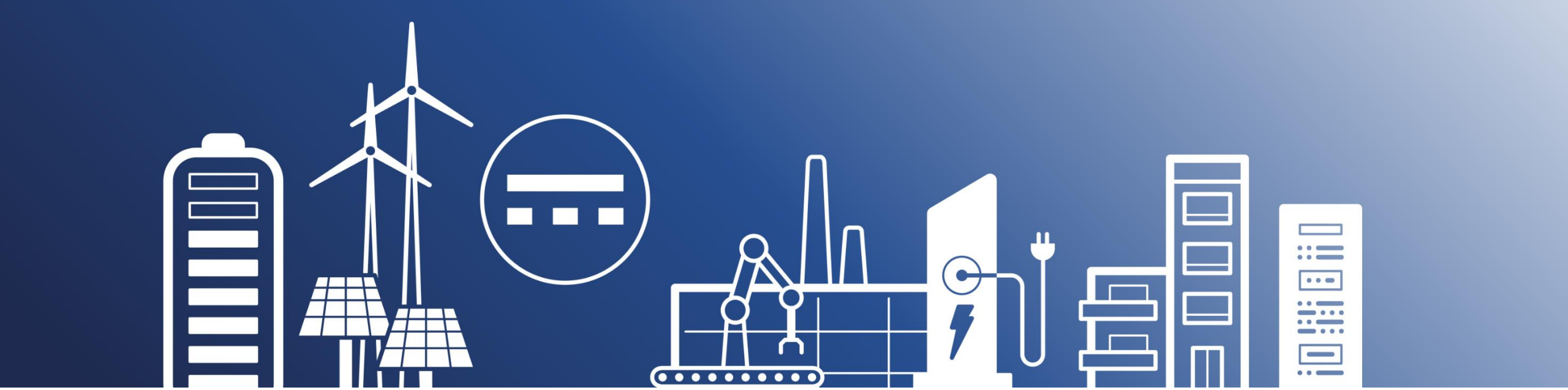

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Open Direct Current Alliance

Overview, characteristics, technology, applications, benefits

Dr. Hartwig Stammberger | Eaton | Open DC Alliance | Aug 2025

ODCA direct current by zvei

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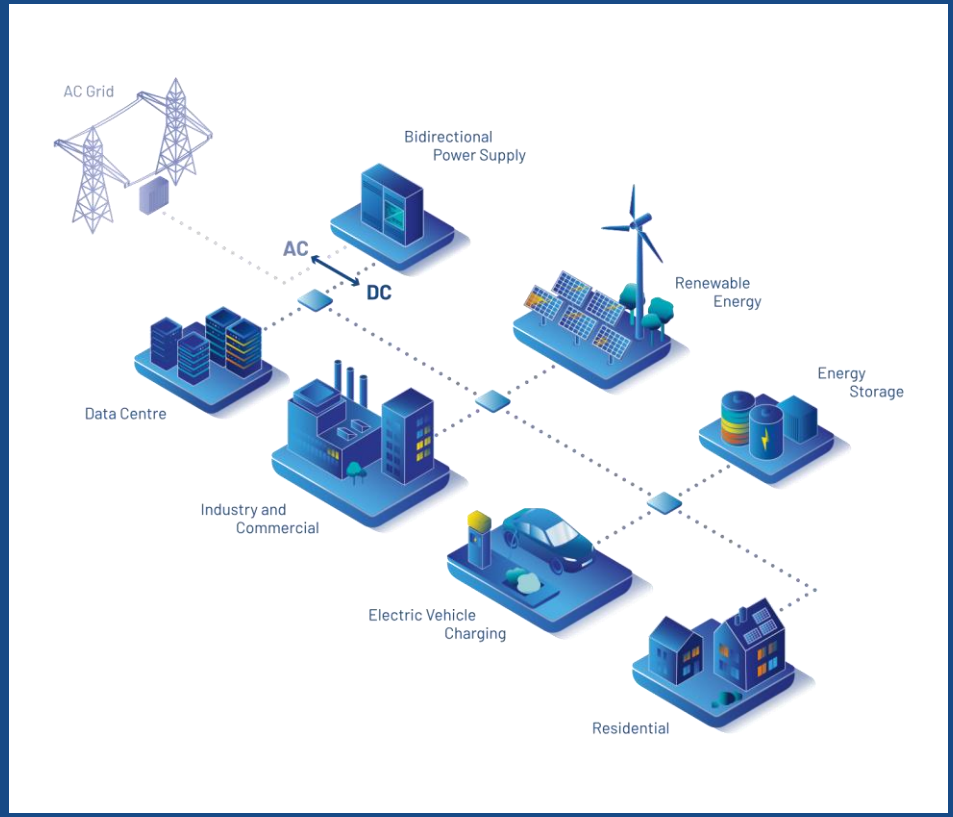
Applications

Benefits



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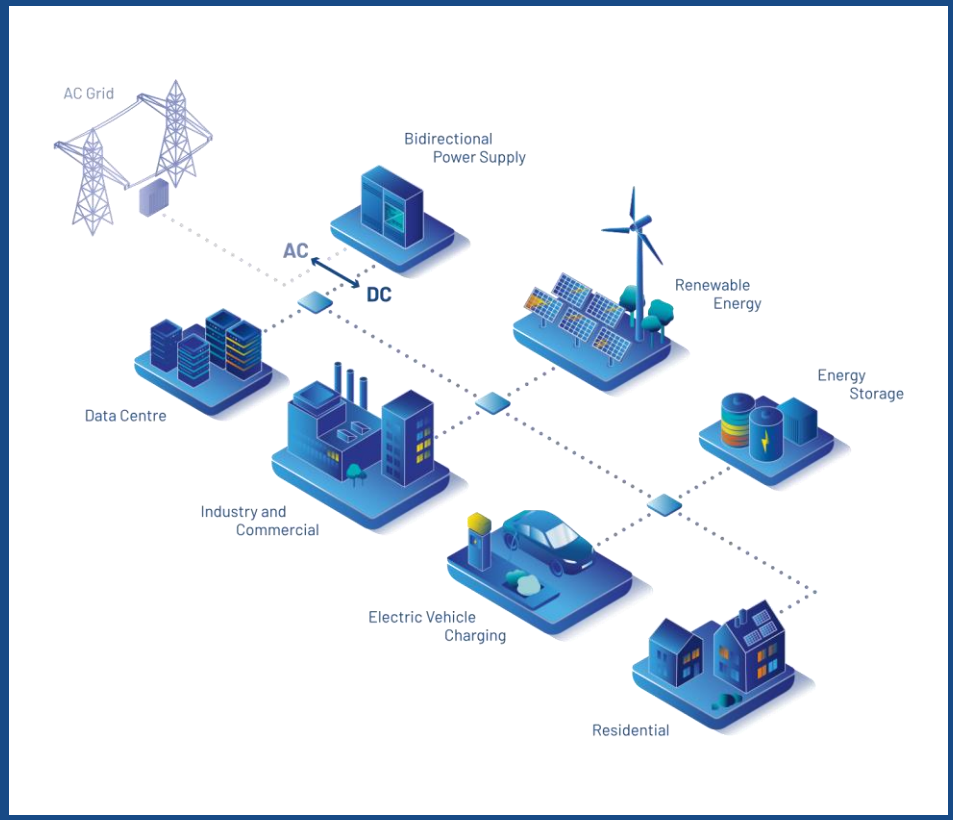

Open Direct Current Alliance ODCA – Who are we?

Plenary meeting March 2025

- **International** non-profit **organization**
- With **80+** members
- In **16** countries
- On **3** continents
- Main office – **dedicated staff**
- **5** active working groups

Open Direct Current Alliance ODCA – What do we do?

ODCA System Document

VDE SPEC 90037

- **Publish system description**
  - Free access
  - Recognized by German standards organization VDE
- Networking
- Knowledge exchange
- Best practice sharing
- Contribute to IEC & UL standardization

ODCA: Vision and Mission

Vision

- DC contributes to a sustainable world

Mission

- Establish an international DC ecosystem

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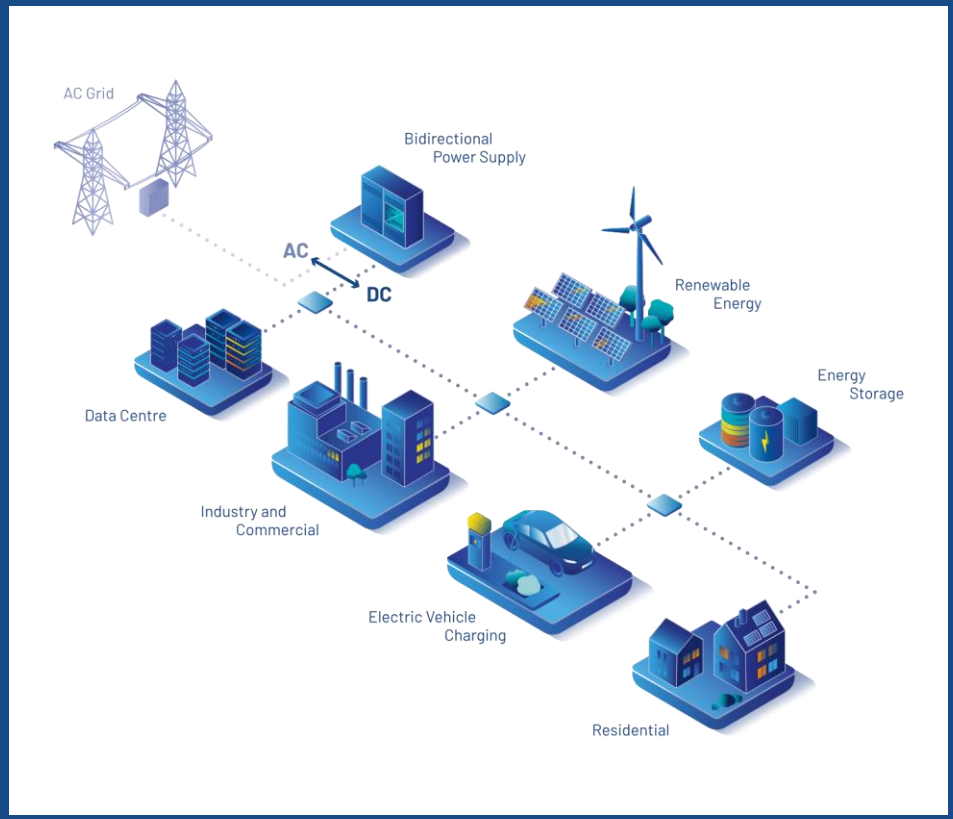


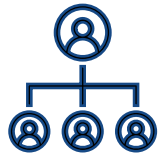
Our organizational DNA

Open technology

- System description freely available
- Based on existing certification
- Liaison with global standardization

