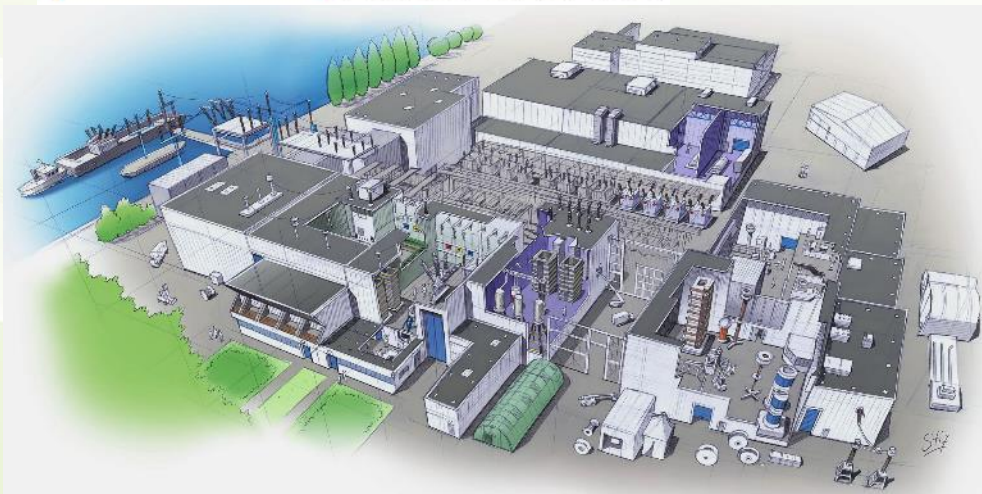


HVDC Circuit Breaker Technologies and Performance Demonstration

KEMA

Laboratories



PROMOTioN

PROGRESS ON MESHED HVDC
OFFSHORE TRANSMISSION
NETWORKS

Nadew A. Belda, Innovation Engineer
KEMA Laboratories, Innovation

Outline

- Introduction
 - ✓ HVDC Grid Protection – Options
 - ✓ AC Vs DC Current Interruption
- DC Current Interruption Techniques
 - ✓ HVDC Circuit Breaker Technologies – PROMOTioN Project
- Testing Experience of HVDC Circuit Breakers – PROMOTioN Project
 - ✓ Test results - useful input for test requirement specification
 - ✓ Focus on electrical stresses - current, voltage and energy
- Summary

HVDC Grid Protection – Options

- Using AC Circuit Breakers

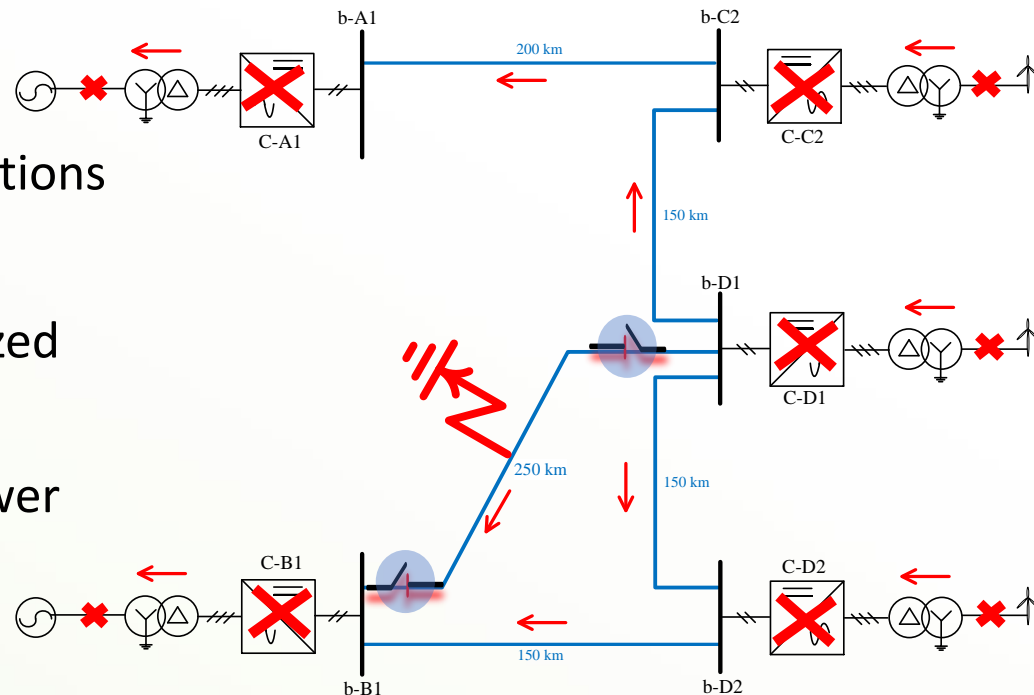
- ✓ De-energizes DC side
- ✓ Power flow interruption
- ✓ Used in point-to-point connections

- Using full-bridge converters

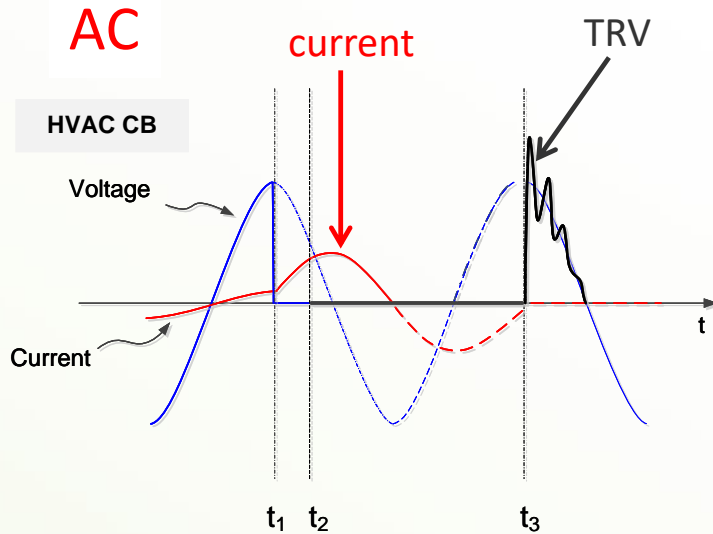
- ✓ DC lines and cables de-energized
- ✓ Power flow interruption
- ✓ Losses and the number of power electronics

- Using HVDC CBs on the DC lines

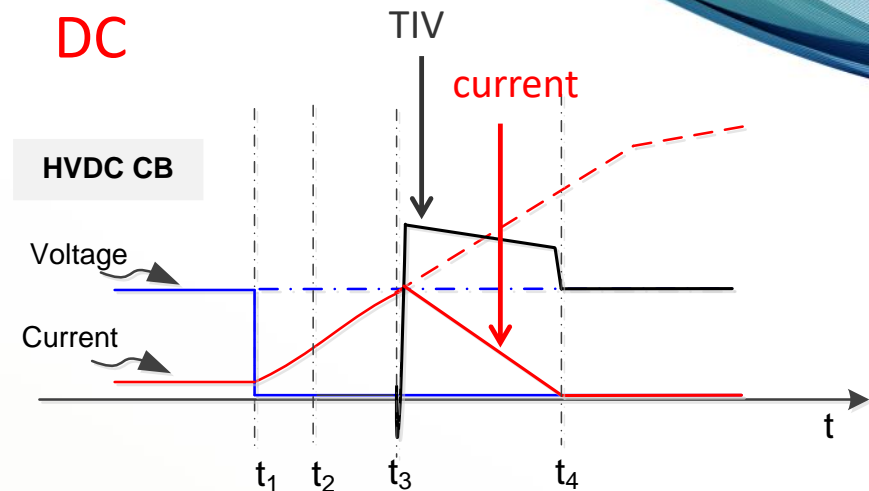
- ✓ Selective isolation of fault
- ✓ Power flow in the healthy part



