2024-09-03, CATHY CHEN, ABB ELECTRIFICATION BUSINESS RESEARCH MANAGER

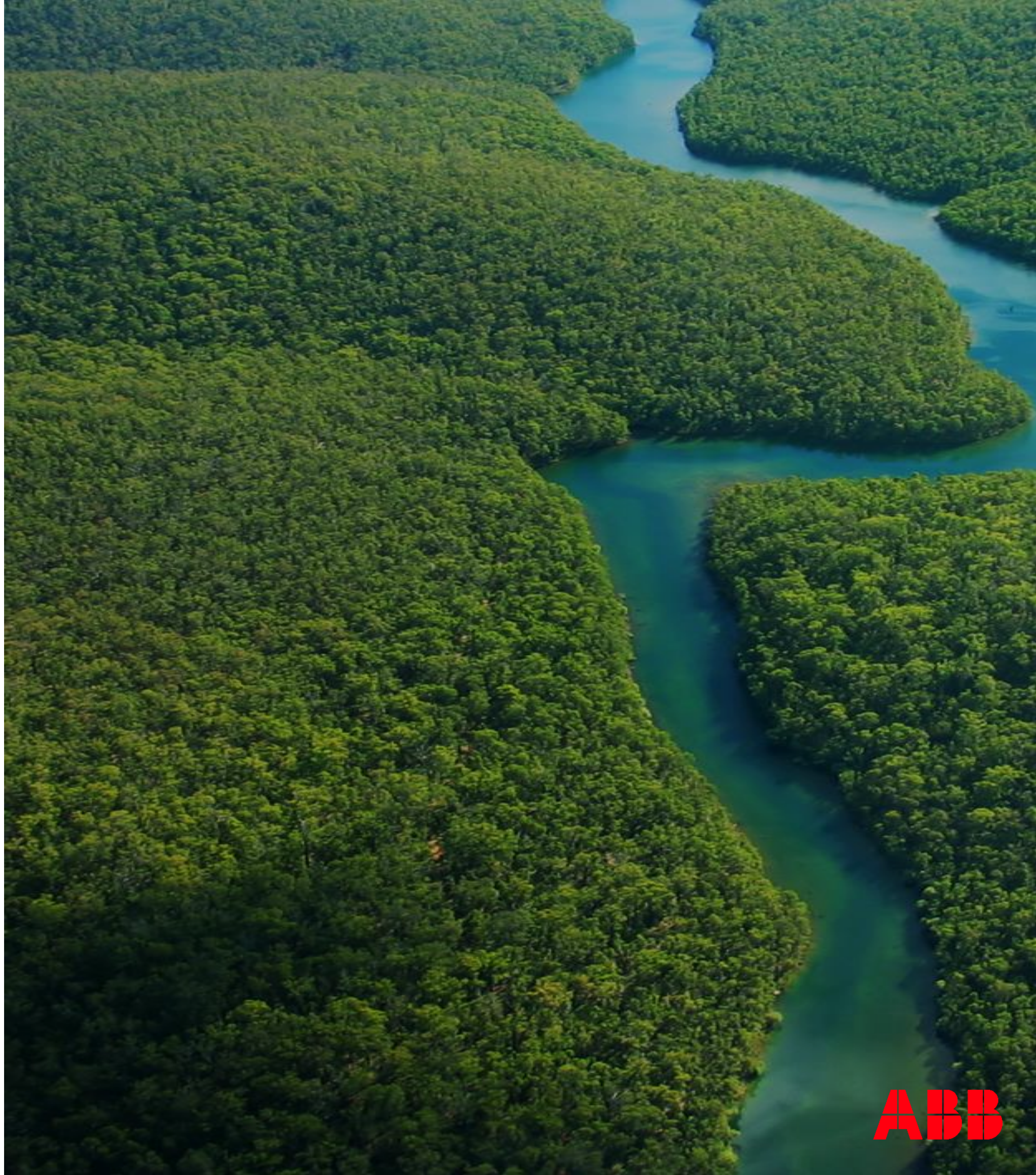
DC Power Distribution - A Technology Enabler for Energy Transition

ECCE Europe 2024, Darmstadt, Germany

ABB

Agenda

1. Energy transition and DC distribution
2. Key challenges and enabling technologies
3. Standardization and pilot projects



The world needs electrification solutions more than ever

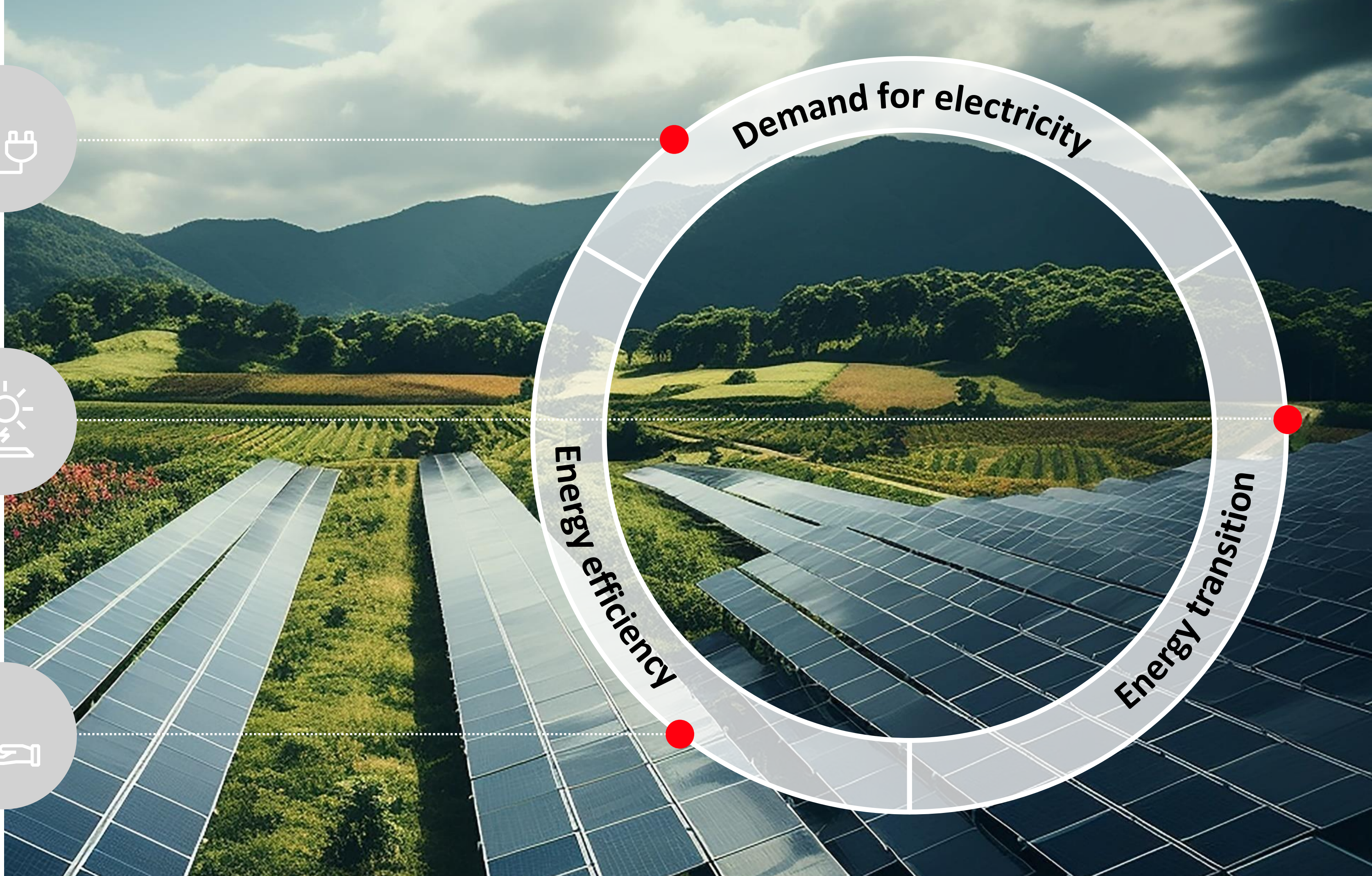
>2x projected growth
in global electricity demand in 2050

