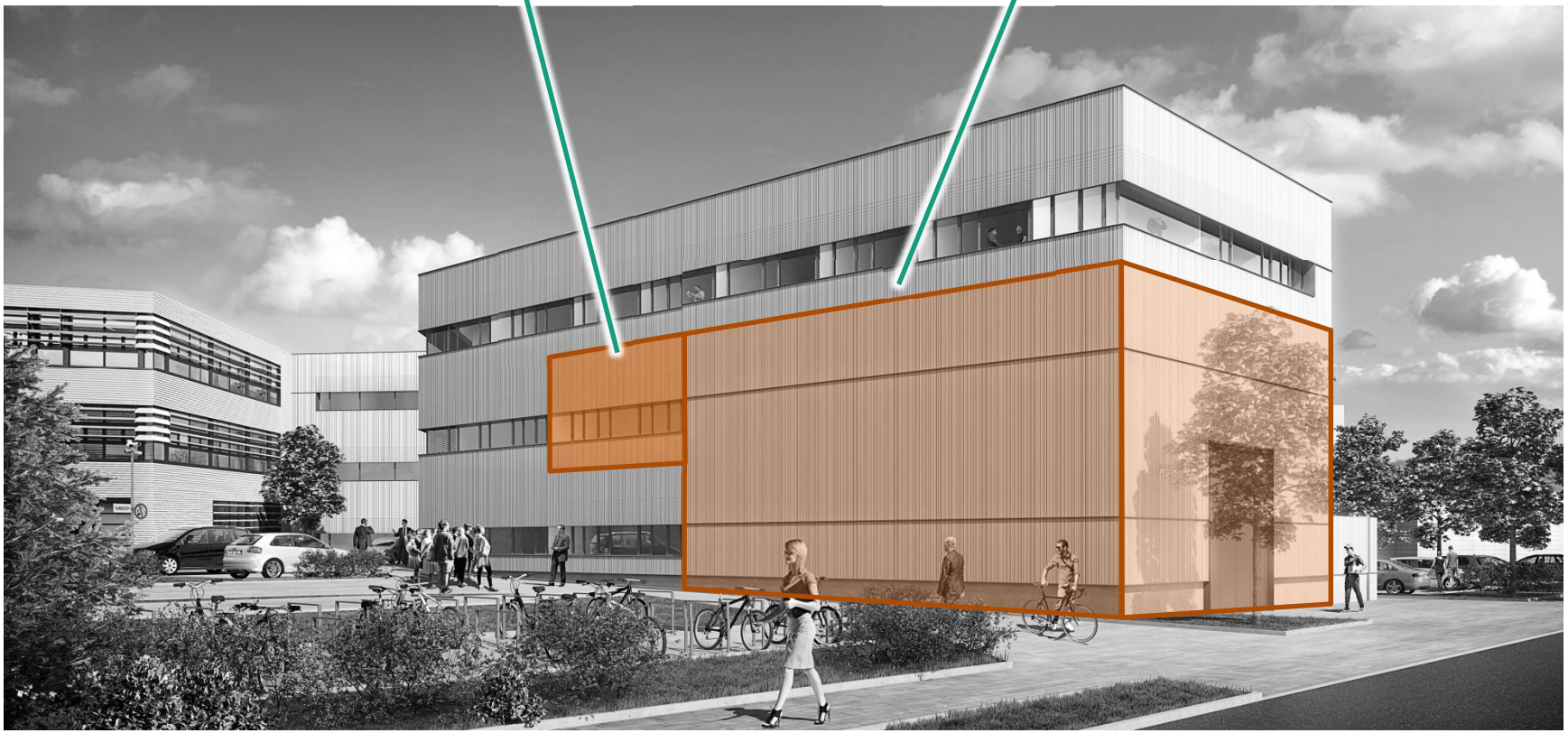
Goal

- High power test infrastructure for today's and future medium voltage energy grid

