Progress in HVDC Grid Protection

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MITSUBISHI ELECTRIC EUROPE

for

The National HVDC Centre

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Agenda

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1	Mitsubishi Electric Introduction
2	HVDC Circuit Breaker
3	HVDC Protection IED

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Product range

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Switchgear

Protection & Control Systems

Protection Relays

Power Transformer

760MVA-345kV OIT

Power Systems

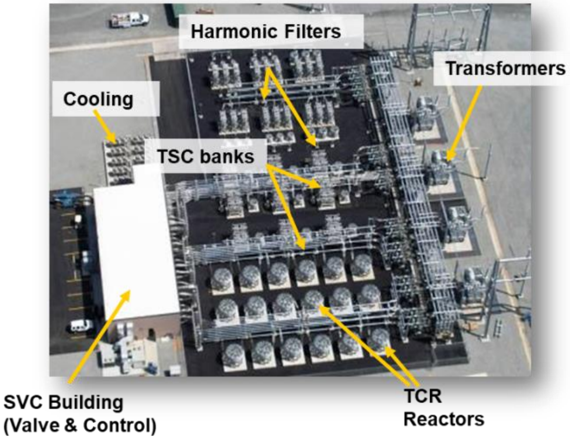
SCADA

Product range

HVDC Transmission

Kii-Channel HVDC

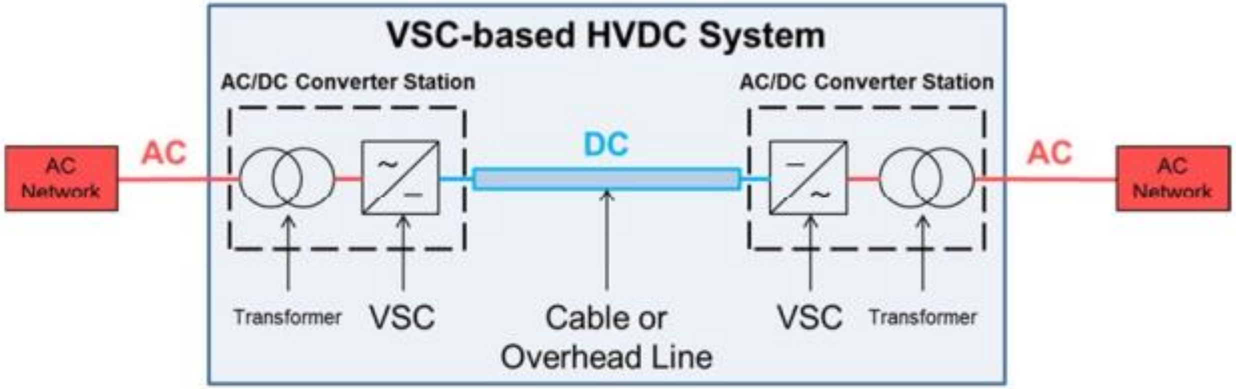
FACTS (SVCs and STATCOMs)



SVC

Mitsubishi Electric's – IGBT used in MMC STATCOMs

50MW Back-Back VSC Verification

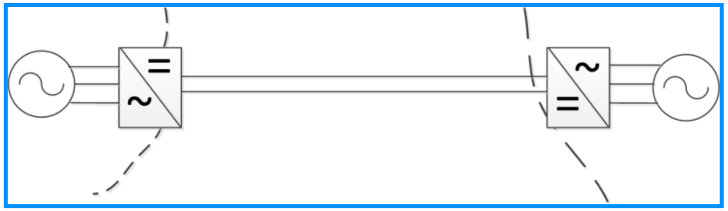


Example of VSC-based HVDC Configuration
(simplified schematic above may vary from actual system configurations)

Location	*8-1-1 Tsukaguchi Honmachi, Amagasaki, Hyogo Prefecture, Japan*
Building Area	*1,217.6 square meters (approx. 13,450 square feet)*
Floor Space	*1,767.8 square meters (approx. 18,300 square feet)*
Structure	*Two-story steel-frame*
Start of Operation	*November 26, 2018*
Products	*50MW VSC-based Back-to-Back System**
Main Facility	*Converter, Control and protection, AC equipment*

