

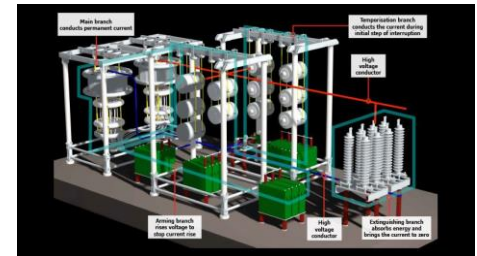
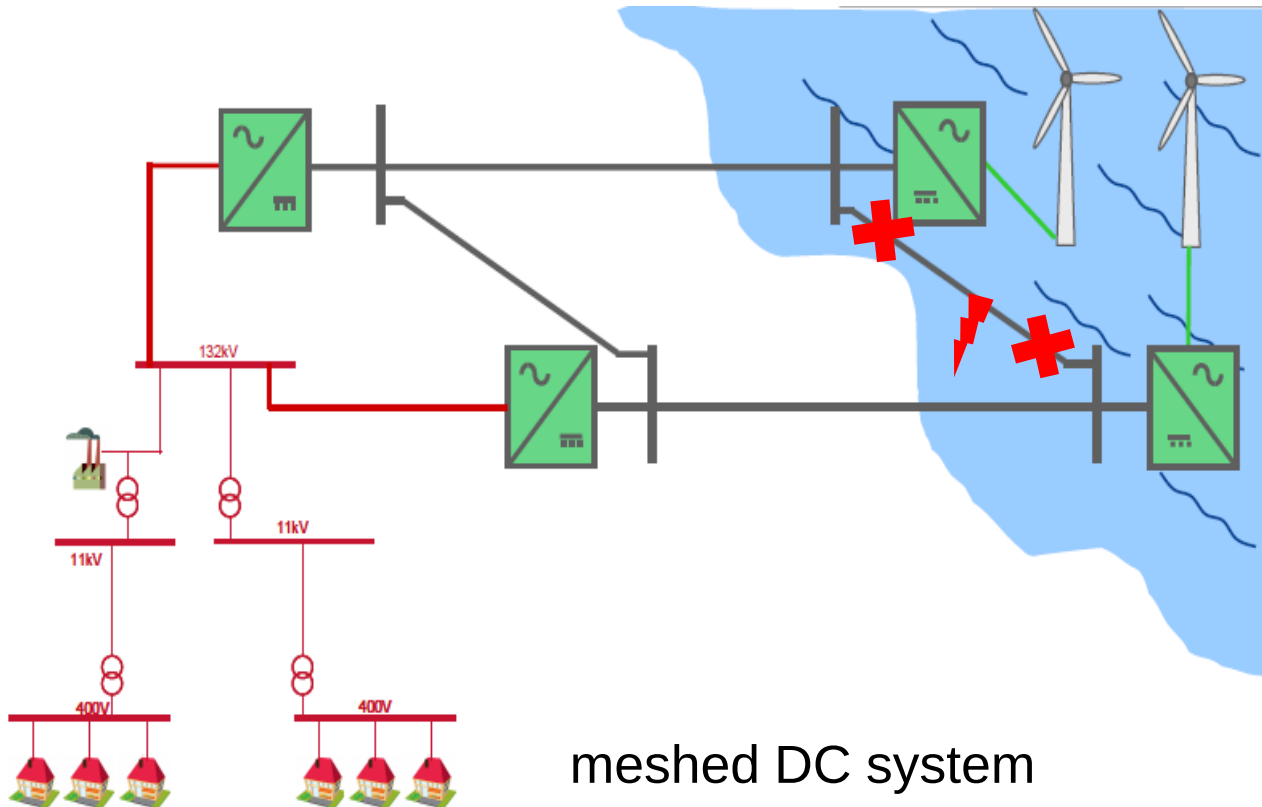
Current interruption in DC systems

