PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

HVDC Circuit Breakers

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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.

- HVDC breakers protect HVDC grids
- HVDC interruption: what is the problem?
- Technology status
- Future

PROMOTioN research work on HVDC breaker stresses @ KEMA labs

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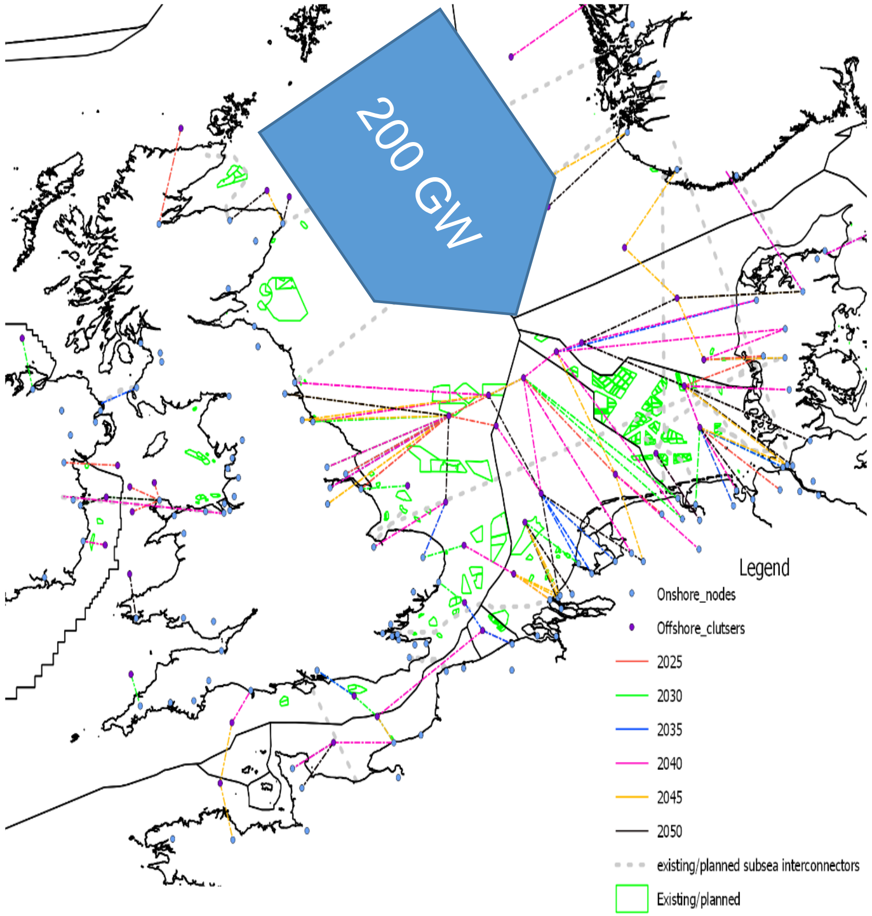
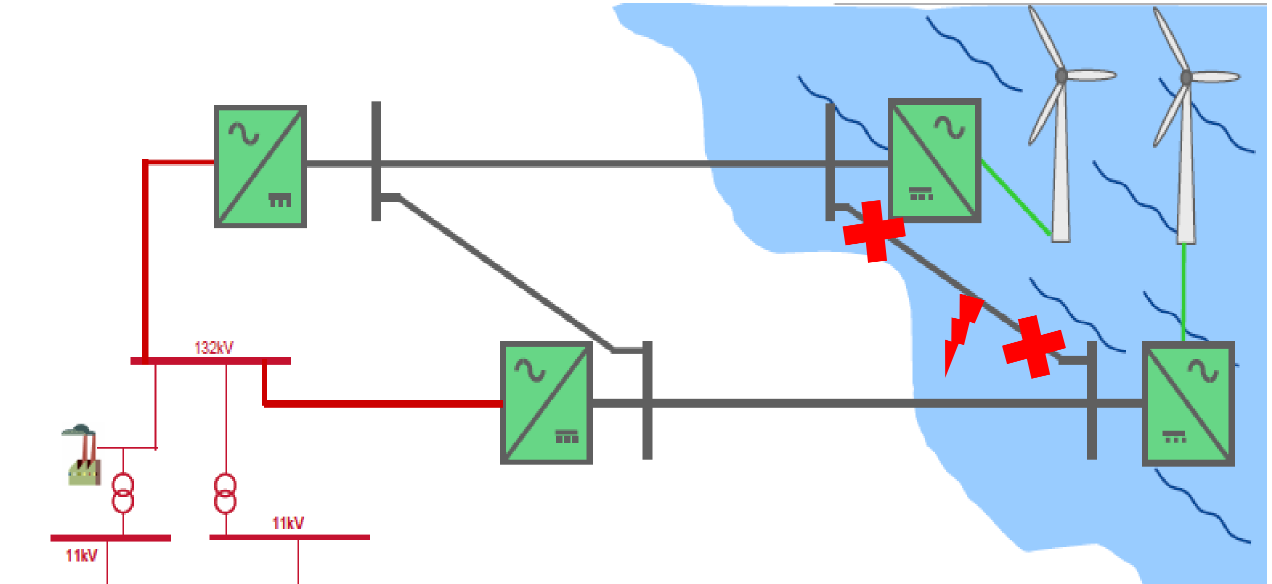
HVDC circuit breakers protect HVDC grids