Specification

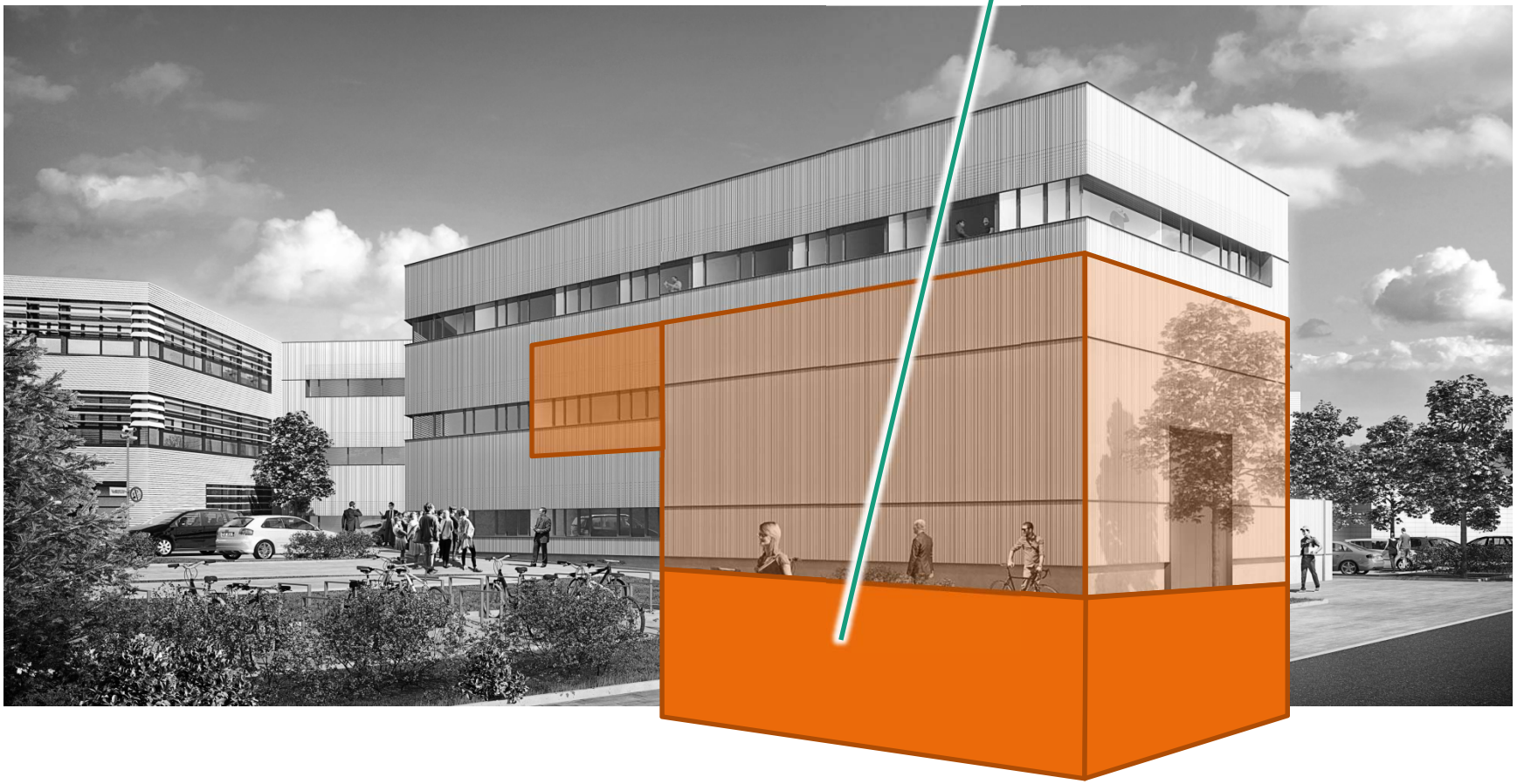
- Up to 30 kV test voltage
- 3 MVA power supply
- DC and AC voltage
- 2 independent sources / sinks
- Robustness: 12 pulse rectifier and low frequency transformer

Medium voltage test bench

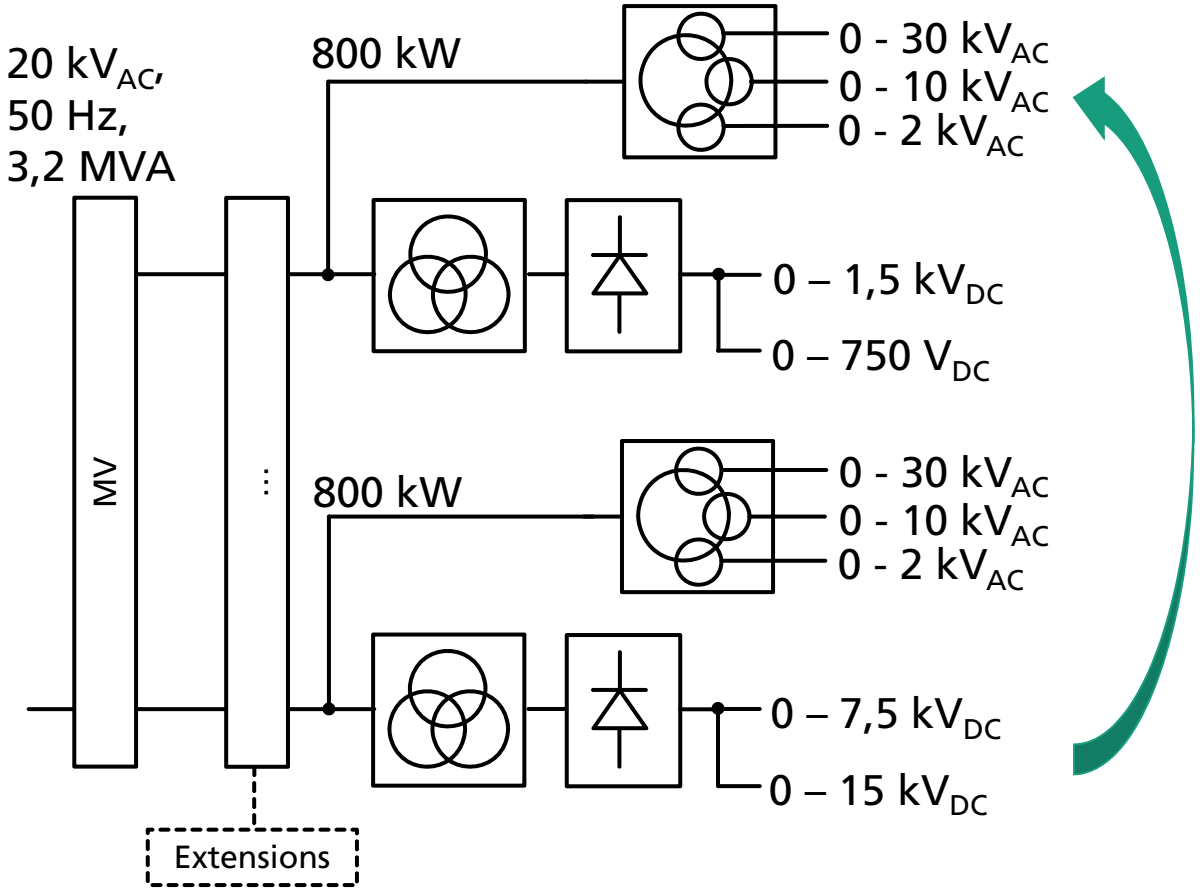


Medium voltage test bench

Fraunhofer IISB



Realization (simplified example)



