2018 CIGRE SESSION

HVDC CIRCUIT BREAKER WITH CURRENT INJECTION

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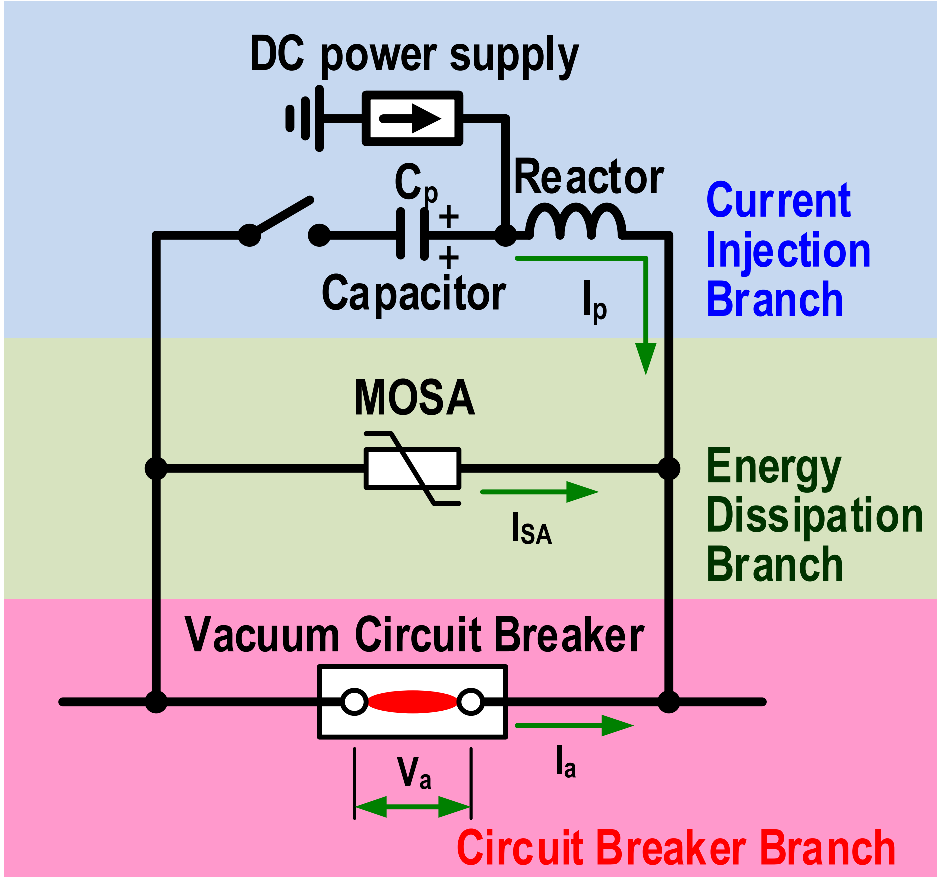
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

MITSUBISHI ELECTRIC
Changes for the Better

DCCB Topology

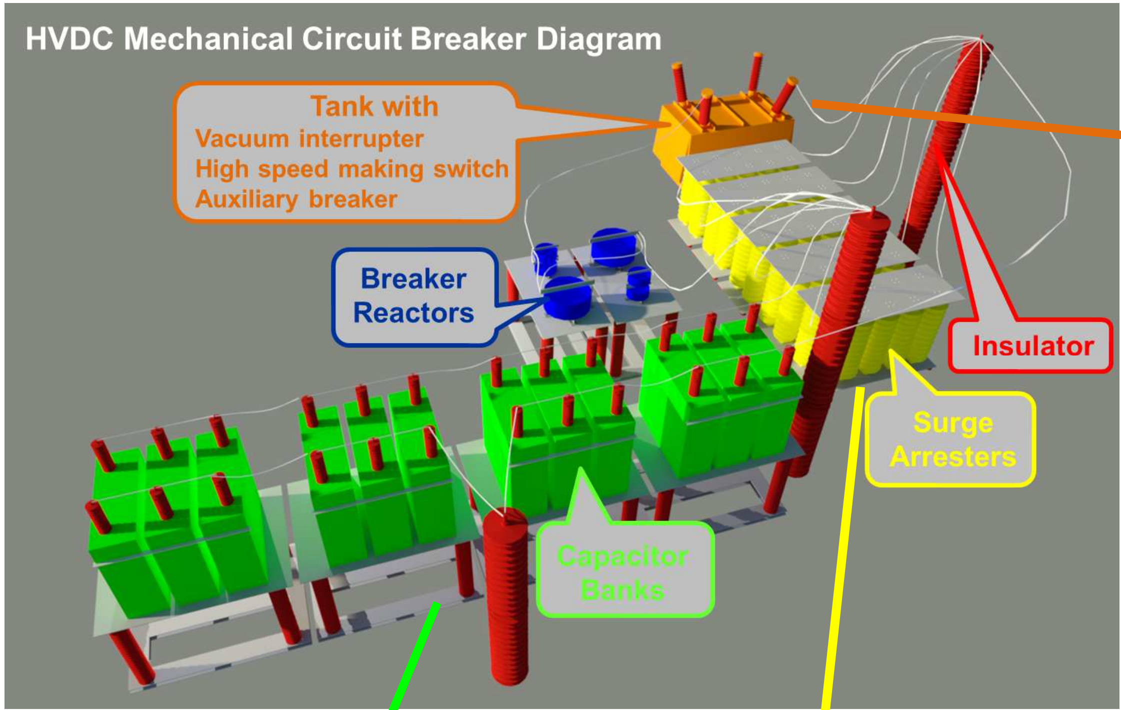


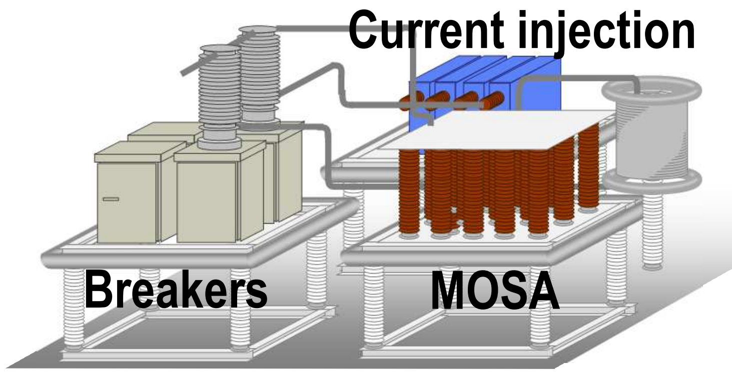
Current Injection Branch
Making switch, Pre-charged capacitor, its DC power source and inductance

