KEMA Labs

René Smeets – Nadew Belda

Webinar July 7, *2020*

HVDC switchgear

CESI

1

Content

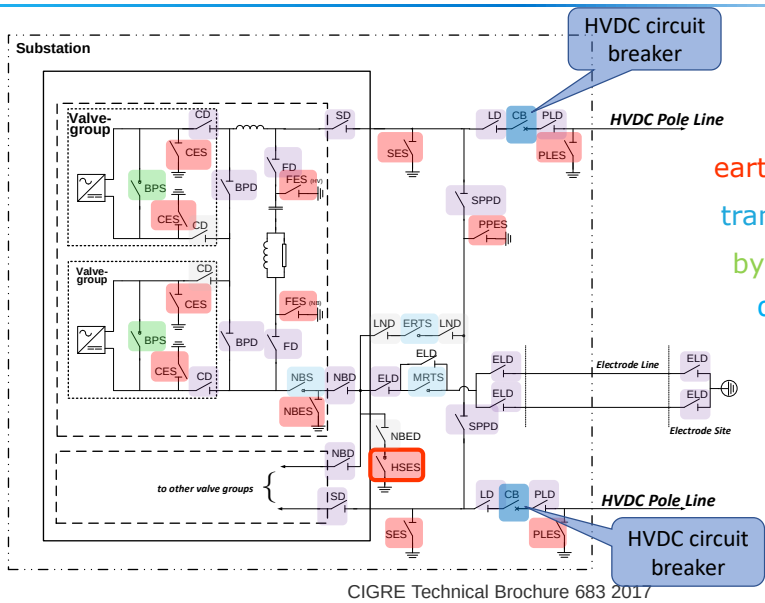
This project has received funding from the European Unions Horizon 2020 research and innovation programme under grant agreement No 691714.

- HVDC Switchgear → Overview
- HVDC GIS → Why special?
- HVDC Breakers →Why essential?
- Faults in HVDC Grids → What is the issue?
- DC vs AC Current Breaking → Fundamentals
- HVDC Breaker → Technology Status
- Testing → Challenges, Current Status
- Future → Trends and developments

PROMOTioN

Research work on HVDC breaker stresses @ KEMA labs

HVDC Switchgear → Overview



CIGRE Technical Brochure 683 2017

disconnectors
earthing switches
transfer switches
bypass switches
circuit breakers

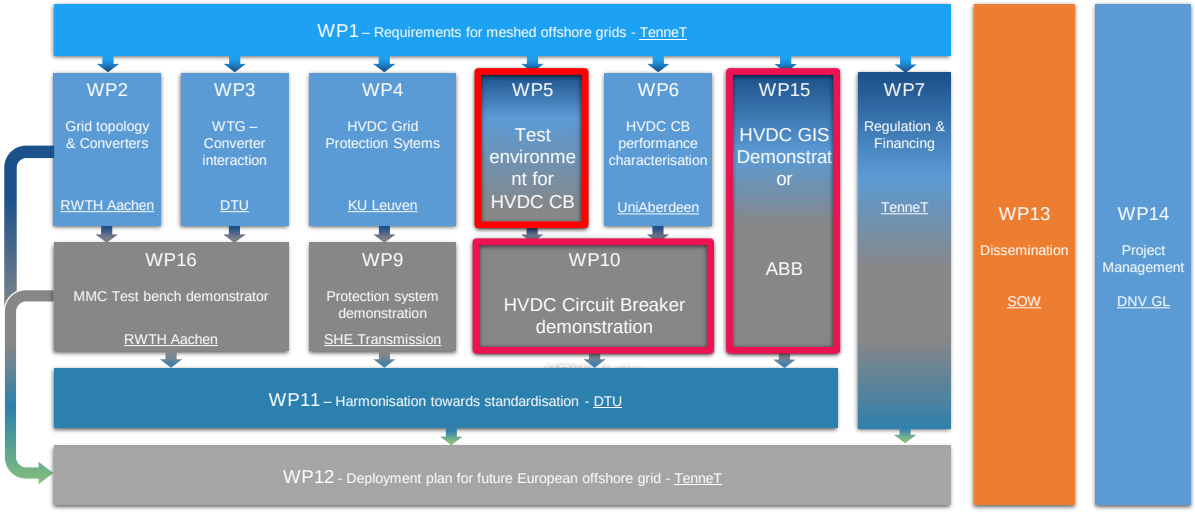
350 kV DC GIS

816 kV DC transfer switch

1120 kV DC by-pass switch

3

PROMOTioN PROJECT

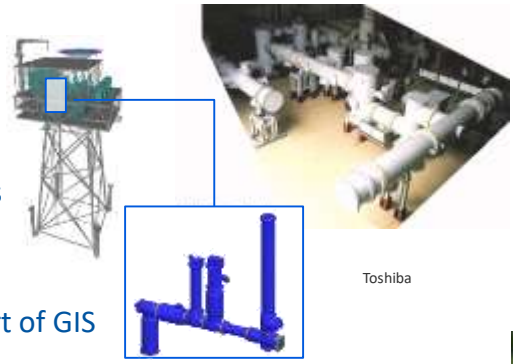


- 33 consortium partners
- 11 European countries
- 40 M€
- 2016-2020

4

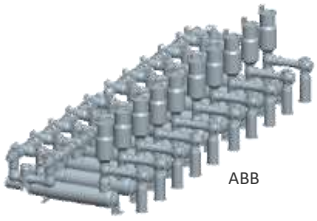
HVDC GIS

- Compact HVDC platforms and stations
- Connections of cables to OHL for MT systems
- Up to 500 kV in development
- Circuit breaker not part of GIS