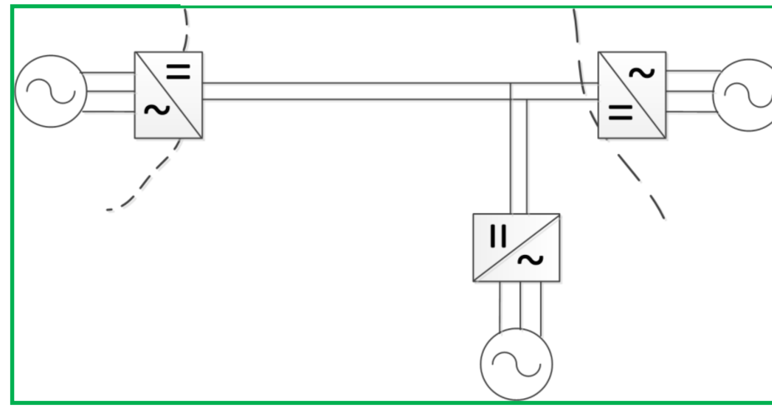
Towards Meshed DC Grids

Point to point link



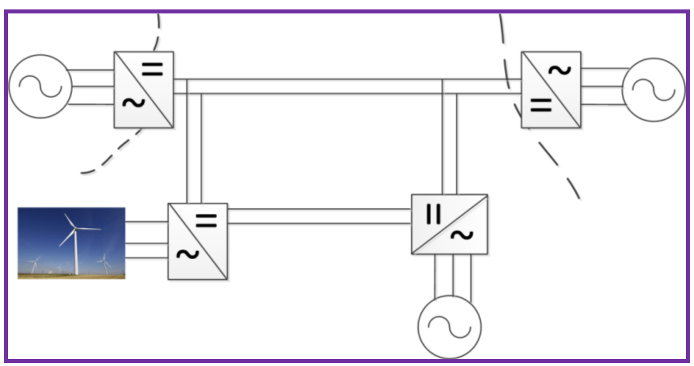
>200 Installations so far

Multi Terminal Link



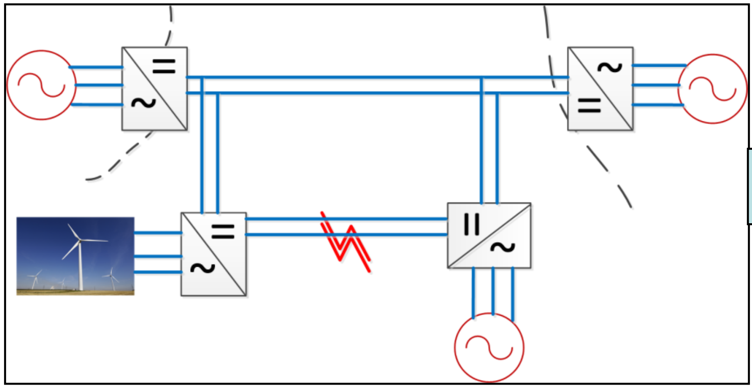
- 2 LCC and 3 VSC HVDC
- Future - Caithness-Moray HVDC link, SouthWest link, Tres Amigas Superstation, FAB link, and COBRAcable

Meshed HVDC Network

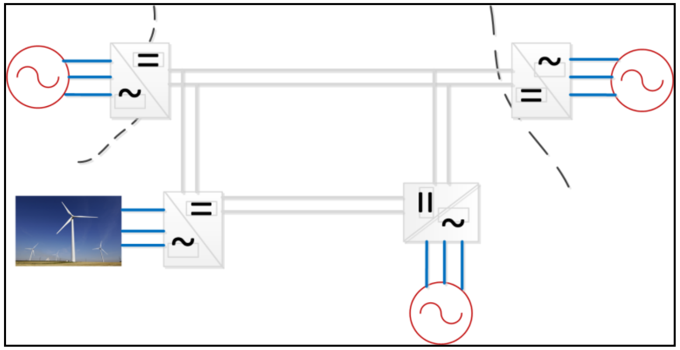


Many concepts being proposed.