René Smeets, KEMA Laboratories DNV GL

PROMOTiON

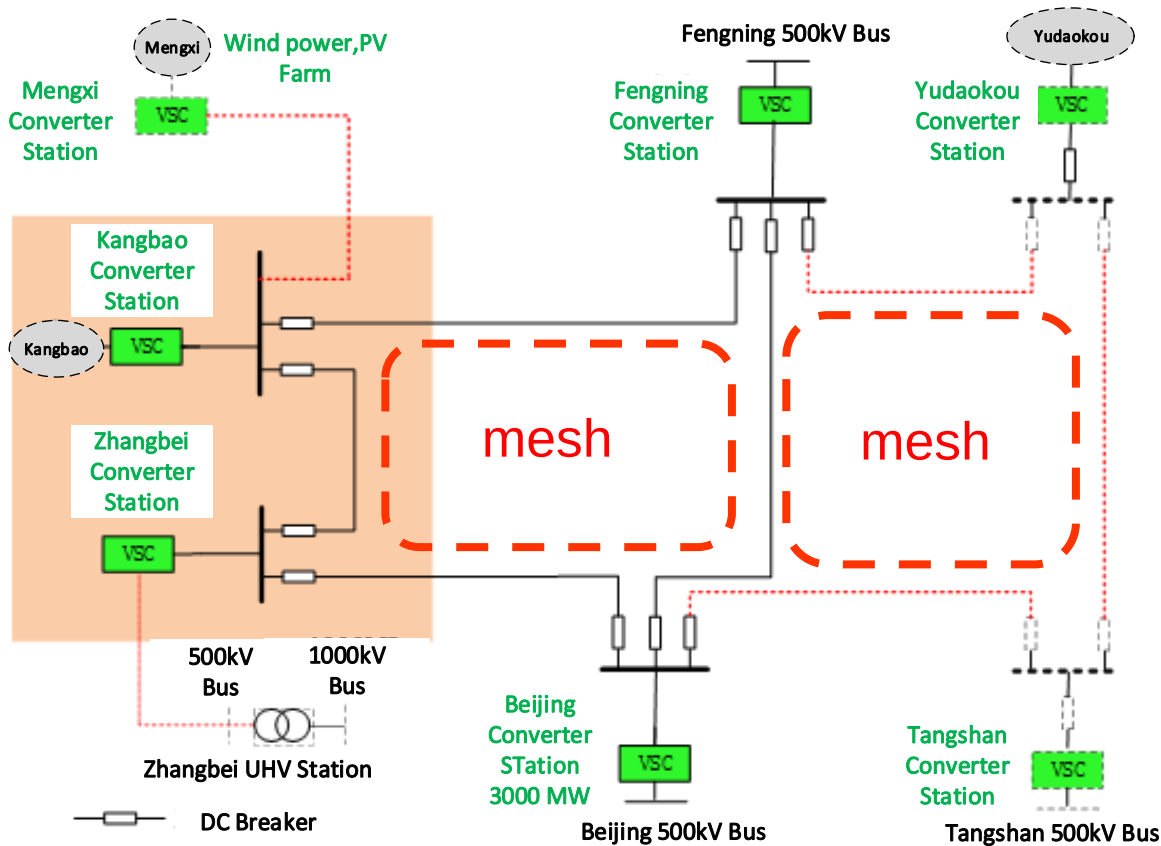
PROgress on Meshed HVDC Offshore Transmission Networks

Fault current interruption in DC

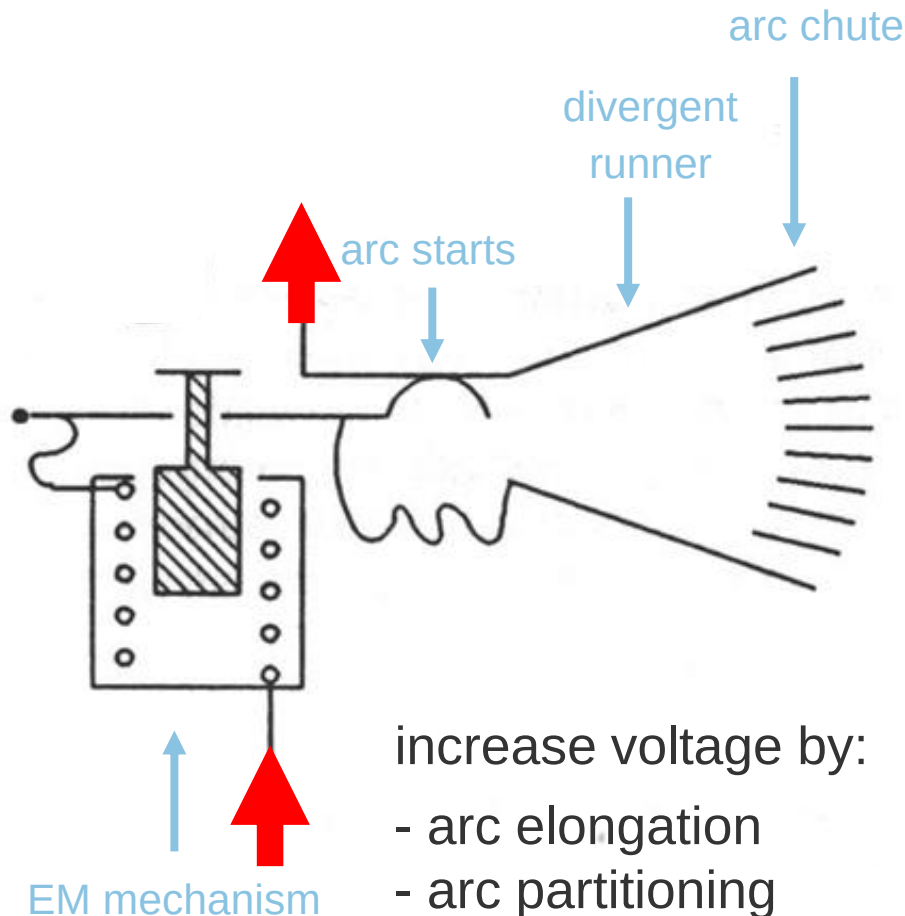


Meshed DC grids

country	term.	techn	volt (kV)	name	year
China	4 (6)	VSC	± 500	Zhangbei project	2018 / 2020

