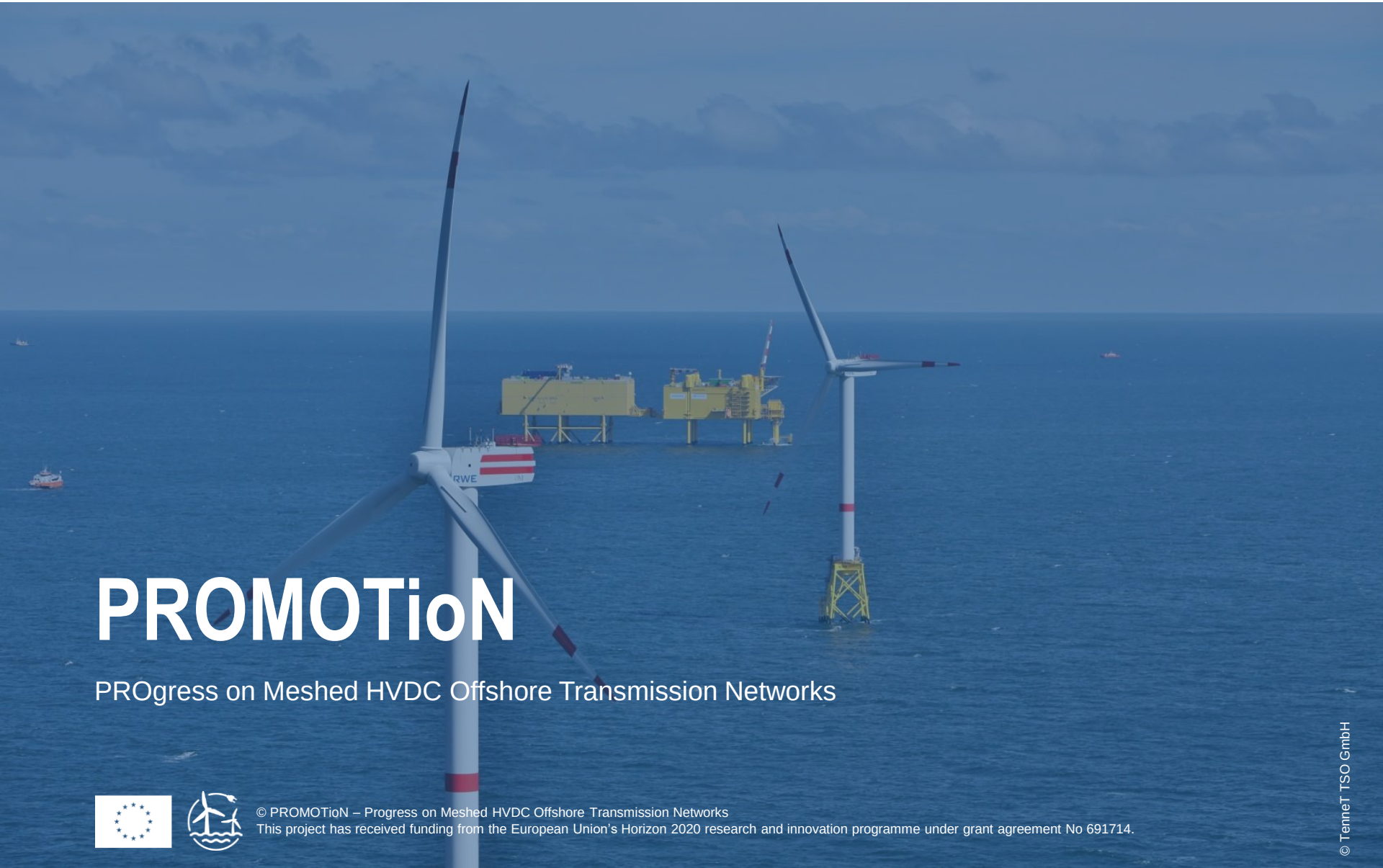
PROMOTioN
PROGRESS ON MESHED HVDC
OFFSHORE TRANSMISSION
NETWORKS



PROMOTioN

PROgress on Meshed HVDC Offshore Transmission Networks

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

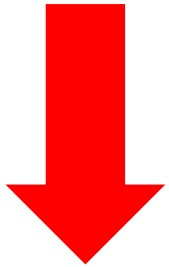
↗PROMOTioN

↗HVDC Circuit Breaker Testing

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

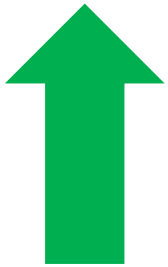
European Commission energy strategy

By 2030…..



40%

cut in greenhouse gas emissions compared to 1990 levels

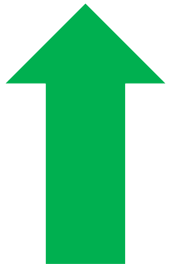


27%

share of renewable energy consumption

27%

energy savings compared with the business-as-usual scenario



15%

electricity interconnection target

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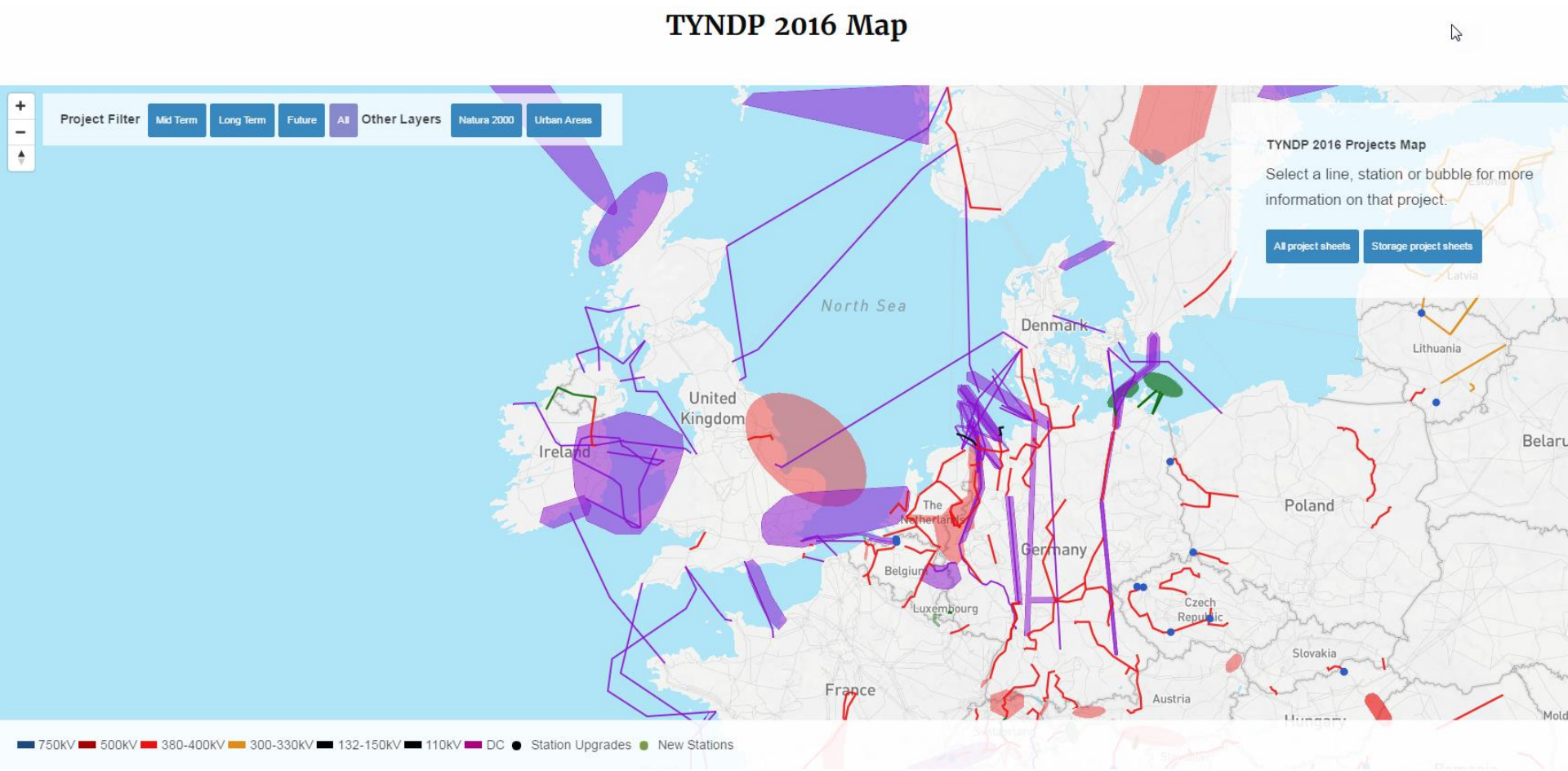
ENTSO-E vision 2030 for the North Sea



Source: www.entsoe.eu

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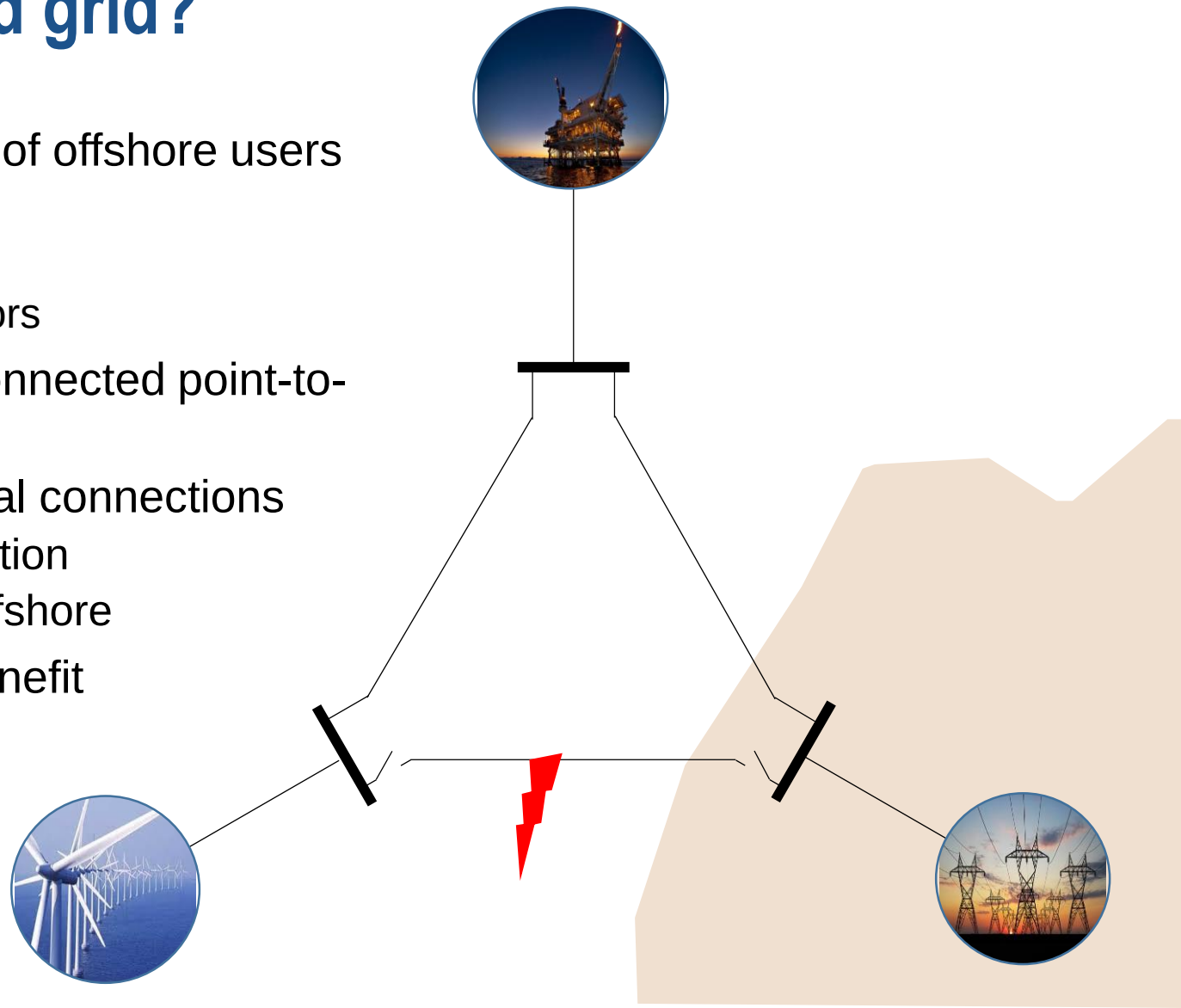
Why meshed grid?