O. Antoine et al., “Towards a deployment plan for a future European offshore grid: development of topologies”, paper B4-131, CIGRE 2020

meshed DC system



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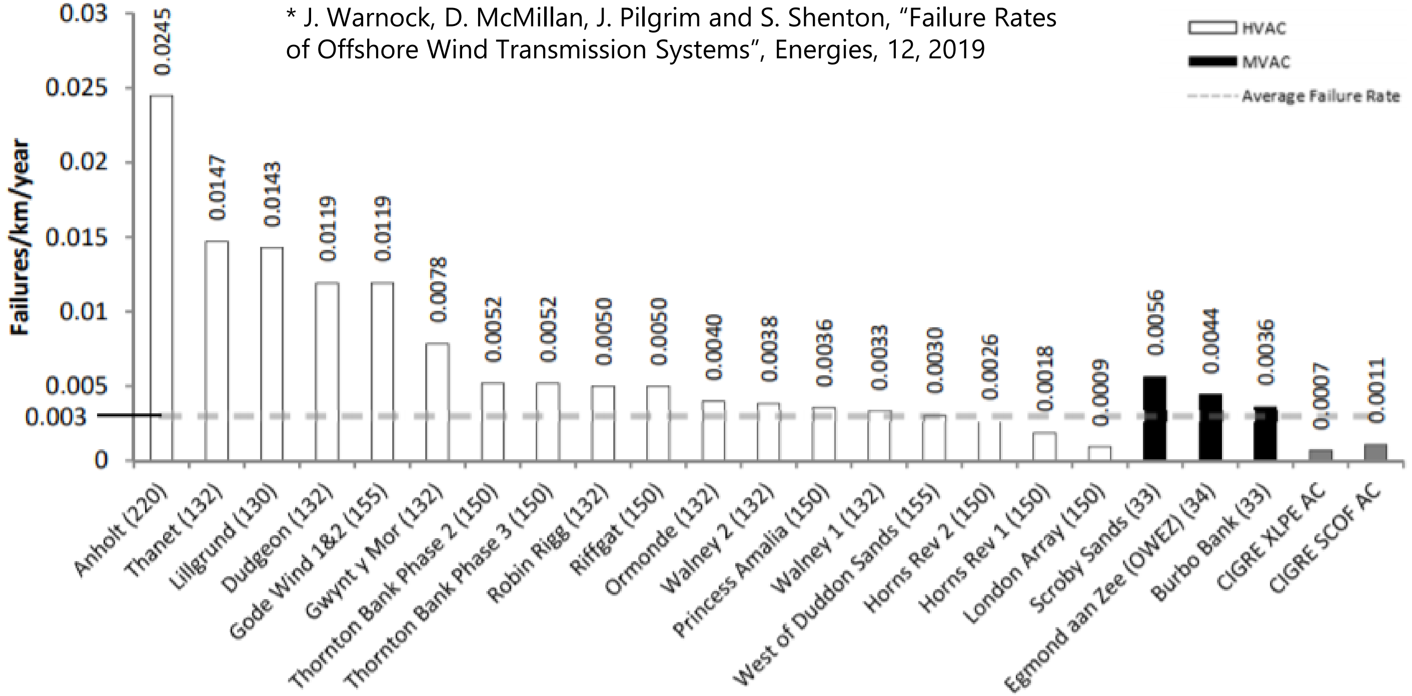
Submarine power cable faults do occur

- 70-80% of pay-outs from insurers to windfarm operators are related to cable faults**
- By 2030 10-40 large subsea cable repairs per year**
- Faults threaten system integrity


DC cable damage after boat anchoring (IEEE P&E, May 2019)



HVAC offshore cables: 3 faults per 1000 km per year*
HVDC offshore cables: 0.5 – 2.0 faults per 1000 km per year**