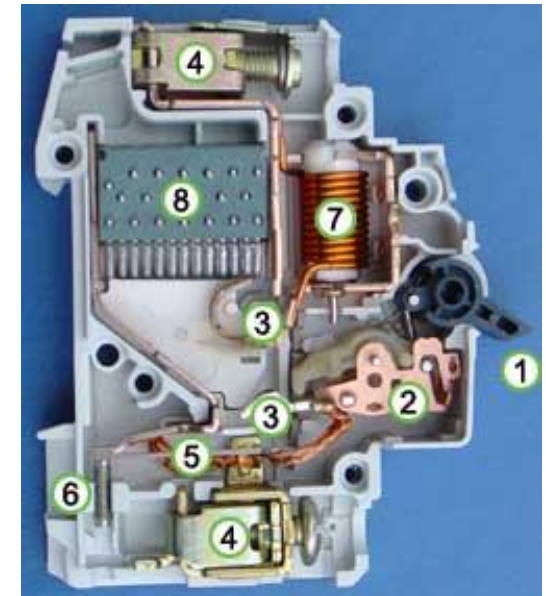
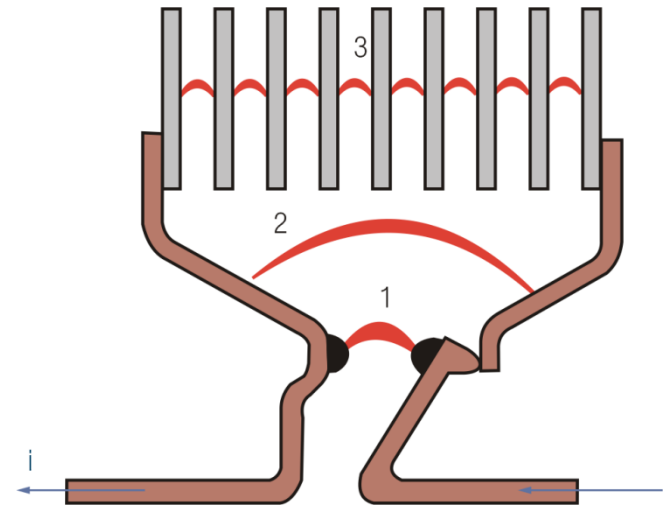


Low-voltage circuit breaker

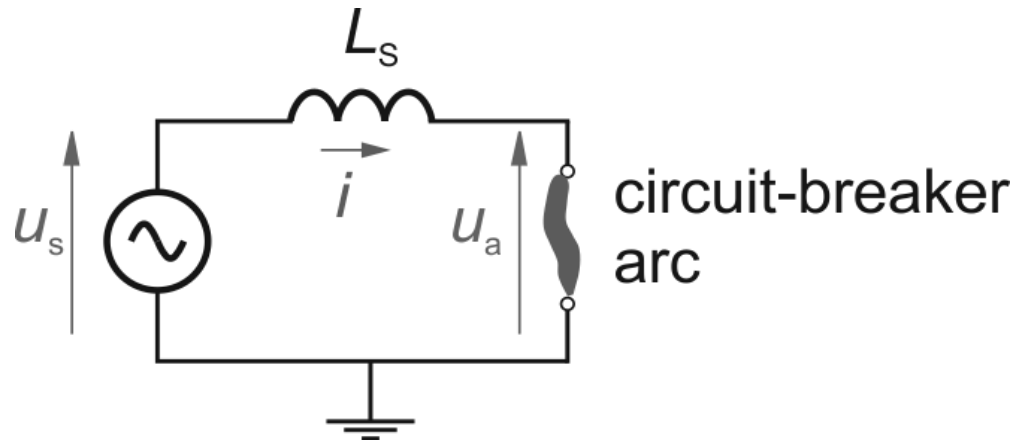


increase voltage by:

- arc elongation
- arc partitioning
- arc cooling



Basic equation

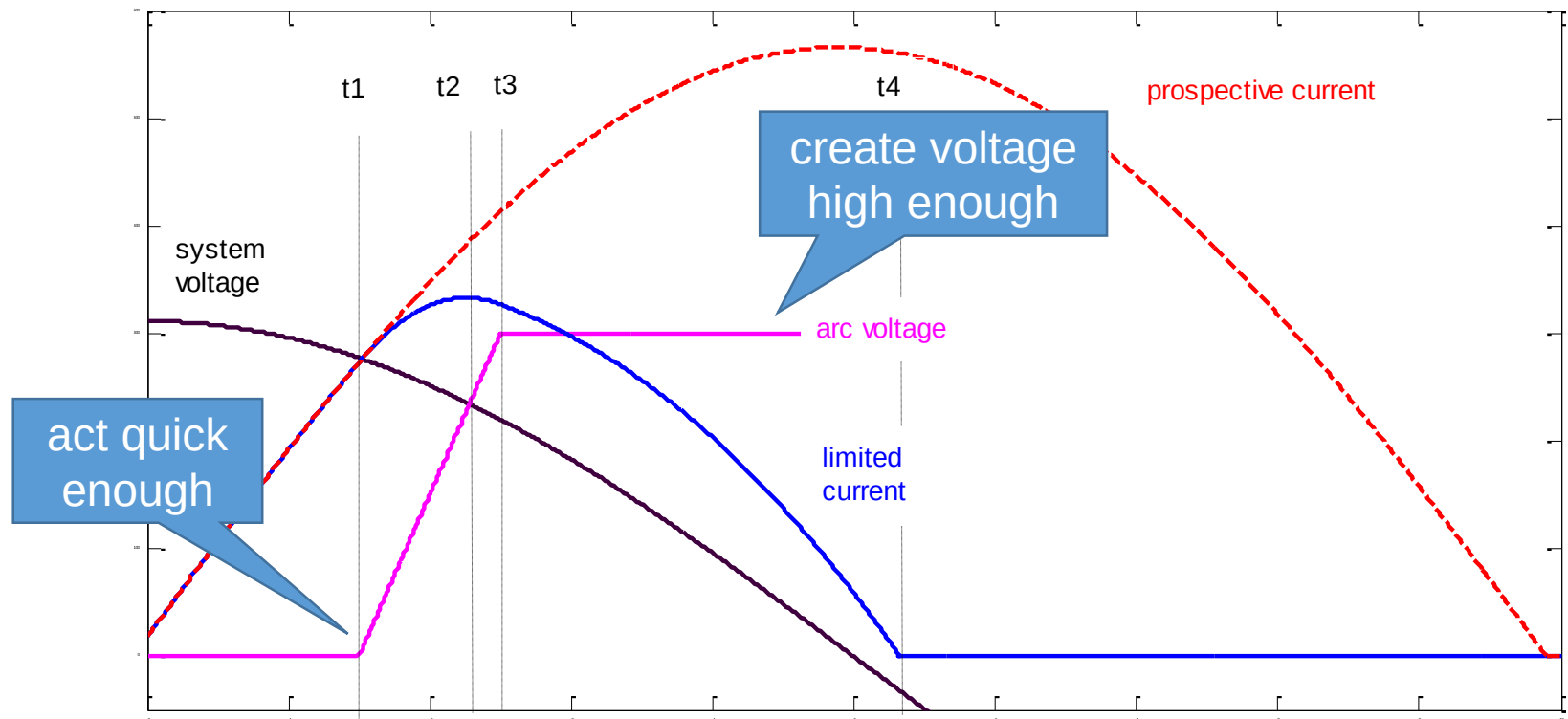


$$L_s \frac{di}{dt} + u_a(t) = \hat{U} \cos(\omega t) \Rightarrow \frac{di}{dt} = \frac{1}{L_s} \left[\hat{U} \cos(\omega t) - u_a(t) \right]$$

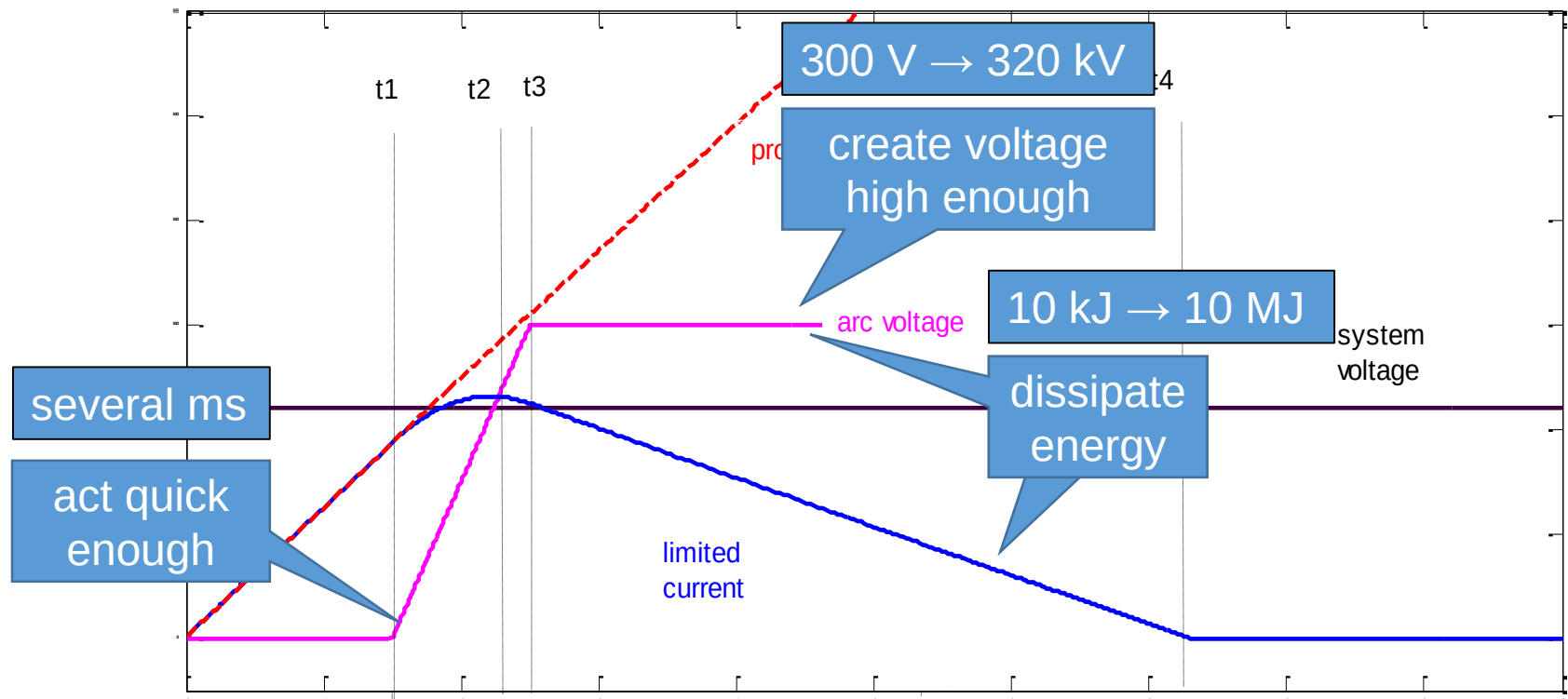
sign of di/dt changes
when CB voltage exceeds source voltage:

$$\frac{di}{dt} = \frac{1}{L} (U - u_{cb})$$

Forced – zero interruption in LV AC



Essence of DC interruption: counter voltage



$$\frac{di}{dt} = \frac{1}{L} (U - u_{cb})$$

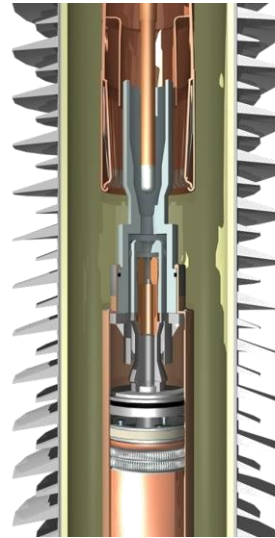
Current interruption: the technology



low voltage



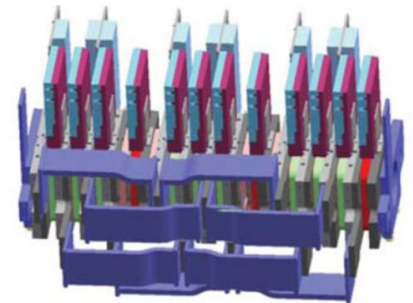
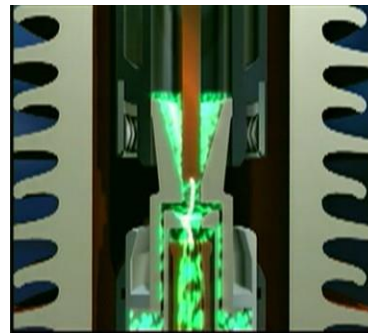
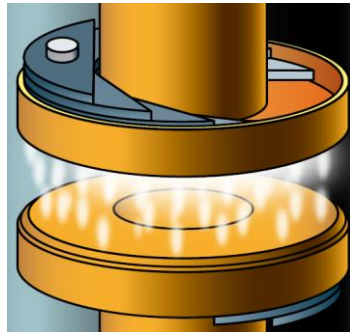
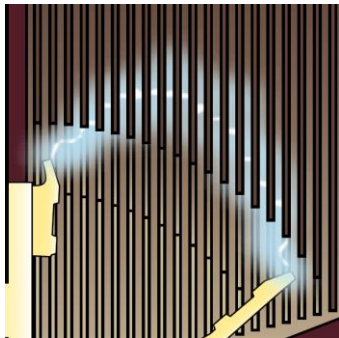
distribution