- Different types of offshore users
  - Consumers
  - Producers
  - Interconnectors
- Traditionally connected point-to-point
- Dedicated radial connections
  - Lower utilisation
  - Reliability offshore
- Mesh offers benefit



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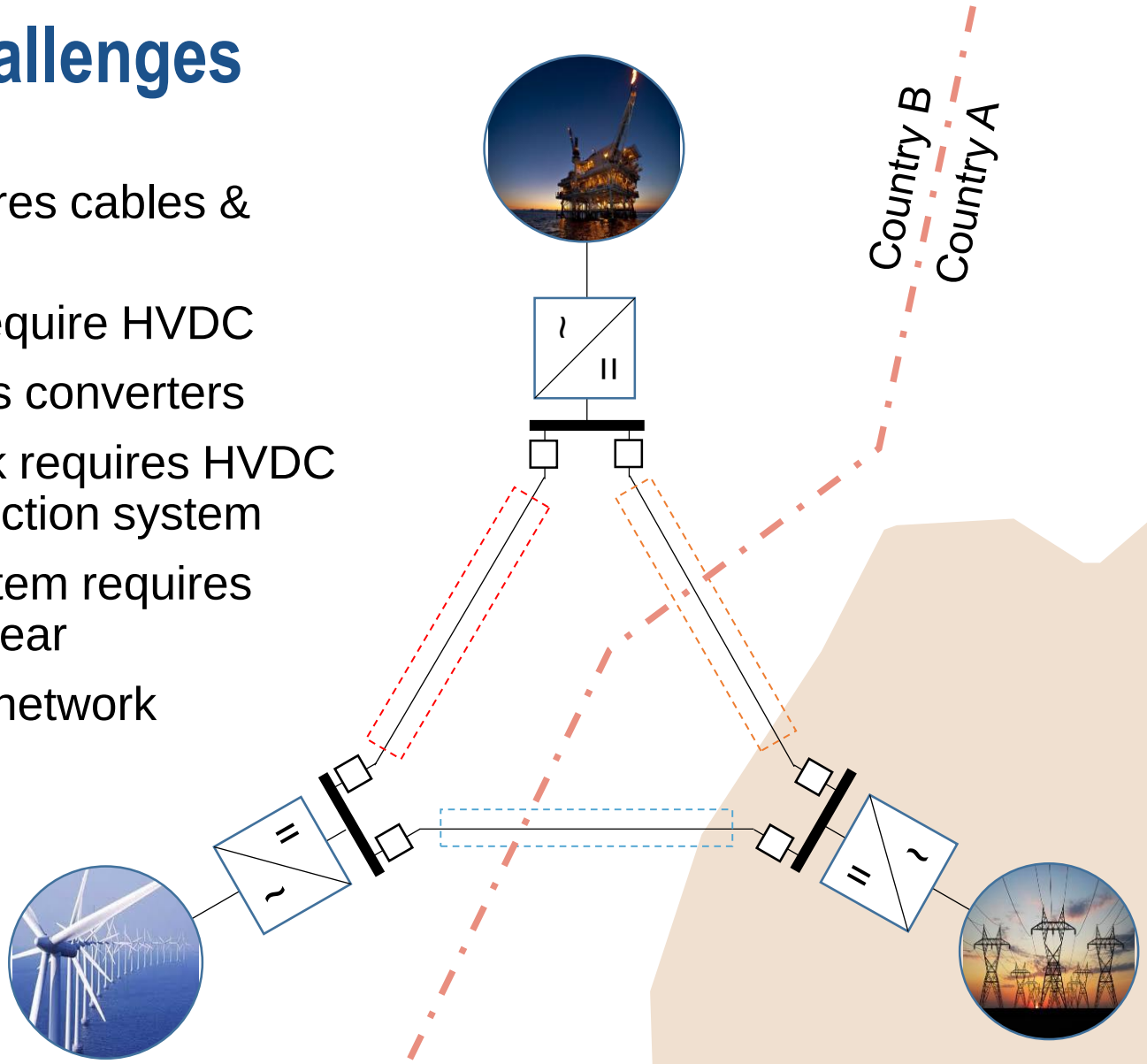
Offshore challenges

- Offshore requires cables & platforms
- Long cables require HVDC
- HVDC requires converters
- HVDC network requires HVDC control & protection system
- Protection system requires HVDC switchgear
- Transnational network



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Objectives

- Identify **technical requirements** and investigate possible **topologies** for **meshed HVDC offshore grids**
- Develop **protection schemes** and **components** for HVDC grids
- Establish components' **interoperability and initiate standardisation**
- **Demonstrate cost-effective** offshore HVDC equipment
- Develop recommendations for a coherent EU and national **regulatory framework** for HVDC offshore grids
- Develop **recommendations for financing mechanisms** for offshore grid infrastructure deployment
- Develop a **deployment plan** for HVDC grid implementation

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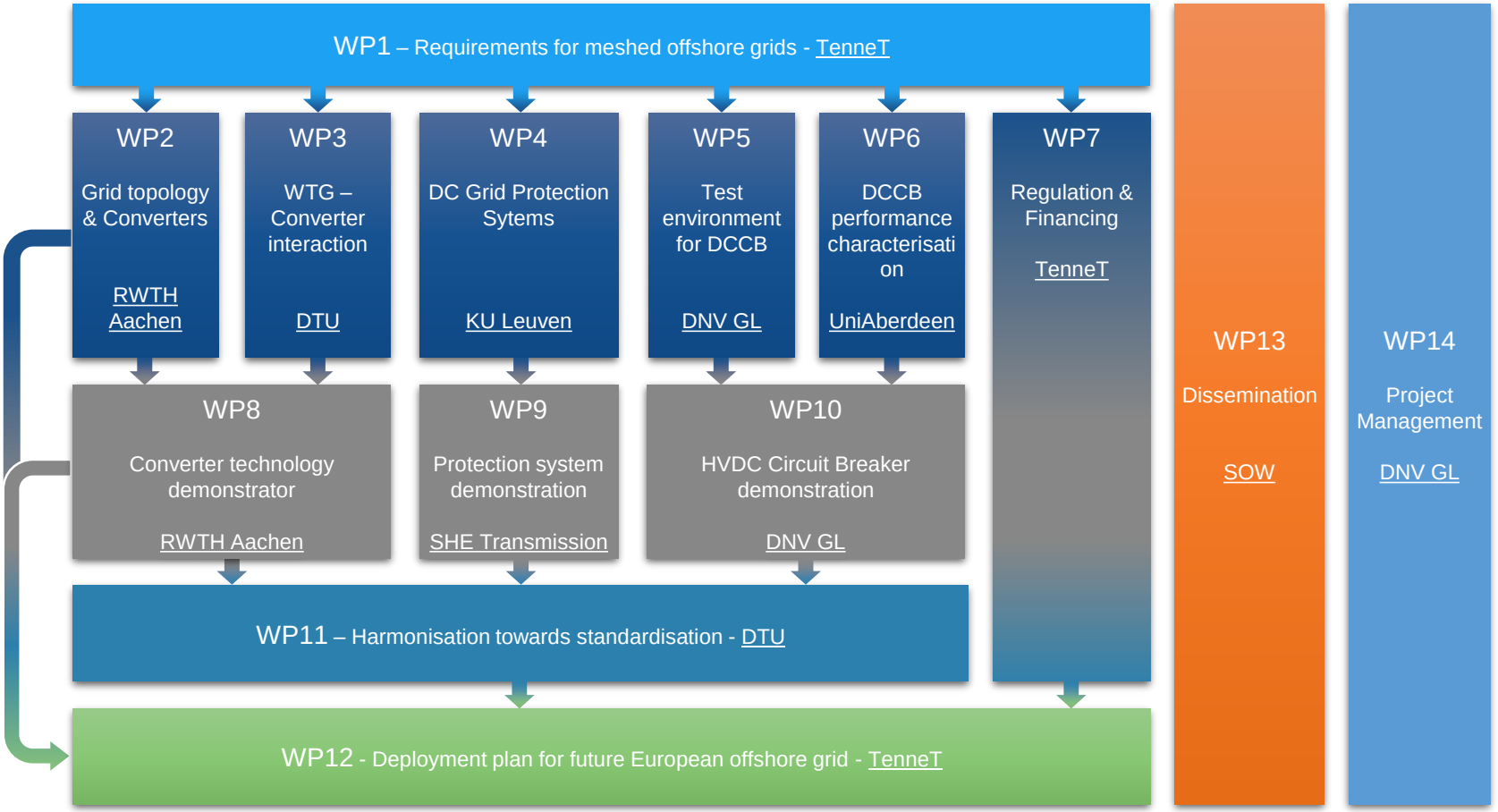
Work Package Structure



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Partners

ABB

MITSUBISHI ELECTRIC

SIEMENS

ALSTOM

Prysmian Group

SCiBreak
Enabling the Supergrid

MHI VESTAS OFFSHORE WIND

Adwen
AN AREVA GAMESA COMPANY

TenneT
Taking power further

sse

ENERGINET.DK

Rte

SVENSKA KRAFTNÄT

EIRGRID

DONG energy

IBERDROLA

Statoil

RWTH AACHEN UNIVERSITY

UNIVERSITY OF ABERDEEN

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

KTH VETENSKAP OCH KONST

DTU

KU LEUVEN

TU Delft

rijksuniversiteit groningen

European University Institute

University of Strathclyde

DNV·GL

TRACTEBEL Engineering
GDF SUEZ

DEUTSCHE WINDGUARD

STIFTUNG OFFSHORE WINDENERGIE

CARBON TRUST

T&D europe

FGH

SuperGrid Institute

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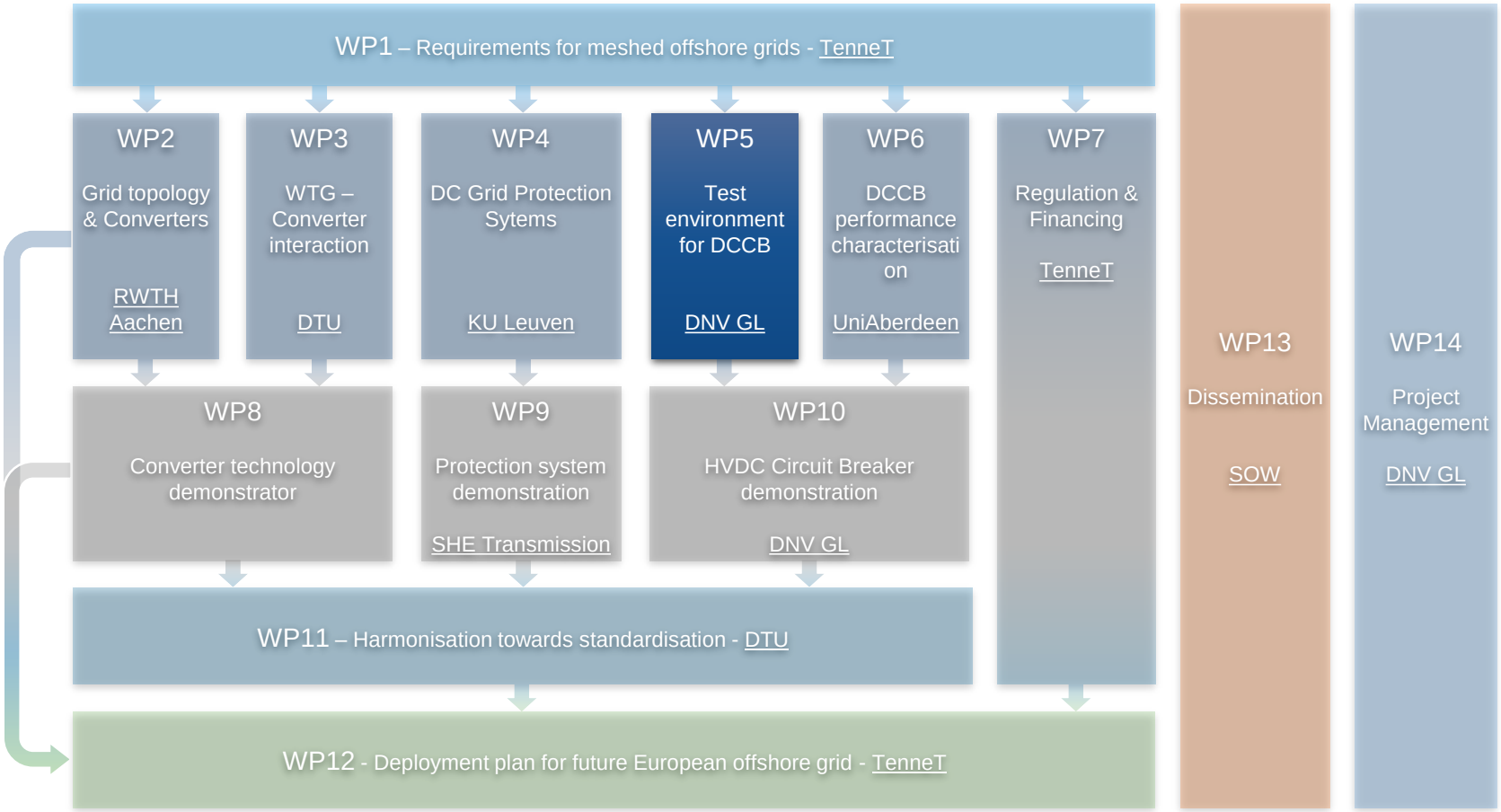
HVDC circuit breaker testing