Organization

- Full-time independent staff
- Transparent working groups
- Elected board & working group chairs

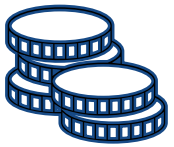


Equal access

- One member – one vote
- Same rights for all
- Bringing together the entire DC ecosystem

Membership fees

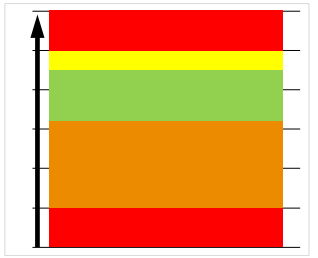
- According to company size
- Everyone contributes



Our technical DNA – overview

Symmetry

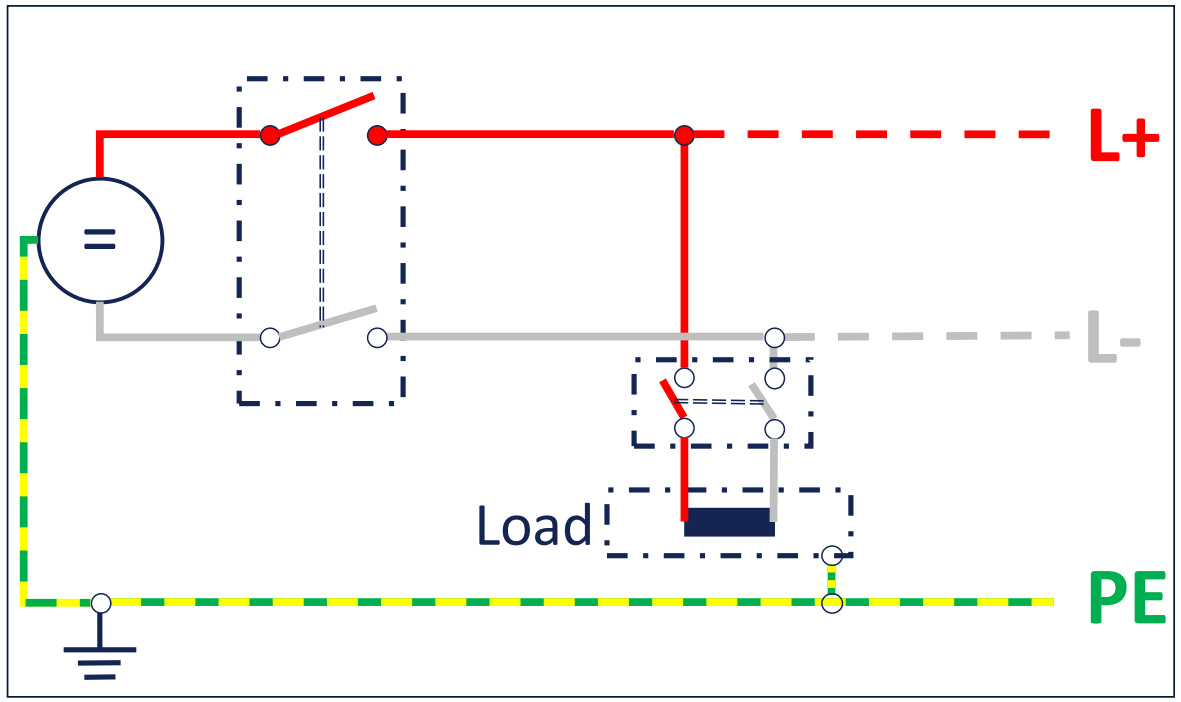
Voltages



Power management

Protection

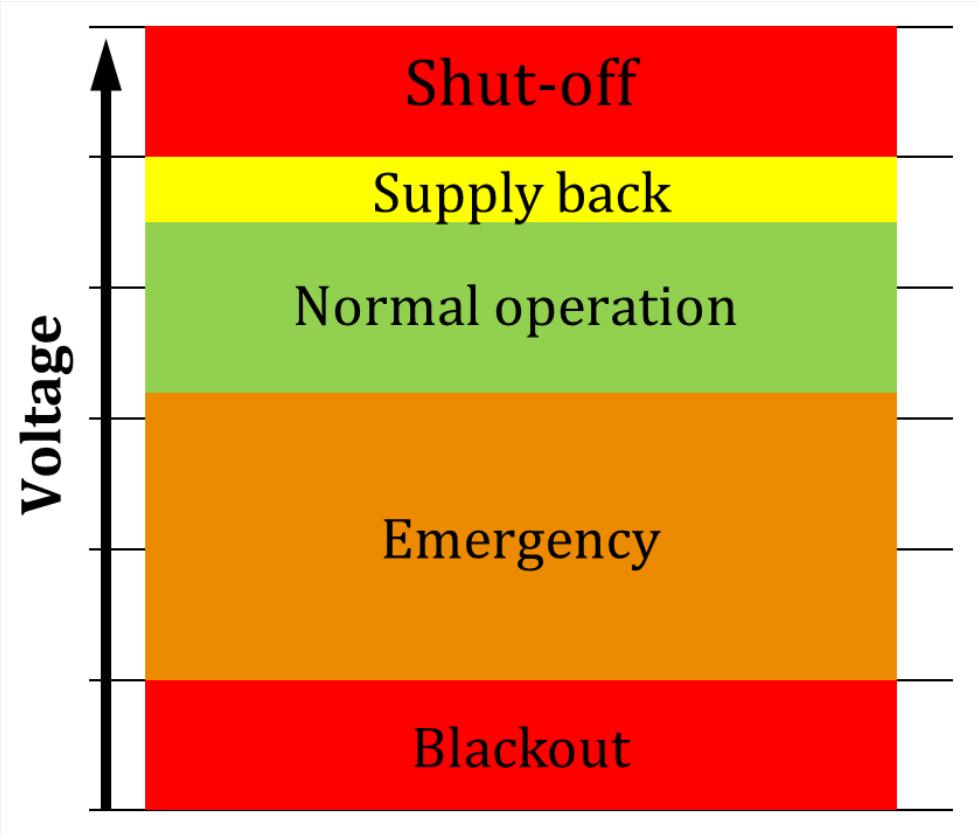
Our technical DNA 1 / 4



Symmetrical system

- L+ and L-
- Simple wiring
- Simple control
- Simple protection
- Smaller insulation distance
- No active wire at / near ground potential

Our technical DNA 2 / 4

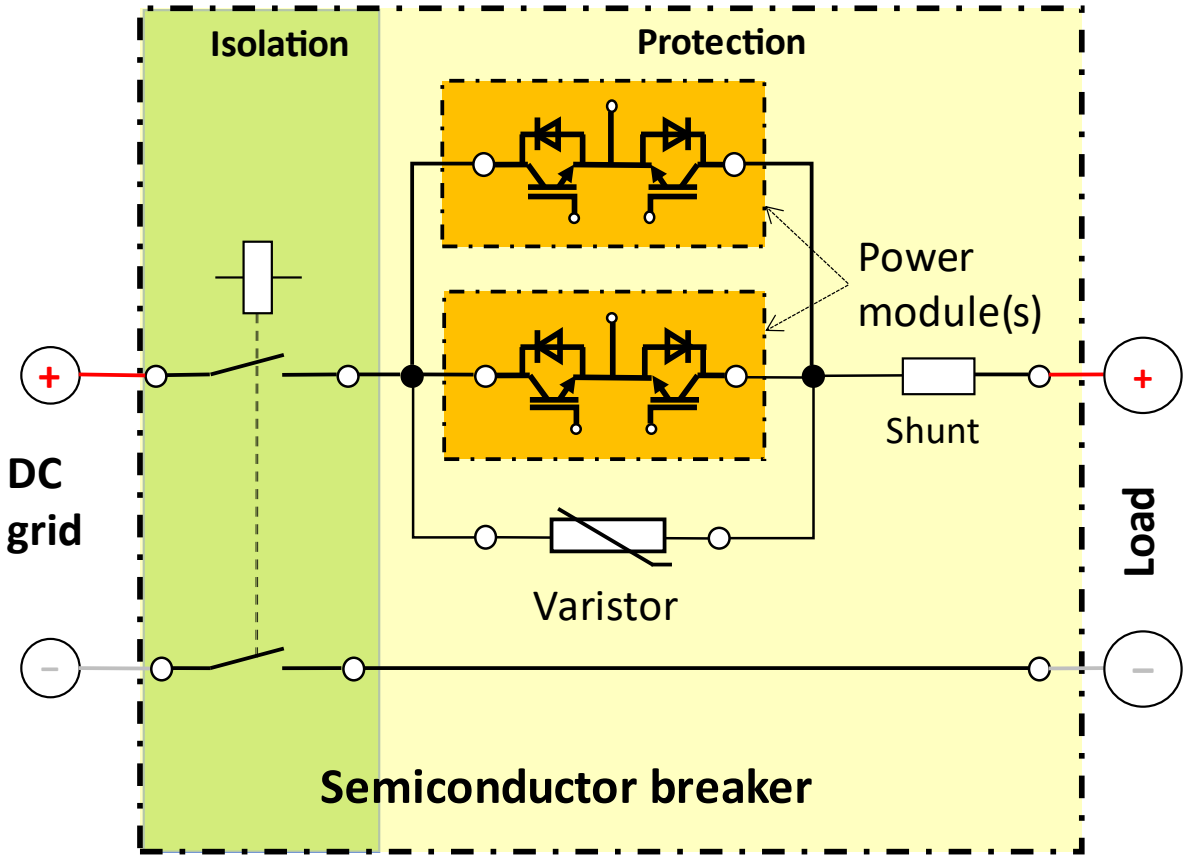


- Voltage band
  - Full function in green band
  - Based on IEC TR 63282
  - Compatible to AC voltage levels

