PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Performance Demonstration of HVDC substation equipment

Demonstration der Eignung und Leistungsfähigkeit von HGÜ Schaltanlagen

Stuttgarter Hochspannungssymposium 2018, 6th & 7th of March 2018

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PROMOTioN - Context

European Commission energy strategy 2030

40% cut in greenhouse gas emissions compared to 1990 levels

27% share of renewable energy consumption

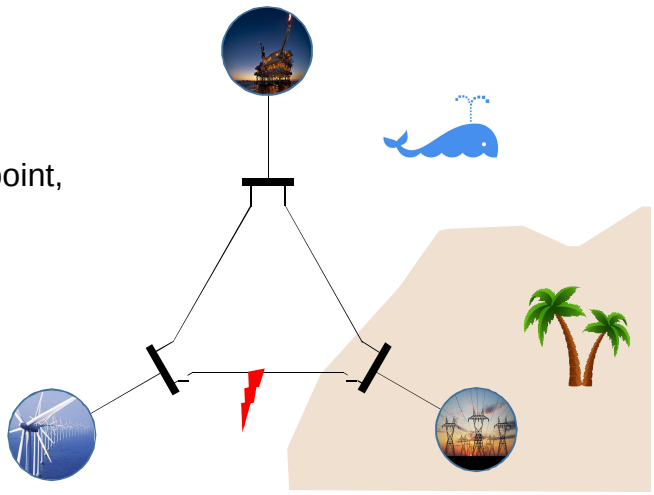
27% energy savings compared with the business-as-usual scenario

15% electricity interconnection target

PROMOTioN - Context

Why meshed grid?

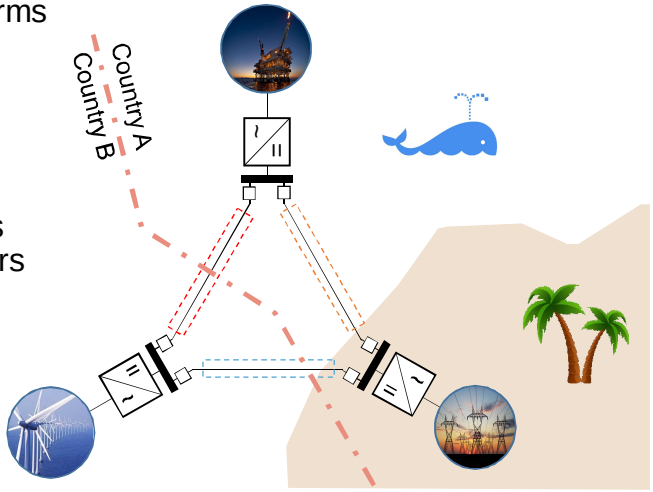
- Different types of offshore users
  - Consumers
  - Producers
  - Interconnectors
- Traditionally connected point-to-point, dedicated connection
  - Lower utilisation
  - Reliability offshore
- Mesh offers benefit



PROMOTioN - Context

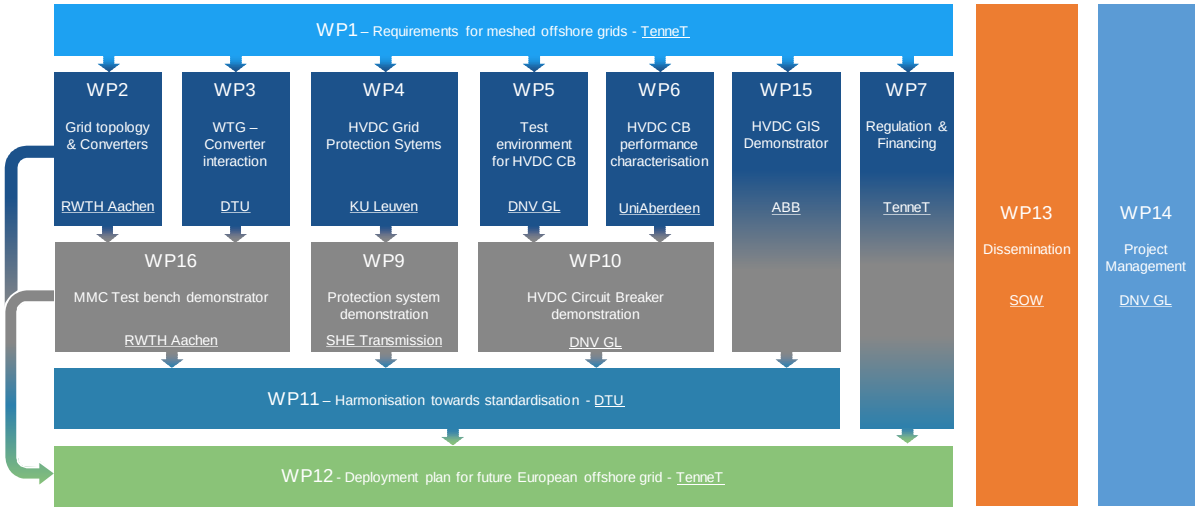
Challenges

- Offshore requires cables & platforms
- Long cables require HVDC
- HVDC requires converters
- HVDC network requires HVDC control & protection system
- HVDC protection system requires HVDC switchgear / circuit breakers
- Transnational network
  - Regulations
  - Business models
  - Financing