Work Package 5 – Objectives & Interfaces



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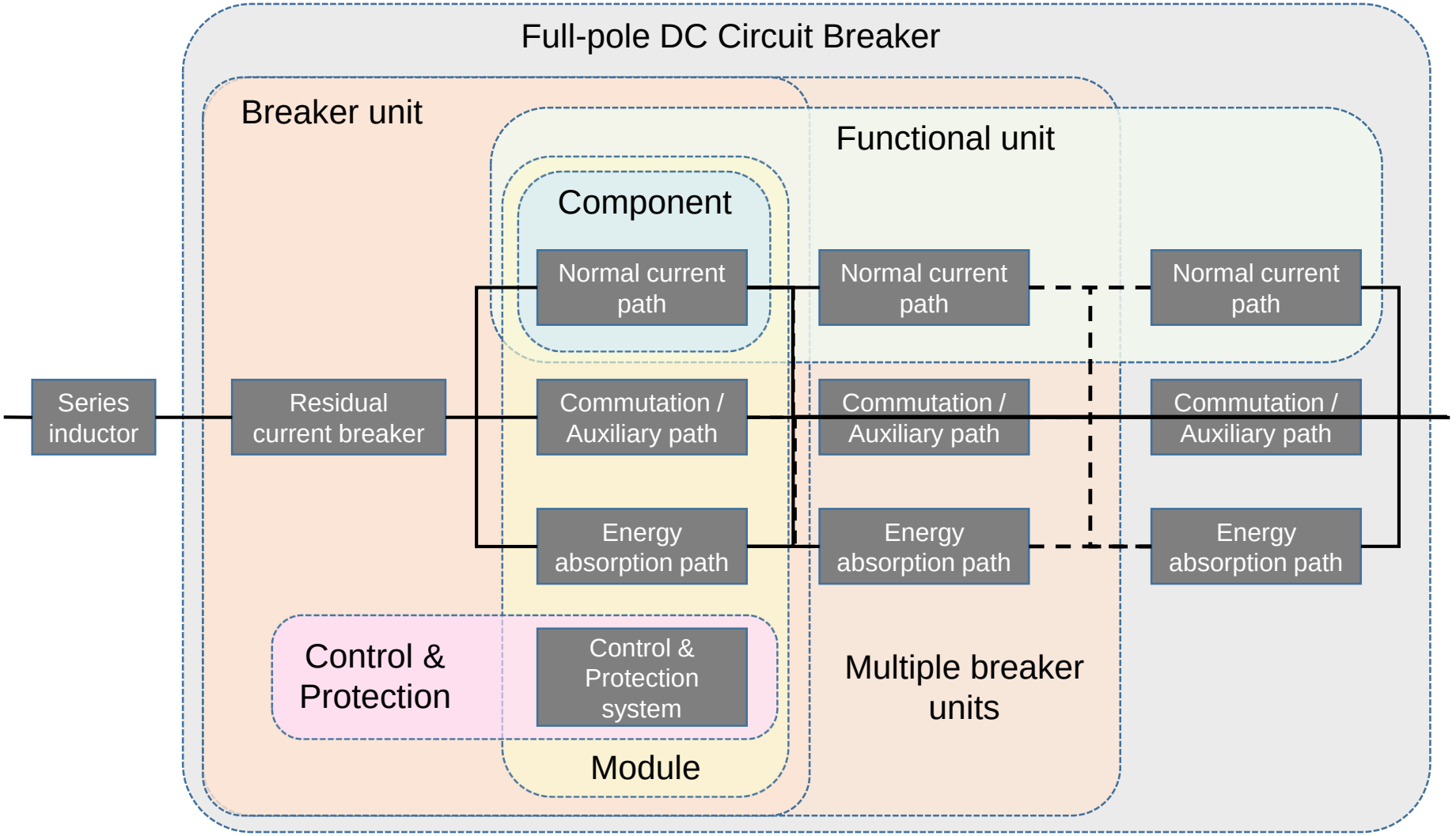
HVDC circuit breaker terminology & modularity



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HVDC circuit breaker test requirements

- ↗Dielectric testing
  - ↗Between terminals
  - ↗Support structure
- ↗Operational testing
  - ↗Loss / resistance measurement
  - ↗Temperature rise
  - ↗Current withstand
- ↗Current interruption testing
  - ↗Breaking
  - ↗Re-closing
- ↗Special
  - ↗Current limiting
  - ↗Soft closing

Standard test circuits

Non-standard test circuits

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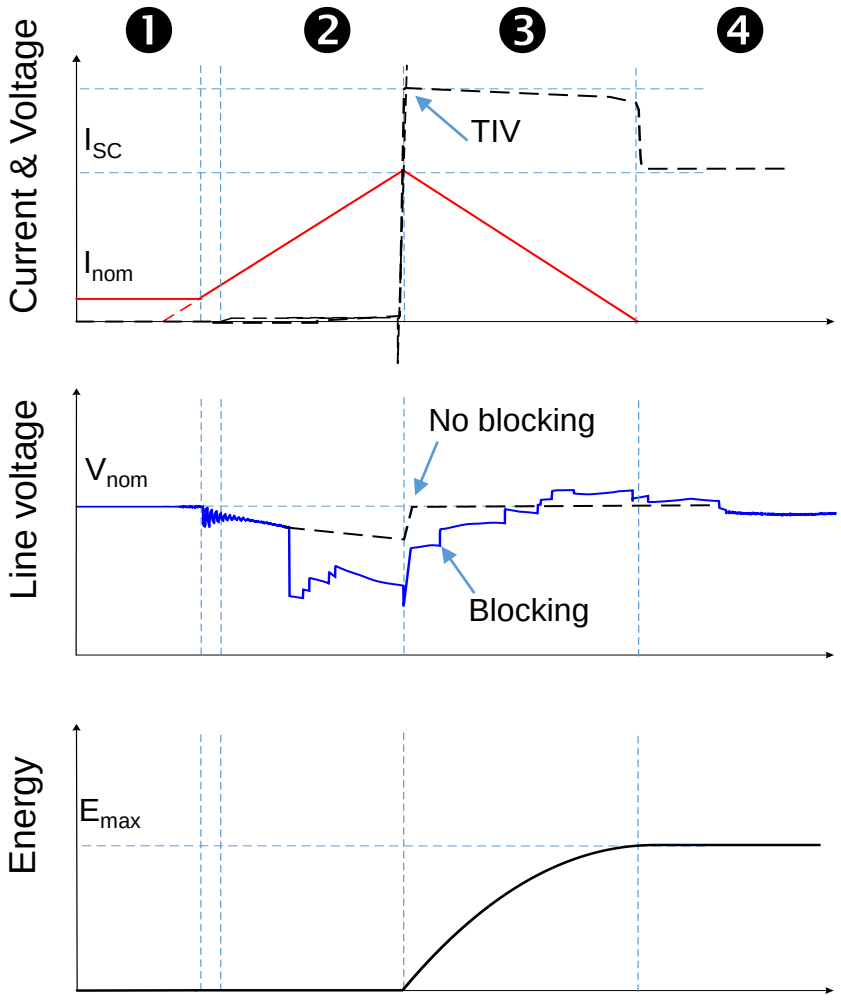
Current interruption test circuit requirements

1. Normal operation
   - ↗ Apply heating – Pre-condition
   - ↗ Supply power to auxiliary systems
2. Current commutation time
   - ↗ Supply sufficient di/dt
   - ↗ Bidirectional, different duties
3. Fault current suppression time
   - ↗ Supply sufficient energy
   - ↗ Withstand Transient Interruption Voltage
4. Post suppression
   - ↗ Apply DC voltage stress
5. Protection of test-circuit and test object



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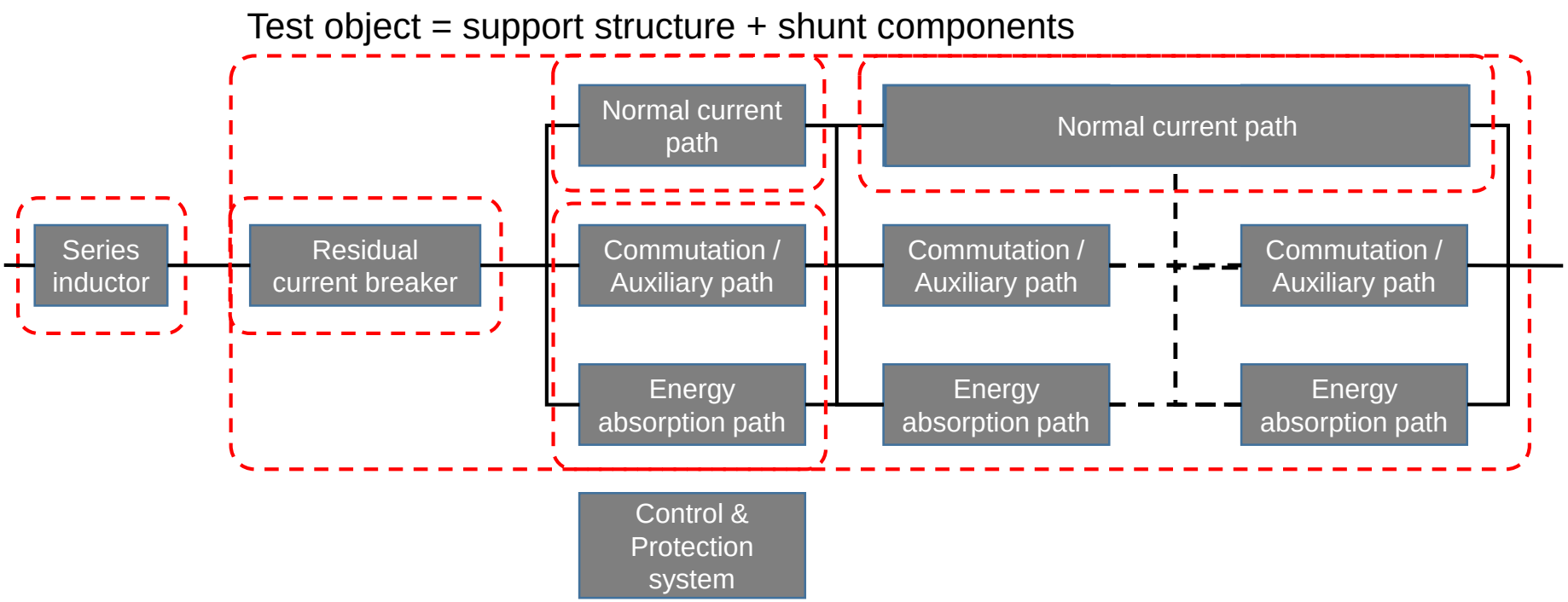
Modular testing – dielectric tests



