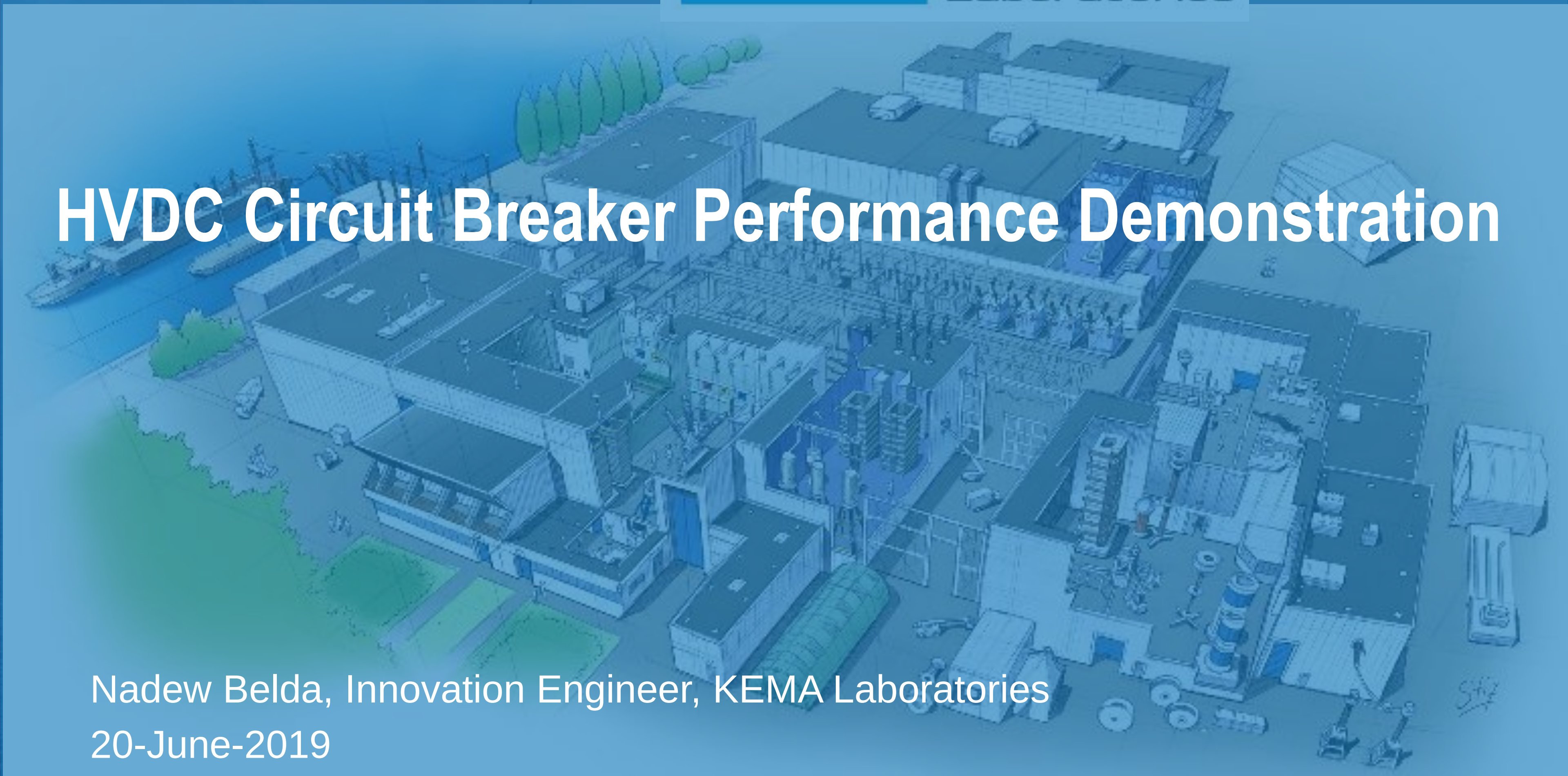
PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

KEMA Laboratories

HVDC Circuit Breaker Performance Demonstration



Nadew Belda, Innovation Engineer, KEMA Laboratories

20-June-2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691714.

