International Conference on DC Microgrids

DC-Microgrid Application, Use Cases and Standardization in Europe

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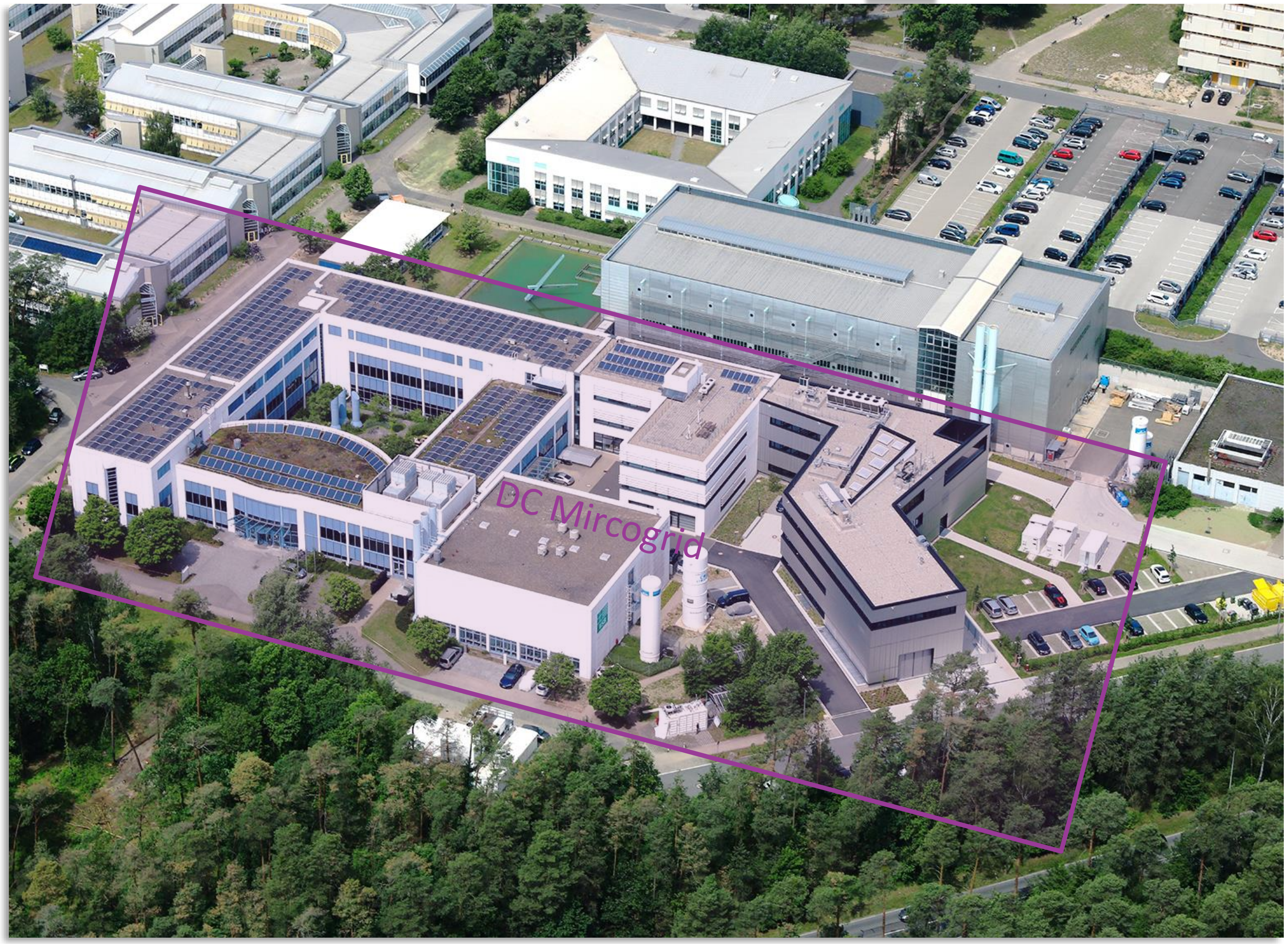
Introduction – Fraunhofer IISB

Location: Erlangen (Germany)

Fraunhofer Society
- Applied Research Organization
- Around 29 000 Employees
- 75 Research Institutes
- Annual Budget: 2.8 GEUR

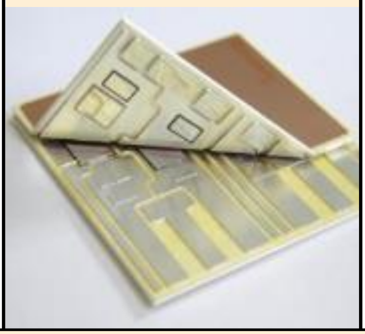
Fraunhofer IISB in Erlangen
- Director: Prof. Dr. Jörg SCHULZE
- R&D Fields:
  - Semiconductor Technologies (Si & SiC)
    (1000 m² clean room ISO 4/5 Class 100/1000)
  - Power Electronic Systems
- Cooperation with the Friedrich-Alexander-University Erlangen-Nürnberg (FAU) and with the University of Bayreuth (UBT)
- Staff: 280 Employees (210 Scientists and Engineers)
- Annual Budget: ~25 MEUR
  - 30% Public Funding + 70% Project Revenues
- Homepage: www.iisb.fraunhofer.de



Introduction – Fraunhofer IISB

Organization of the Fraunhofer IISB in 6 Research Departments

Fraunhofer IISB

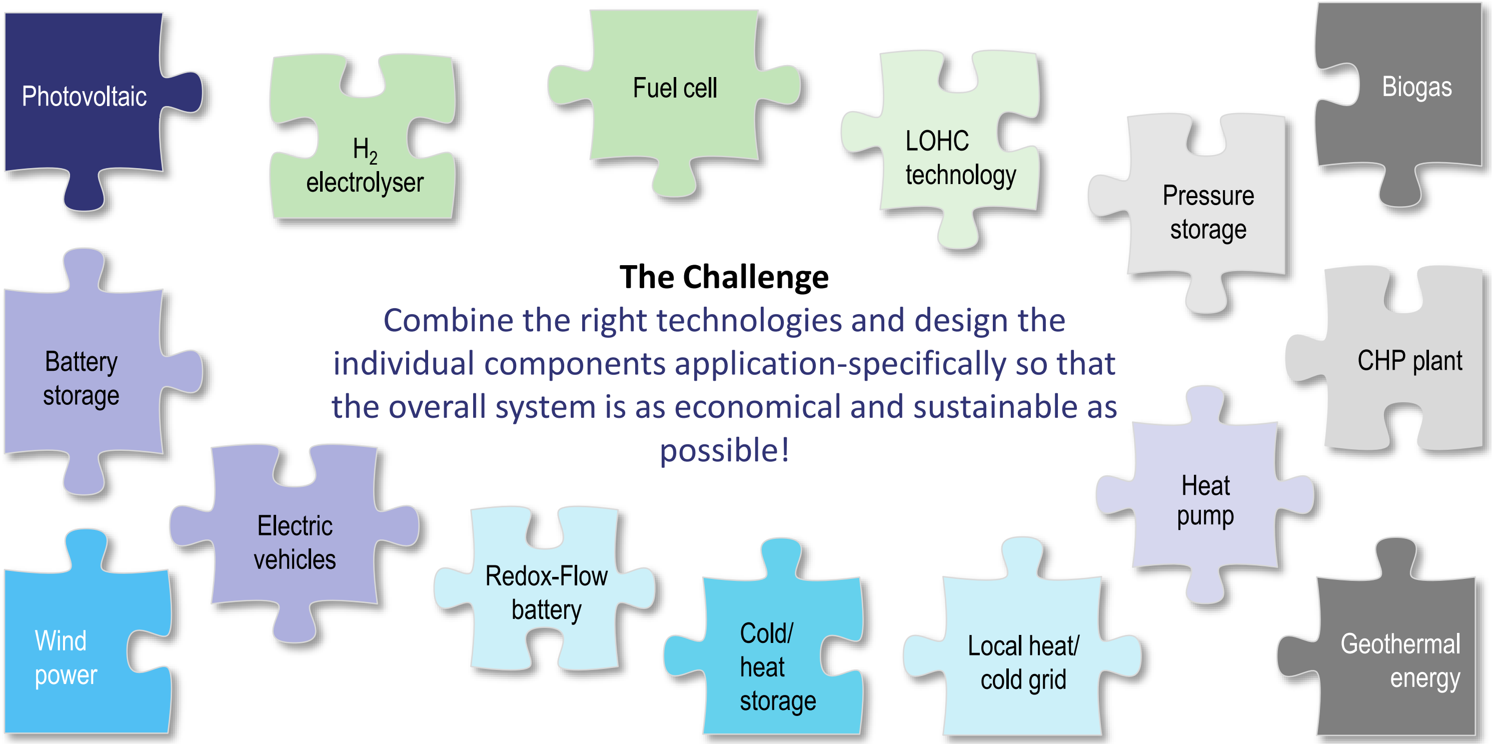
Semiconductor Technology			Power Electronic Systems	
Materials	Technology and Manufacturing	Packaging and Reliability	Vehicle Electronics	Intelligent Energy Systems
				

Modelling and Artificial Intelligence

Challenges and Use Cases for DC Microgrids

“Less technical, but rather normative and regulatory challenges should be addressed.“

Technology Kit for Sustainable Energy Systems Already Exists



The Challenge

Combine the right technologies and design the individual components application-specifically so that the overall system is as economical and sustainable as possible!

"DC is a simple way to create complex energy systems with many different technologies. When DC standards and best practices have been established, we regain simplicity in advanced energy systems."

What makes optimizing energy systems so difficult?

Complex energy infrastructures with close coupling of (sub)systems

Coupled energy systems with different energy sectors
- Electrical networks (AC and DC)
- Heating & Cooling (HVAC, Process Cooling)
- Gases (hydrogen, natural gas, process gases)
- Compressed air, vacuum

The energy sectors are coupled via generation plants
- Optimization of a component or subsystem does not lead to improve the overall system
- Therefore, all relationships between components and networks are considered

High number of boundary conditions, constraints, and optimization goals

Boundary conditions of the components
- Different classes of components: import/export, generation plants, energy storage and consumers
- Each component has individual boundary conditions, such as rated powers, state of charge limits, dynamic behavior...

Typical optimization goals in energy systems
- Optimizing self-sufficiency through renewable energies
- Efficiency of generation plants and energy distribution
- Peak load reduction and load shifting

→ Emission reduction, cost savings

- Holistic view of the energy system of interest necessary
- High complexity requires tools for optimization

Tools for Designing, Optimization and Operation of DC Microgrids

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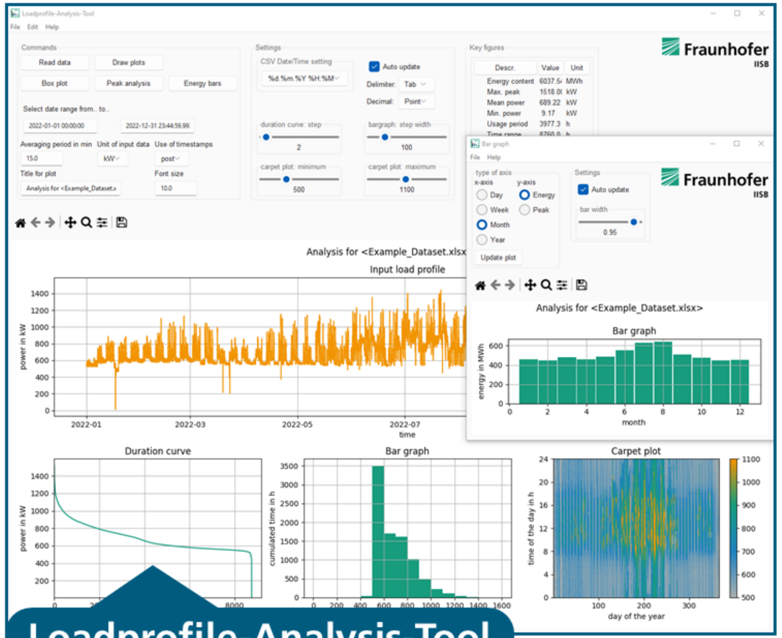
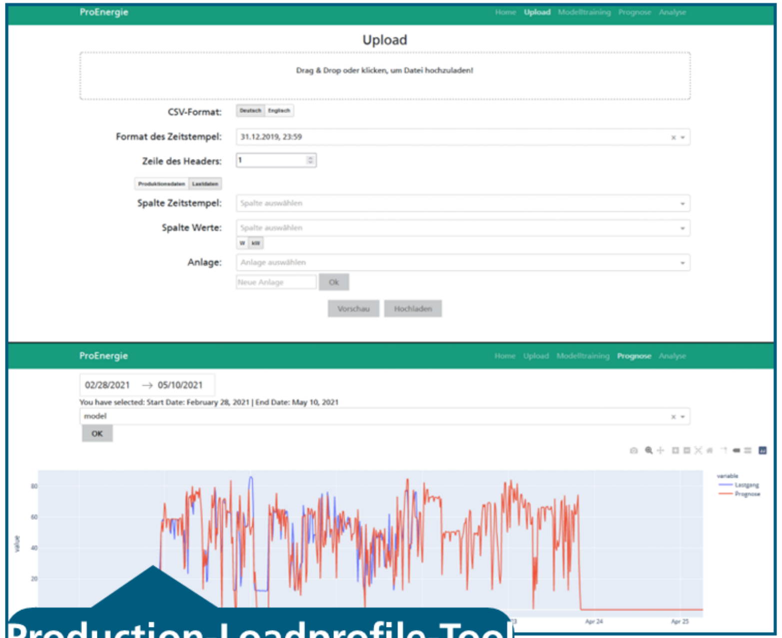
Overview of IISB software toolbox

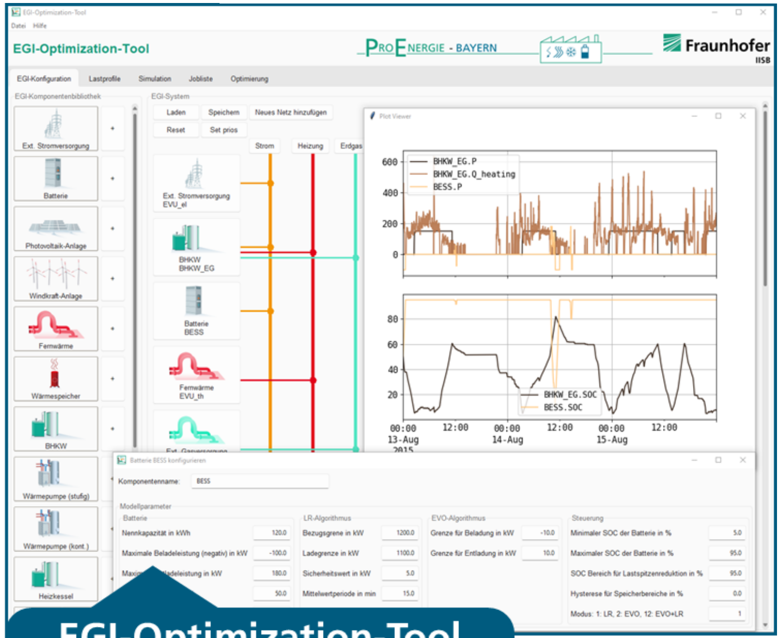
CPE Cognitive Power Electronics



Loadprofile-Analysis-Tool
Load profile analysis incl. useful plots und key figures