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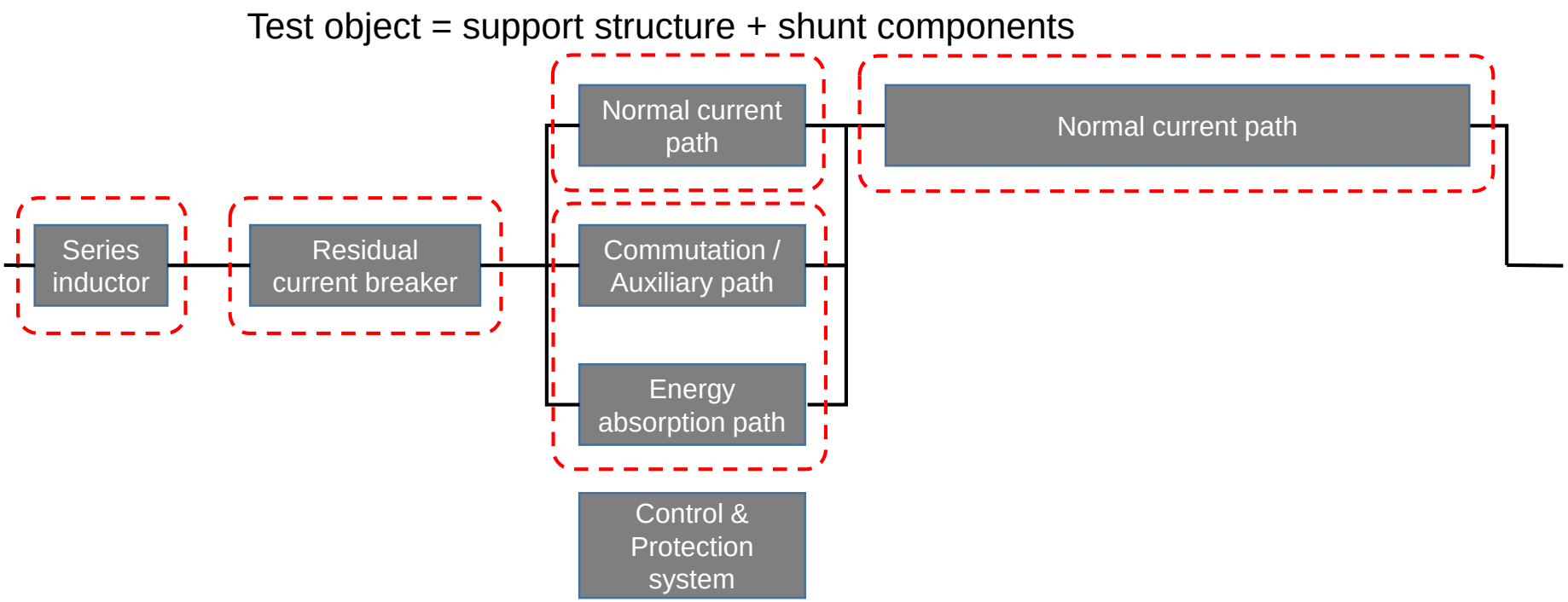
Modular testing – dielectric tests



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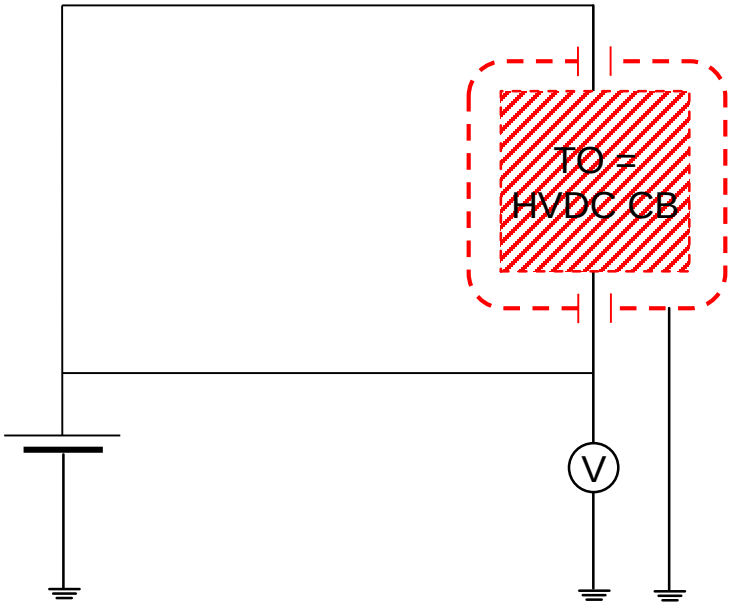
Dielectric tests – test circuit



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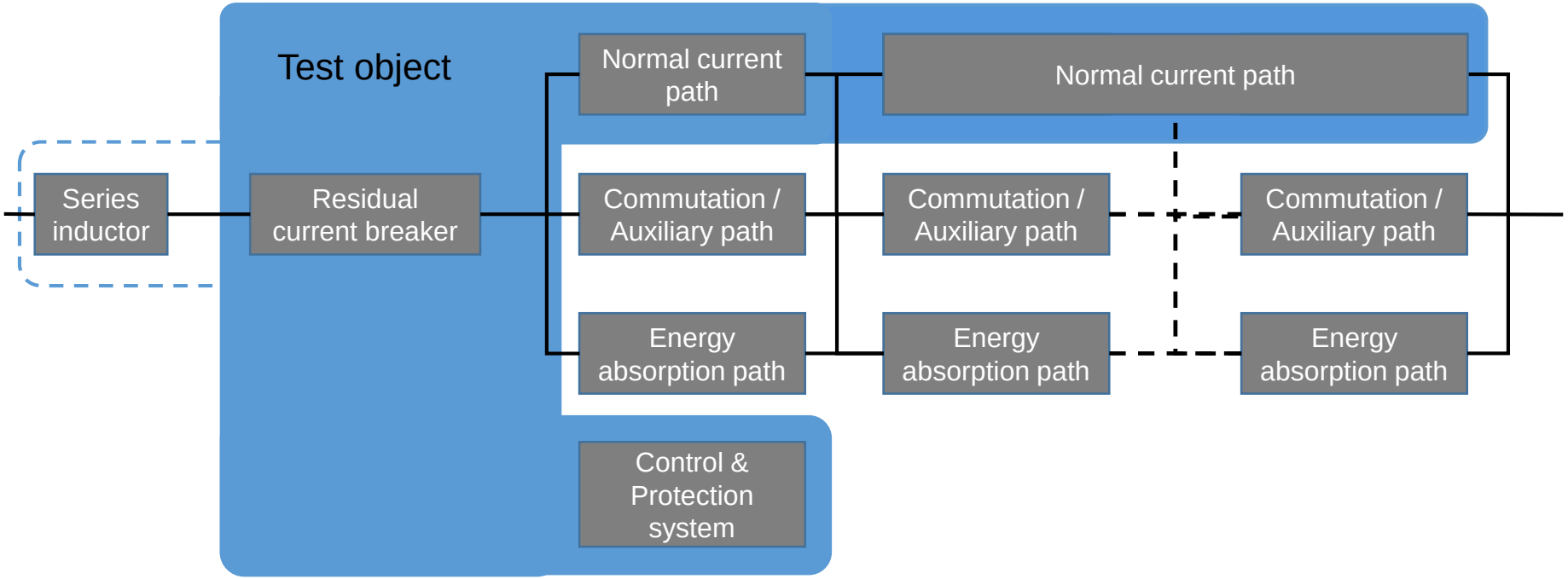
Modular testing – operational tests



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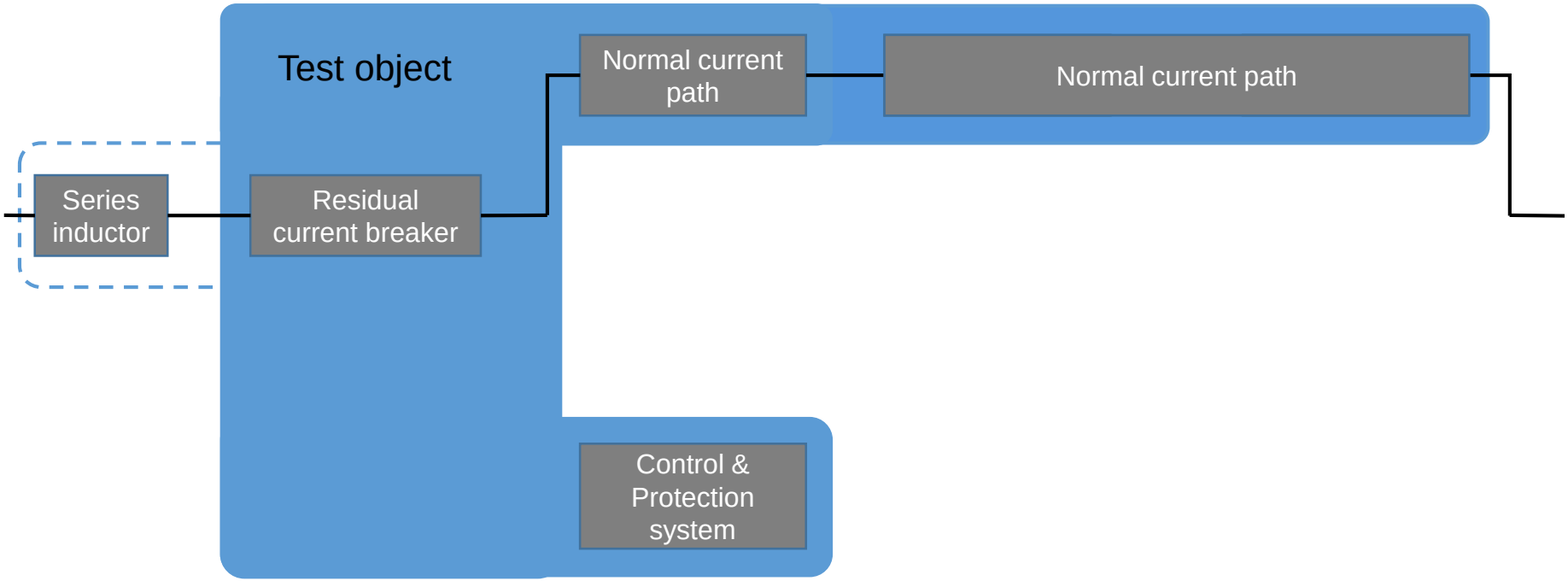
Modular testing – operational tests



