

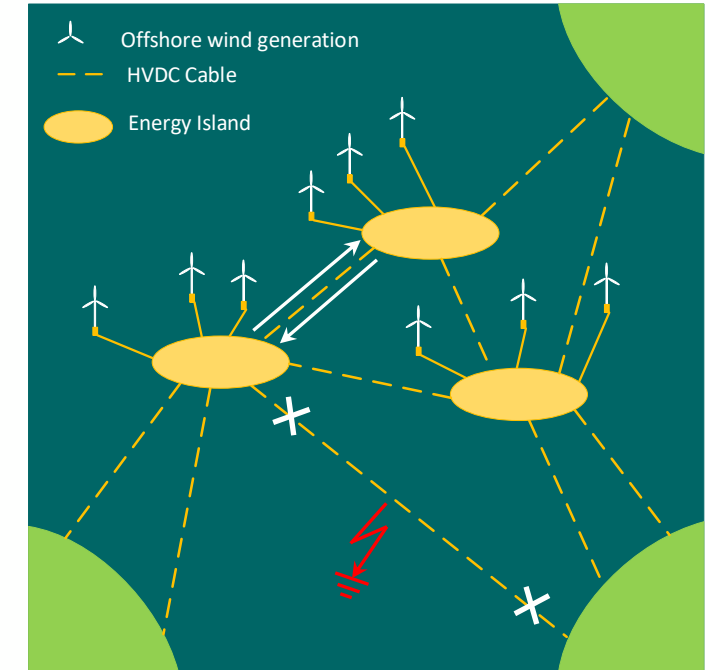
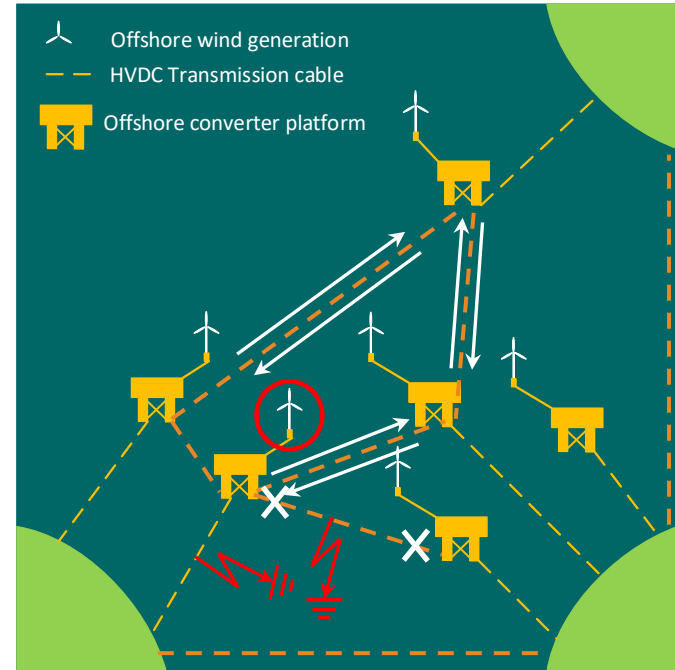
Recent Developments and Testing of HVDC Switchgear for Meshed Grid

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December 2, 2021

From Multiple Point-to-Point → Meshed Grid

- Multiple point-to-point projects
- Multi-purpose interconnectors
 - **Multi-terminal, Multi-Vendor?**
- Meshed offshore HVDC grid
 - **Reliability, secure supply, resource optimization**
 - **Energy islands (3 - 15 GW)**
- Main issue
 - **Protection during short-circuit conditions**
 - **HVDC CBs are needed**

