IISB Jahrestagung 2018

Leistungselektronik und Schutztechnik im lokalen DC-Microgrid

Bernd Wunder
Group Leader, DC-Microgrids, bernd.wunder@iisb.fraunhofer.de

Fraunhofer IISB

Content

- Overview Fraunhofer IISB Microgrid
- DC Microgrid components
- Grid control and voltage regulation
- Introduction DC protection devices
- Project examples

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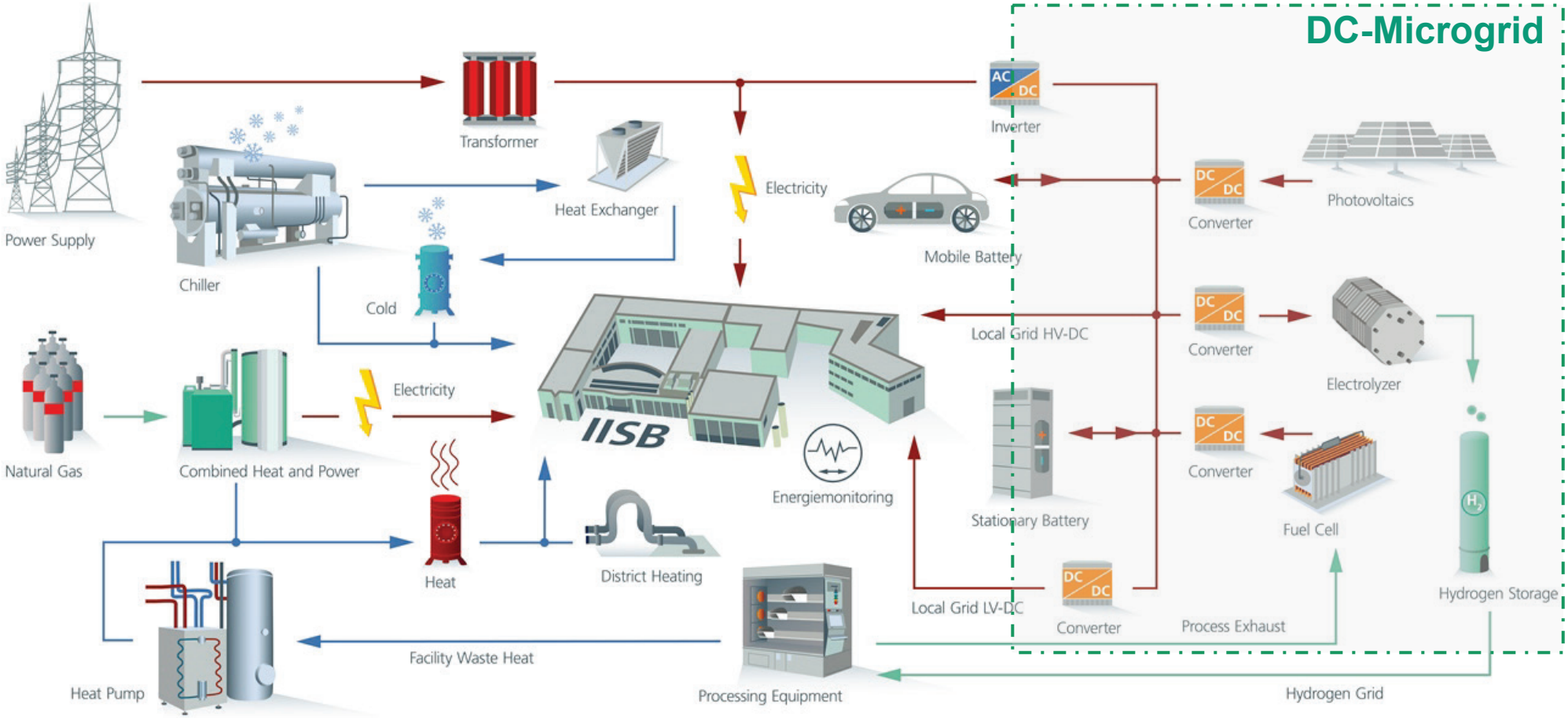
Application Platform for Decentralized Energy Systems



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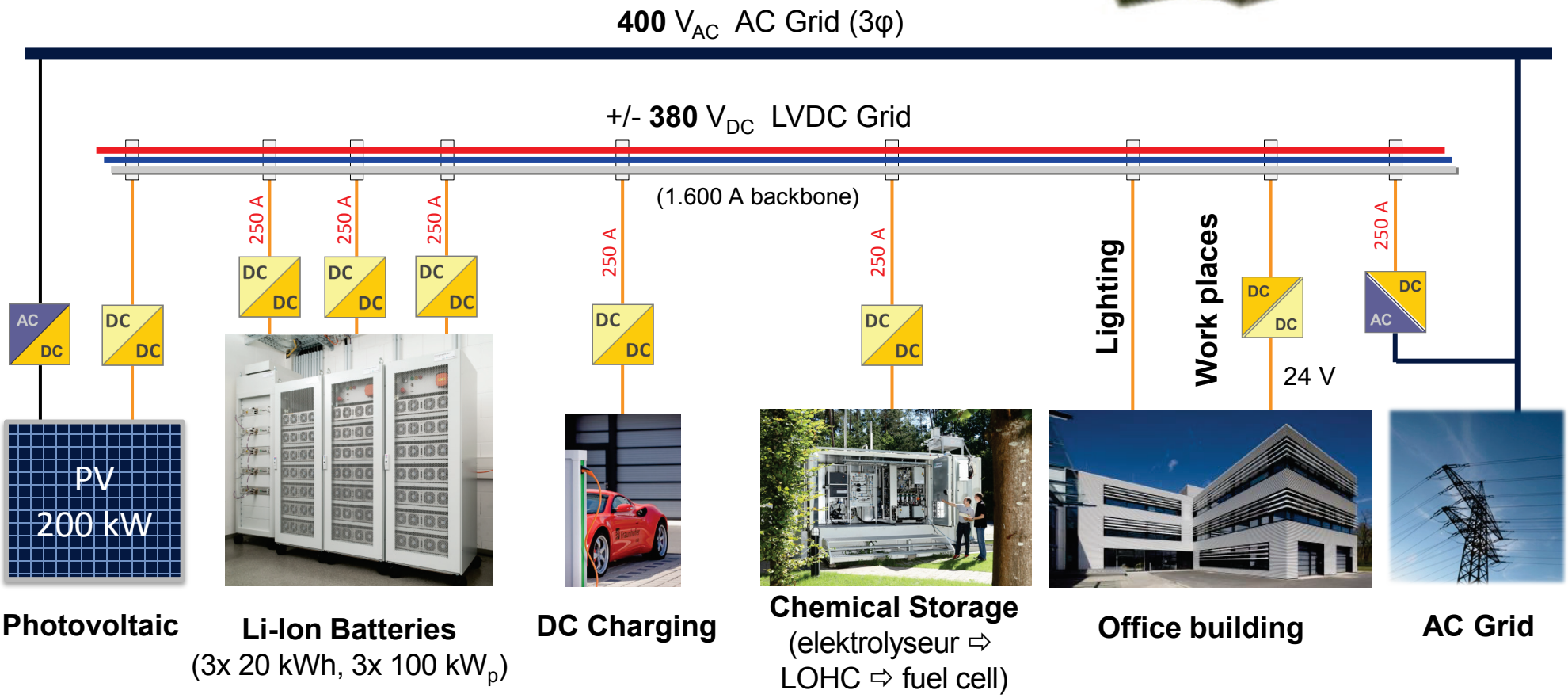
The High-Power DC Grid at Fraunhofer IISB

in field operation for peak load shaping



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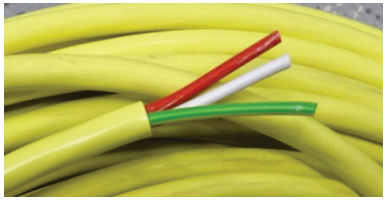
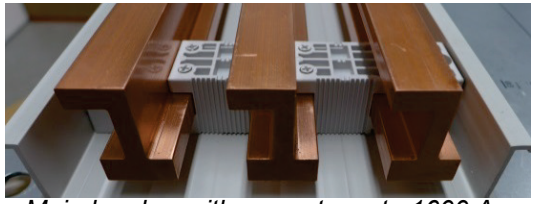
High Power DC - Distribution (HPDC)