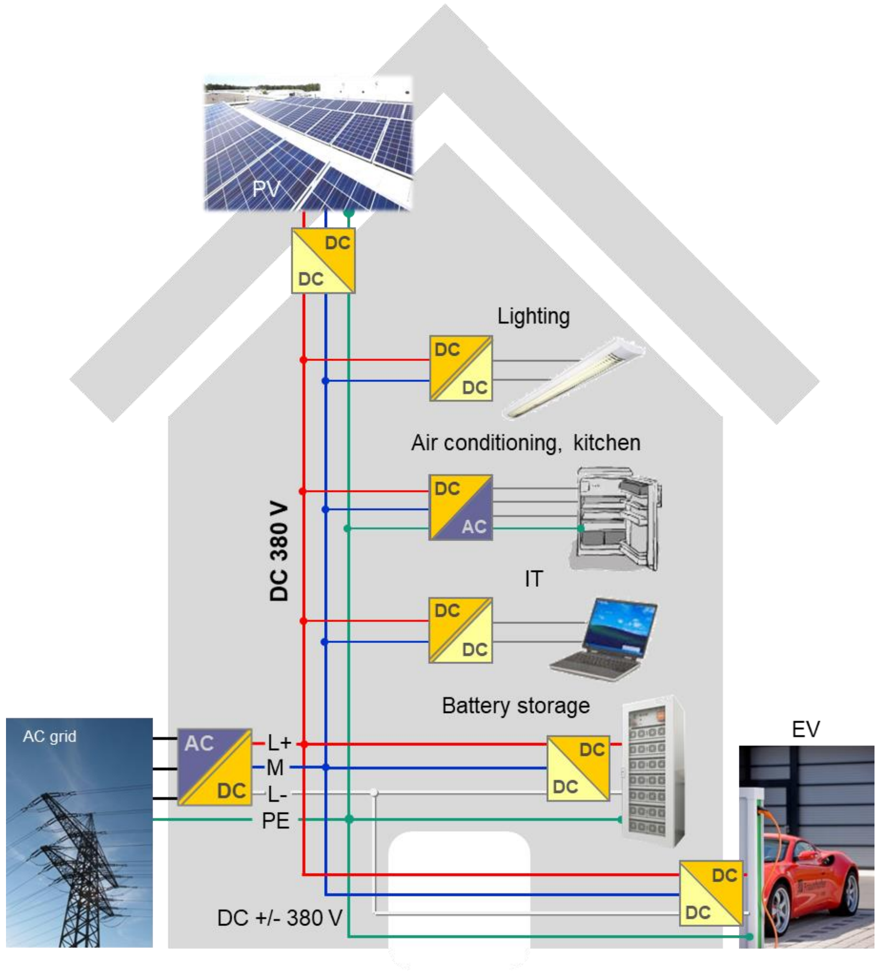
Production-Loadprofile-Tool
Load prognosis based on ML-model incl. model trainings

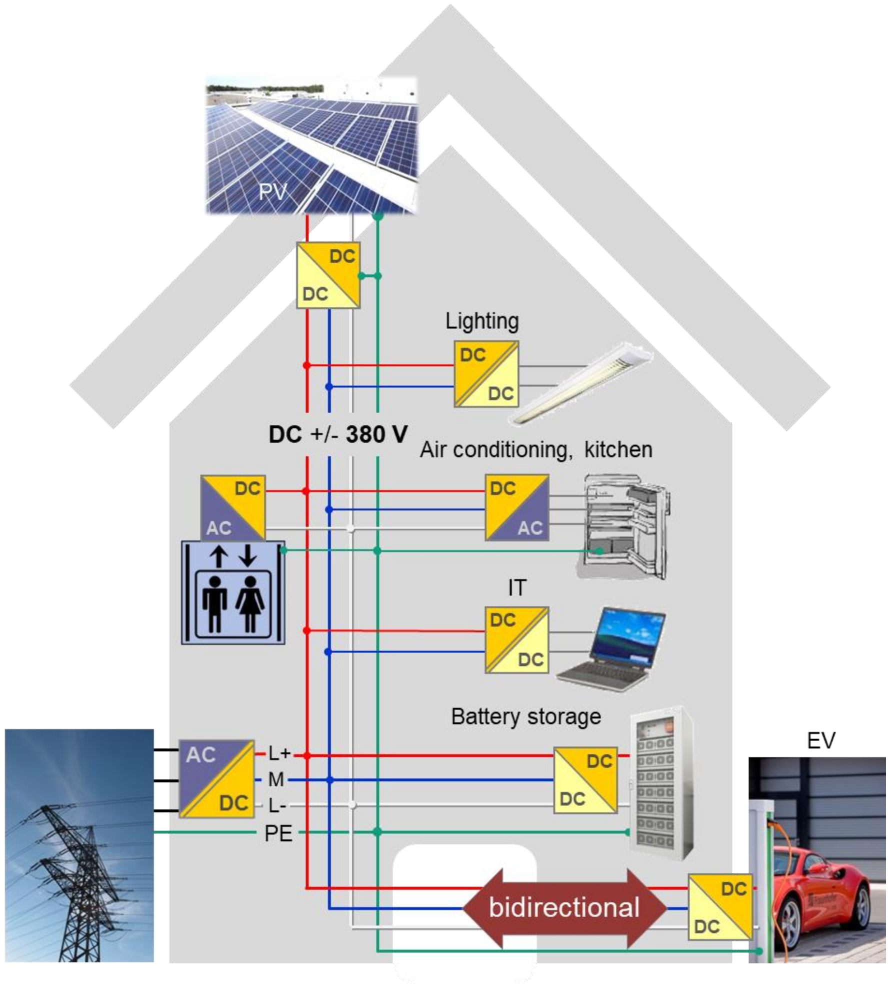


EGI-Optimization-Tool
Simulation and optimization of the free configurable EGI

Screenshots of the ProEnergie software toolbox (https://proenergie-bayern.de), freely available at: https://gitlab.cc-asp.fraunhofer.de/proenergie

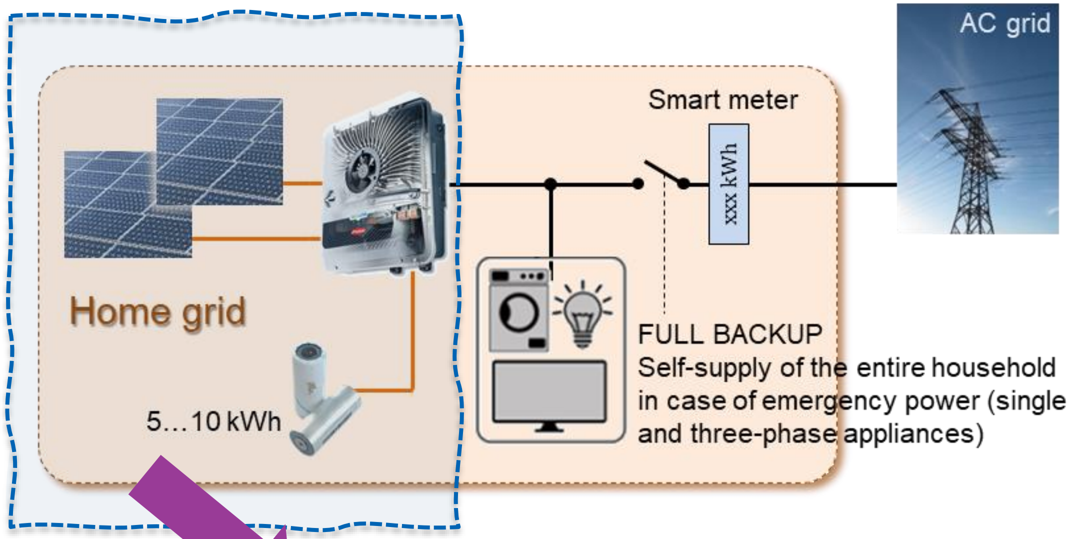
Use Case DC Homes / Commercial Buildings





USE Case: Decentral Home Energy System

typical DC coupled PV/Battery installation with AC backup are easy to install

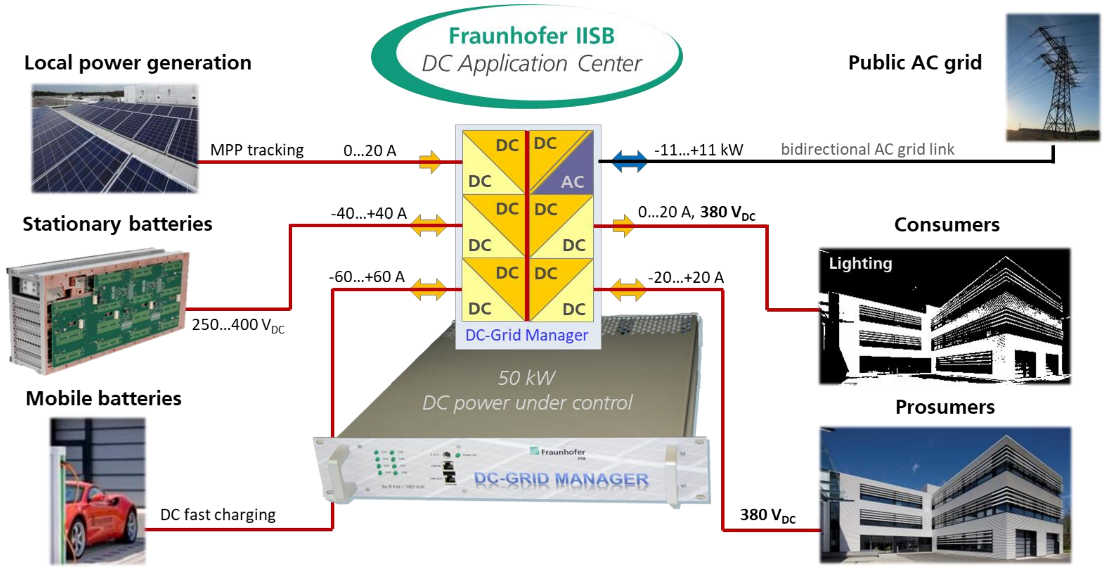


DC Side in homes is growing:

- DC coupled DC charging
- Coupling of DC link in Heat pumps
- More and more Battery powered tools
- Most small equipment uses USB-C

DC Microgrid in a converter system for DC grids

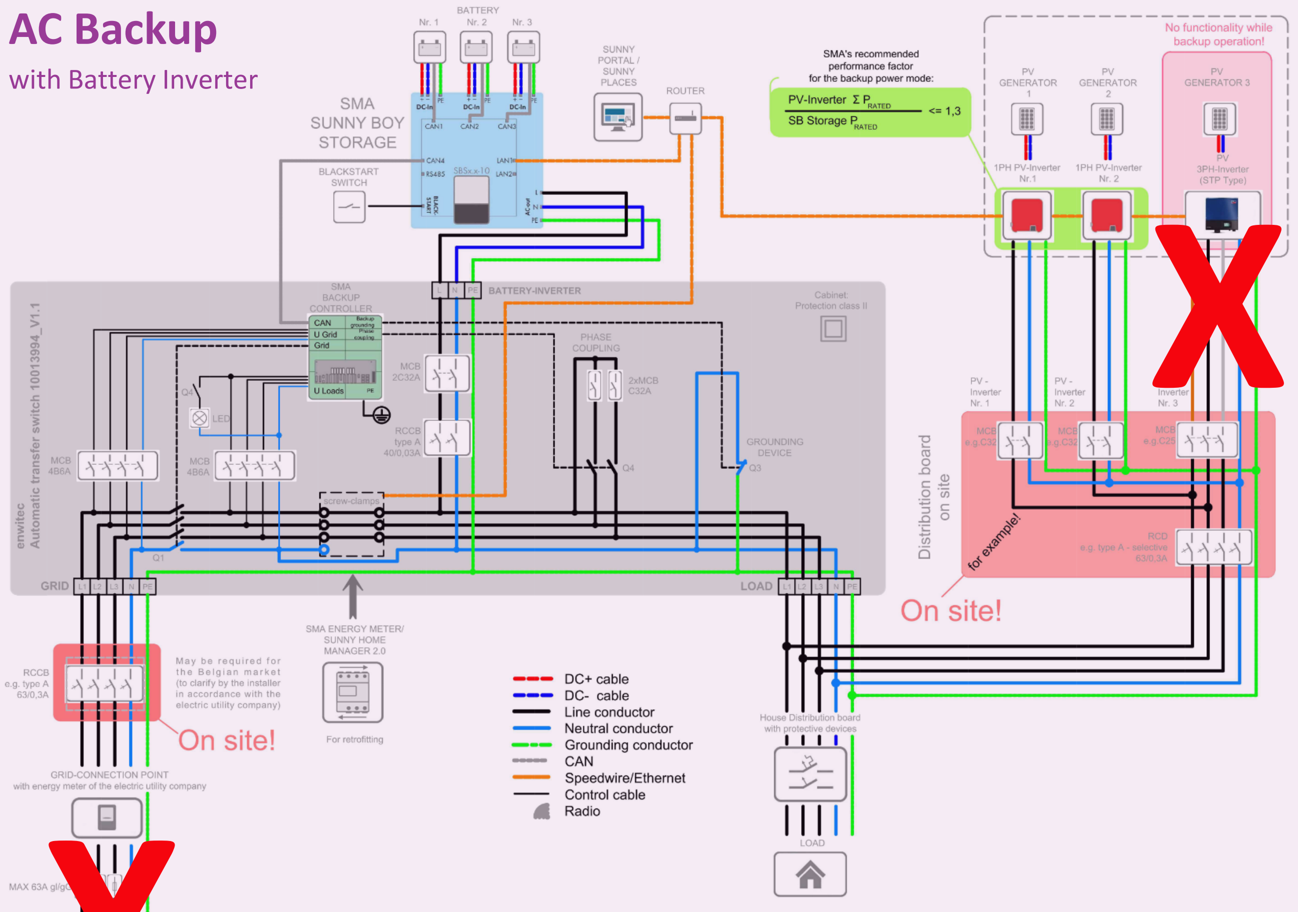
for small DC Microgrids, e.g. residential buildings,
all in one Device solutions are very easy to install.



USE Case: Decentral Home Energy System - Backup

AC Backup

with Battery Inverter



AC-Backup requires coordination and comes with a lot of restrictions like limited power. Often only a part of the system is running in backup.

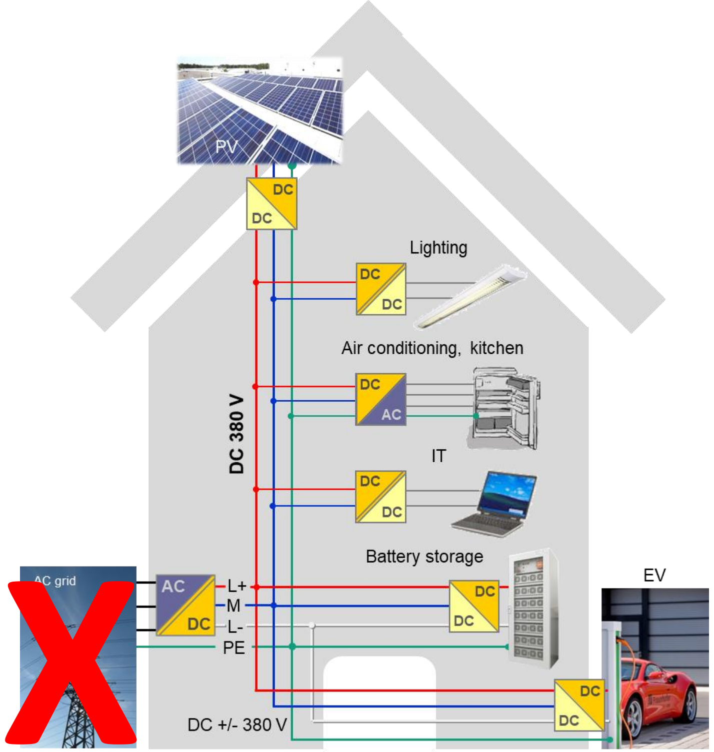
AC Backup

with Hybrid Inverter

Hybrid Inverter (10 kW backup) or Backup generator (8kVA) can provide backup

only single source system

DC Backup



DC-Backup requires no change in the System and works as normal no Backup Box or Backup Controller needed.