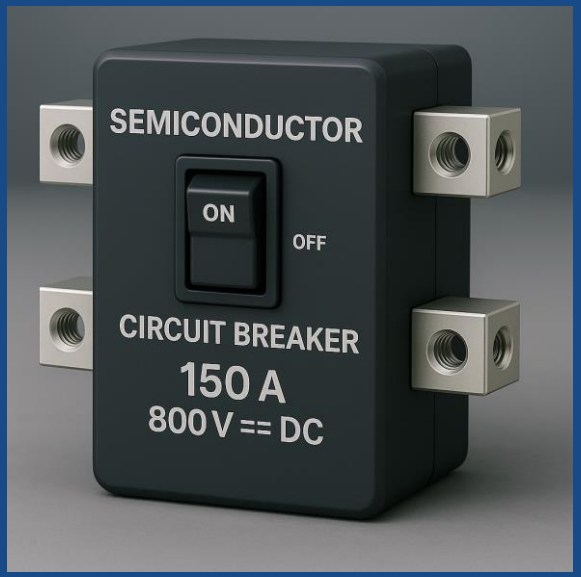
Our technical DNA 3 / 4

- Power management
  - Droop curve
  - Measure voltage → control power

Our technical DNA 4 / 4



- Protection
  - Electronic solution preferred
  - Same safety rules as for AC



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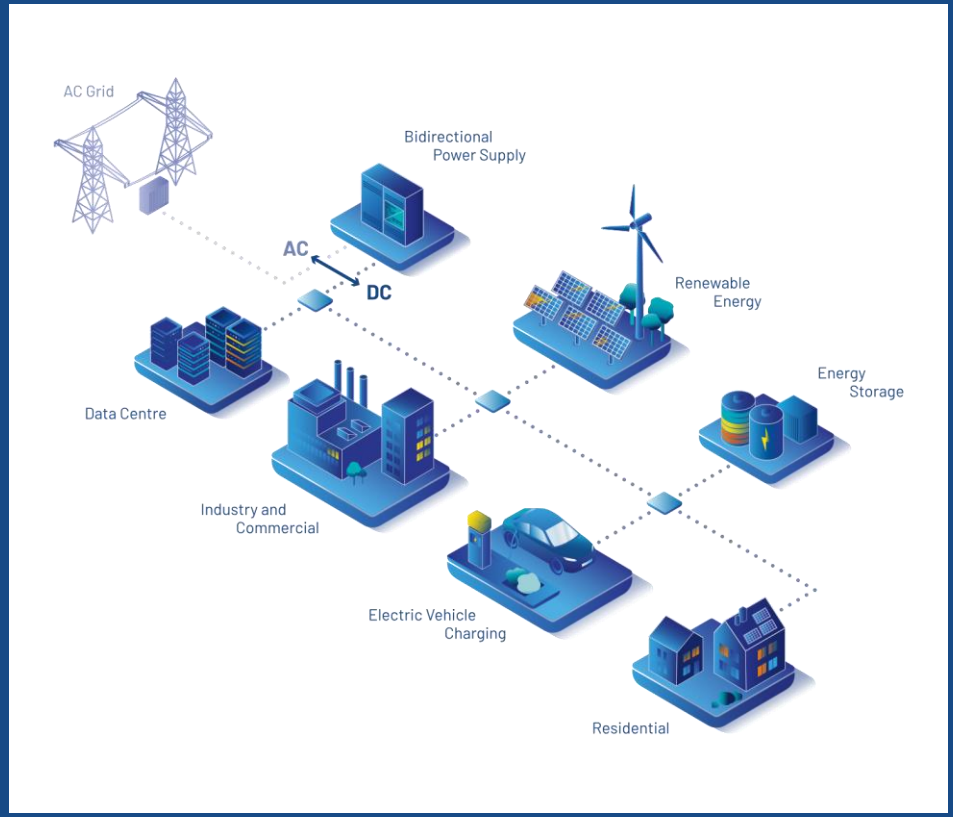
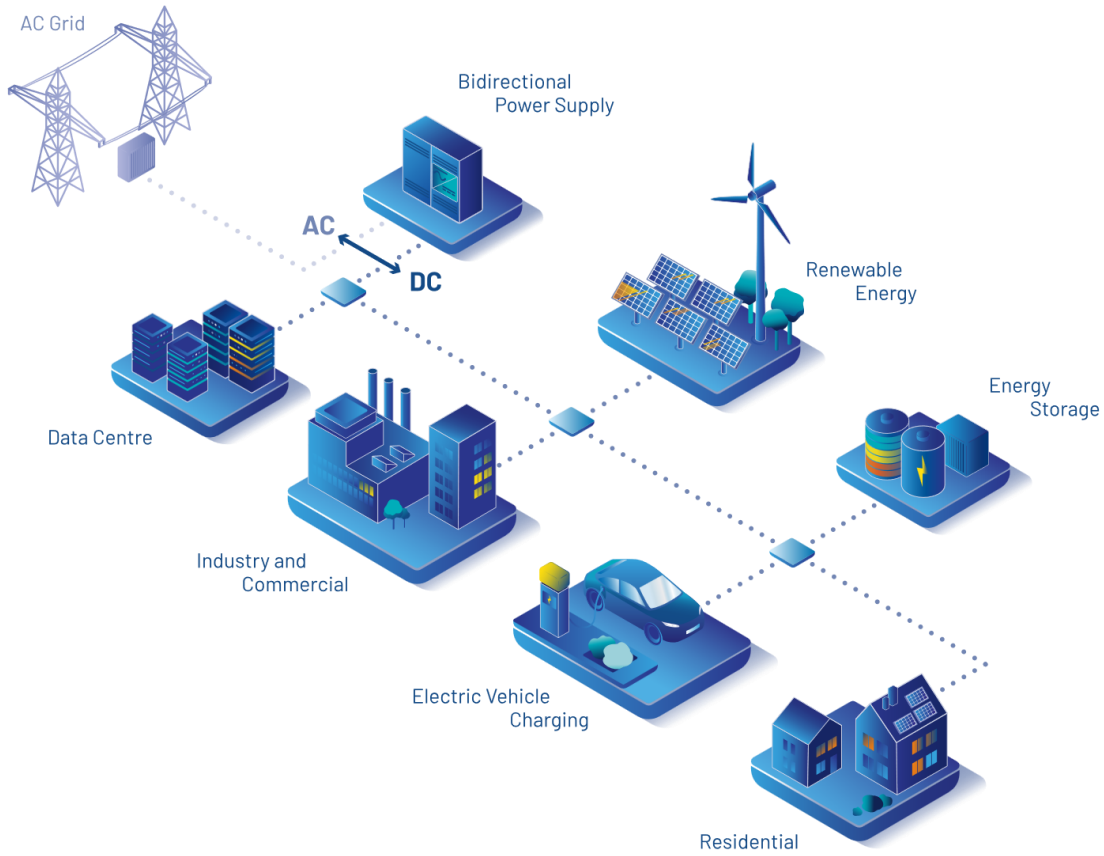
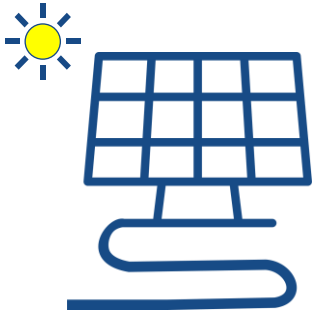


Topology of a DC grid

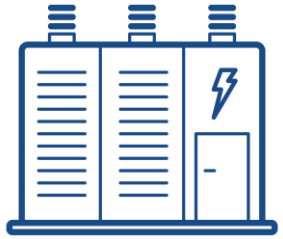


- DC link connects sources and loads with each other
- Central bi-directional connection to AC supply grid
- Reduce conversion steps