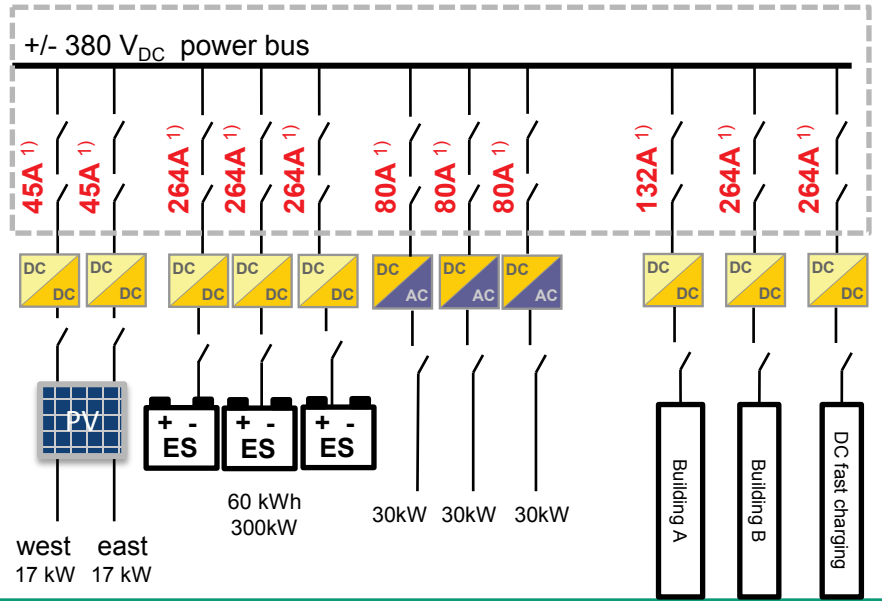
- **Distribution with ±380 V_{DC}, Droop Control and Interface to Energy Management**
- **Integration** of lithium-ion battery systems, solar power, DC-Grid Manager, AC/DC-Bridge DC/DC converters, office and lighting applications and DC charging



DC cables according to new standard IEC 60445 ED 6.0



Main bus bar with currents up to 1600 A and a bipolar 380 V_{DC} voltage



battery capacity: 3 racks with each 20 kWh
AC/DC bridge with up to 100 kW
HPDC-Distribution up to 1600 A / 800 V_{DC} (on main bus bar)

1) nominal currents of circuit breaker; not the max currents of the converters as shown on slide 4

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DC Microgrid components

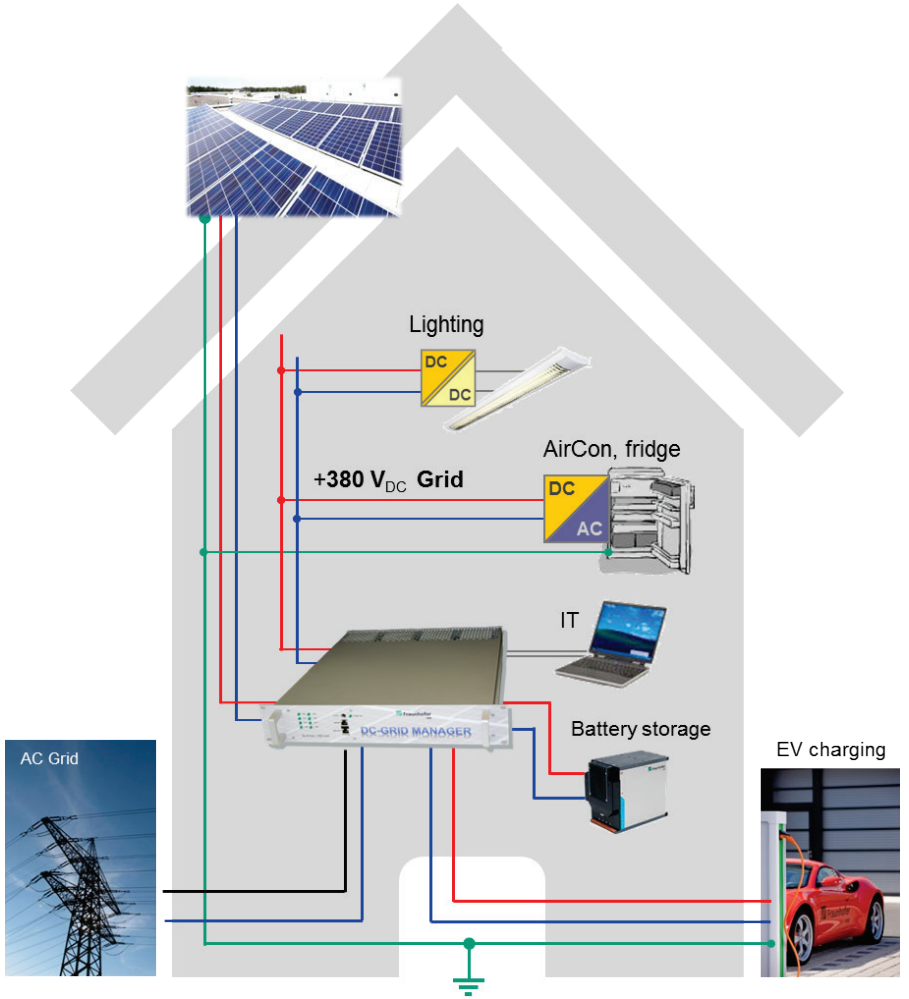
Central (starlike) **Grid**

advantages:

- ideal for small size DC microgrids
- “Plug and Play” solution
- minimum installation effort
- low costs
- only one main component
- good controllability

disadvantages:

- less flexibility according to scalability and expendability
- low reliability



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DC-Grid-Manager

Smart, local and central managed LV DC Microgrids

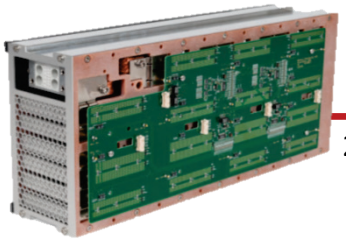
Public AC grid

Local power generation

MPP tracking 0…20 A

-11…+11 kW bidirectional AC grid link

Stationary batteries



250…400 V_{DC}

-40…+40 A

-60…+60 A

0…20 A, **380 V_{DC}**

-20…+20 A

DC DC DC AC
DC DC DC DC
DC DC DC DC
DC DC DC DC
DC-Grid Manager

Consumers

50 kW
DC power under control

Mobile batteries

DC fast charging

380 V_{DC}

Prosumers

1) DC-Grid Manager: 19“, 2 HU, 8 DC channels à 20 A

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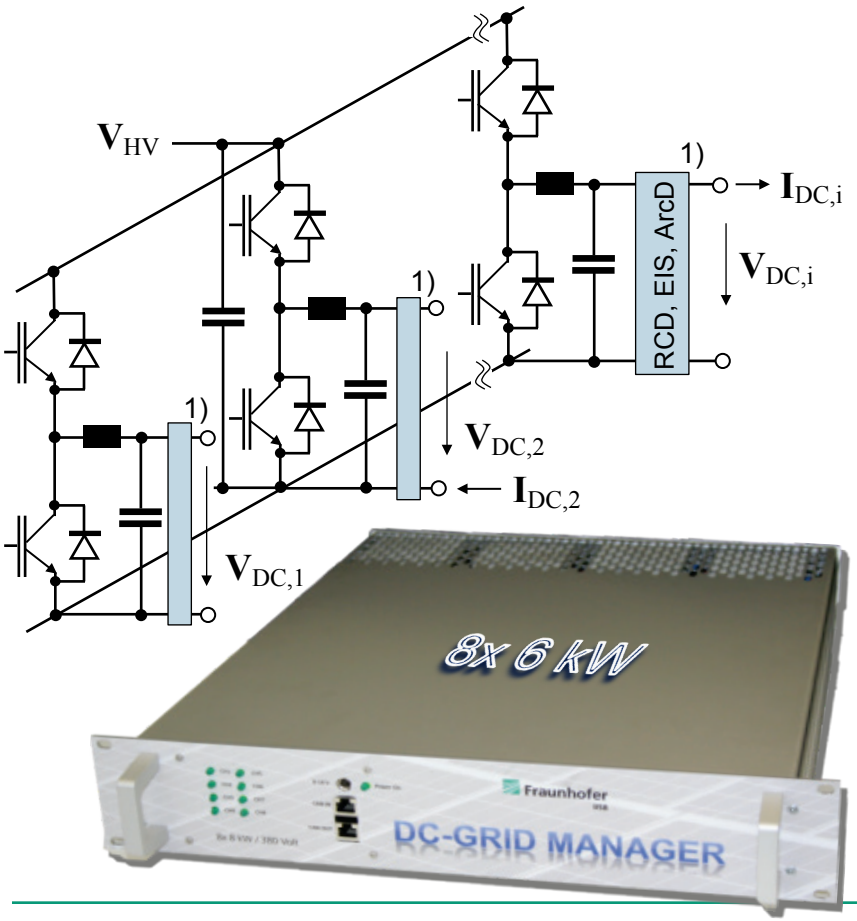
DC-Grid-Manager

energy routing via software-defined-power

Example: Fraunhofer **DC-Grid Manager**



Characteristics

- Via IP/LAN arbitrarily configurable DC channels for
  (voltage a/o current controlled source a/o sink)
  - complex control functions
    (MPP tracking, battery management, droop control, etc.)
  - individual current limiting characteristics
    (short circuit and overload characteristics)
- Load/grid monitoring[1)] via
  - Residual Current Detection (RCD)
  - Electric Impedance Spectroscopy (EIS)
  - EM-noise analysis (for arc detection - ArcD)
- Self-monitoring and controller self-adaption[1)]
- Smart meter functionality[1)]
- Emergency operation modes[1)]
- Very high control dynamics for fast fault-control, fault isolation, and lowest fault energy

1) in next „DC-Grid Manager“ generation

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DC Microgrid components

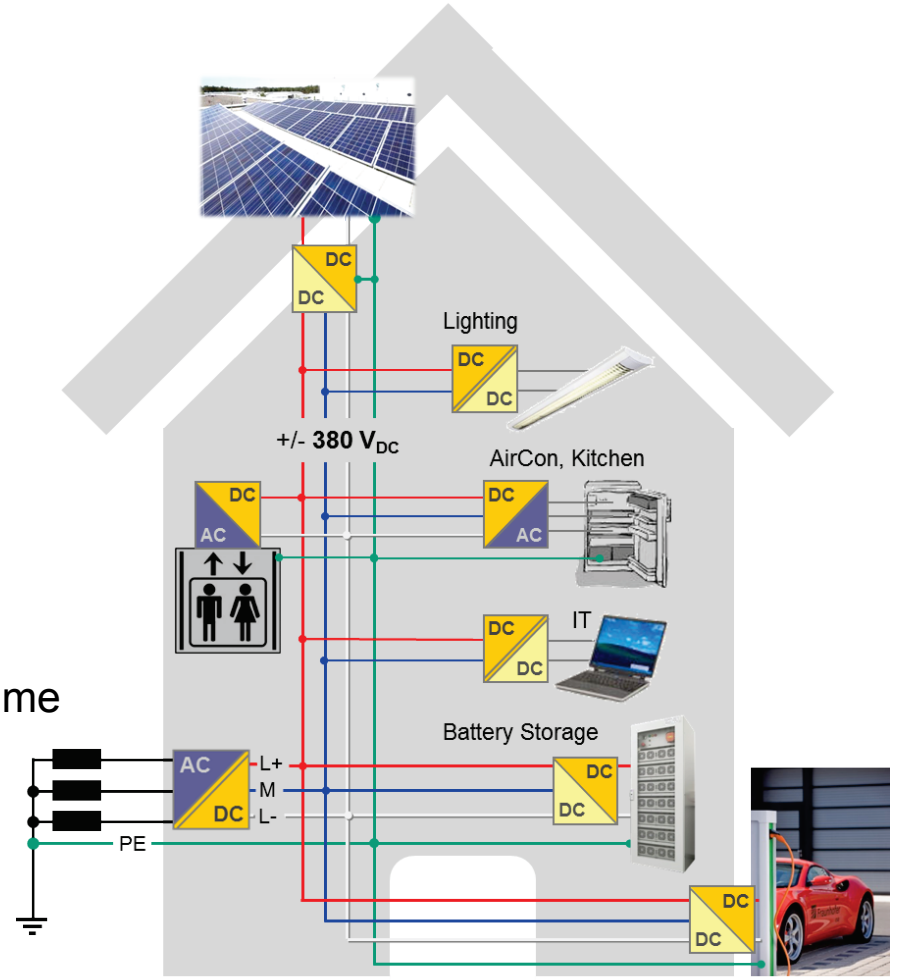
Decentral (buslike) Microgrid

advantages:

- ideal for medium and large size DC microgrids
- medium installation effort
- low maintenance costs
- high flexibility according to scalability and expendability
- medium reliability

disadvantages:

- difficult decentralized control or alternative real time communication necessary
- grid stability depends on the composite of all converter
- selectivity and protection is more complex



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Modular Power Distribution System (MPDS)

Features / Characteristics MPDS:

- **„building block“** for a decentral DC microgrids
- free combination of up to 4 different DC resources per rack
- modules and racks can be used in parallel
- functions: different MPP-Tracker, charging and discharging of Li-Ion batteries, CC, CV, CP, DC fast charging, energy monitoring, safety features
- High saleable power supply system up to MWs

IoT Controller

technical data:

voltage:	0-1000 V_{DC}
current	20 A / module
power	15 KW / module
modules	4
efficiency	> 99 % (over wide range)
MPP tracker voltage	50-1000
height	3 HU

power module 2 (industry version)

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Modular Power Distribution System (MPDS)

MPDS

Internet

IPv6 / Ethernet

IoT

IoT Controller

power electronics
module 1-4

CAN

Ethernet SPI | CAN | CAN SPI

microcontroller / FPGA

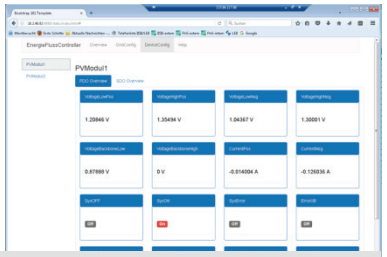
sensors | driver | I²C, SPI, ...

control board

Protocol Stack FhG-IISB of the IoT Controller

Browser / mobile phone

LZE Leistungszentrum Elektroniksysteme



application layer

Running in user space (browser)