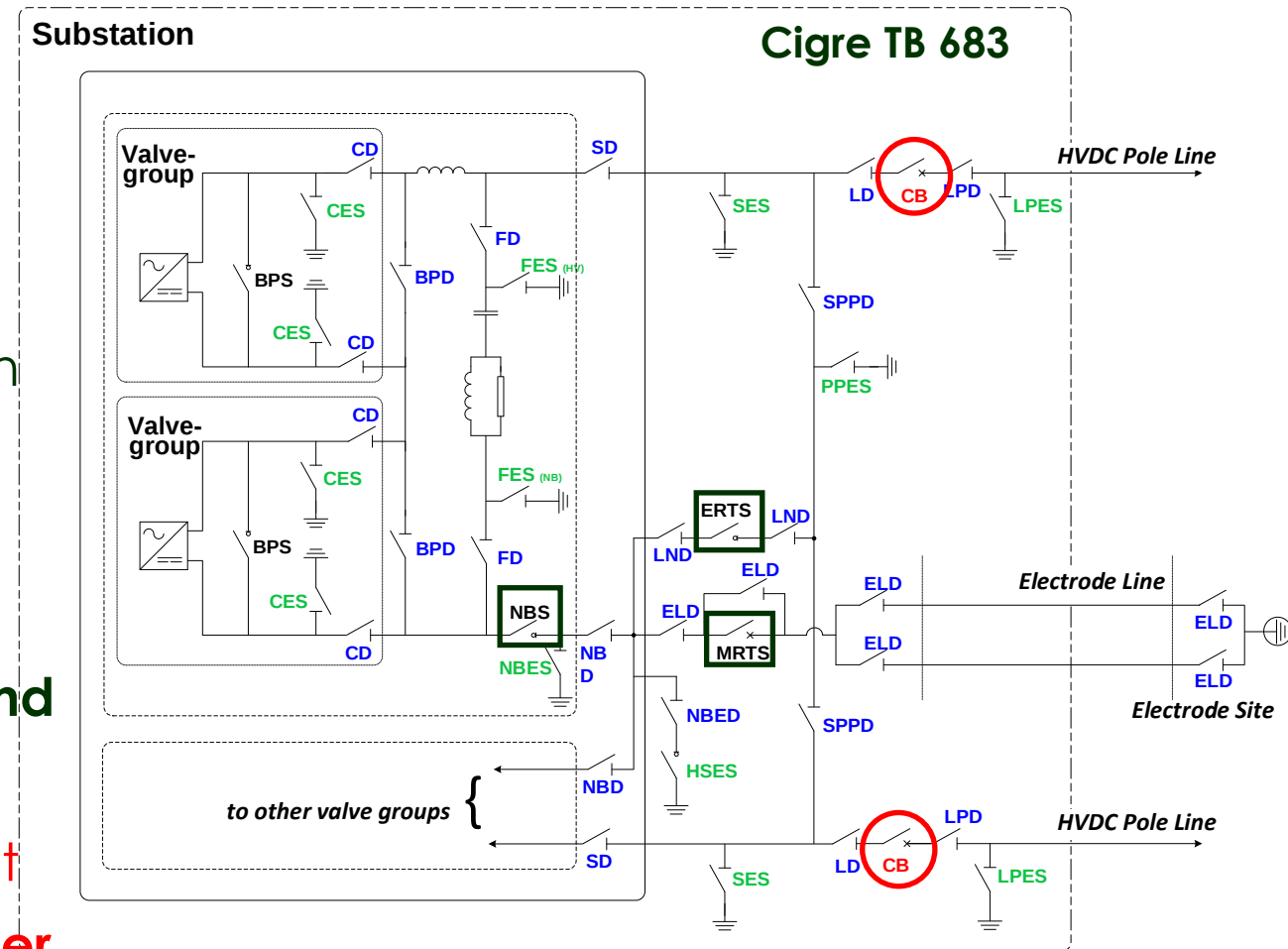


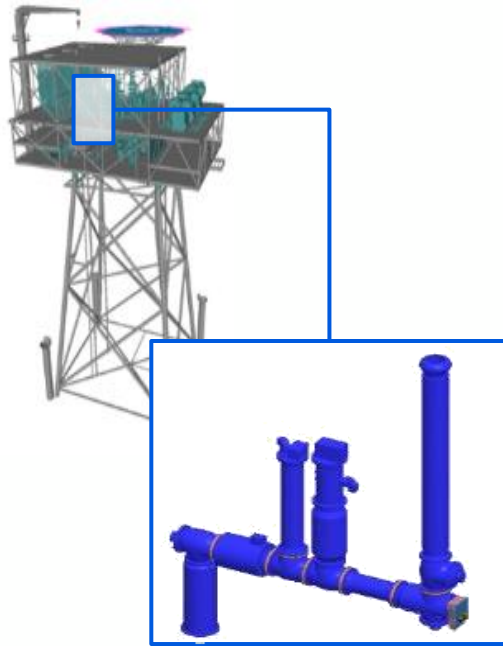
<https://www.tebodin.bilfinger.com/services/energy-transition-solutions/solutions-overview/>

HVDC Switchgear and Ongoing Standardization Activities

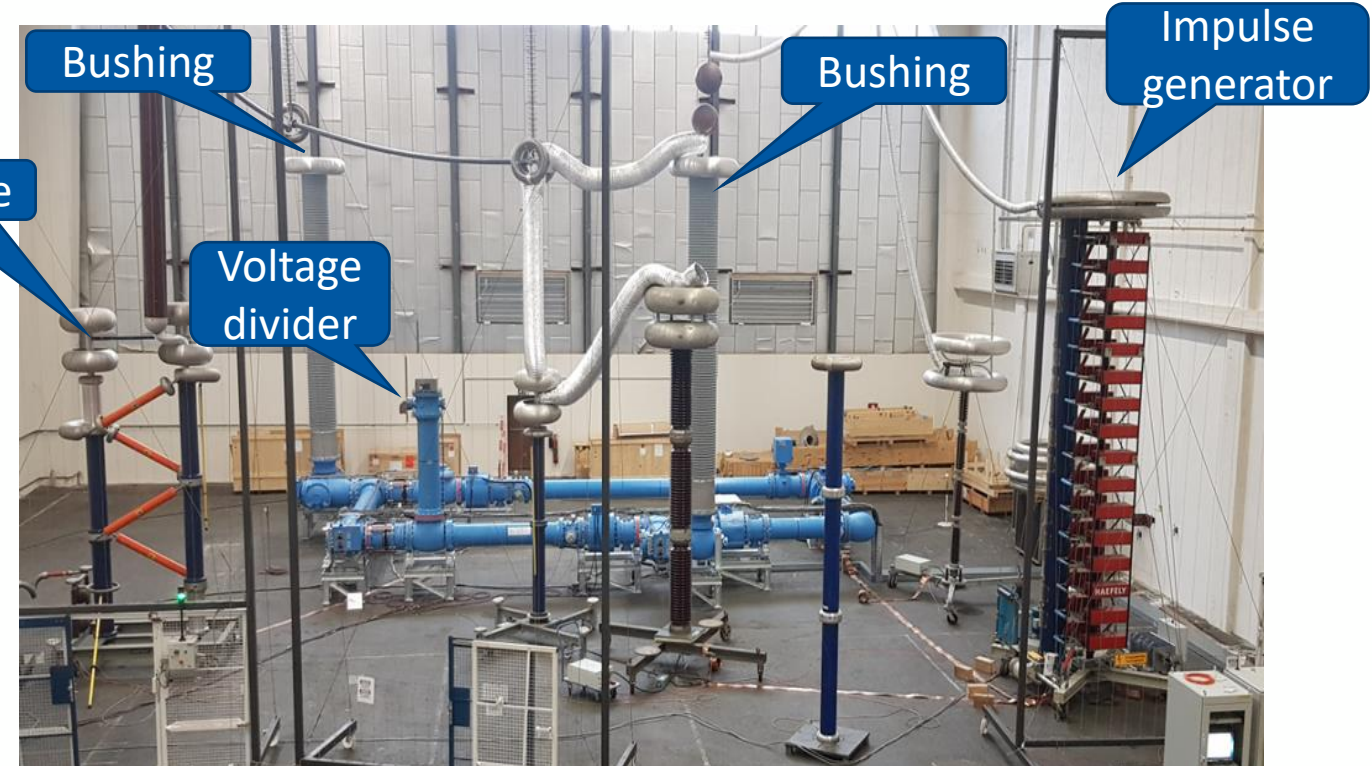
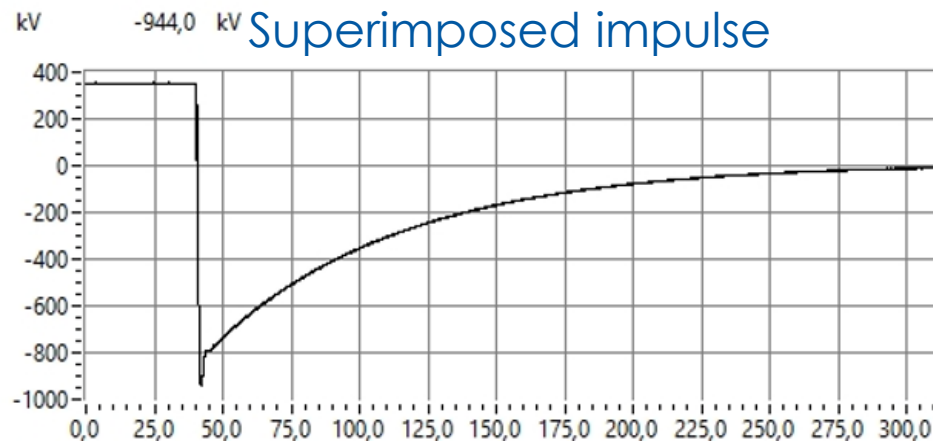
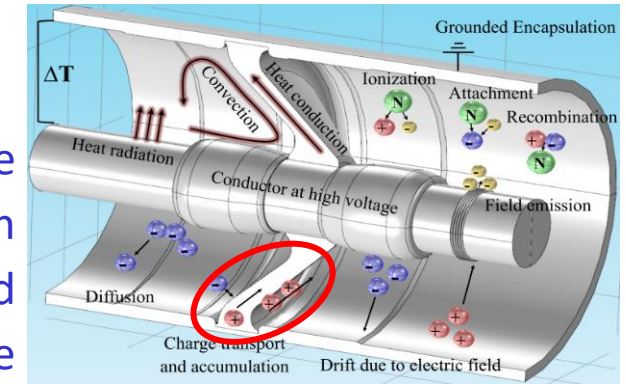
- **Disconnect Switches** – Isolate a component
 - Load current, short-circuit current
- **Earthing Switches** – Discharge energized
 - In conjunction with disconnect switch
 - IEC TS 62271 – 314: Direct current **disconnect** and **earthing switches**
- **Transfer Switches** – circuit (re-)configuration
 - IEC TS 62271 – 315: Direct current (DC) transfer switches
- **By-pass switches and paralleling switches**
 - IEC 62271-316: DC by-pass switches and paralleling switches
- **Circuit Breakers** – Break short-circuit current
 - IEC TS 62271 – 313: HVDC Circuit Breaker