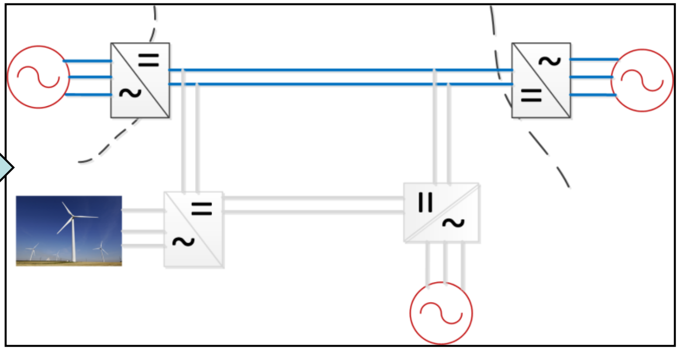
DC Grid Protection Concepts



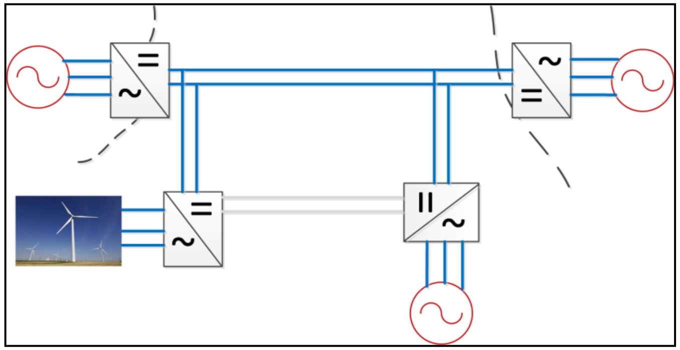
Non selective



Partially selective



Fully selective

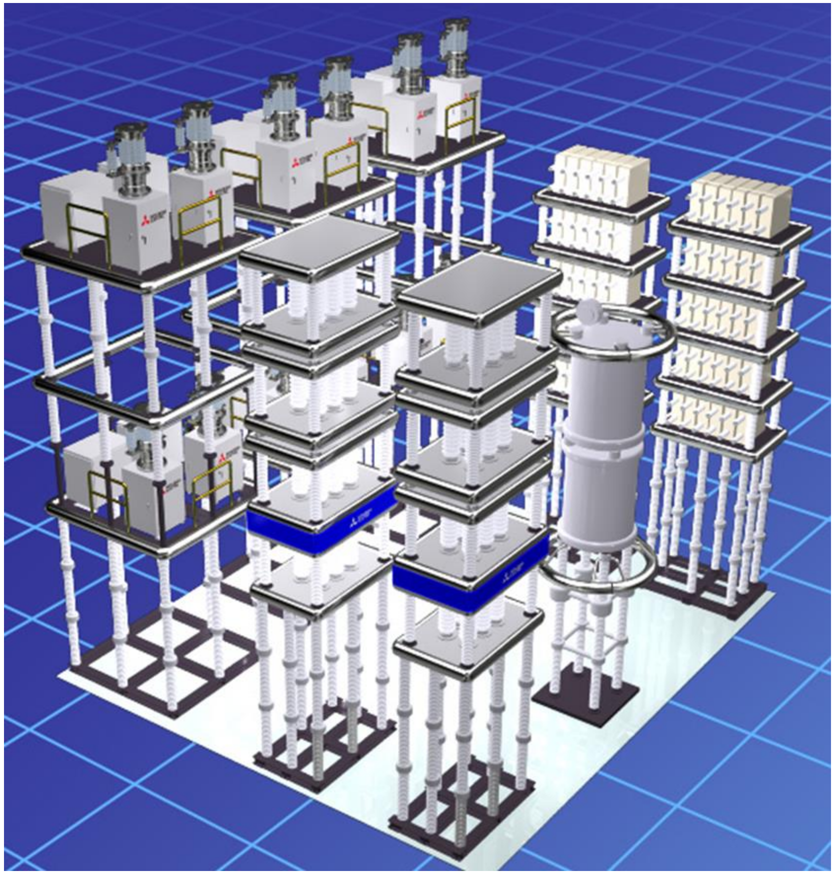


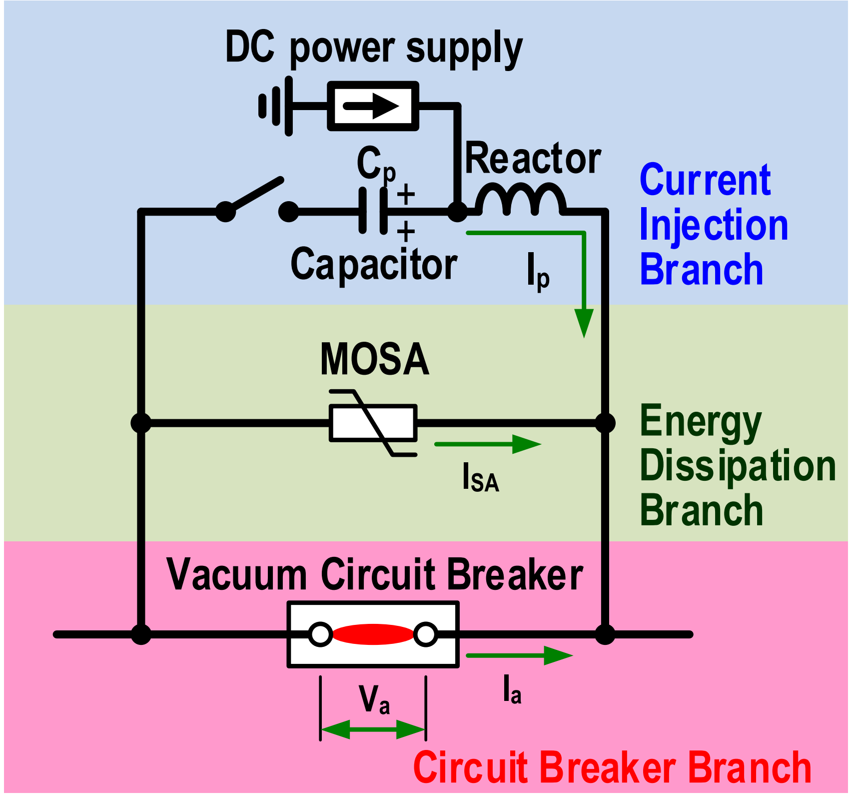
Fully selective strategy is ideal to improve reliability and availability of DC grid, and to reduce impact on ac grids.

Challenges DC Grid Protection

- Requires Faster operation
  - Higher fault current
  - High rate of change of fault current
- Absence of zero crossing in current
- Significant energy absorption required
  - The breaker must absorb energy supplied during the fault from the converter/ac and dc networks

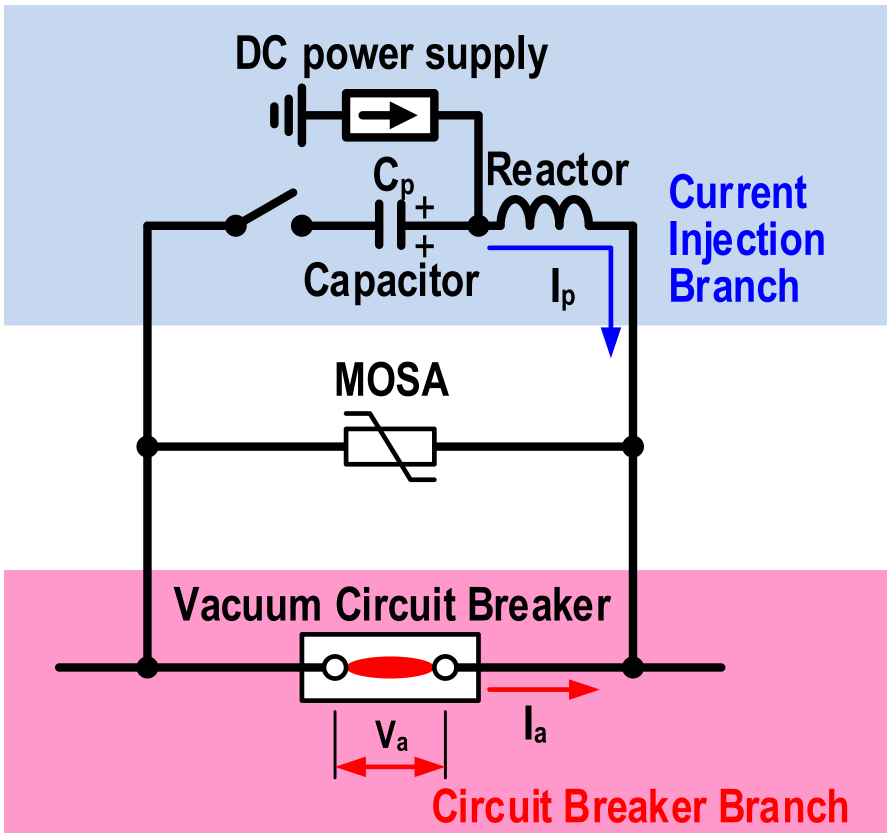
Mechanical DC CB with current injection

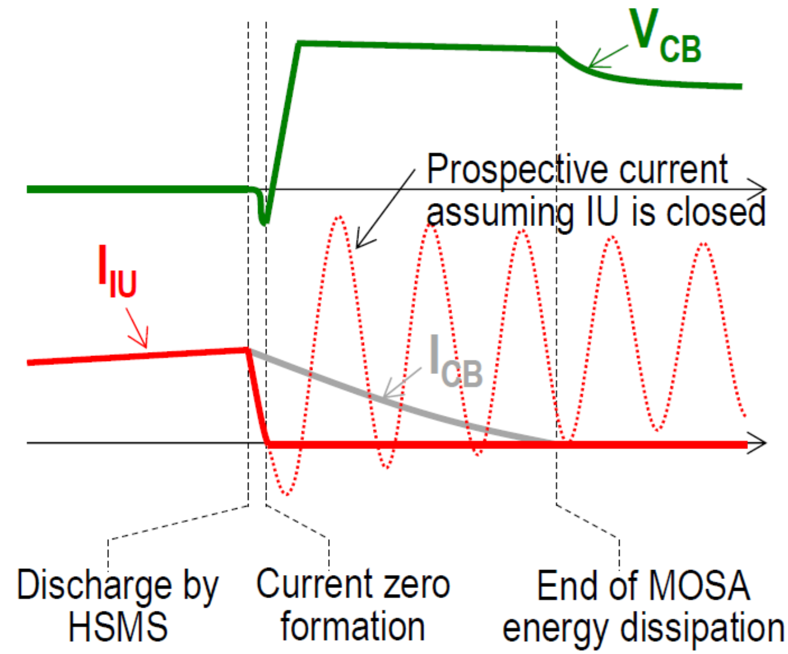




Current zero creation scheme

A current zero is created by superimposing high frequency current on DC current charged by the capacitor bank.