DC is already (almost) everywhere



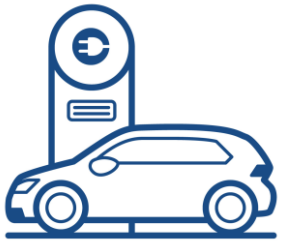
Photovoltaics



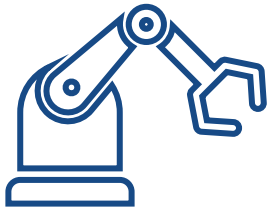
Battery storage

Wind energy

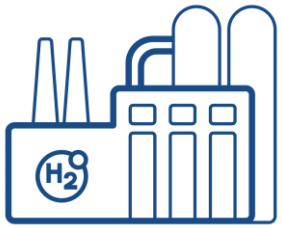
Rail



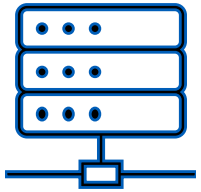
E-cars



Industry

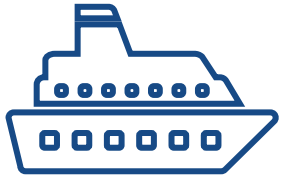


H_2 Electrolyser



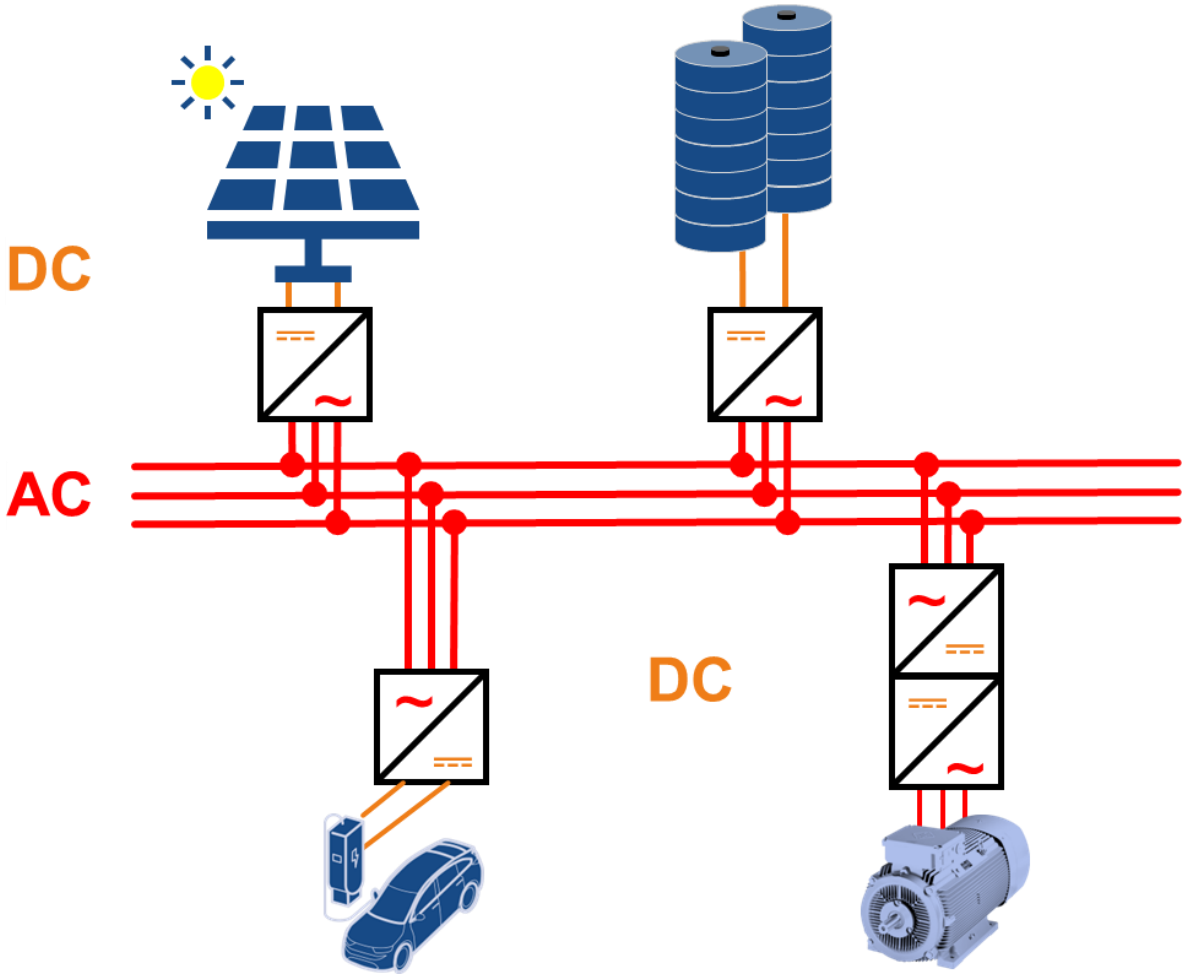
Data & IT

Lighting



Marine

Traditional AC supply

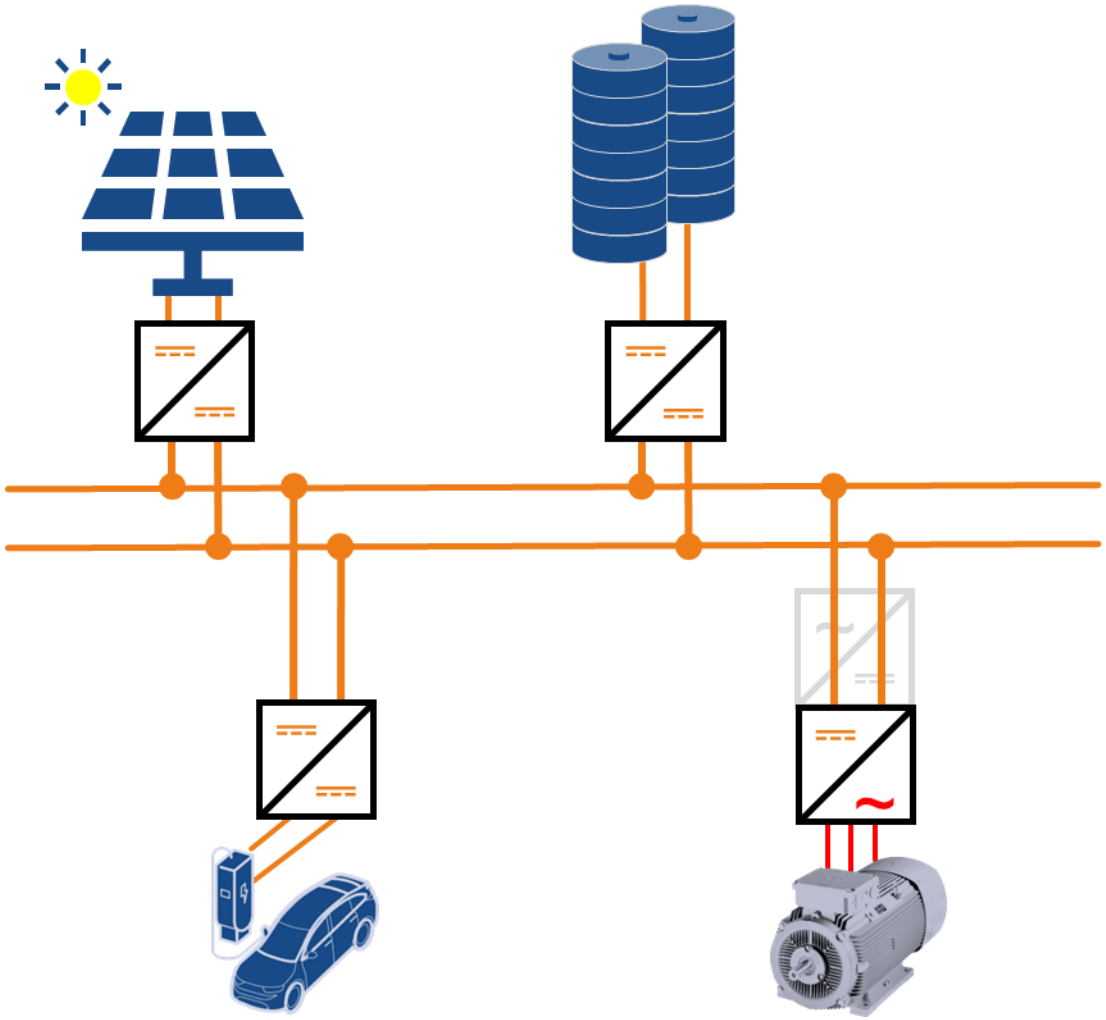


Multiple conversion steps from direct current DC to alternating current AC and vice-versa

- Many devices
- Many resources
- More cabling
- Higher maintenance
- Higher power loss

In one word: Waste

DC Microgrid



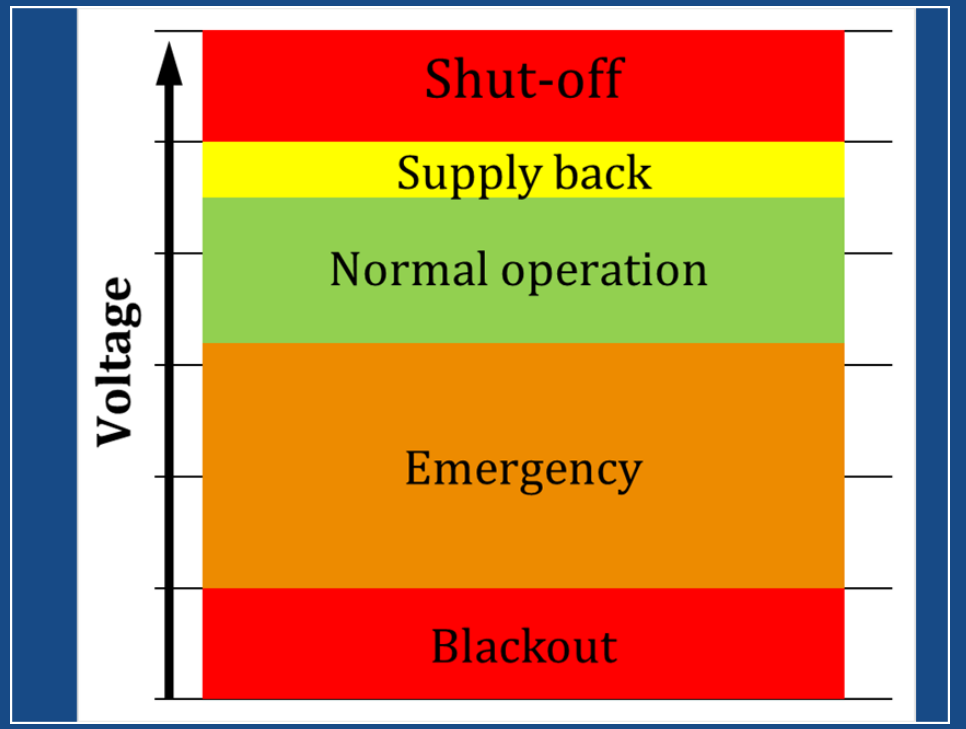
DC connection

- Fewer conversion steps
- Fewer resources
- Higher efficiency
- Less maintenance
- Higher resilience

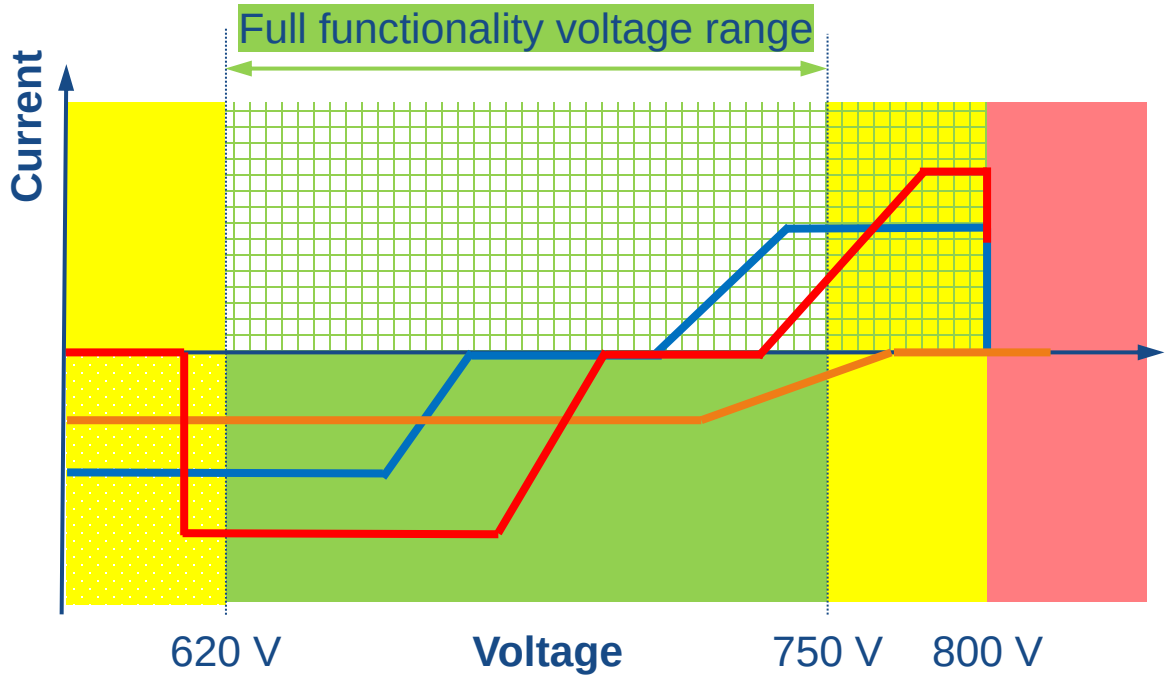
Simply put: Better solution

Voltage and voltage bands

- DC grids operate in voltage bands
  - No need to stay at a fixed value
  - Different from AC frequency (50 / 60 Hz)
- The DC grid has “breathing room” in the green band
  - 620 V to 750 V for 3-phase 400 V AC
- In DC, voltage mirrors power balance
  - Supply < load → voltage drops ↘
  - Supply > load → voltage rises ↗



Power management with droop curves:
$i = f(u)$



Grid (active infeed converter)