➤ IEC 62271 – 5: Common specifications for DC switchgear



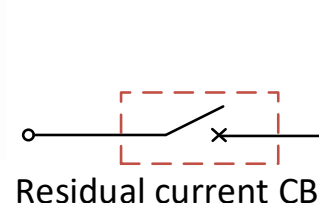
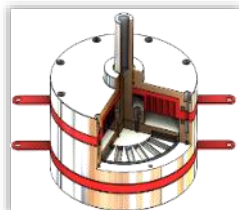
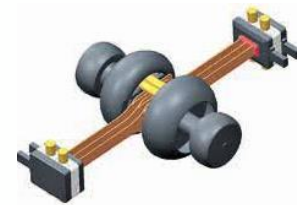
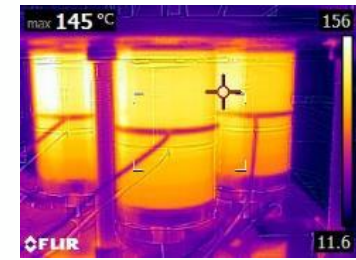
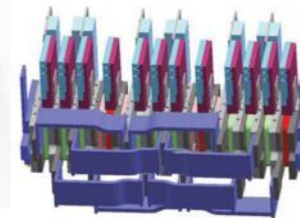
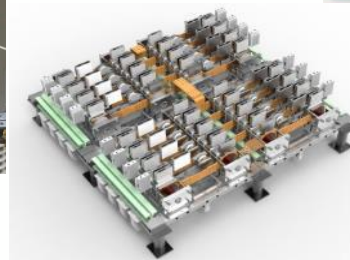
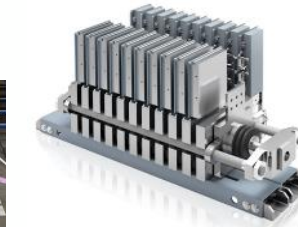


Charge accumulation to gas-to-solid interface



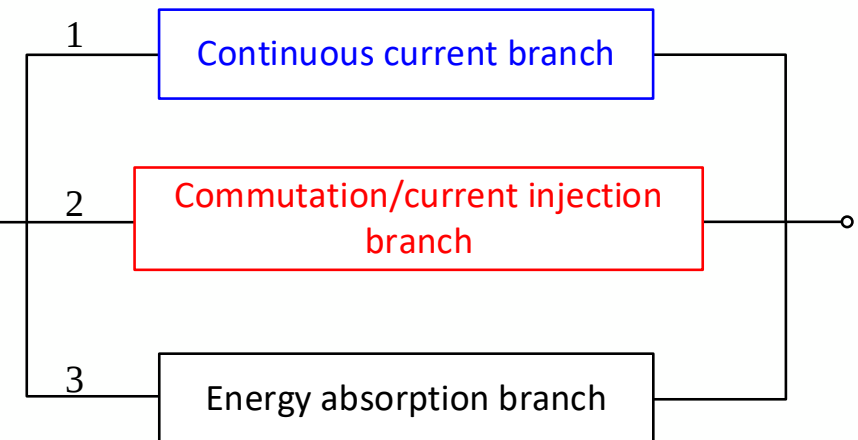
HVDC Circuit Breaker – Technique

- HVDC Circuit Breaker is a system of components
 - **Several current branches**
 - Generate the counter voltage
 - **As quickly as possible**
 - **Sufficient magnitude**
 - **Absorb system energy**
- Standard components ➔ non-standard application