Energy Dissipation Branch
Large capacity Metal Oxide Surge Arresters (MOSA)

Circuit Breaker Branch
Vacuum Interrupter, Main current carrying circuit

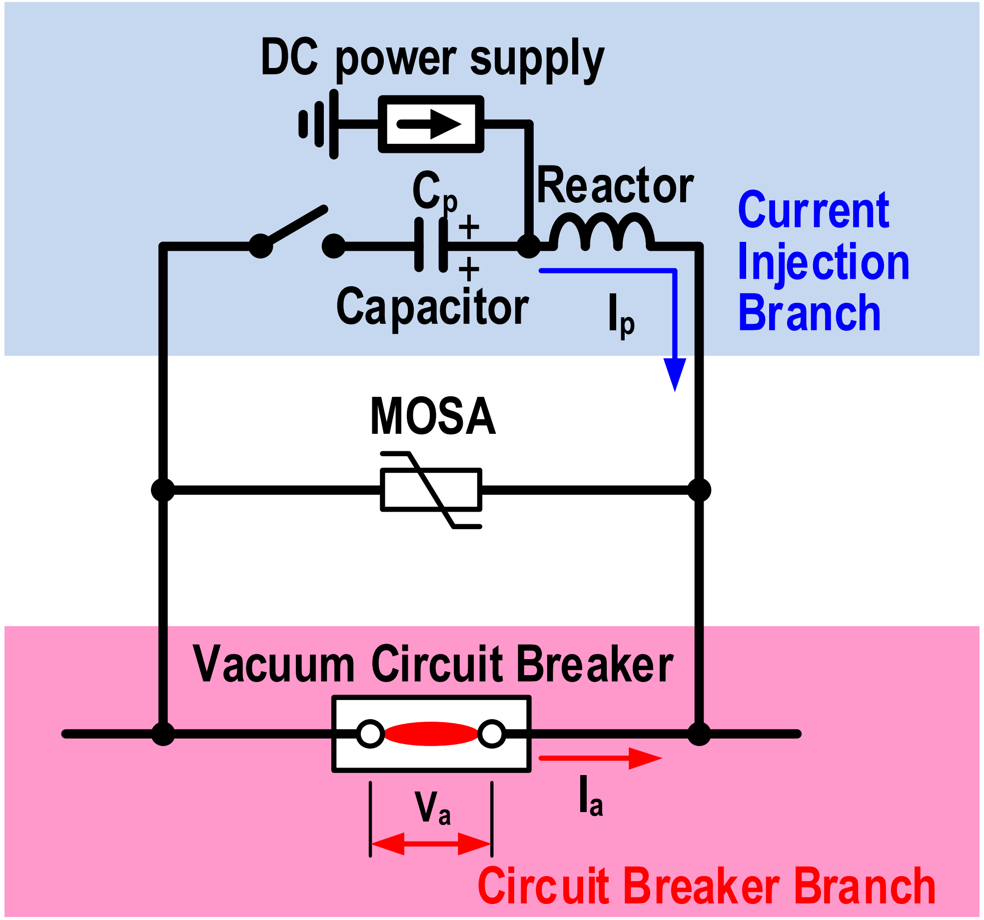
HVDC circuit breaker with 80 kV 16 kA capability