50% of total energy consumption
driven by electrification in 2050

3x renewable energy capacity
needed by 2030

5x annual increase of
BESS capacity between now and 2030

2x energy intensity improvements
annually by 2030
to reach net-zero by 2050



1. IEA Net zero by 2050 – a roadmap for the global energy sector, link
2. IEA Renewables 2023 – analysis and forecast to 2028, link
3. McKinSey & Company, Enabling renewable energy with battery energy storage systems, link
4. IEA Energy Efficiency 2023, link

Conventional Grids vs Future Grids

Unidirectional power flow
Passive loads
Loads consume energy

Bidirectional power flow
Passive and active loads
Loads consume / generate / store energy
Added intelligence → smart grids, microgrids

Microgrids Value Streams

Resilience

Backup power (keep alive the critical end-use loads)
Support for the bulk power system (e.g., peak shaving)
Alleviate grid congestions
Resilience to cyber attacks to the central grid

Sustainability

Lower carbon footprint by aggregation, integration and utilization of DERs
Enabling DERs sharing (energy communities)
Enable access to electrification for remote / rural areas

Economics

Participate in energy markets and ancillary service markets
Cost optimization with optimal dispatching of distributed resources / loads
Lower capex, faster option for grid upgrades

Why DC Distribution?

AC and DC coexist
Small power plants
Fossil-fuel based generation
The first grid: A DC microgrid

1890s~

AC dominates
Large power plants
Long distance transmission
Fossil-fuel, nuclear

1950s~

AC challenged
Renewable penetration
Inverter-based resources
Power quality
Stability, complexity

2000s~

Energy Efficiency

Less conversion stages / losses
Straightforward energy regeneration
Elimination of reactive power

Flexibility and Simplicity

Inherent DC nature of both distributed energy resources, loads, and battery energy storage systems
No synchronization requirements
Fewer harmonic issues

Resource Efficiency

Less conductors, higher voltages, lower fault energy, no skin effect, less copper
Less potential stress, less insulation materials

IEC SyC LVDC Presentation to the Community, link

DC Distribution

Emerging applications

Onboard DC Grid™ for Marines

Leverages DC output of fuel cells and batteries

DC Buildings

Electrification, energy efficiency, decarbonization

E-Mobility

Simplified system topology, reduced power conversion stages, energy efficiency improvement

DC Factories

Flexible, intelligent, and energy-efficient production

Future Data Centers

Superior efficiency, small-footprint & high-power density

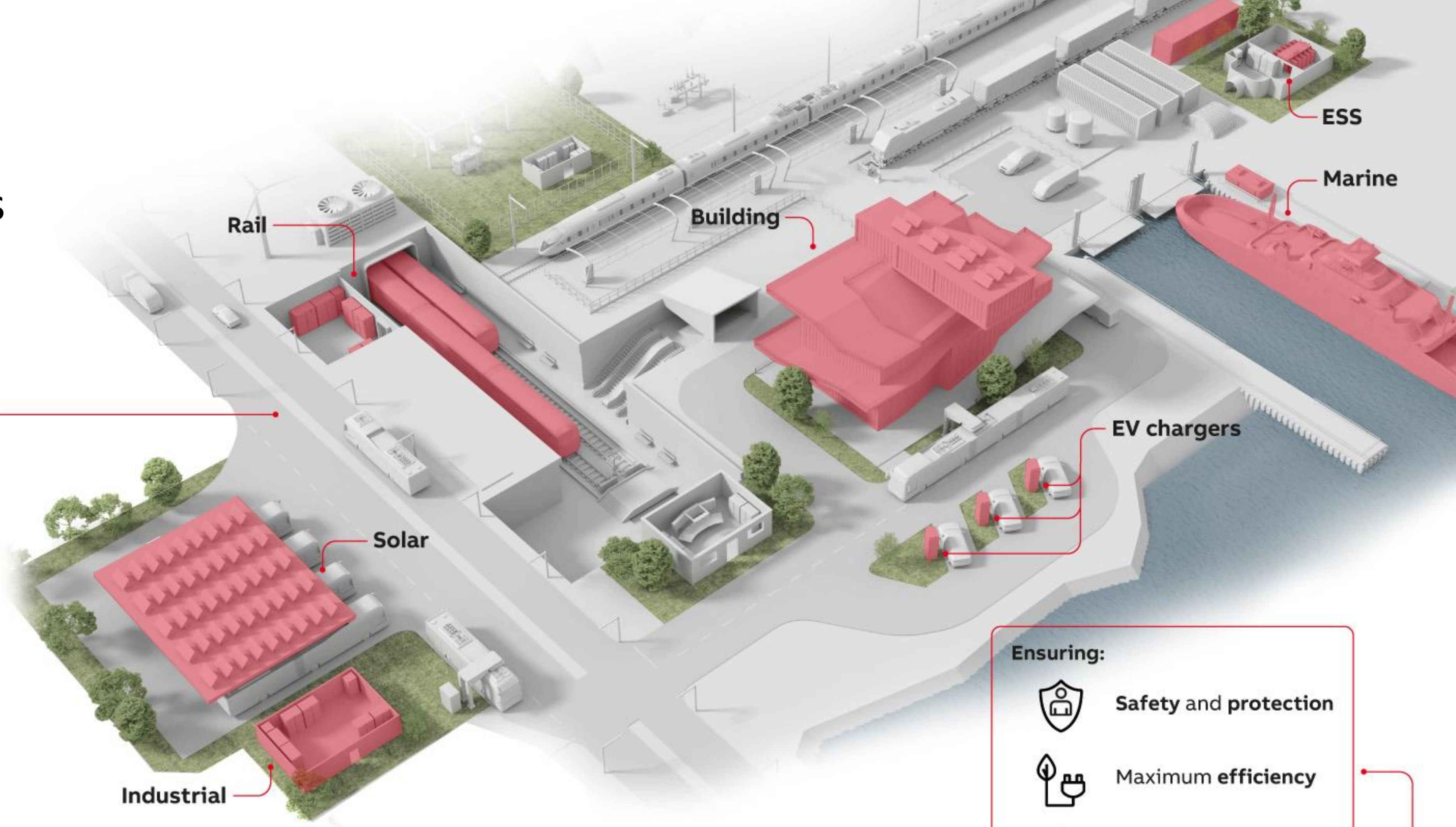
DC Distribution
Key technical challenges