Power Hardware in the loop

Device under test:
Medium voltage
Converter

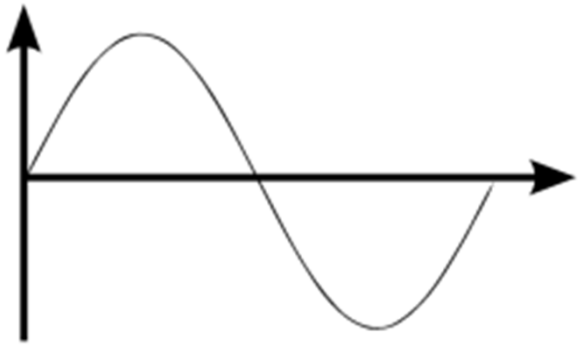
Test bench has to supply the losses only

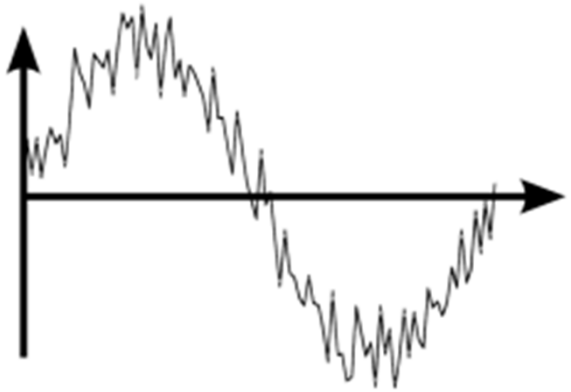
→ Power of the device under test can be much higher!

This test bench allows for tests under **ideal** conditions

But no specific tests at **application relevant** conditions:

- ? Voltage dip
- ? Load dump
- ? Activation of producers
- ? Harmonics
- ? Transients





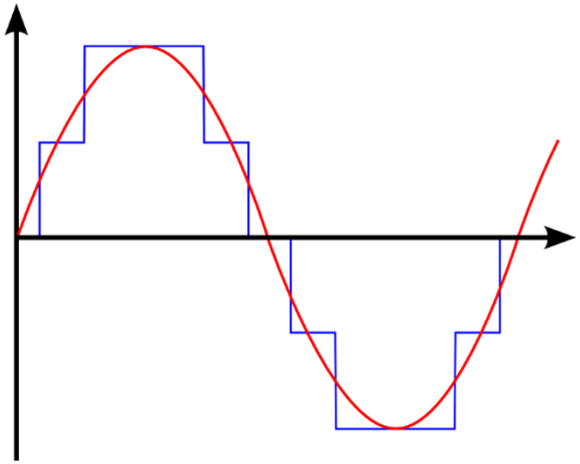
➔ **The transistion from a test bench to a grid simulator!**

Desired characteristics

	Test bench	Test bench + transformer	Grid simulator
Voltage	Step by step	variable	variable
Frequency	50 Hz	50 Hz	variable
Harmonics, transients, …	-	-	✓

Grid simulator:

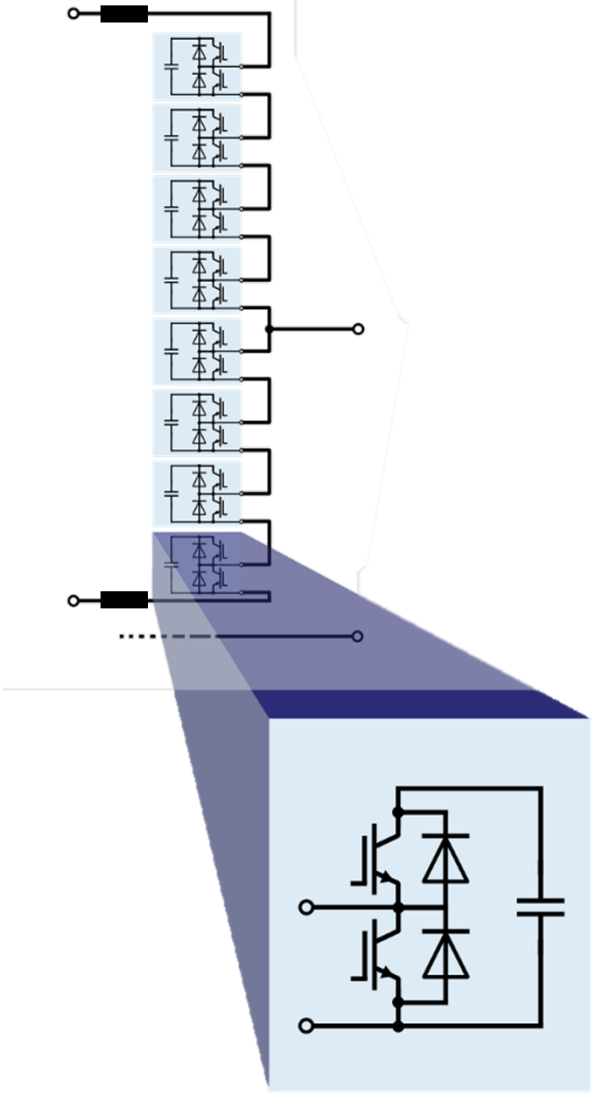
- 100 V – 20 kV test voltage
- Variable frequency
- Sinusoidal waveforms with freely configurable anomalies
- Modular multilevel converter (M2C) instead of 3 level inverters