Outline

- Introduction
  - ✓ HVDC Converter Operation
  - ✓ Fault Condition in HVDC Grids
  - ✓ HVDC Grid Protection – Options
- AC Vs DC Current Interruption
- Testing Method and Test Circuit of HVDC Circuit Breaker
- Test Program
- Expected Test Result
- Summary

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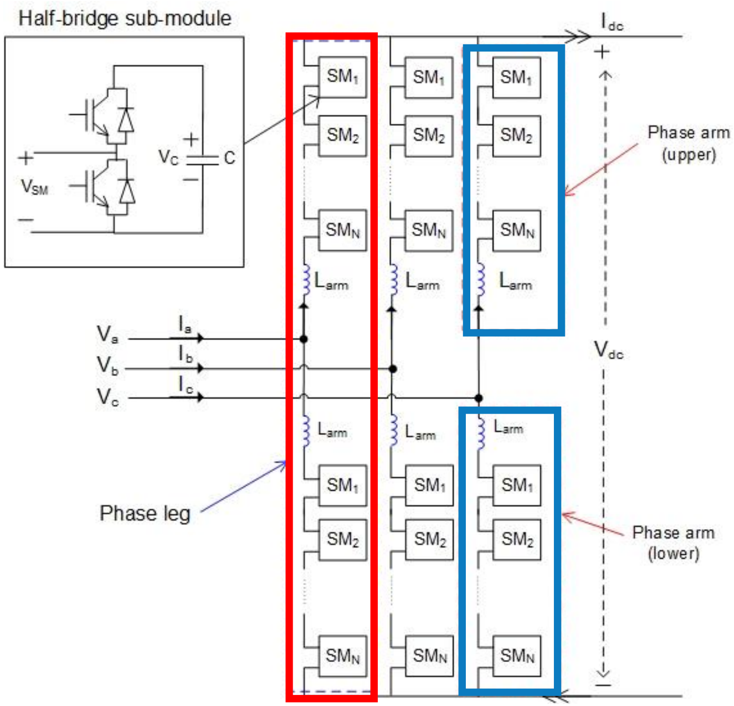
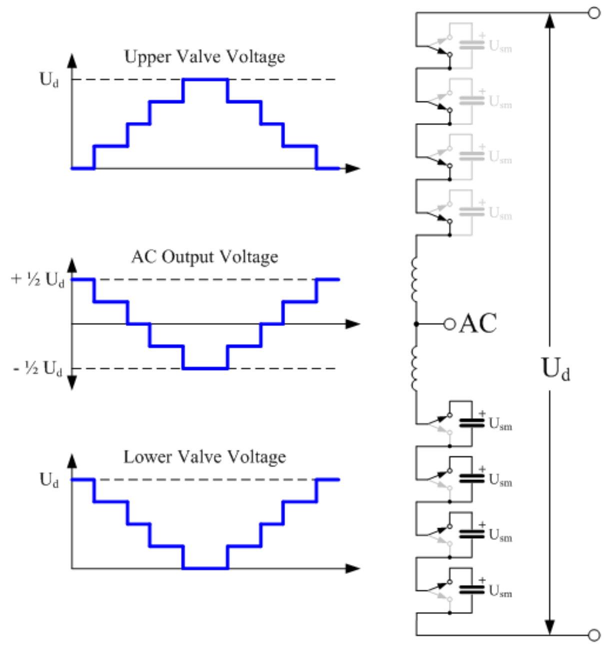
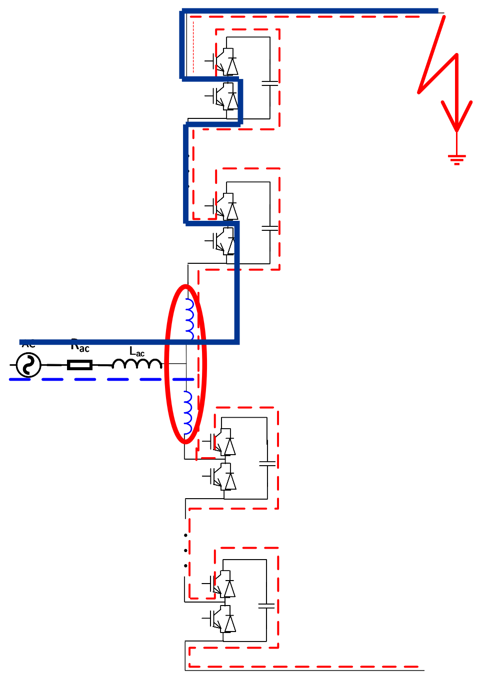
HVDC Converter – Half-bridge Modular Multi-level Converter (MMC)