AC Vs DC Current Interruption



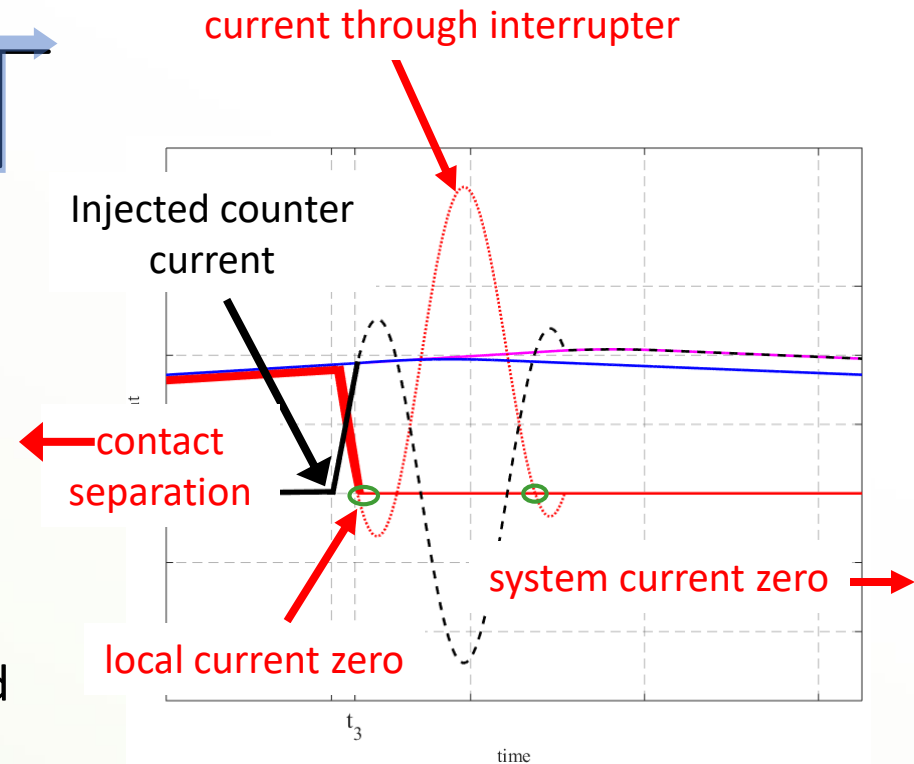
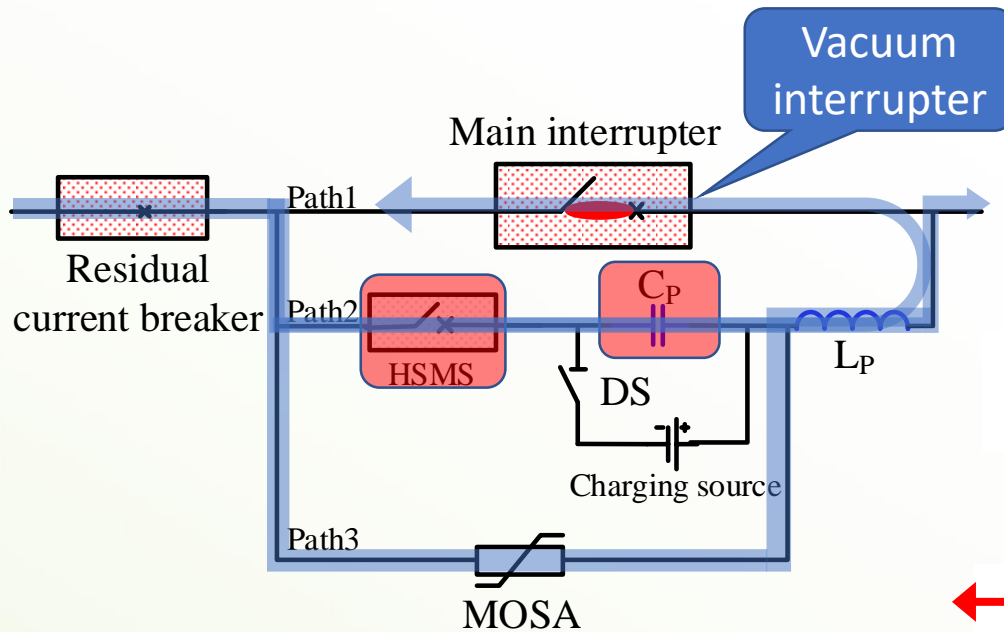
- AC CB is passive –system determines short-circuit current
- System imposes TRV
- Synthetic test method can be applied



- DC CB is active - determines the peak current
- DC CB determines the TIV
- Needs MegaWatts to test