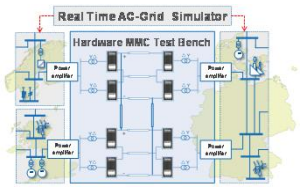
PROMOTioN – Project organisation

Work packages



PROMOTioN - Demonstrators

Demonstrators

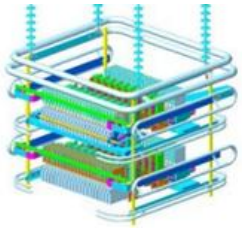


HVDC network control

MMC test bench
RWTH Aachen
Aachen, Germany

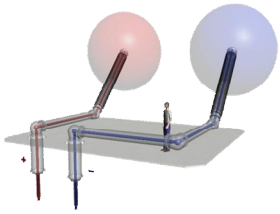
HVDC network protection

Multi-terminal test centre
SSE Transmission
Glasgow, UK



HVDC circuit breakers

KEMA High Power Lab
DNV GL
Arnhem, Netherlands

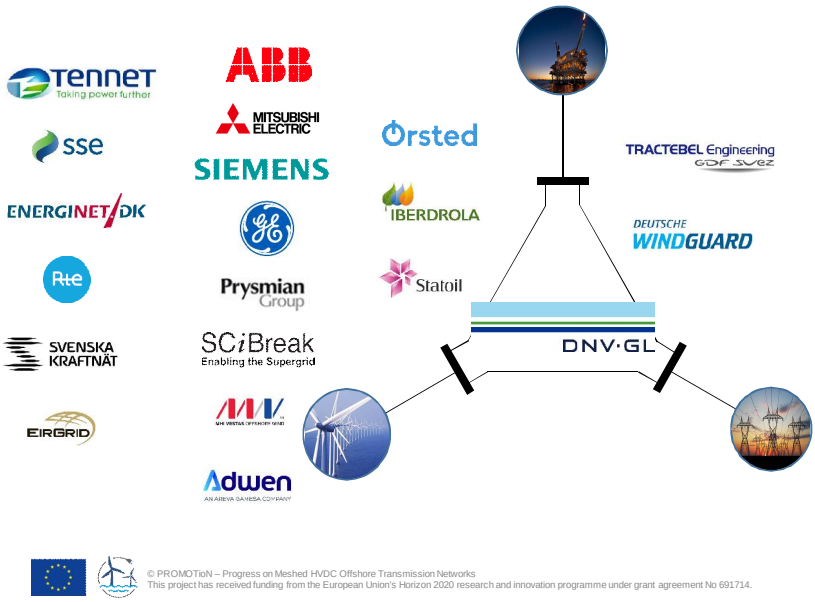


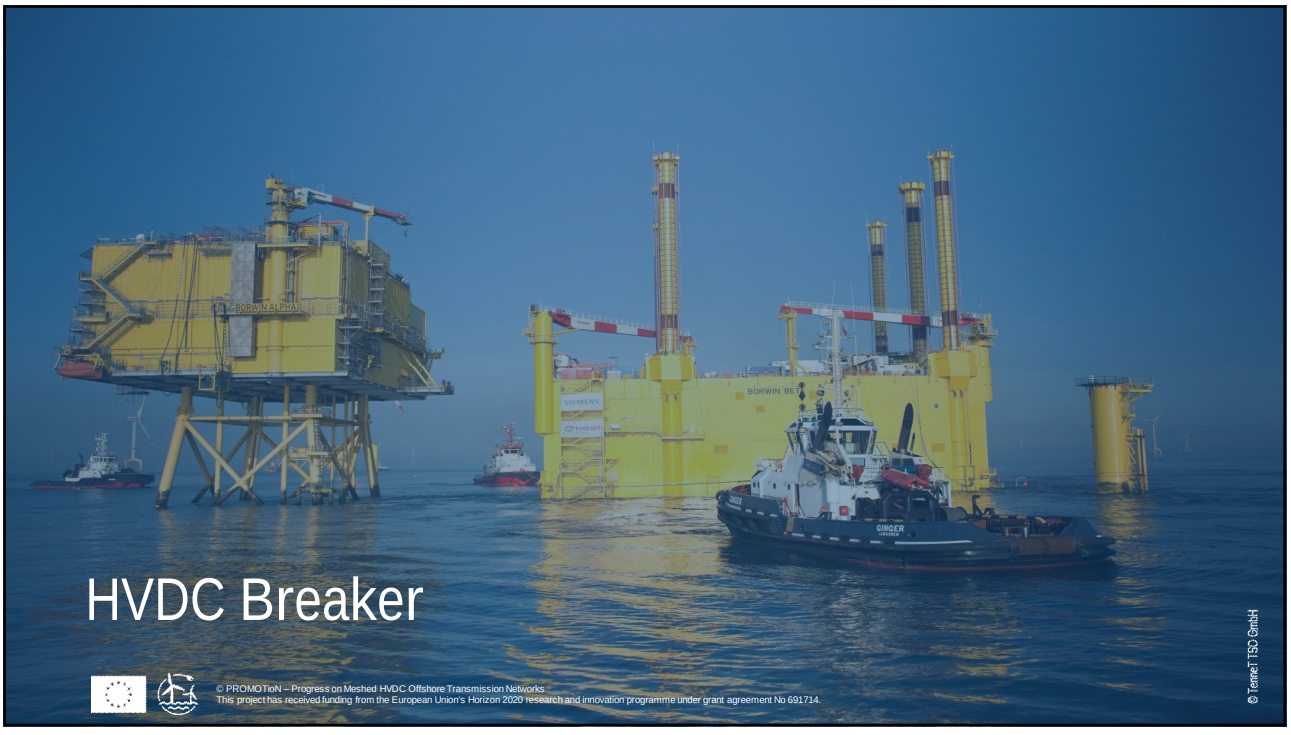
HVDC gas insulated system

KEMA High Voltage Lab
DNV GL
Arnhem, Netherlands

PROMOTioN – The Project

Partners

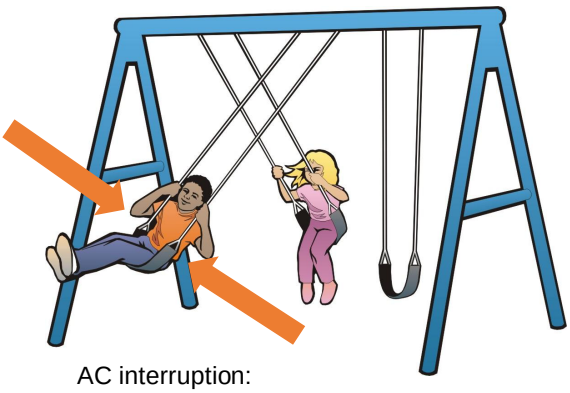




HVDC Breaker

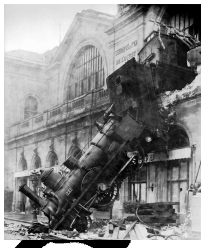