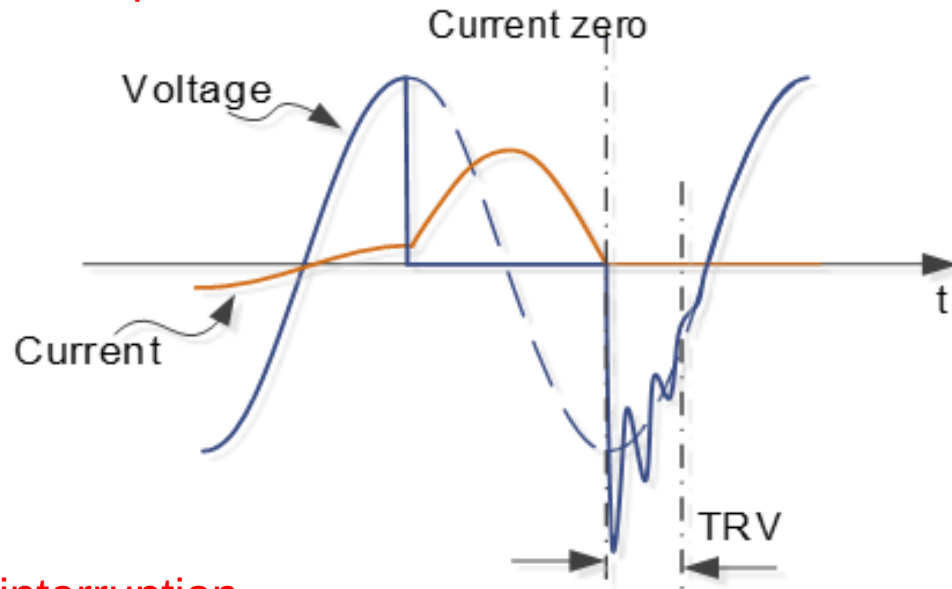
transmission



HVDC

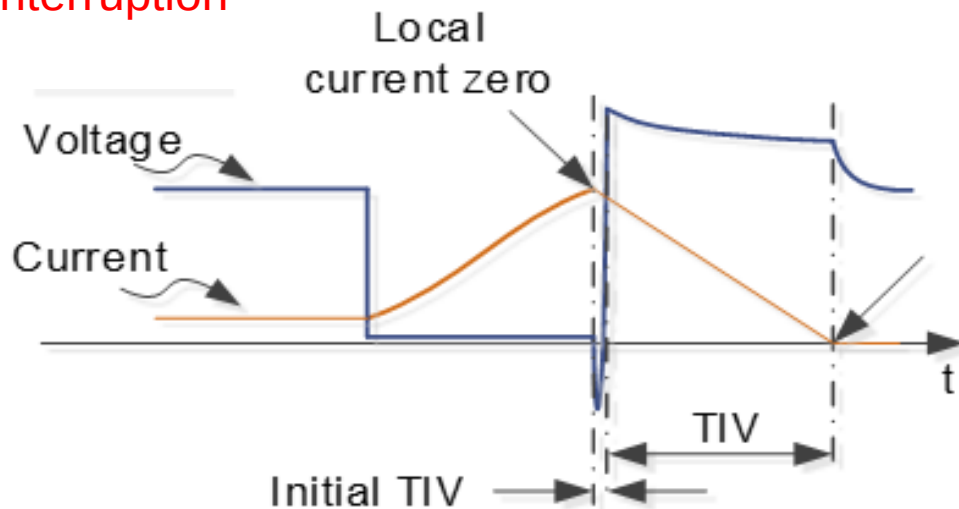


AC interruption



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

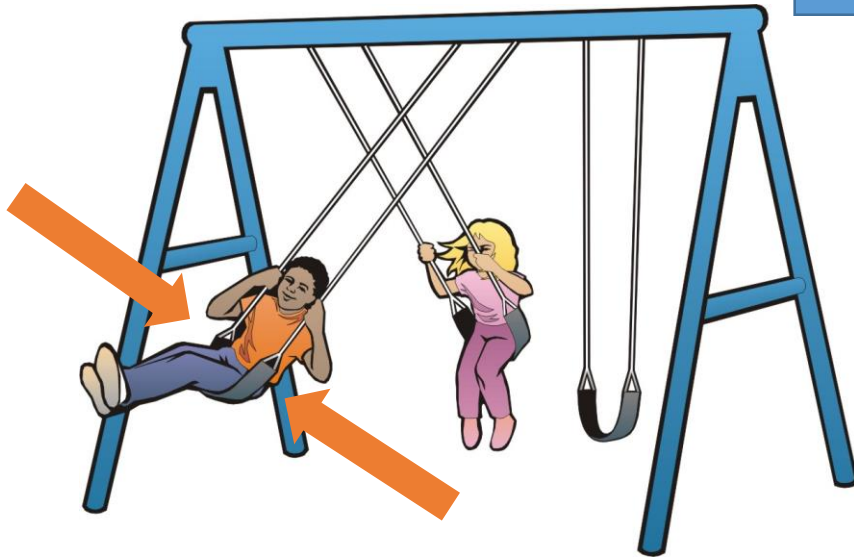
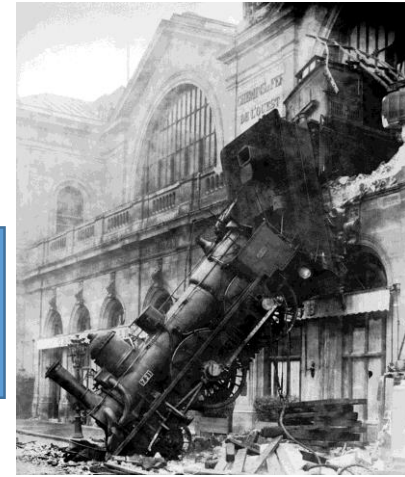
DC interruption