Energy storage

Photovoltaic

Positive current: Energy is fed back

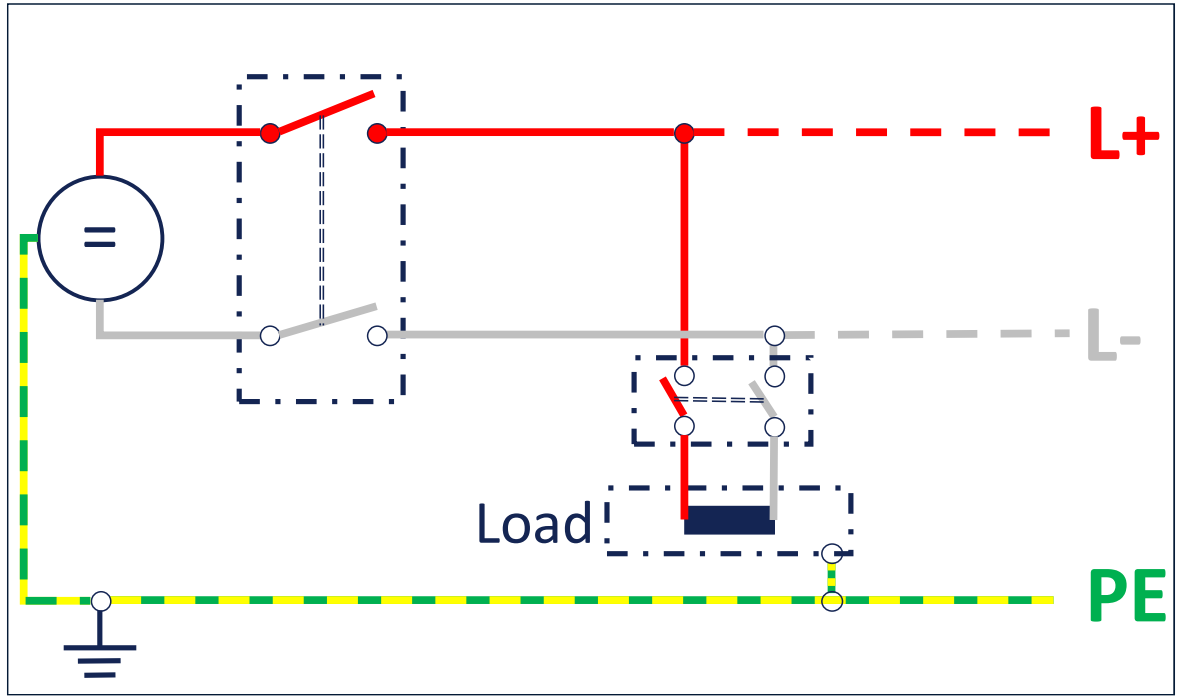
Energy is drawn from the grid (red line) photovoltaic (green) or storage (blue)

Limited functionality

No operation

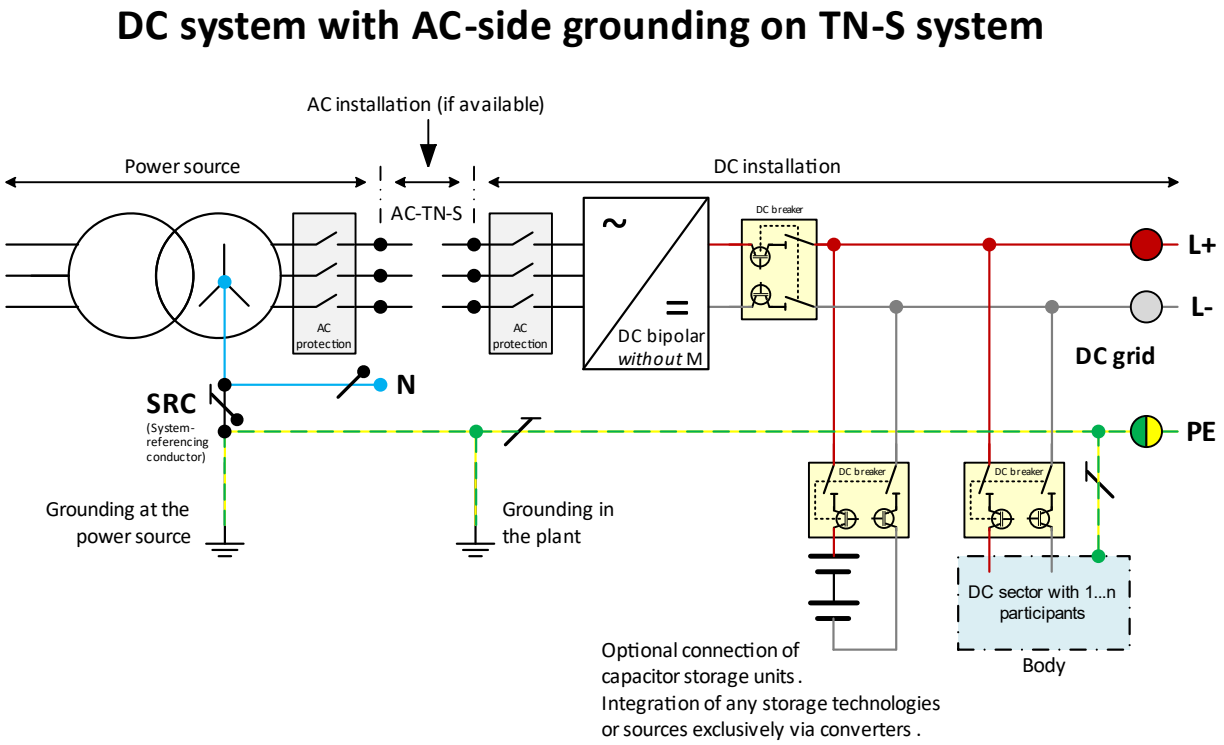
- DC voltage change is indicator for power balance
  - Supply < load → voltage drops ↘
  - Supply > load → voltage rises ↗
- Power balancing
  - Active components measure voltage at their terminals …
  - … and adjust power output to pre-defined current-voltage “droop-curve”
- No communication needed – voltage carries the information!

Symmetrical system L+ and L-



- Two active wires
  - No mid point conductor
  - Symmetrical voltages to ground (PE)
  - Simpler wiring
  - Simple control: one voltage only
  - Smaller insulation distance: $U_n/2$ to ground
- Like 3~AC w/o neutral

Grounding: AC-side grounding



Ground reference for the DC system is the star point of the AC transformer.
AC/DC converters without galvanic isolation; as rectifier or as switching converter (AIC).
Fast overcurrent protection in both poles (L+ and L-).

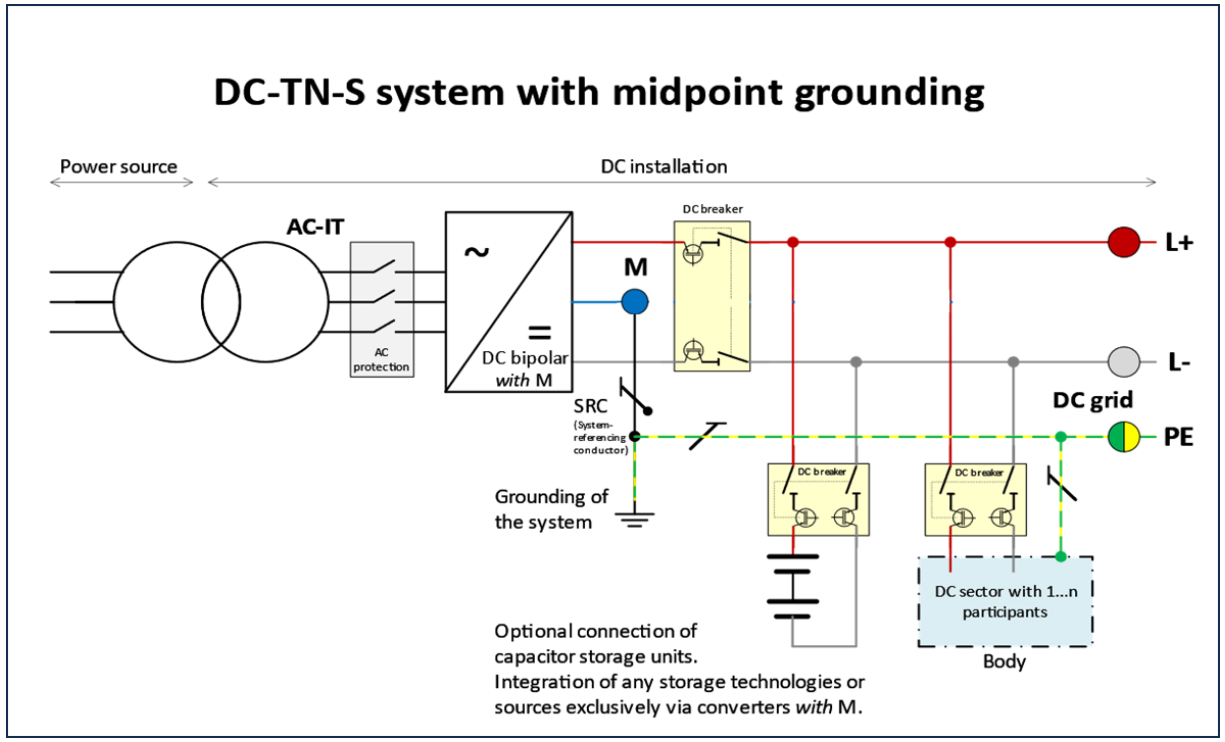
NOTE 1 Additional grounding of the PE in the installation may be provided (base grounding)

NOTE 2 In case of loss of the AC power source(s), the DC grid changes to an IT system

Source: ODCA system description, Fig. 7.1 / VDE SPEC 90037

- Star-point ground of (AC) transformer is used
- Two-wire DC system
  - L+ and L-
  - No mid point conductor
- AC applications can be used behind the same transformer
- New IEC 60364-1will include this grounding option