** M. Kurkowska, "Cable malfunctions", Offshore Cabling, 2018

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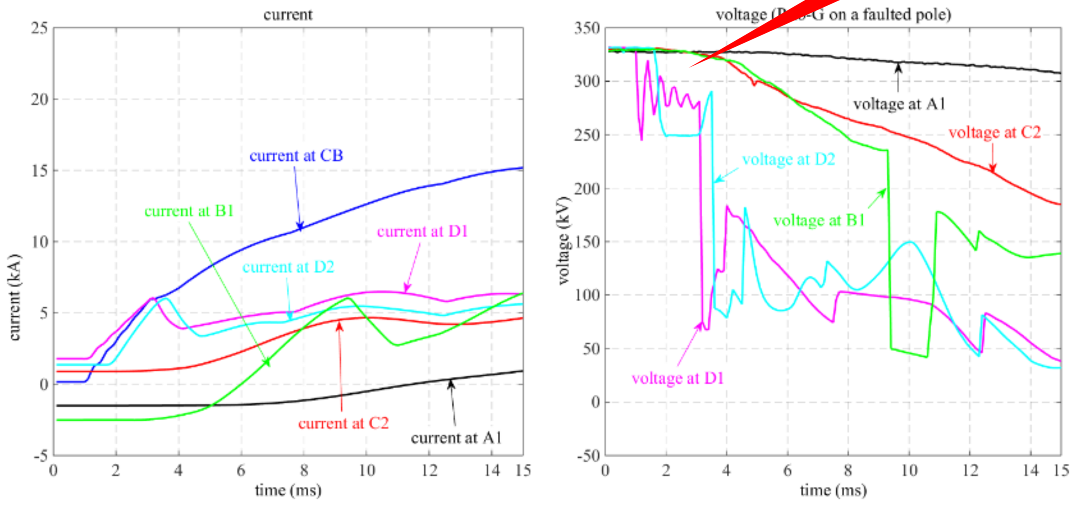
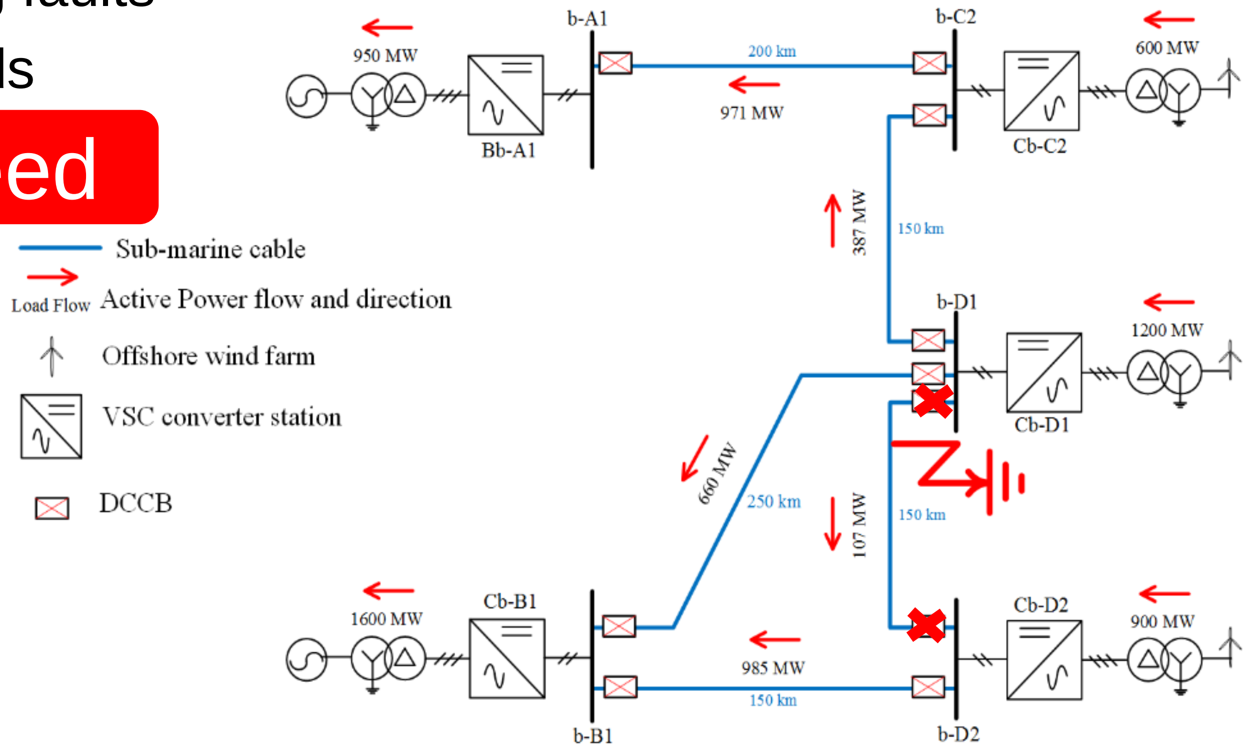
Understanding stresses in systems that do not exist yet