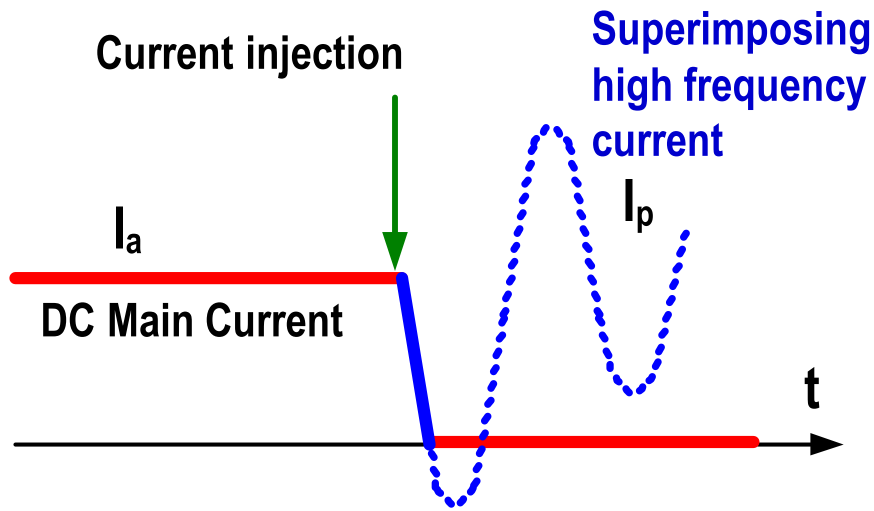




Current zero creation

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



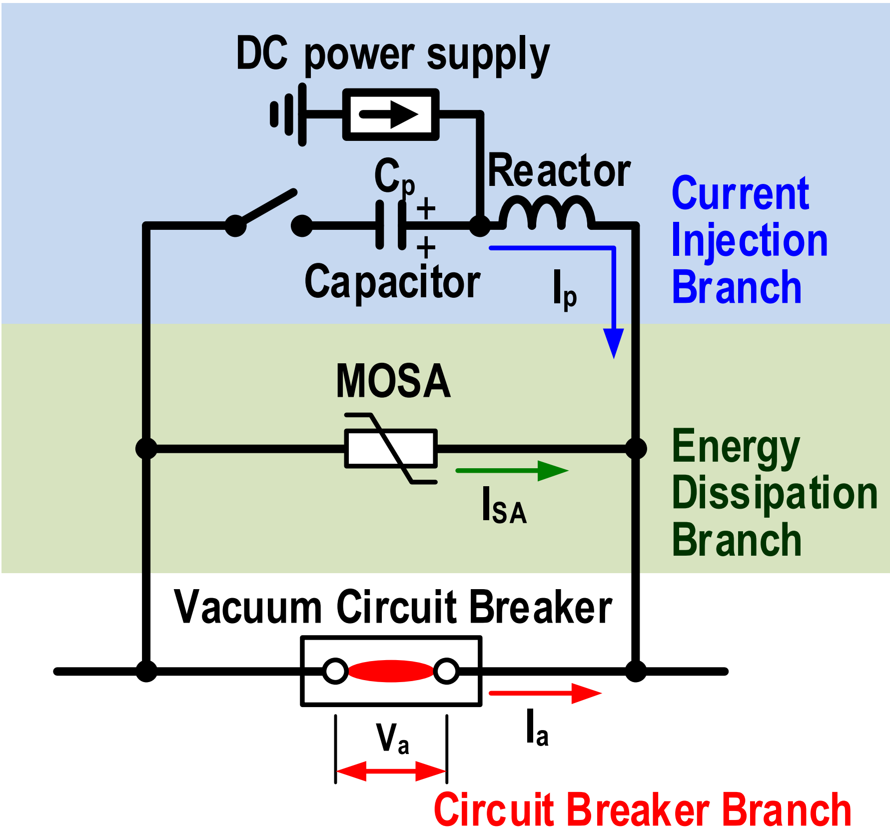


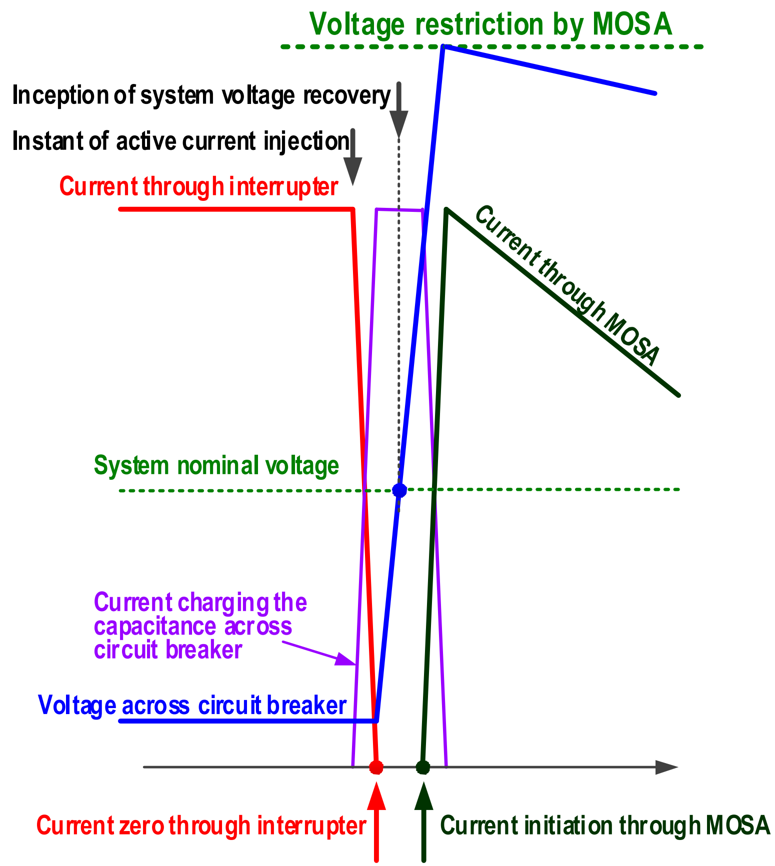
MOSA energy dissipation

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).

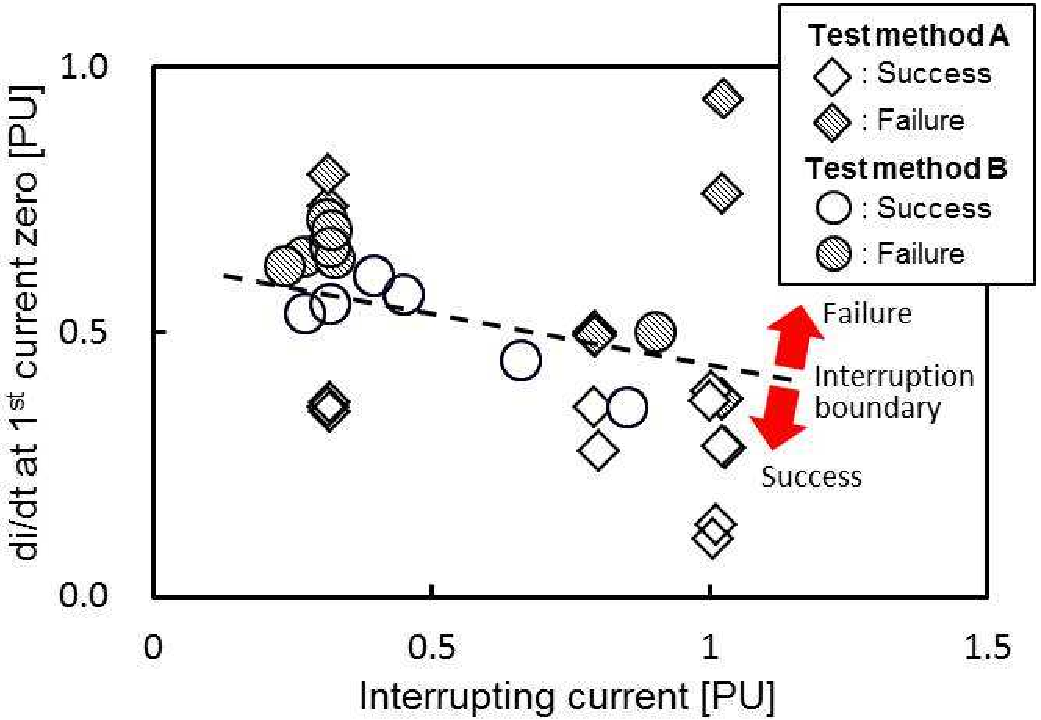




High frequency interruption capability with Vacuum

High frequency interruption capability depends on the contact gap of vacuum interrupter and its conditions such as interrupting currents (around 16 kA and above).