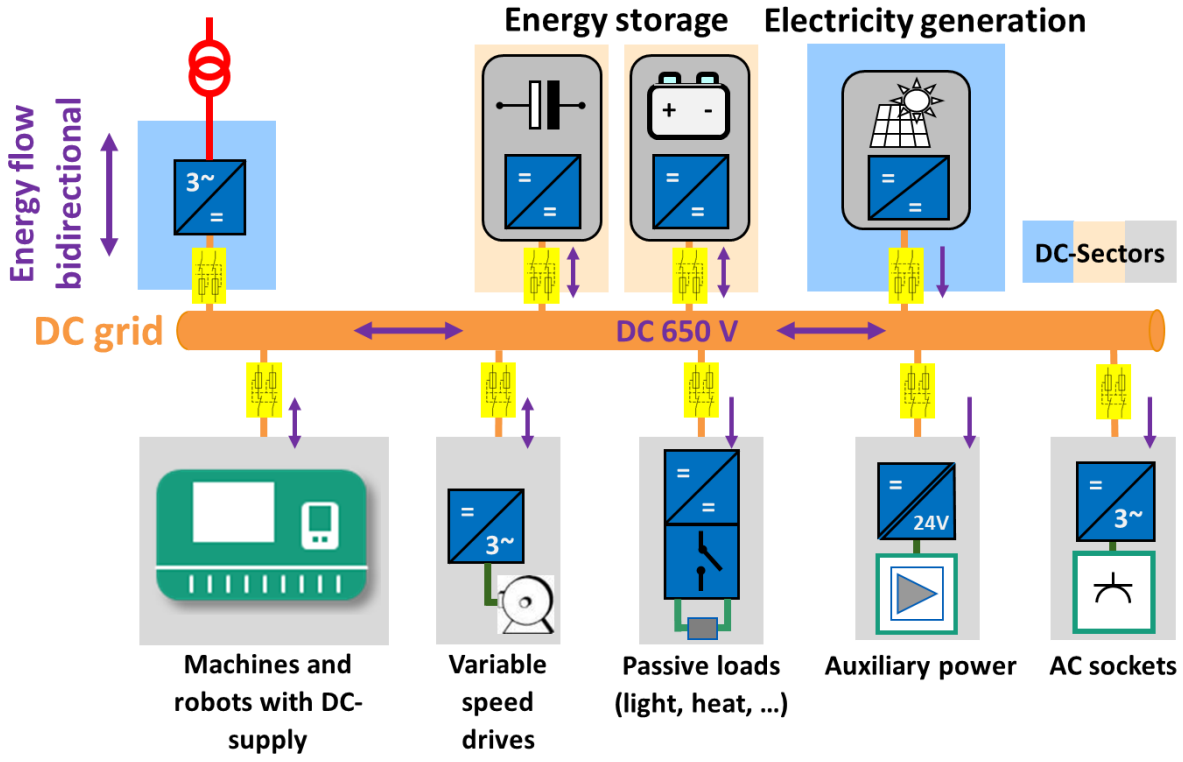
Grounding: DC-side grounding & IT system



Source: ODCA system description, Fig. 7.6 / VDE SPEC 90037

- Properties
  - Isolated to AC
  - Grounded on DC side: M
  - Two-wire DC system
    - L+ and L-
    - Mid point conductor not distributed
  - Symmetrical voltages to PE
- Other topologies possible
  - IT system

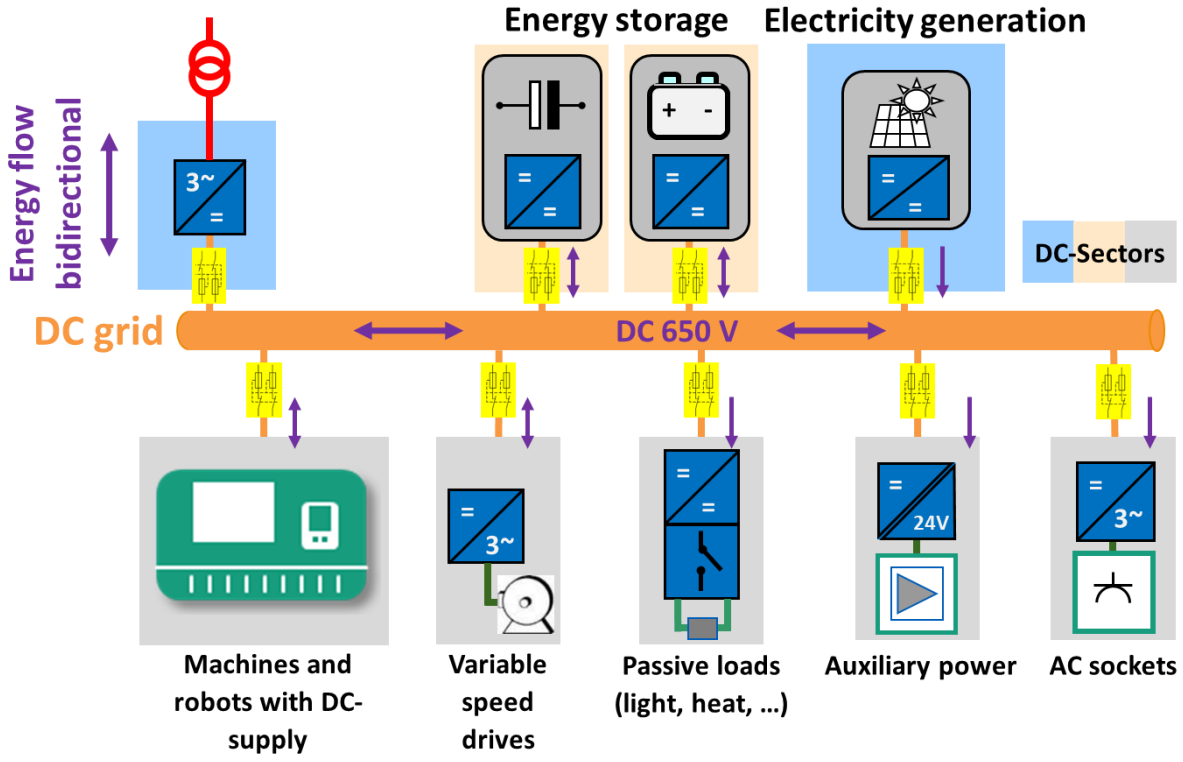
Protection devices



Source: ODCA system description, Fig. 5.1 / VDE SPEC 90037

- General requirements
  - Conduct current
  - Detect fault currents
  - Interrupt operational & fault currents
  - Isolate
- No difference between AC and DC

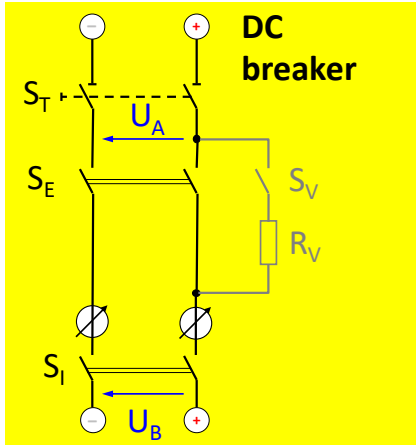
Protection devices

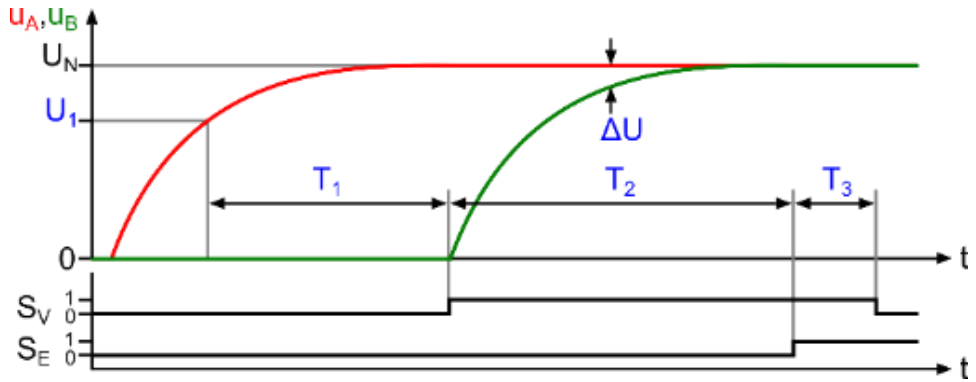


Source: ODCA system description, Fig. 5.1 / VDE SPEC 90037

- Special DC requirements
  - Inrush current of capacitors
    - ➢ Limit pre-charge current
  - Many distributed sources, capacitive grid
    - Rapid rise of short-circuit current
    - Ultrafast operation
  - No strict “top-down” energy flow
    - Detect direction of current for selectivity
  - No natural current-zero crossing
    - Force current to zero