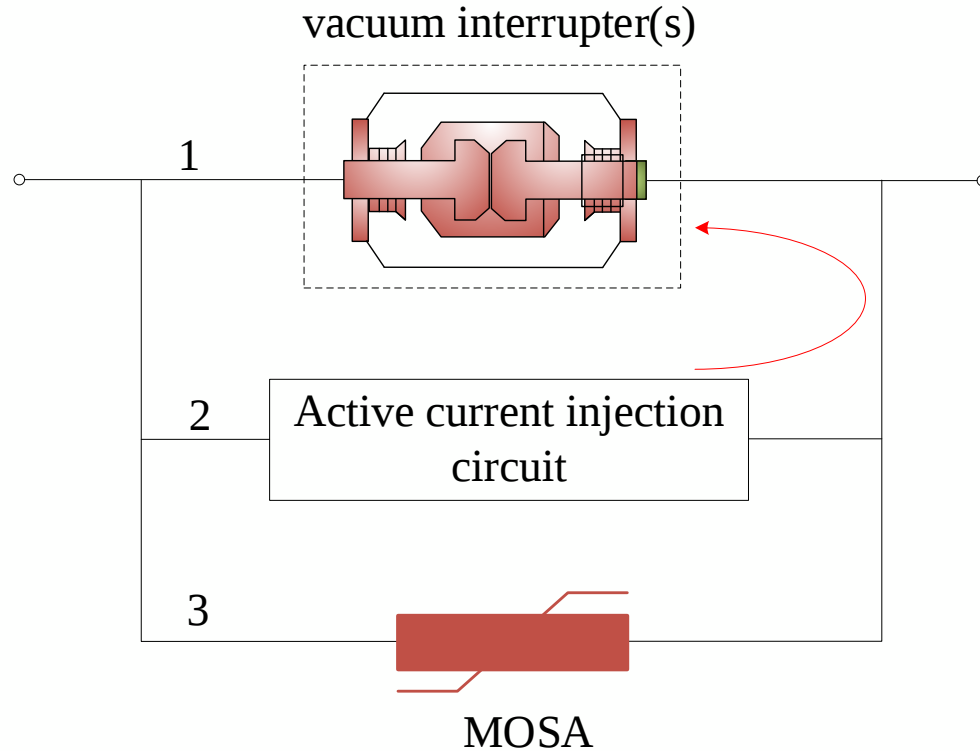
EPRI

Current limiting reactor



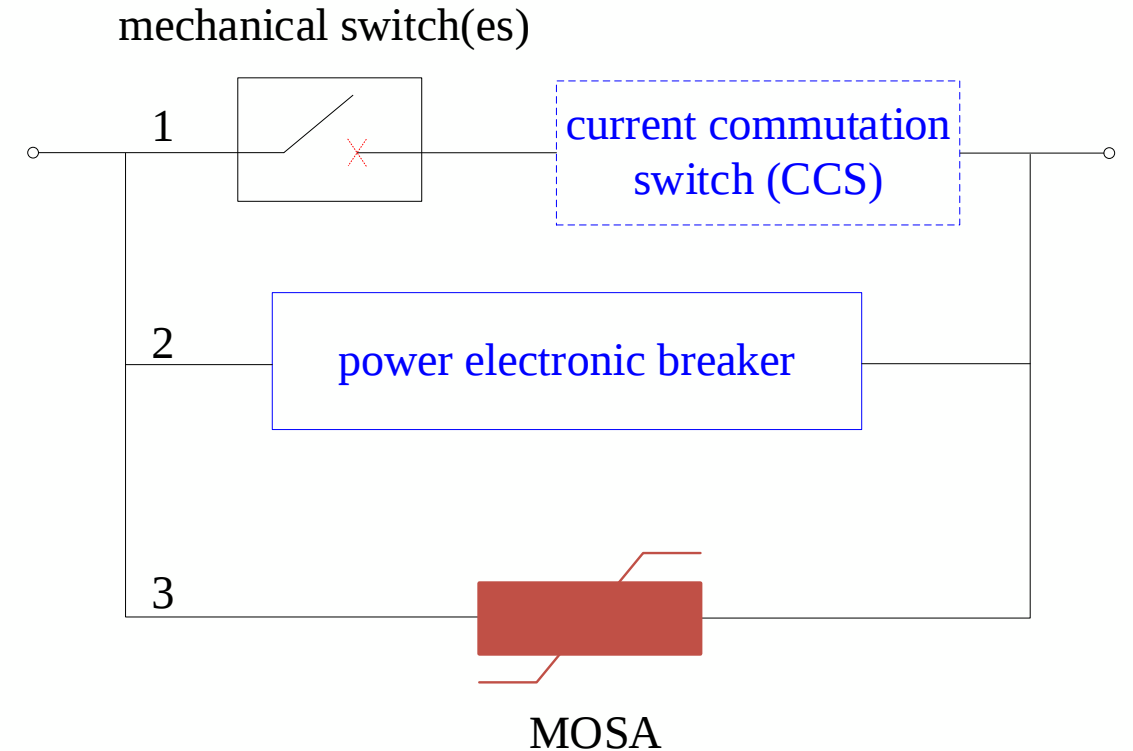
Two Leading Technologies HVDC CBs

Active Current Injection HVDC CB



- Mechanical switches
- Artificial current zero creation
- Pre-charged capacitors