The current injection scheme with capacitors and inductors controls the amplitude of reverse current and its frequency, and ensure successful interruption at current zero.



Rapid interruption cannot allow vacuum interrupters to fully open at current injection.

HVDC circuit breaker interrupting tests

demonstrated at DNV-GL/ KEMA HPL lab

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Rated DC Current Interruption at DNV-GL KEMA HPL

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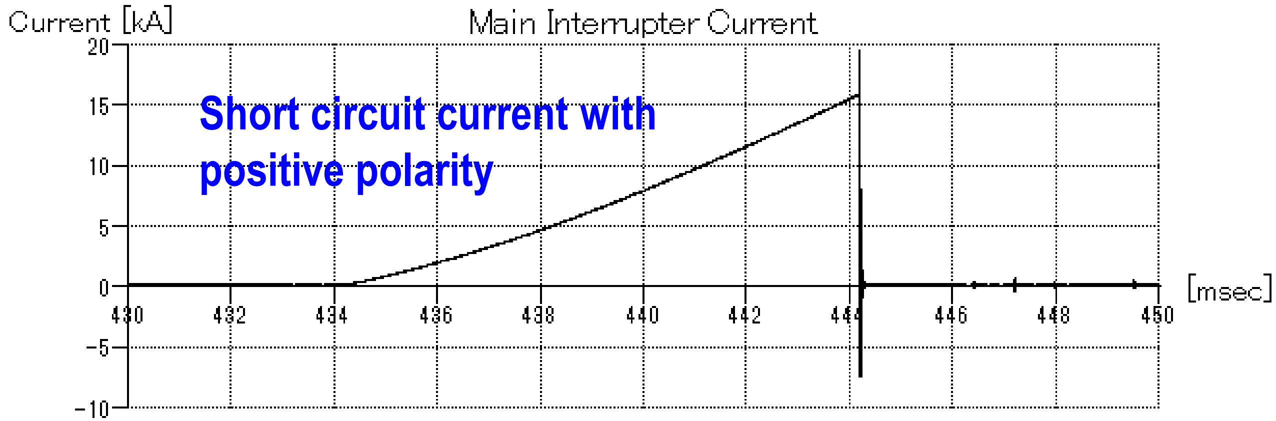
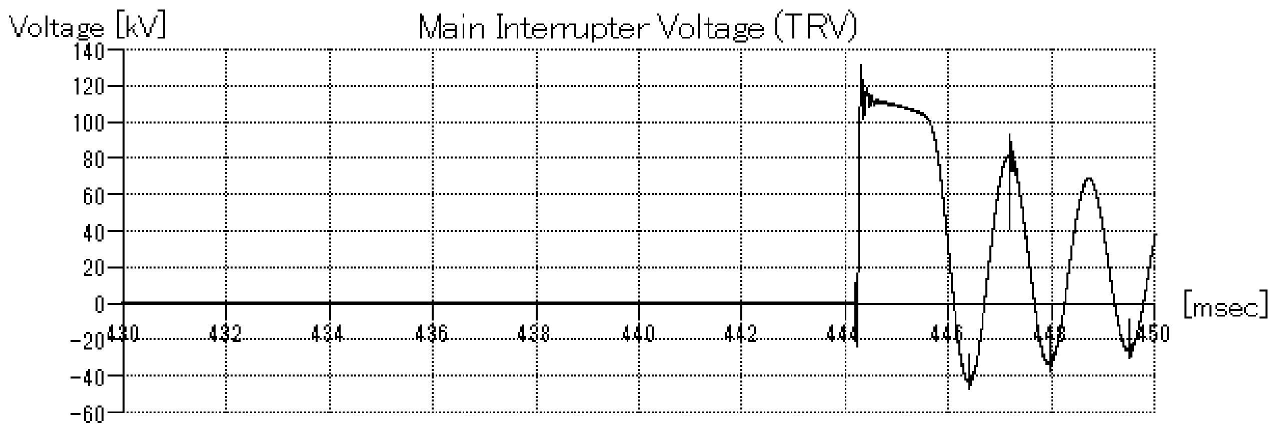
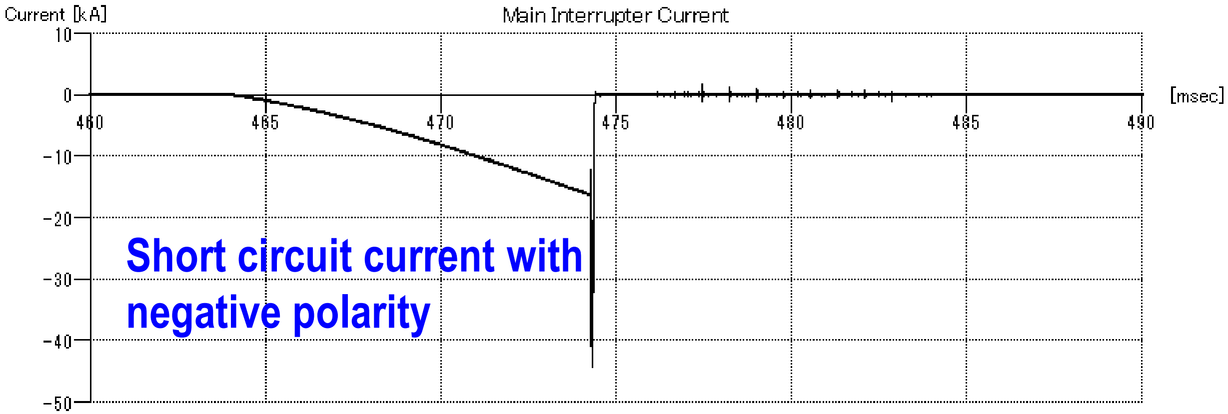
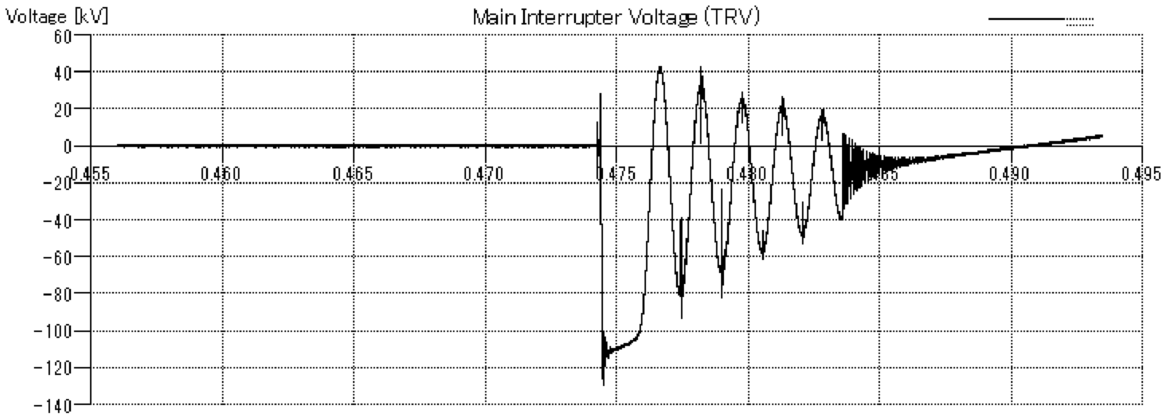