PROMOTioN – HVDC Breaker

Principles of AC / DC interruption



AC interruption:
Capture the swinging mass in its outer position (current zero).
Zero kinetic energy

15 kA in 100 km line = 11 MJ
= 30 ton train at 100 km/h

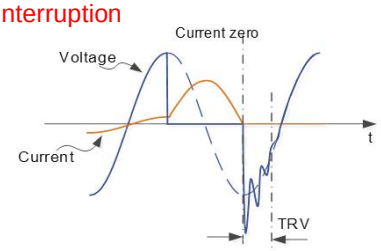


DC interruption:
Oppose the motion of a linearly moving mass (counter voltage)

PROMOTioN – HVDC Breaker

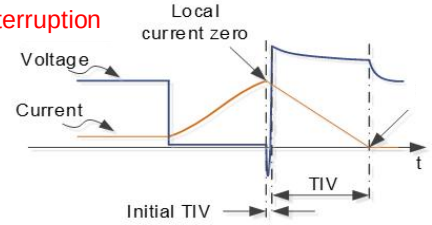
HVDC circuit breaker stress analysis

AC interruption



- Circuit breaker passive
- System imposes current
- System imposes TRV
- Test synthetically

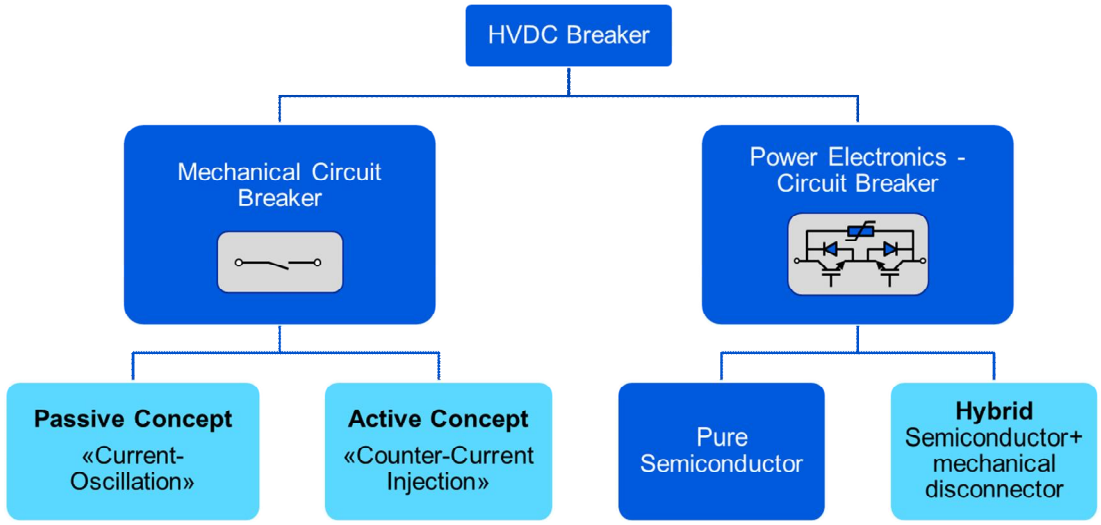
DC interruption



- Circuit breaker active
- CB determines current
- CB determines TIV
- Needs MW to test