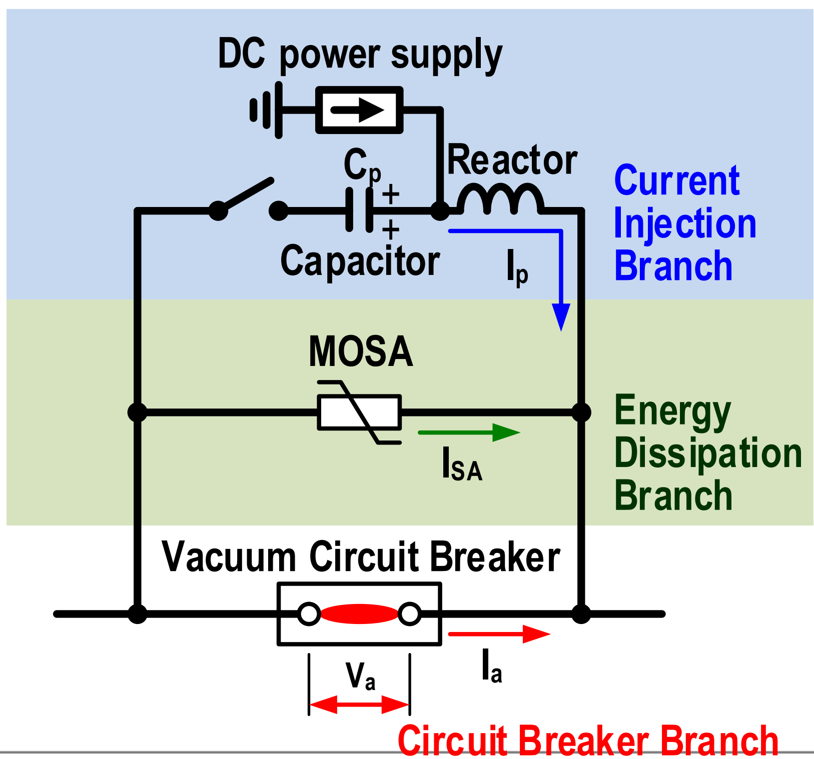


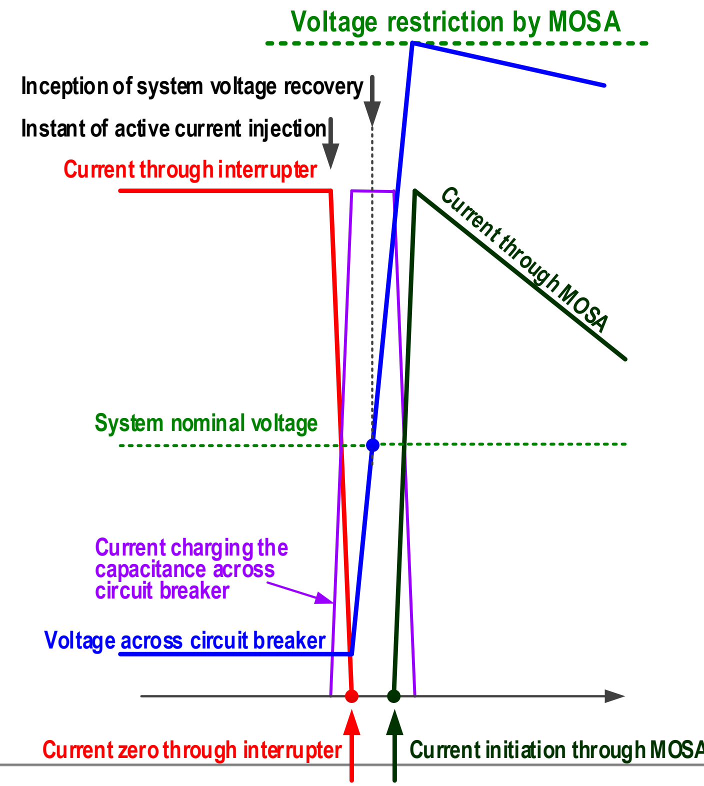
MOSA energy dissipation process

After current injection, residual current through vacuum circuit breaker is commutated to the current injection branch, which charges the capacitor.

The voltage across the vacuum interrupter is quickly recovered and surpassed beyond the nominal system voltage.

Then the transient recovery voltage is clipped by the MOSA restriction voltage (typically about 1.5 pu of the rated voltage in accordance with V-I characteristic) and energy stored in inductive circuit is dissipated by the MOSA .





HVDC circuit breaker requirements

The requirements for HVDC circuit breakers (no international standards)

HVDC transmission system voltages: 525 kV/ 320 kV

Short-circuit currents: up to 16-20 kA depending on fault current clearing time

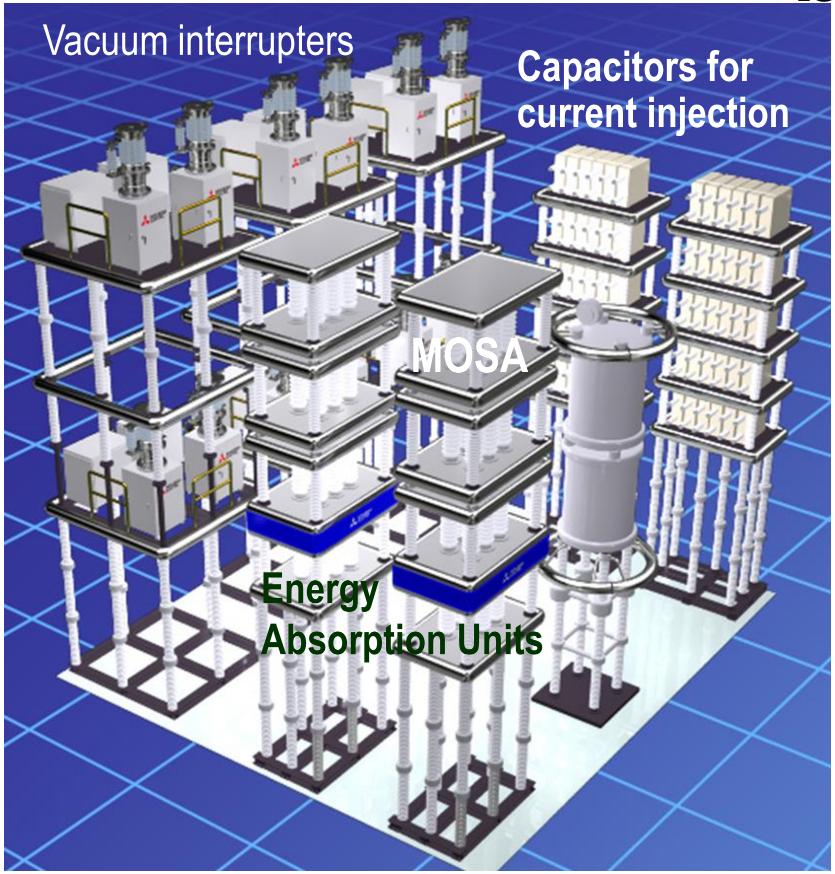
Fault current clearing (neutralization) time: 3-8 ms depending on system inductance