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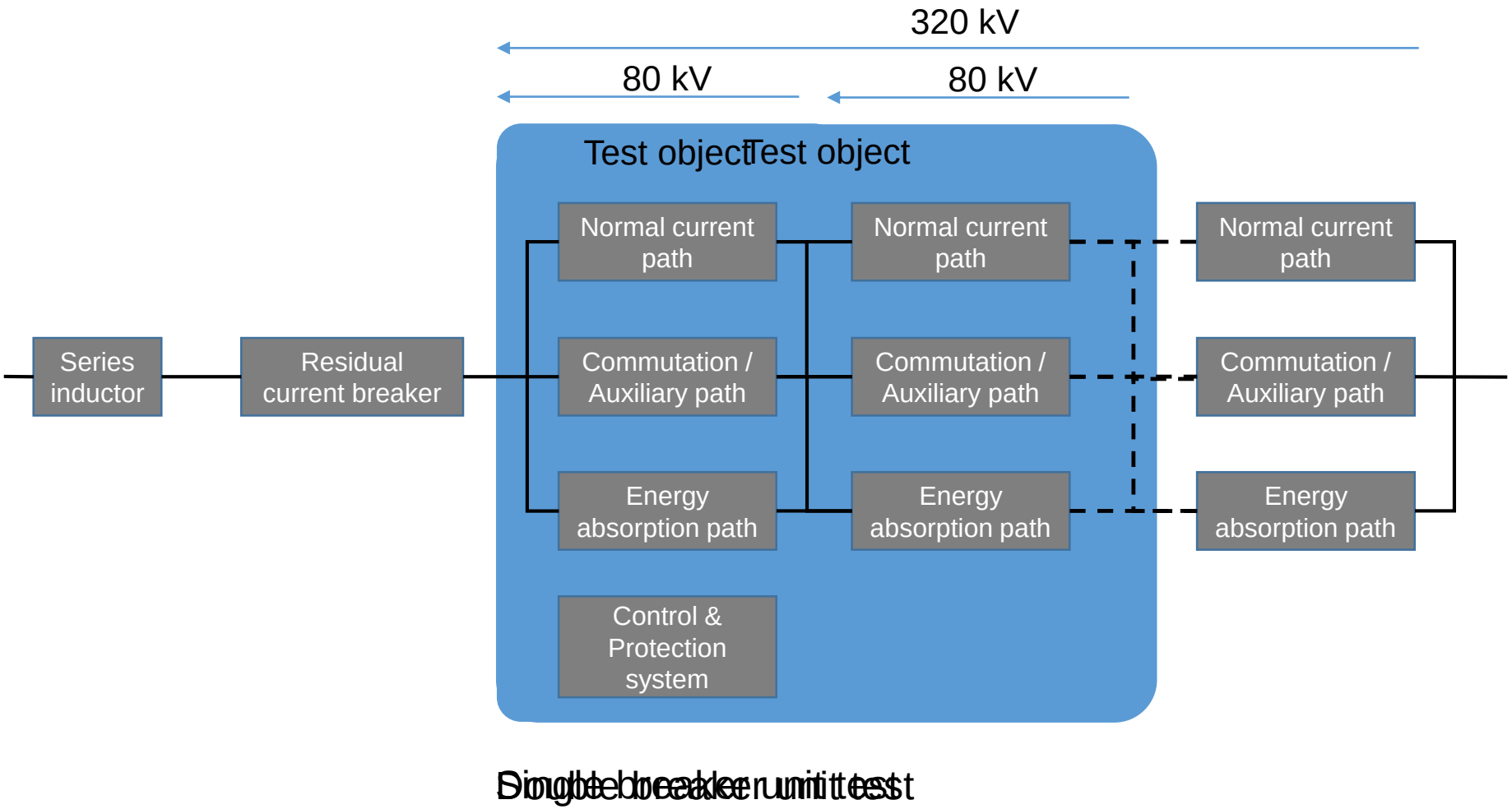
Modular testing – current interruption



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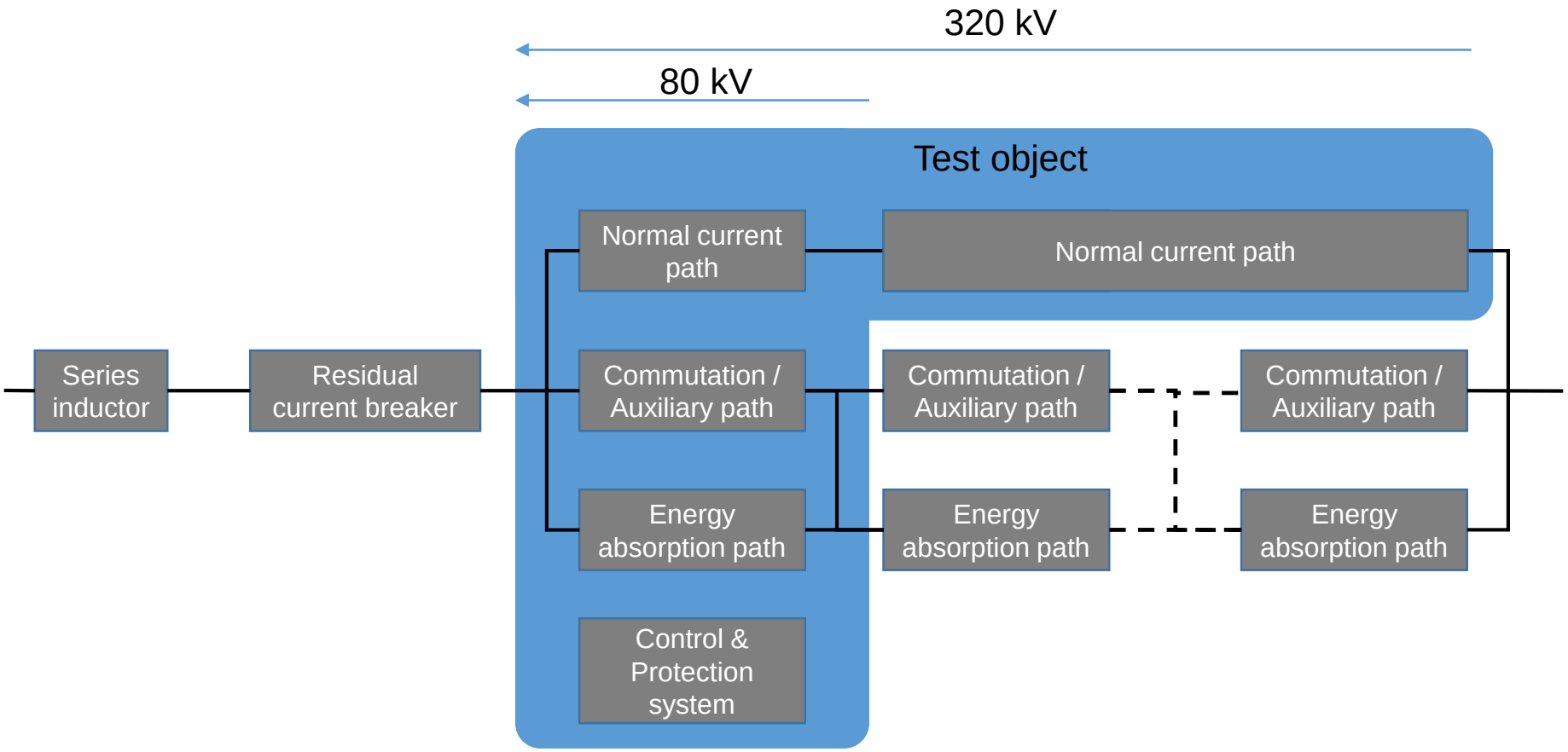
Modular testing – current interruption



Single breaker unit test with full pole component

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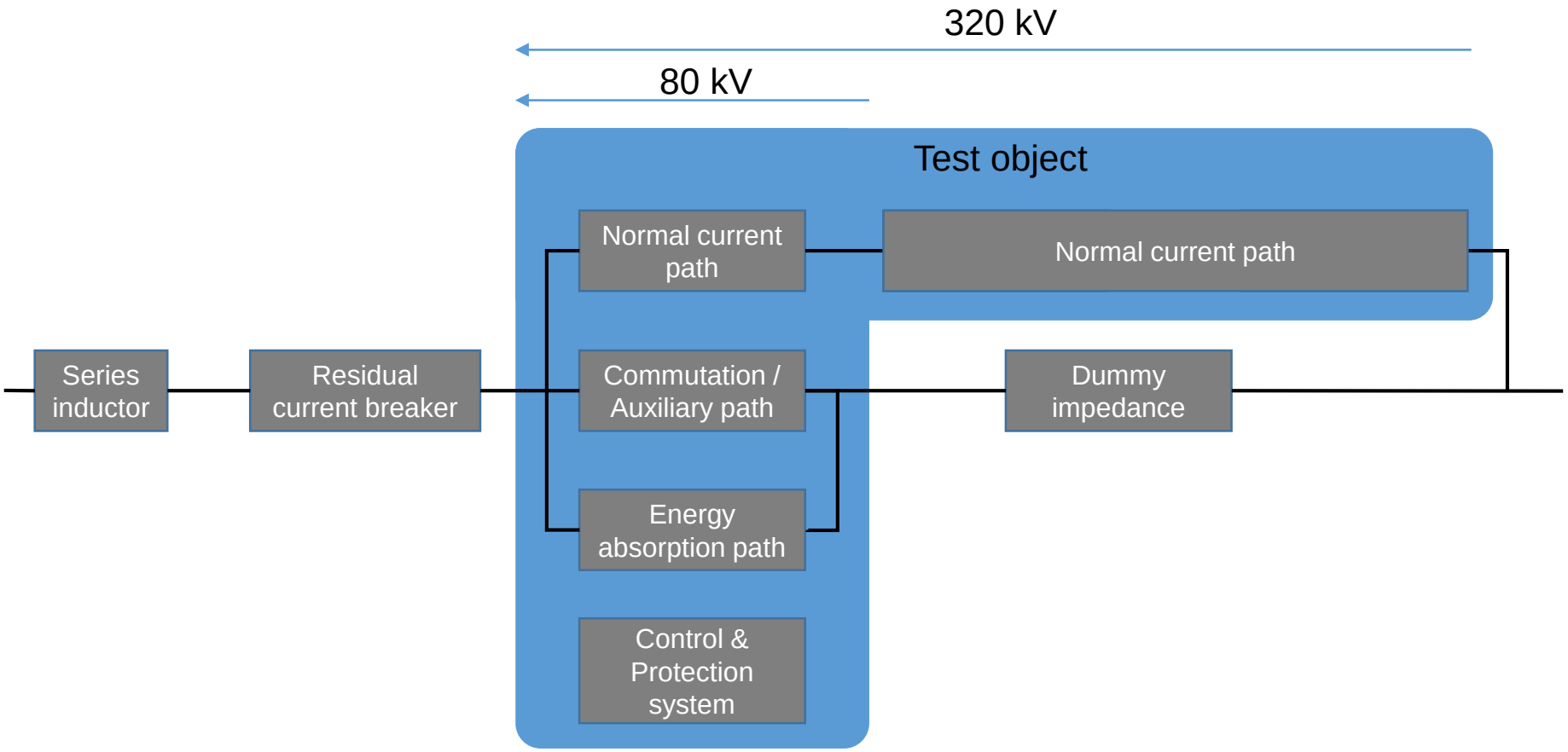
Modular testing – current interruption



Single breaker unit test with full pole component

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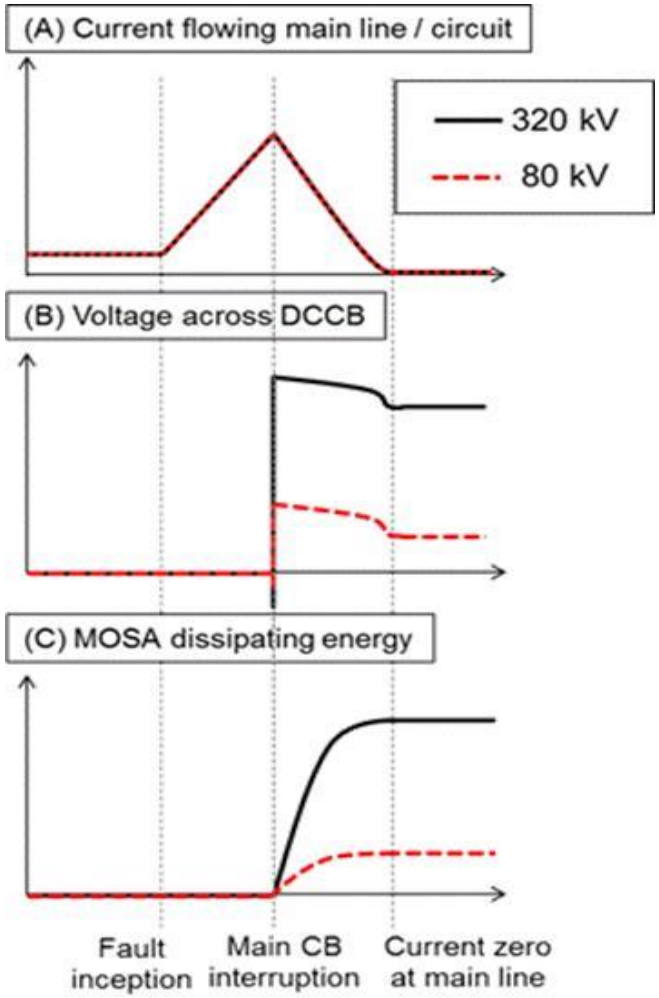
Modular testing - Prorating