Successful interruption demonstration at the rated current (16kA) with positive polarity

Rated DC Current Interruption at DNV-GL KEMA HPL





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Successful interruption demonstration at the rated current (16kA) with negative polarity

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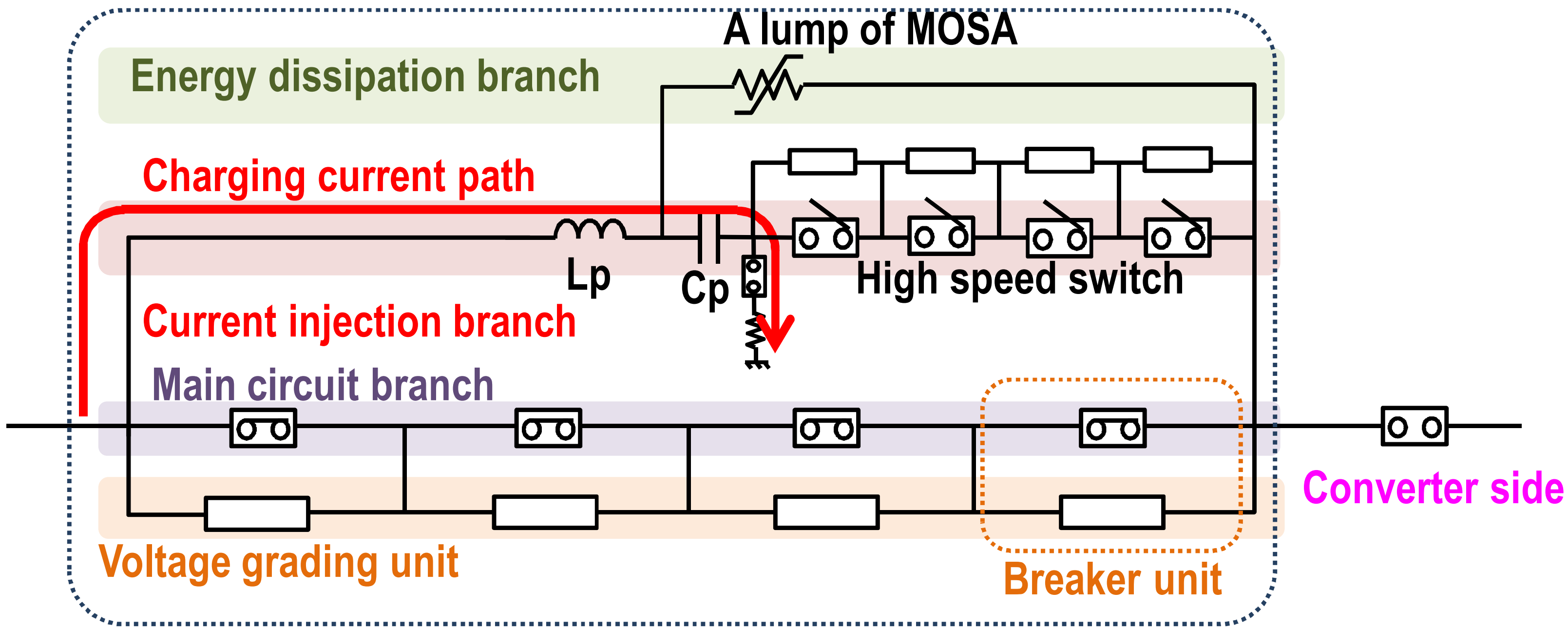
Multi-break DCCB configuration (A)