MOSA energy dissipation: 20-40 MJ depending on system inductance

Technology: Mechanical DCCB with current injection vs Hybrid DCCB

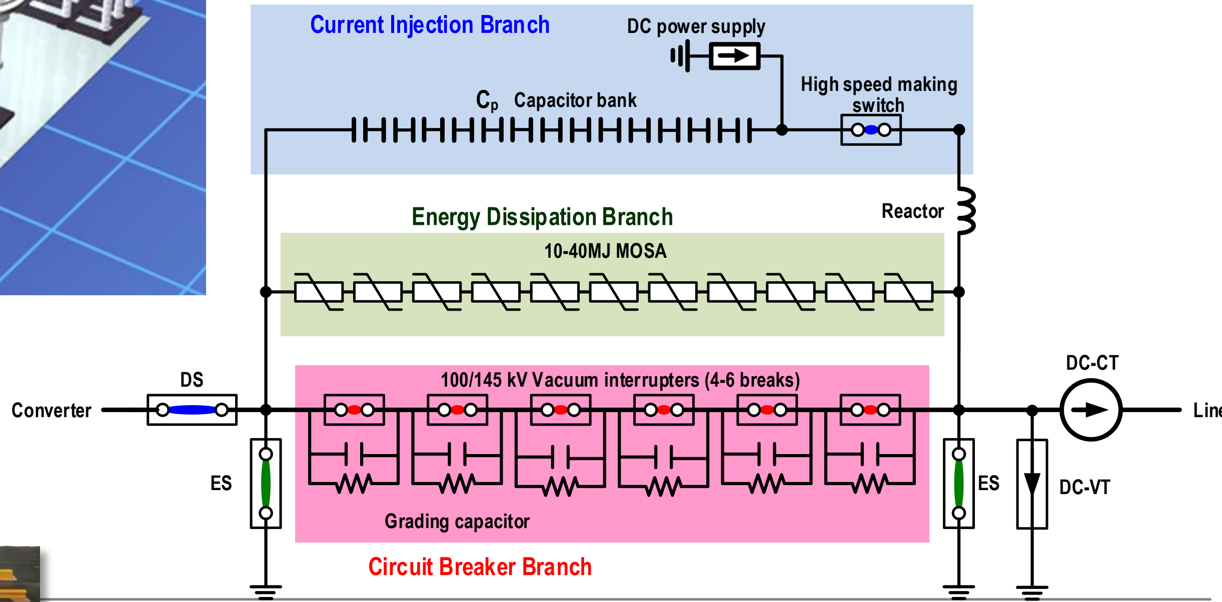
- **Rapid fault current clearing after the detection**
- **Rapid making switch operation for current commutation or current injection**
- **Long term reliability, less maintenance works, economic cost**
- **Large energy dissipation with multi-colums MOSA units**
- **Disconnecting residual current though MOSA units**
- **Rapid auto reclosing for HVDC OHL**
- **Minimum current carrying loss**