Toshiba

Siemens

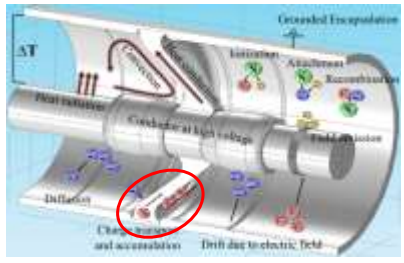


ABB

Mitsubishi Electric

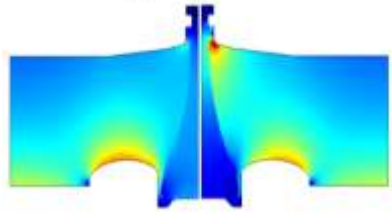
Electrical Stresses in HVDC GIS spacers

- Accumulation of space charges determines critical E field stresses
- Time constants are tens of day – weeks, depending on temperature

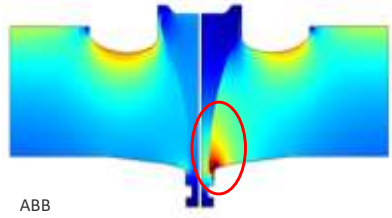


Charge accumulation on gas-to-solid interface

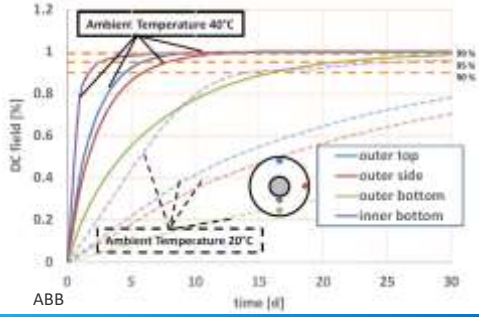
Siemens



AC DC



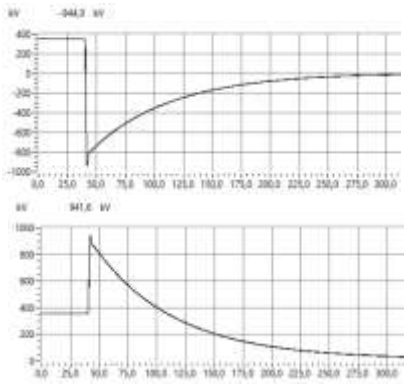
ABB



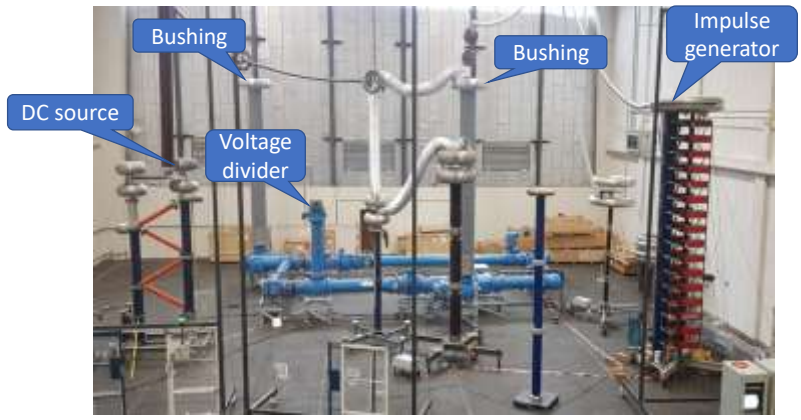
ABB

350 kV HVDC GIS prototype installation test at KEMA Labs

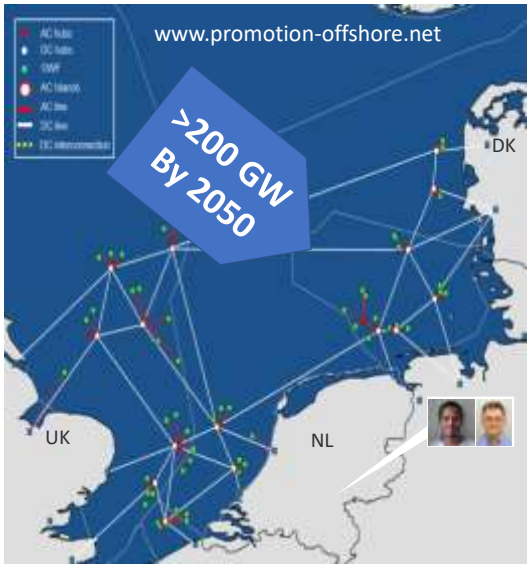
- Long term test → 1.5 year
  - ✓6 Load cycles
- AC & DC PD measurements
- Lightning and Switching impulse



