DC-Microgrids Worldwide
Fraunhofer IISB Installation

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DC-Installations Worldwide

Worldwide Activities

- SAP 380 V\text{DC}
- INTEL 380 V\text{DC}
- Univ. CA 380 V\text{DC}
- NEXTEK NextEnergy NextHome 380 V\text{DC}
- ARDA Power 380 V\text{DC}
- North American Telecom; 380 V\text{DC}
- ETSI 260/380/400V\text{DC}
- IEC SEG4
- Fraunhofer IISB 380 V\text{DC}
- Netpower 350/380 V\text{DC}
- China Telecom 240/380 V\text{DC}
- NTT Group 380 V\text{DC}
- China Mobile 380 V\text{DC}
- Bachmann 380 V\text{DC}
- Green (CH) 380 V\text{DC}

- Data Centers
- Telecom
- Demo Infrastructure
- Industry and R&D Consortia, Standardization
“DC components and grid“

- European project (2012 – 2015)
- Reduce device size and cost
- Increase efficiency and solar power usage
- Less conduction losses
First test installation for demonstration purposes at Fraunhofer IISB in Erlangen

- Various renewable energy sources like photovoltaic and μCHP
- Typical loads for office buildings
- Power ~20 kW
- Still in use today with some modifications – integration into building-wide DC microgrid
Today: SEEDs

Application Platform for Decentralized Energy Systems

=> The DC-Microgrid as Interface for Various Energy Systems
Grid Structure

The High-Power DC Grid at Fraunhofer IISB
in field operation for peak load shaping

400 $V_{AC}$ AC Grid (3φ)

$\pm 380 \, V_{DC}$ LVDC Grid

(1.600 A backbone)

Photovoltaic

Lighting

Li-Ion Batteries

Work Places

(3x 20 kWh, 3x 100 kW_p)

24/48 V

DC Charging

Office Building

Chemical Storage

AC Grid

(elektrolyzer $\Rightarrow$ LOHC $\Rightarrow$ fuel cell)
Grid Structure

Building A

Photovoltaic

Lighting, IT and Office Equipment

AC Grid

Batteries

DC Charging

LOHC Container

Building B

Laboratories

Lighting, IT and Office Equipment

AC Grid

Battery Container

DC Charging

Outdoor Installations
Power Distribution

- Main distribution cabinet
- High-power DC switches for bipolar operation
- Pre- and discharge resistors where needed
- Voltage and current measurement for every channel
- Data logging to database via Modbus
- Online monitoring
- Overcurrent protection
- Insulation monitoring

Bidirectional 100 kW AC/DC

11x channels 80 – 250 A, main busbars up to 1600 A

Control Power supply
Power Distribution

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- High-power DC switches for bipolar operation
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Input/Output Connectors
- Current Sensor $-380 \, \text{V}_{\text{DC}}$
- Current Sensor $+380 \, \text{V}_{\text{DC}}$
- Resistors for Pre- and Discharge
- Precharge Contactor
- Discharge Contactor
- PLC

Main Contactor / Circuit Breaker
- ABB Tmax T4 for $+380 \, \text{V}_{\text{DC}}$

DC-Backbone
- 1600 A, 1000 V

- $+380 \, \text{V}_{\text{DC}}$
- $0 \, \text{V}_{\text{DC}}$
- $-380 \, \text{V}_{\text{DC}}$
Power Distribution

- High-power DC switches ABB Tmax
- Remote actuation
- Overcurrent protection
- Connection of large sources and loads

- MCCB style (four pole)
- Remote actuation
- Overcurrent protection
- Connection of branch circuits and smaller devices

- Insulation monitoring for IT-system
- Several distributed and coordinated devices

- DC cabling
- Color coding according to latest version of IEC 60445
Energy Storage Systems

Features
- Battery storage with up to 14 modules
- Energy per rack: 20 kWh
- Nominal power per rack: 100 kW
- Voltage range: 315 V – 567 V
- Lifetime 15,000 (full cycles)
- Temperature range: -30°C…+55°C

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DC Lighting

- Conversion of electronic AC lamp ballast for fluorescent lighting
- Connection to the DC-link
- Operation with 380 V is possible
- Control and switching either with bus system (EIB/KNX) or with semiconductor switch

- 380 V DC LED lighting (from DCC+G)
- 48 V DC LED lighting for offices and laboratories
Office DC Power Supply

- Bidirectional isolated 48 V supply for every office
- Compact low-cost non-isolated converters for office appliances (laptop, monitor)
- Safety for users
- High efficiency
- Optional energy storage for distributed USV functionality
High Power DC Charging

- Non-isolated electric vehicle DC charging
- Modular power electronic converters for easy scalability
- Flexible power sharing between vehicles
- High efficiency and compact volume
- For future vehicle requirements up to 1000 V and 150 kW
- Bipolar load (760 V)
Grid Voltage Regulation

Voltage Specification used in the Fraunhofer DC-Grid

DC grid voltage in Volt

- **Self-protection**: Switch-off for self-protection allowed
- **Transient over-voltage**: Transient operation with limited functionality and power derating
- **Stationary over-voltage**: Operation with full functionality, power derating allowed
- **Nominal voltage range**: Operation with specified functionality
- **Stationary under-voltage**: Operation with full functionality, power derating allowed
- **Transient under-voltage**: Transient operation with limited functionality and power derating
- **Special function range**: 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
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
Grid Voltage Regulation

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Grid Stability and Measurement

How to measure stability in a DC grid?

Functional principle:

Example (DC/DC Converter (Grid Manager)):
Current DC Projects

DC-Schutzorgane ("DC safety elements") ■ BMWi Research Project

- "Protection concept and devices for future direct current grids"
- See presentation at ICDCM 2019 for current results

- Funding volume ca. 1.700.00 Mio. €
- Duration 12/2016 – 11/2019
Current DC Projects

DC-Industrie ▪ BMWi Research Project

- Increasing industrial plant energy efficiency by 10%
- Reducing cost for devices up to 20%

- Funding volume ca. 10.000.000 €
- Duration: 07/16 – 06/19
Publications

Y. Han, J. Kaiser, L. Ott, M. Schulz, F. Fersterra, B. Wunder, M. März: Non-isolated three-port DC/DC converter for ±380 VDC microgrids. PCIM, Nuremberg 2016