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

Principles of AC / DC interruption

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



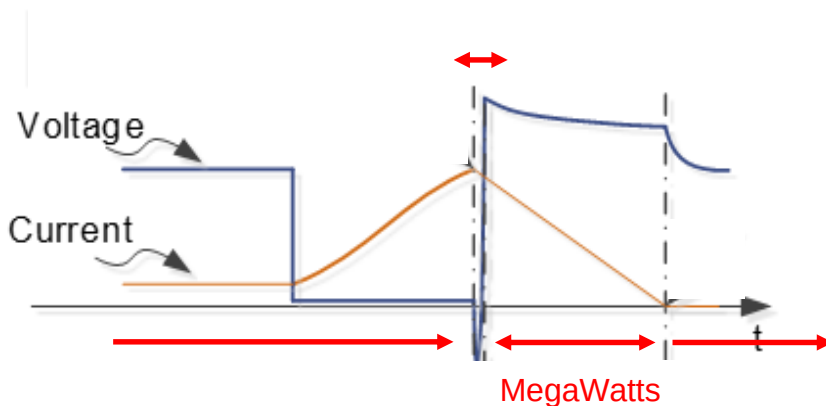
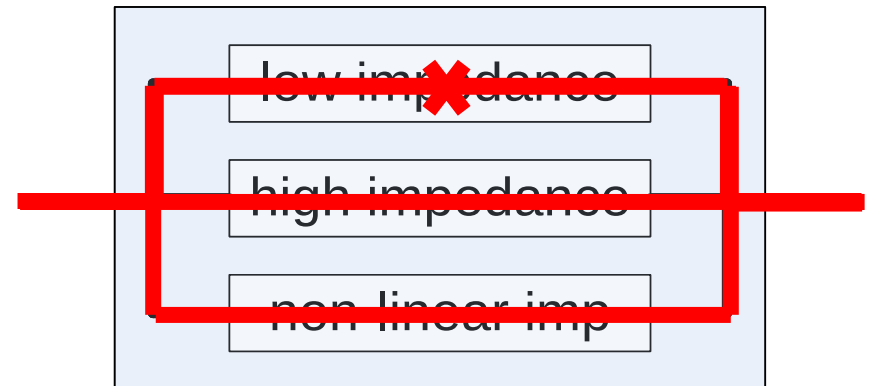
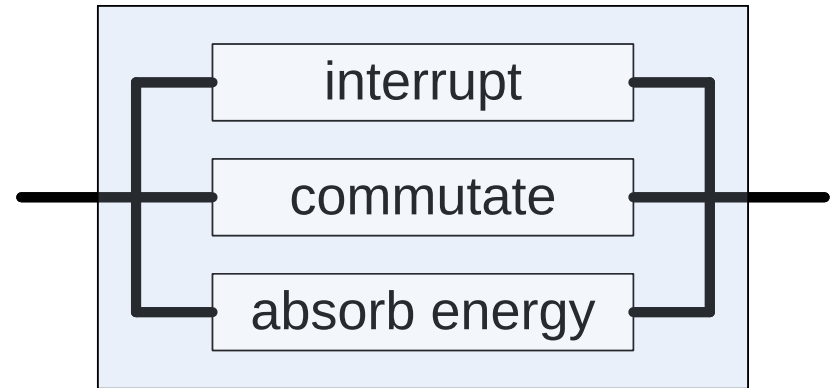
AC interruption:
Capture the swinging mass in
its outer position (current zero).
Zero kinetic energy

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

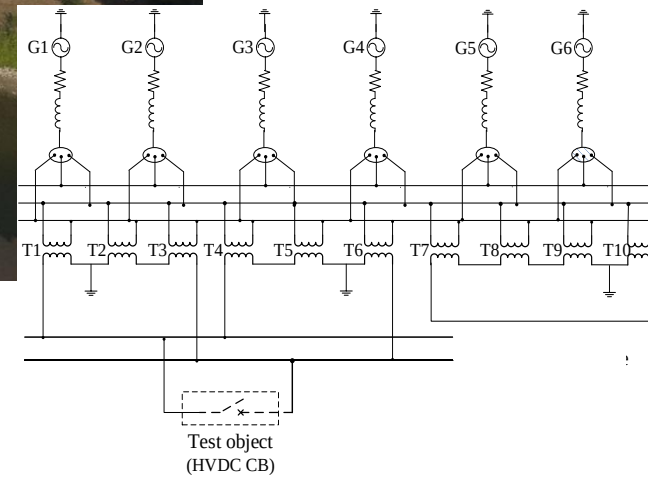


Current interruption: the technology

- How to generate counter voltage?
- Strategy:
 - Create a current zero in the main path: interrupt
 - Commutate the current in path that causes voltage rise: commutate
 - Limit and sustain the counter voltage with a MOSA: absorb energy