IoT Controller

JSON API | XML API | database

IISB Middleware

MPDS or Server

HAL (Hardware Abstraction Layer)

CAN Transceiver | USB | Ethernet Controller

MPDS Hardware

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Smart Battery Storage and foxBMS

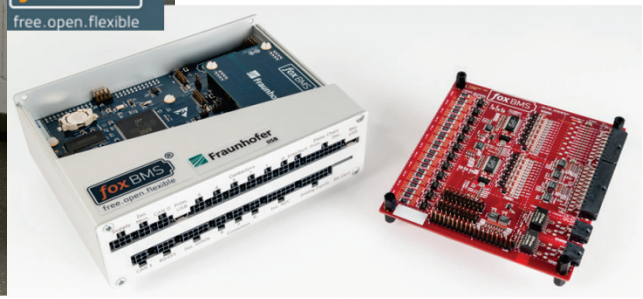
Smart Battery (IoT ready)

technical data:

- battery storage with up to 14 modules
- energy / rack: 20kWh
- nominal power / rack: 100kW
- voltage range: 315V – 567V
- lifetime 15.000 (full cycles)
- temperature range: -30°C…+55°C

foxBMS free.open.flexible

https://www.foxbms.org/



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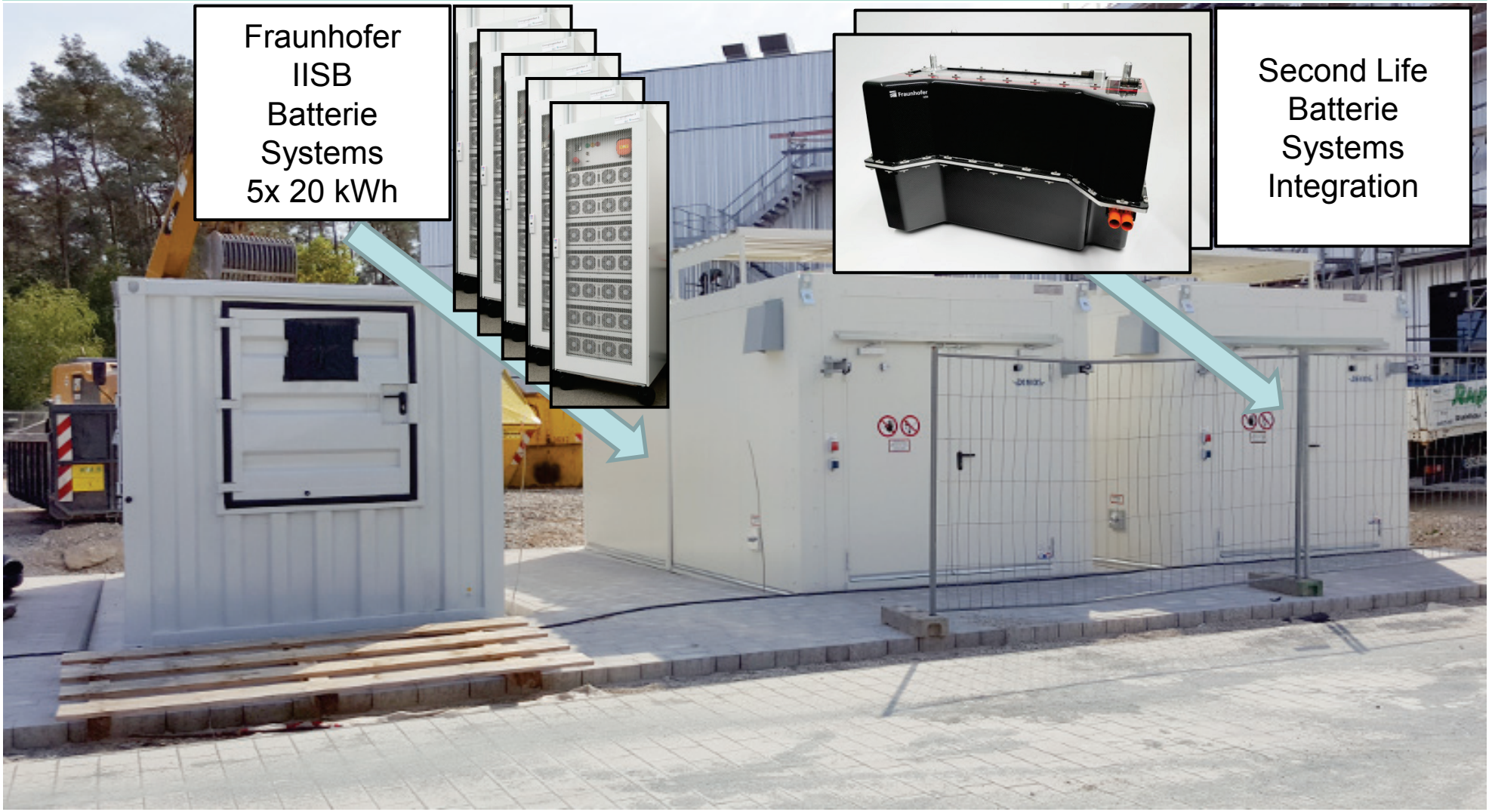
Smart Battery Storage and foxBMS



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Hydrogen storage system

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DC Charging Technologies

DC Microgrid connected high power charging

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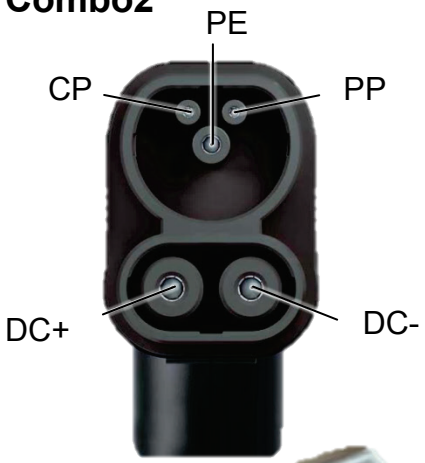
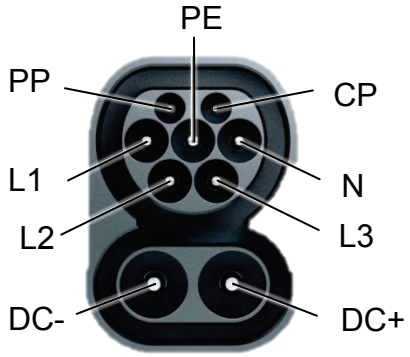
DC Charging Technologies

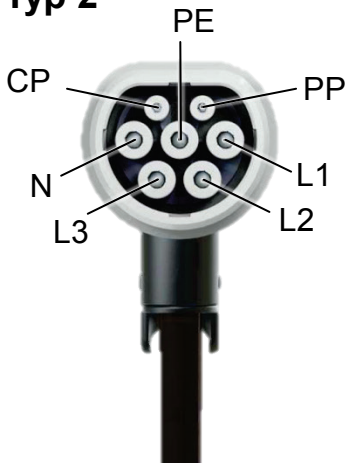
Combined Charging System (CCS)

Combo2





Typ 2



Pin	Function
CP	Control Pilot
PE	Protective Earth
PP	Proximity Pilot (Plug Present)
DC+, DC-	DC Power contacts
L1, L2, L3, N	AC Power contacts