- System simulation studies in order to understand electrical stresses on HVDC breakers during faults
- For definition of test-requirements / standards consider breaker as a black-box
- Standardization now starting

speed





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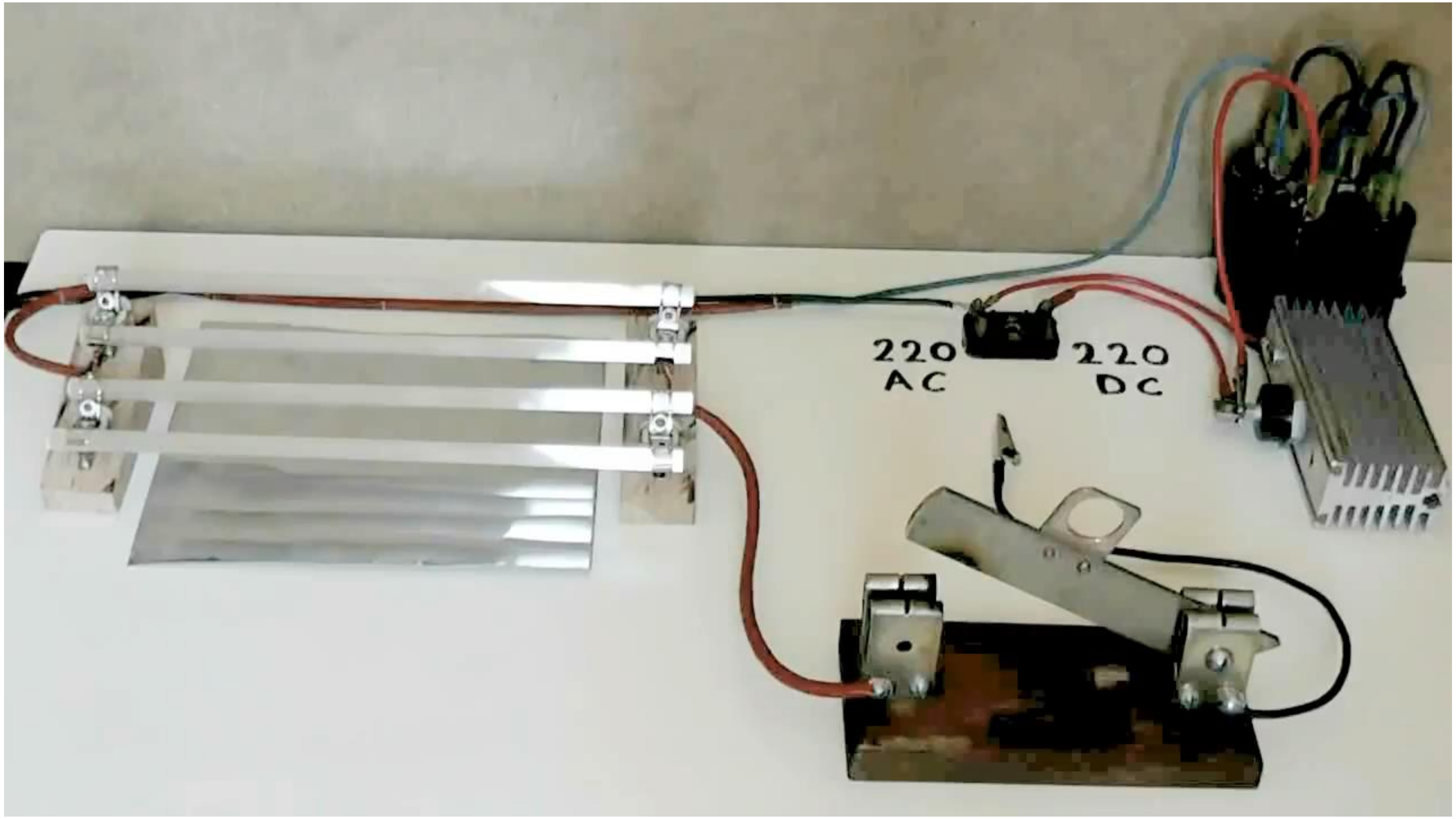
Interruption of 5 A @ 220 V AC and 220 V DC



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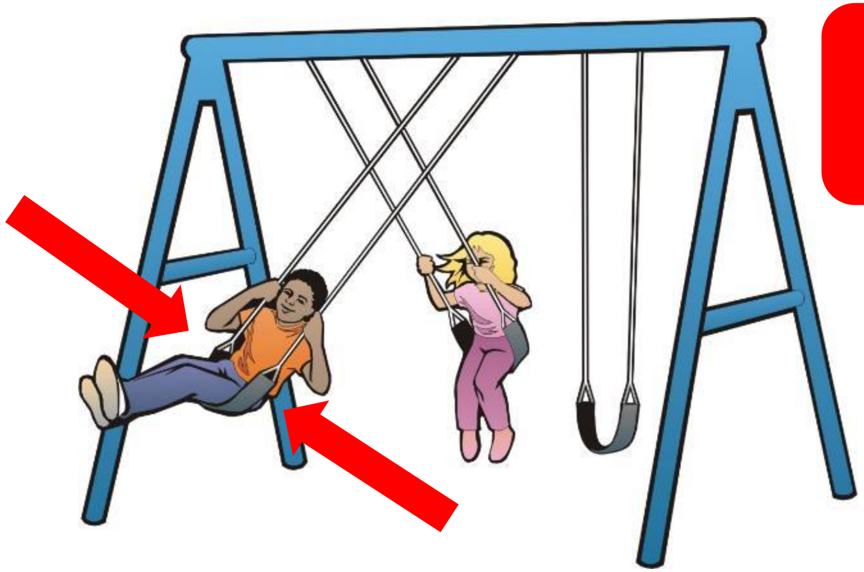
DC vs AC interruption