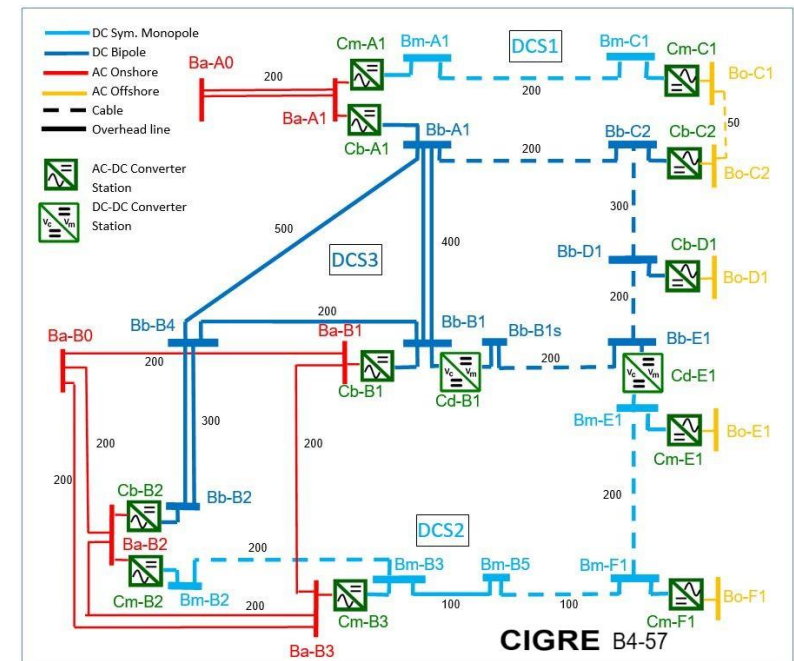
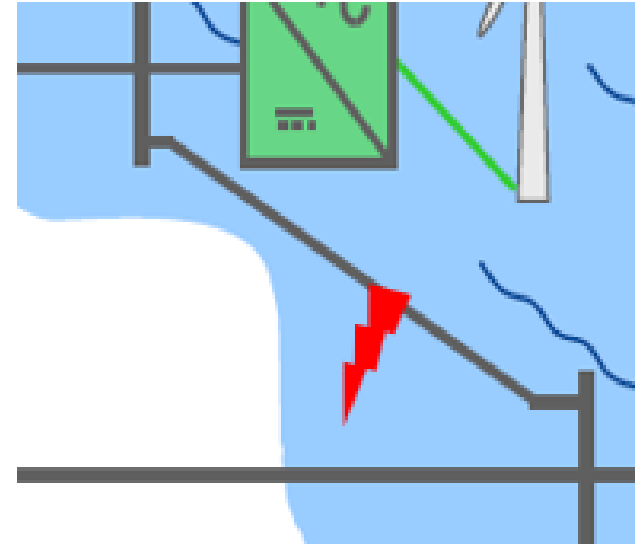
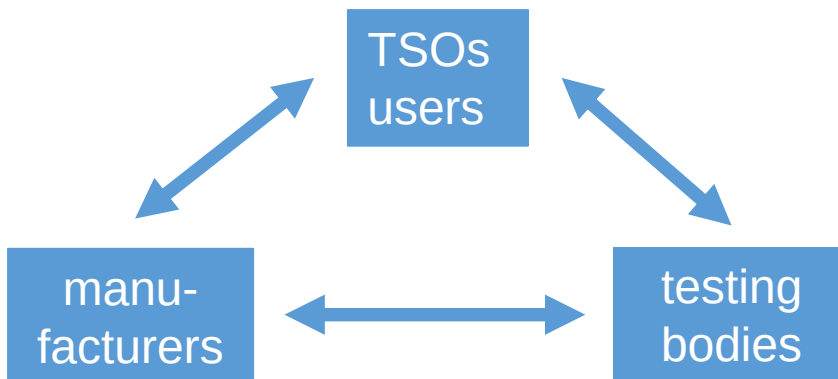


MegaWatts are needed



What stresses are involved?

- No MTDC grids in operation
- No standards developed
- No products in service
- **Could we develop a “Recommended Practice” guidance document?**



Documented efforts on DC protection by CB

- CIGRE JWG A3B4.34: DC switchgear
Publication TB Q2, 2017
- CIGRE WG A3.xx: MV DC circuit breakers (2017)
- IEC ad hoc WG 04: DC switchgear
draft report finalized, to TC 17A meeting
- IEC TC115 WG9: Test requirements for DC side
equipment, incl. switchgear
- CIGRE JWG B4/B5.59: Control & protection of
HVDC grids, incl. required performance of HVDC
switchgear
- CIGRE WGs B4.57,58: Model test-system for
MTDC systems
- CIGRE B4.56: DC grid code, fault currents &
protection specifications
- Draft Chinese standard for HVDC CB

TECHNICAL REQUIREMENTS AND SPECIFICATIONS OF STATE-OF-THE-ART HVDC SWITCHING EQUIPMENT

JWG A3/B4.34

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Thank you for your attention!

René Smeets, KEMA Laboratories DNV GL

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