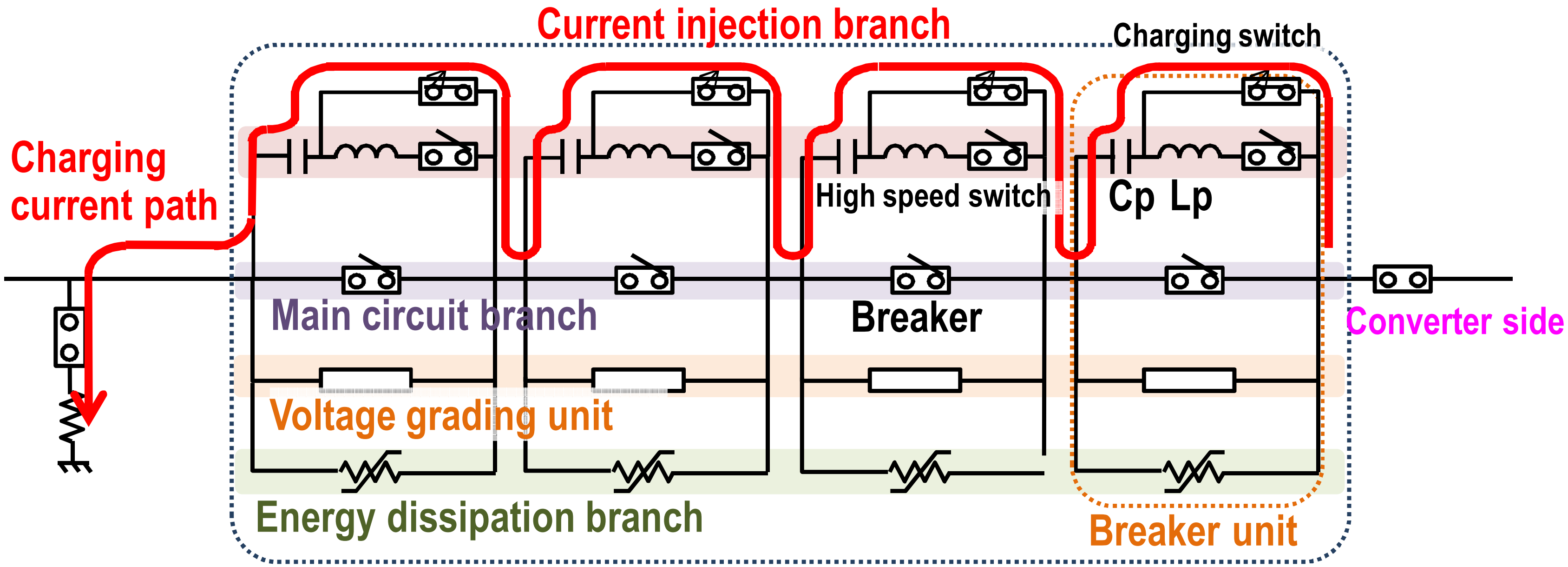
Lump current injection and MOSA design



Current injection branch is common for multi-break interrupter units
Current injection sequence for the charged capacitor is relatively simple

Multi-break DCCB configuration (B)

Module current injection and MOSA design



Each interrupter unit has their own current injection branch and MOSA.
This configuration has design flexibility for higher voltage levels.
For example, four series connection of 80 kV breaker unit can configure 320 kV