PROMOTioN – HVDC Breaker

HVDC circuit breaker topologies



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HVDC circuit breaker test requirements

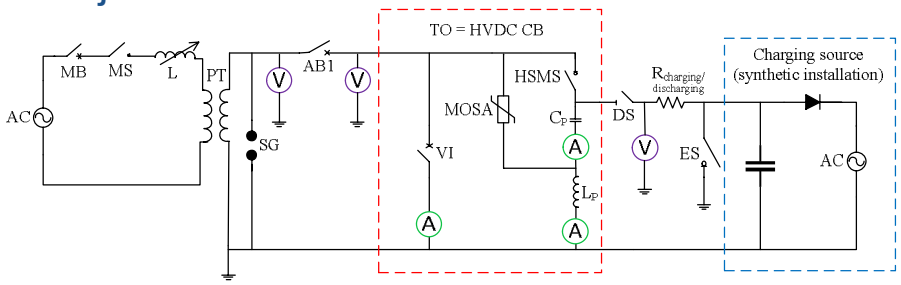
- Dielectric testing
  - Between terminals
  - Support structure
- Operational testing
  - Loss / resistance measurement
  - Temperature rise
  - Current withstand
- Current interruption testing
  - Breaking
  - Re-closing
- Special
  - Current limiting

Standard test circuits

Non-standard test circuits

PROMOTioN – HVDC Breaker

Implementation with mechanical circuit breaker with active current injection



Frequency: 16.7 Hz
Interrupting current: ± 2 kA - ± 16 kA
Breaker operation time: 8 ms
Voltage rating: 72.5 kV / 108 kV
Energy dissipation: 1 - 4 MJ

- VI: Vacuum Interrupter
- HSMS: High Speed Making Switch
- C_p: Capacitor
- L_p: Reactor

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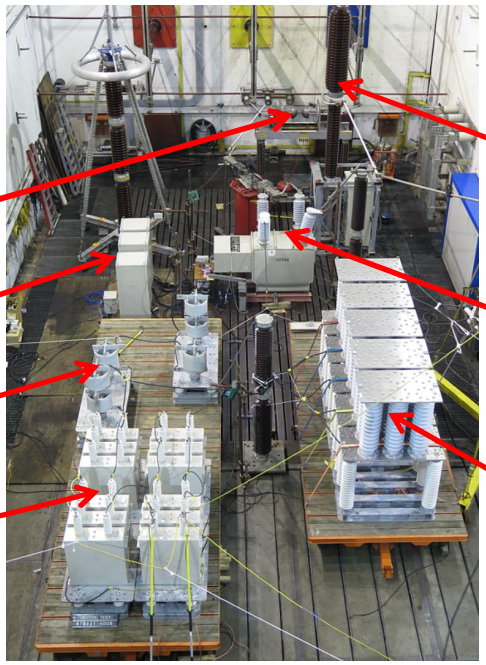
Achievements



Triggered making gap

DCCB Control Panel

Reactors

Counter current injection capacitors

Auxiliary SF_6 AC CB

HV and making vacuum interrupter switch

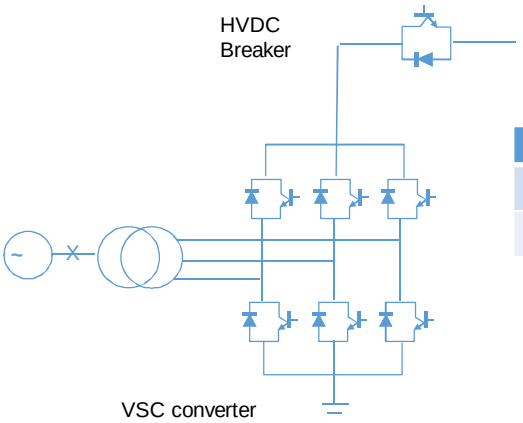
Energy absorbing MOSA

KEMA Laboratories

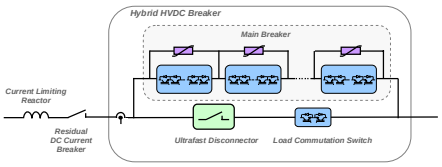
PROMOTioN – HVDC Breaker

Hybrid HVDC Breaker (HHB)

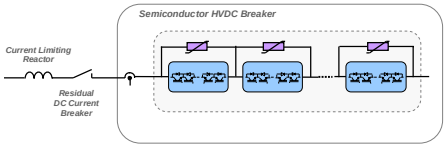
Design alternatives to meet technical requirements