Source: Wikipedia

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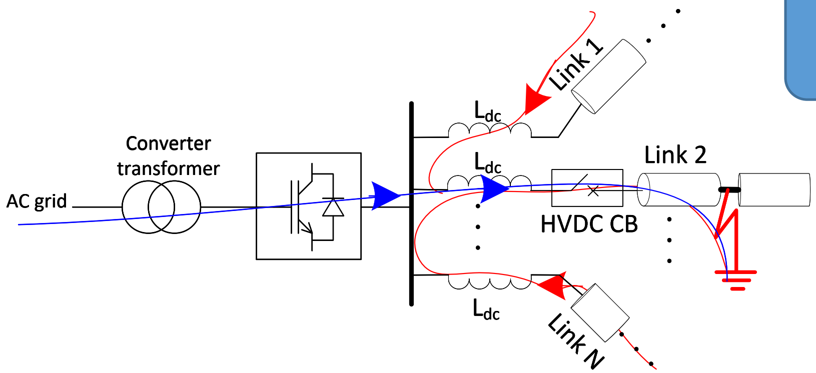
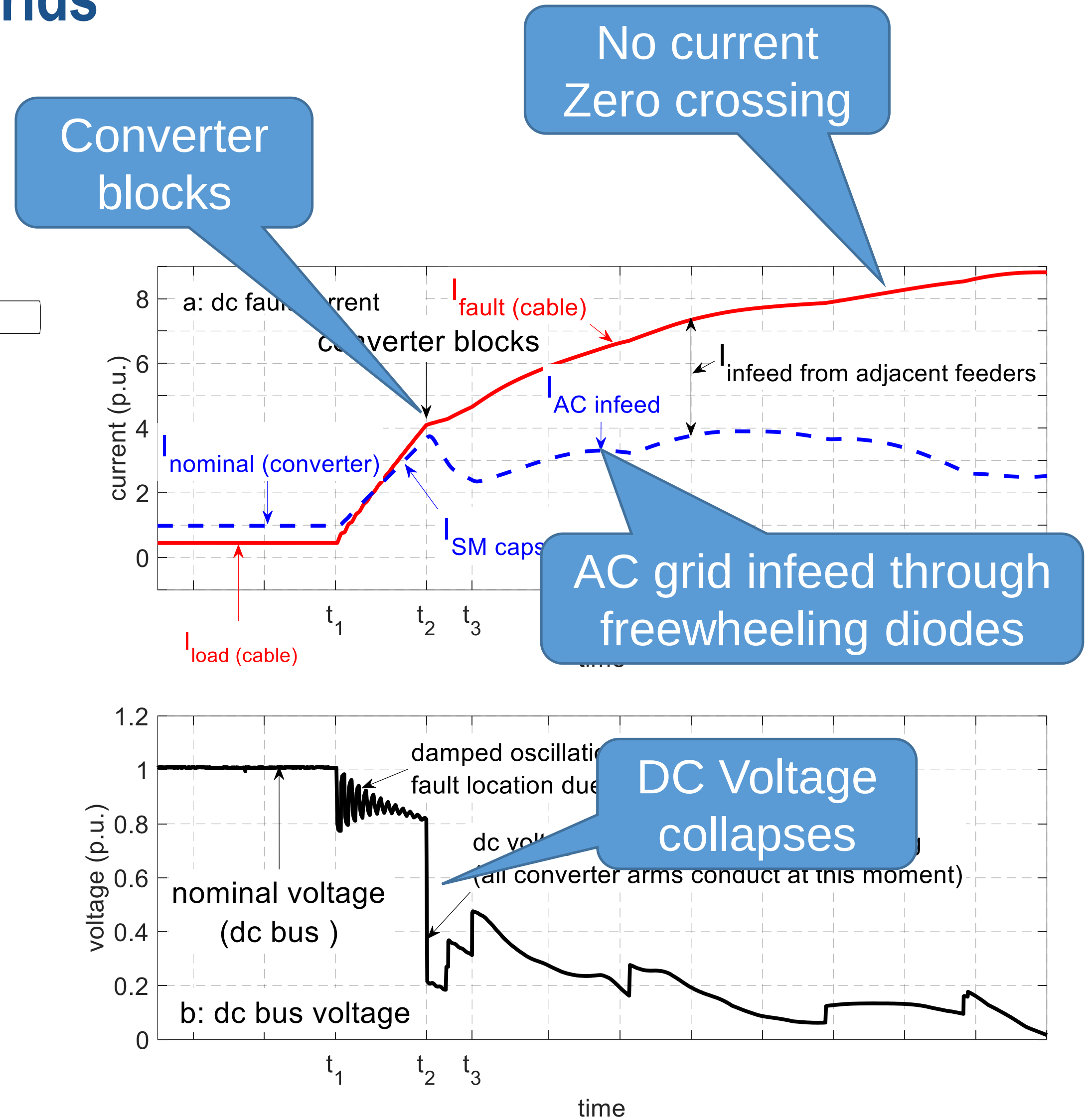
Fault Condition in HVDC Grids