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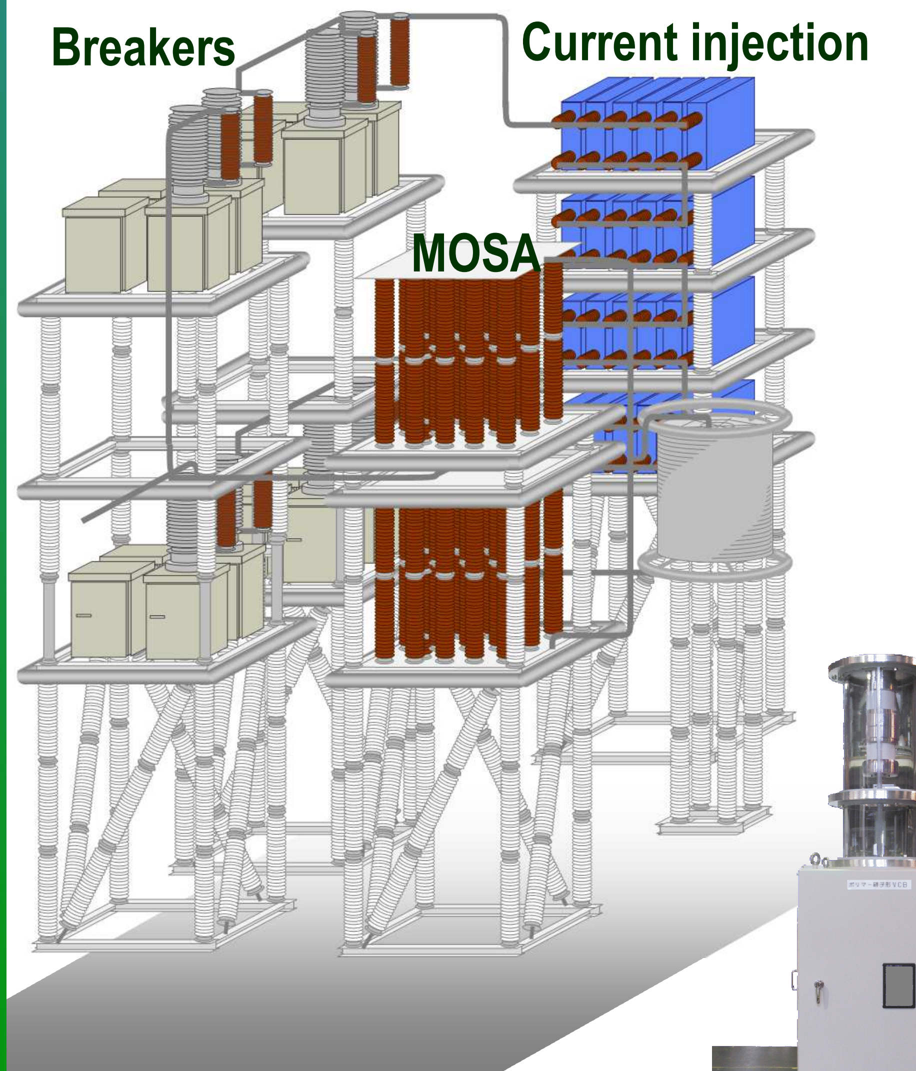
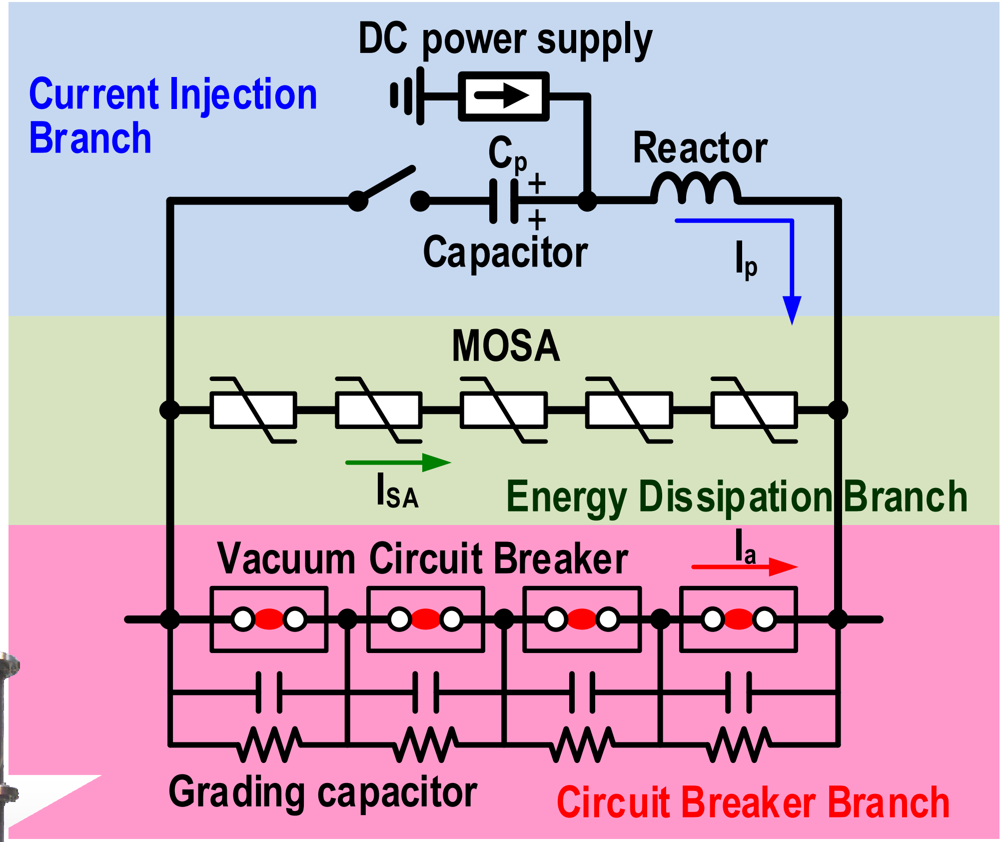
Comparison of Multi-break DCCB configuration

Item	Configuration (A), "Lump design"	Configuration (B), "Module design"
Capacitor charging sequence	Simple	Complicated
Design flexibility for higher voltage levels	Less flexible	More flexible
Impact of mechanical switch operation variation	Small	Large

DC circuit breaker prototype of 320 kV 16 kA capability



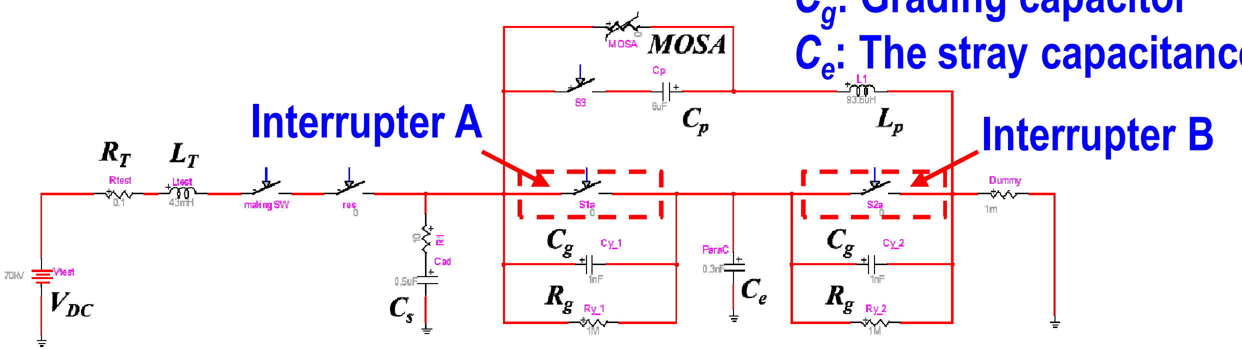


HV vacuum interrupter

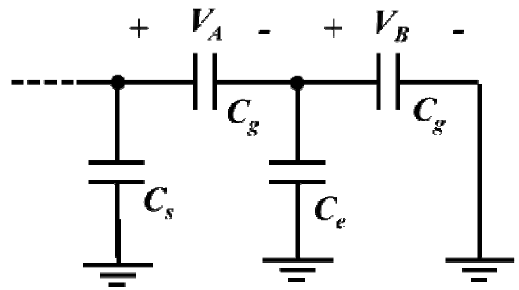
Voltage distribution of multi-break DC circuit breakers