525/600 kV 16 kA DC circuit breaker

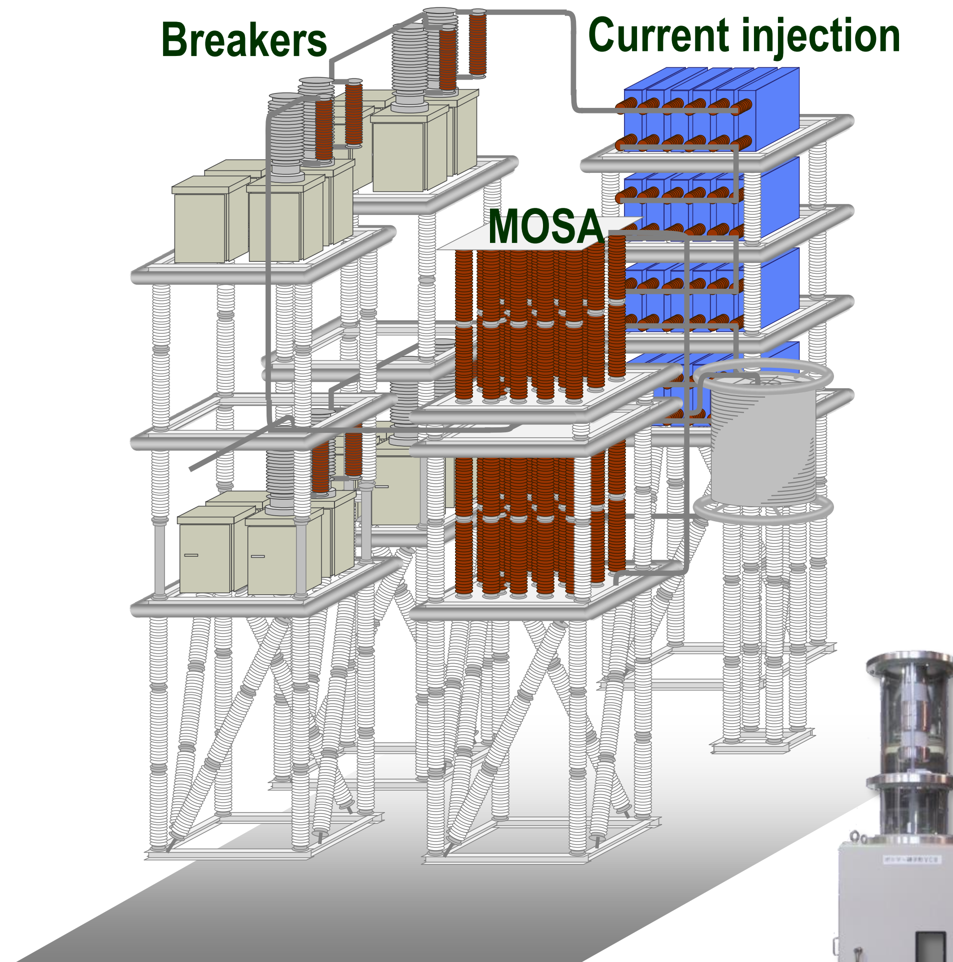


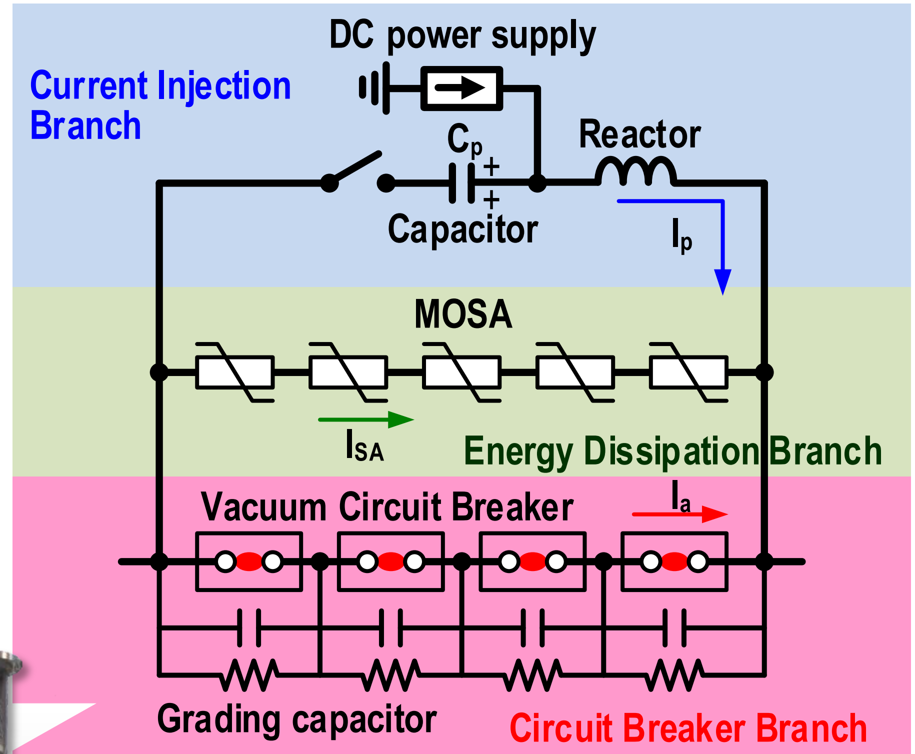
HVDC switchgear (switching equipment) composes of multi-break vacuum interrupters, multi-column MOSA units, a capacitor bank, high speed making switch and DC DS.

100-120kV Vacuum interrupter



320/400 kV 16 kA DC circuit breaker





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160/200 kV DCCB Testing Setup at KEMA

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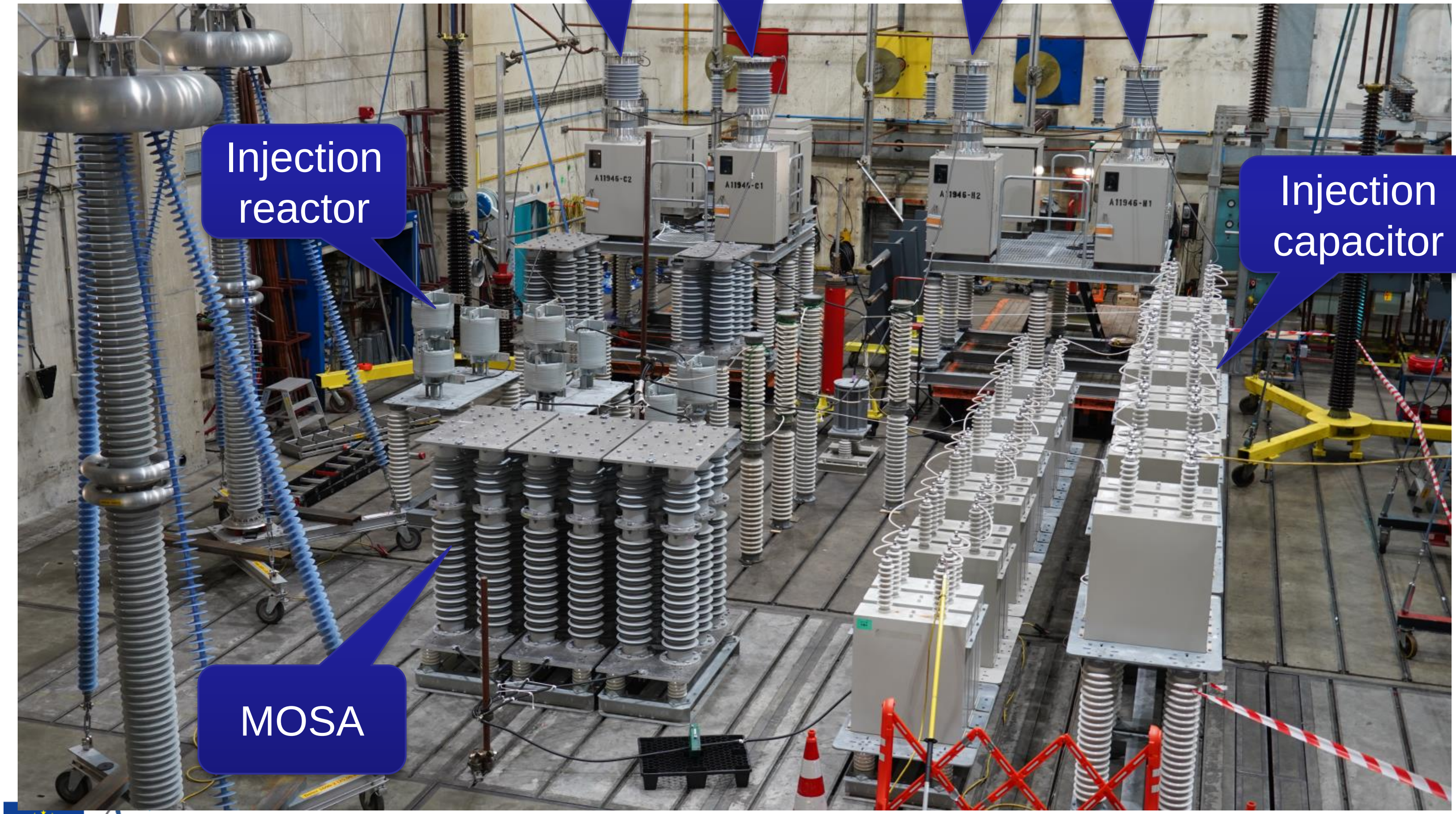