Medium voltage grid simulator

Fraunhofer IISB

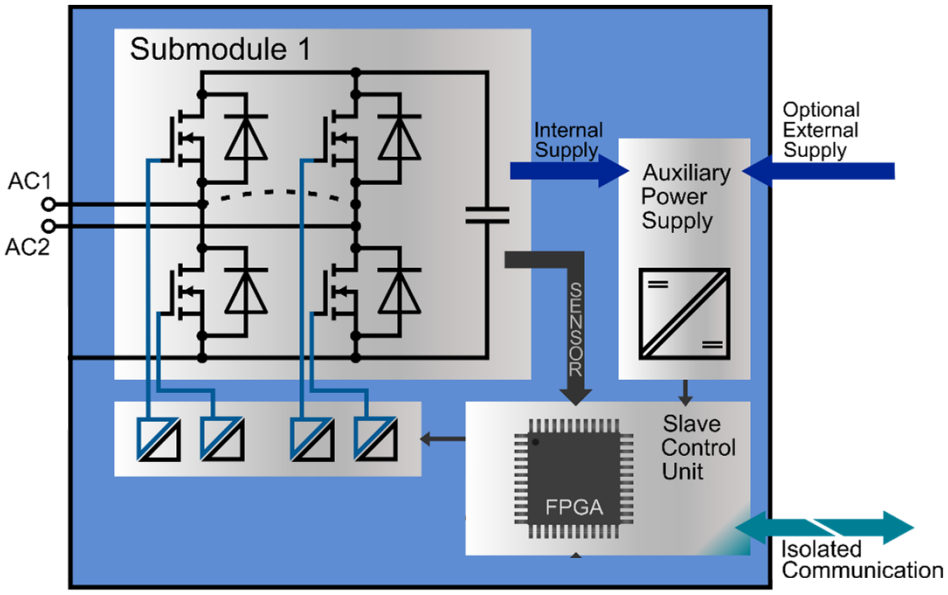
Schematic of single cell



IISB solution

- ✓ 1200 V IGBT (full bridge)
- ✓ Control and Monitoring of 10 system parameters per cell
- ✓ Fast automated control and FPGA real time system with ARM dual core CPU's
- ✓ Galvanic isolation by optic fibers