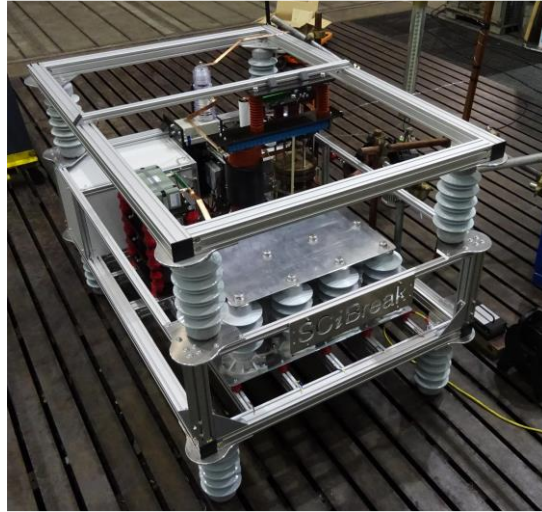
Hybrid HVDC CB



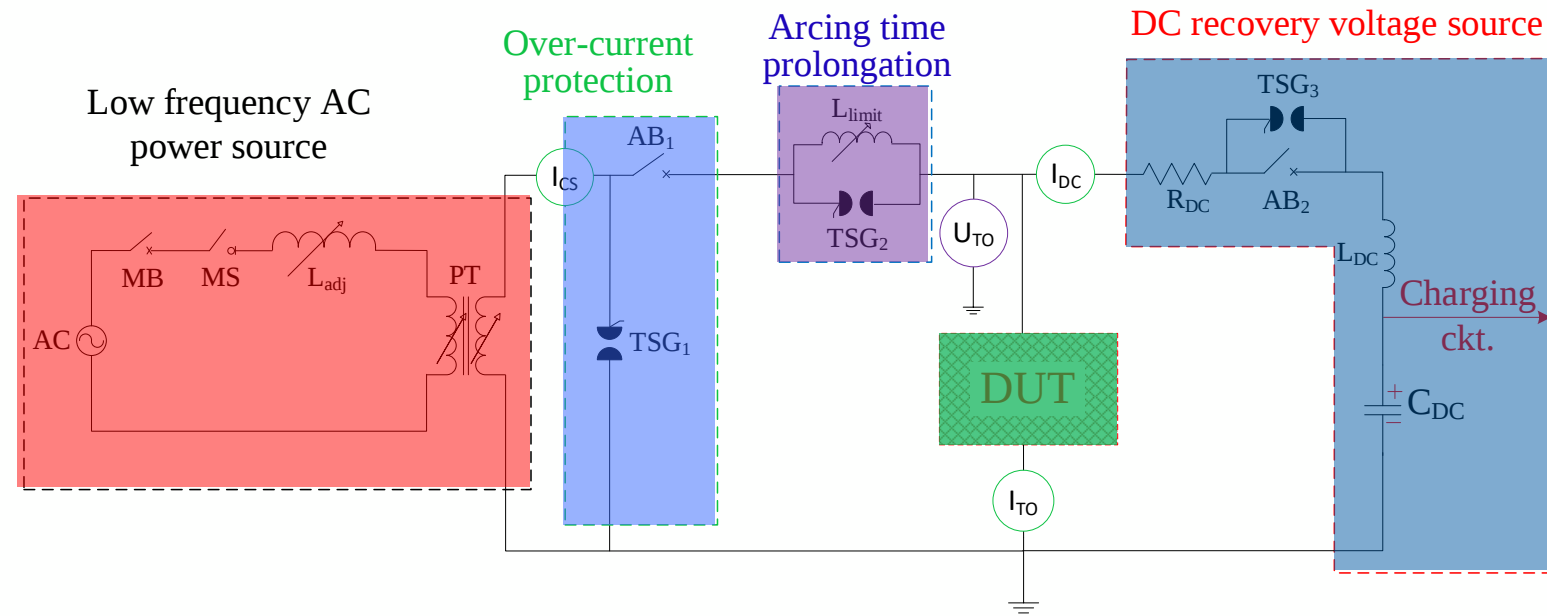
- Power electronics + mech. switch(es)
- Power electronic breaker
- No arcing → Lighter mech. Switches