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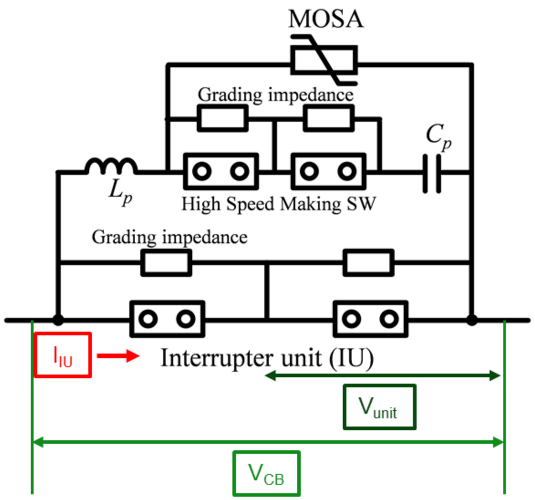
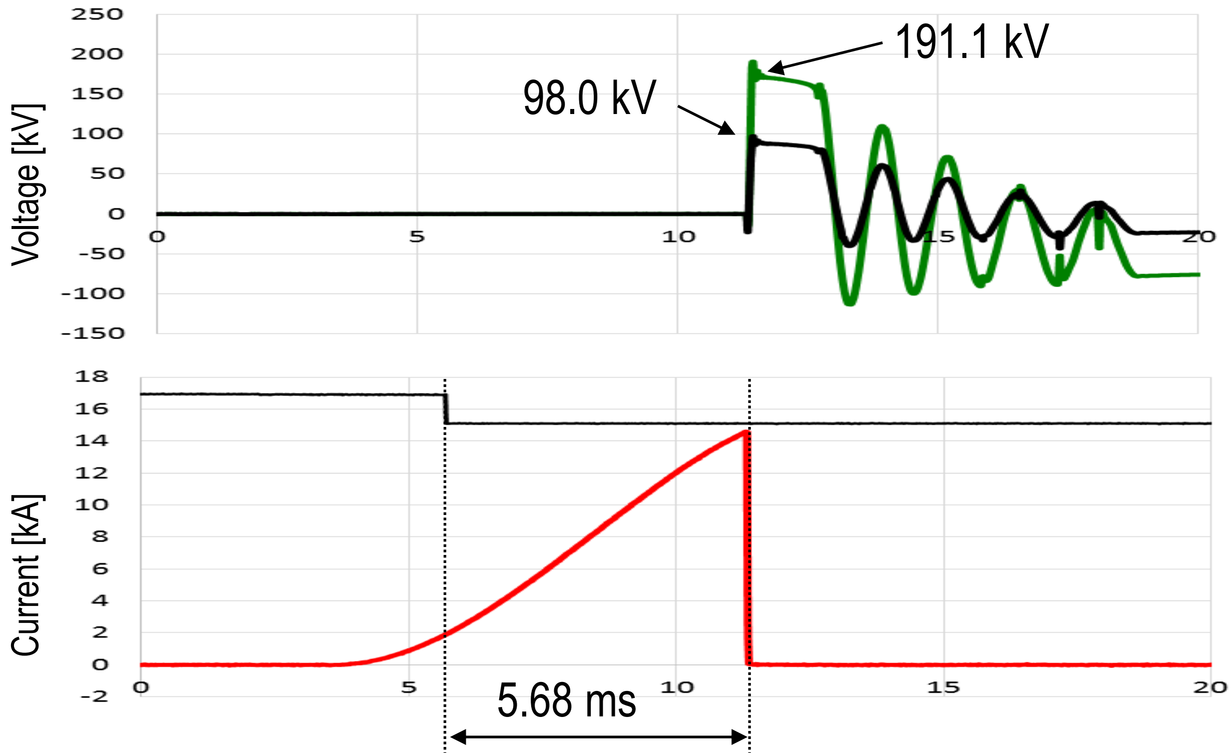
DCCB with double break vacuum interrupters (120 kV)

- Interruption tests at DCCB voltage of 120 kV, 16 kA conditions have been operated using the mechanical HV CB with double break vacuum interrupters.
- TIV peak of 191 kV TIV (TRV) was successfully interrupted.
- The voltage sharing was confirmed to be as good as 51:49.