Picture source: Phoenix Contact

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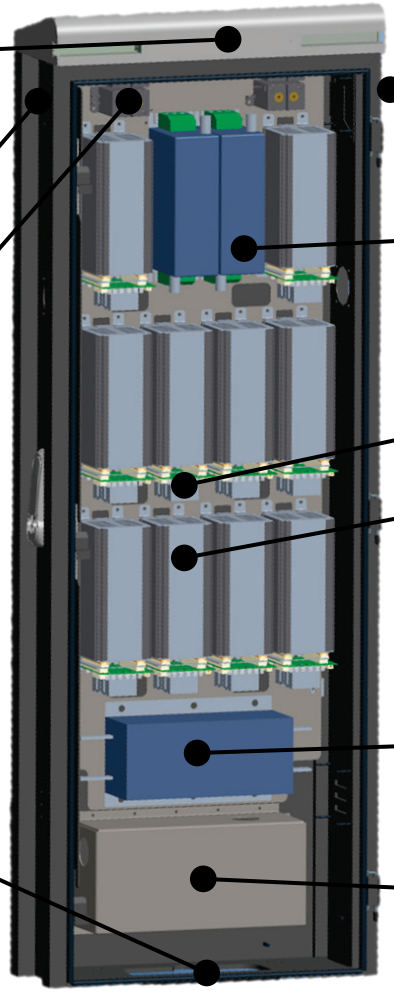
DC Charging Technologies

control electronics
- PLC modem
- auxiliary supply
- control module

DC charging point 1

DC charging relay
2x pro Ladepunkt



DC charging point 2

EMC filter (vehicle)

backbone with energy switch

DC/DC converter module:
- 10x 15 kW power module
- 50-1000V, 0-20A
- η up to 99%

EMV-Filter (power supply)

cooling equipment for high power cables

entry and clamping area for energy cables

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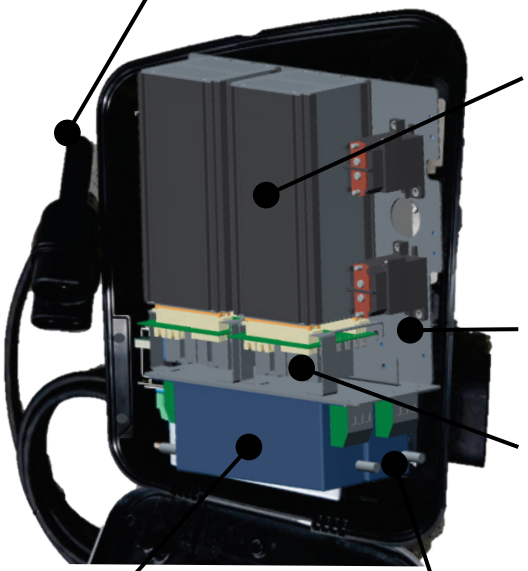
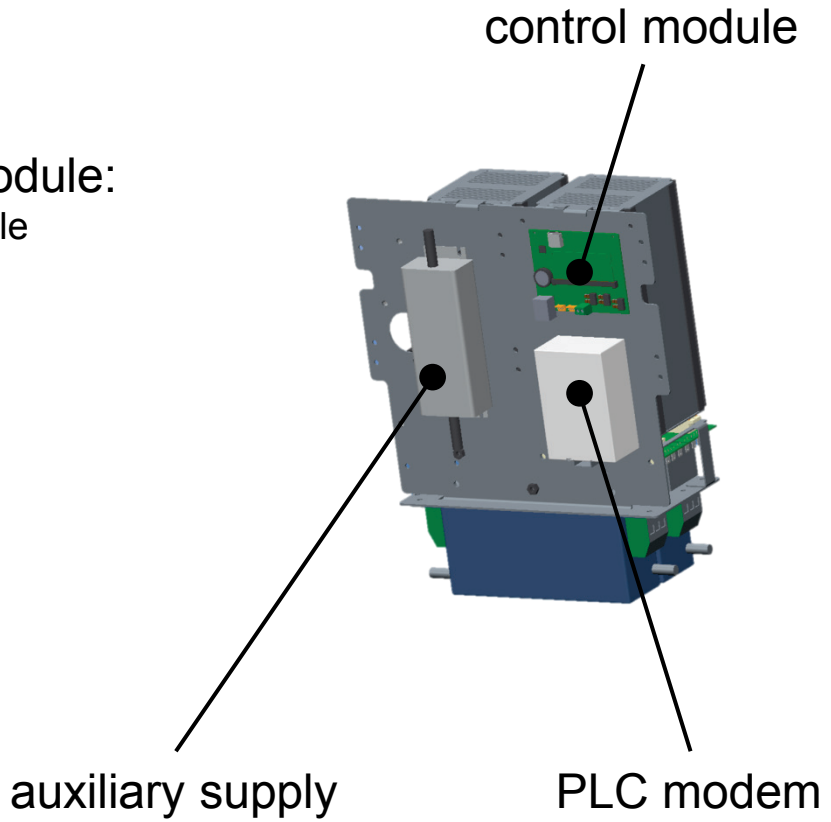
DC Charging Technologies





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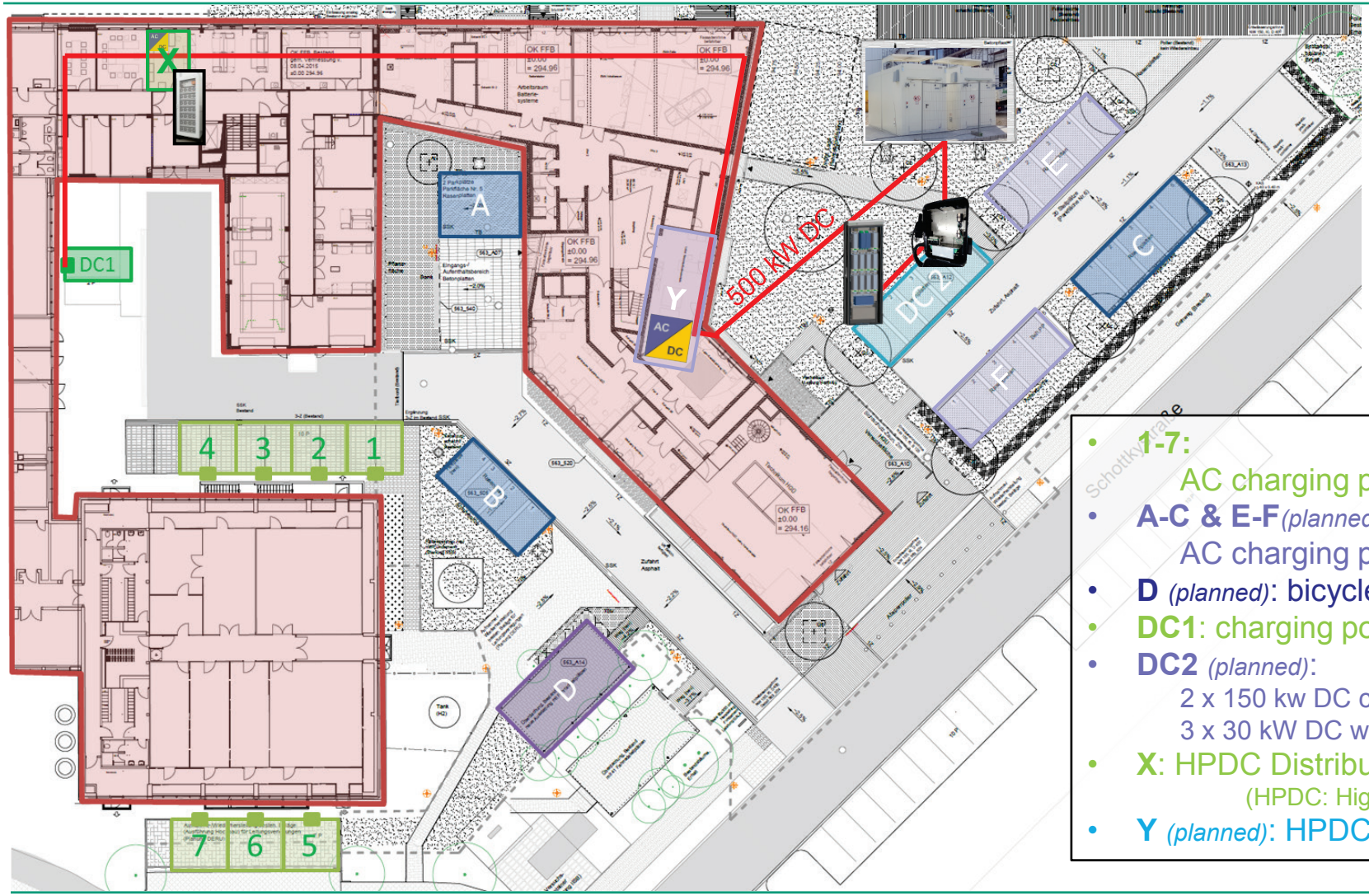
DC Microgrid components integration