Uniform voltage distribution is required for Multi-break EHV DC circuit breakers

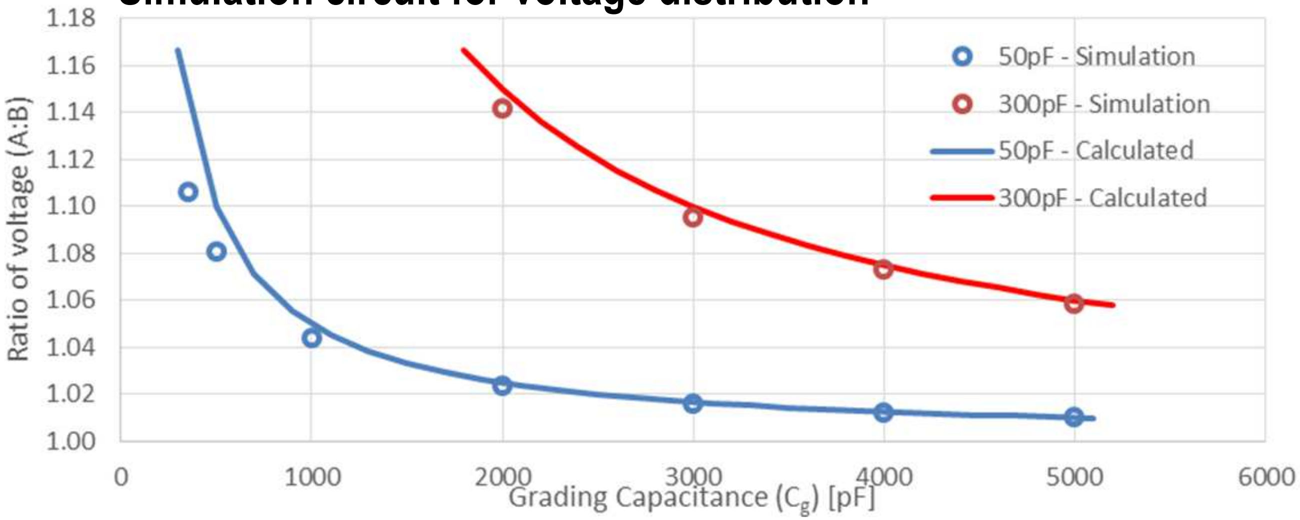
C_g: Grading capacitor
C_e: The stray capacitance to earth.



Simulation circuit for voltage distribution



Capacitance for multi-break

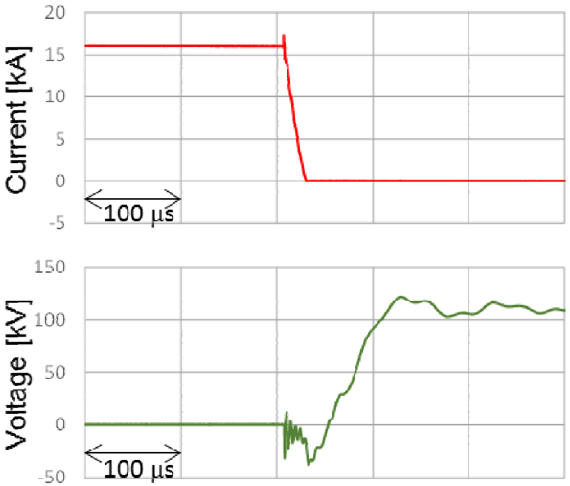


Simulation parameters
C_s [μF]: Stray assumed
C_e [pF]: 300, 50
C_g [pF]: Variable 500-5000
R_g [MΩ]: 1

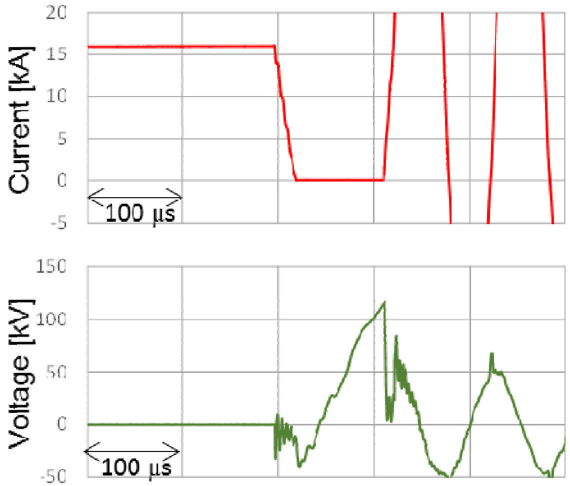
Theoretical calculation
$V_a : V_b = (C_g + C_e) : C_g$

Depending on circuit breaker design, uniform voltage distribution is expected in case of smaller C_e (grounding capacitor)

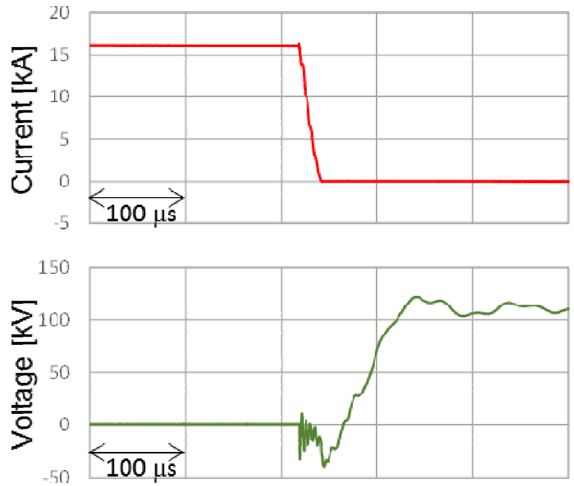
DC Interruption tests with single-break and double-breaks DC circuit breakers



Case 1



Case 2



Case 3

Double-break DC circuit breakers show better successful thermal and dielectric interruption performance with shorter arcing time (shorter contact gap) compared with the single-break.

Case No.	Test current (kA)	Number of the breaks	Arcing Time (Contact gap)	Success or failure	
				Thermal	Dielectric
1	16	1	Standard (100%)	Success	Success
2	16	1	Shorter (70%)	Success	Failure
3	16	2	Shorter (70% x 2)	Success	Success