Protection devices: Pre-charging

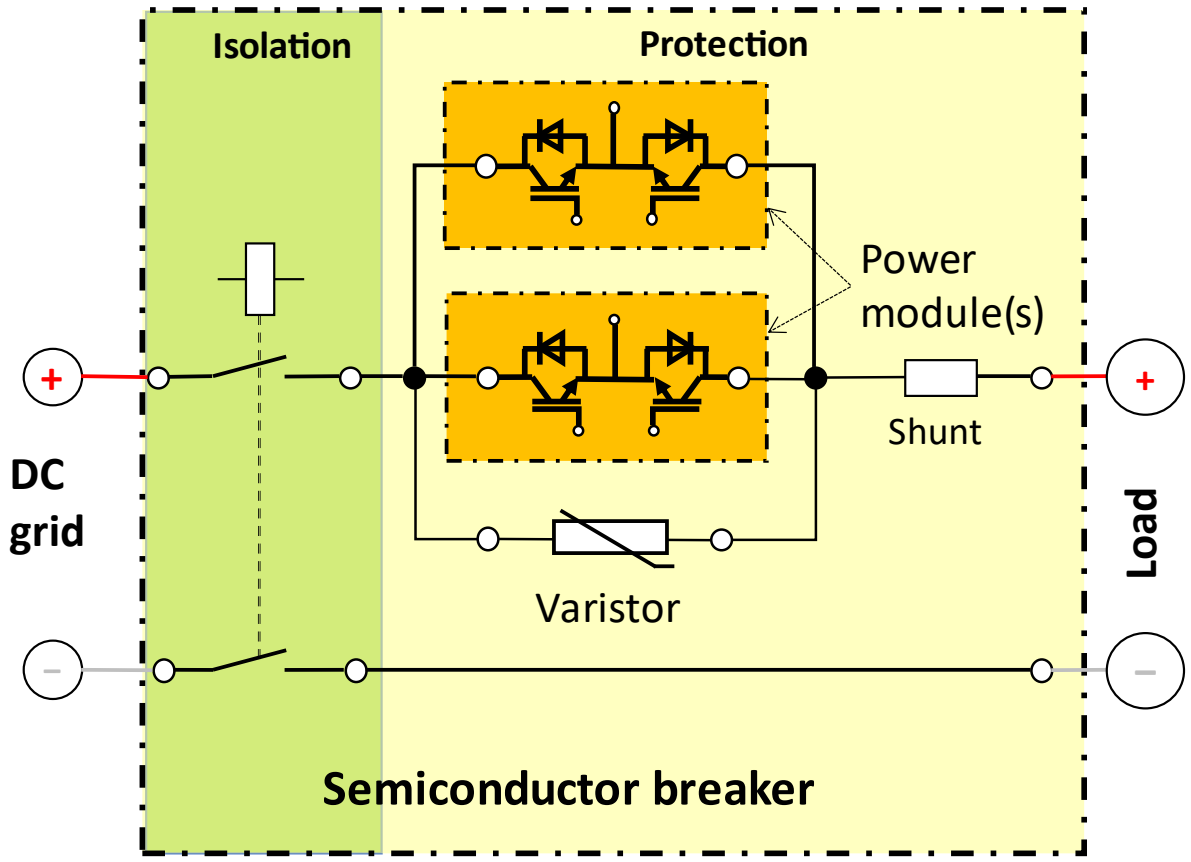




Source: ODCA system description, Fig. 8.2 / VDE SPEC 90037

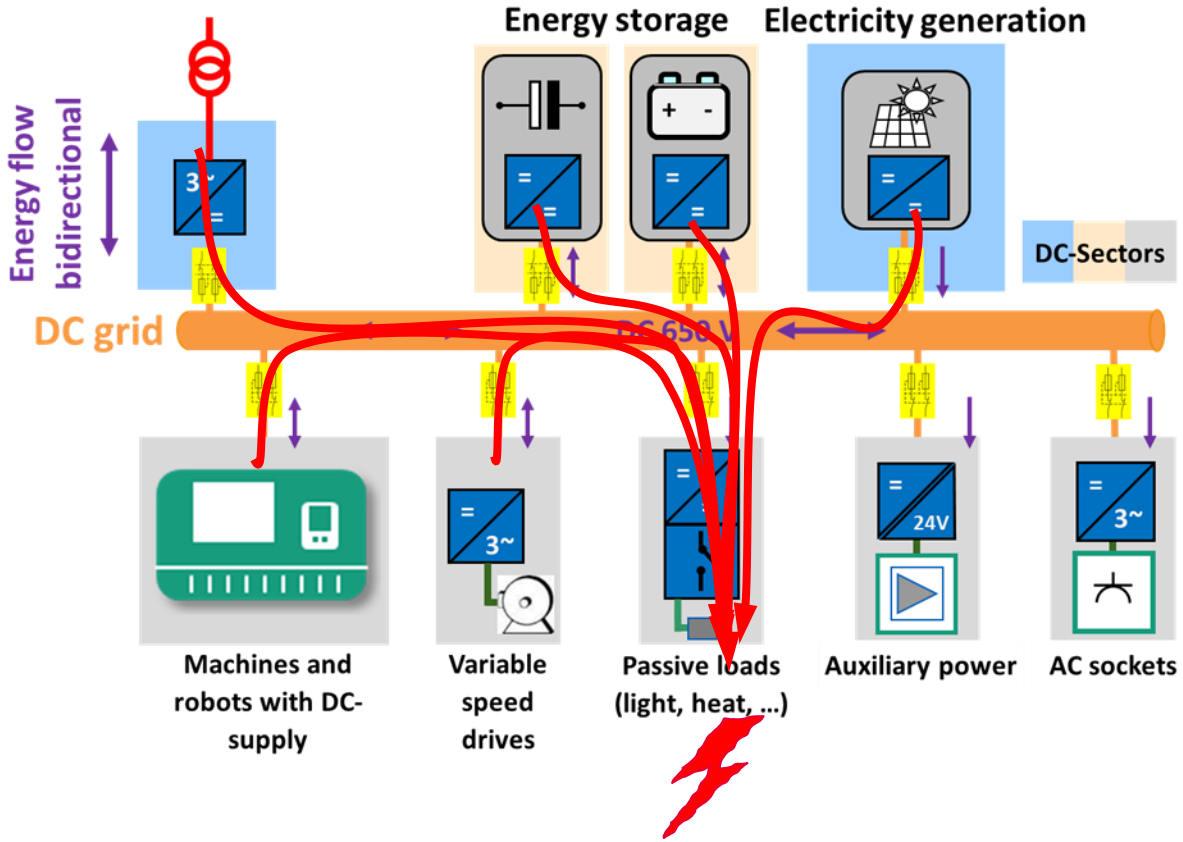
- Uncharged capacitors in a sector
  - Pull high charging current upon switch-on
  - Will trip the breaker if not limited
  - Pre-charging scheme needed
- Voltage controlled pre-charging scheme
  - Input voltage U_A exceeds threshold → triggers pre-charging
  - Output voltage U_B rises → Pre-charge sequence ends when $\Delta U = U_A - U_B$ falls below threshold

Protection devices: Semiconductor circuit breaker



- Rationale for fast operation
  - Ensure operation of healthy parts of the system (voltage drops below green band)
  - Avoid discharging of storage devices
- Solution
  - Power semiconductors shut-off
  - Varistor limits voltage and dissipates circuit energy
  - Isolation contacts disconnect w/o current
- Other functions
  - Detection of over- & undervoltage
  - Energy measurement
  - Communication
- Properties
  - Fast (< 100 µs switch-off time)
  - Very low fault energy: << 1% of mechanical breaker

Protection devices: Selectivity



- All sources feed a fault
  - Capacitors in DC-links
  - Storage
  - In-feed …
- Only breaker of faulty sector shall interrupt
  - More challenging than in top-down (AC) structure
  - Breakers of parallel sectors shall not trip
- Solution
  - Semiconductor breakers needed
  - Technical options
    - Detect direction of current flow and delay tripping for reverse current
    - Balance rated current of parallel DC sectors.
    - More parallel sectors improve selectivity

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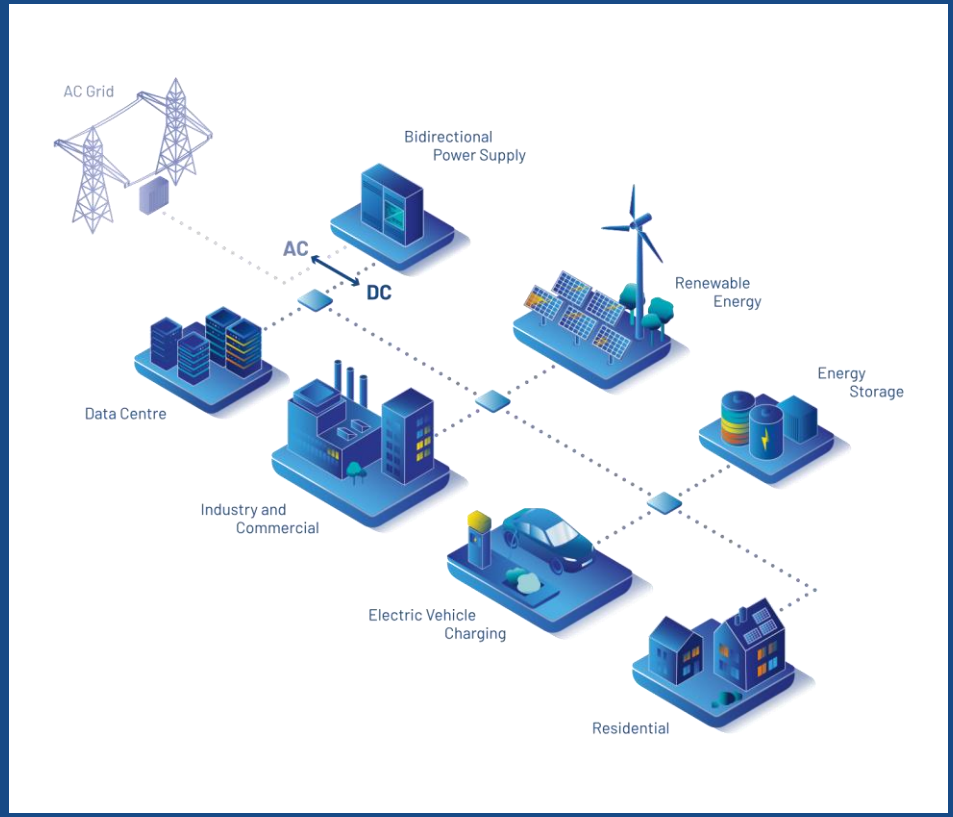

Application Schaltbau NeXT Factory

- 1.3 MWp PV
- 10 MWh thermal storage
- Battery storage
- E-car charging

© Schaltbau GmbH: https://www.schaltbau.com/en/about-us/current-events/news-and-press/press-releases/schaltbau-opens-next-factory-in-velden/

- > 70% self-consumption of 1.3 MWp PV
- 85% peak power reduction in fully automated storage & retrieval system
- 30% peak-power reduction overall
- 35% lower energy cost
- ODCA concept was base for regulatory approval

Application Phoenix Contact AES Arena

Sources: ODCA Linkedin Post 27. May 2025; https://www.cencenelec.eu/media/CEN-CENELEC/Events/Events/2023/AES/aes_presentation_possel-doelken_2023-12-04.pdf

- 650 V DC grid
- Positive overall energy balance
  - 2.5 GWh/a generated
  - 1.9 GWh/a needed
- Thermal-electric sector coupling
  - 1500 m³ ice storage
  - Uses phase-change energy (solid-to-liquid) for seasonal storage (winter → summer)

Application Mercedes-Benz Factory 56

- 220 000 m² production area
- 2 MW DC grid for building infrastructure
- Heating and air conditioning
- Battery storage for load shifting
- **Low-voltage Direct Current defined as standard!**
  - In factory automation
  - In building infrastructure
  - Mercedes-Benz world-wide standard “integra.8”

Source: https://odca.zvei.org/

Source: Dr. Davis Meike: Markt & Technik DC Konferenz, 23. Oct. 2024, Munich

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- DC Microgrids
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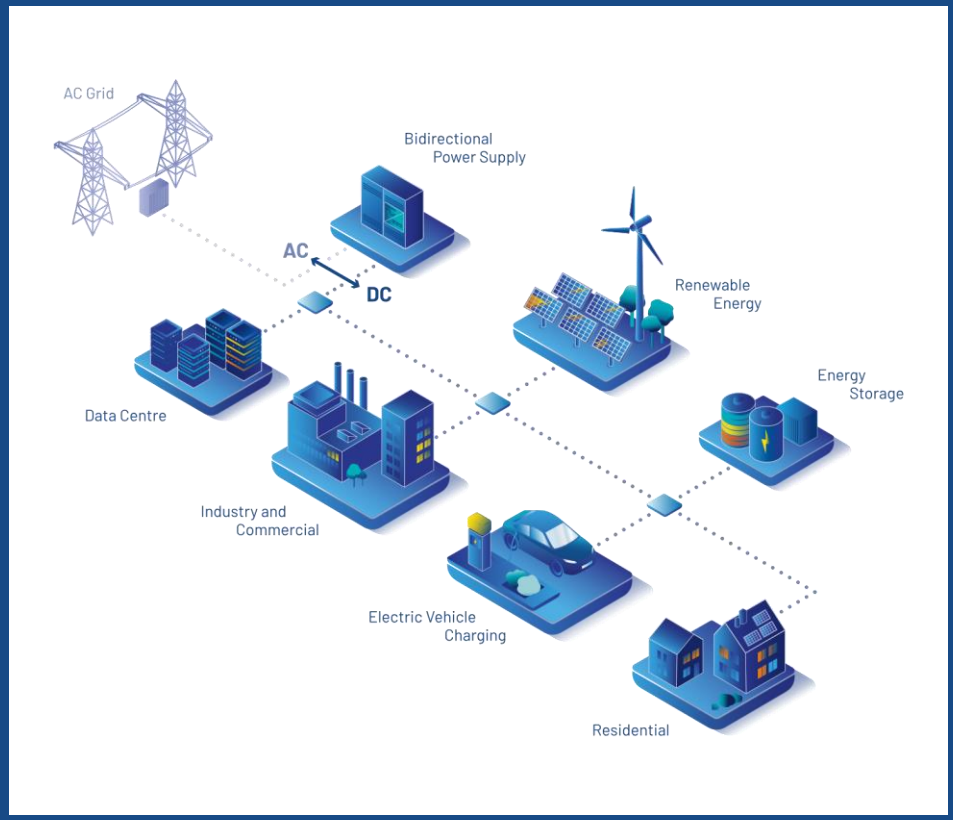
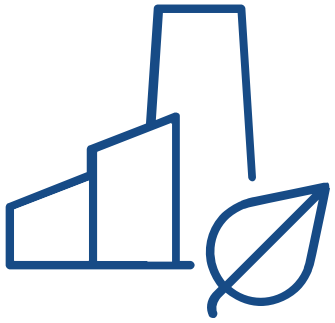
- Benefits