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



counter
voltage

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**

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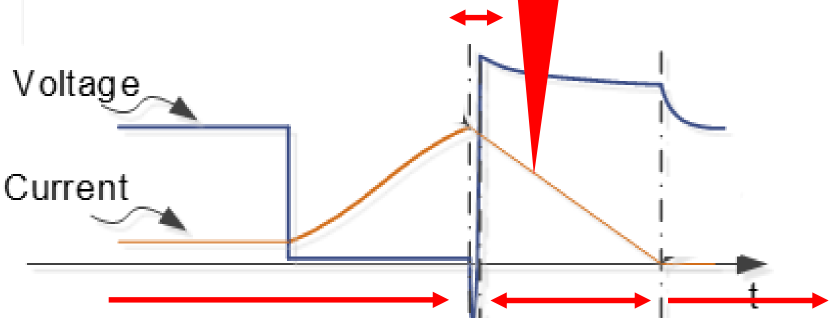
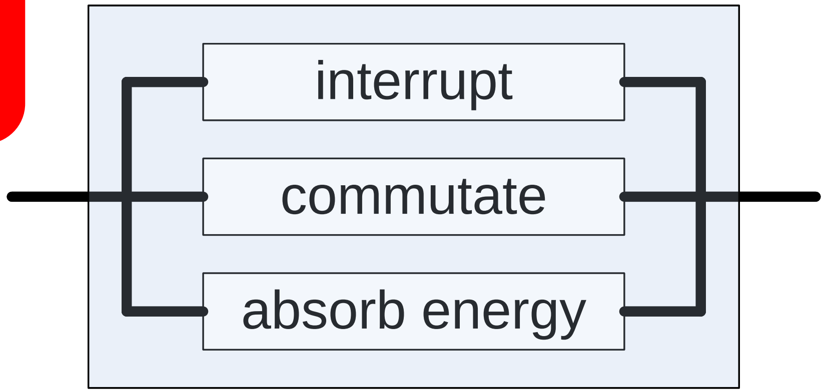
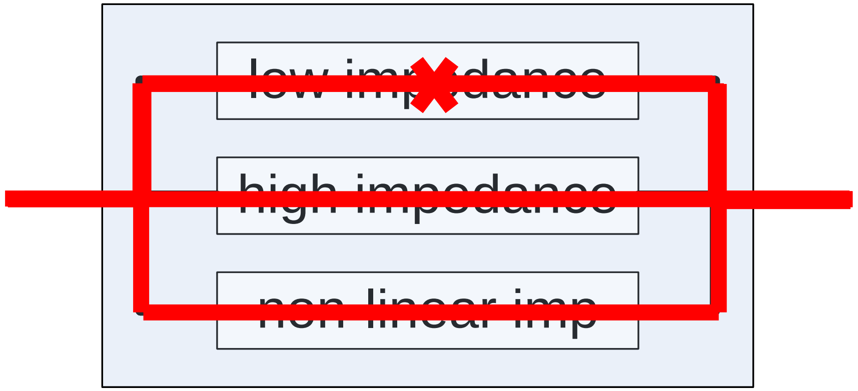
HVDC interruption technology

- 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

energy dissipation







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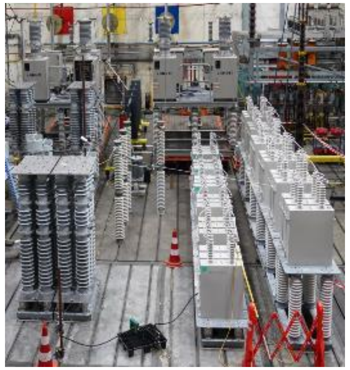
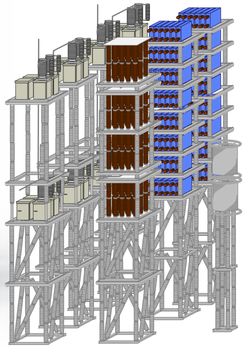
Two mainstream technologies

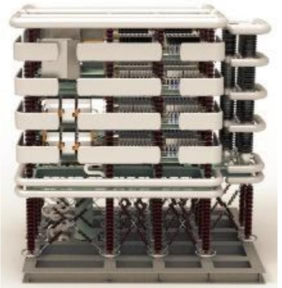
- Active current injection technology
  Create current zero in a vacuum interrupter
  - with discharge of pre-charged capacitor
  - with a power electronics excitation circuit
- In planning up to 500 kV