- Current sharing
  - In series connected modules current, is not divided
- Voltage grading
  - Divided by number of series connected modules
  - Determined by surge arrestors
  - Full-pole components need to be dielectrically tested separately
- Energy grading
  - Divided by number of series connected modules
  - Margin required determined by small differences in timing



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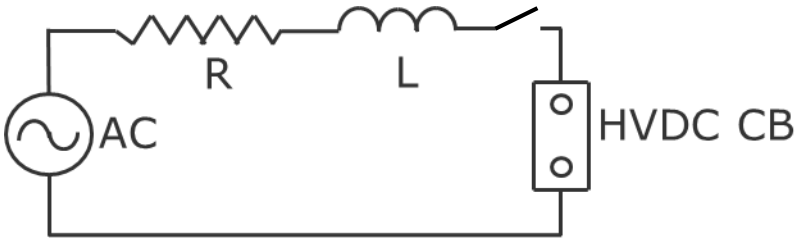
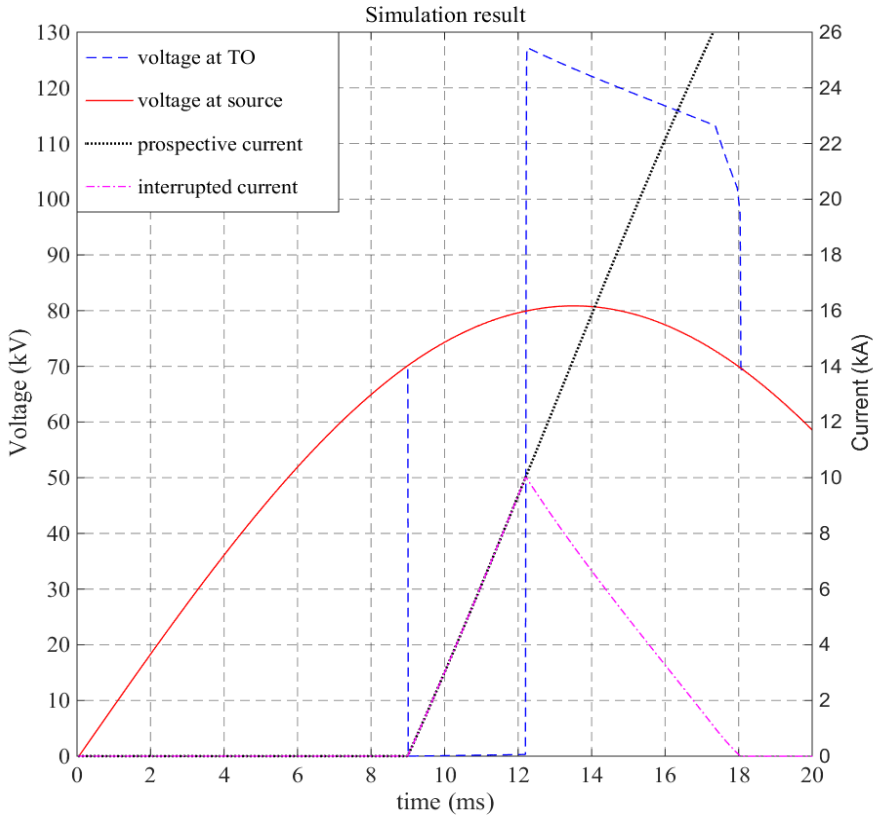
Reduced frequency AC short-circuit generator based test circuit





- Test circuit parameters
  - Generator frequency
  - Circuit inductance
  - Magnitude of source voltage
  - Making angle

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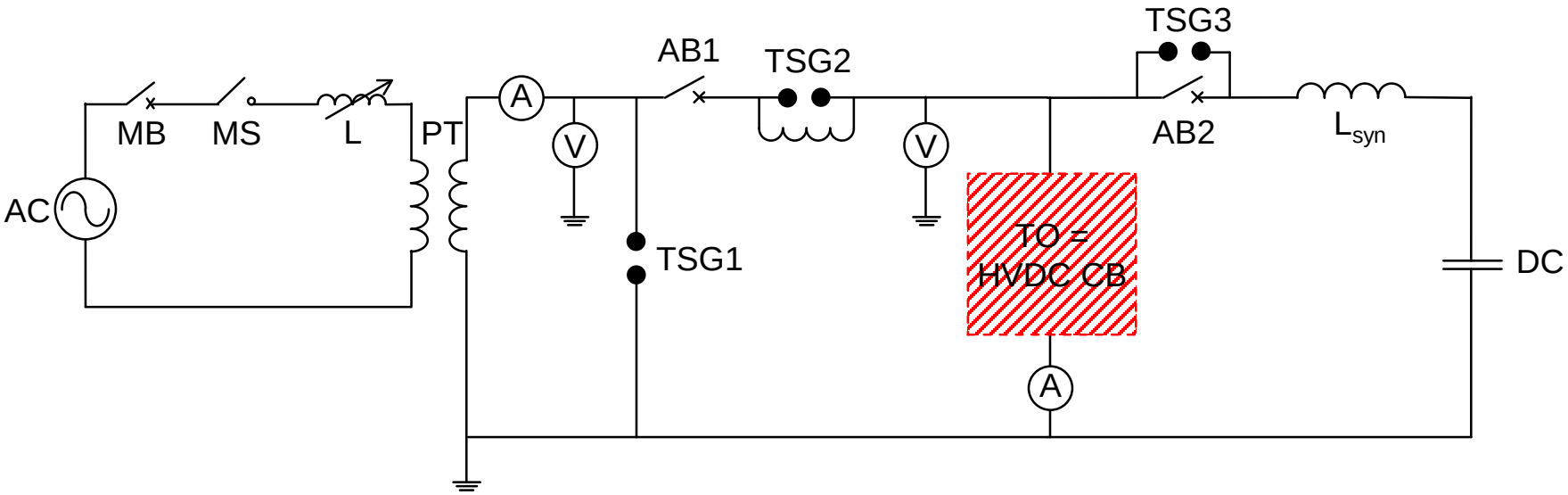
AC short-circuit generator based test circuit



- Create current and energy stresses
- Isolate test object from the short-circuit generator
- Protect HVDC CB from over-current if it fails to clear
- Inject DC voltage stress after current suppression
- Mimic effect of load current and delay operation of fast breakers
- Take measurements

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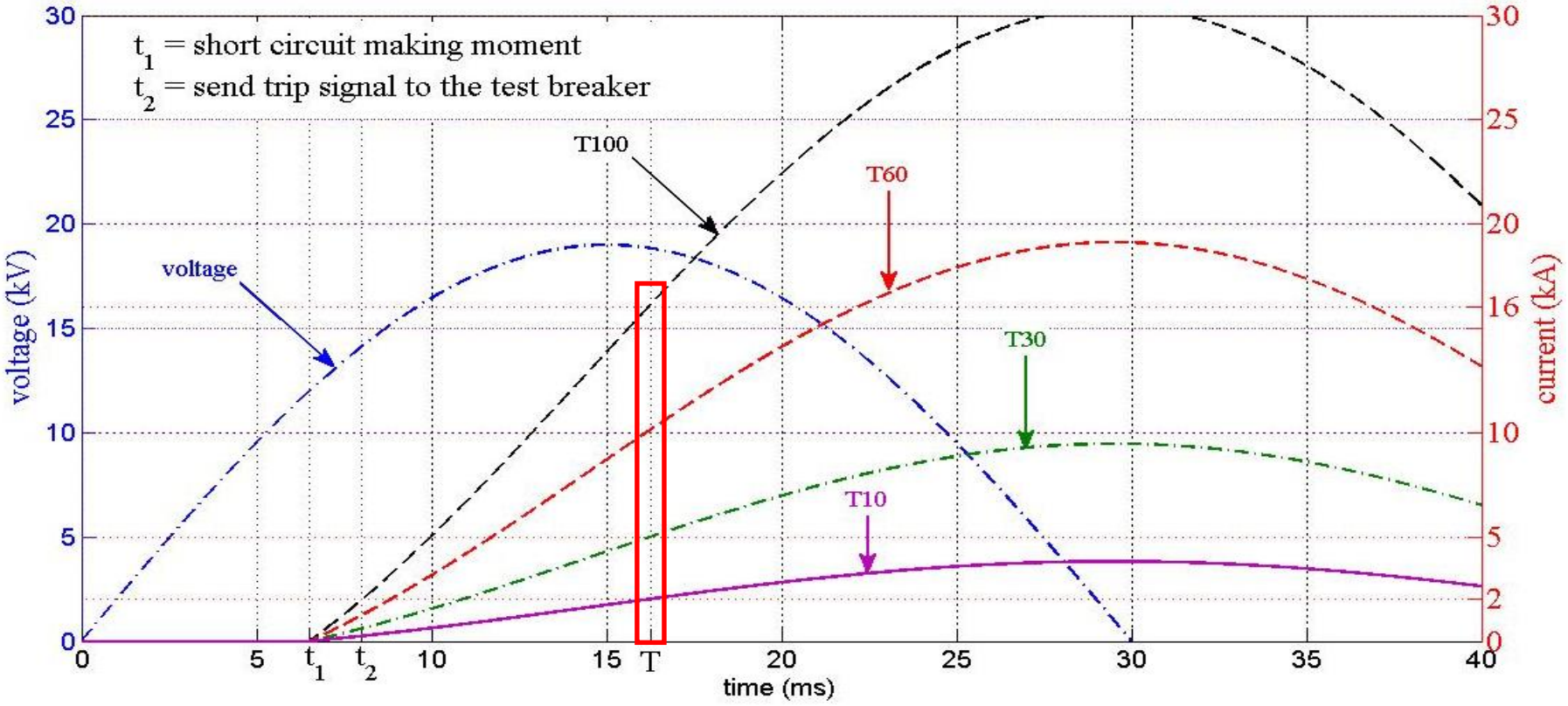
Realizing test duties



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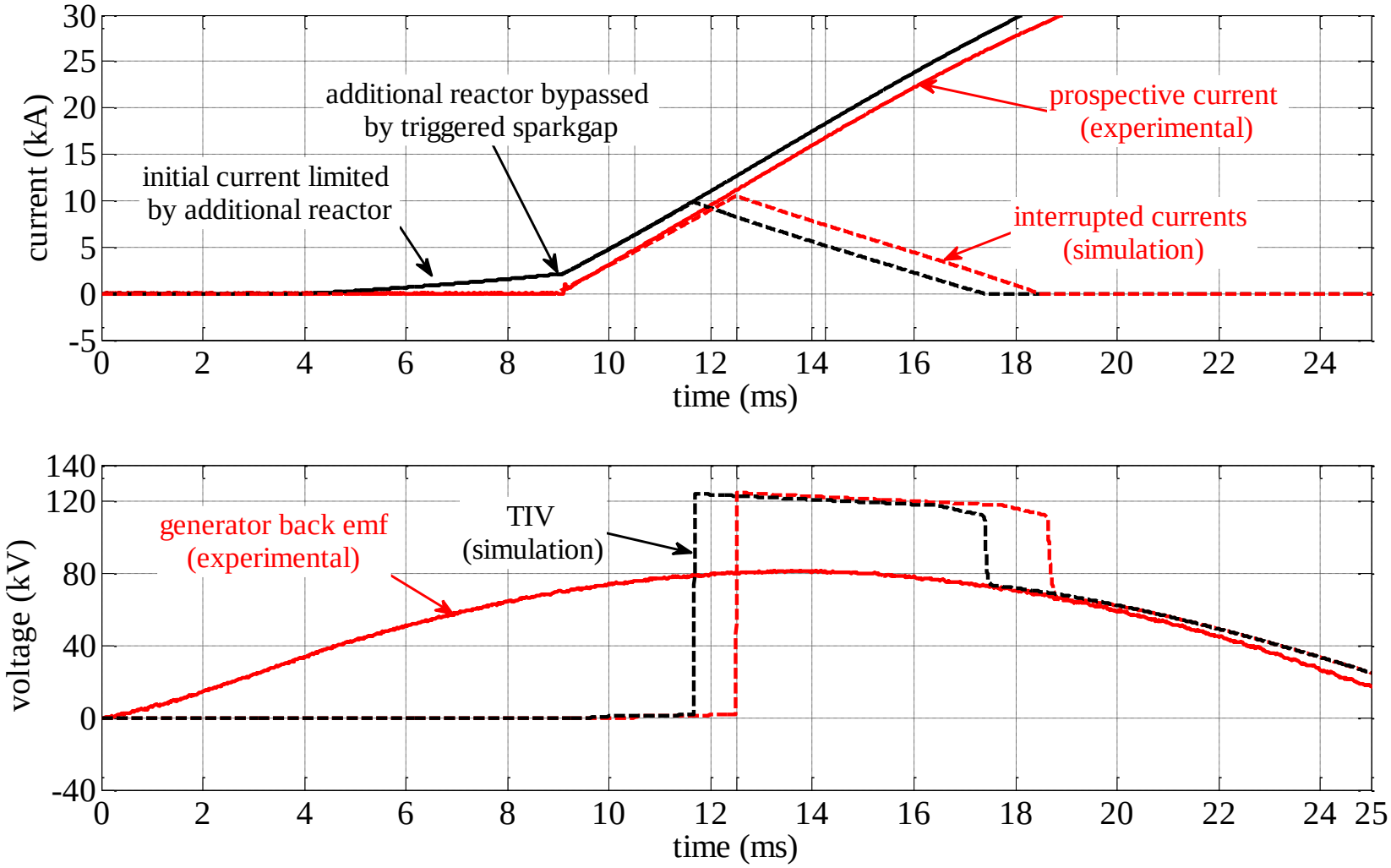
Initial current limiting by additional reactor