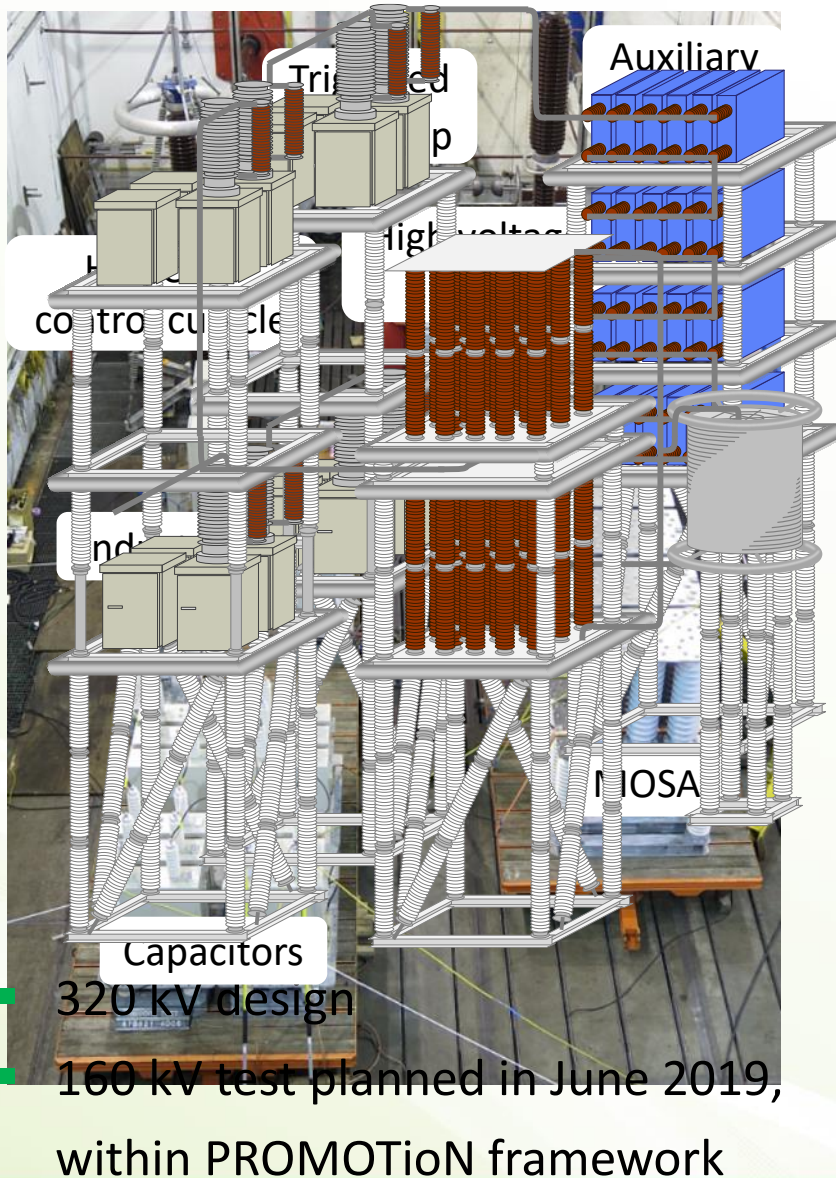


Active Current Injection HVDC CB

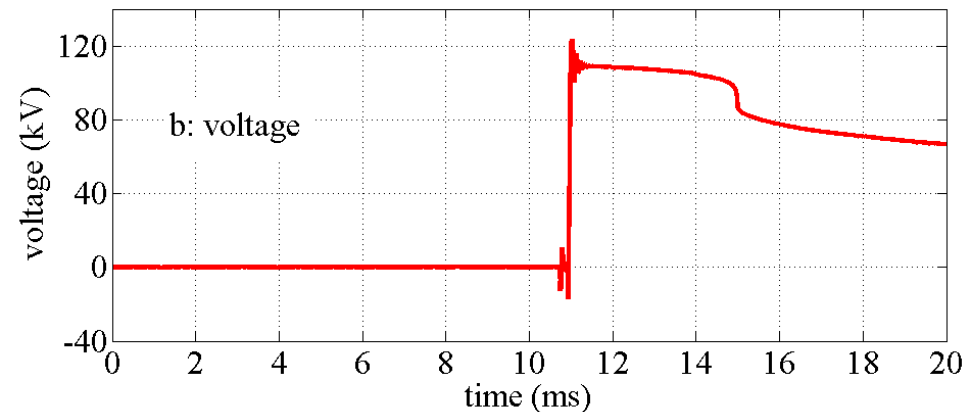
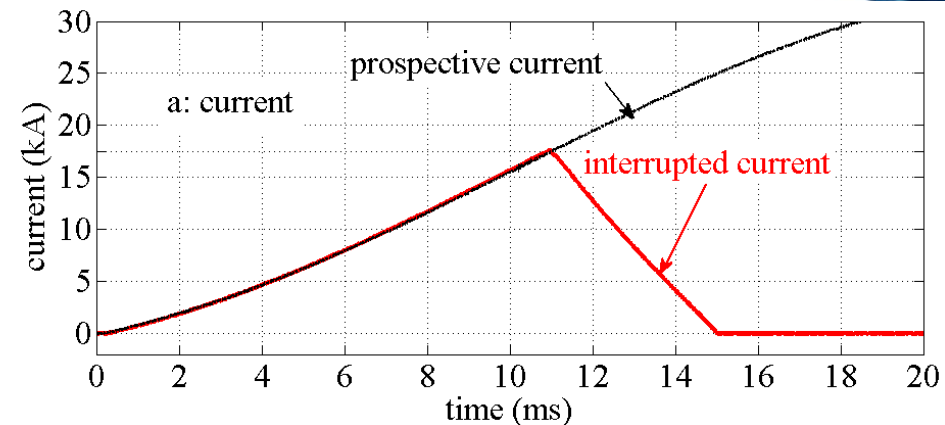


- Faster operation speed can be achieved
- Better performance near current zero crossing compared to gas circuit breaker

Active Current Injection HVDC CB

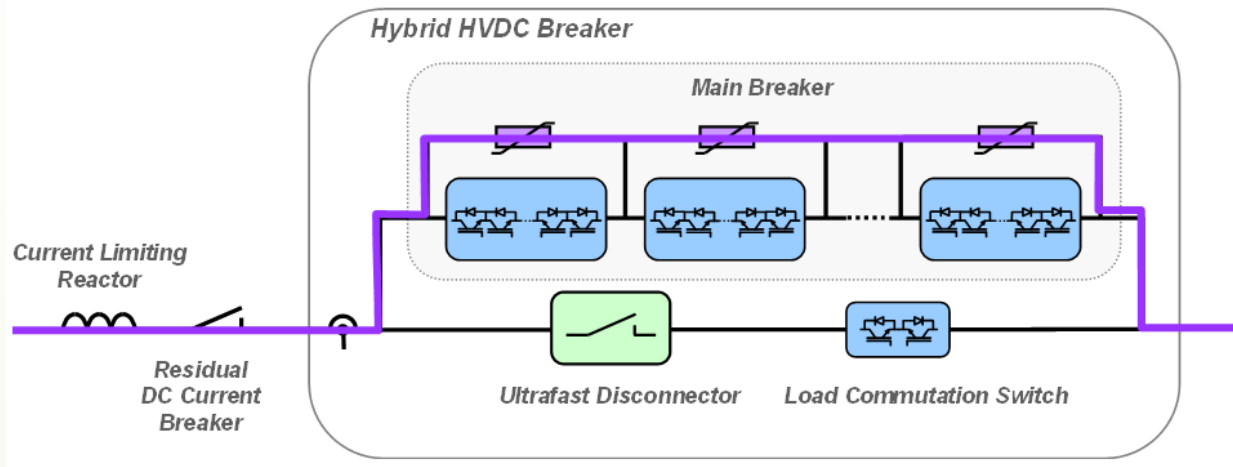


Test Result

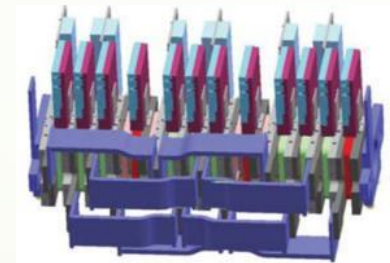
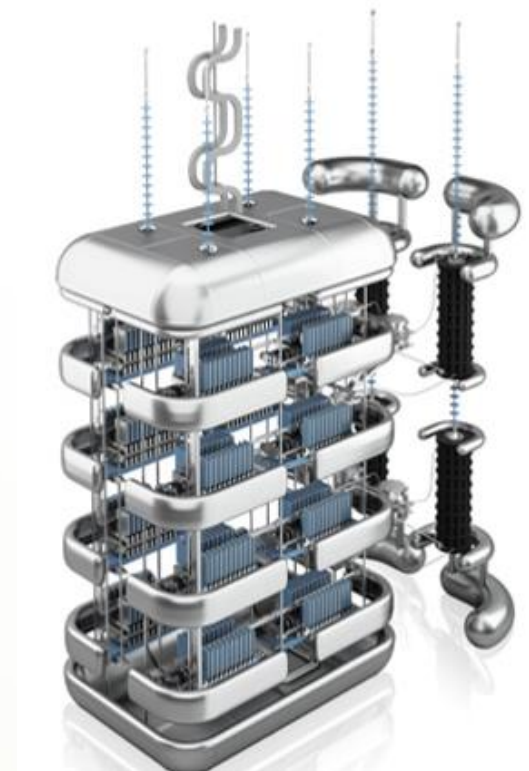
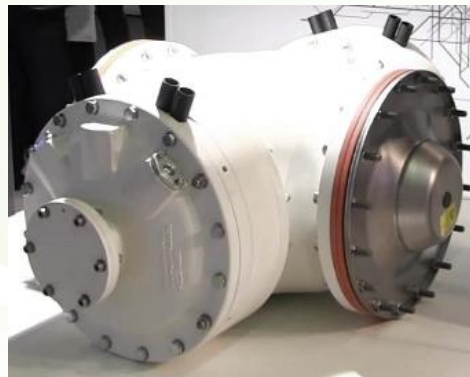


- Bidirectional current interruption tested
- Three test duties, current 2 → 16 kA
- 120 kV peak \bar{U}_V , 4 MJ energy absorbed