Hybrid HVDC breaker



	Time	Loss	Scalable
Hybrid	OK	Very Low	OK
Semiconductor	Very fast	Medium	OK



Semiconductor HVDC breaker

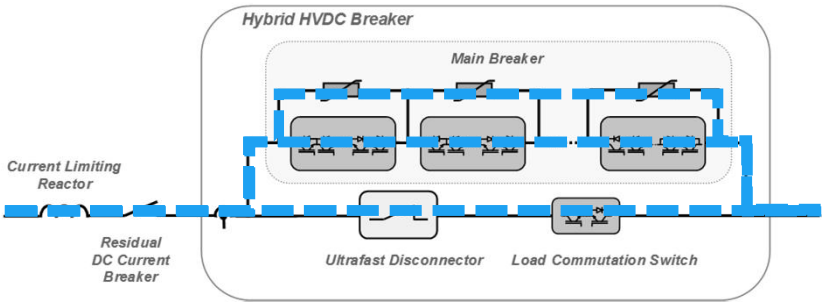
PROMOTioN – HVDC Breaker

HHB Basic functionality

Normal operation: Current flows in low-loss main branch

Proactive control: Load commutation switch commutates current into Main Breaker, the Ultra-Fast Disconnector opens with very low voltage stress

Fault clearance: Main Breaker switch commutates fault current into arrester bank



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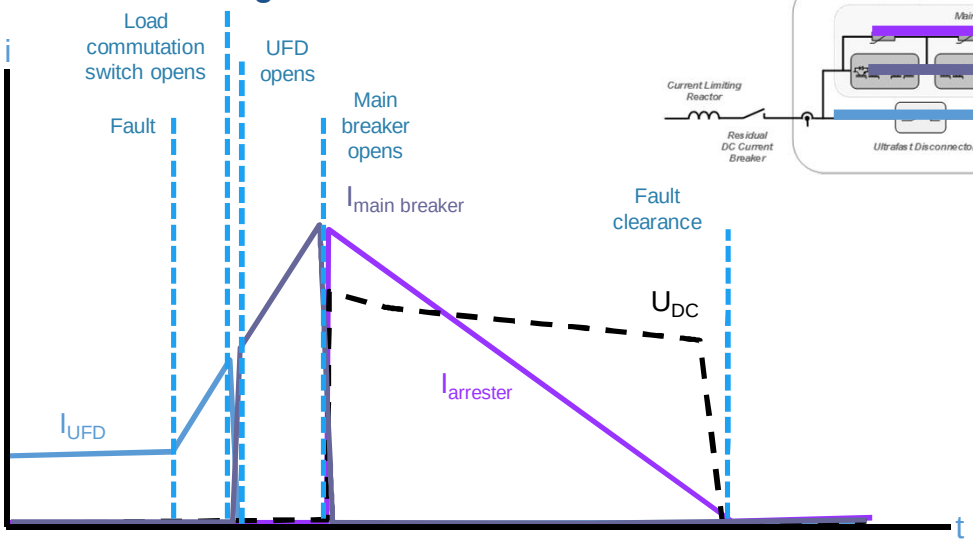
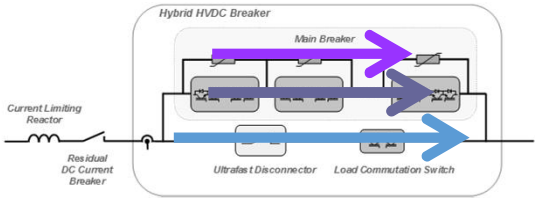
HHB Breaking timeline





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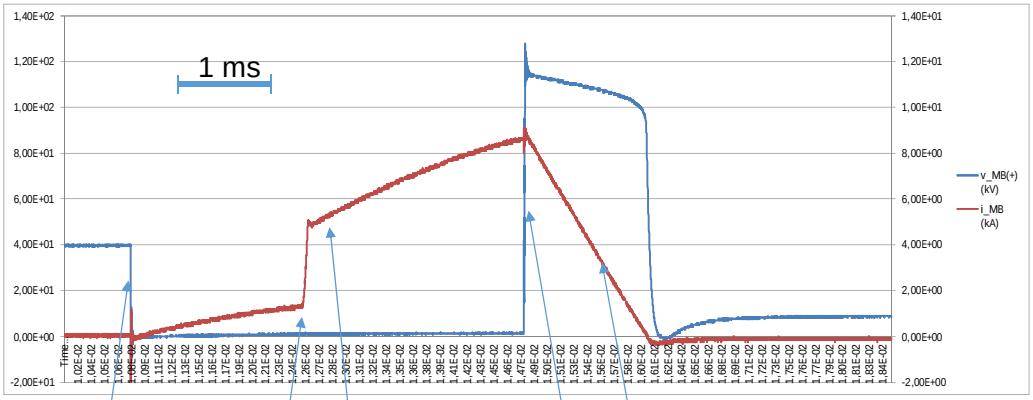
Firts test results



Ignite spark gap

Open UFD

Open Main breaker

Fault current energy dissipated in arresters

Open Load Commutation switch

HVDC GIS

PROMOTioN – HVDC GIS

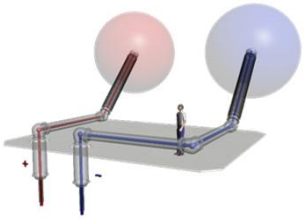
HVAC / HVDC GIS Advantages

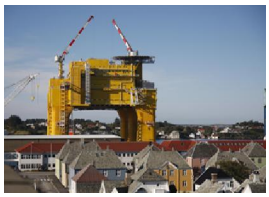
HVDC GIS

A DC-GIS installation can be built with a much **higher degree of compactness** and significantly **lower sensitivity to ambient factors** than with air-insulated switchgear (AIS).