USE Case: Decentral Home Energy System - Backup

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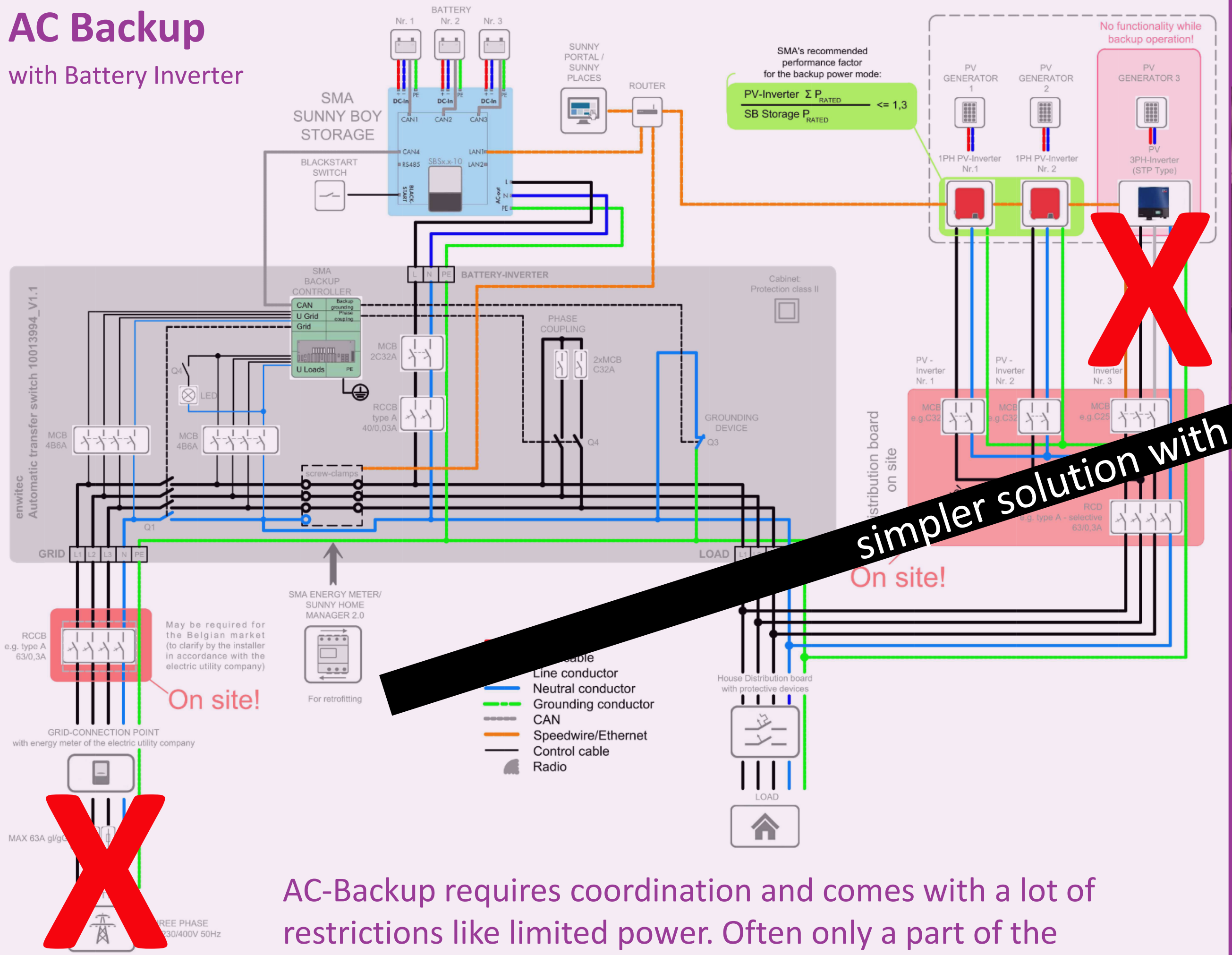
AC Backup

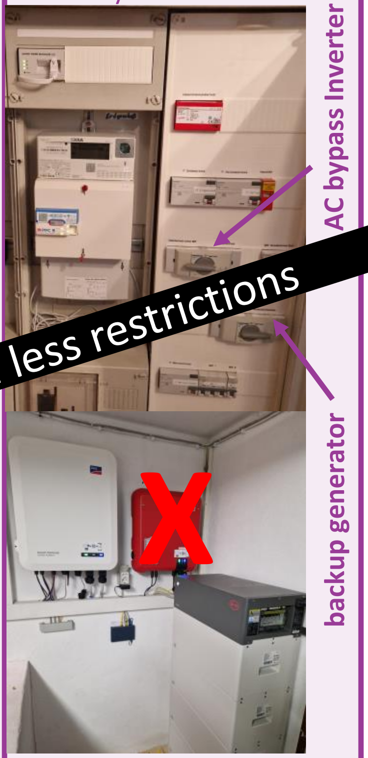
with Battery Inverter



AC-Backup requires coordination and comes with a lot of restrictions like limited power. Often only a part of the system is running in backup.

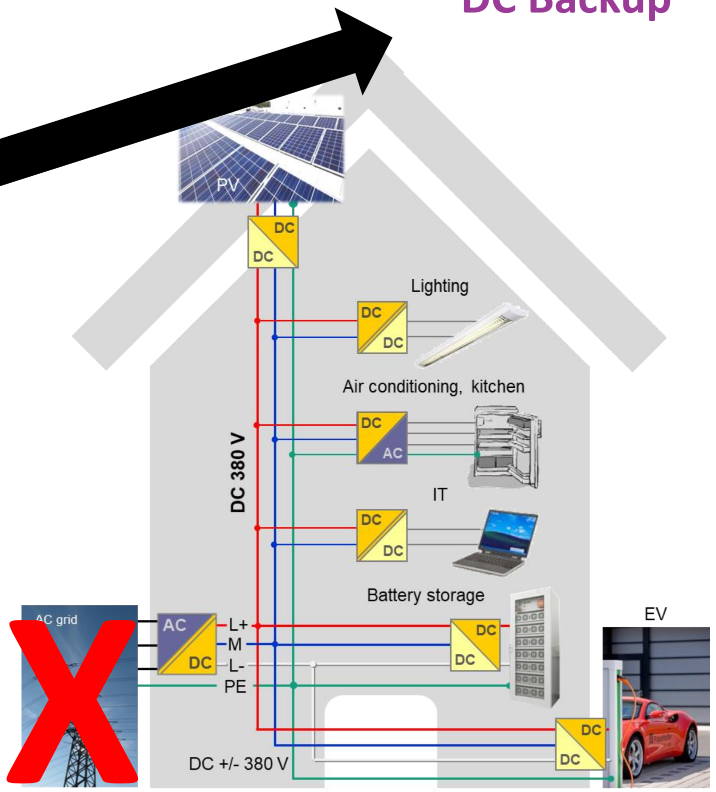
AC Backup

with Hybrid Inverter



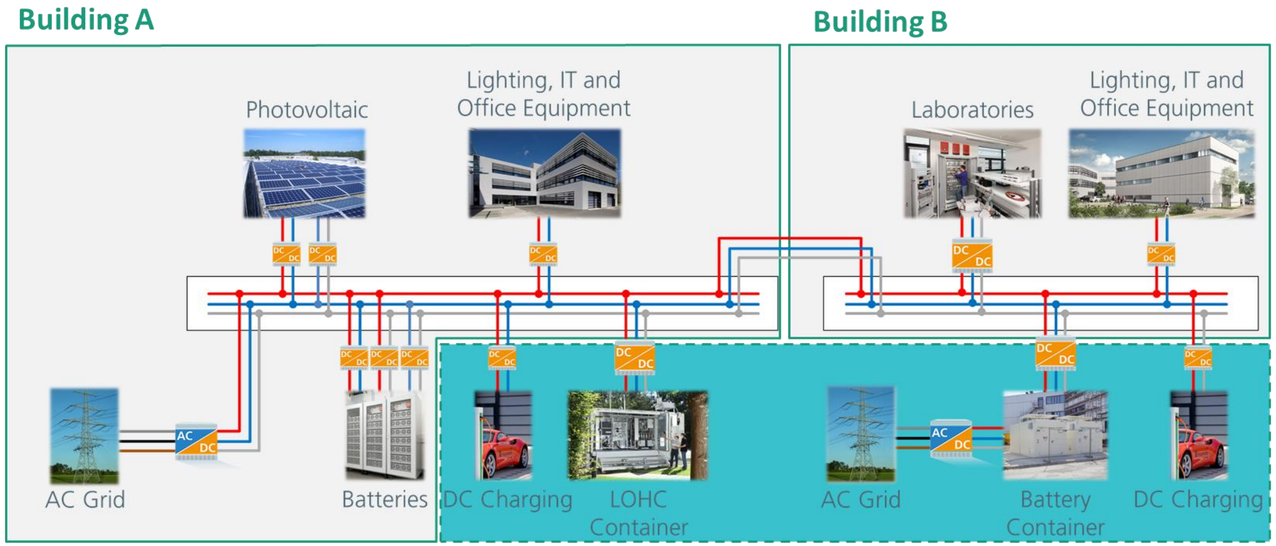
Hybrid Inverter (10 kW backup) or Backup generator (8kVA) can provide backup **only single source system**

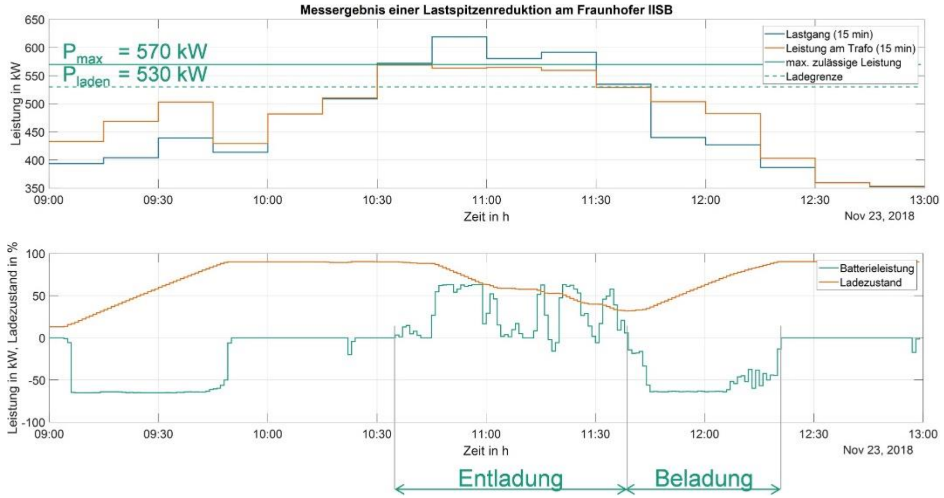
DC Backup



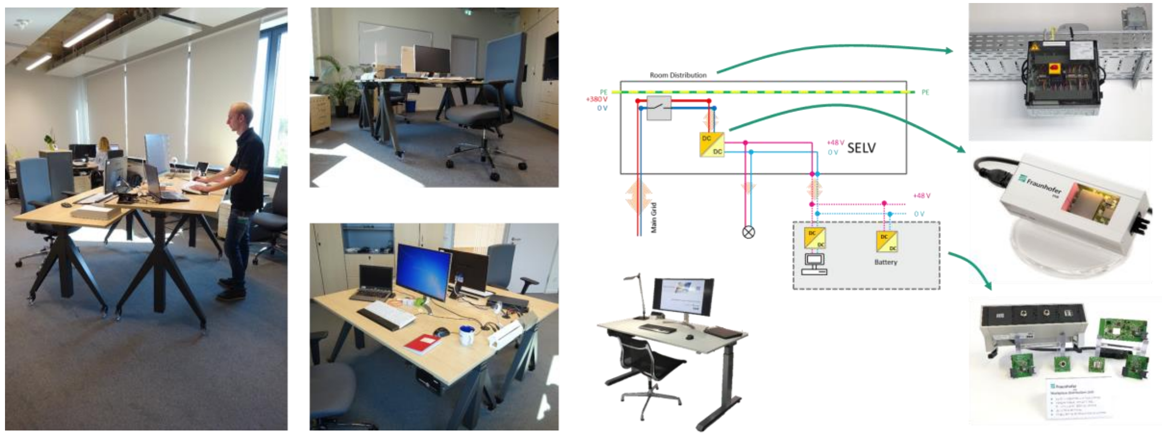
DC-Backup requires no change in the System and works as normal no Backup Box or Backup Controller needed.