- Super imposed impulse
  - ✓ DC 350 kV + LI 940 kV / SI 760 kV
- Incl. SF6 free gas
  - ✓ Novec 5110/4710

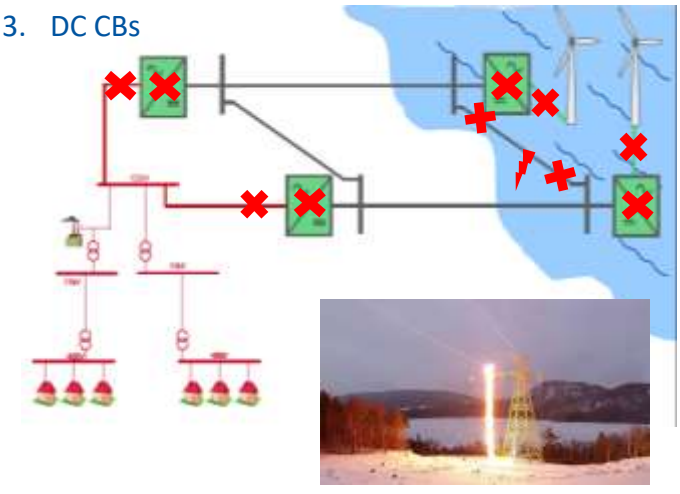


HVDC Circuit Breakers – Enable Selective Protection of HVDC grids



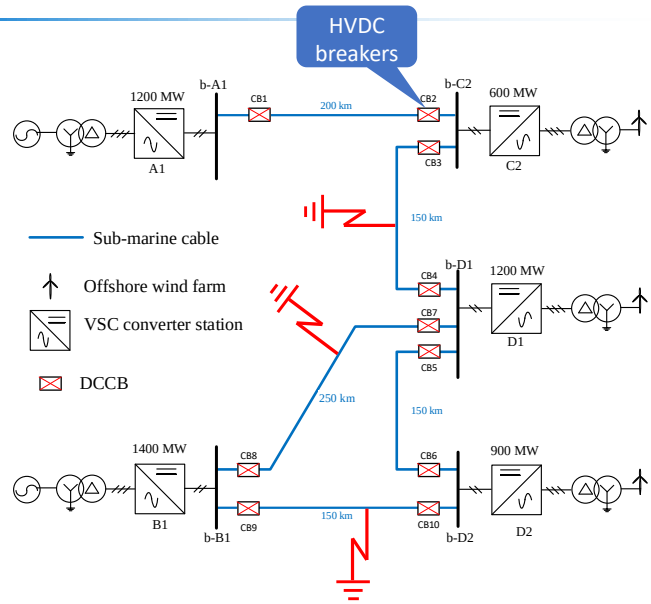
1. AC side →AC CBs
2. Converters
3. DC CBs

Multi-Terminal HVDC System

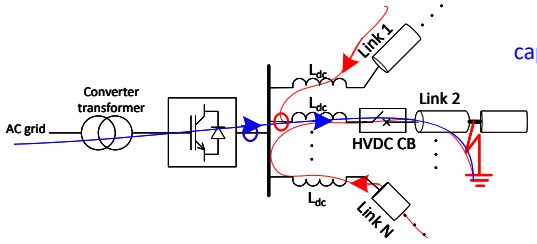


HVDC Fault Current Simulations

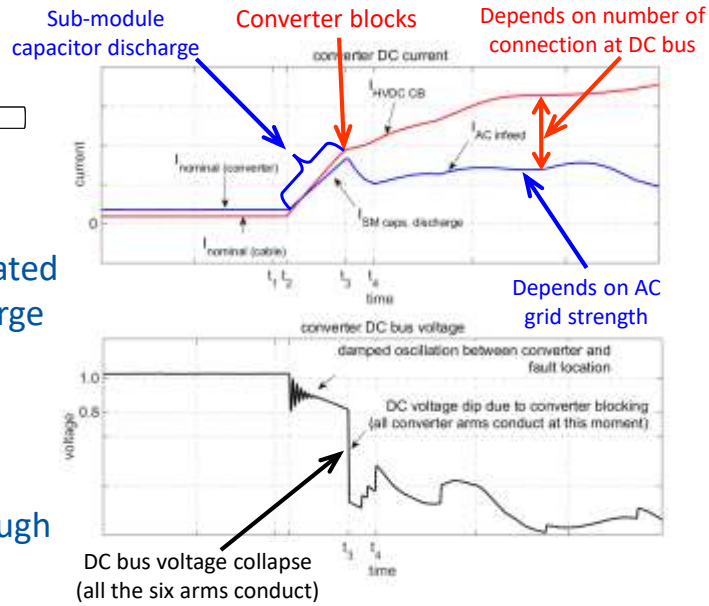
- Five terminal grid with bipolar converter configuration
- ±320 kV, half bridge MMC converter topology
- Only cable interconnection is considered
- Fault analysis without any HVDC Circuit Breaker
- Fault current interruption with models of HVDC circuit breakers embedded