Fault interruption
Rapid rising time, no zero-crossing, critical current

Protection scheme
Fault identification, protection coordination, sensitivity/selectivity

System integration
AC & DC interface, breaker-converter interactions, grounding

Control and stability
Power balancing, disturbance-ride-through, resonance damping



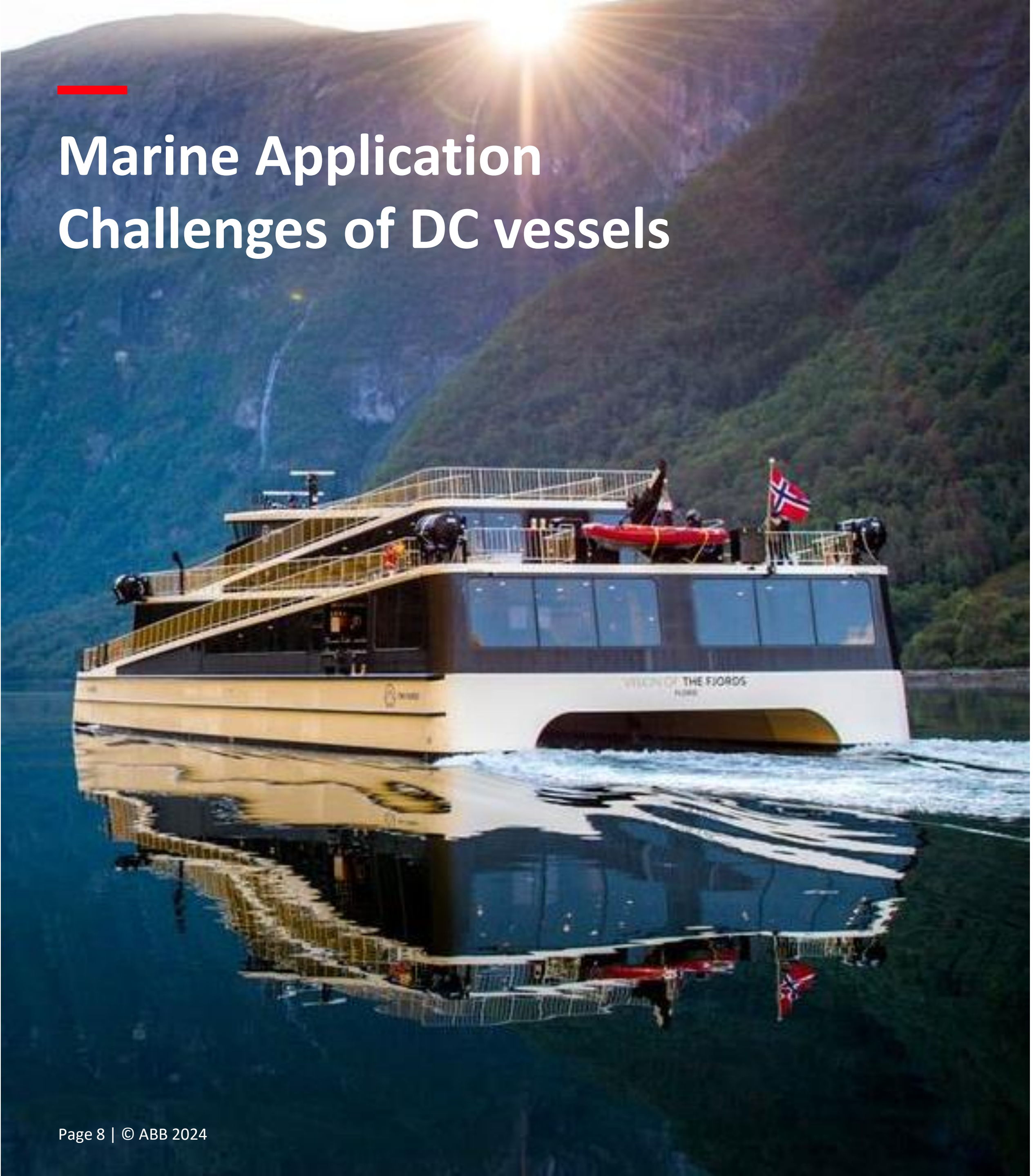
Ensuring:
- **Safety** and **protection**
- Maximum **efficiency**
- Increased **productivity**

Fast & **reliable** DC fault interruption and protection

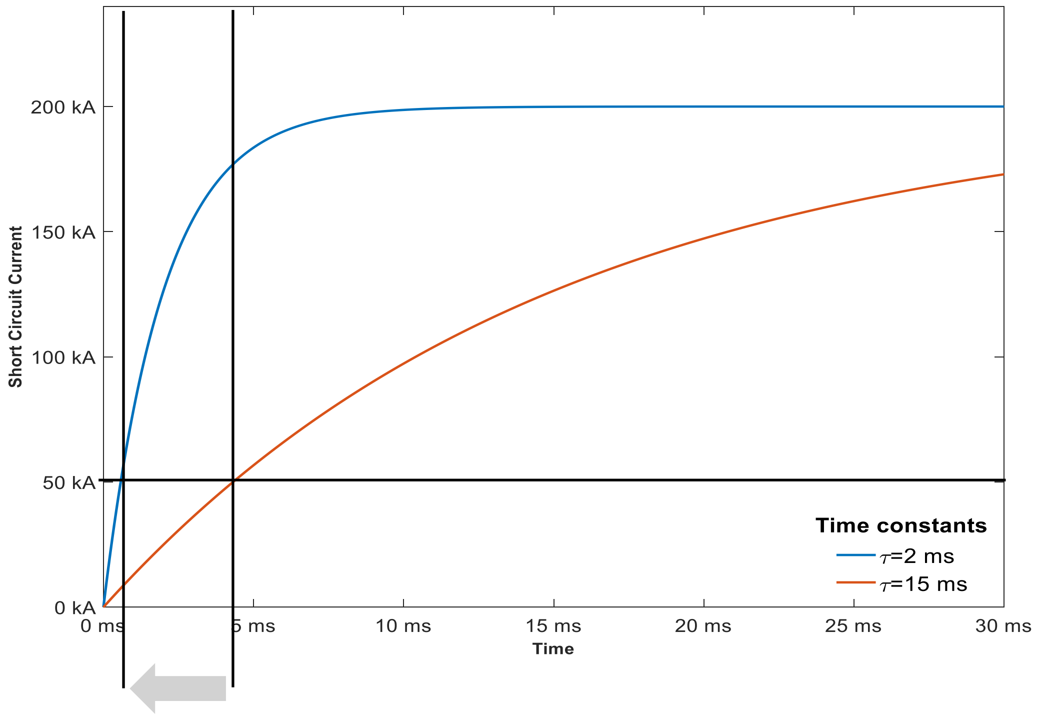
High efficiency & **high-performance** power conversion

Systematic design & **resilient** power management

Marine Application
Challenges of DC vessels



Prospective short circuit currents



Changing of the time constant by new sources and low inductance of a DC grid

Short circuit current of 50kA within 580 us!