Use Case DC-Microgrid in Commercial Buildings

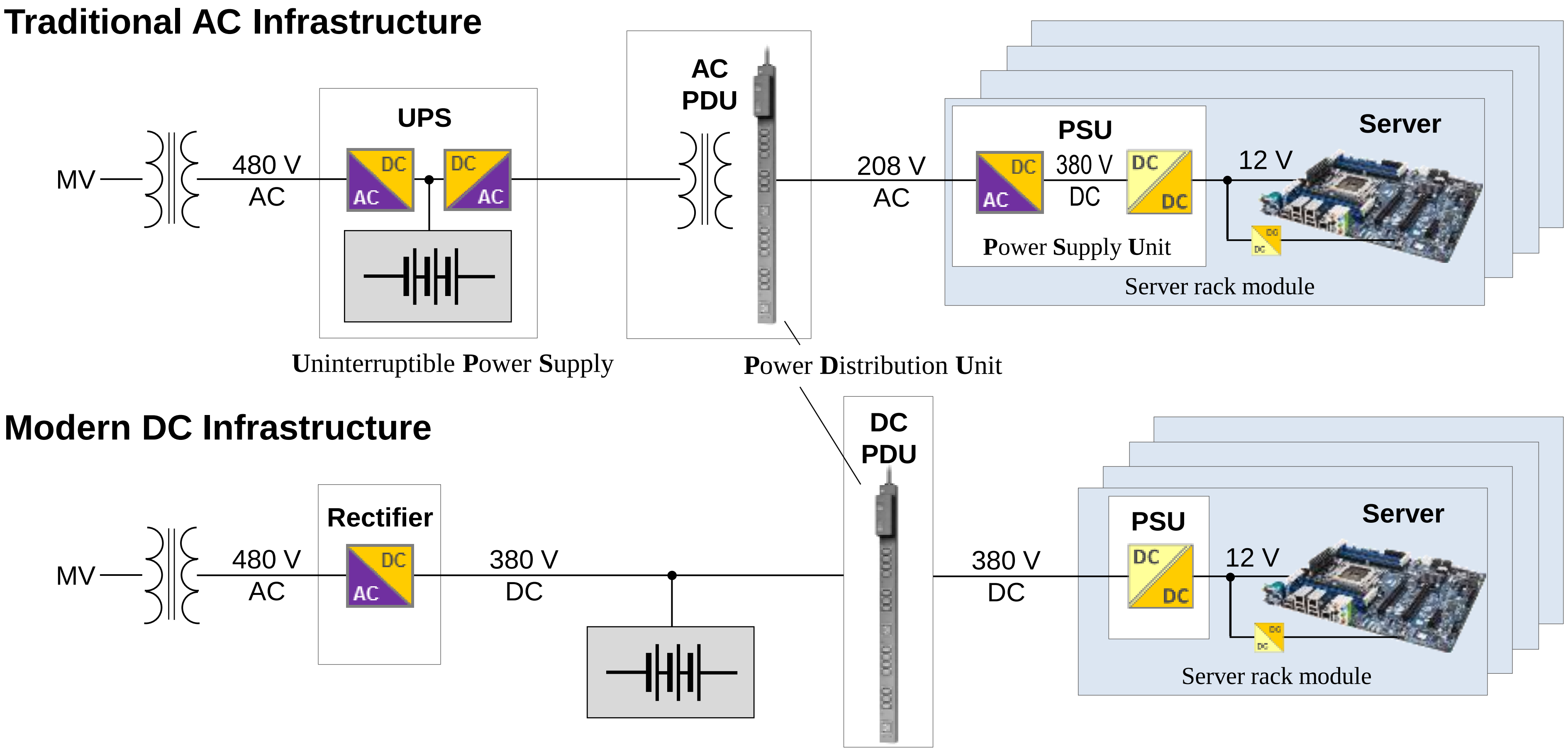




Outdoor Installations



USE Case: Direct Current Data Center

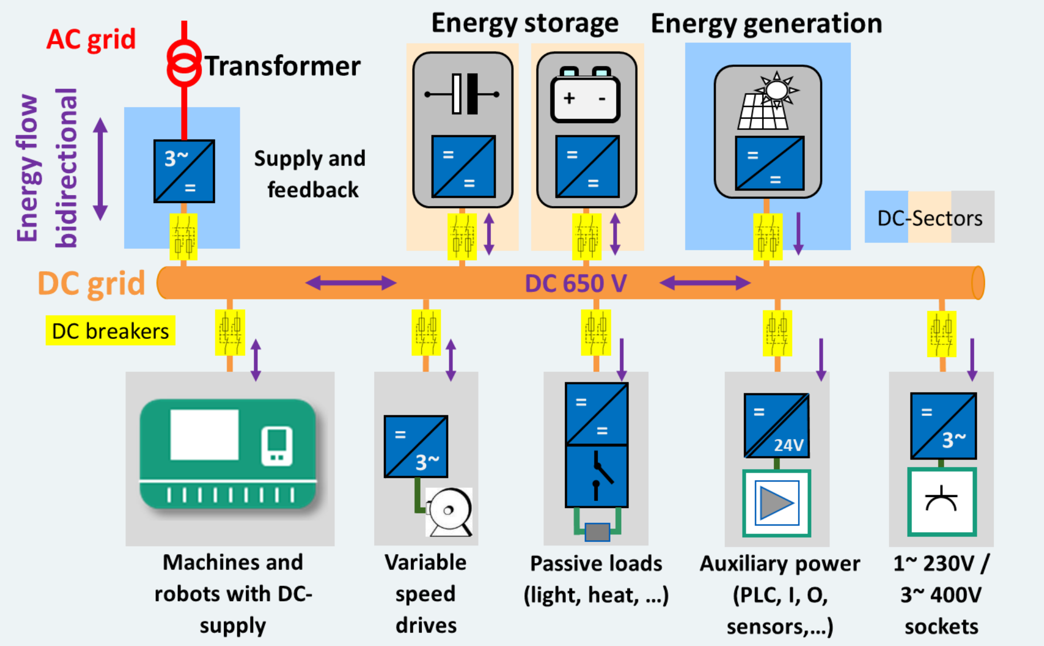


➷ Less investment costs, higher energy efficiency, lower space requirements, significantly higher security of supply

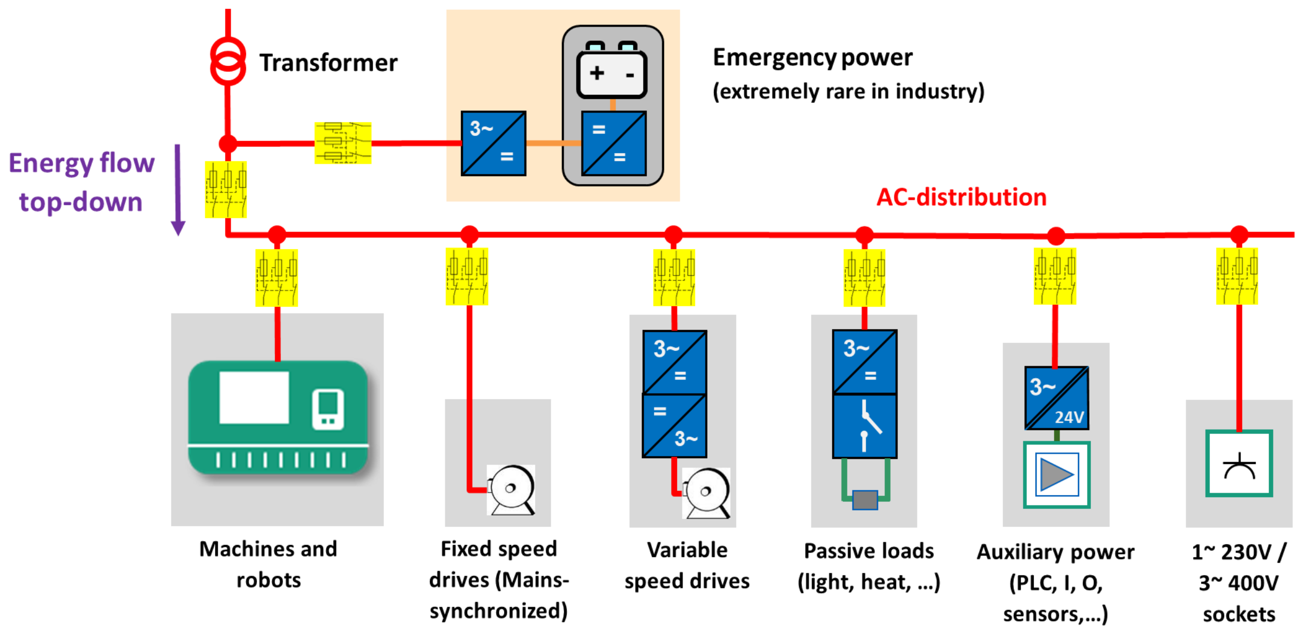
Use Case DC Microgrids in Industry

Overview

DC-Industrie 2:

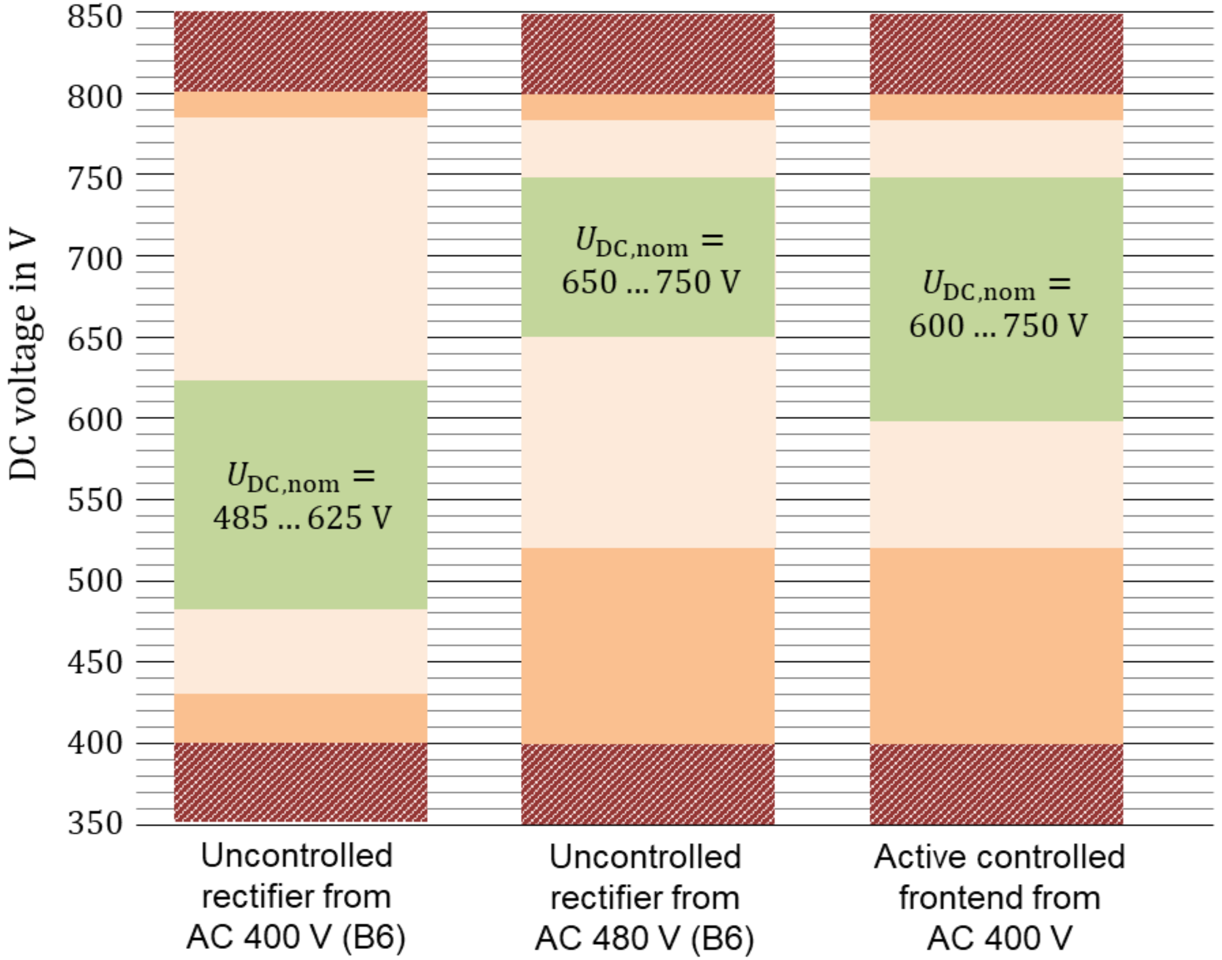


Status quo:



Use Case DC Microgrids in Industry

Voltage Specifications in Industrial Environments



Nominal operation

- fully functional

Stationary over-/undervoltage

- continuous operation permitted
- derating permitted
- active grid participants counteract the voltage deviation

Transient over-/undervoltage

- voltage may be in this range only for a limited time
- functional restrictions are permissible, but must disappear when the nominal voltage range is returned

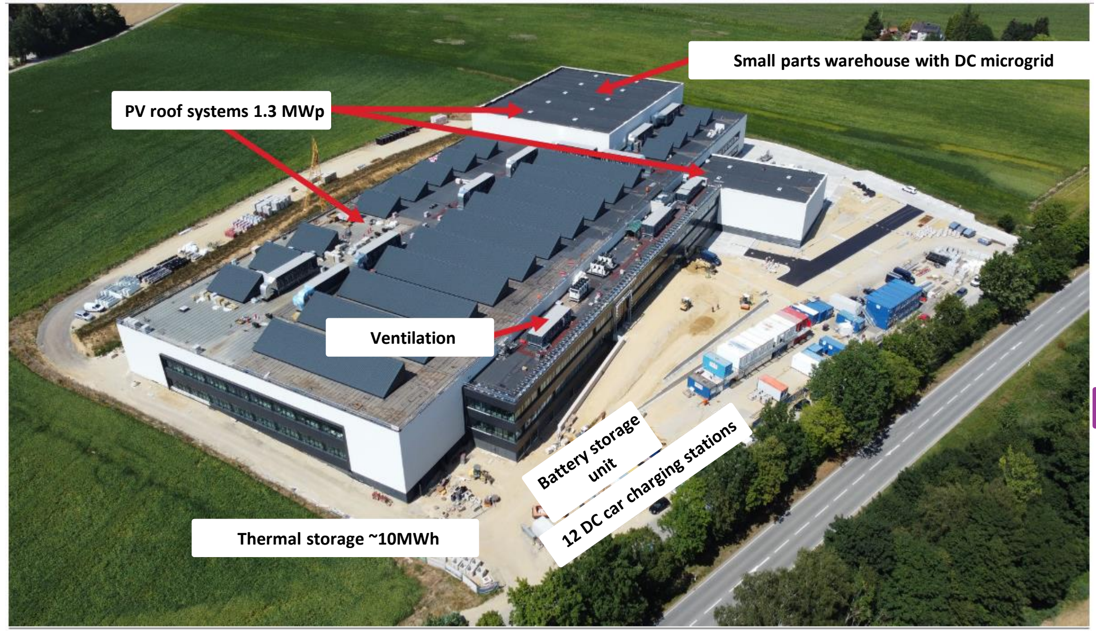
Shutdown areas

- loss of function, devices switch off permanently for self-protection

according to a proposal of the ODCA consortium

Use Case DC Microgrids in Industry

Example Schaltbau

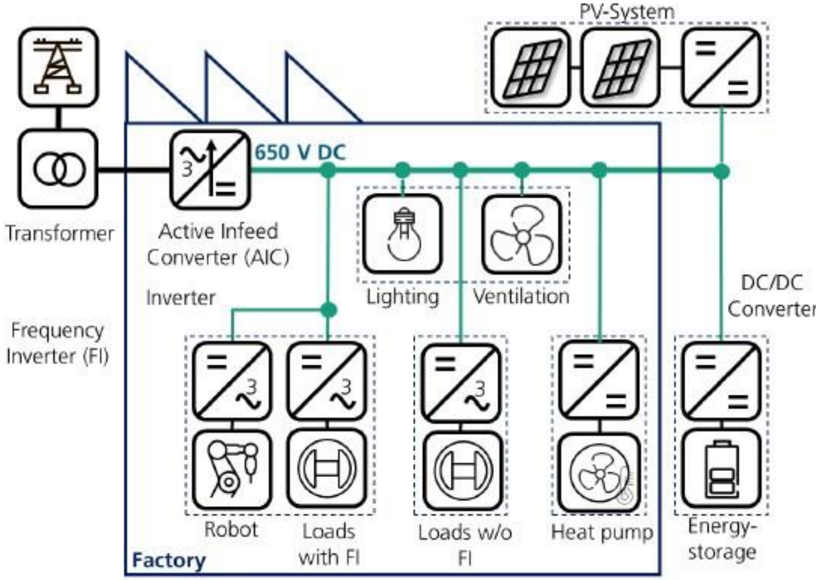


Source: Schaltbau

Properties	Value	Unit
Overall efficiency AC	81.88	%
Overall efficiency DC	88.37	%
Efficiency increase	6.49	%
Total need AC with PV	17 263.04	MWh/a
Total need DC with PV	15 110.24	MWh/a
Comparison of total need	87.53	%
Energy saved	2 152.80	MWh/a
Cost savings vs. AC	430 559.99	€/a
CO2 savings	762.09	tCO_2eq/a
Additional investment for DC	1 513 681.22	€
Amortisation period	3.52	years