The most obvious cost-saving potential can be found on **off-shore converter platforms** where the required air-clearance for AIS leads to much larger and heavier off-shore structures.

By using DC-GIS, the **volumetric space** of the switchgear installation can be **drastically reduced** e.g. by 70%- 90%.





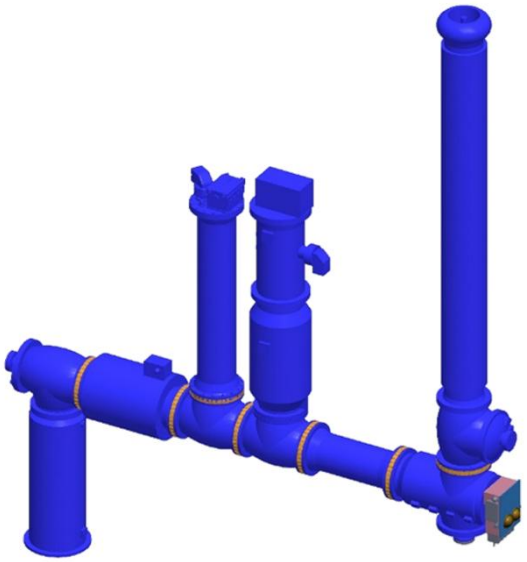
PROMOTioN – HVDC GIS

HVDC GIS Components

HVDC GIS

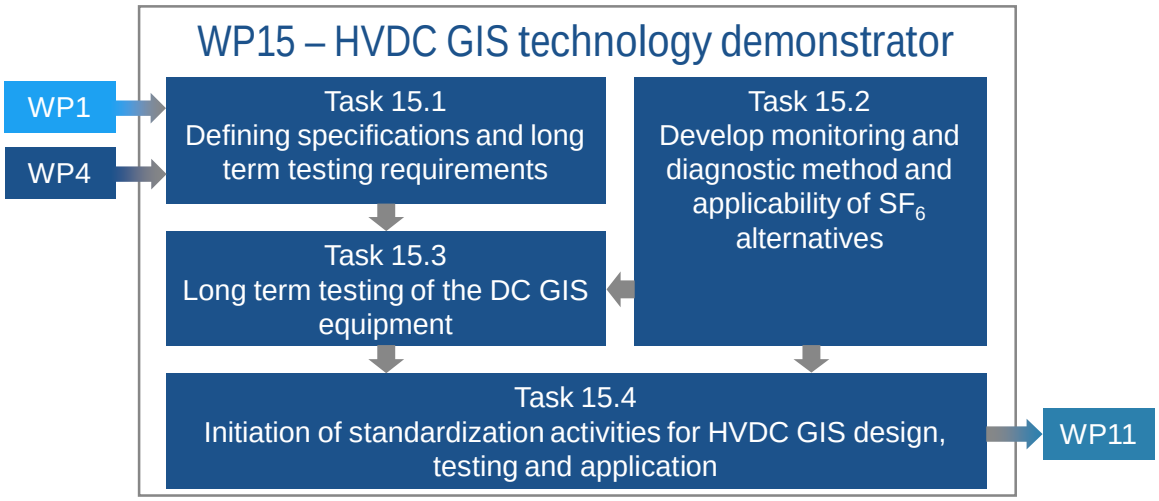
The HVDC-GIS technology spans a number of switchgear components, e.g.:

- Bus-ducts and high voltage DC conductors
- Disconnect- and earthing switches
- Bushings and cable terminations
- Current- and voltage measurement sensors
- Surge arresters



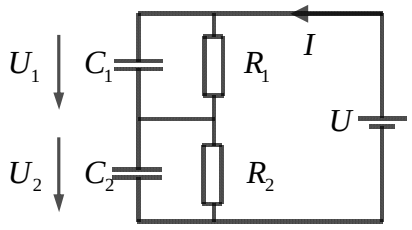
PROMOTioN – HVDC GIS

Work package organisation



PROMOTioN – HVDC GIS

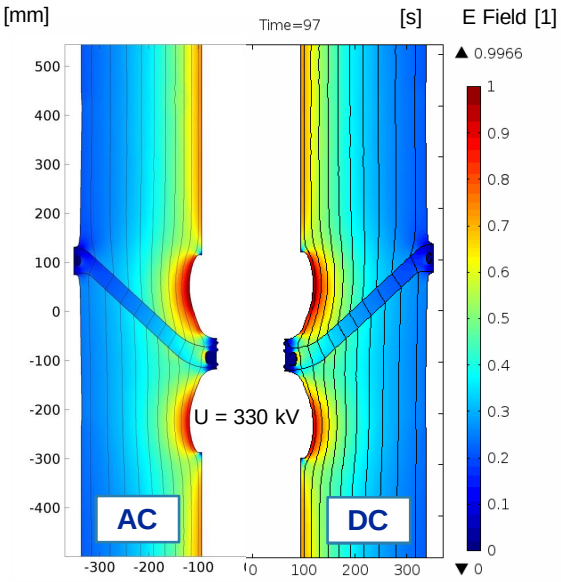
HVDC gas insulated system technology demonstrator