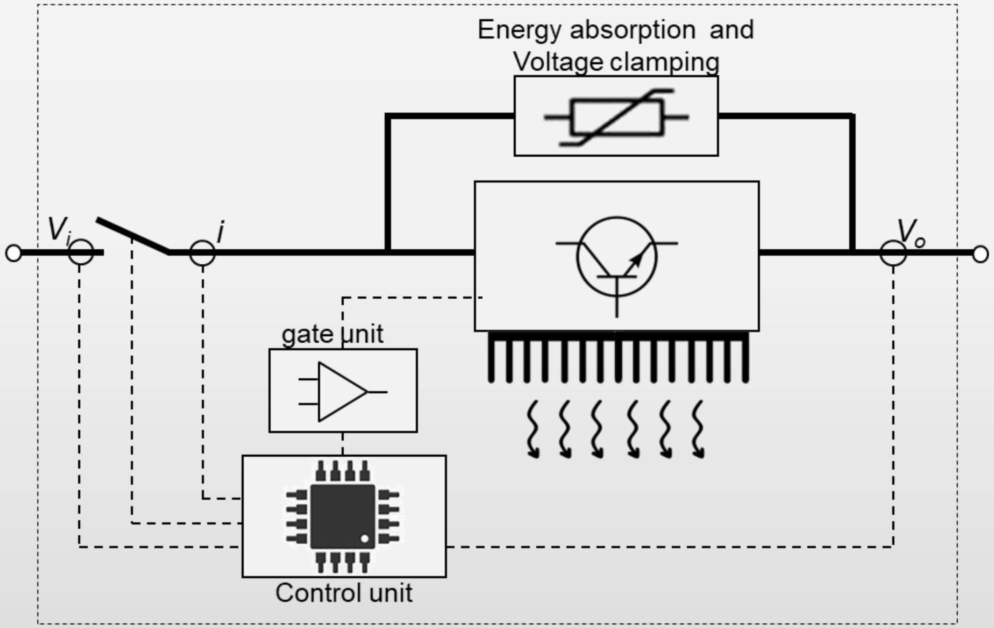
New breaking technology required

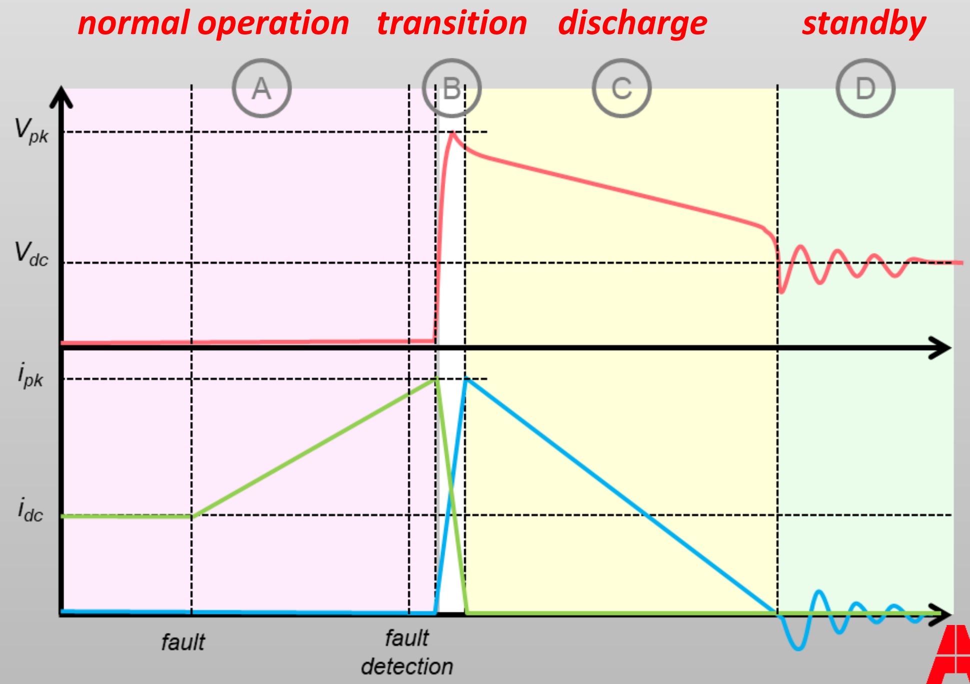
Switching Electrical Power

Revolution ahead for DC Systems

ELECTRIC ARC

SEMICONDUCTOR





Antonello Antoniazzi, Dejan Pejovski. Semiconductor Circuit Breakers for Protection of DC Microgrids, ECPE European PhD School 2024, Gaeta, Italy

Solid State Circuit Breaker

Key challenges toward a complete solution

Semiconductor losses

Fundamental physics:

Semiconductor losses >> conductor losses (e.g. copper & contacts of traditional circuit breakers)

Reduction of system efficiency

Effort for cooling

Cost of ownership

Performance Evaluation

Low fault inductance:

Critical rate of rise of the current

High fault inductance:

Max switchable inductance

Galvanic Isolation

Leakage currents must be prevented

Dielectric withstand category

Certification relevant

Integration

Footprint

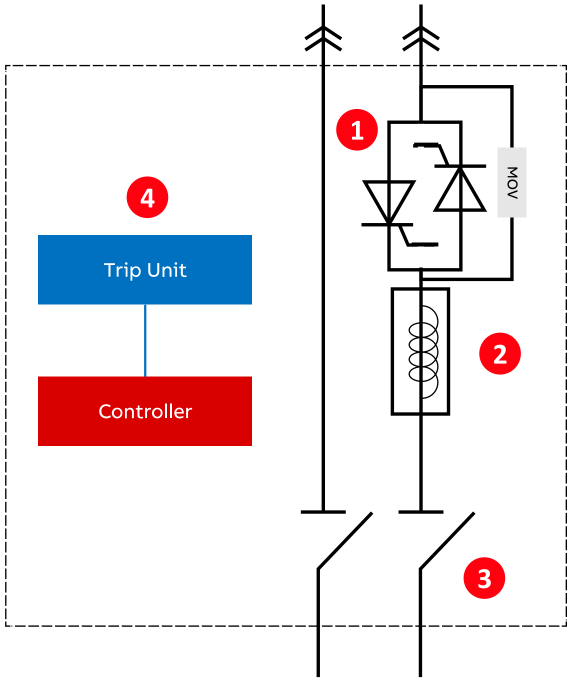
Reliable coordination inside the device

Design for installation and maintenance

Digital connection

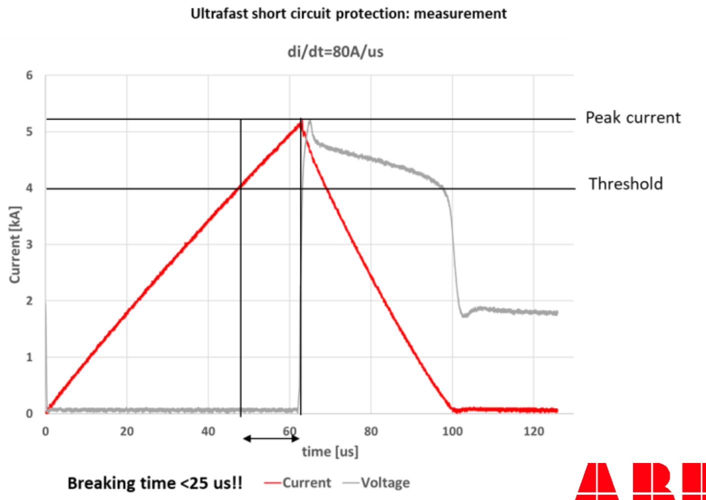
SACE Infinitus–
Solid-State Circuit Breaker

All-in-One Device Concept

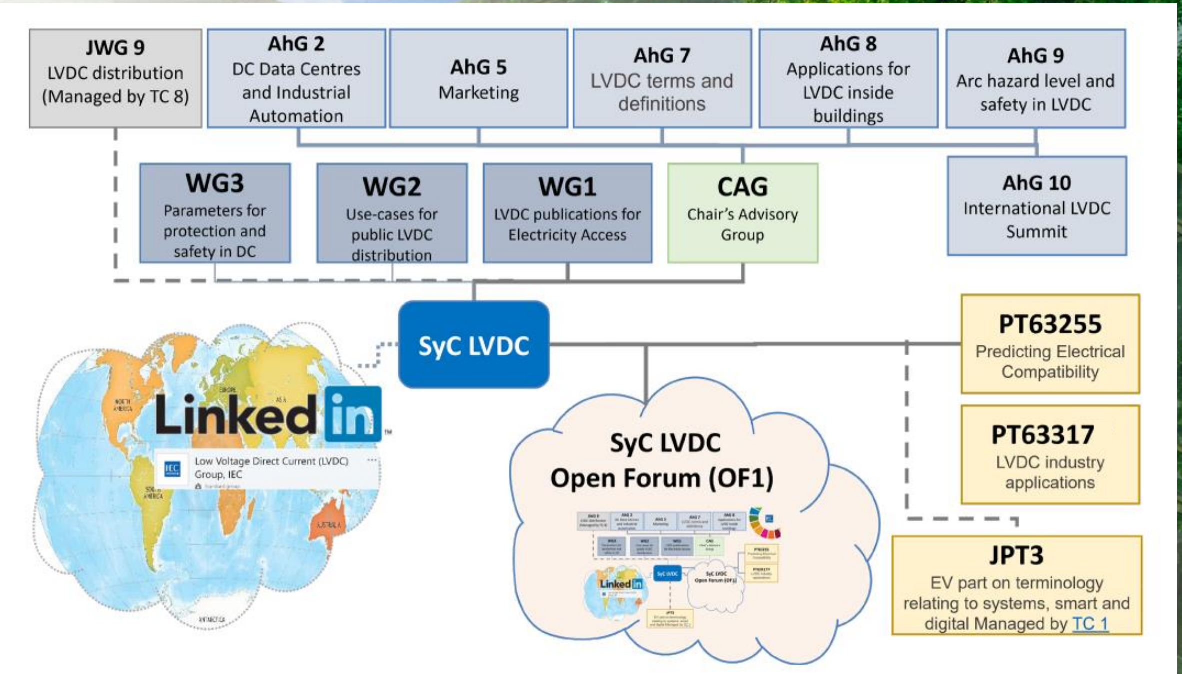


1. **Power electronic**
   Low loss RB-IGCT technology
   Energy absorbing MOV
   Fully bi-directional
2. **Inductance**
   0 – 3.5 - 16µH
3. **Isolation switch**
   CAT IV
   Motor-controlled
4. **Protection unit**
   Advanced protections
   Network analyzer
   Metering
   Communication

Up to 1000x faster than traditional circuit breaker technology!



IEC Systems Committee LVDC



Provide system level understandings
Guide future directions
Bring urgency to development

1. IEC System Committee Low Voltage Direct Current and Low Voltage for Electricity Access, link
2. IEC SyC LVDC Strategic Business Plan, link
3. IEC SyC LVDC Standardization Map 2024, link

Theme topics in IEC standardization framework

Basic Technology

- Regulatory requirements
- Foundation for overall standard framework
- Terminology, voltage, power quality, measurement, etc.

Construction and Operation

- LVDC system planning and design
- Equipment installation
- Safety protection
- Operation and maintenance

Installation

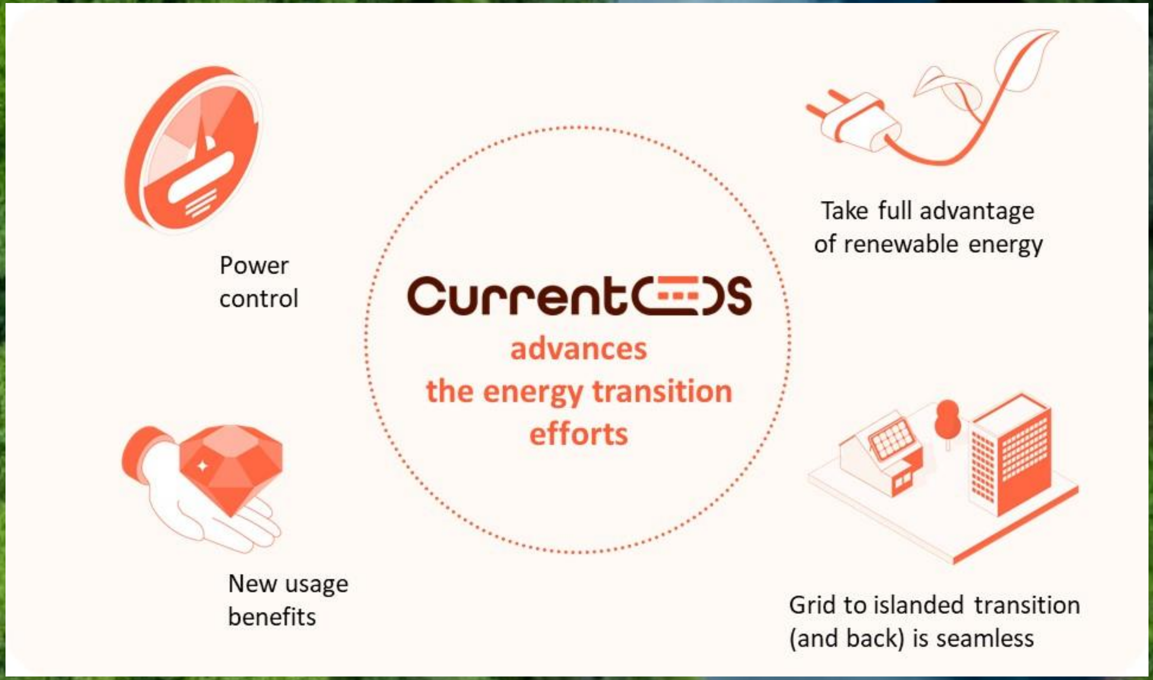
- Technical requirements for the installations
- General equipment like cables, accessories, switches, power electronics

Application

- Specific requirements for the concrete application scenarios
- Power source side: PV, wind, battery storage, etc.
- Load side: buildings, household appliances, EVs, etc.