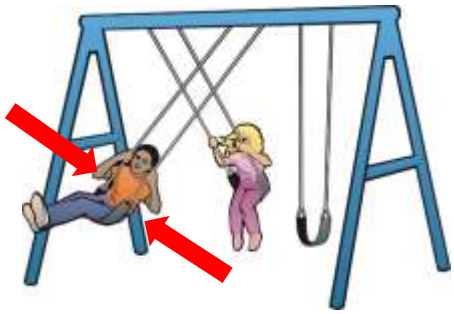
Fault Current Analysis first



- The first few millisecond dominated by sub-module capacitor discharge
- At t_3 converter blocks.
- The DC voltage drops following converter blocking
- From t_4 onwards AC infeed through freewheeling diodes



DC vs AC interruption

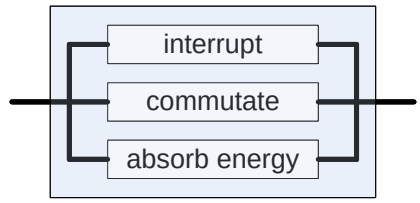


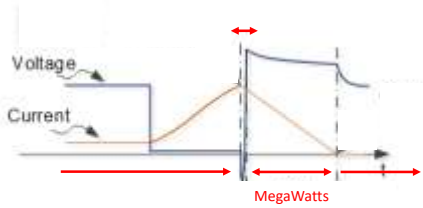
15 kA in 100 km line = 11 MJ
= 30 ton train at 100 km/h

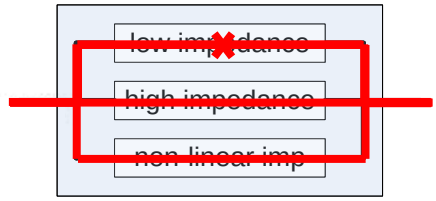
- AC interruption:
  - ✓ Capture the swinging mass in its outer position (current zero)
  - ✓ Zero kinetic energy → Max potential energy
- DC interruption:
  - ✓ Oppose the motion of a linearly moving mass ---> **counter voltage**
  - ✓ The sooner the better →min. momentum

HVDC Fault Current Interruption Technique

- How to generate counter voltage?
- Strategy:
  - ✓Create a current zero in the main path: interrupt
  - ✓Commutate the current in high-impedance path: commutate
  - ✓Limit and sustain the counter voltage with a MOSA: absorb energy
- Current will be suppressed to zero

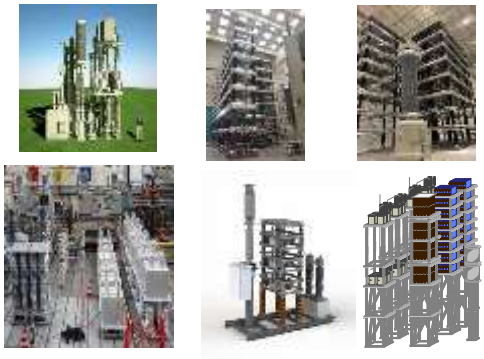






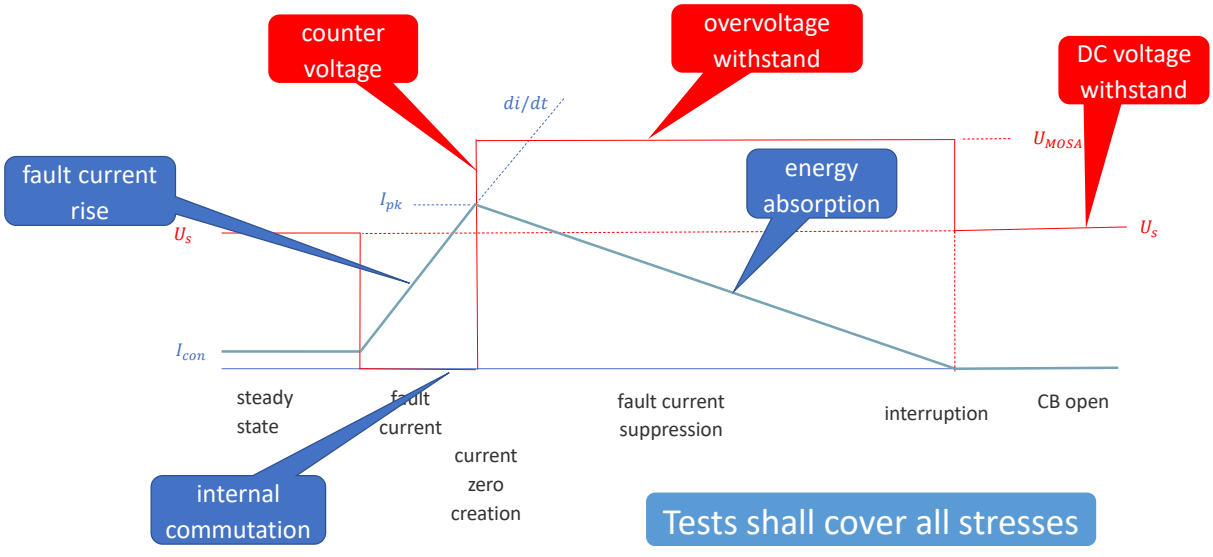
Two Mainstream HVDC Circuit Breaker Technologies