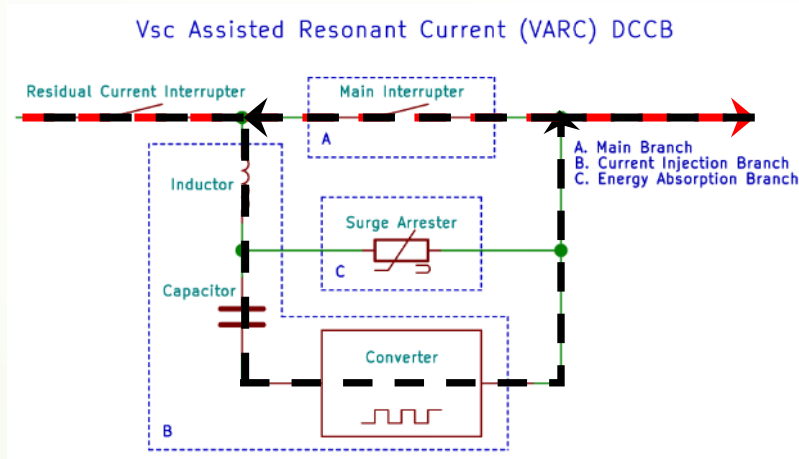
Hybrid HVDC CB



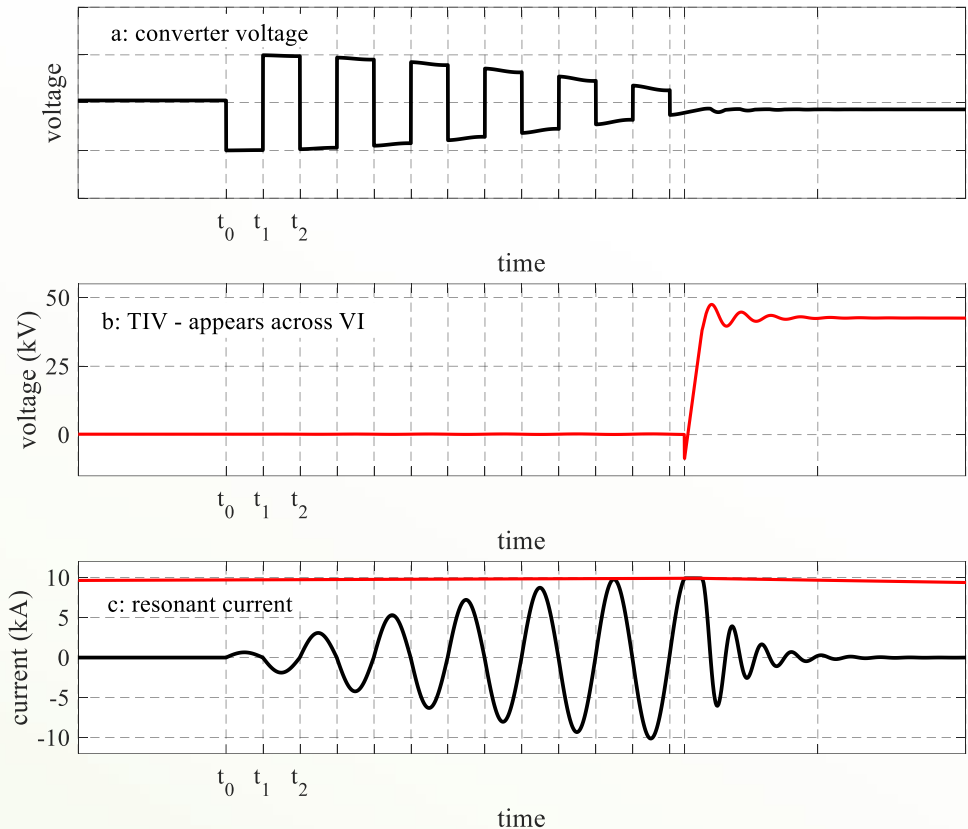
- 350 kV Hybrid HVDC CB to be tested within PROMOTioN framework
- 15 kA, up to 500 kV TIV
- 10 MJ energy absorption



VSC Assisted Resonant DC CB (VARC)



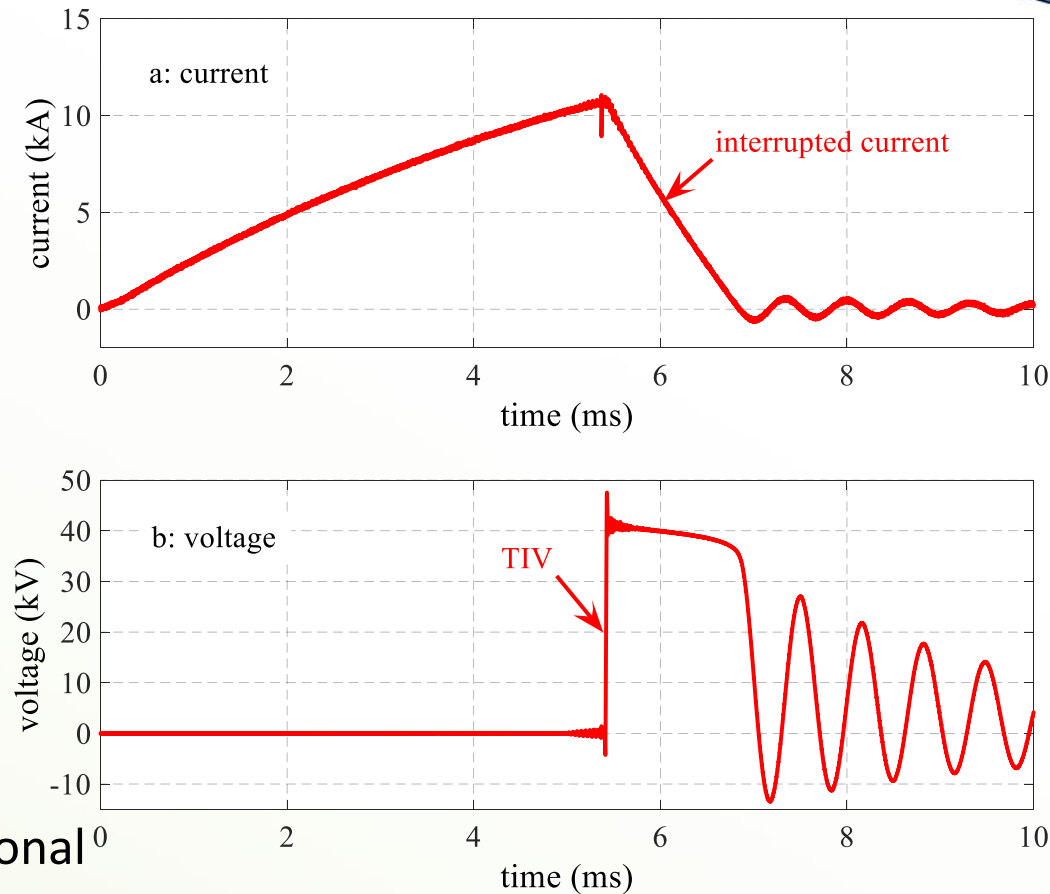
- A new concept - VSC converter assisted oscillation
- Vacuum interrupter - as the main interrupter
- The VSC uses a few power electronics



VSC Assisted Resonant DC CB (VARC)



Test Result



- Test performed at 10 kA, bidirectional
- Breaker produced 40 kV TIV
- Three series connected modules planned for testing beginning of 2020

Some other experiences – CIGRE 2018

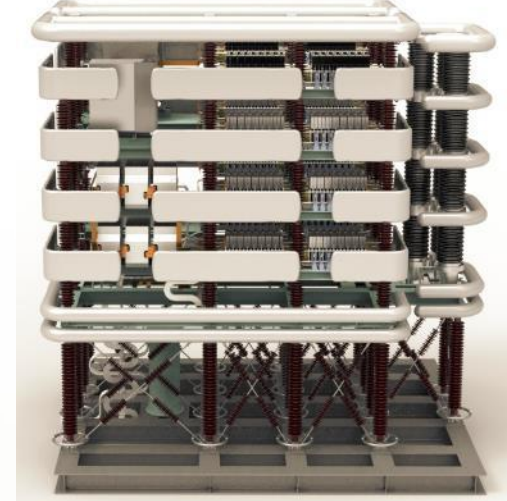
160 kV, mechanical active injection, in service in Nan'ao