Current/OS Foundation
A global DC partnership

50+ partners of manufacturers & electricity stakeholders
Ecosystem of DC-certified products & services
A leading research and innovation partnership



OPEN standard system for DC energy distribution

The set of rules

- Building DC microgrids simpler, safer, cheaper
- Enabling resilience and opportunistic behavior
- Offering unseen level of safety to people and assets

Zoning

- Risk classification in DC installations
- Five zones identified based on risk levels
- Zone 0 (highest risk) to Zone 4 (lowest risk)

Voltage bands

- Voltage acts as a meaningful signal for power availability
- Voltage level triggers the operating modes of load and sources
- No communication / central control required

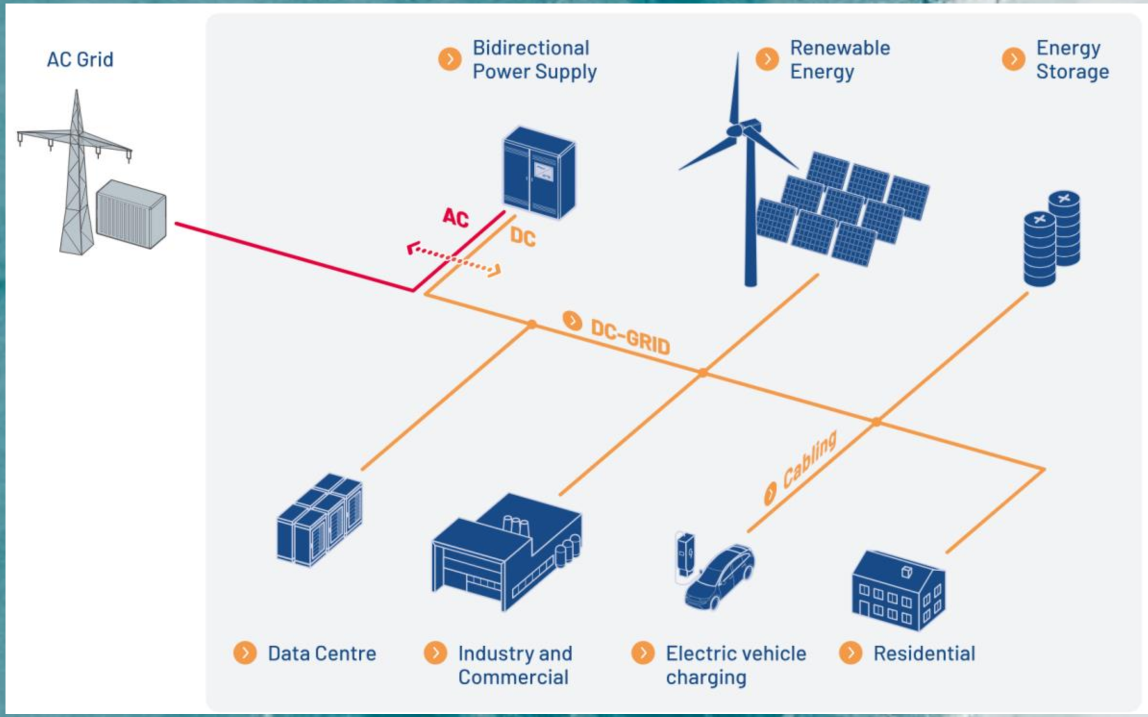
Droop curves

- Describe the power response of circuits to different voltage levels
- Can be pre-defined or adjusted in real time
- Important for power balancing and voltage stability

Current/OS Foundation, link

Open Direct Current Alliance
An international DC ecosystem

DC for a resource-saving and CO2-neutral world
68 members under the umbrella of ZVEI
Strong focus on sustainable industrial DC grids



1. Open Direct Current Alliance, link
2. DC INDUSTRIE2 – Open DC grid for sustainable factories, link

ODCA direct current by zvei

Low voltage DC-INDUSTRIE grids

Features

- Multiple DC sectors, operation of electrical drives
- Bi-directional energy flow
- Fault protection and selectivity
- Defined voltage bands and voltage-time behavior
- Power management designed for stability