Benefits summary of DC Microgrids

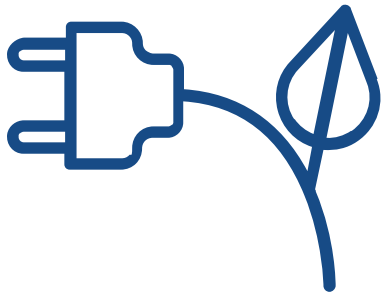


Resource efficient

- ✓50 % less copper (cabling)
- ✓Fewer components

Energy efficient

- ✓10 % reduction achieved
- ✓Full recovery of braking energy (lifts, robots, …)



Direct integration of green energy

- ✓Reduce grid connection load

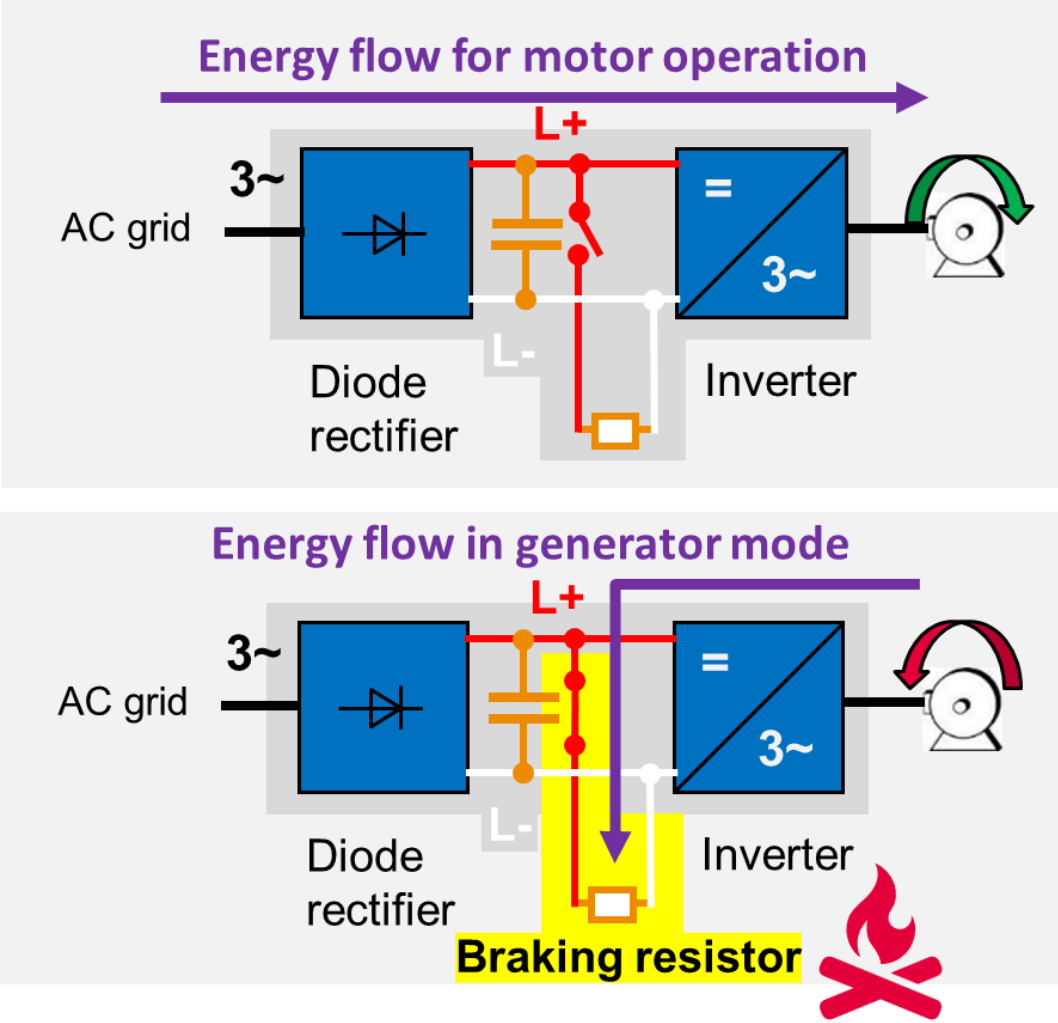
Resilient

- ✓Backup power
- ✓Lower failure risk

Peak Power reduction

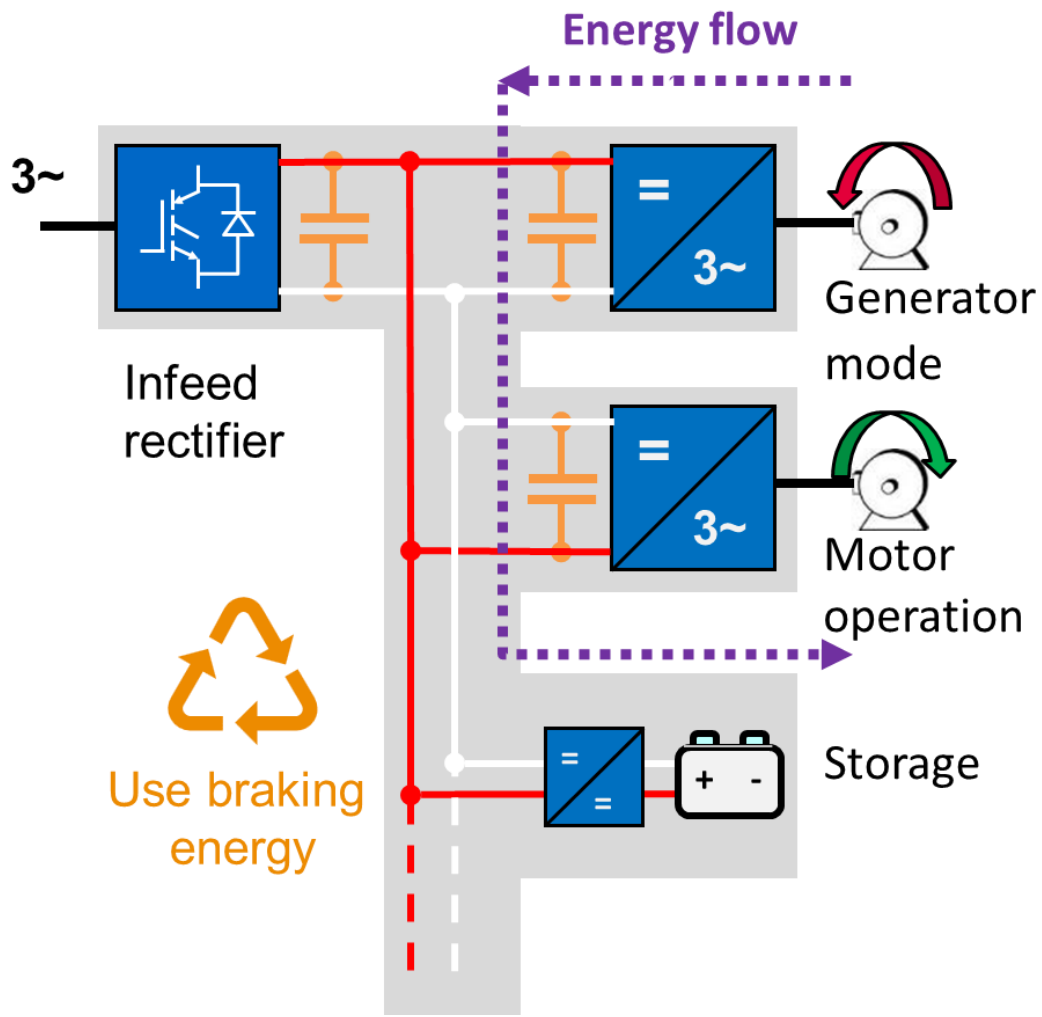
- ✓80% achieved
- ✓“Grid friendly”
- ✓Lower power bill

AC disadvantage: Braking energy is wasted



- Frequency converters are optimized for motor operation
- In generator mode (slowing down), the inverter needs to get rid of the stored energy.
- Typically, the energy is converted to heat in braking resistors

DC benefit: Braking energy is used

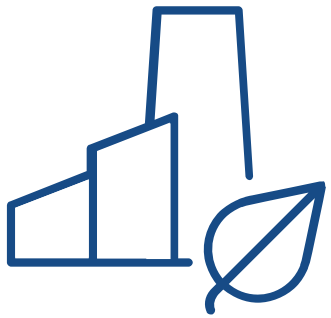


- Less effort
  - AC/DC conversion for each drive is redundant
  - Fewer components
- 100% recuperation of braking energy
  - Into different motor
  - Into storage device
- No need to “cool-away” the braking energy → additional saving

ODCA
direct current by zvei

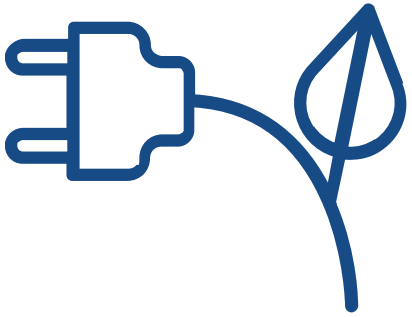
WE CAN DO BETTER – WITH DC!

For more information:



Resource efficient

Energy efficient



Direct integration of green energy

Resilient

Peak power reduction

ODCA

direct current by zvei

https://www.linkedin.com/showcase/opendcalliance/

https://odca.zvei.org/