- **1-7:**
  AC charging points (up to 22 kW)
- **A-C & E-F** *(planned)*:
  AC charging points (up to 43 kW)
- **D** *(planned)*: bicycle charging points
- **DC1**: charging point (up to 50 kW)
- **DC2** *(planned)*:
  2 x 150 kw DC charging points
  3 x 30 kW DC wallboxes
- **X**: HPDC Distribution (100 kW)
  (HPDC: High Power DC)
- **Y** *(planned)*: HPDC (500 kW)

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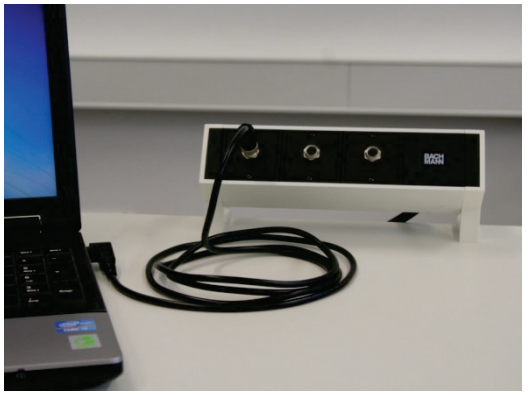
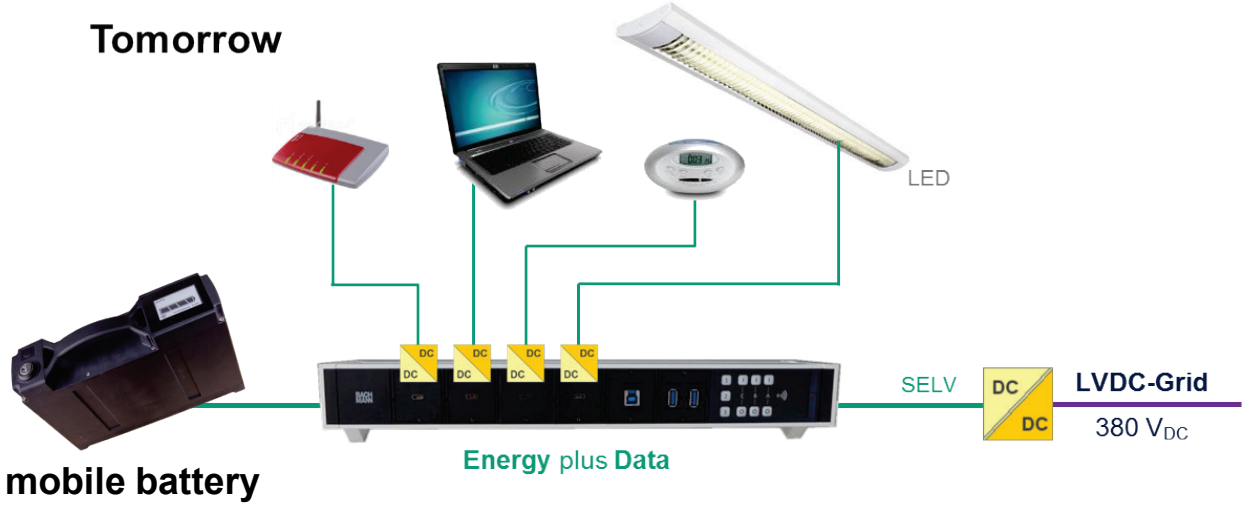
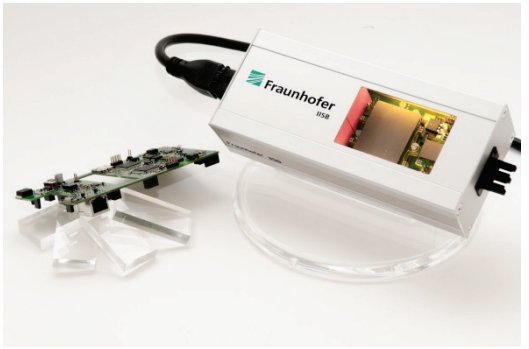
Electric Building Infrastructure

■ Today and Tomorrow



DC-Desk Distribution





DC/DC 380V <-> 24V / 48V

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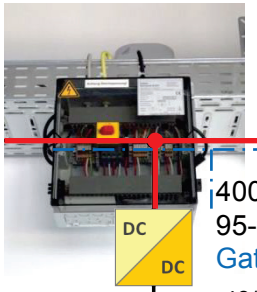
Smart Workplace Distribution Unit for Local DC Microgrids

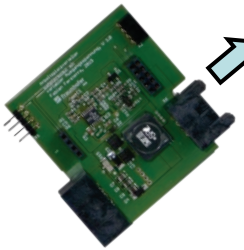
Modular DC/DC Converter for Low Power Loads

- Multiple independent DC/DC converters in one enclosure
- **Autodetection** of output voltage (5 V – 24 V), output power up to 100 W per channel
- Efficiency: up to 96%
- Integrated protection functions (overcurrent, overtemperature)
- Integrated power meter functionality
- Communication Bus between Converters
- Automatic shutdown if no load connected (**Standby**)

DC/DC for office buildings

up to 600W,
V_{in} = 380 V_{DC}
V_{out} = 24 o. 48 V_{DC}





3-5 x DC/DC / WDU

up to 100W / modules, 5-24 V_{DC} output
Workplace Distribution Unit (WDU)

Ceus t13

1kwh, 24 V_{DC}, 200-600W
Fraunhofer IISB DC/DC converter integrated

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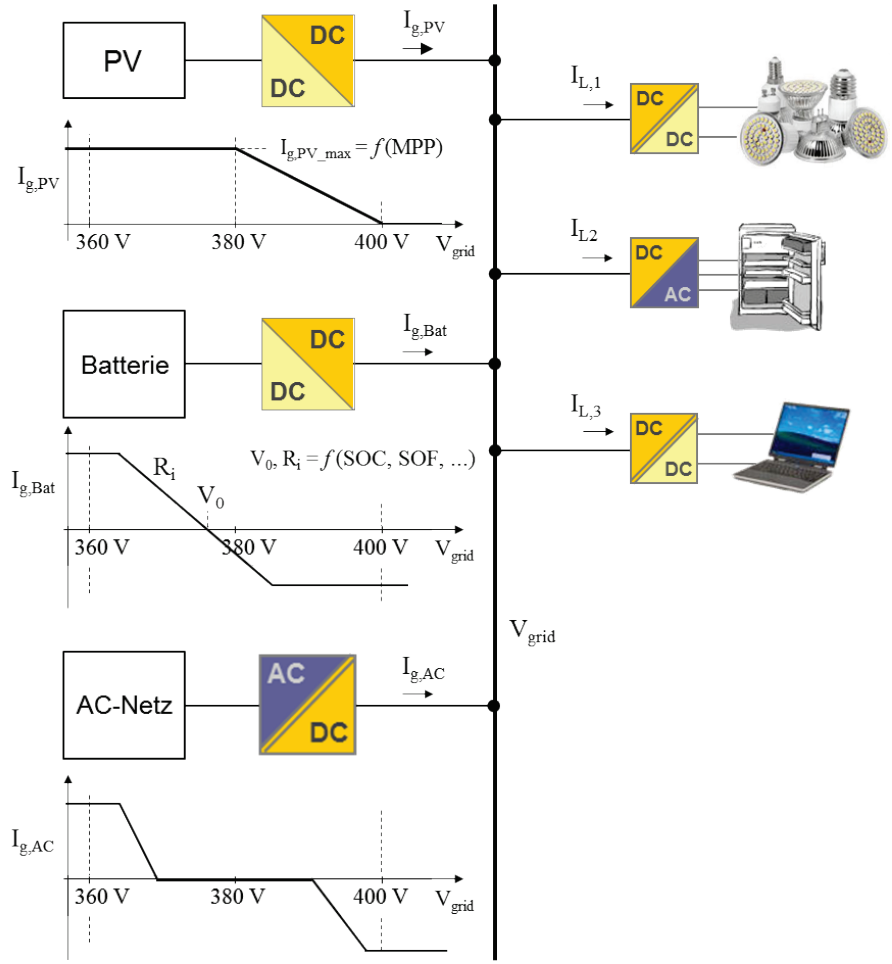
Droop control