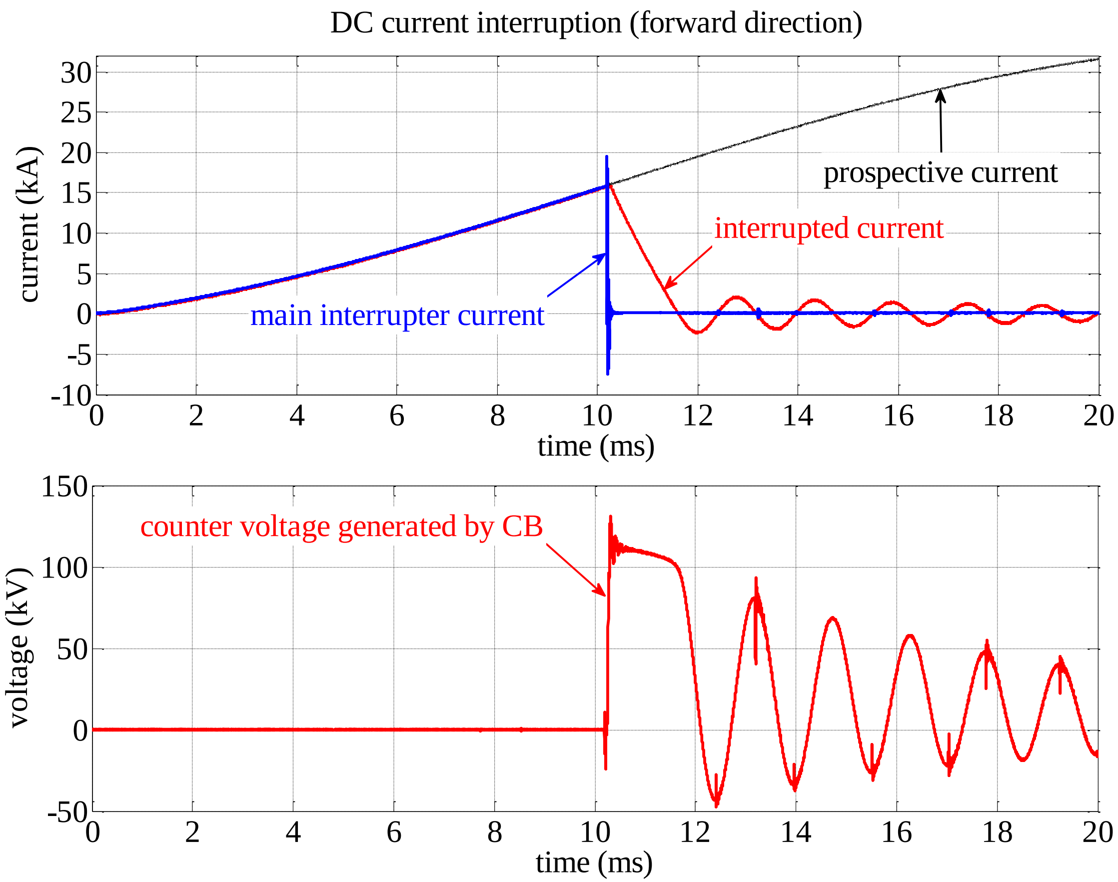


Circuit diagram of double break mechanical DCCB



Typical waveform of current and voltage at the interruption test

Test Results of HVDC CB at KEMA (16 kA)



Test Results of HVDC CB at KEMA (-16 kA)

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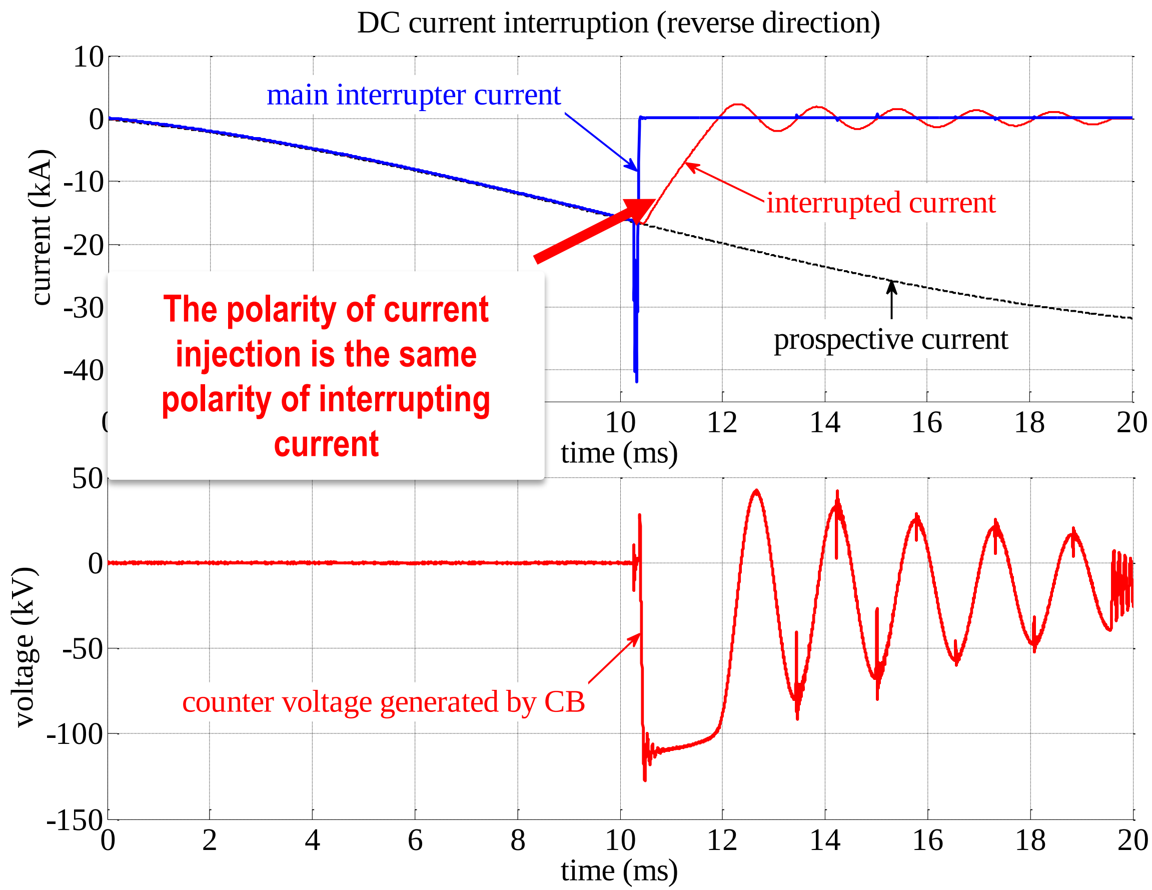

The polarity of current injection is the same polarity of interrupting current

Progress summary

Case	Test voltage (kV)	Test current (kA)	Breaker Operation Time (ms)	TIV Peak (kV)	MOSA (MJ)
1	120	+8	7	+180	1
2	120	+16	7	+180	1.5
3	160	±16	7	±250	2
4	160	+2	7	+250	4
5	160	+0.2	7	+250	< 1

- During testing at KEMA in June 2019, the DCCB successfully interrupted DC fault currents of low (200 A) and high (16 kA) amplitude at 160 kV.
- Multi-break HVDC circuit breaker with current injection applied with the multi-column well-screening MOSA units as well as the equal voltage division technique can be feasible for 550/320 kV 16 kA ratings.

Thank You