Properties	Value	Unit
Total output of the factory	5	MW
Total energy of the factory per year	18 750	MWh/a
Factory size	15 000	m^2
Energy price	0.20	€/kWh
CO_2-emissions	354	gCO_2eq/kWh
Output of the production loads	3 925	kW
Heat pump output	530	kW
Power of the ventilation system	395	kW
Power of the lighting system	150	kW
Output of the PV system	530	kWp
Utilisation of the PV system	Self-consumption optimisation in combination with battery storage	

Source: Schaltbau



Source: Schaltbau

- Warehouse, production, laboratory, development
- **85% lower peak load of the high-bay warehouse compared to AC**
- Reduced stress on the supply network

Use Case Electric Vehicle

the driver for DC solutions with a high quantity market

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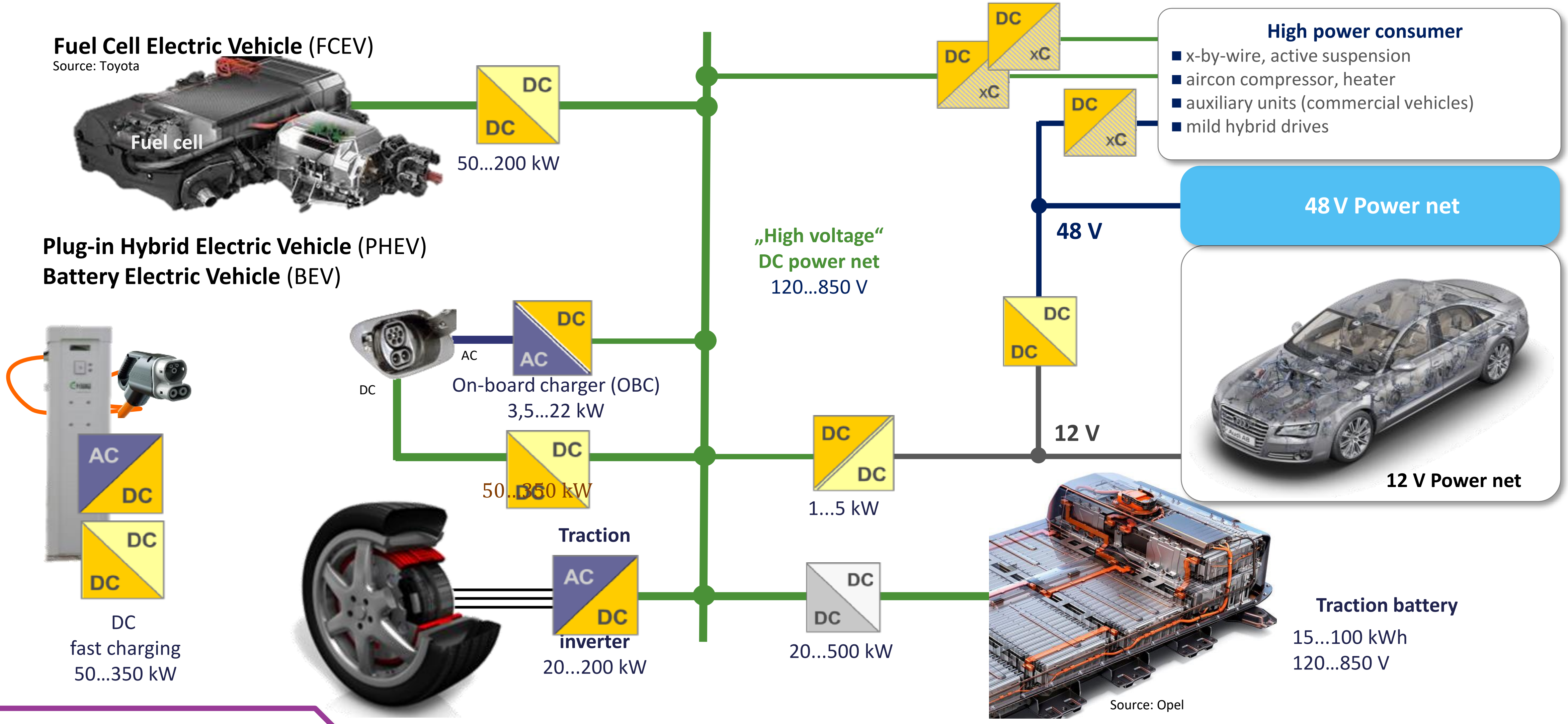
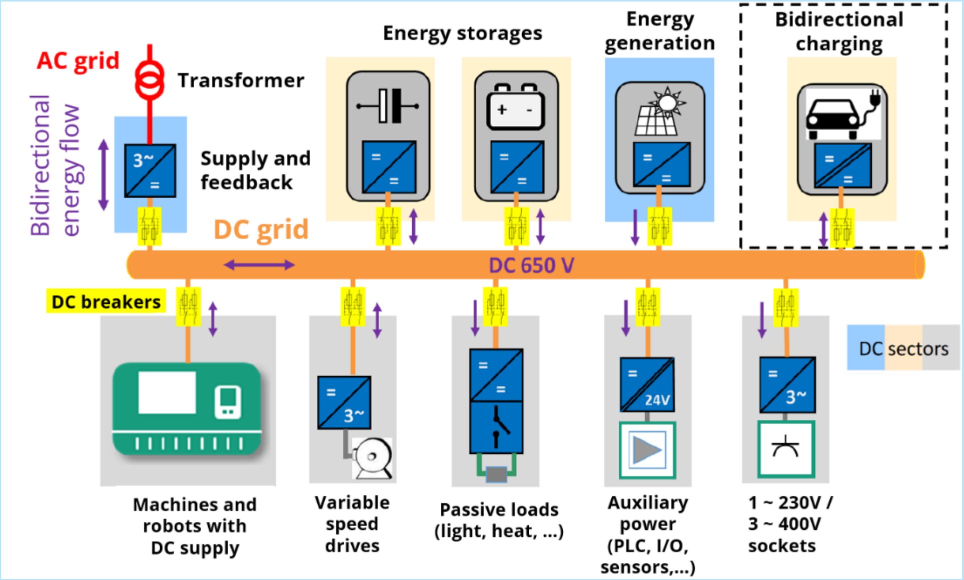
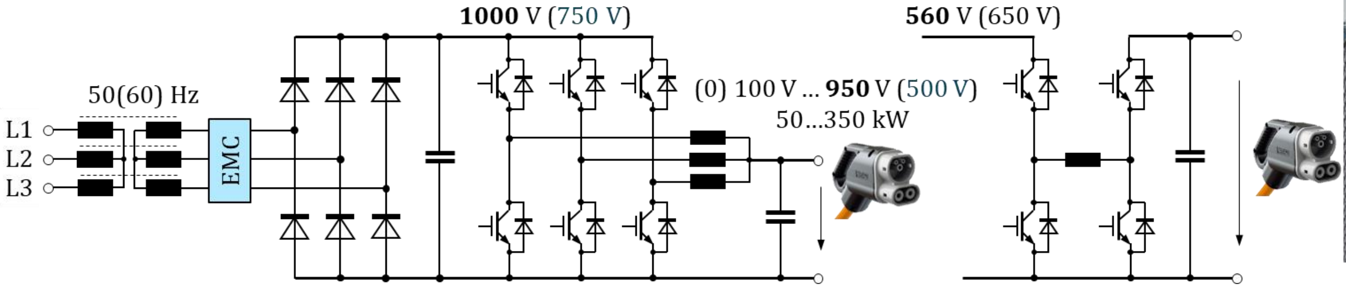


Use Case DC Charging from a DC Microgrid



German Project DCI4Charge extends "DC-Industrie" Concept with DC charging Use Case.

DCI4Charge specify DC Charging from a 650V DC-Microgrid

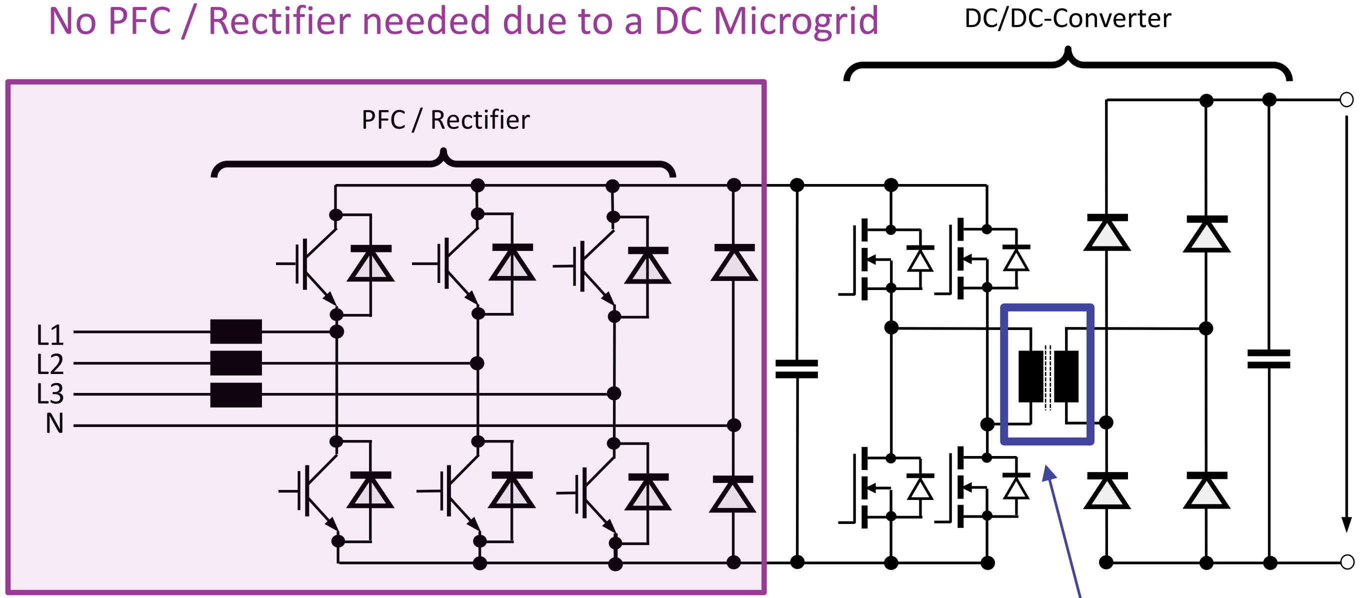


Classic DC fast charging architecture: galvanic isolation done on grid side and 1000V DC-Bus inside of the charging station.
This concept only enables one fast DC charger behind the transformer (according to IEC 61851-23).

Use Case DC Charging from a DC Microgrid

DC fast charging: galvanic isolation done inside the converter

No PFC / Rectifier needed due to a DC Microgrid



Isolating stage
Medium frequency transformer

Medium Frequency transformer

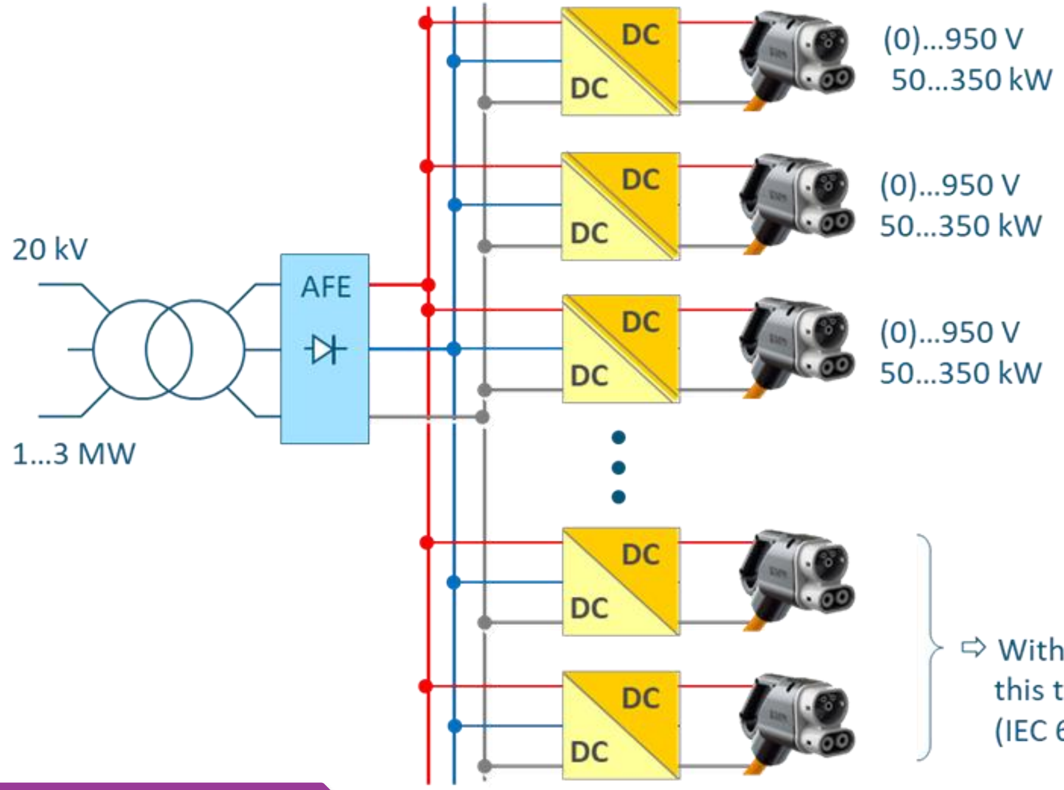
- Compact size and reduced weight
- Reduced efficiency and reliability due to additional semiconductors

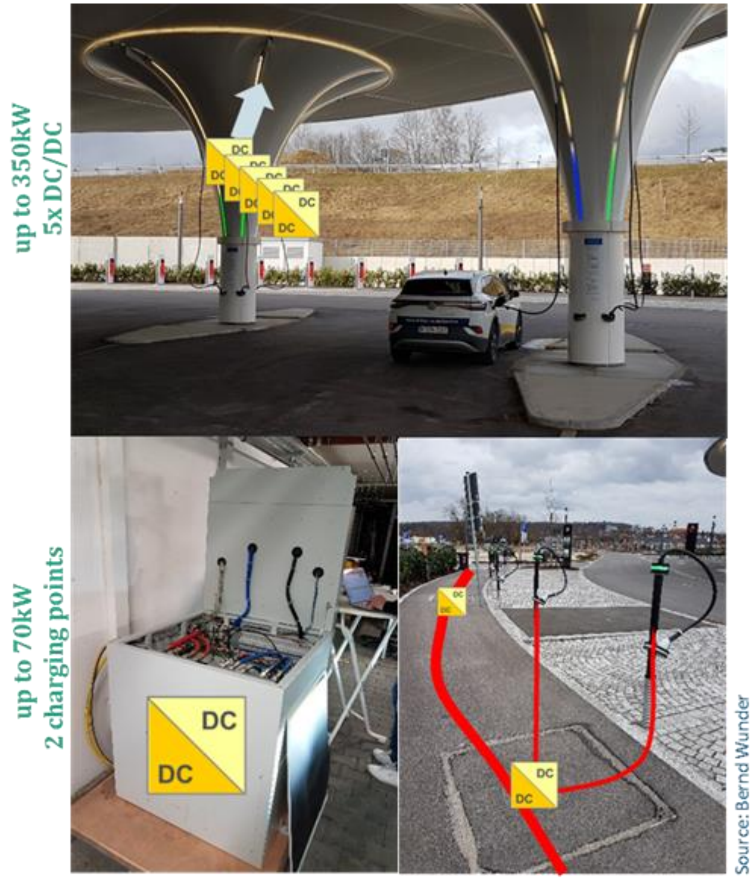
⇒ **Cost savings through fewer power electronic components, more efficient installation, and lower connection costs**