Some on site testing, Nan'oa



200 kV, hybrid, in service in Zhoushan



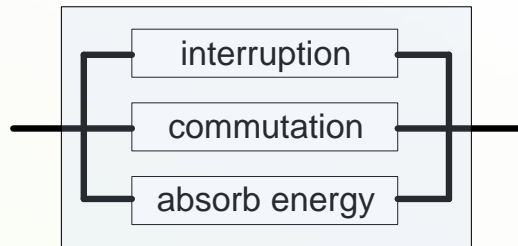
500 kV Hybrid HVDC CB



Zhangbei, ± 500 kV, 4 terminal



DC interruption process



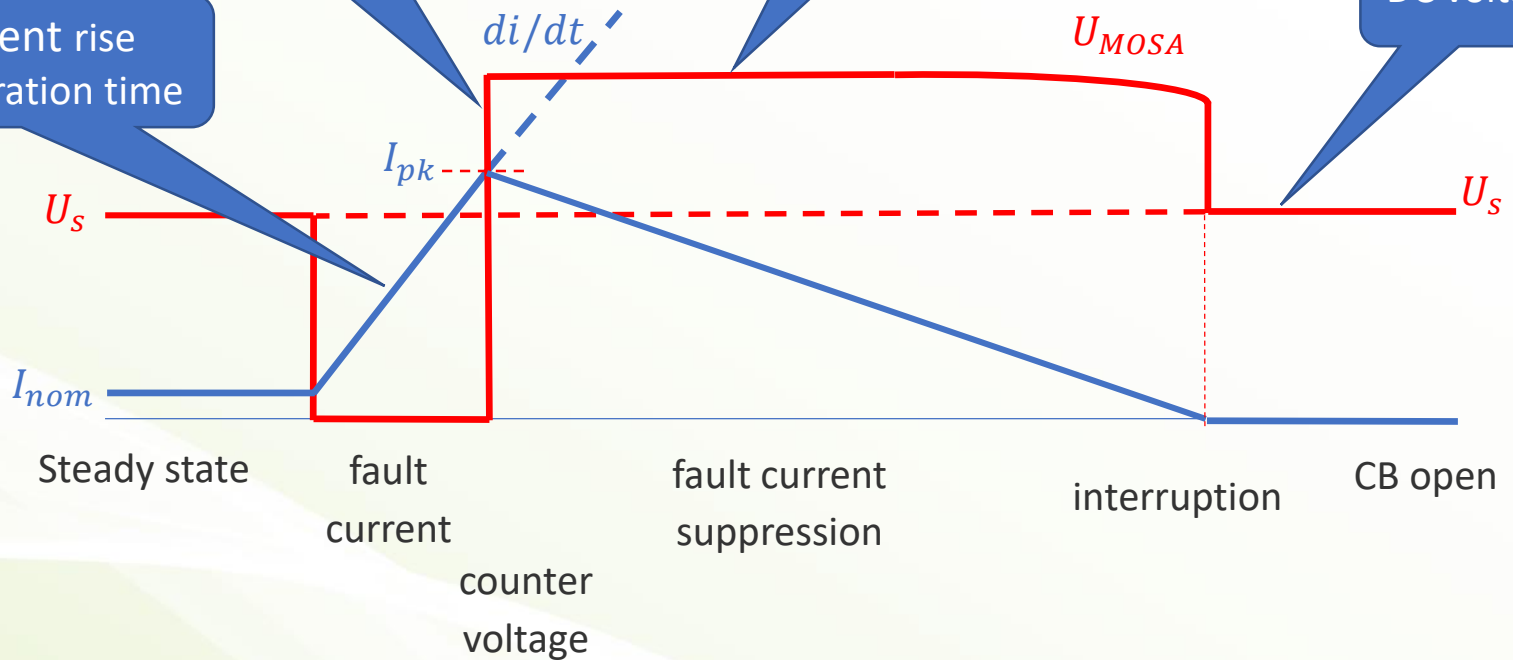
Test methods shall cover all stresses

commutation and counter-voltage

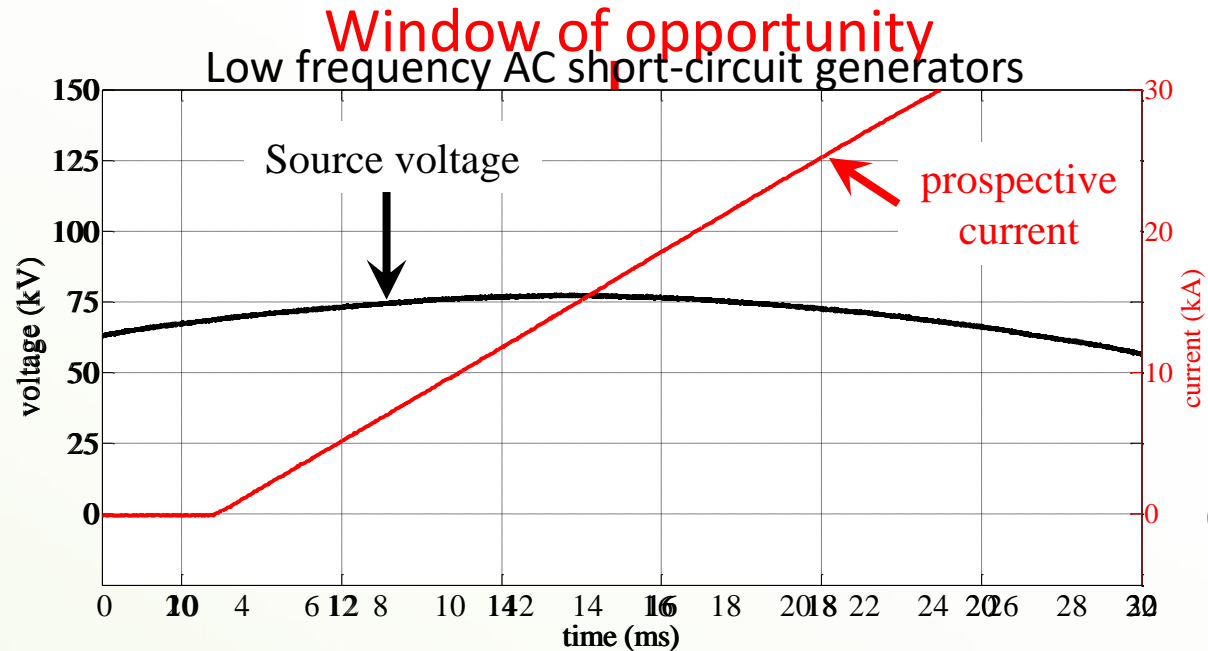
energy absorption and overvoltage

DC voltage

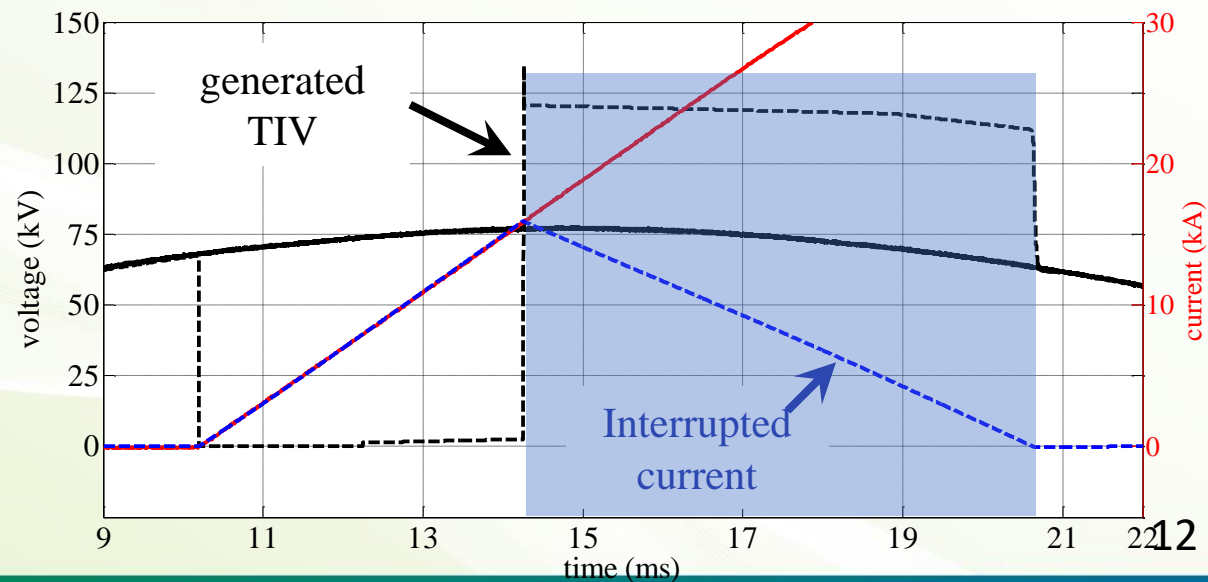
fault current rise
Breaker operation time



Test Method

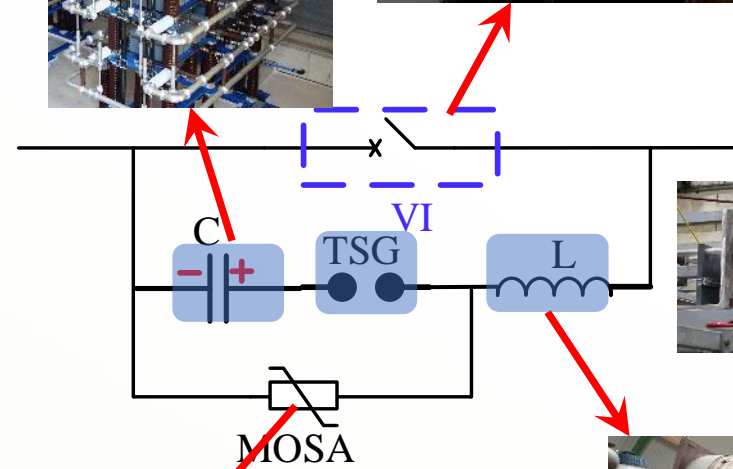
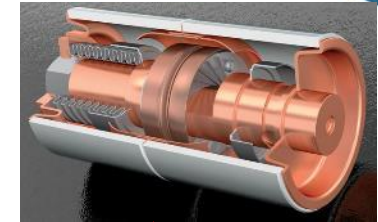
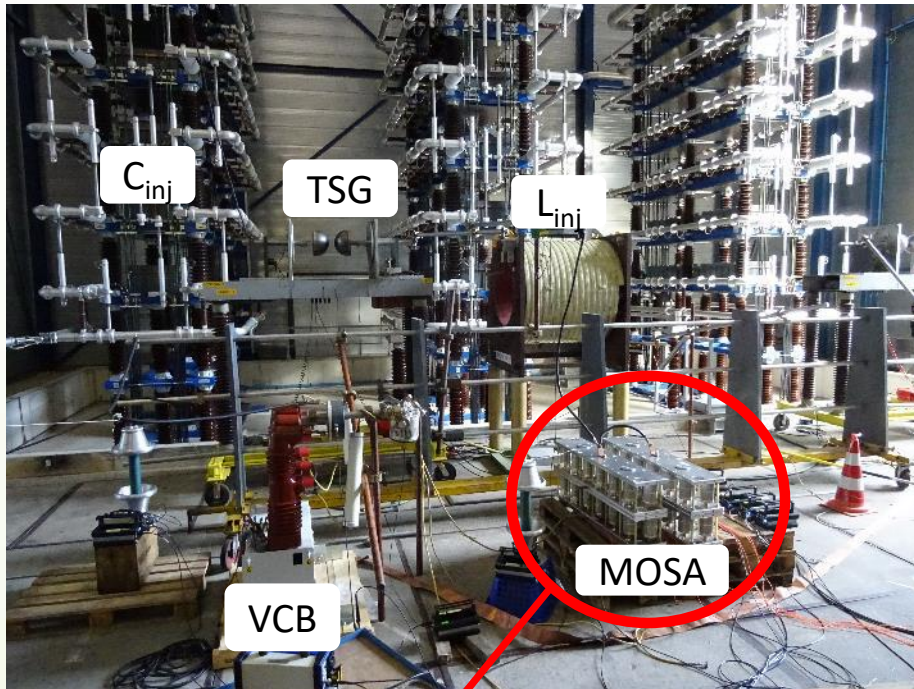