Communication and sensor concept



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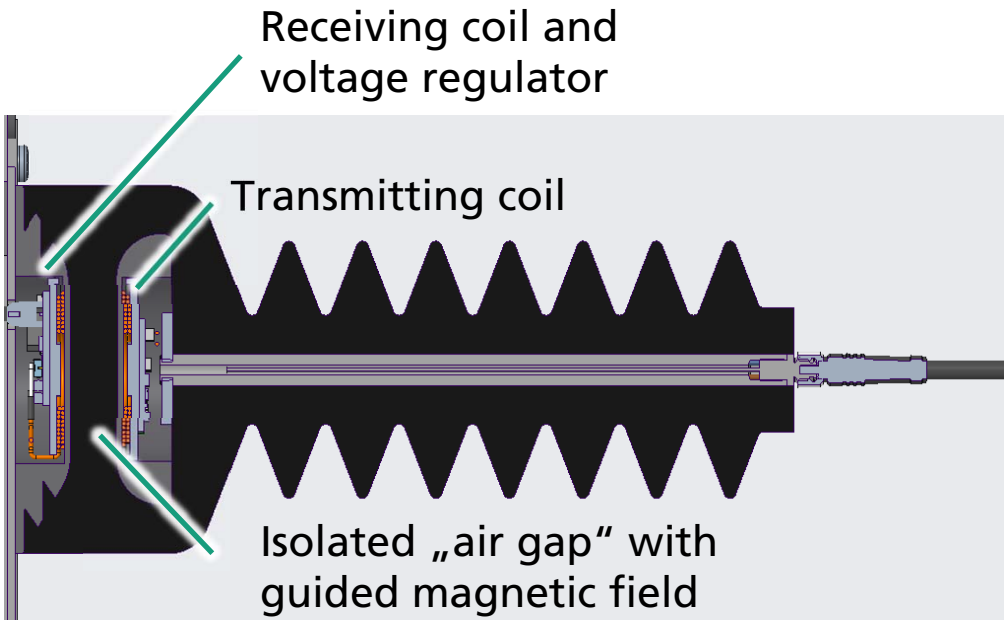
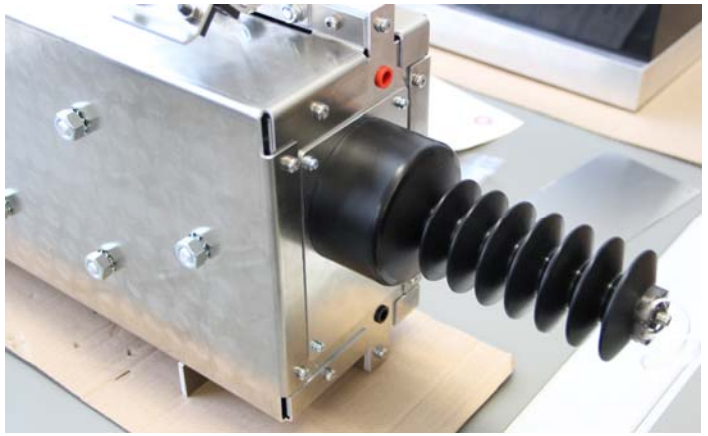
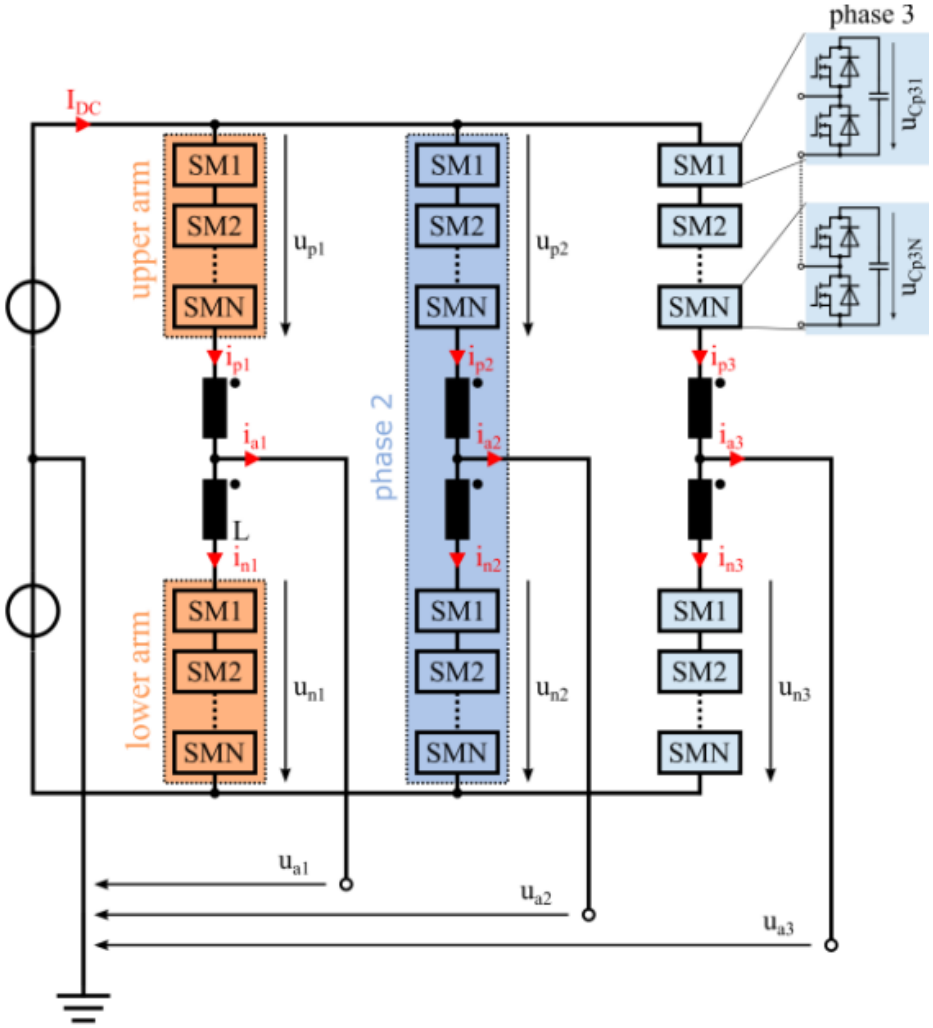
Auxiliary power supply

- 15V, 30W, galvanically isolated for 20 kV
- Inductive power transfer molded in PU-isolator
- No partial discharge at least 50 kV