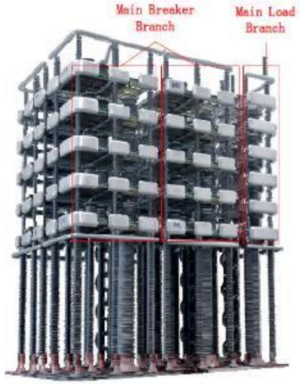





- Hybrid technology
  - Block main current path and isolate fast
  - Force current into a power electronics path
  - Interrupt with power electronics
- In planning up to 500 kV







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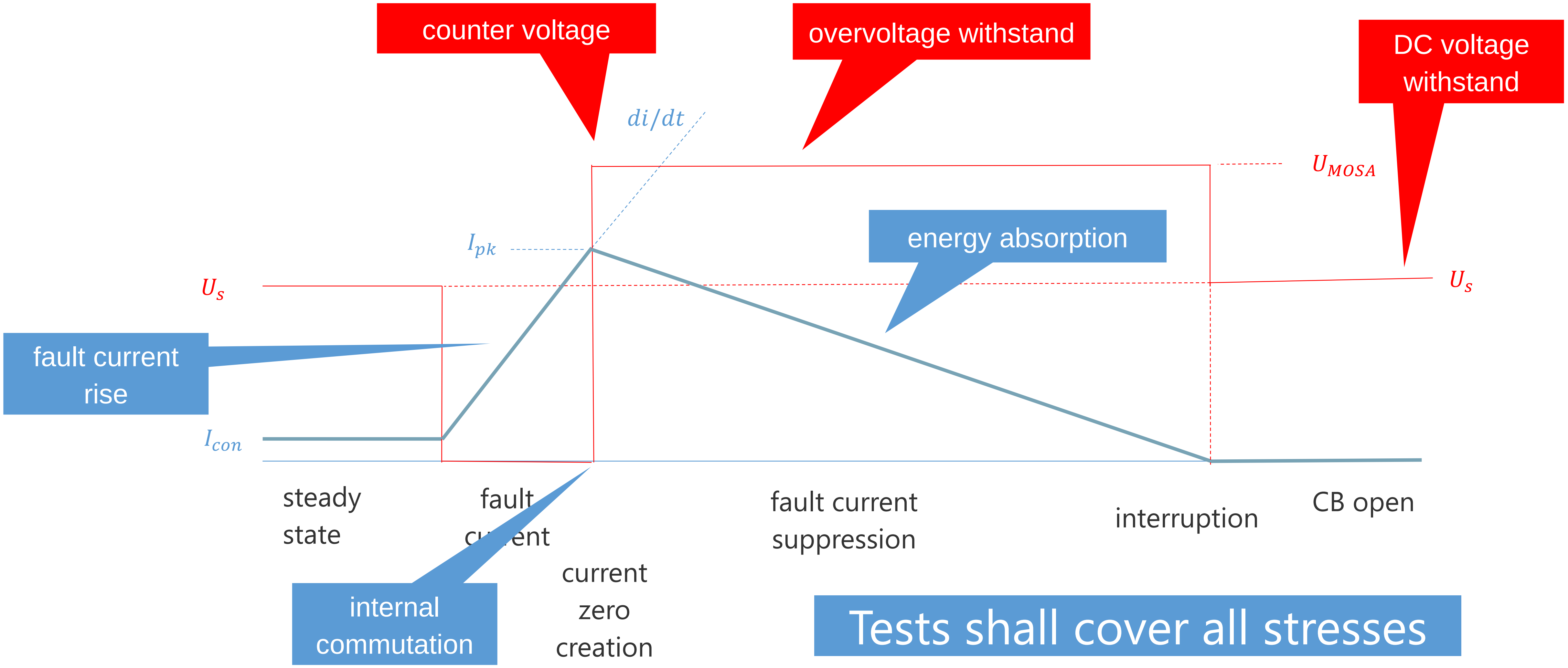
The critical stresses on HVDC circuit breakers