6 Short-circuit Generators

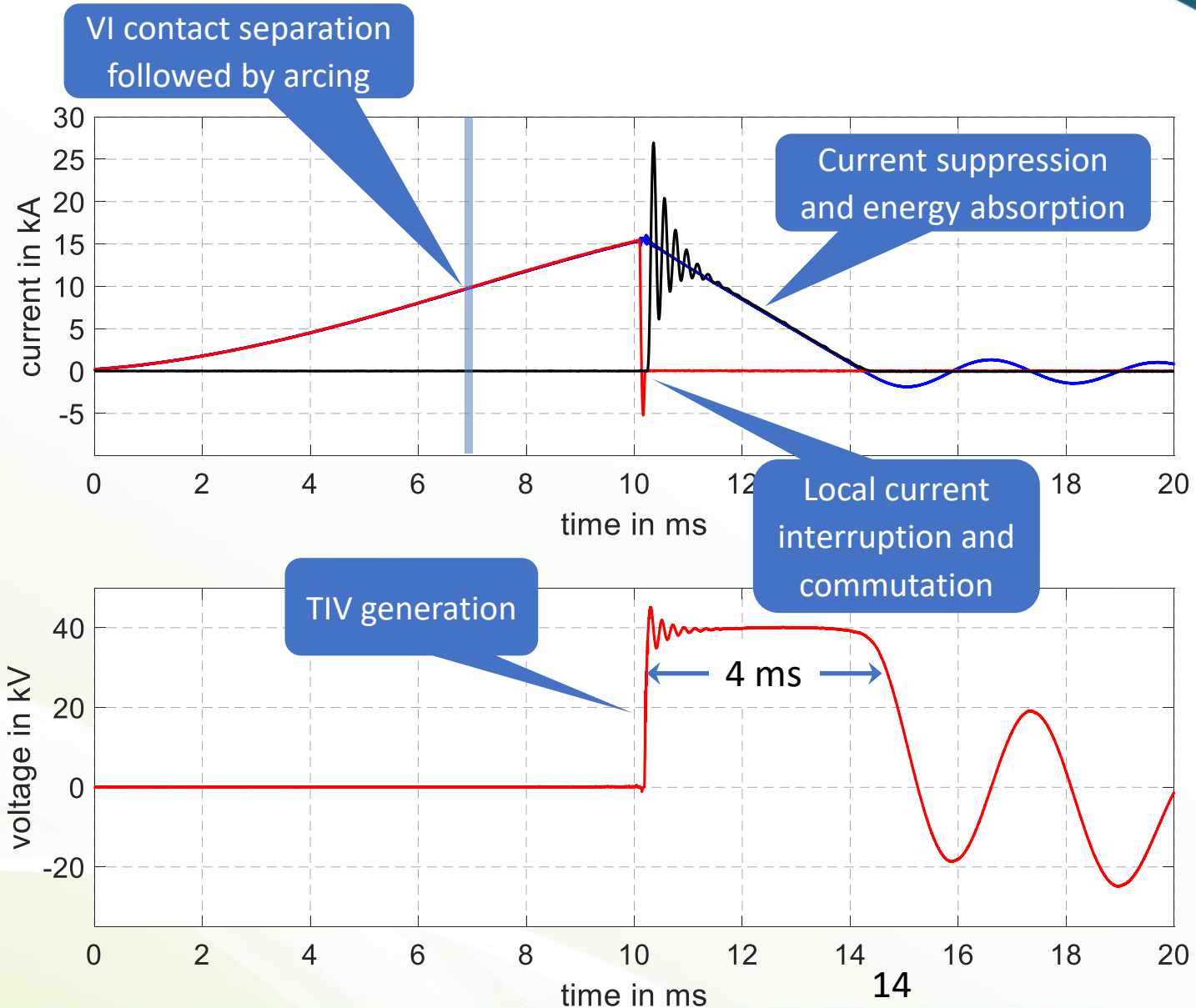


10 Step-up Transformers

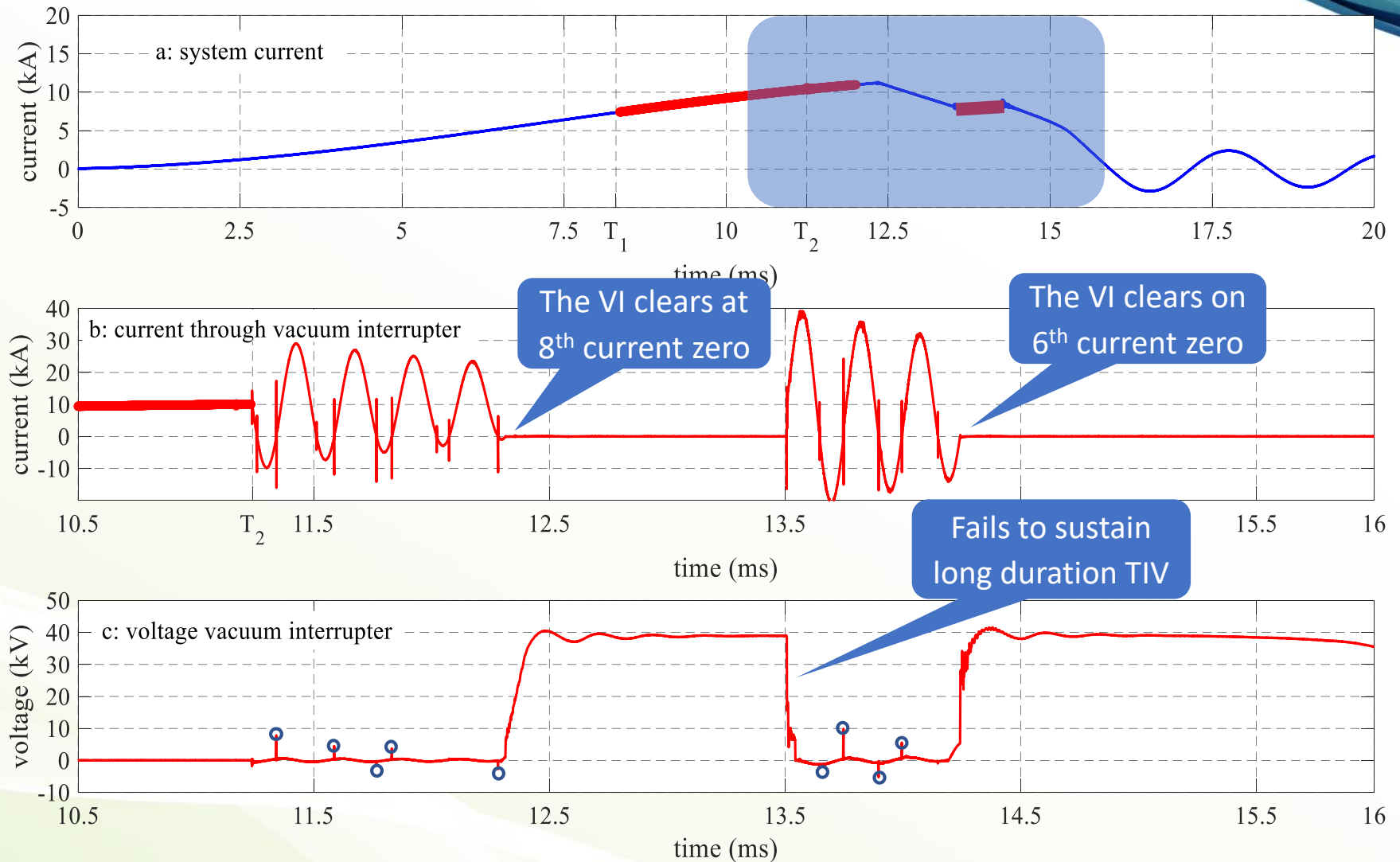
Experimental DC CB setup



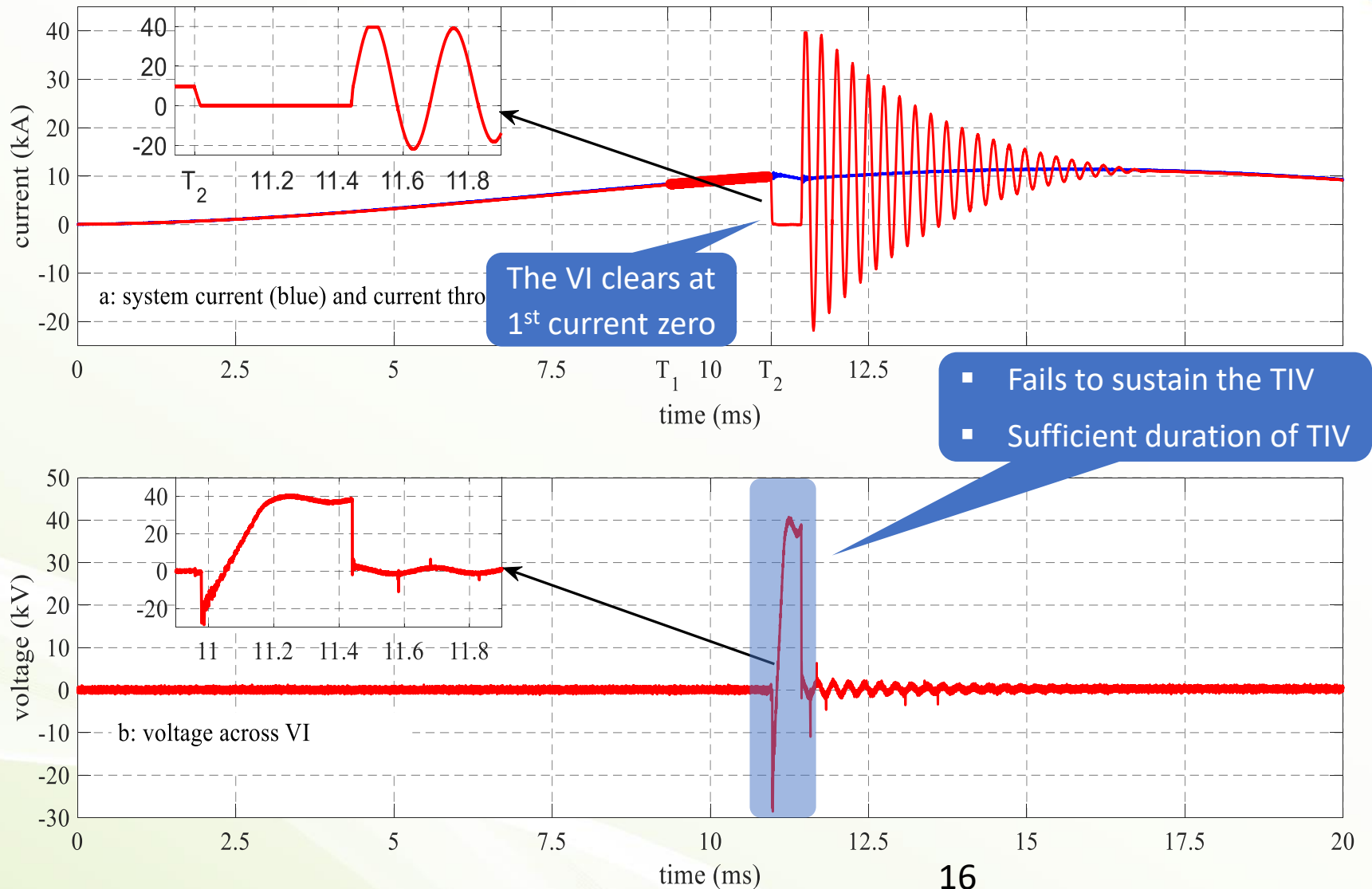