- The fault current grows rapidly
- Prevents discharge of SM capacitors
  - Protects power electronic components

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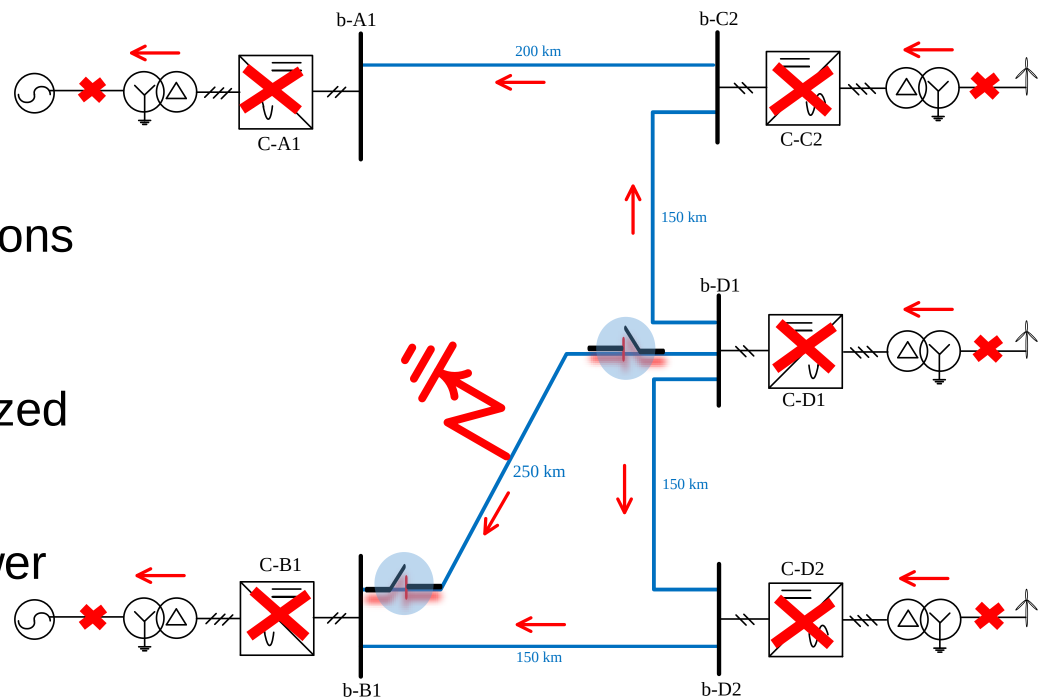
HVDC Grid Protection - Options