- Active current injection technology
  - ✓Create current zero in a vacuum interrupter
  - ✓with discharge of pre-charged capacitor
  - ✓with a power electronics excitation circuit
- Realized up to 500 kV



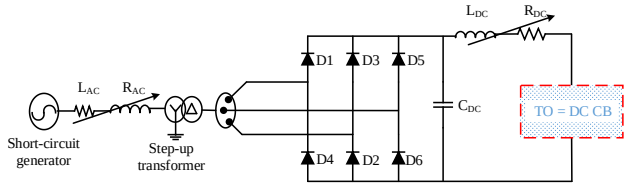
- Hybrid technology
  - ✓ Block main current path
  - ✓ Force current into a power electronics path
  - ✓ Interrupt with power electronics
- Realized up to 500 kV

The Critical Stresses on HVDC Circuit Breakers

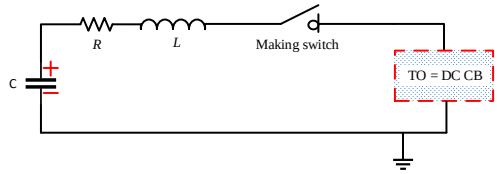


HVDC Circuit Breaker Test Methods and Circuits

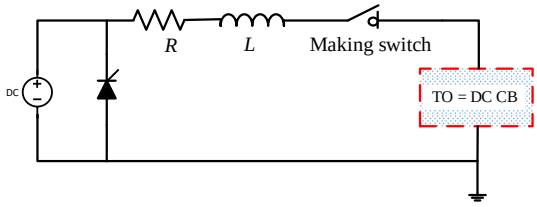
Rectifier



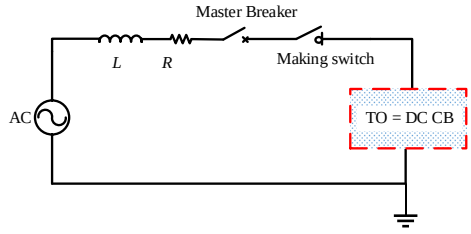
Charged capacitor



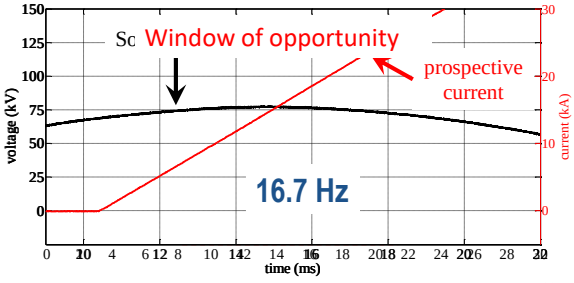
Charged reactor