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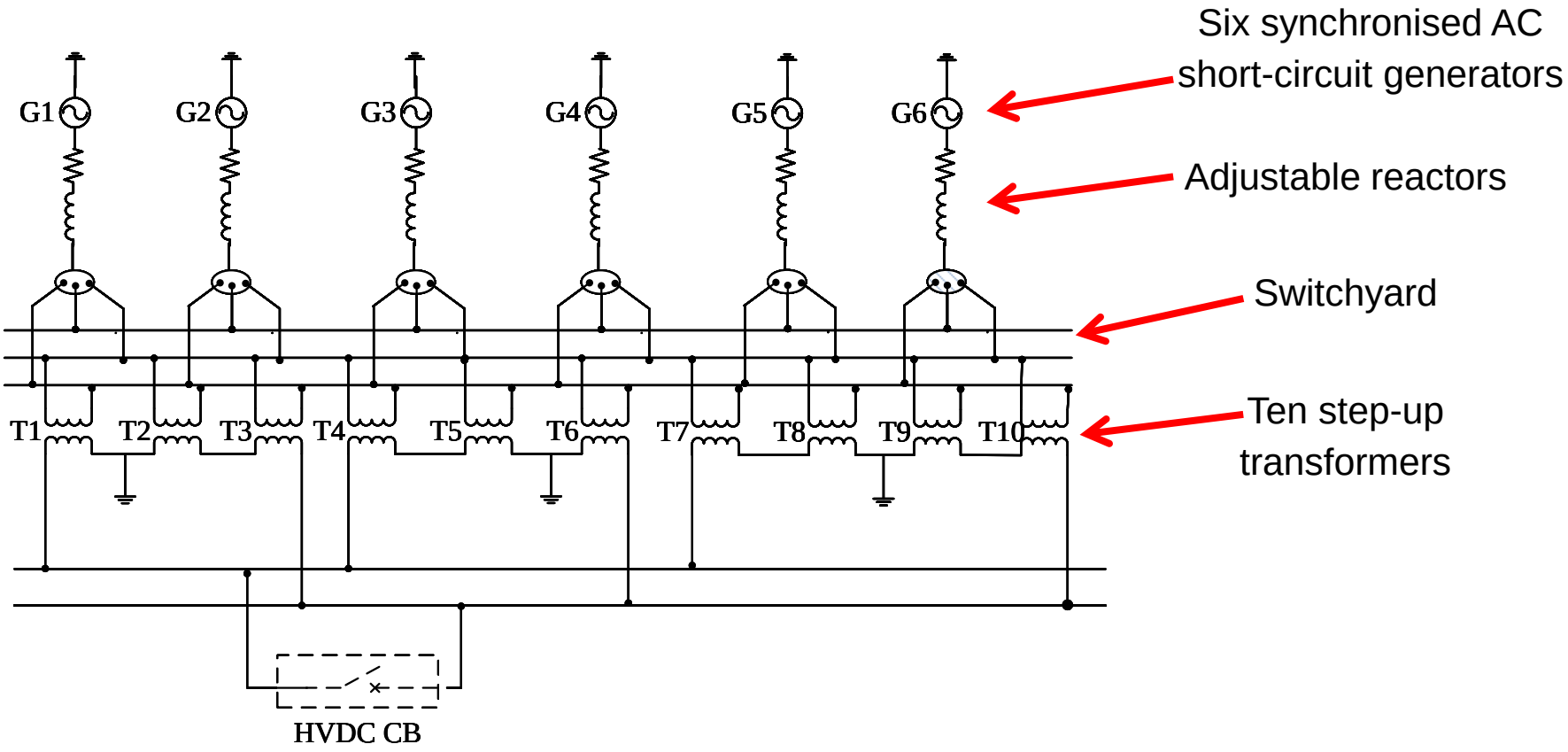
KEMA High power laboratories



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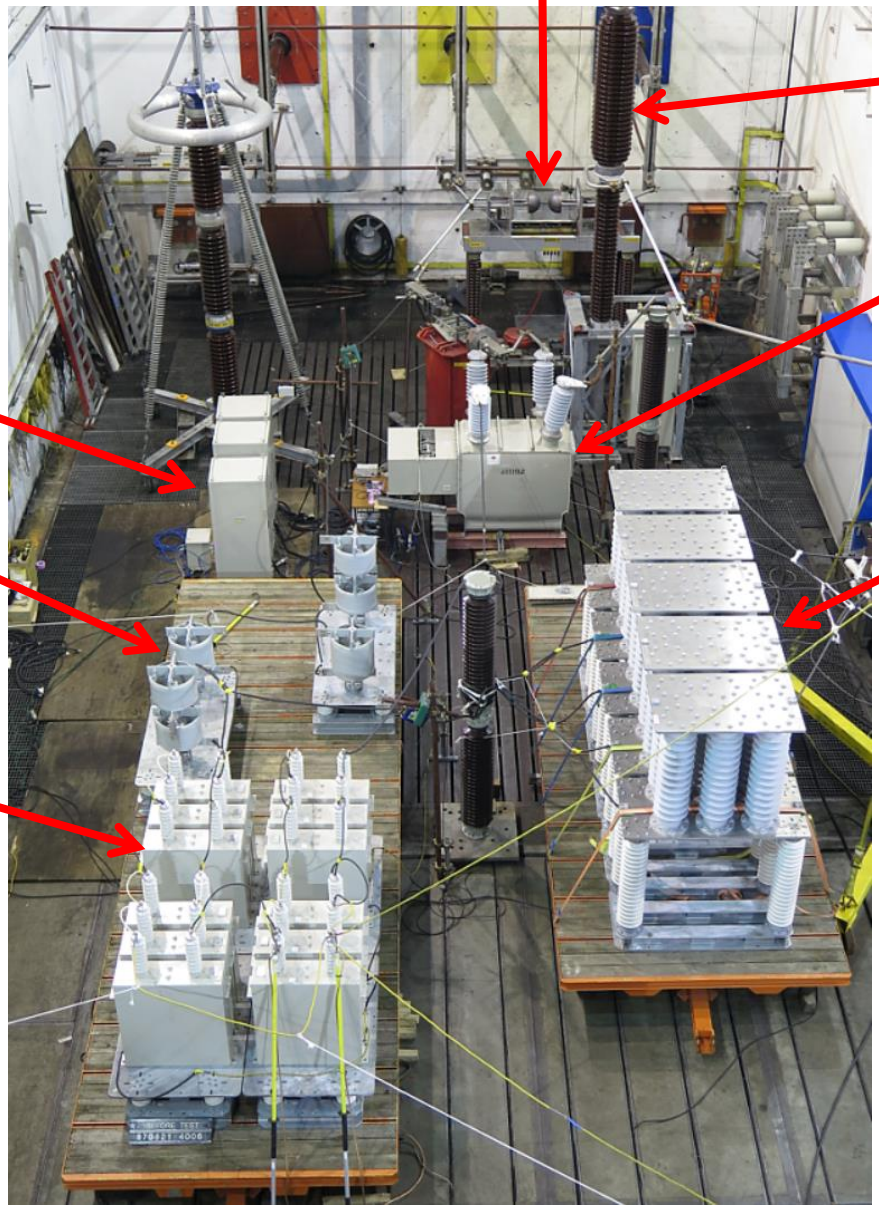
PROMOTioN

Test set-up



MITSUBISHI ELECTRIC

KEMA Laboratories

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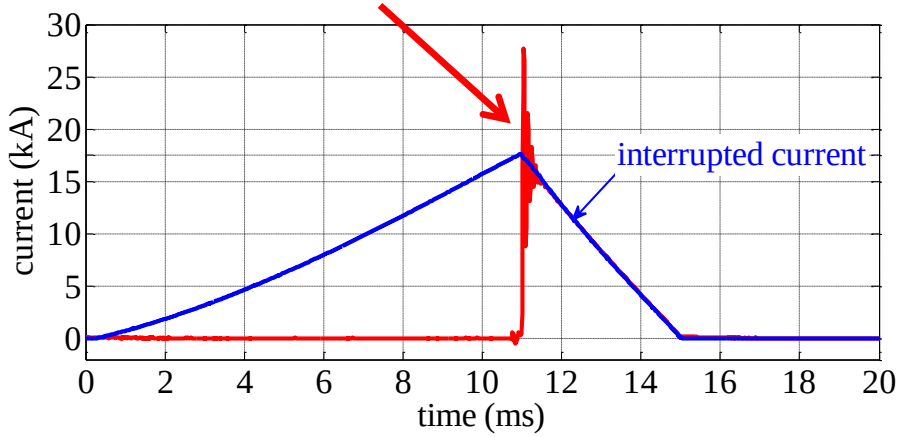
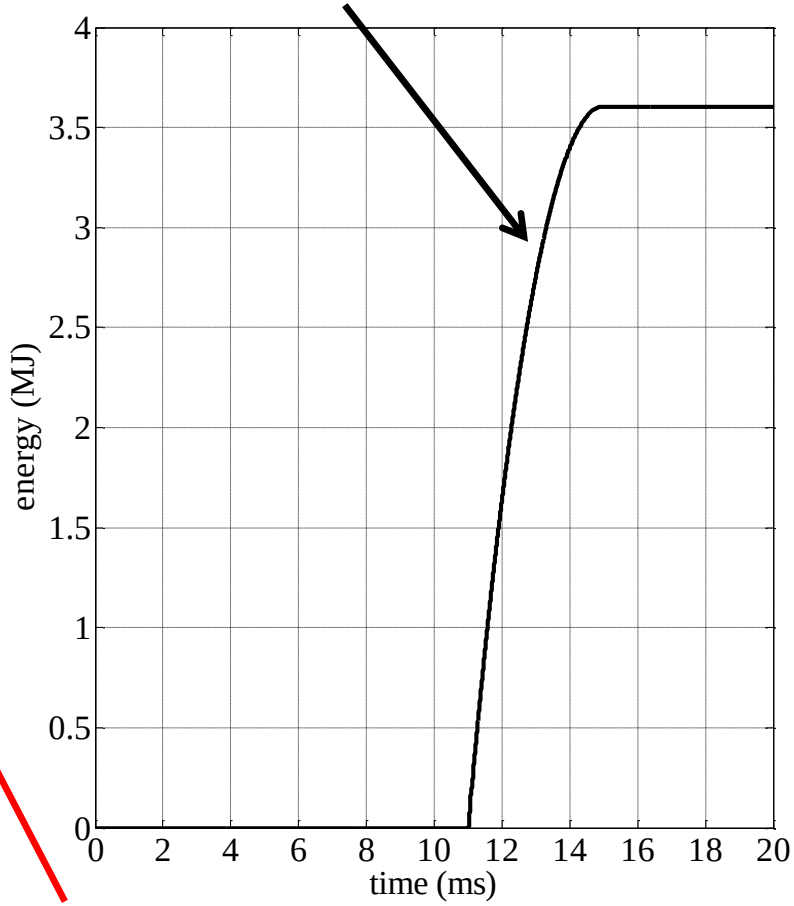
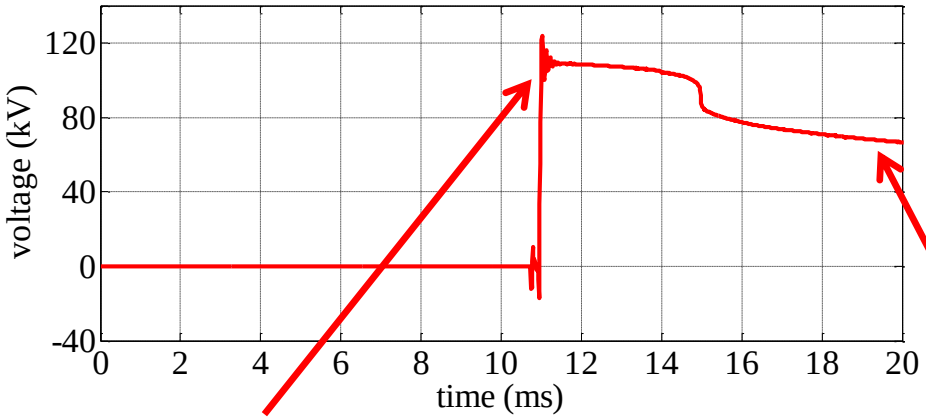
16 kA interruption (positive) + dielectric stress