Use Case DC fast Charging park with a DC Microgrid

many charging points connected to a single DC-link

Example: Sortimo Innovationspark in Zusmarshausen, Germany
144 charging options, 120 DC fast chargers
1000 V DC Microgrid





⇨ Without galvanic isolation between the charging points, this topology is normatively not authorized (IEC 61851-23 ED2 FDIS 2022)

Use Cases for bidirectional charging

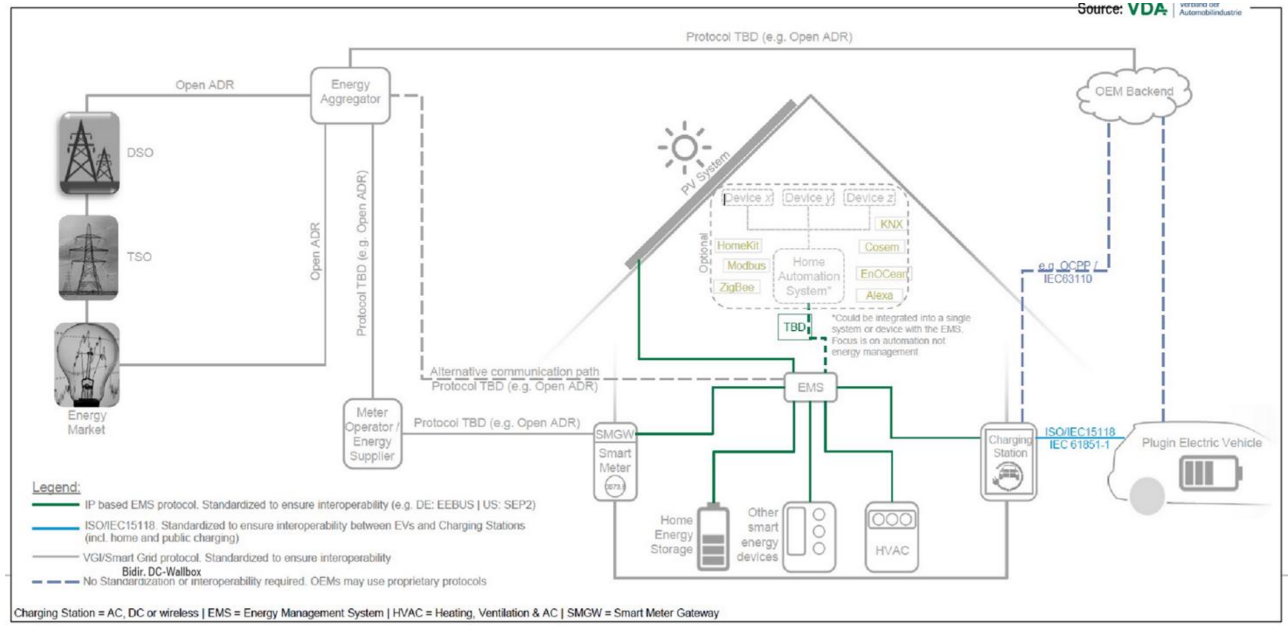
Overview

Many Use Cases for bidirectional charging:

- Standardization needed for broad adoption of bidirectional charging
- Complex Interfaces between all stakeholders

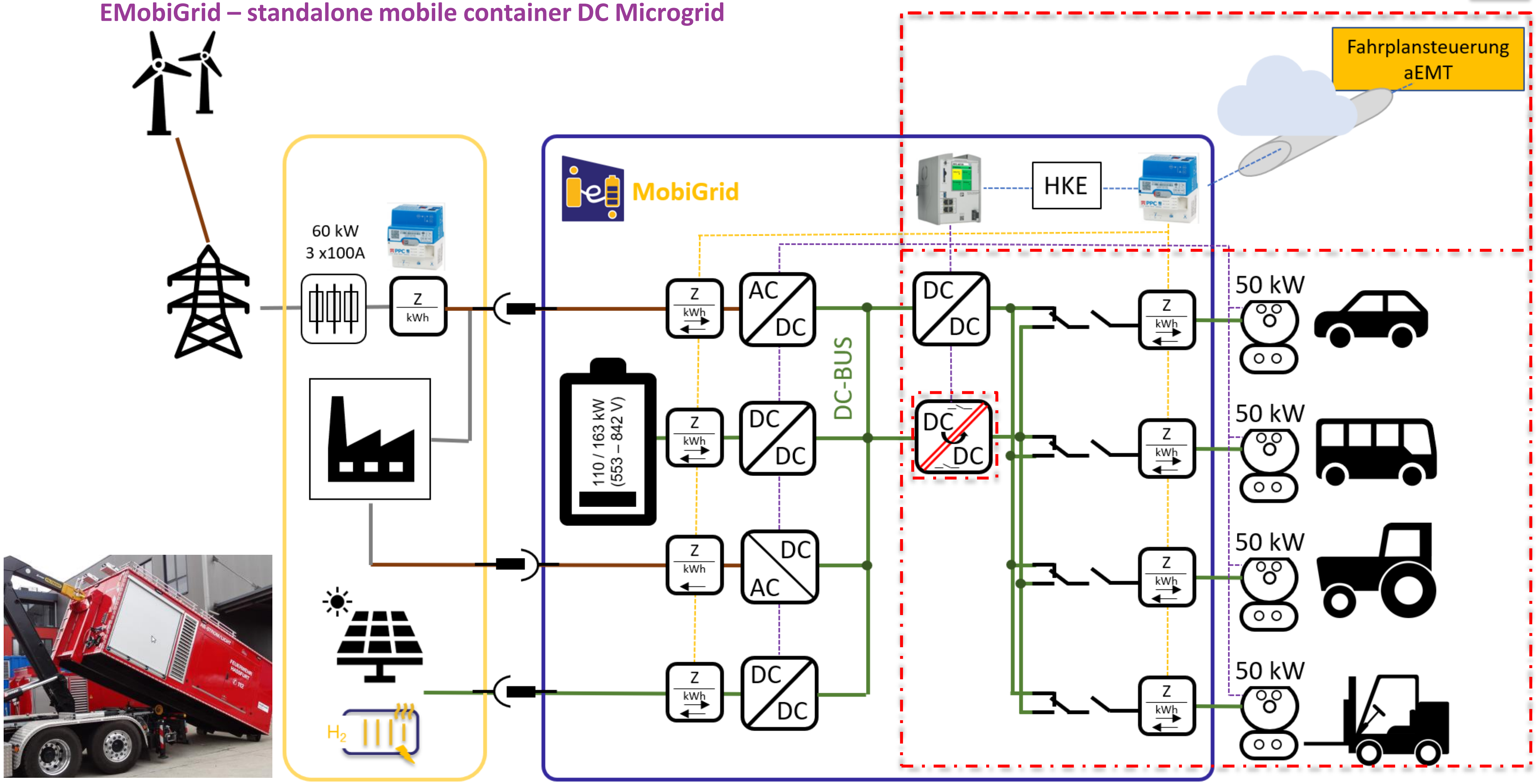
National Committee DKE 353.0.401B wrote a report about bidirectional charging Use Cases.

Gruppe	Use Case	Erlös-Ort	Kunden-gruppe	Regelung
V2H	Eigenverbrauchserhöhung			Lokal
V2H	Tarifoptimiertes Laden/Entladen			Lokal
V2H	Notstromversorgung			Lokal
V2G	Intraday-Handel			Zentral
V2G	Primärregelleistung (PRL)			Lokal
V2G	Redispatch			Zentral
V2B	Spitzenlastkappung (Peak Shaving)			Lokal
V2B	Flottenmanagement			Lokal
Mobil	Mobile Powerbox	-		Lokal
V2X	CO2 optimiertes Laden			Lokal
V2V	Vehicle-to-vehicle charging	-		Lokal
	Systembild – Customer Energy Management System – System Integration - Deutschland			



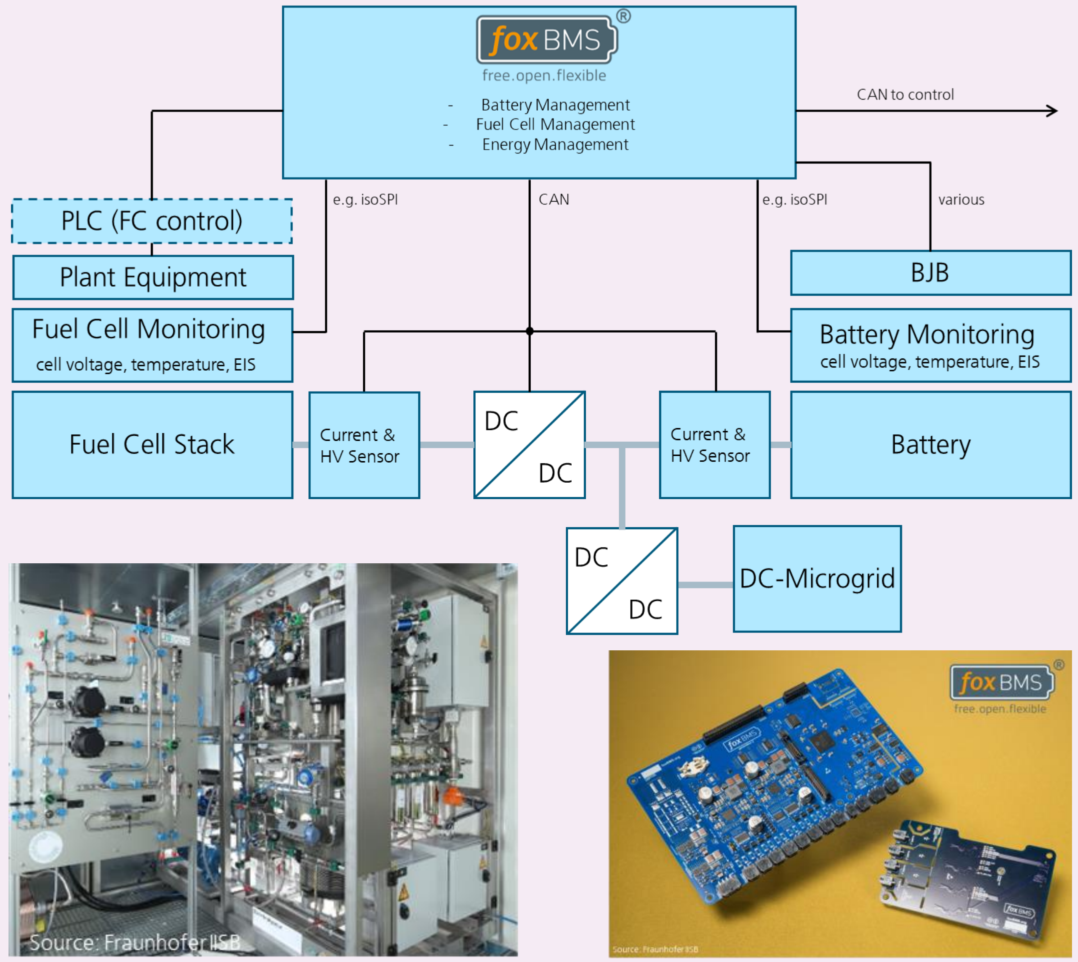
Use Cases for bidirectional charging

EMobiGrid – standalone mobile container DC Microgrid



Use Case with Fuel Cell System or Redox Flow Battery

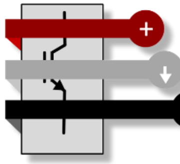
direct coupled storage systems

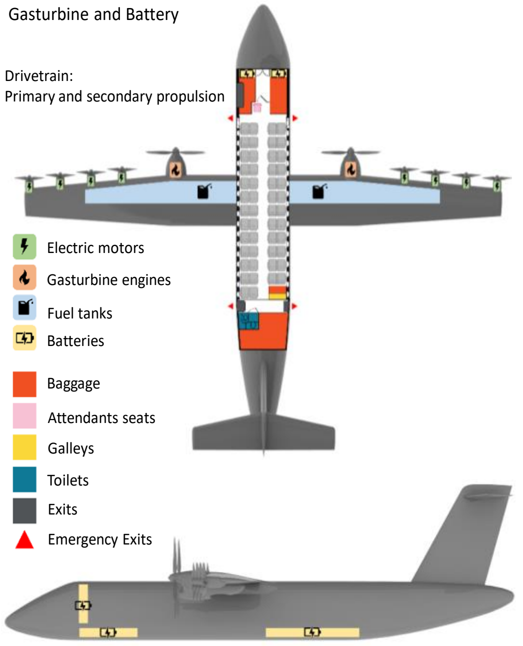


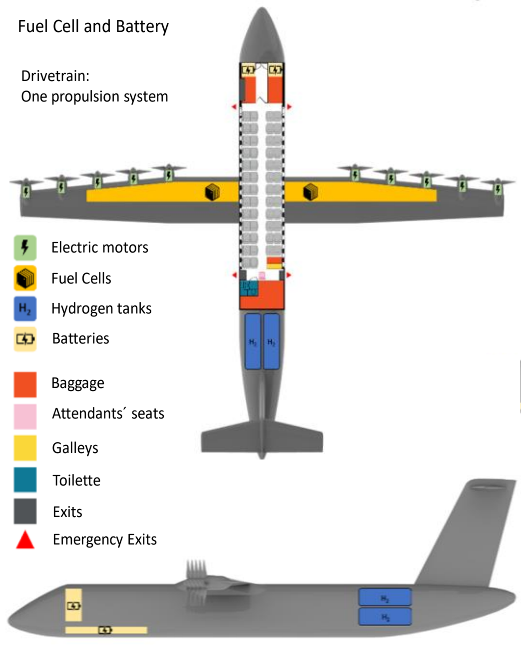
Fuel Cell System in DC-Grid

Redox Flow Battery in DC-Grid

Use Case Electric Aviation





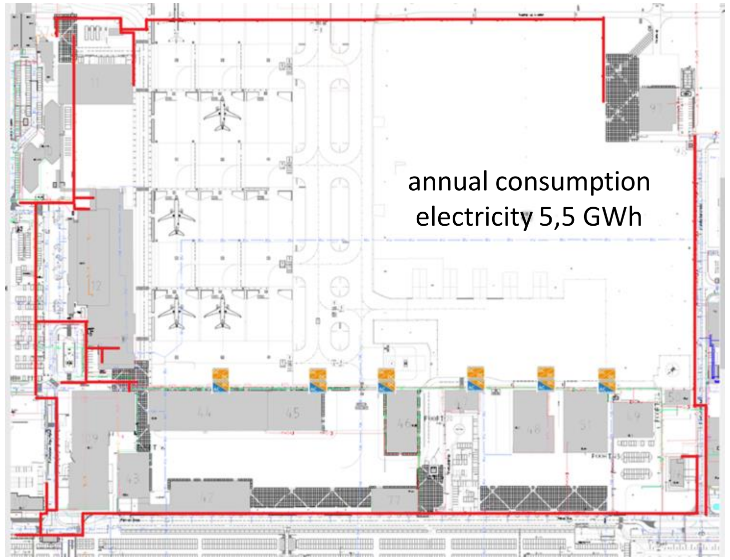


Typ:
Regional hybrid-electric (ATR-42)