Tests shall cover all stresses

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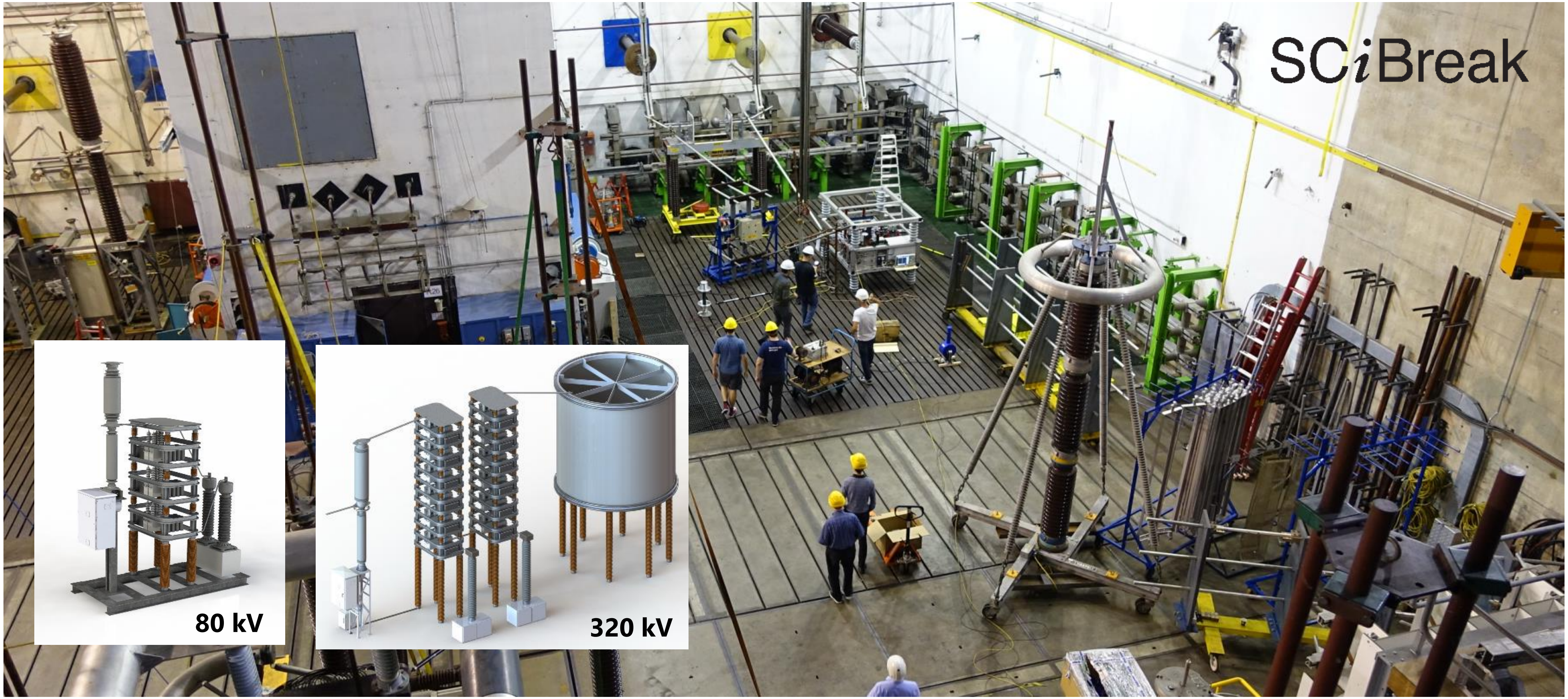
SciBreak 24 kV / 10 kA DC breaker under test - 2018



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MEU 160 - 200 kV / 16 kA HVDC breaker under test - 2019

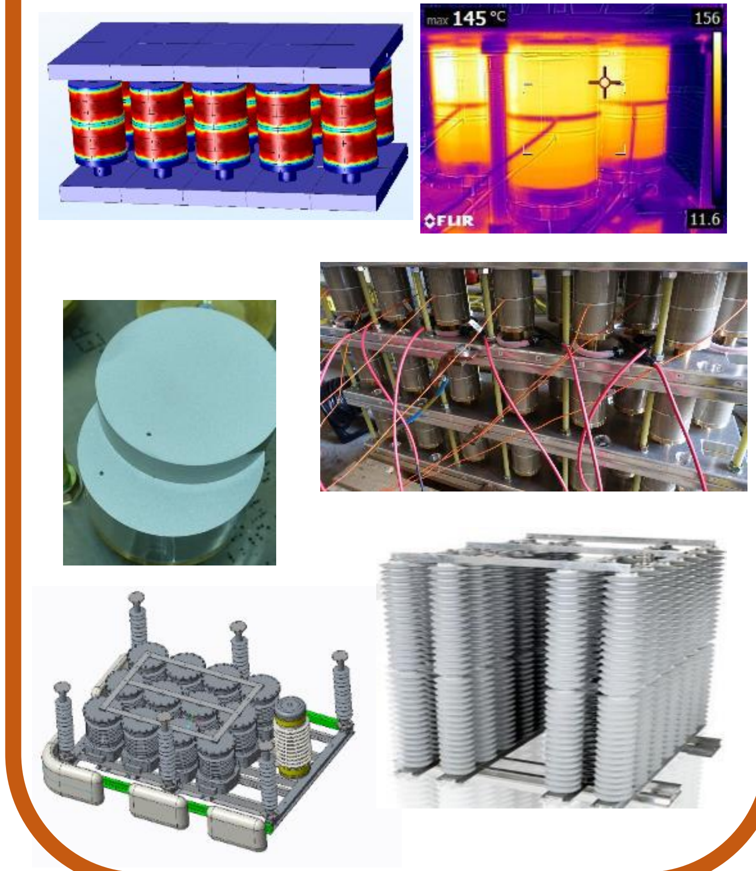
ABB 350 kV / 16 kA HVDC breaker under test - 2020