Test Results – expected operation



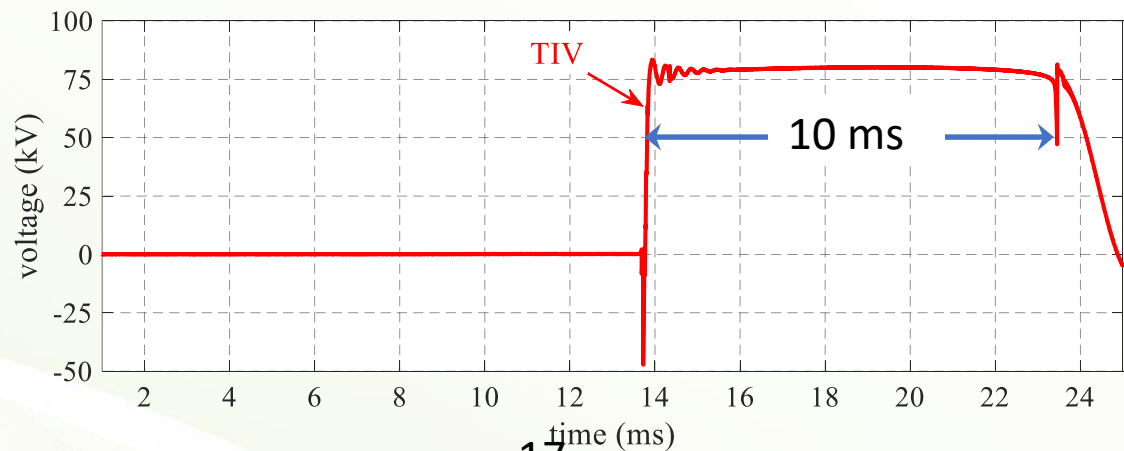
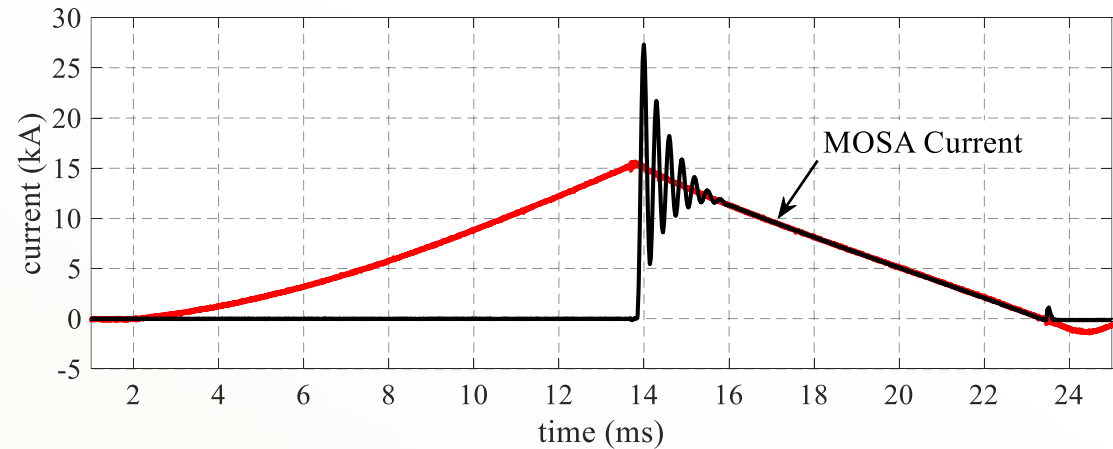
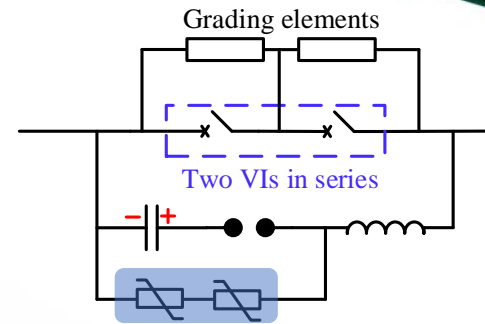
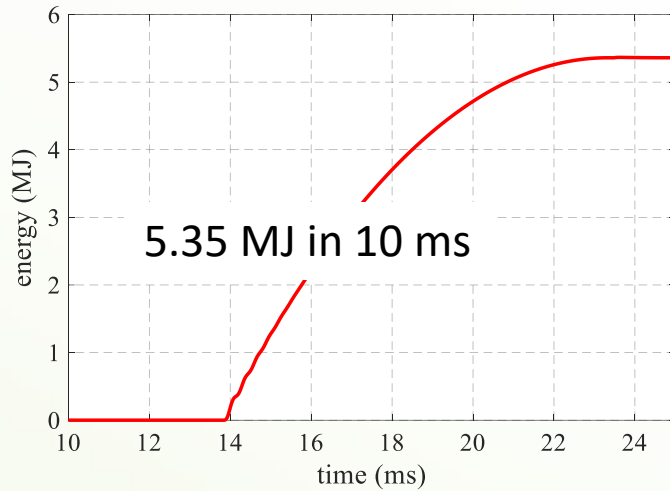
Test Results – late restrike