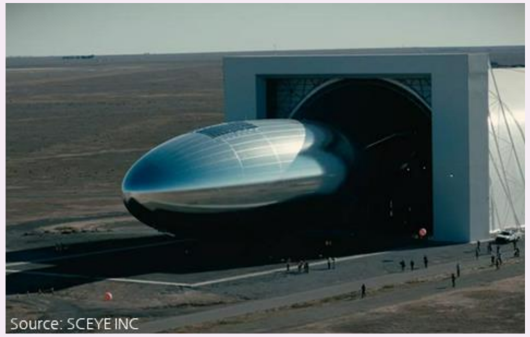
Passengers:
50 PAX

Distance:
600 NM (nmi)
~1112 km

Cruise altitude:
6100 m
20,000 ft



Concept for DC Microgrid at Airport Rotterdam
Source: Project GENESIS

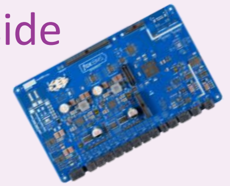


High altitude air ship

Hydrogen powered UAV

Electrified Sling TSi

IISB Technology inside



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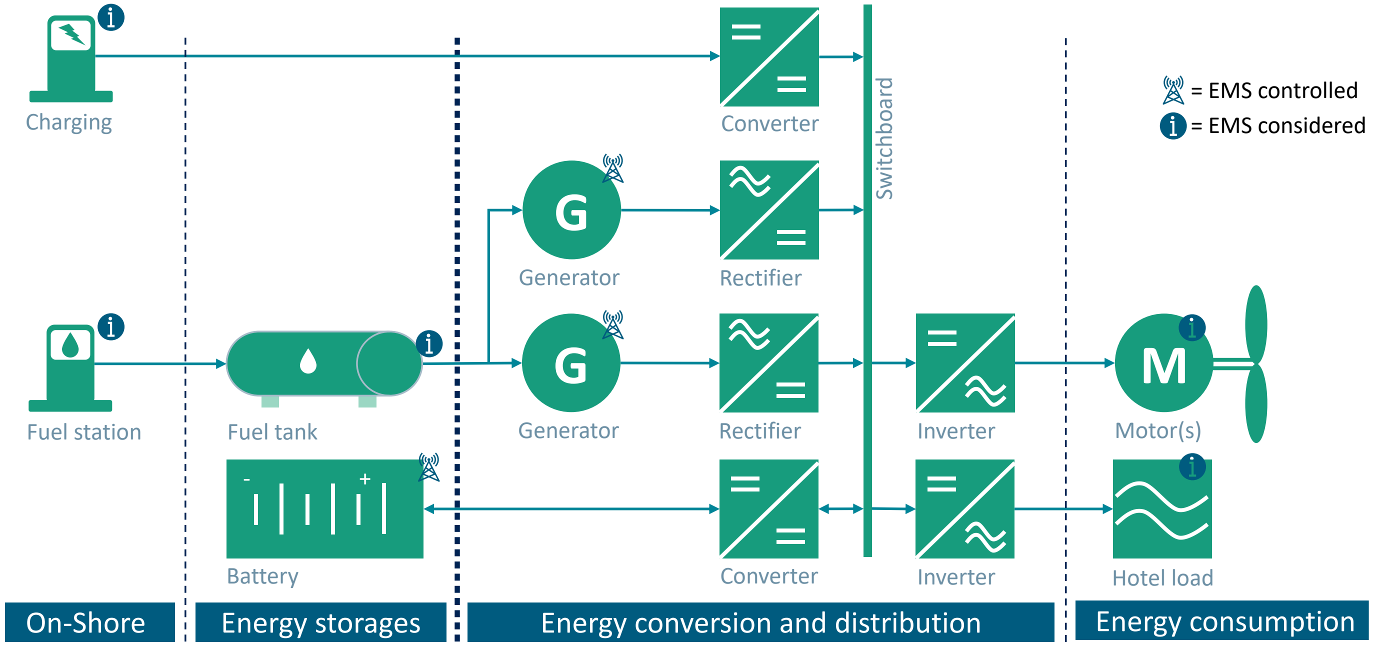
Use Case Electric Ships

FLEXSHIP

Flexible and modular large battery systems for safe on-board integration and operation of electric power, demonstrated in multiple type of ships

FLEXSHIP has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement № 101095863.

Schematic representation of a energy supply system of a hybrid electric vessel



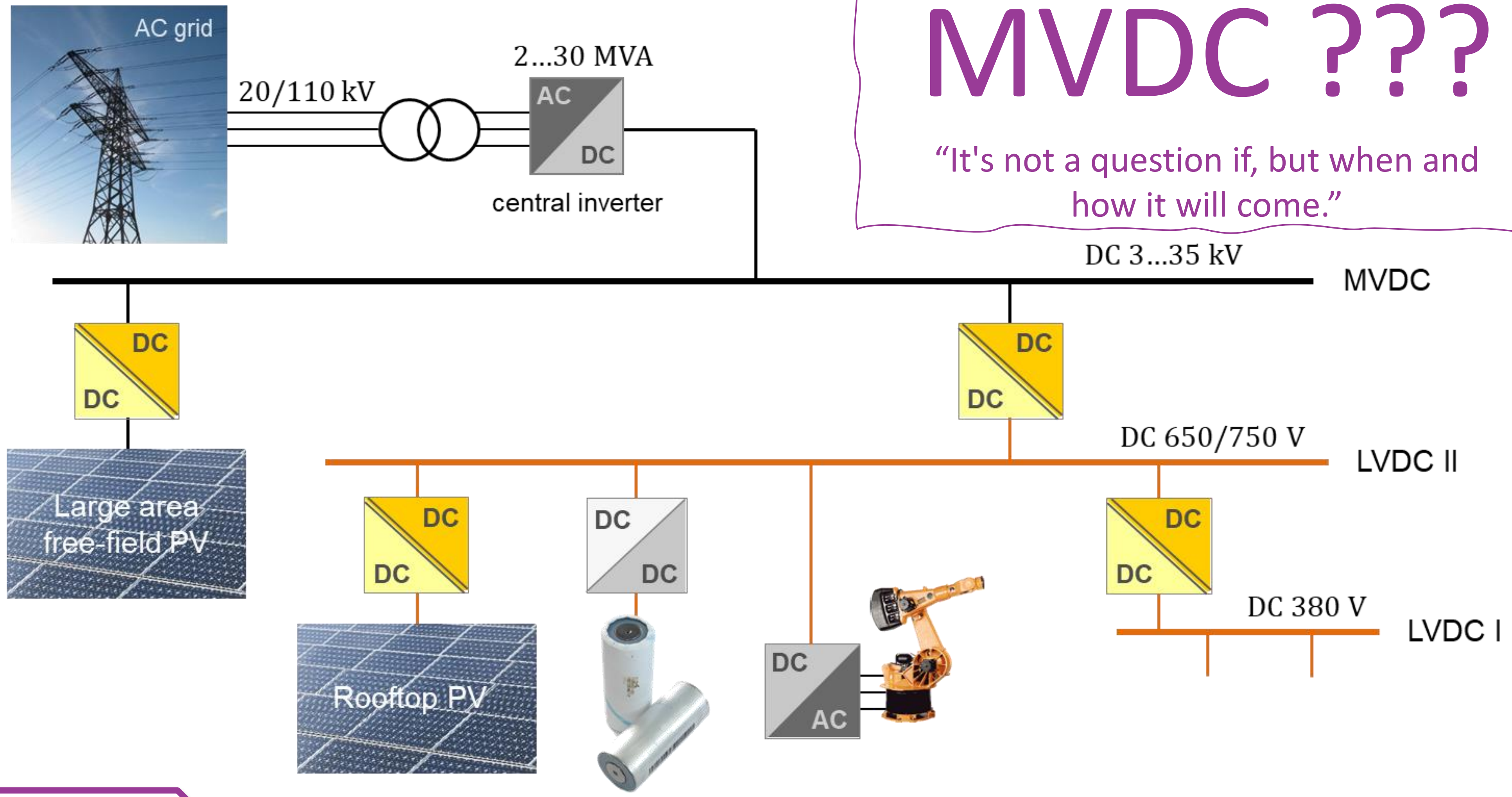
Source: https://www.flexship-project.eu/

DEMO-1: R/V Gunnerus (Photo: Fredrik Skoglund, R/V Gunnerus - Research vessel - NTNU)

DEMO-2: Atatürk (Photo: Oguz Eroguz, ATATURK, Passenger vessel, IMO 8619900)

Use Case: Local MVDC Industrial Plant

Continuously increasing power demand in various use cases will sooner or later also require MVDC Grids



MVDC ???

"It's not a question if, but when and how it will come."

Standardization for DC Microgrids

“Many standards are indeed applicable to both AC up to 1000 V and DC up to 1500 V, but they are often written with AC in mind. However, many relevant standards are currently being revised. Often, this is done by AC experts with only a few DC experts in the technical committees.”

IEC SyC LVDC - Low Voltage Direct Current and Low Voltage Direct Current for Electricity Access

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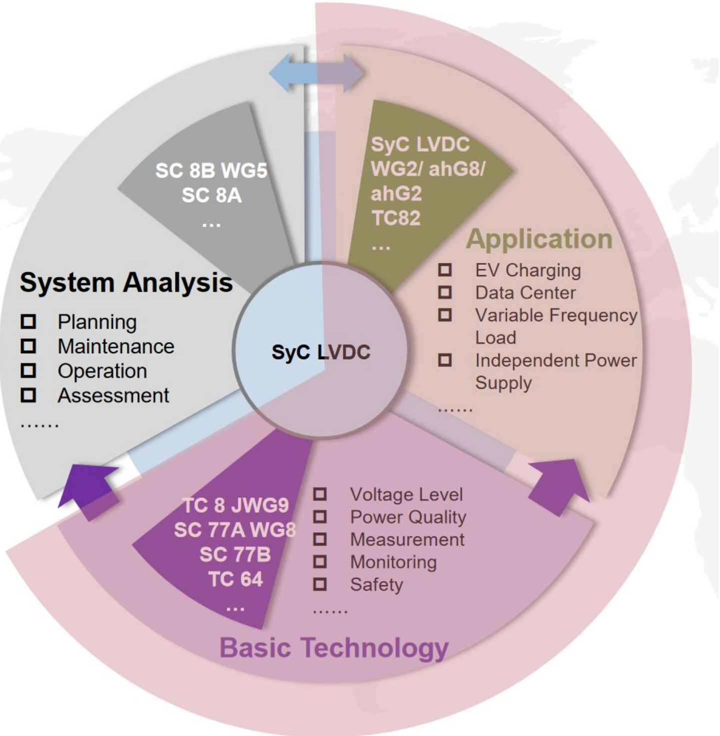
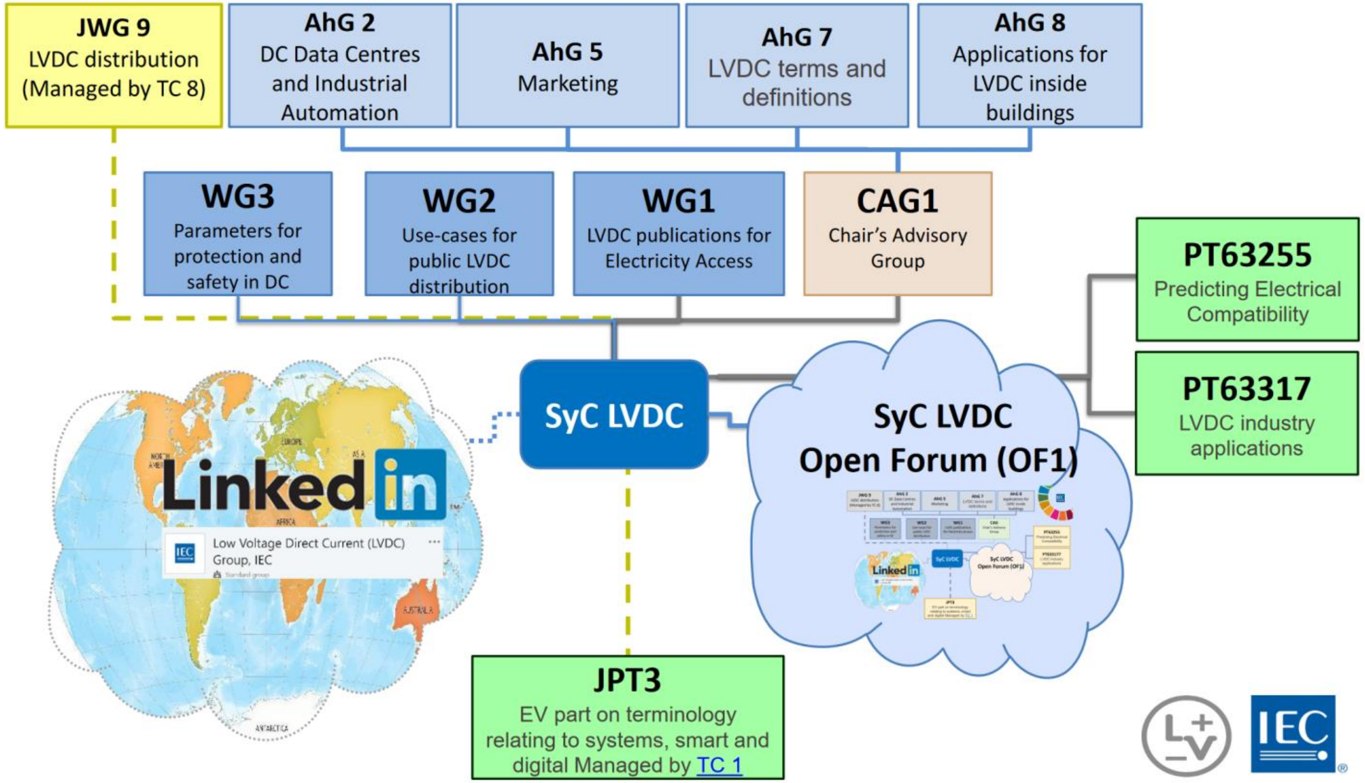




IEC TC8 – JWG9 – TR 63282 – LVDC distribution

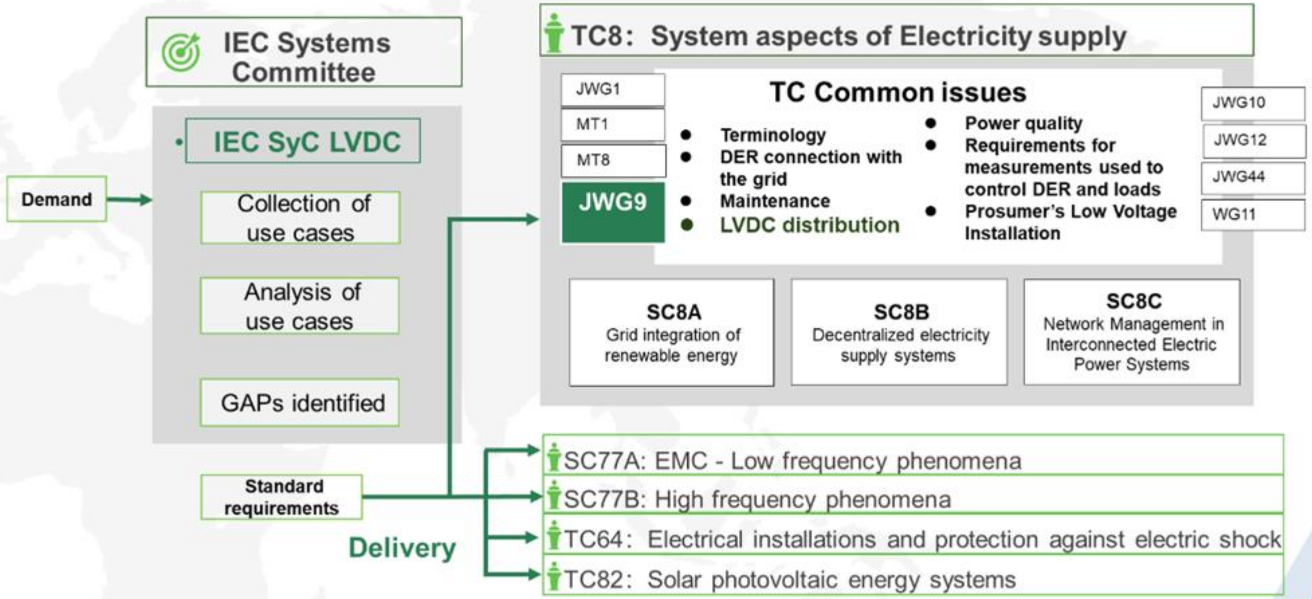
Title: LVDC distribution

Task:

To prepare IEC TR 63282: Assessment of standard voltages and power quality requirements for LVDC distribution.