Schematic of modular multilevel converter



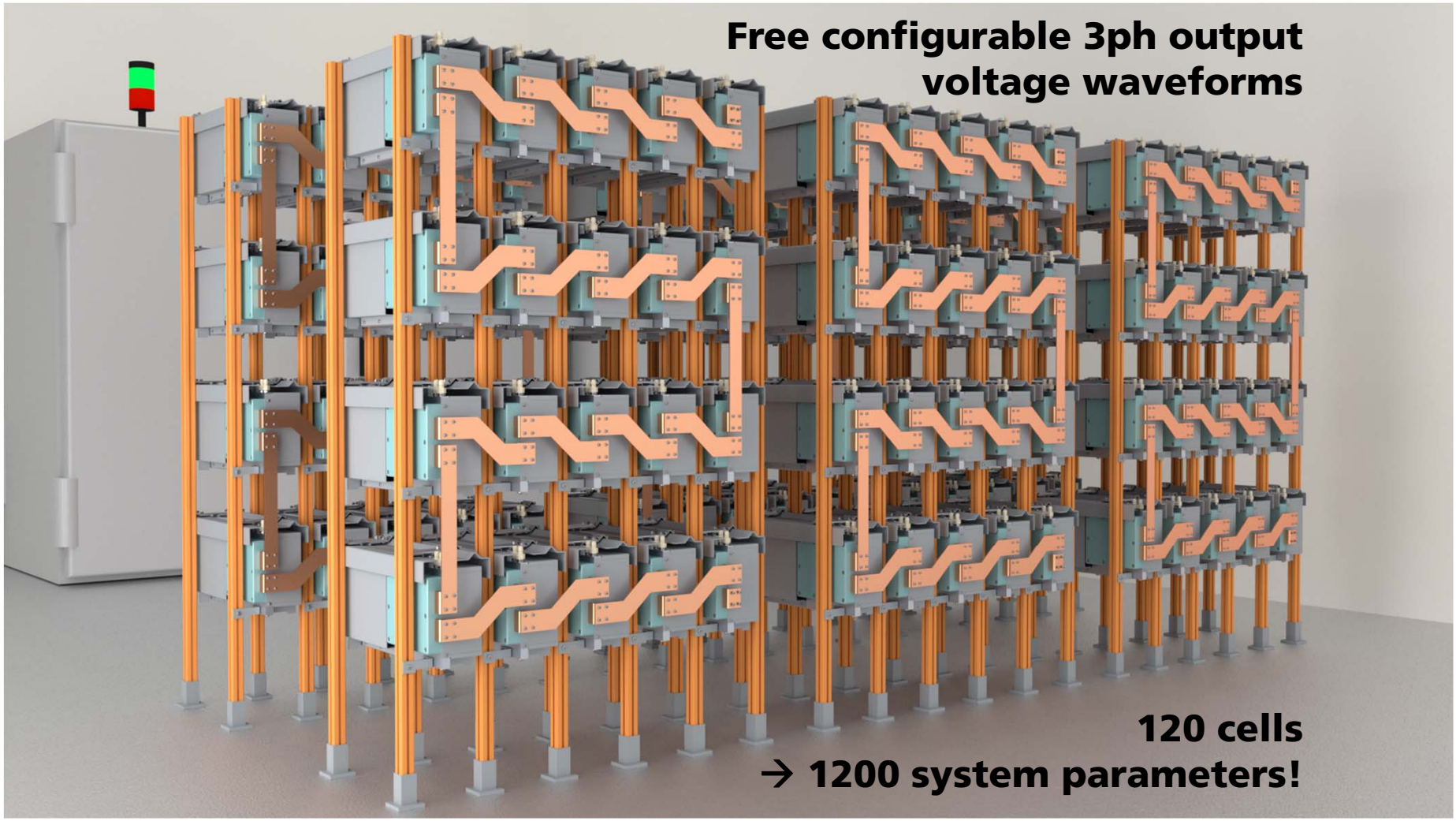
Characteristics

- ! Monitoring and balancing of cells capacitor voltages necessary
- ! Galvanically isolated measurement and communication
- ! High software effort

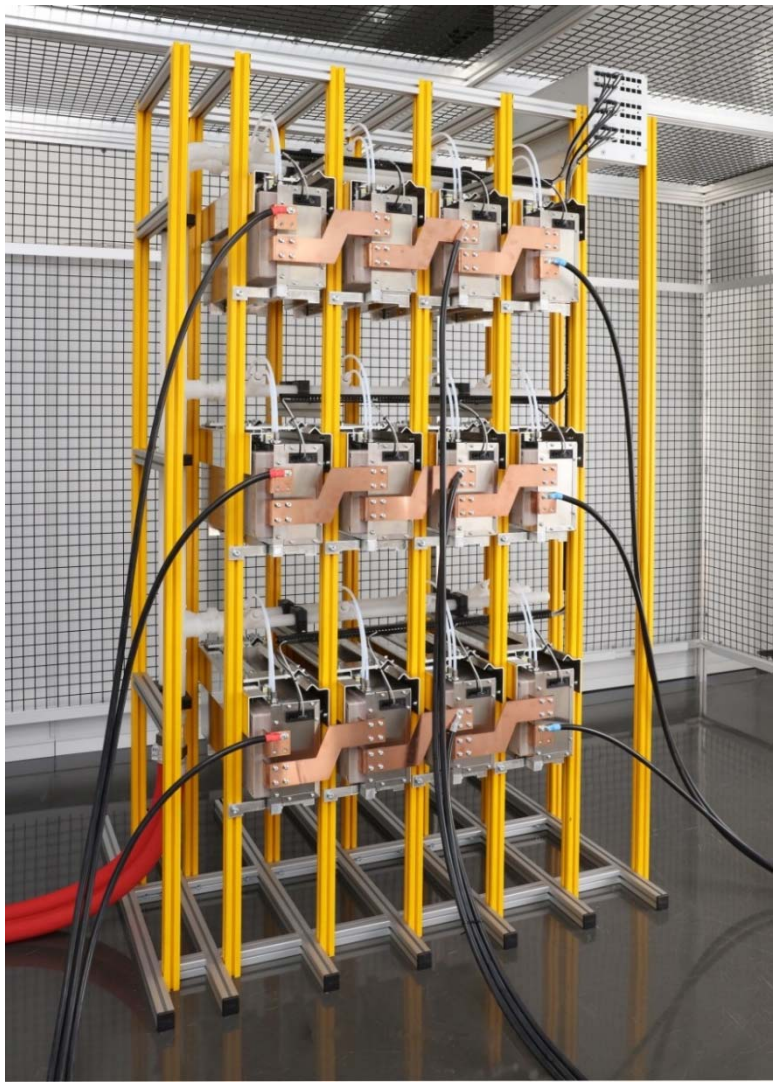
But very flexible!