Active Current Injection HVDC CB

Hybrid HVDC CB

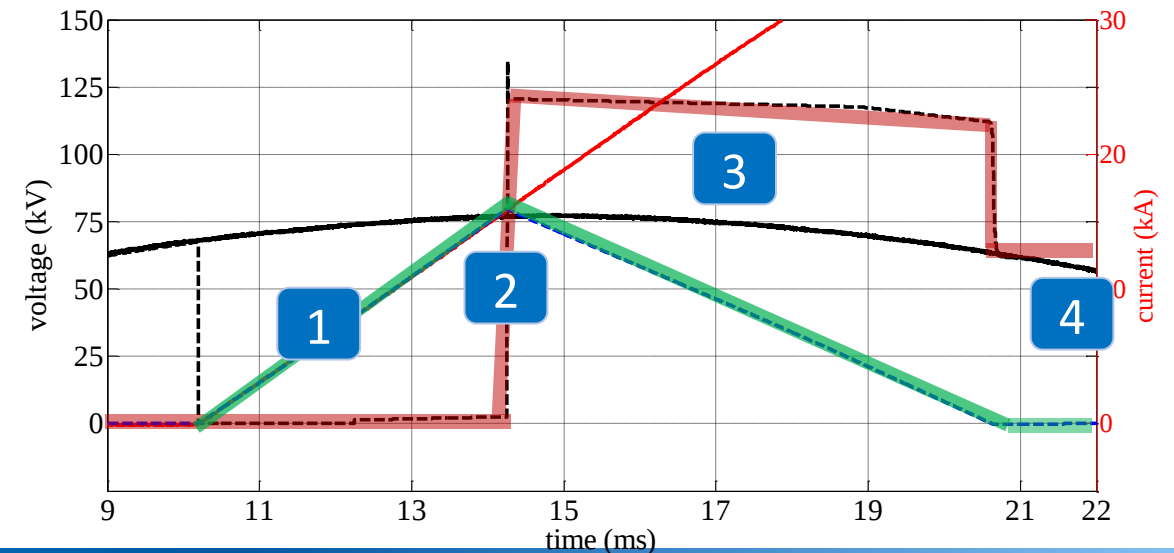
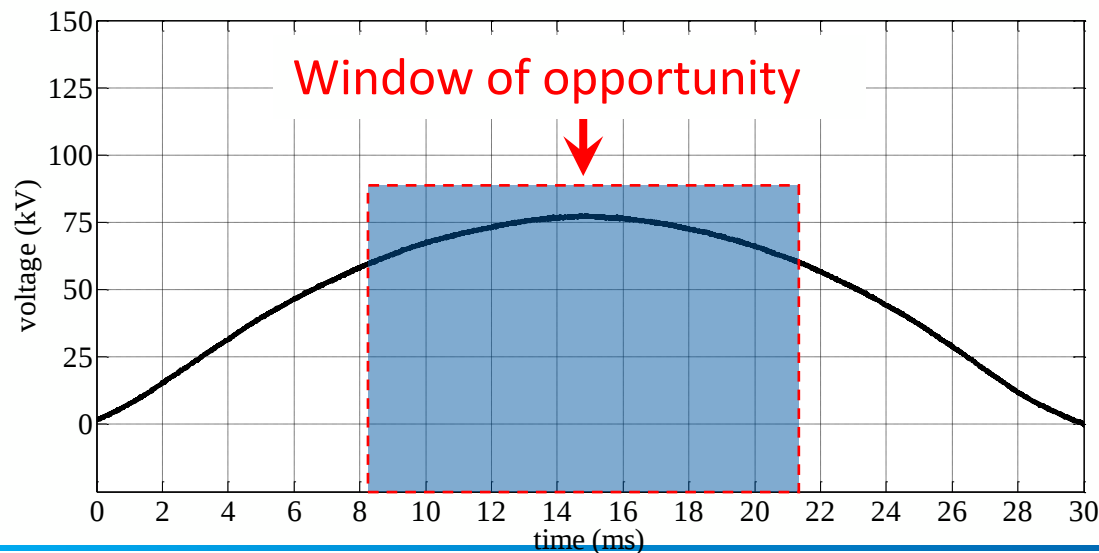