$$I = \frac{U}{R} + C\frac{d(U)}{dt} \qquad t = RC = \frac{e_0 e_r}{s}$$

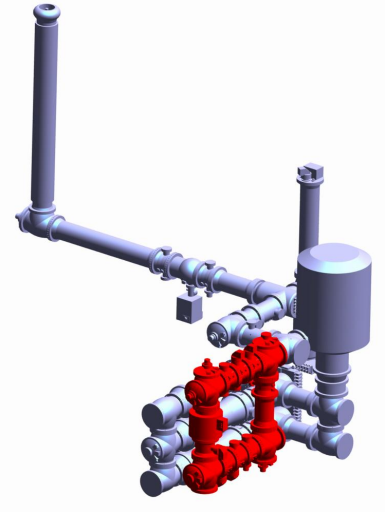
$t = 0$ ("AC") $\quad t \to \infty$ ("DC")

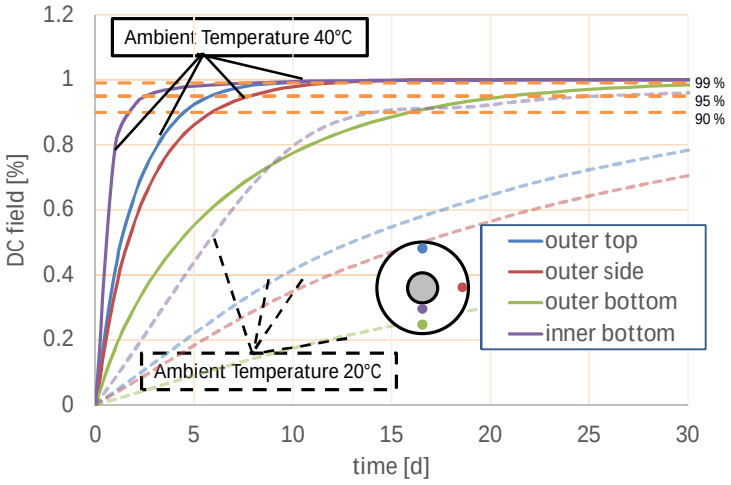
$$\frac{U_1}{U_2} = \frac{C_2}{C_1} \qquad \frac{U_1}{U_2} = \frac{R_1}{R_2}$$



PROMOTioN – HVDC GIS

HVDC GIS - Verification Test for Insulators





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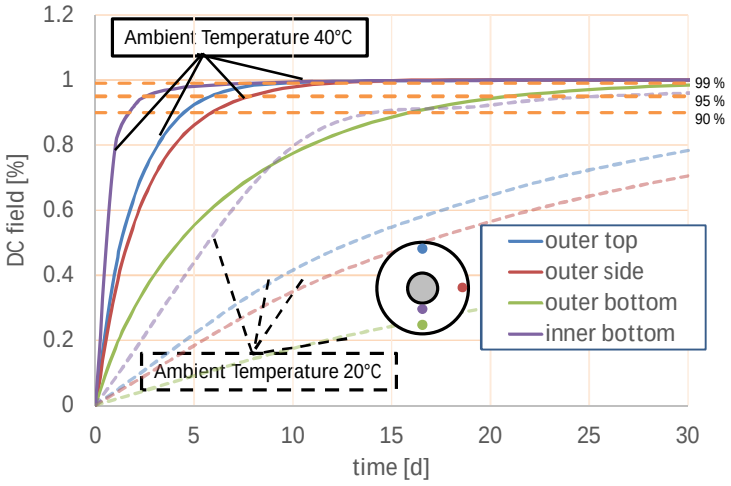
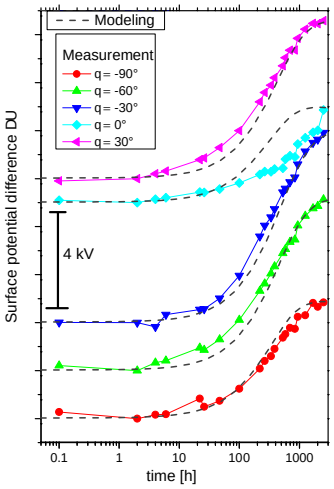
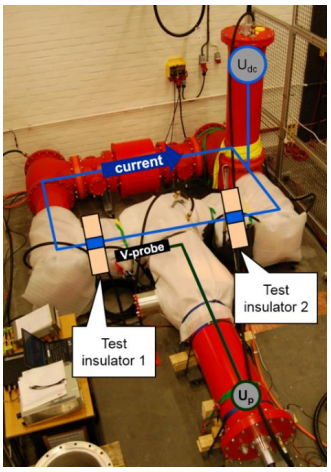
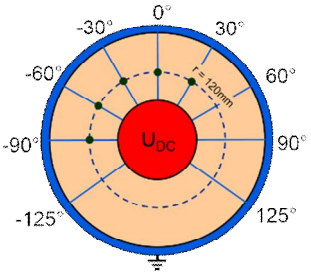