Benefits

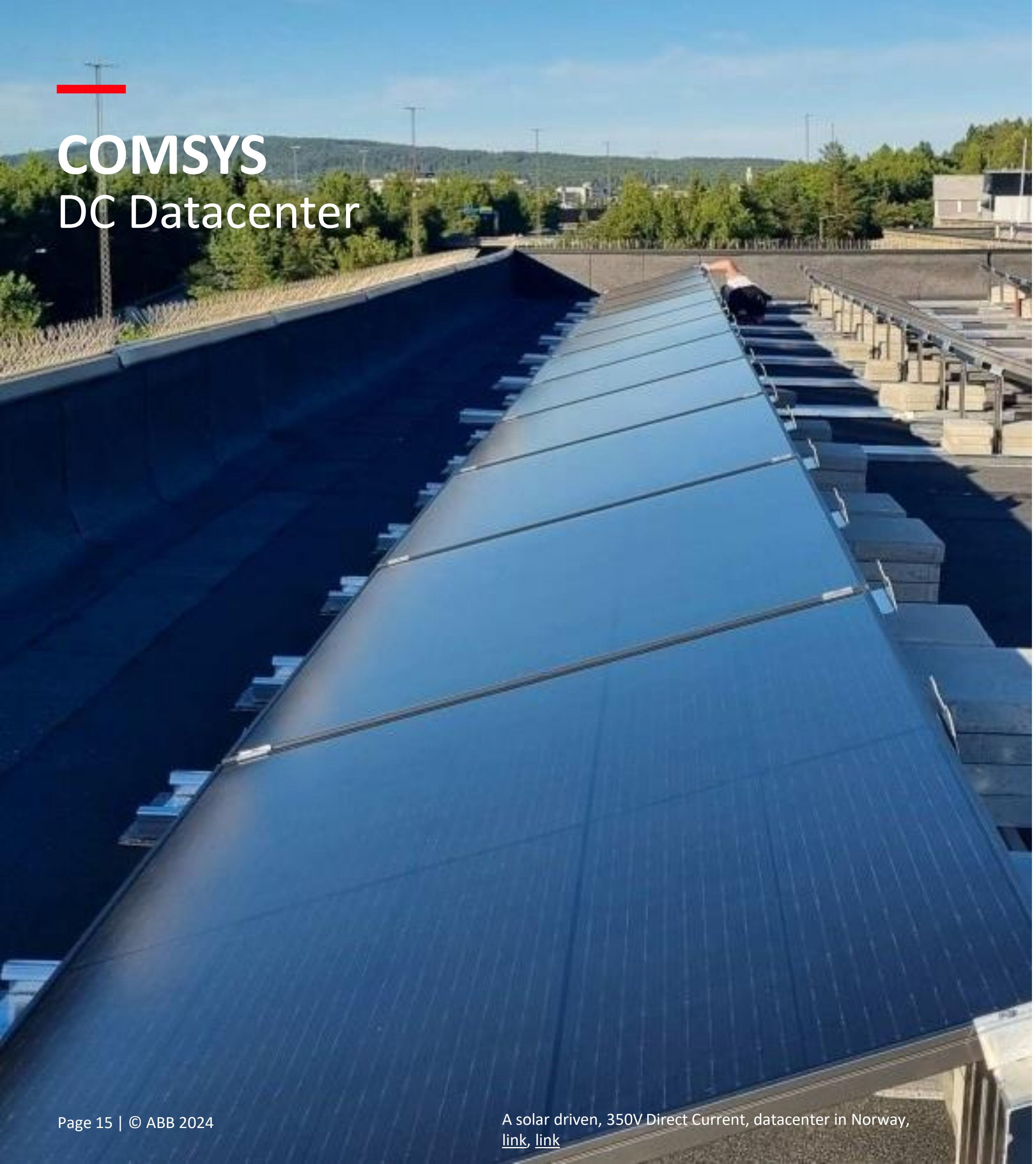
- 50% less copper and 50% reduced power losses in cabling
- Complete recovery of braking energy
- Simple integration of renewables and energy storage
- Up to 80% reduction of the peak power demand from AC
- Increased system availability

Standardization

- Direct contribution to IEC SyC LVDC PT 63317
- System reference deliverable LVDC industry applications

ABB

COMSYS
DC Datacenter

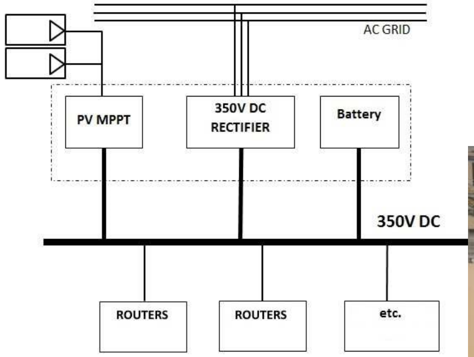


A solar driven, 350V Direct Current, datacenter in Norway, [link](), [link]()

350V Direct Current installation with rooftop solar at the Blix Solutions datacenter in Oslo, Norway

LVDC system design according to ETSI as well as Current/OS specifications to make the installation more energy efficient

- 13 kW roof-top PV generation feed the DC bus through high efficiency DC/DC converters
- Power supply from AC grid with rectifiers when PV energy is not enough
- DC UPS with 350VDC output, providing 20min of backup energy

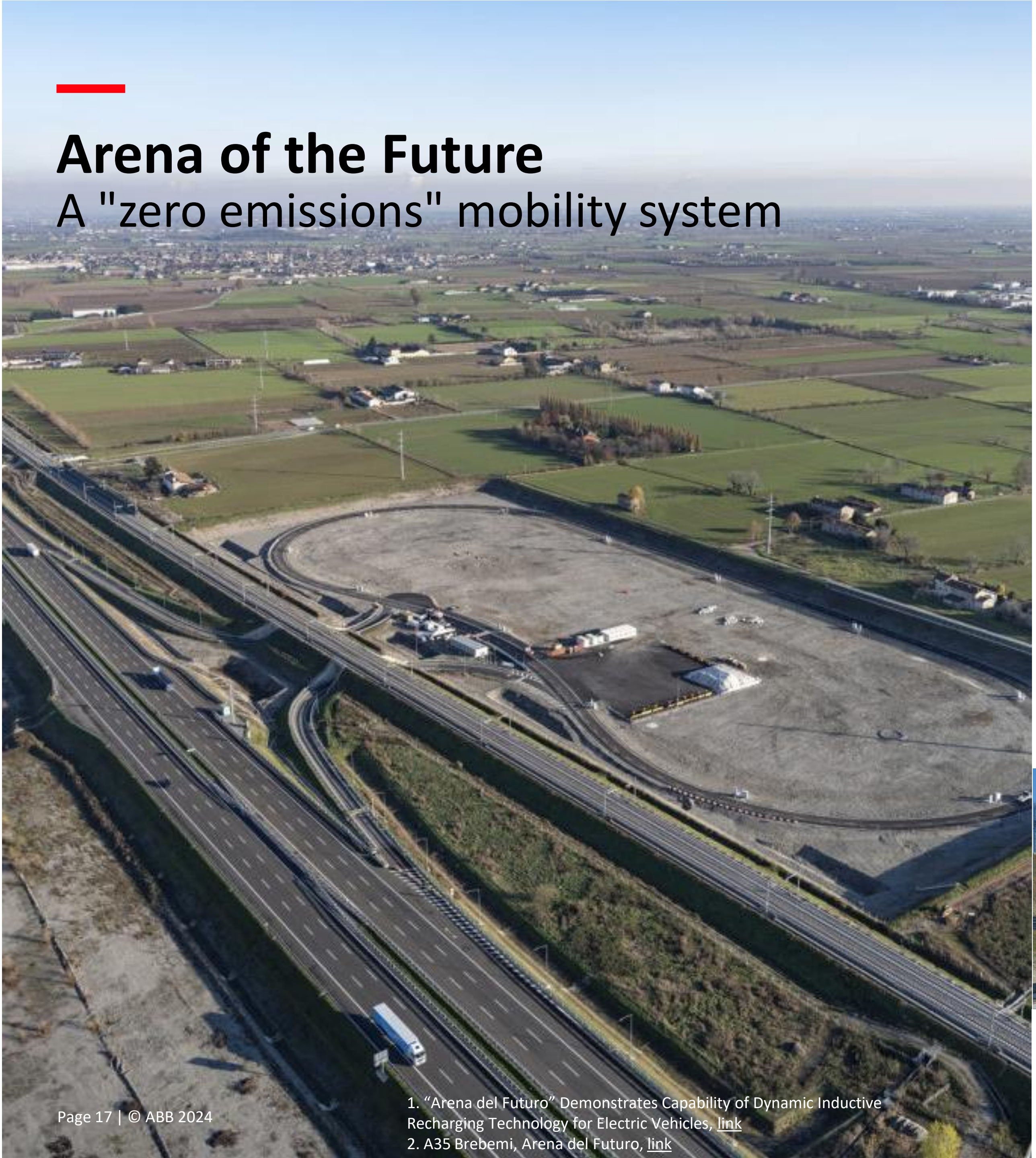


Mercedes-Benz
Industrial DC grid pilot

DC grid pilot for the next generation of electrical power distribution in new car assembly hall, “Factory 56”, Sindelfingen, Germany