Standard components used in a non-standard application

switching gaps and drives

semiconductor switches

metal oxide surge arresters



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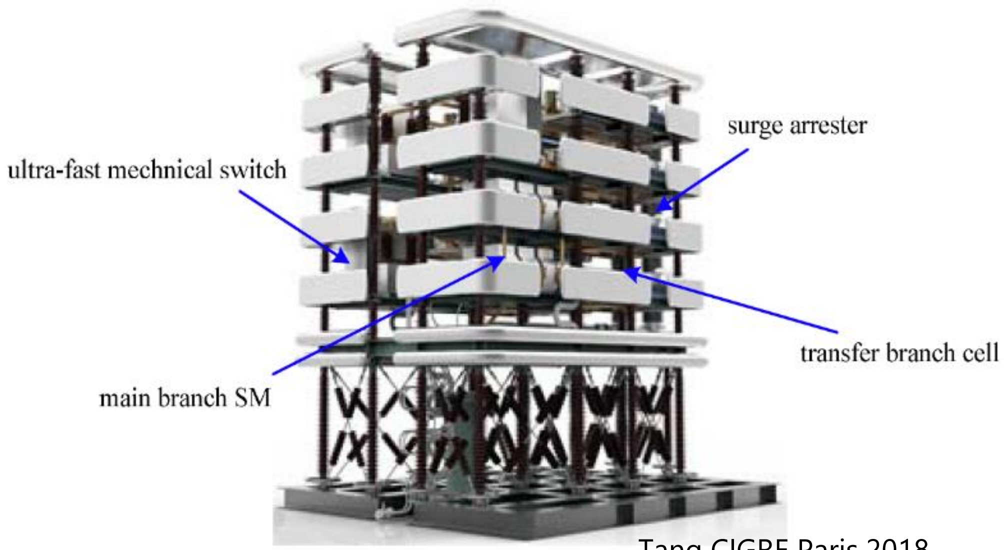
China's HVDC circuit breaker progress

- China's HVDC multi-terminal projects incl. HVDC circuit breakers:
  - 160 kV (realized)
  - 200 kV (realized)
  - 500 kV (2020) 16 CBs, 4 designs

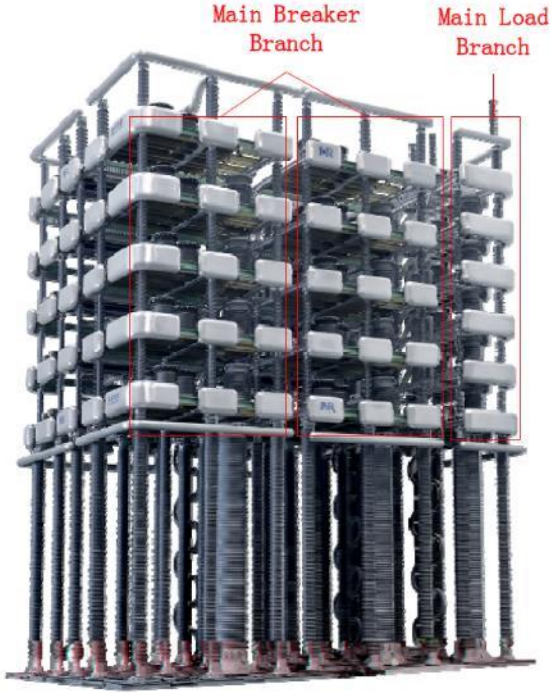


Tang CIGRE Paris 2018

Rated voltage: 200 kV
Rated current: 2000 A
Rated interrupting current: 15 kA

Hu, IEEE 2018

Rated voltage: 160 kV
Rated current: 1000 A
Rated interrupting current: 9 kA



Yang, CIGRE Winnipeg 2017

Rated voltage: 500 kV
Rated current: 3000 A
Rated int. current: 25 kA
Opening time: < 3 ms

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What these activities in PROMOTioN achieved

Situation before PROMOTioN

- Obstacle in the development of HVDC grids
- Technology "Chinese only"
- No service experience available
- Requirements unknown
- No international standards
- Only limited functions tested (China)
- Costs unknown

PROMOTioN's contribution

- Incentive to develop and test prototypes of 3 technologies: TRL to 6 -> 8
- European breaker technology demonstrated
- Test experience gathered and shared
- Agreement on test-requirements
- Initiation of standardization IEC, CIGRE
- Full-power one-shot test solution developed
- System level models available
- Protection < 9% of total grid investment

J. Moore et al., "Towards a deployment plan for a future European offshore grid: cost-benefit analysis of topologies", paper B4-123, CIGRE 2020

Future events

- **PROMOTioN demo testing**
  SciBreak VSC assisted 80 kV HVDC circuit breaker
  April 30, KEMA Arnhem

- **Final conference:**
  North Sea Grid for a European Green Deal
  How to unlock Europe’s offshore wind potential – a deployment plan for a meshed HVDC grid
  May 26 – 27, Royal Museum of Fine Arts, Brussels

- **CIGRE conference**
  Workshop on Meshed Offshore HVDC Transmission Grid Development
  August 26, Palais des Congrès, Paris

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APPENDIX

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