a method to control a grid without a superordinate master



- The grid voltage (V_{grid}) serves as the central control parameter
- All feed-in converters behave like **voltage sources with internal resistance**

Advantages

- No superordinate grid controller necessary
- Maximum in reliability, availability and flexibility
- High level functions can be realized by changing the droop characteristics

Challenges

- Ensuring unconditional dynamic grid stability

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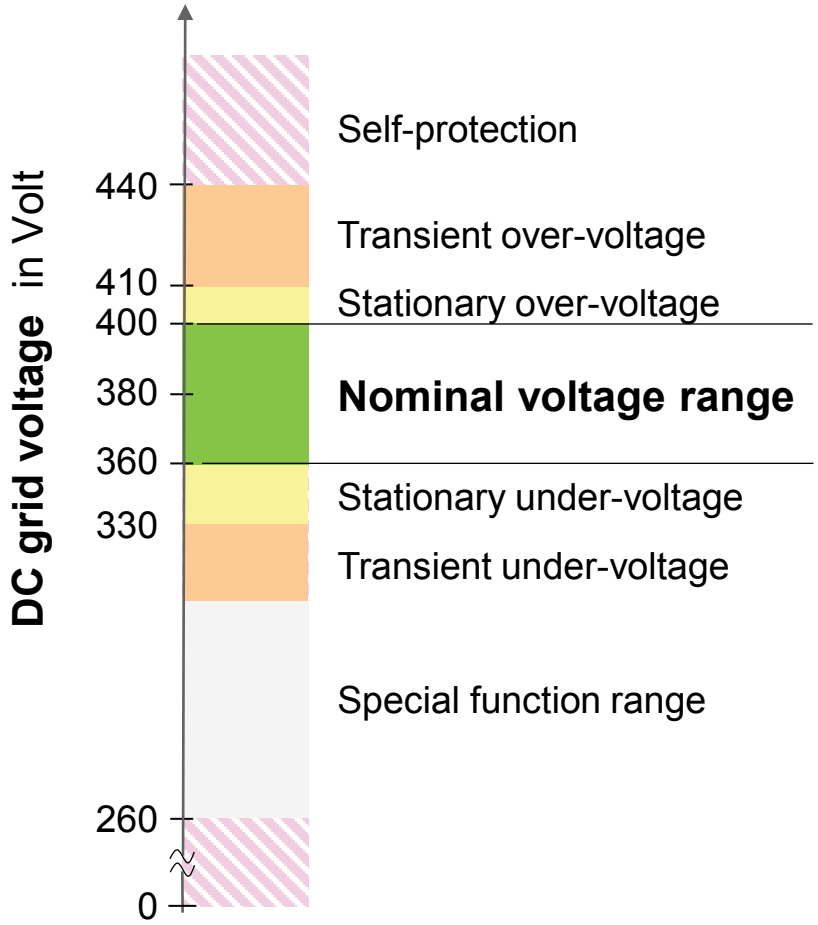
Voltage Specification used in the Fraunhofer DC-Grid



Behavior of devices and components

Switch-off for self-protection allowed	
Transient operation with limited functionality and power derating	
Operation with full functionality, power derating allowed	
Operation with specified functionality	
Operation with full functionality, power derating allowed	
Transient operation with limited functionality and power derating	

To be used for various protection and safety functions

Emergency mode (e.g.): only dedicated loads, like emergency lighting or IT-server, are allowed to stay operational

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Grid Control Layers

BASIS FUNCTION (even if communication fails!)

Droop Control and Validation enables safe operation without communication

Basis Layer

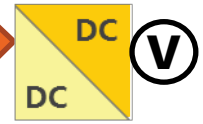
Hardware

Additional Functions

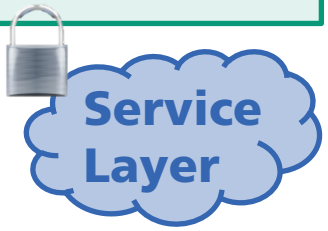
Communication enables smart features and add features, helps to identify system behavior (logging, monitoring, …)

Funktion Layer

Software



Local validation by the DC/DC converter in the hardware level!!! Decoupling from communication



Cloud

Increasing IT-Security, reducing realtime requirements
ignore external parameters out of a save operation area (SOA) which is based on the physical hardware behavior of the grid (e.g. Voltage)

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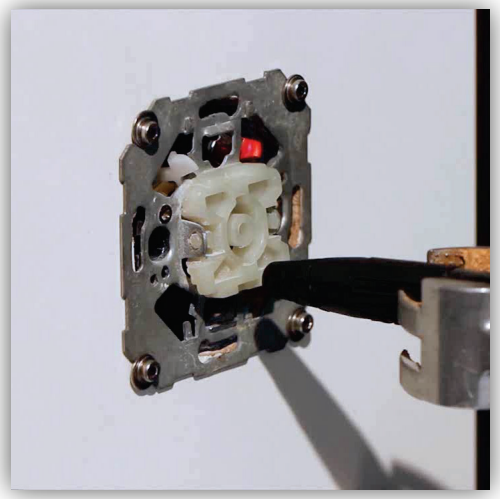
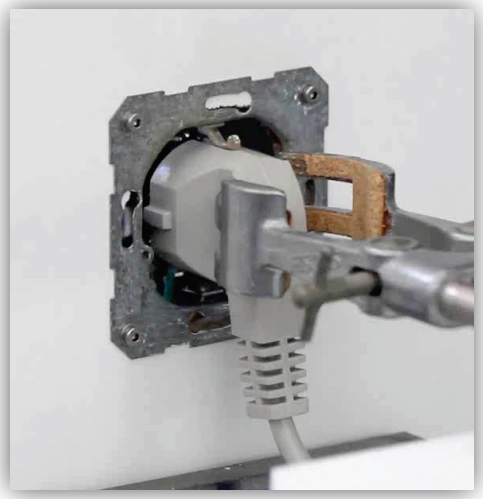
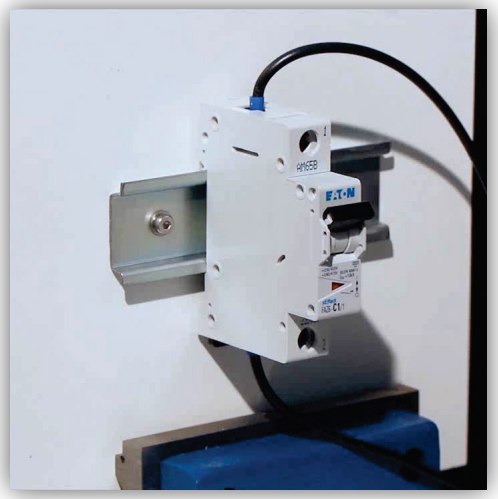
Mechanical Disconnecting Devices