Testing → Test Circuit based on AC Generator

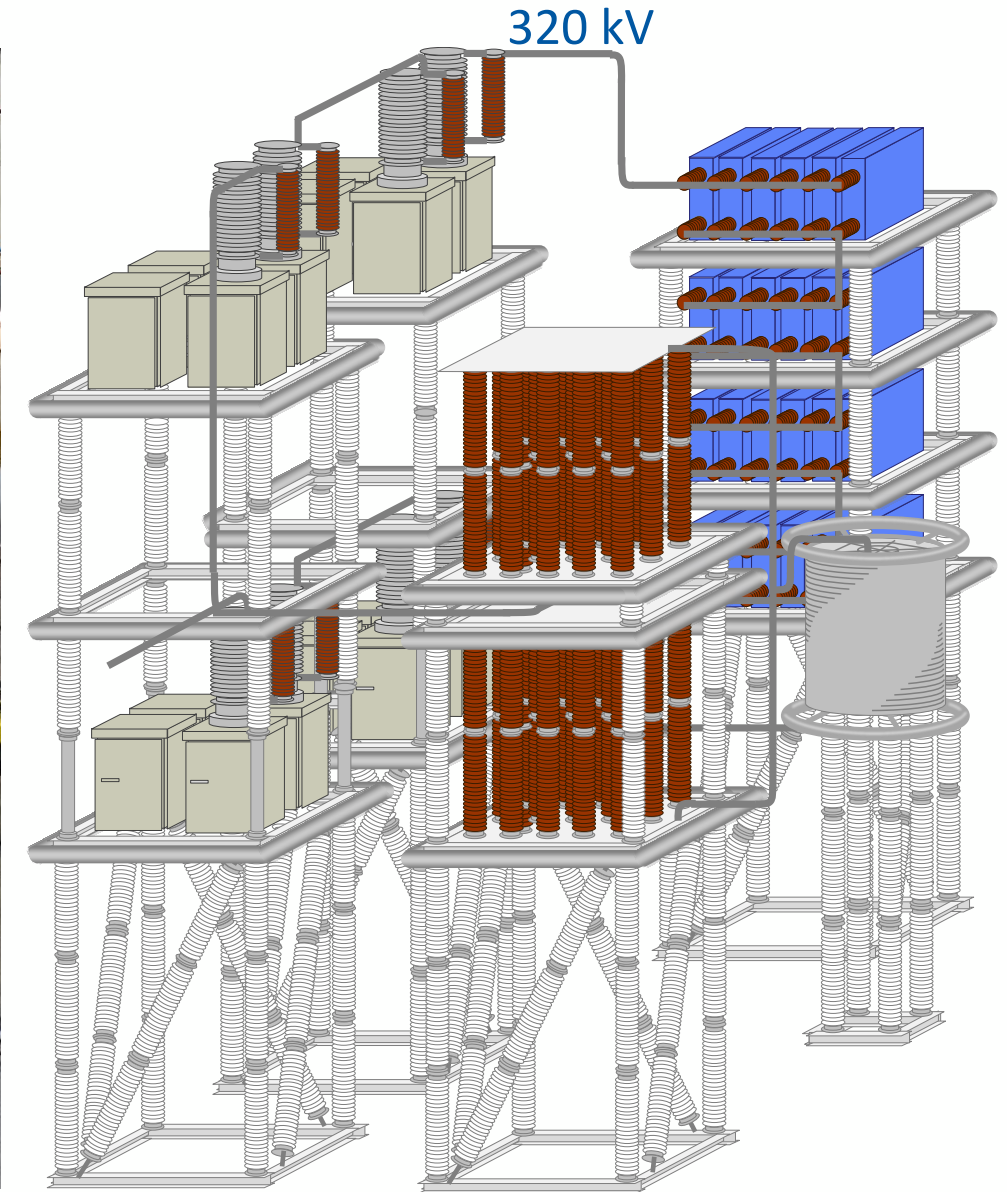
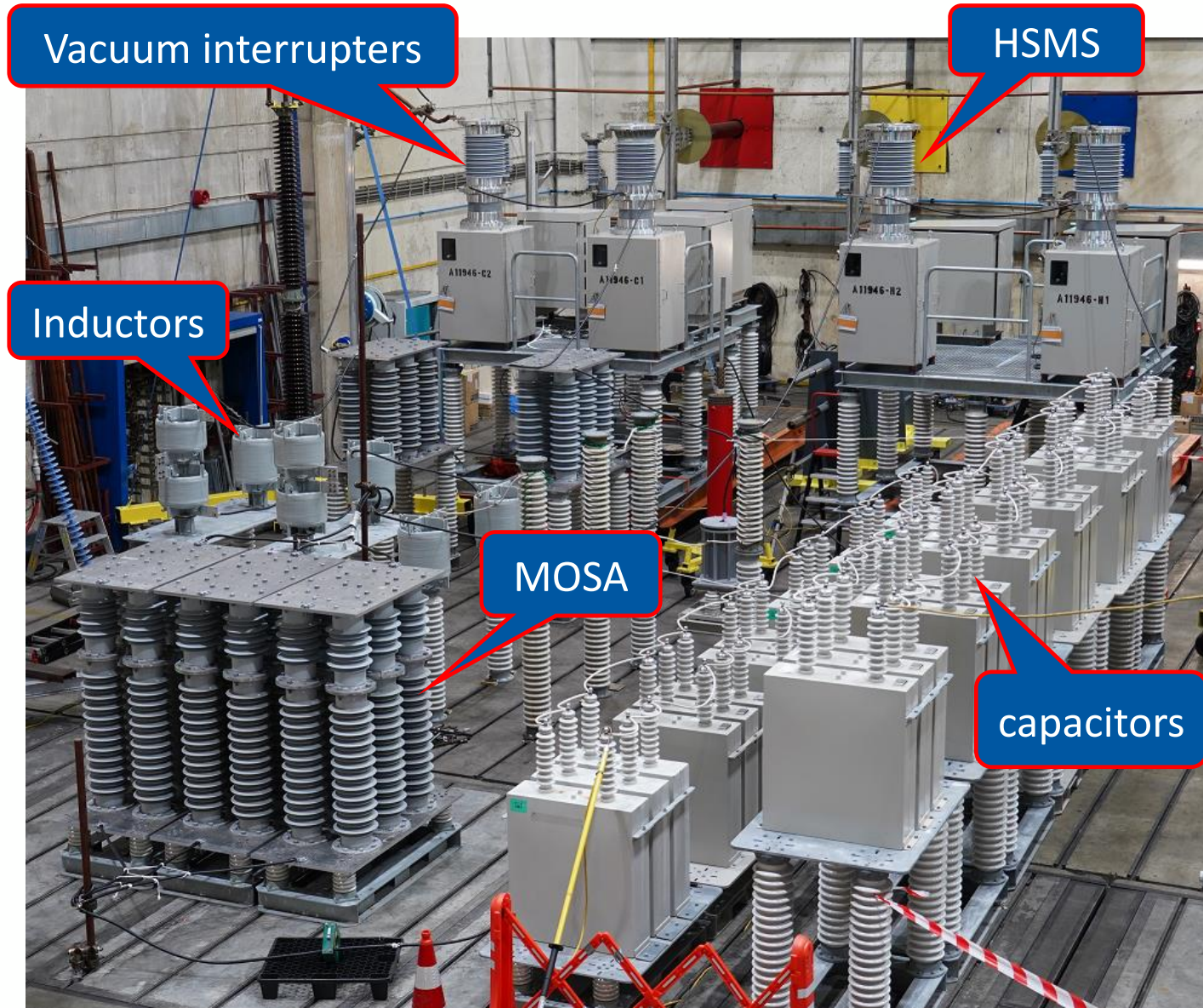


Stages of Current Interruption

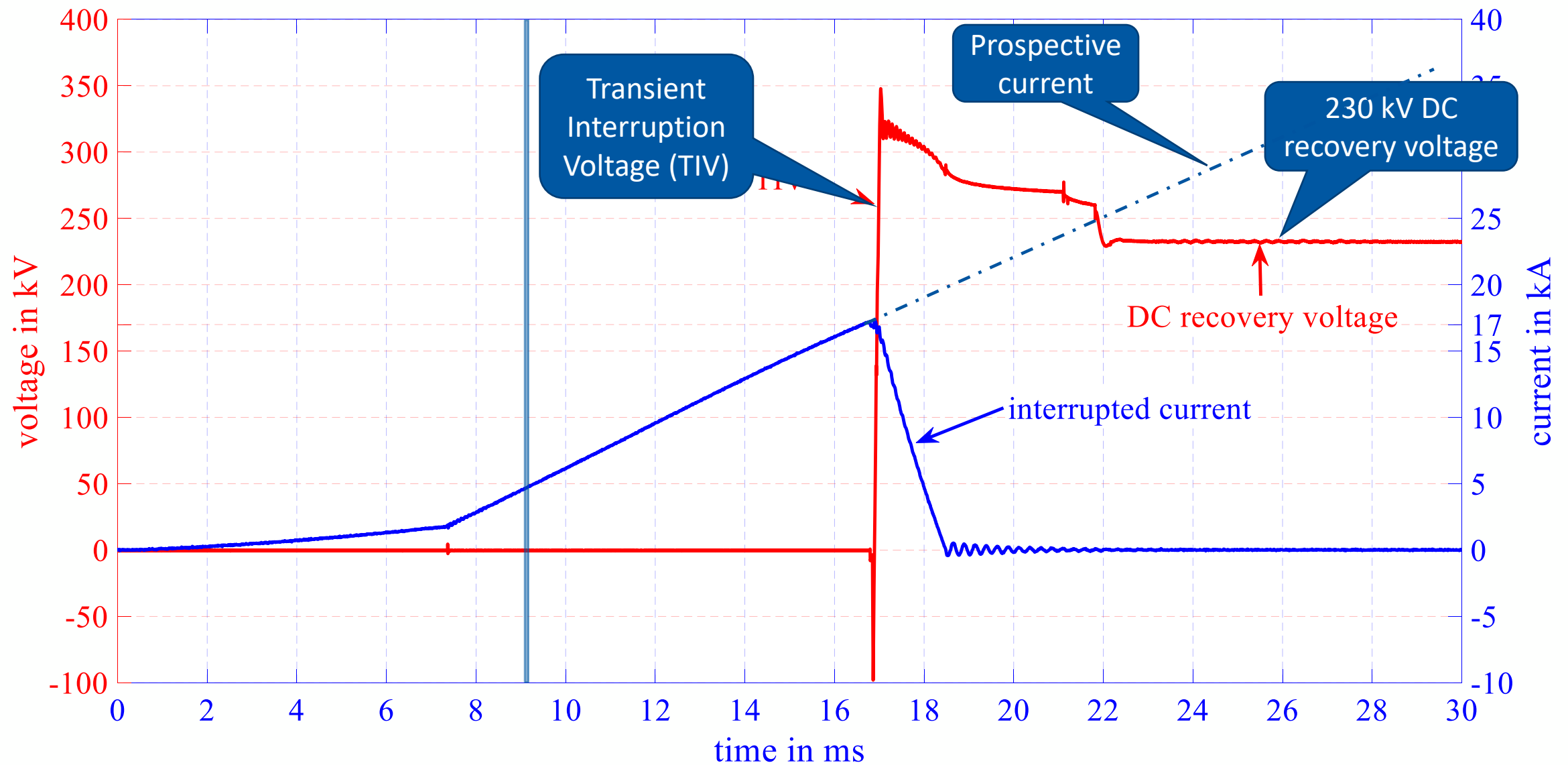
1. Internal Current Commutation
2. The generation of TIV
3. Energy absorption
4. DC voltage withstand