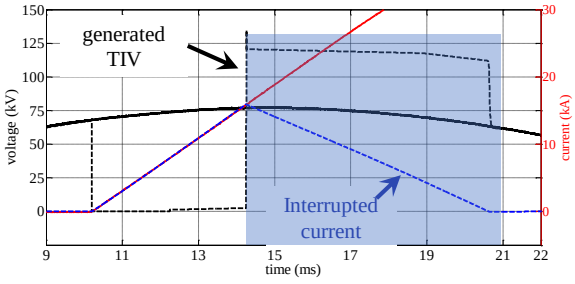


AC source

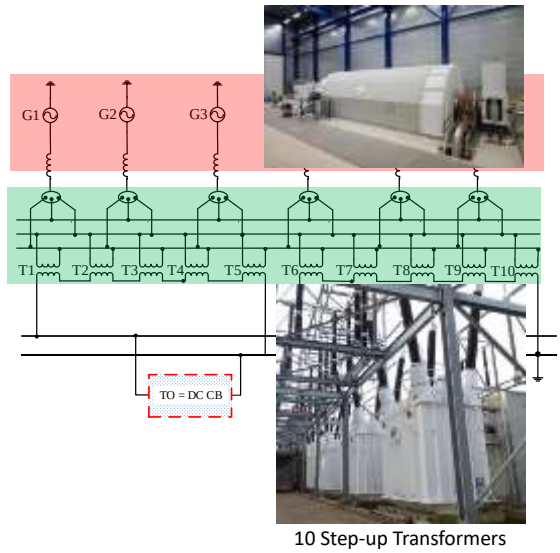


KEMA Method → Using Low Frequency AC Generators



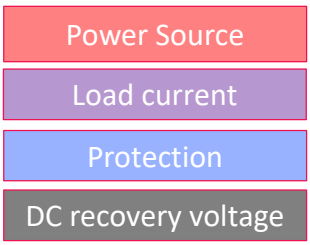


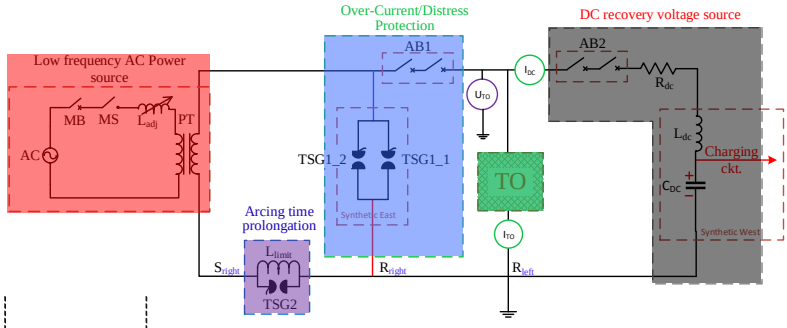
6 Short-circuit Generators

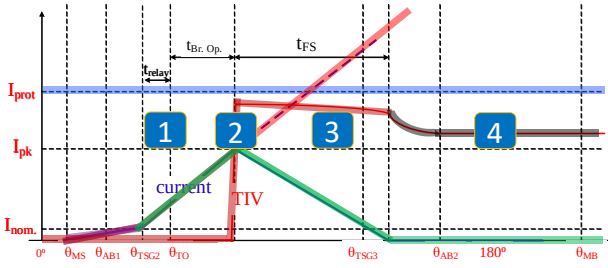


10 Step-up Transformers

Test Circuit for HVDC Circuit Breakers → Critical Aspects







Four Critical Stages of Current Interruption

1. Internal Current Commutation
2. The generation of TIV
3. Energy absorption
4. DC voltage withstand

SciBreak 24 kV 10 kA DC Breaker under Test – 2018 @KEMA Labs

Mitsubishi Electric 160 - 200 kV / 16 kA HVDC Breaker under Test @KEMA Labs

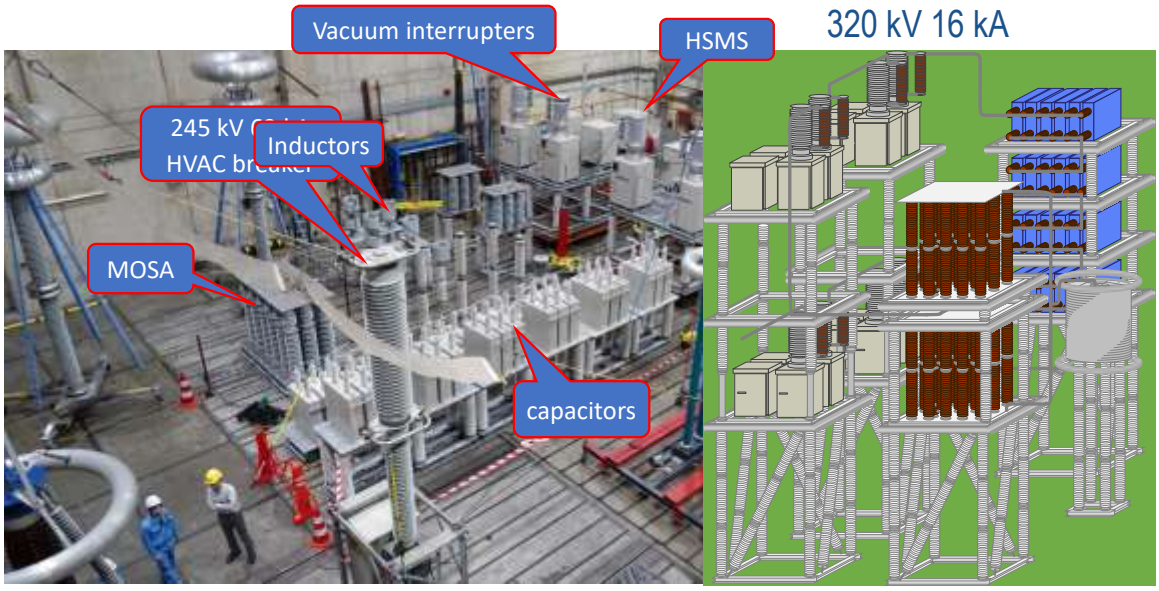
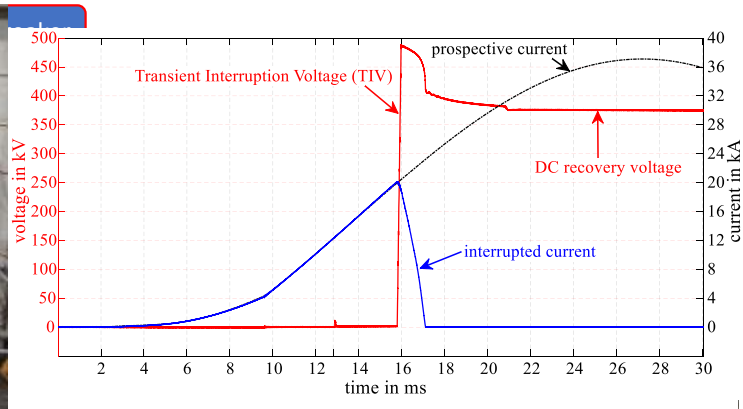