The objective being to provide input for future normative works, as an example, a first list of the interested entities is:

- TC8 MT1 (voltages)
- TC8 WG11 (PQ requirements)
- SC77A WG8 (EMC-LF/Compatibility Levels)
- SC77A WG9 (EMC-LF/Measurement Methods)



IEC TR 63282 Ed. 2 defines the concept of Voltage Bands for DC

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Voltage bands and voltage limits for equipment [from DC-INDUSTRIE2, based on IEC Technical Report TR63282 Ed. 2 2023]

Operating status as a function of voltage and time

Upper voltage limit Ux in DC grid for nominal voltage 540 V / 650 V	Voltage band	S1: $t < 50\ \mu s$	S2: $50\ \mu s \leq t \leq 1$ ms	S3a: $1\ ms \leq t \leq 5$ s	S3b: $5\ s \leq t \leq 60$ s	S4: $t > 60$ s
	B7	A7				
U6: 2000 V	B6	A6	A7			
U5: 880 V	B5	A4	A5	A5	A7	A7
U4: 800 V	B4	A3	A3	A3	A4	A5
U3: 750 V	B3	A3	A3	A3	A3	A3
U2: 485 / 620 V	B2	A4	A4	A2	A2	A2
U1: 400 V	B1	A4	A2	A1	A1	

Voltage ↑ Time →

	Band	Nominal voltage: 540 V	Nominal voltage: 650 V
	B7	**Forbidden band** - Damage of devices is very likely	
U6		2000 V	
	B6	**Overvoltage protection band** - Switching operations can cause this voltage range - Surge protection devices (SPDs) operate and try to protect devices	
U5		880 V	
	B5	**Temporary overvoltage band** - Surge protection devices (SPD) are **not** active - Breakers disconnect in this band - Insulation and components shall withstand this for up to 5 s - Devices may lose functionality in order to protect themselves	
U4		800 V	
	B4	**Overvoltage band** - Devices may reduce their power - This shall not last longer than 60s - Measures to reduce the voltage must be taken (e.g. charge storage, switch-on power resistors)	
U3		750 V	
	B3	**Nominal band** - Normal operating range - Devices shall be operated permanently - Devices perform with their rated power	
U2		485 V	620 V
	B2	**Emergency band** - Overload condition - Loads have to be reduced - AIC must only be operated for a few milliseconds	
U1		400 V	
	B1	**Blackout Band** - Smart Breakers disconnect - Band will be used during pre-charging - Occurs briefly during short-circuit conditions	

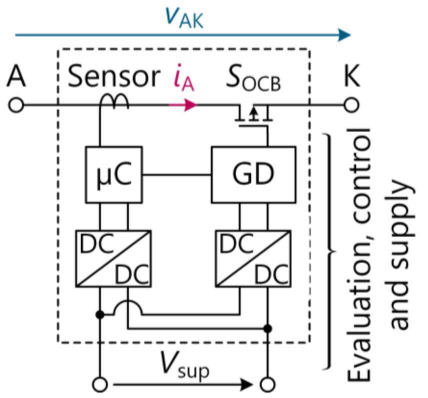
Semiconductor Circuit-Breakers

IEC 60947-10 ED1 – First Circuit-Breaker standard with Semiconductor

IEC 60947-10 ED1
Low-voltage switchgear and controlgear – Part 10: Semiconductor Circuit-Breakers

Scope: *"This part of IEC 60947 series applies to semiconductor circuit-breakers for protection, isolation and switching intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V AC or* ***1 500 V DC****."* Quelle: IEC 121A/489/CD

„SiC DC-Breaker" Prototype on DBC-Substrate: © Thomas Richter / Fraunhofer IISB



State-of-the-art semiconductor-based OCB: solution on system level

SC 121A Low-voltage switchgear and controlgear

Scope | Structure | Projects / Publications | Documents | Votes | Meetings | Collaboration Platform

Work programme > Project: IEC 60947-10 ED1

en | fr

Detail

Committee	Working Groups	Project Leader	Current Status	Frcst Pub Date	Stability Date
SC 121A	PT 60947-10	Mr Andreas Bäumler	CDM	2025-06	

History

Stage	Document	Downloads	Voting Result	Decision Date	Target Date
prePNW				2020-08-25	
PNW	121A/381/NP	1411 kB	APPROVED	2020-08-28	
PRVN				2020-11-20	2020-11
ACD	121A/401/RVN	657 kB 909 kB		2020-11-28	2021-10
ACD	121A/401A/RVN	661 kB 963 kB		2020-11-28	2021-10
ACD	121A/401B/RVN	1147 kB 1587 kB		2020-11-28	2021-10
CD	121A/489/CD	4658 kB		2022-04-15	2021-10
PCC				2022-08-05	2022-08
CDM	121A/517/CC	1003 kB 549 kB		2022-08-12	2022-08
A2CD	121A/517A/CC	2696 kB 984 kB		2023-06-23	2023-06
2CD	121A/565/CD	4255 kB		2023-06-30	2023-06
PCC				2023-09-22	2023-09
CDM	121A/575/CC	632 kB 222 kB		2023-09-29	2023-10

Project

IEC 60947-10 ED1
Low-voltage switchgear and controlgear – Part 10: Semiconductor Circuit-Breakers

Related documents:
SMB/7613B/INF
612 kB

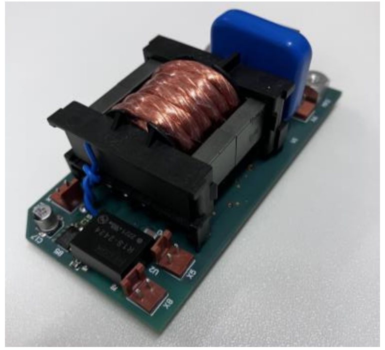
Initial Project Plan

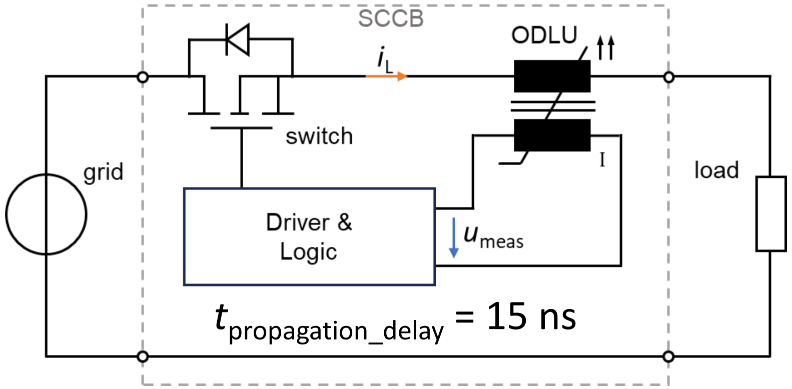
Committee	Enquiry	Approval	Publication
2021-10-31	2022-11-30	2023-09-29	2024-01-31

Up-to-date Project Plan

Committee	Enquiry	Approval	Publication
2023-06-30	2023-11-30	2024-09-29	2025-01-31

Ultra fast Overcurrent Detection and Limitation Unit ODLU





IEC 63317 – DC Industry Applications

International Conference on DC Microgrids

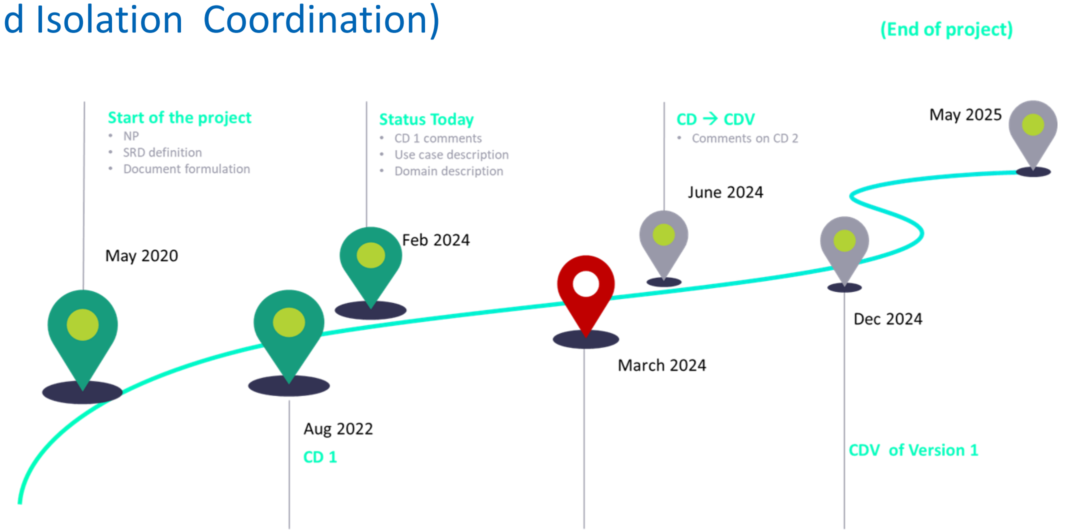
Goal: To describe certain aspects of standardization of LVDC in Industry applications

Deliverable: SRD document

Current Status: Finalizing SRD to Circulate CD2 by 28th March 2024

Scope: Motivation, Domain description, Gap analysis
System description: The Aspects of DC grids for Industrial usage
(preconditions to connect to DC grids, Grid topologies, System voltage, stability, network configuration, Fault protection, and Isolation Coordination)

Use Case description – Recuperate Energy



Open Direct Current Alliance

rapidly growing European association for the promotion, standardization and market preparation of DC

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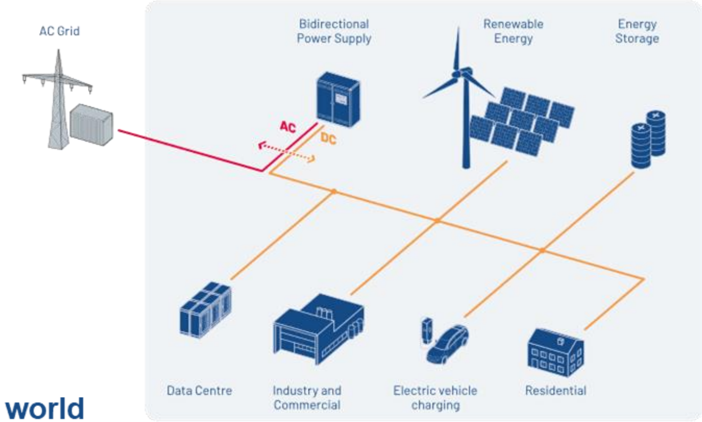


Mission and objectives

Vision

- **DC contributes to a sustainable world**

Mission

- **Establish an international DC ecosystem**

Objectives

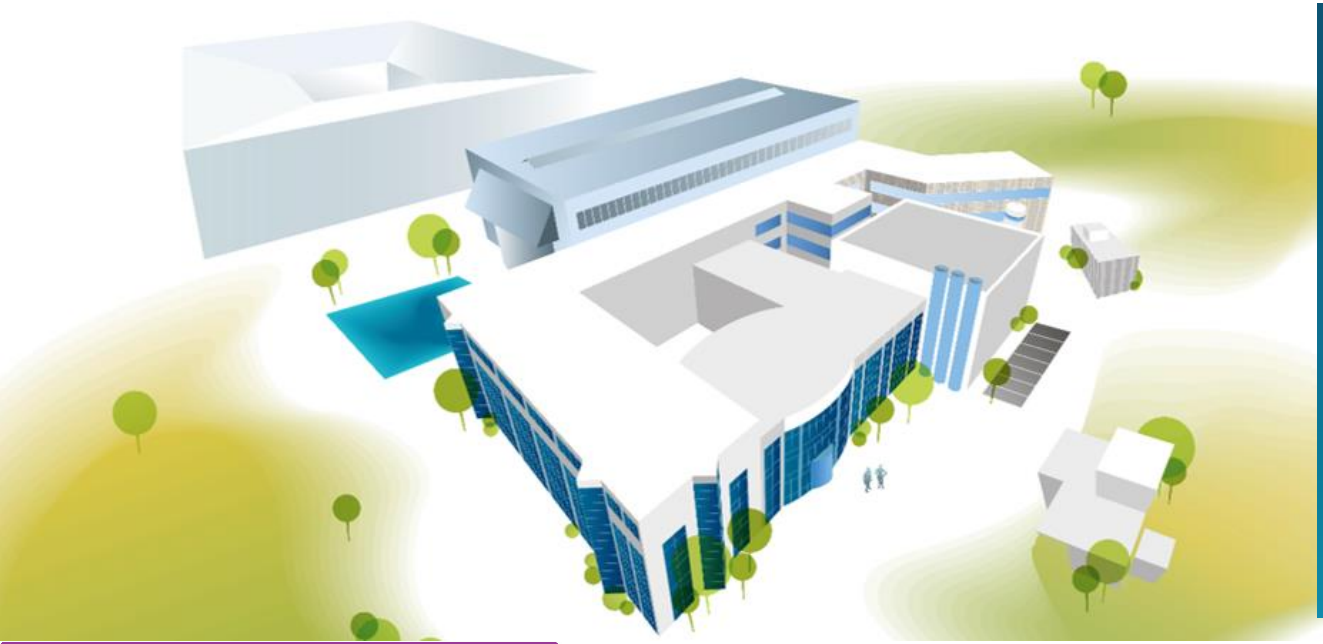
- **Ecosystem:** Close cooperation between users, planners, manufacturers, suppliers, research institutions and associations
- **Dissemination:** International dissemination of knowledge and solutions on DC grids. Conformity label for investment security for manufacturers and users.
- **Technology, research and standardisation:** implementation of requirements. Platform for the design of further research projects. Target group-relevant standardization
- **Politics and regulation:** Direct current is an important building block for the energy transition. Support in the development of the necessary framework conditions.

Target groups

- Manufacturer | Supplier | Users | Grid operator | Planner | Installer | Industry associations | Science | Standardization | Politics and Society

https://openDCalliance.org

Thank you for your attention



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