- 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



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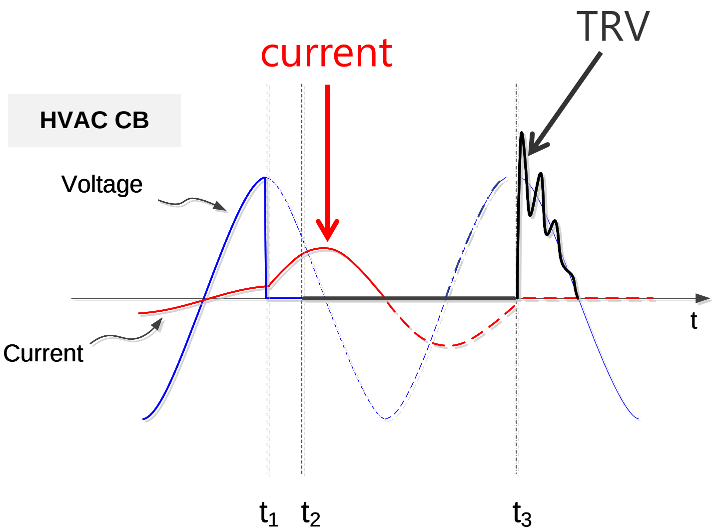
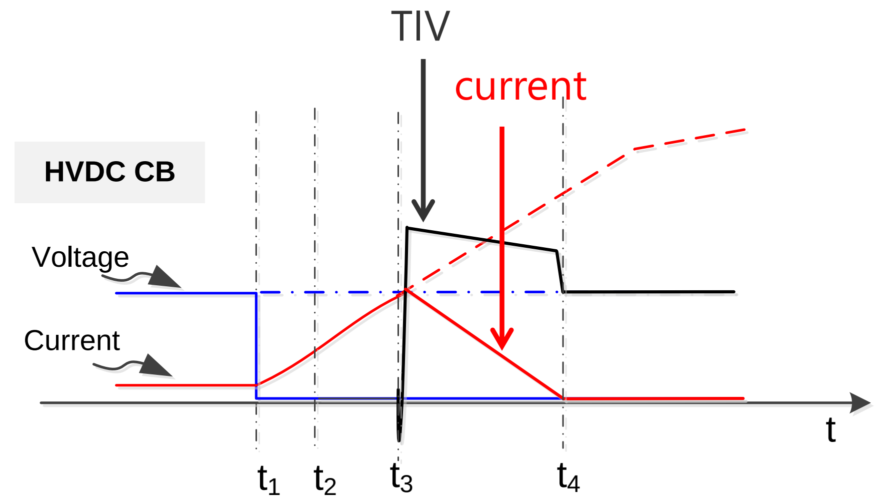
AC Vs DC Current Interruption

AC interruption



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

DC interruption



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

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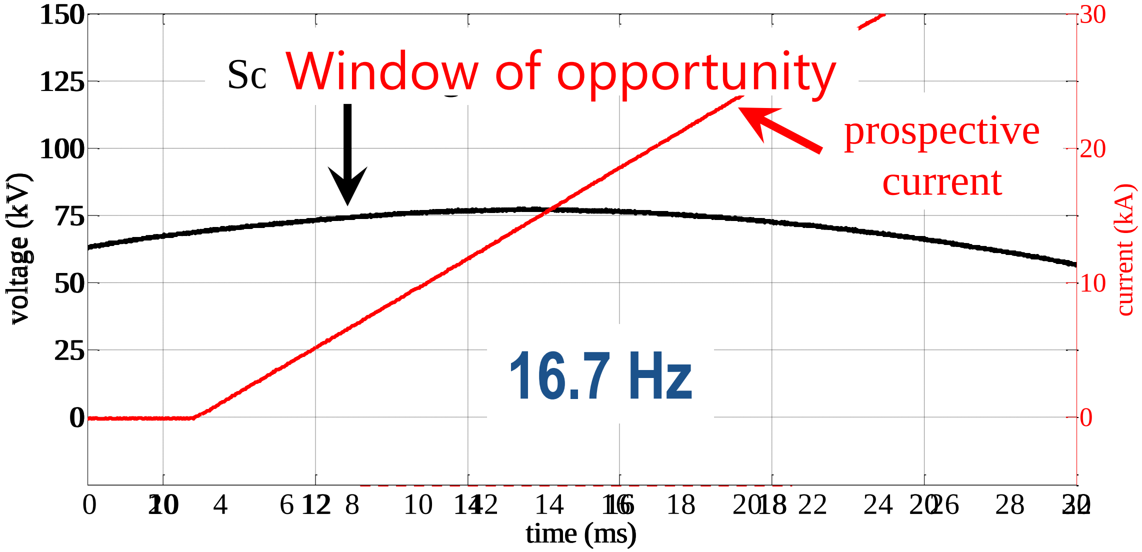
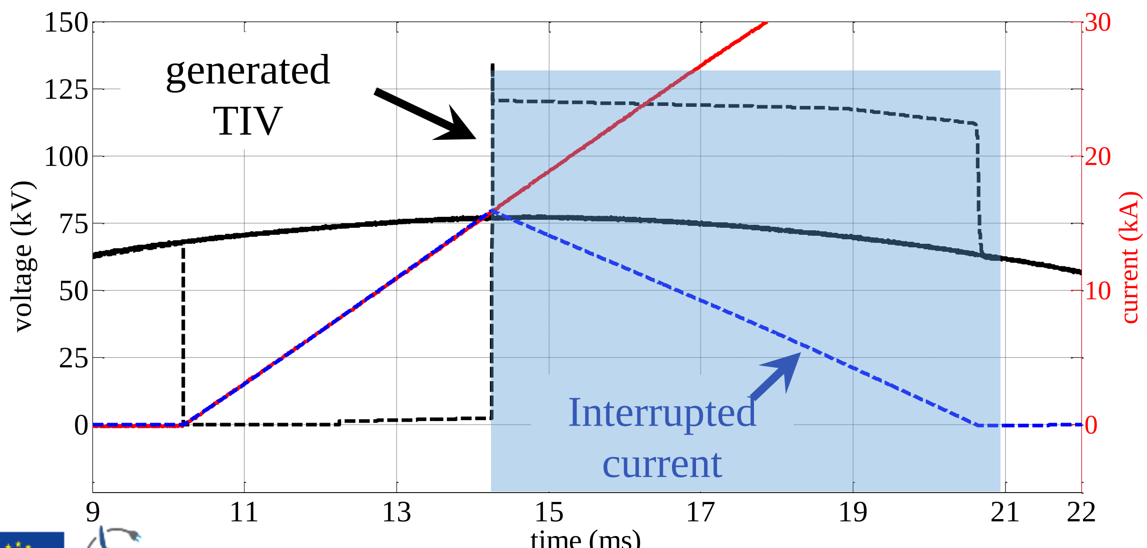
Test Method – Using Low Frequency AC Generators