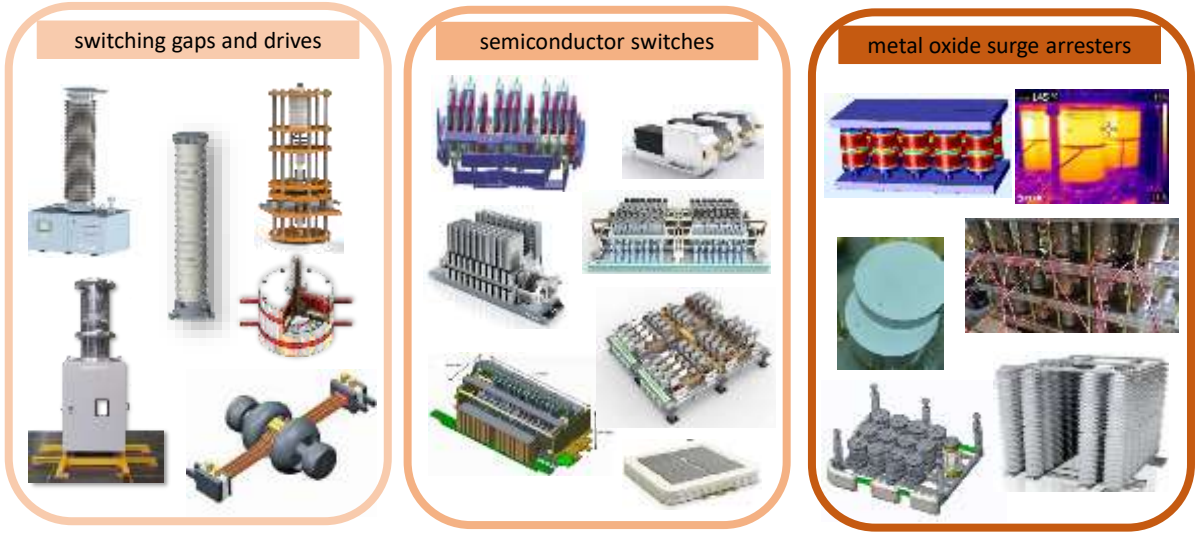
ABB 350 kV 20 kA Hybrid HVDC Circuit Breaker under Test @KEMA Labs



- 20 kA – current interruption
- 480 kV - TIV peak
- 3 ms operation
- 380 kV DC recovery voltage applied (1 second)

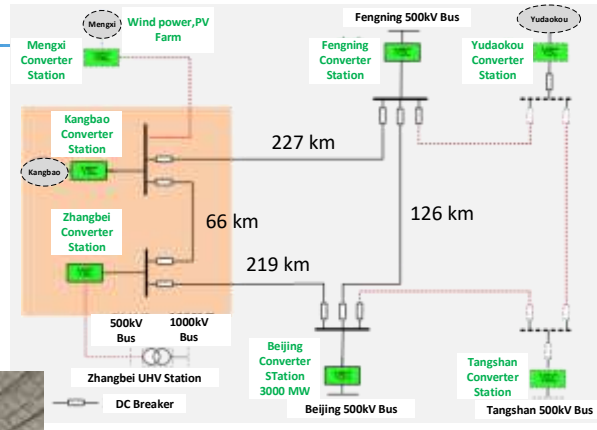
ABB 350 kV 20 kA Hybrid HVDC Circuit Breaker under Test @ KEMA Labs

Standard Components used in a Non-standard Application → New Stresses



Zhangbei project China 2020

- ± 500 kV 4-terminal onshore project
- Symmetric bipolar, half-bridge MMC
- 4.5 GW renewable energy
- 16 HVDC circuit breakers
  5 manufacturers, 3 technologies

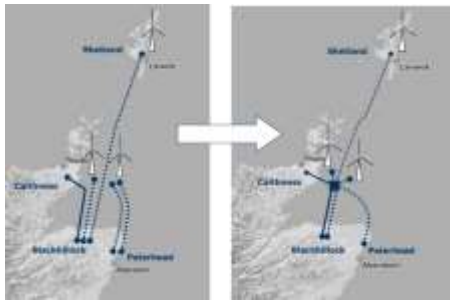


State Grid Co of China

Future projects → 2020

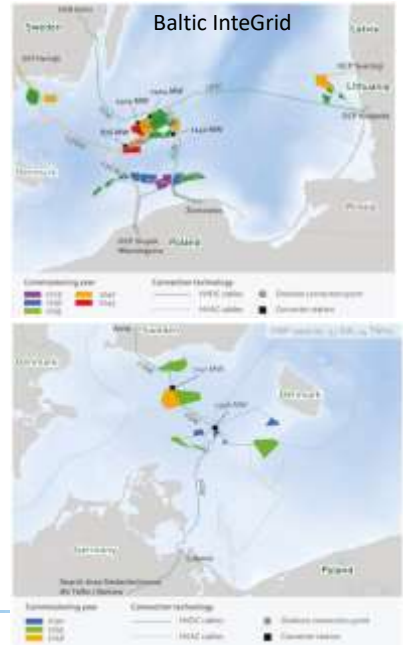
- Small-scale multiterminal projects in Italy (SACOI), Canada, China
- Future projects, extensions,
  - Baltic Integrid
  - European Offshore Busbar