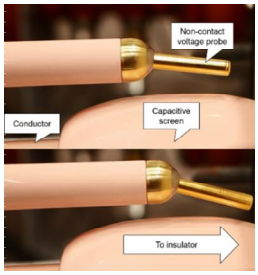
PROMOTioN – HVDC GIS

HVDC GIS - Verification Test for Insulators









PROMOTioN – HVDC GIS

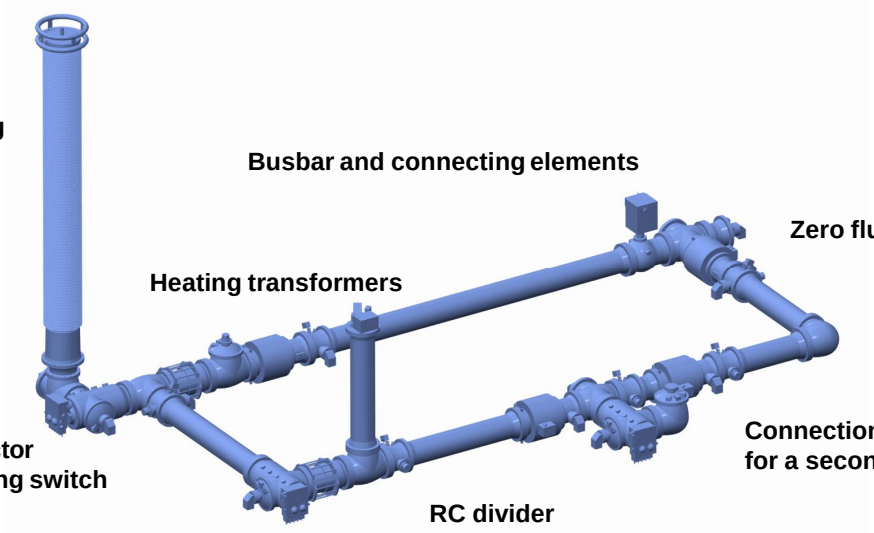
HVDC GIS - Demonstrator

Insulation system test

Prequalification test

PROMOTioN – HVDC GIS

HVDC GIS demonstrator – Set-up



PROMOTioN – HVDC GIS

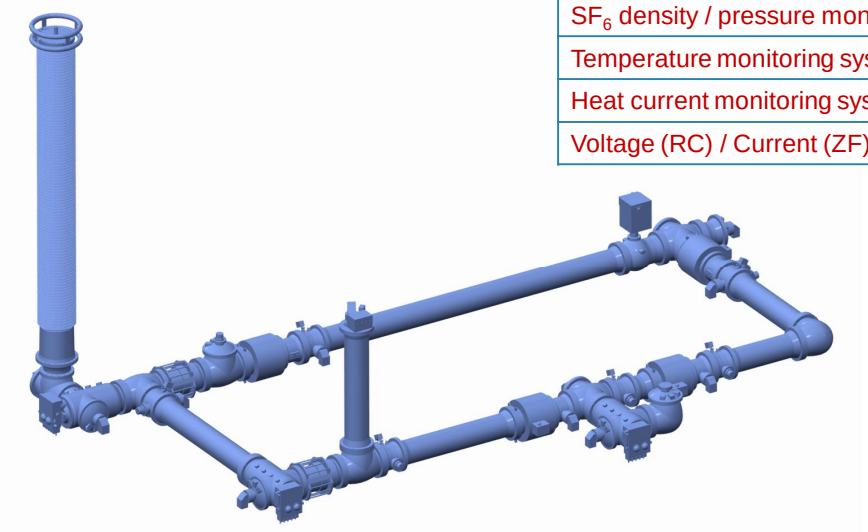
HVDC GIS demonstrator – Test values

Demonstrator	Value	Unit
Pre-Tests Thermal calibration, Commissioning tests, PD, LI, SI		
Long-term test cycles with DC	± 1.0 …1.2 HL (AC equivalent)	pu
Rated superimposed LI / SI withstand voltage	± 0.8	pu
Long-term test cycles with DC	± 1.0 …1.2 ZL	pu
Rated superimposed LI / SI withstand voltage	± 0.8	pu
Final verification tests & additional tests		

PROMOTioN – HVDC GIS

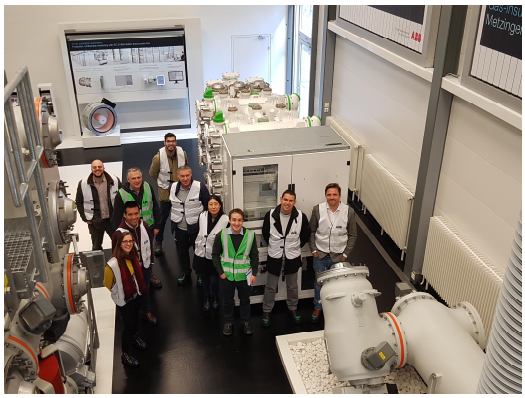
HVDC GIS demonstrator - Diagnostic

Monitoring
PD-Monitoring UHF / Optics
SF_6 density / pressure monitoring system
Temperature monitoring system enclosure
Heat current monitoring system
Voltage (RC) / Current (ZF)



PROMOTioN – HVDC GIS

Kick-off – WP15



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APPENDIX

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.