6 Short-circuit Generators



10 Step-up Transformers

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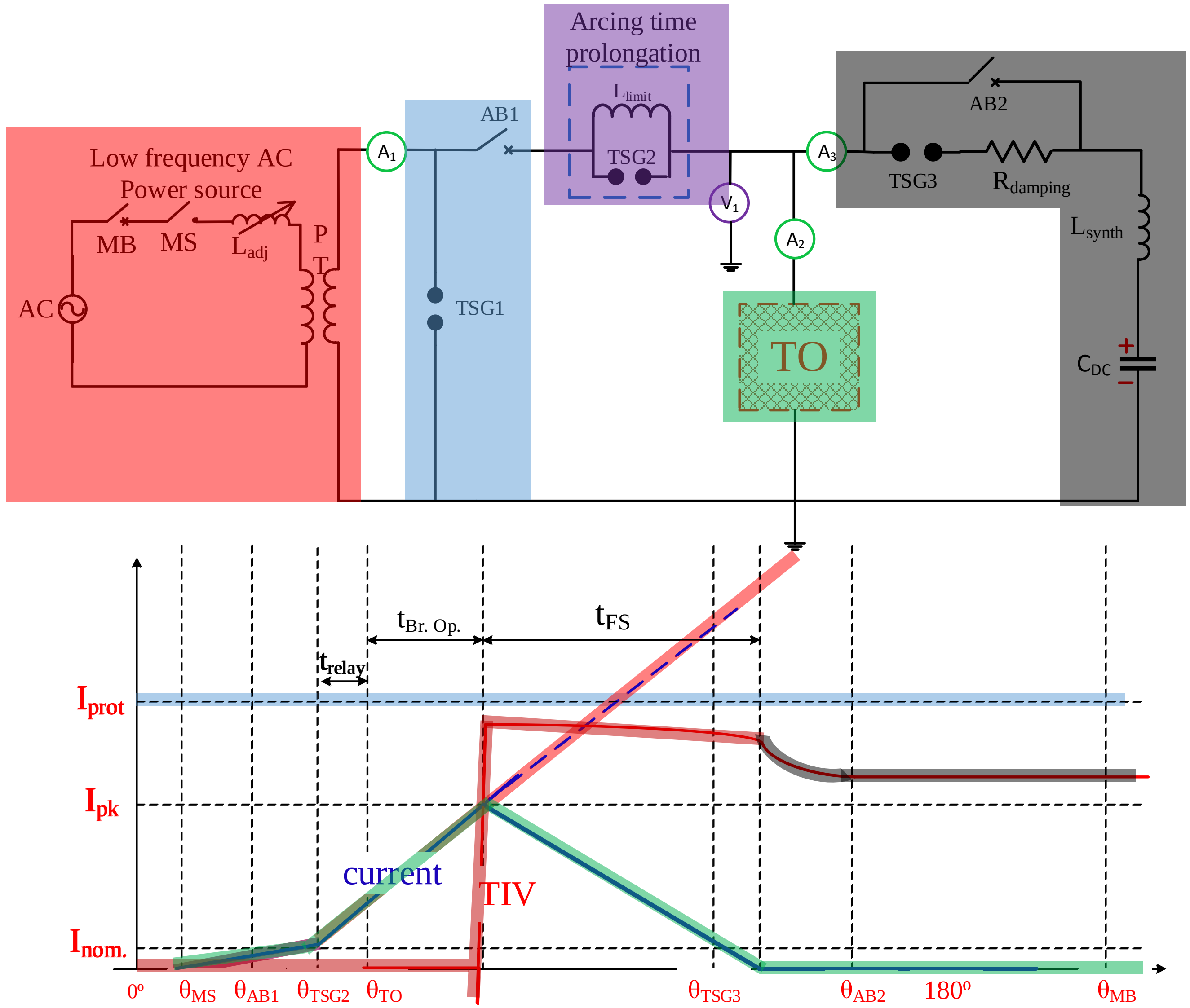
Test Circuit