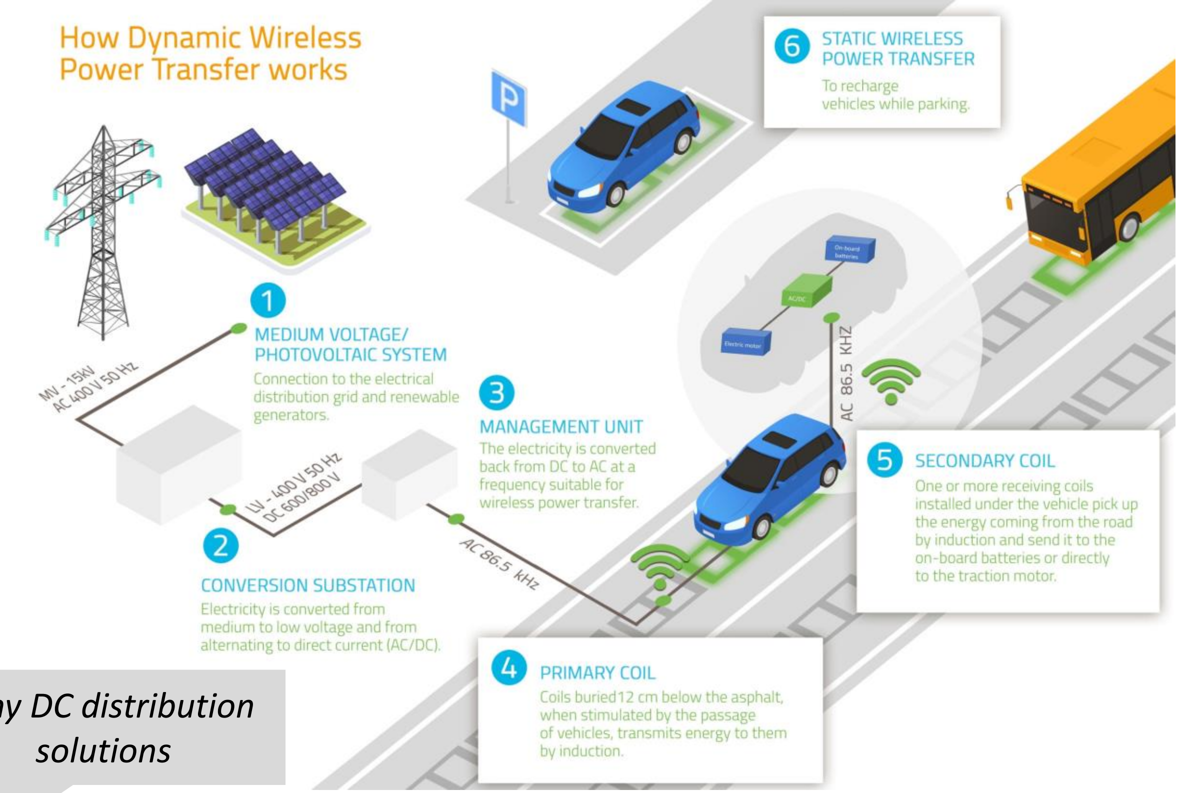
One of the largest pilot projects in line with ODCA industrial DC system design for CO_2-neutral production
- 222 000 m^2 production area
- 2 MW DC grid for hall infrastructure
- 1 MW roof-top solar energy generation, 5.7MW peak
- 1.4 MWh battery energy storage

1. DC-INDUSTRIE2 – open DC grid for sustainable factories, link
2. Mercedes-Benz is presenting the future of production, Factory 56, link
3. DC Factory Enables Higher Efficiency, Lower Costs, link



Arena of the Future

A "zero emissions" mobility system



Why DC distribution solutions

- Reduced power losses in the energy distribution process
- Direct integration with renewables without extra power conversion
- Reduced cost thanks to thinner cables, less packaging and lighter weight

A35 Brebemi · ALEATICA · ABB · electreon · IVECO · IVECO BUS · MAPEI · PIZZAROTTI · POLITECNICO MILANO 1863 · Prysmian Group · STELLANTIS · TIM · FIAMM · ROMA TRE UNIVERSITÀ DEGLI STUDI · UNIVERSITÀ DI PARMA

1. "Arena del Futuro" Demonstrates Capability of Dynamic Inductive Recharging Technology for Electric Vehicles, link
2. A35 Brebemi, Arena del Futuro, link

R&D Collaborations

Intelligent, Grid-Friendly
1MW EV Fast Charging with DC Distribution

1 MW DC power distribution system for EV Fast Charging Infrastructure

- MVAC-LVDC solid state transformer with grid compensating capability
- DC distribution system at 750 V
- Main source & BESS circuit breaker up to 1500 A
- Fast charging branches up to 500 A

Worst case di/dt **above to 250A/µs**

Protection Coordination
in less than 10 µs!

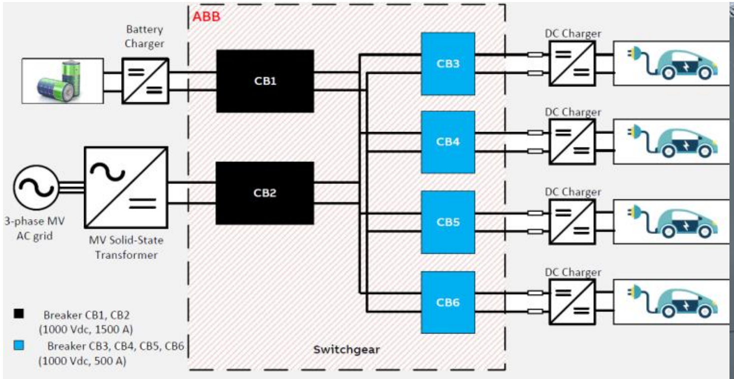


ABB NC STATE UNIVERSITY New York Power Authority U.S. DEPARTMENT OF ENERGY Energy Efficiency & Renewable Energy VEHICLE TECHNOLOGIES OFFICE

DOE Vehicle Technologies Office Annual Merit Review, Project ID:ELT238, Award No:DE-EE0008450, link

Conclusions

R&D
Radical innovations
Technology breakthrough

Regulation
Policies and regulatory requirements

Products
COTS DC equipment
Interoperability

Standardization
Safeguard investment
Reduce cost of approvals

Pilots
Fill up knowledge gap
Hands-on experiences

Training & Education
Skillsets for LVDC grids design, commissioning and operation

Electrifying the world
in a safe, smart and
sustainable way