- ✓ Scalable maximum voltage amplitude and ripple by number of cells
- ✓ Scalable number of phases

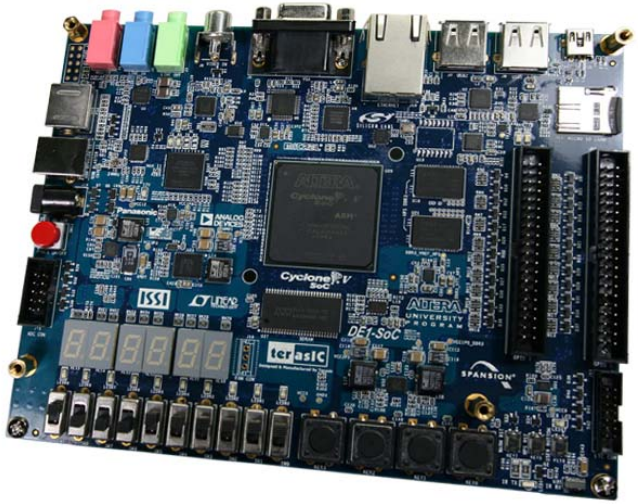
System in construction



First setup for medium voltage



- 12 submodules
- Initial operation of control
- Reduced voltage and hardware effort
- Verification of thermal setup
- Open for customer tests



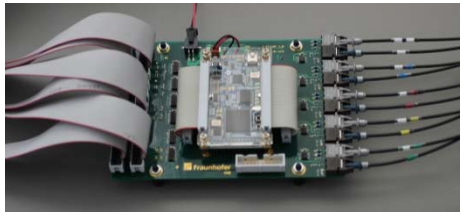
Low voltage M2C test setup

Plecs-RT-Box I
Digital communication

Analog measurements

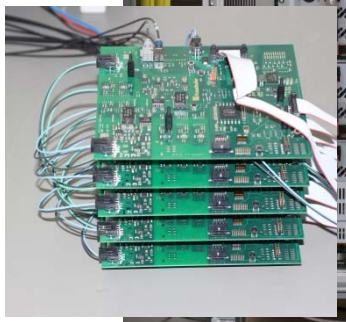
Fast test of control algorithms with auto code generation

Plecs-RT-Box II
Control + Modulation



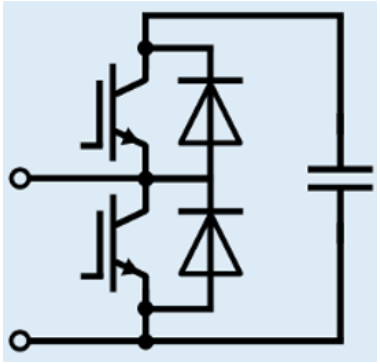
Aux-Boards (x3)

Optical fibers

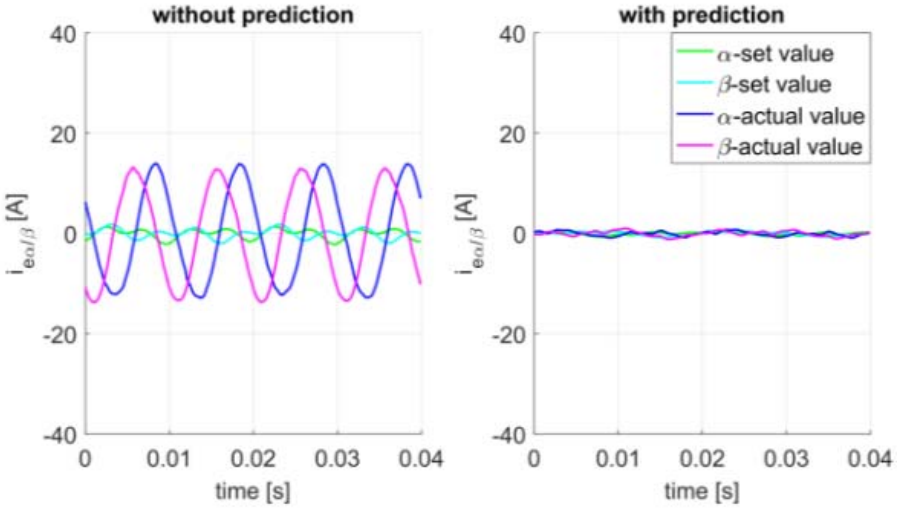


Cell Control Unit (x15)

Cell voltage estimation with Kalman filter



Cell voltage
U_C

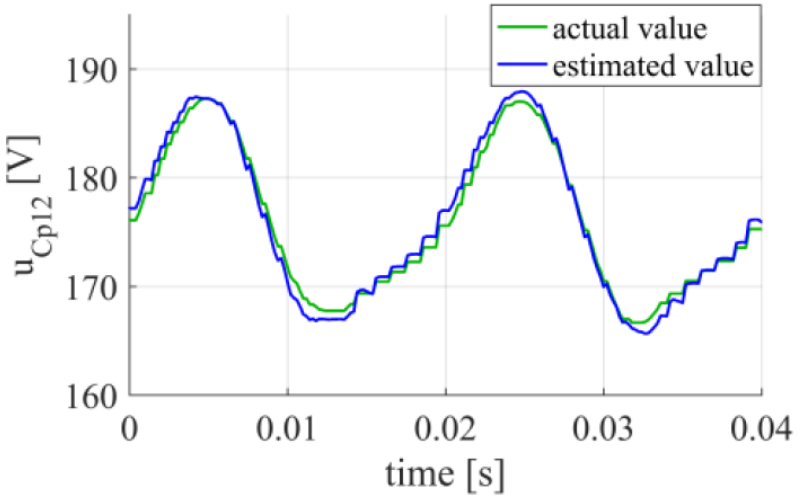


Classical approach:

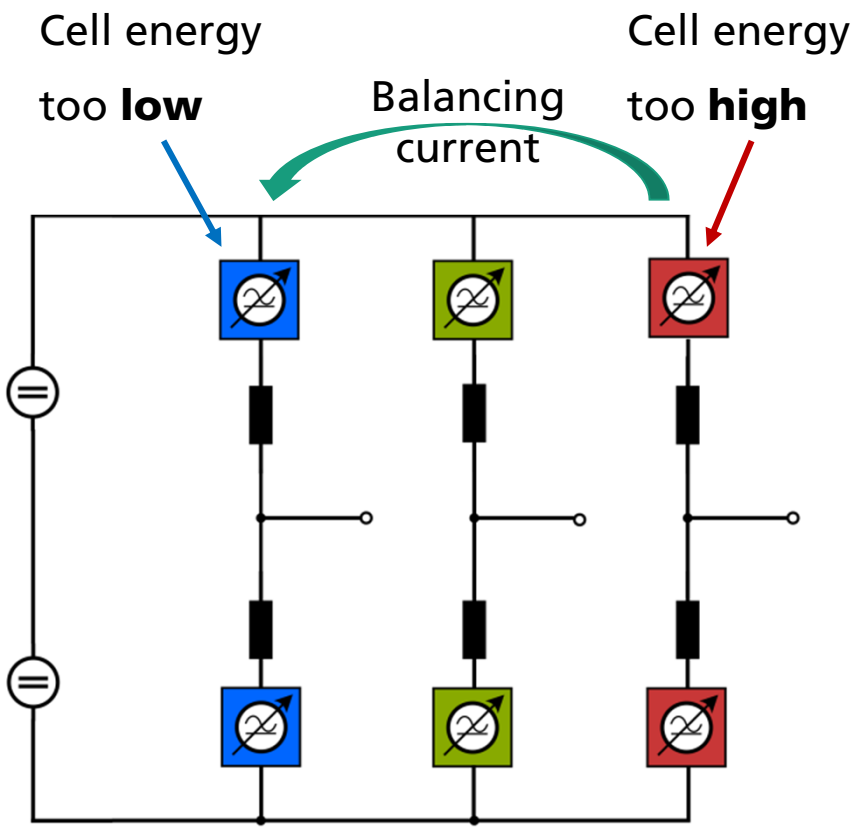
- Measurement with time delay
- Isolated communication

New approach:

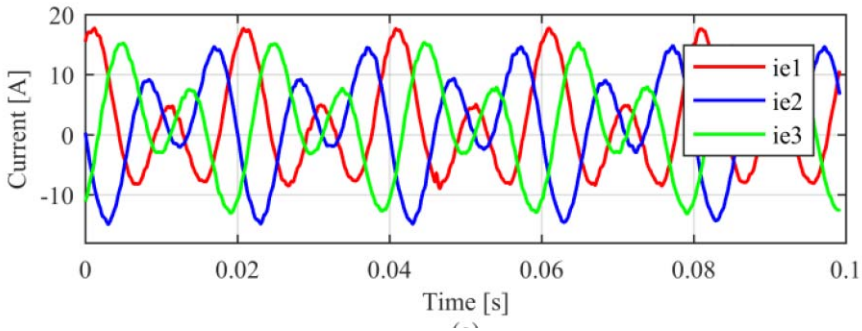
- ✓ Instantaneous estimation
- ✓ Less isolated communication
- ✓ Less sensors needed



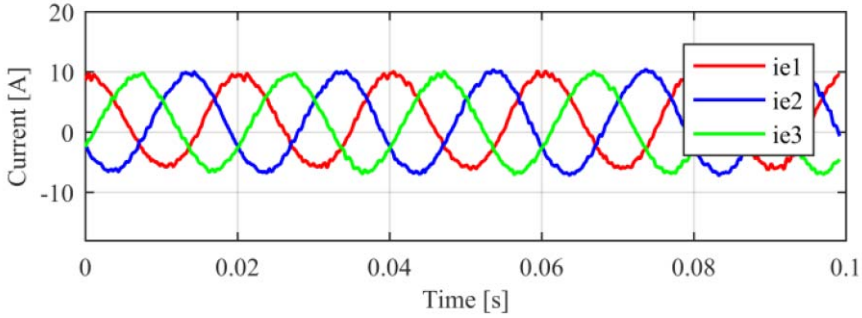
Circulating current control



Without notch filter



With notch filter



Reasons:

- Cell capacitance imbalance
- Load / device under test asymmetries

Summary

- More than a test bench with a big power supply!
- Power hardware in the loop tests
- Functionality defined by software – despite the high hardware effort
- Open for customers

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