A Problem »Mechanical Disconnecting Devices« (switches, plugs, fuses)

AC Wall Switch	AC Wall Plug	AC Breaker
		
380 V_{DC} / 10 A	**380 V_{DC} / 10 A**	**380 V_{DC} / 10 A**

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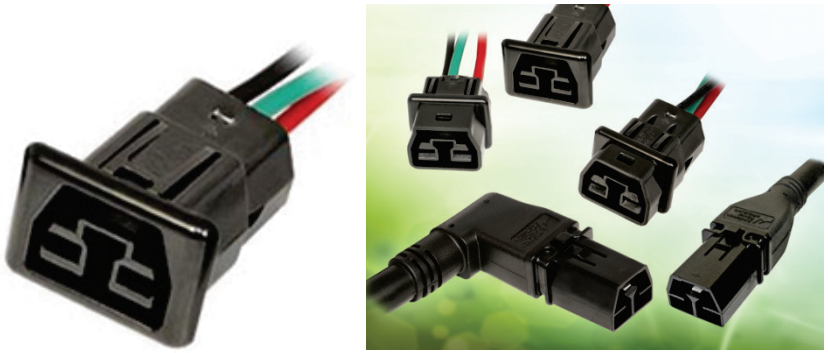
DC Connector Solutions

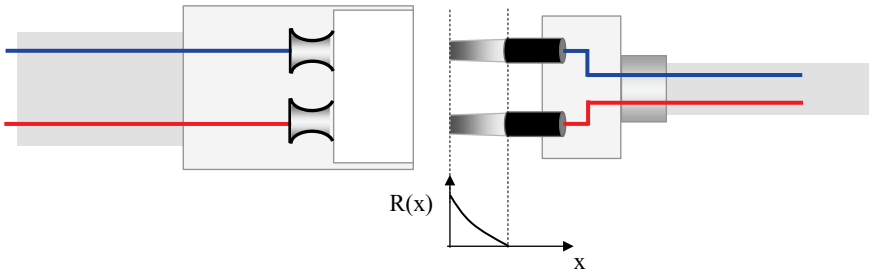
Passive LVDC Connectors



Picture: Safe-D-Grid® 400 from Anderson Power Products (APP)

- Purely passive LVDC connectors are possible for a limited number of plug-in cycles
- Important: material selection, contact design and release force profile
- Example: Safe-D-Grid® 400 from APP (250 plug-cycles under full load 30 A / 400 V_{DC})

Resistive Contact Tip



- Resistive contact tips (e.g. of SiC ceramic)
- Intrinsic precharge function for capacitive loads
- Fault situation "incomplete plug-in" must be suitably intercepted

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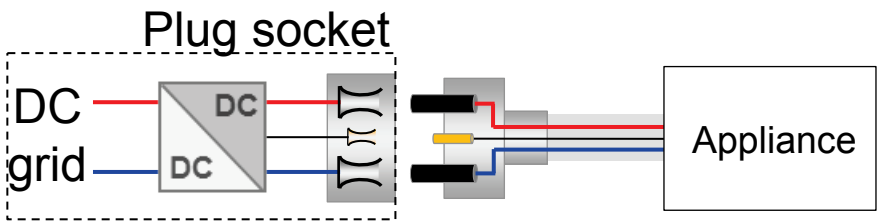
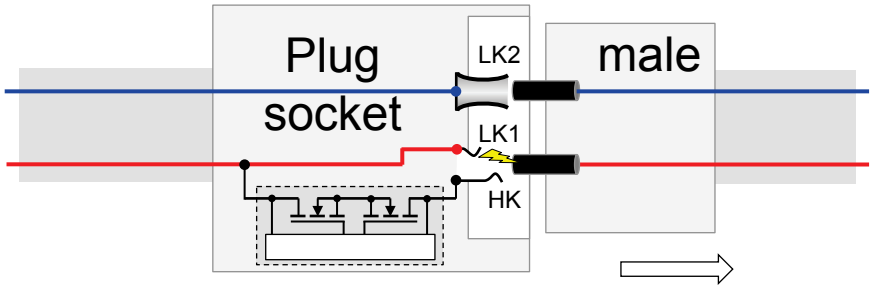
DC Connector Solutions

Pilot Contact



- Plugging is always **currentless**
- Load turns-off current consumption, when a disconnection is signaled by the leading breaking pilot contact
- Can also be used on the source side for switching off the voltage

Hybrid Connector



The arc voltage arising during the disconnection of the leading-opening load contact LK1 drives a semiconductor switch:

- » Semiconductor switch and auxiliary contact (HK) take over the load current
- » thereby the arc at LK1 immediately extinguishes and
- » the semiconductor switch breaks the load current before the main contacts (HK and LK2) are opening.

Based on ideas from: DE102 25 259 B3 (SMA), DE20 2009 004 198 U1 (E.T.A.) and JP 5862818B1

Bernd Wunder
Energy Electronics / DC-Microgrids

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- DC Microgrid components
- Grid control and voltage regulation
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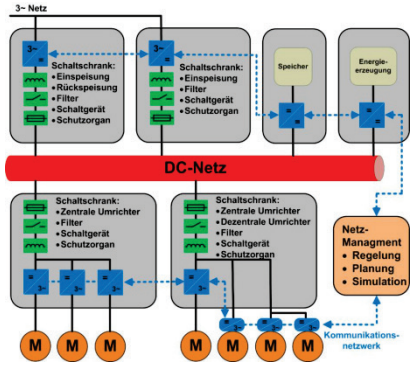
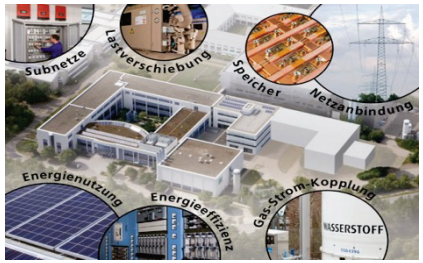
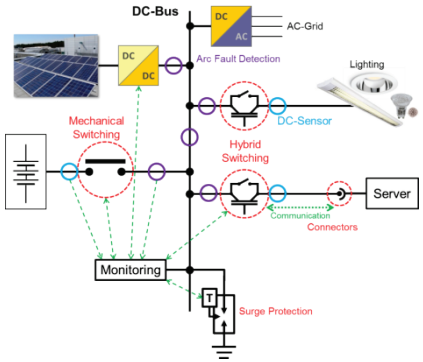
DC-INDUSTIE - Stromversorgung industrieller Anlagen über ein smartes, offenes Gleichstromnetz
https://dc-industrie.zvei.org/



SEEDs – "Keimzellen für die Energiewende im Industriemaßstab"
http://www.energy-seeds.org/



DC-Schutzorgane – Entwicklung eines neuen, integrierten Schutzkonzepts und neuer Schutzorgane für zukünftige Niederspannungs-Gleichstromnetze



Bernd Wunder
Energy Electronics / DC-Microgrids

Fraunhofer IISB

Fraunhofer IISB

Your Partner for leading-edge Power Electronics

Bernd Wunder

Schottkystrasse 10, 91058 Erlangen

Tel.: 09131/761-597

bernd.wunder@iisb.fraunhofer.de

www.iisb.fraunhofer.de

Fraunhofer IISB