current through MOSA



Energy absorbed by HVDC CB





Counter voltage generated by HVDC CB

Dielectric stress

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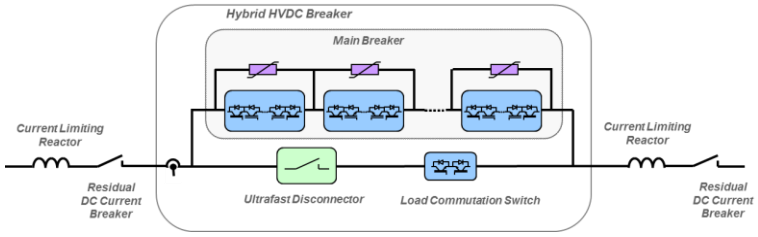
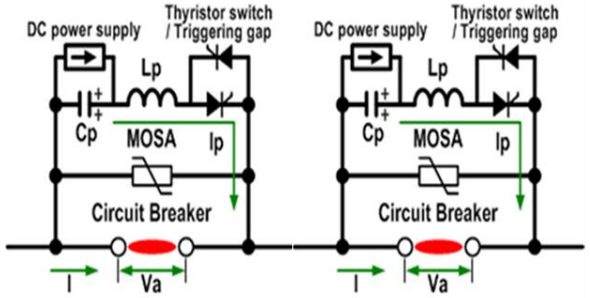
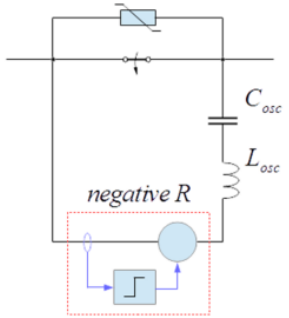
Future work

- ↗Verification of max testing capabilities
- ↗Development of surge arrestor thermo-electrical models
- ↗Development of surge arrestor multi-column testing and measuring method
- ↗Full power testing of ABB Hybrid HVDC circuit breaker
- ↗Full power testing of Mitsubishi Electric multi-breaker unit
- ↗Full power testing of SCiBreak VSC assisted resonance converter breaker







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Conclusions

- ↗Meshed HVDC offshore network is a promising candidate for flexible transmission of offshore wind power
- ↗EU-funded consortium ‘PROMOTioN’ addresses technical, regulatory & economic barriers to implementation
- ↗HVDC circuit breakers enable flexible & resilient power transmission
- ↗Current interruption testing of HVDC circuit breakers requires unconventional test circuit
- ↗HVDC circuit breaker design allows for modular testing
- ↗Reduced frequency AC short-circuit generators and synthetic voltage injection source capable of testing DC current interruption
- ↗Current interruption of Mitsubishi Electric HVDC CB prototype successfully demonstrated at KEMA Laboratories

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Thank you, any questions?

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APPENDIX

DISCLAIMER & PARTNERS

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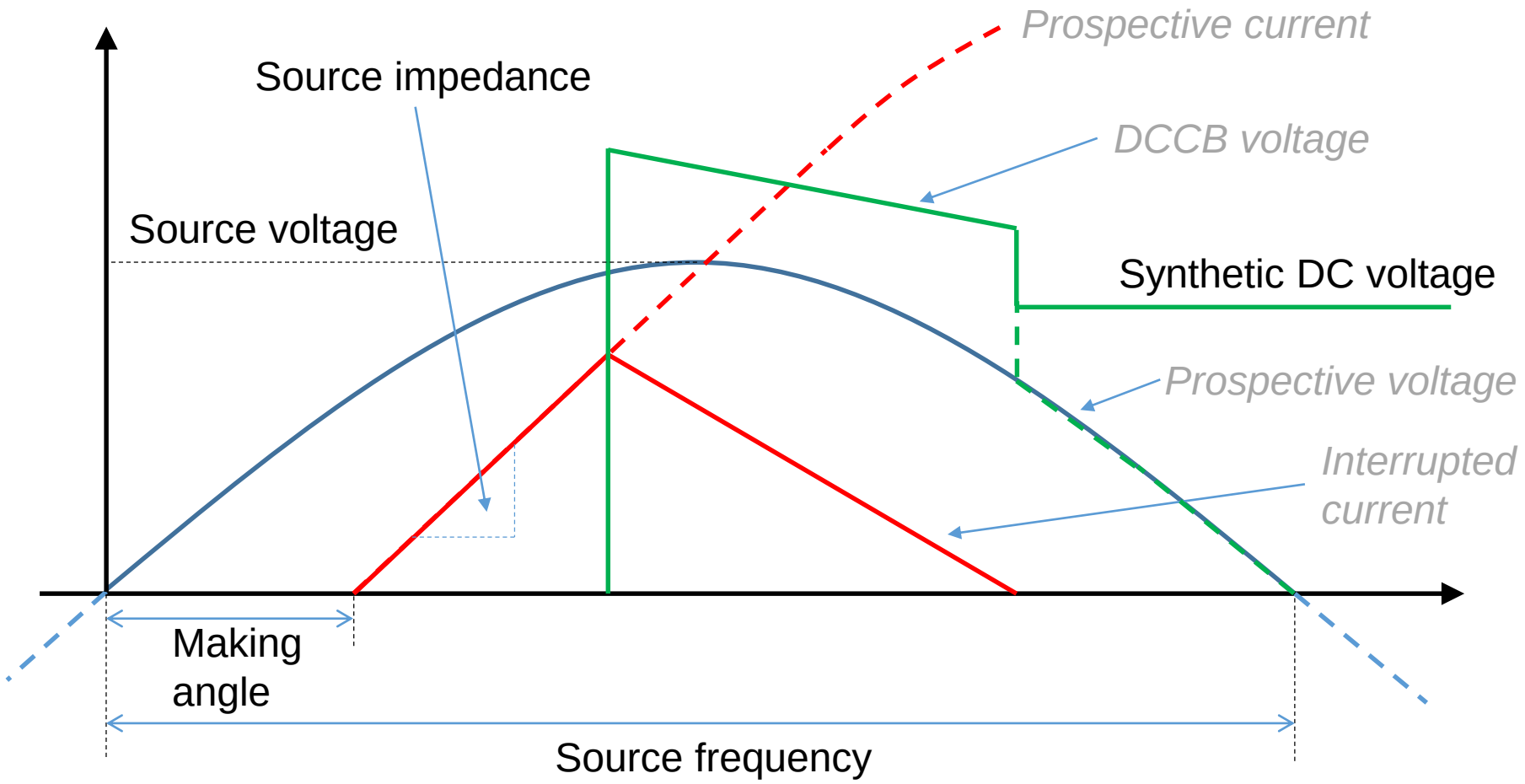
Reduced frequency AC short circuit generator based test circuit parameters



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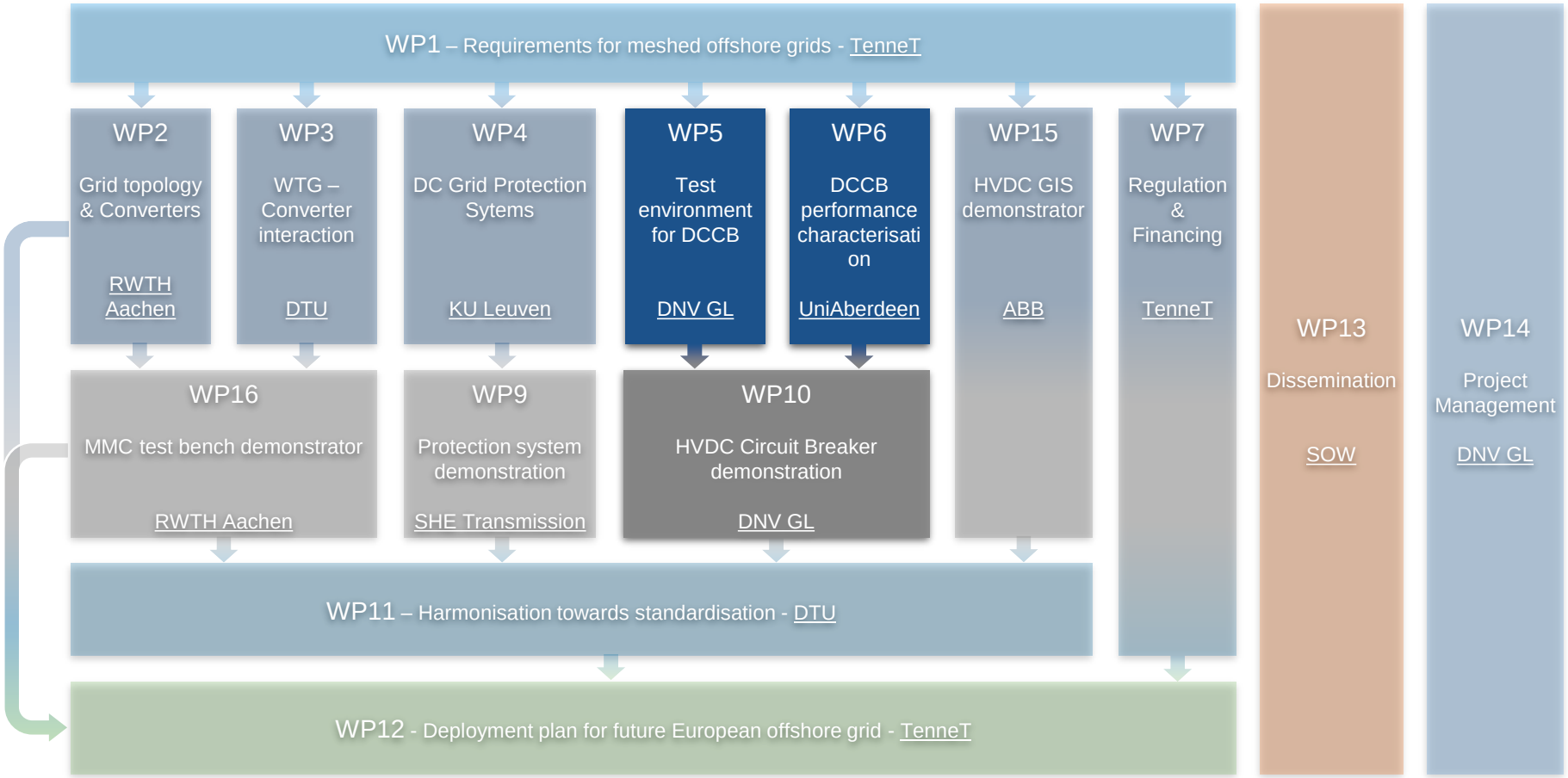
HVDC circuit breaker work stream



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