Power Source

Protection

Arc time prolongation

DC source



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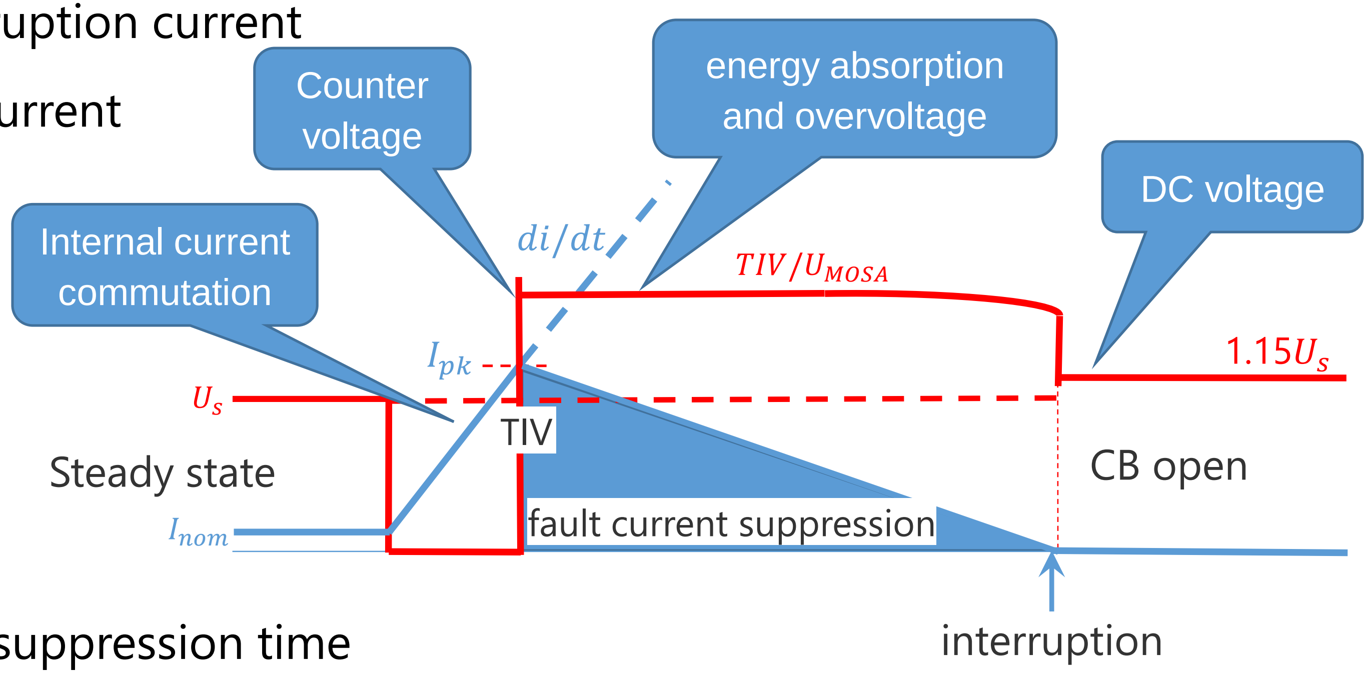
Stresses During DC Current Interruption