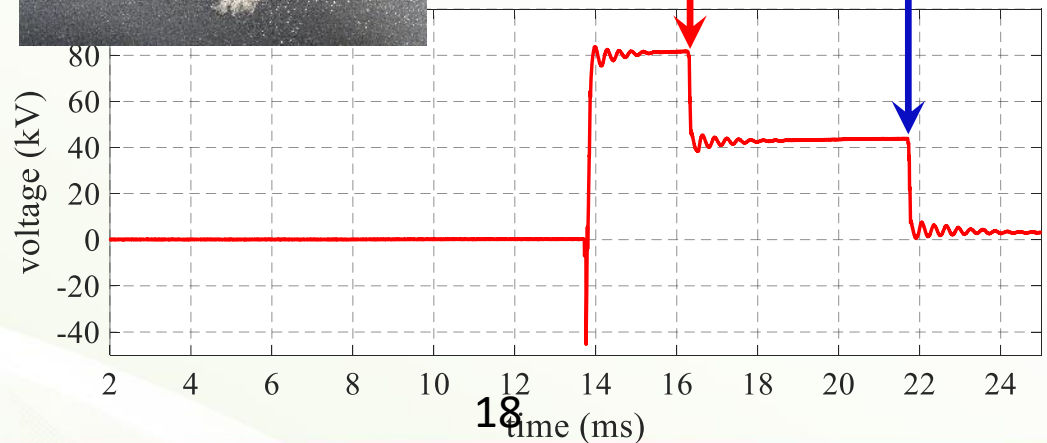
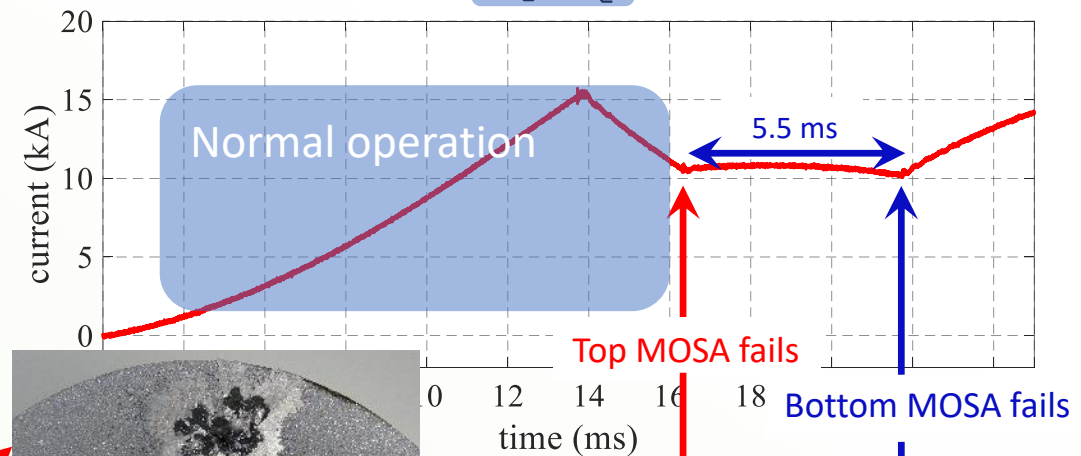
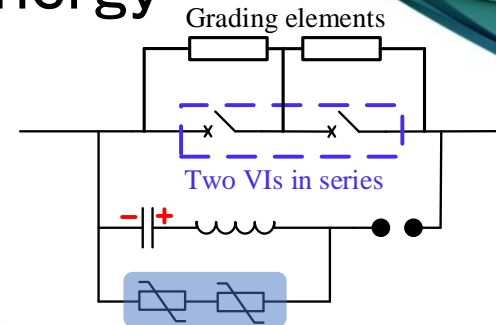
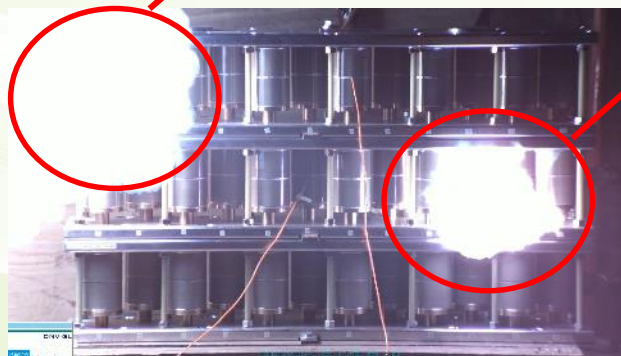
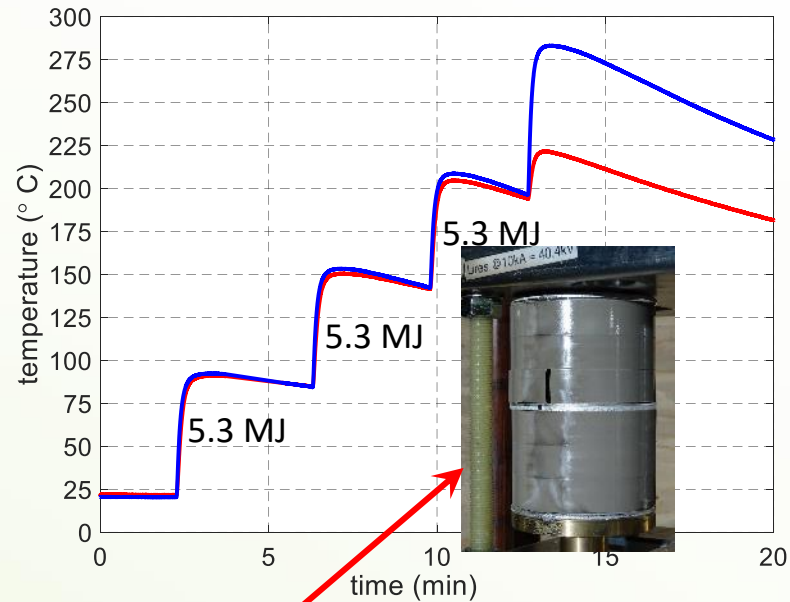
Test Results – late restrike and fail



Test Results – high energy



Test Results – Successive high energy



Summary

- Several HVDC CB concepts have been developed – prototype tested
- Testing so far focuses on proof of concepts – not on complete stress
- Four critical stages in fault current interruption:
 - ✓ Fault current rise – breaker operation time
 - ✓ Commutation and counter voltage – magnitude and duration of TIV
 - ✓ Energy absorption – stresses on internal components
 - ✓ DC voltage stress across open breaker – sufficient duration
- Adequate testing should represent each of these stages, stressing different subcomponents at each stage of current interruption process
- The use of multiple AC generators running in low-frequency offers a one-stop test possibility – developed and verified in PROMOTioN project



Thank you!