Caithness Moray MT proposal SSE, UK

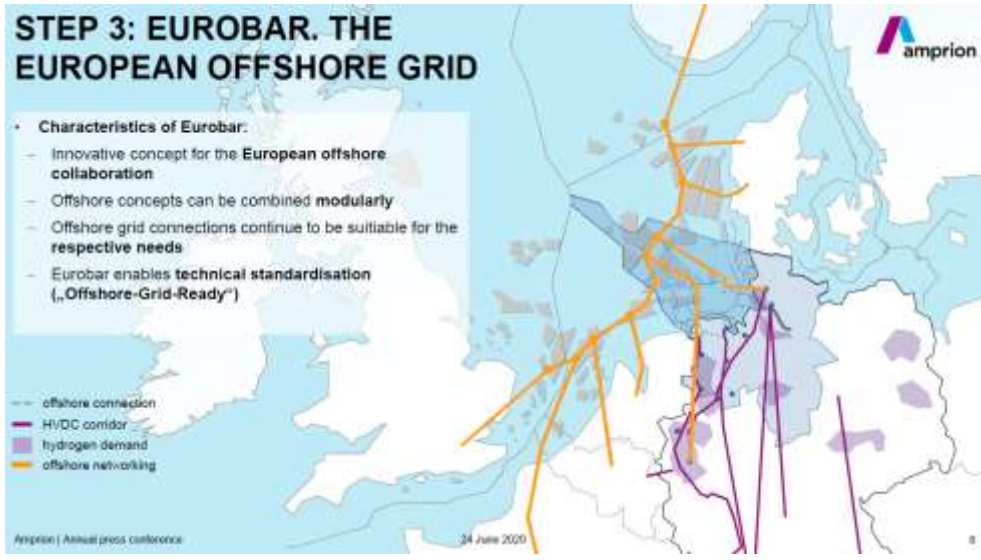


CIGRE TB 713 B4.60
atlanticwindconnection.com

Baltic InteGrid



Future projects → 2020: EuroBar

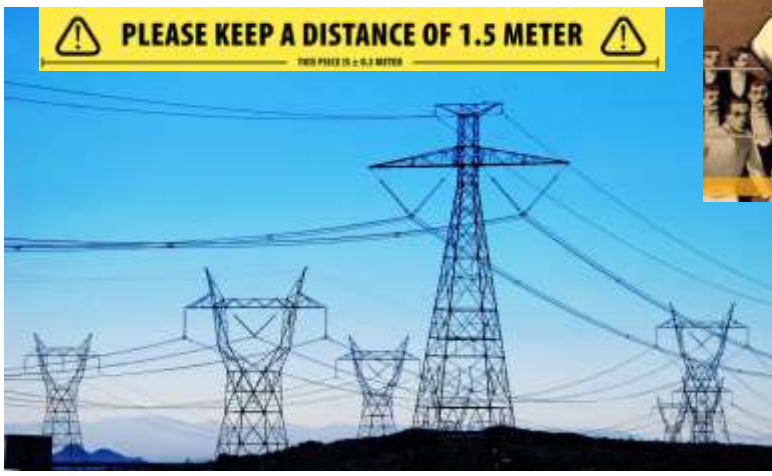


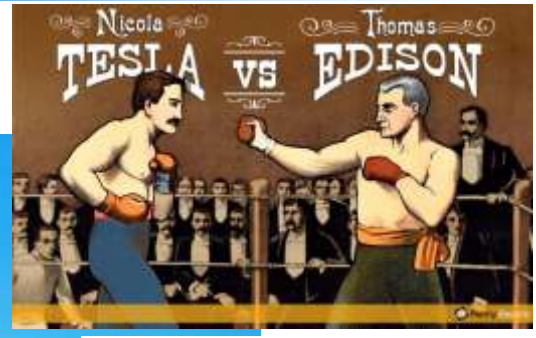
Public Demonstrations → LIVE

SciBreak 80 kV 16 kA

AC and DC will live together in close harmony → no more "current" War

Thank you for your attention!





PROMOTioN @ CIGRE: Aug. 24 14:00-17:30

PROMOTioN Live Q&A 12:00-14:00:
Offshore HVDC Grid Technology Sept 4
HVDC technology qualification Sept 11
HVDC Grid planning Sept 18

Final Conference: Sept. 21
Register www.promotion-offshore.net