Four Critical Stages – need to be verified

- Breaker data needed:
  - U_s = System voltage
  - I_{pk} = Peak interruption current
  - ΔT_{ic} = internal current commutation
  - TIV



- ΔT_{fs} = fault current suppression time
- Energy = Energy absorption

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Proposed breaking test requirements – Test program

Name	Current	Breaking test	#
TC10+	10% of rated continuous current	2 tests in positive current direction	2
TC10-	10% of rated continuous current	2 tests in negative current direction	2
TC100+	100% of rated continuous current	2 tests in positive current direction	2
TC100-	100% of rated continuous current	2 tests in negative current direction	2
TF100+	100% of peak fault current	2 test at specified energy absorption*, positive current direction	2
TF100-	100% of peak fault current	2 test at specified energy absorption*, negative current direction	2
TDT+	TBD	2 test at rated fault current suppression time**, positive current direction	2
TDT-	TBD	2 test at rated fault current suppression time**, negative current direction	2
	*: Specified energy absorption based on specified value of energy absorption (MJ) of the test-object delivered **: Rated fault current suppression time based on *Us, UMOSA, ΔTic, Ipk*, as would be present in service condition		
	All tests are single opening operations		
	In all tests, *Us* (considering 10-15 % overvoltage) will be supplied during 300 ms after main current interruption		

TC = nominal/continuous current

TF = Fault current

TDT = Delta time/Fault suppression

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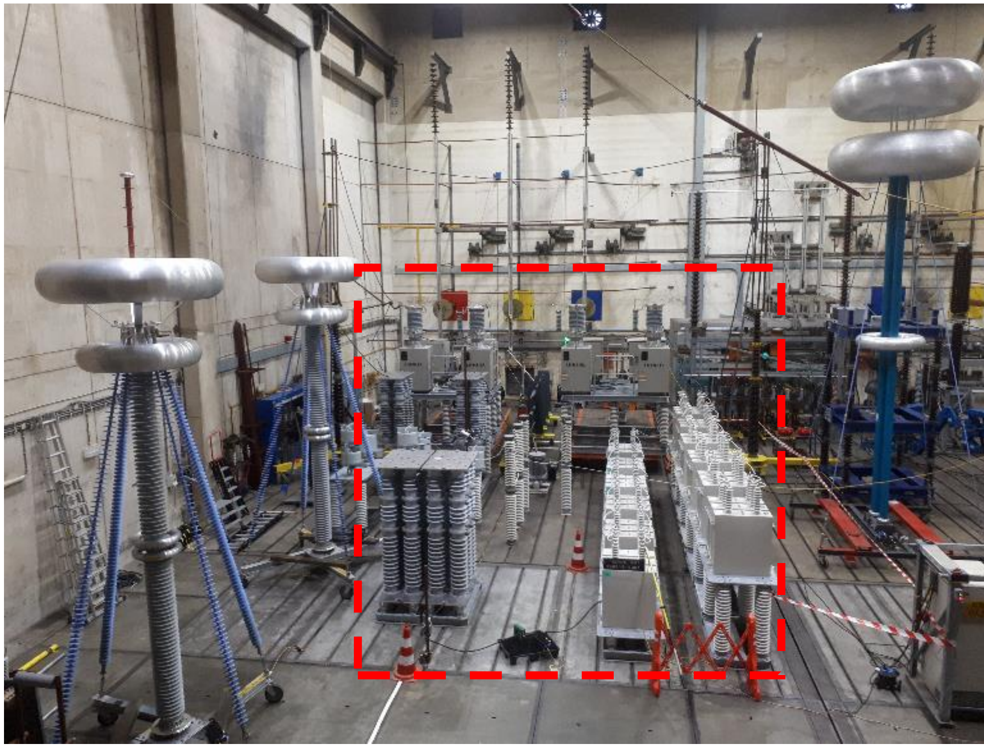
Test setup



- Three Triggered sparkgap
- 2 current limiting reactors
- Three high-voltage circuit breakers
- 4 high-voltage dividers
- 6 current measurements

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Next stop … Other HVDC Circuit Breaker Technologies

Hybrid HVDC CB

VSC Assisted Resonant Current (VARC) HVDC CB

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Summary

- 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

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Thank you!

Questions?

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APPENDIX

COLOR SUMMARY

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