Active Current Injection HVDC CB → Mitsubishi Electric



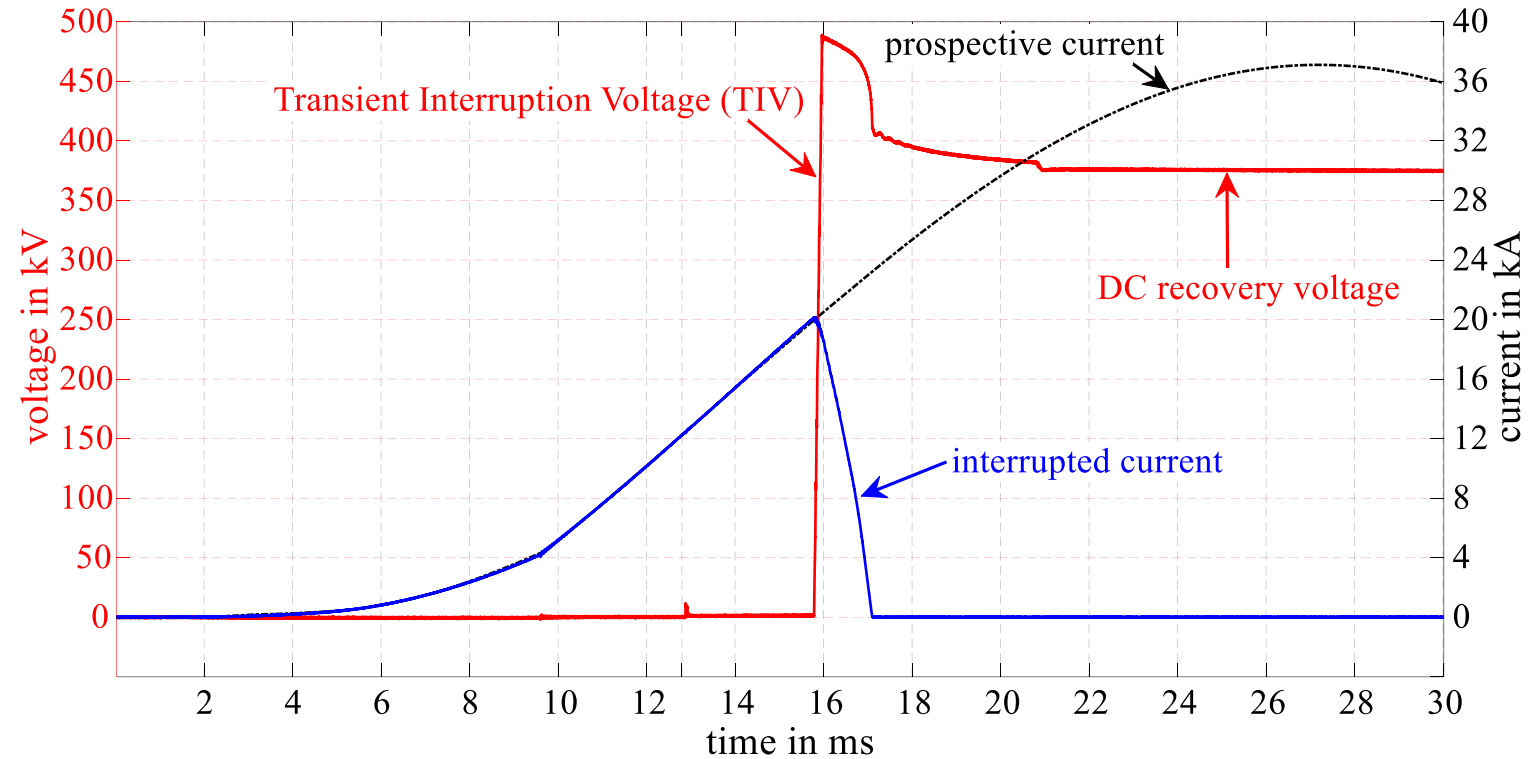
Test Result → Mitsubishi Electric



350 kV, 20 kA → Hitachi Energy



Test Result

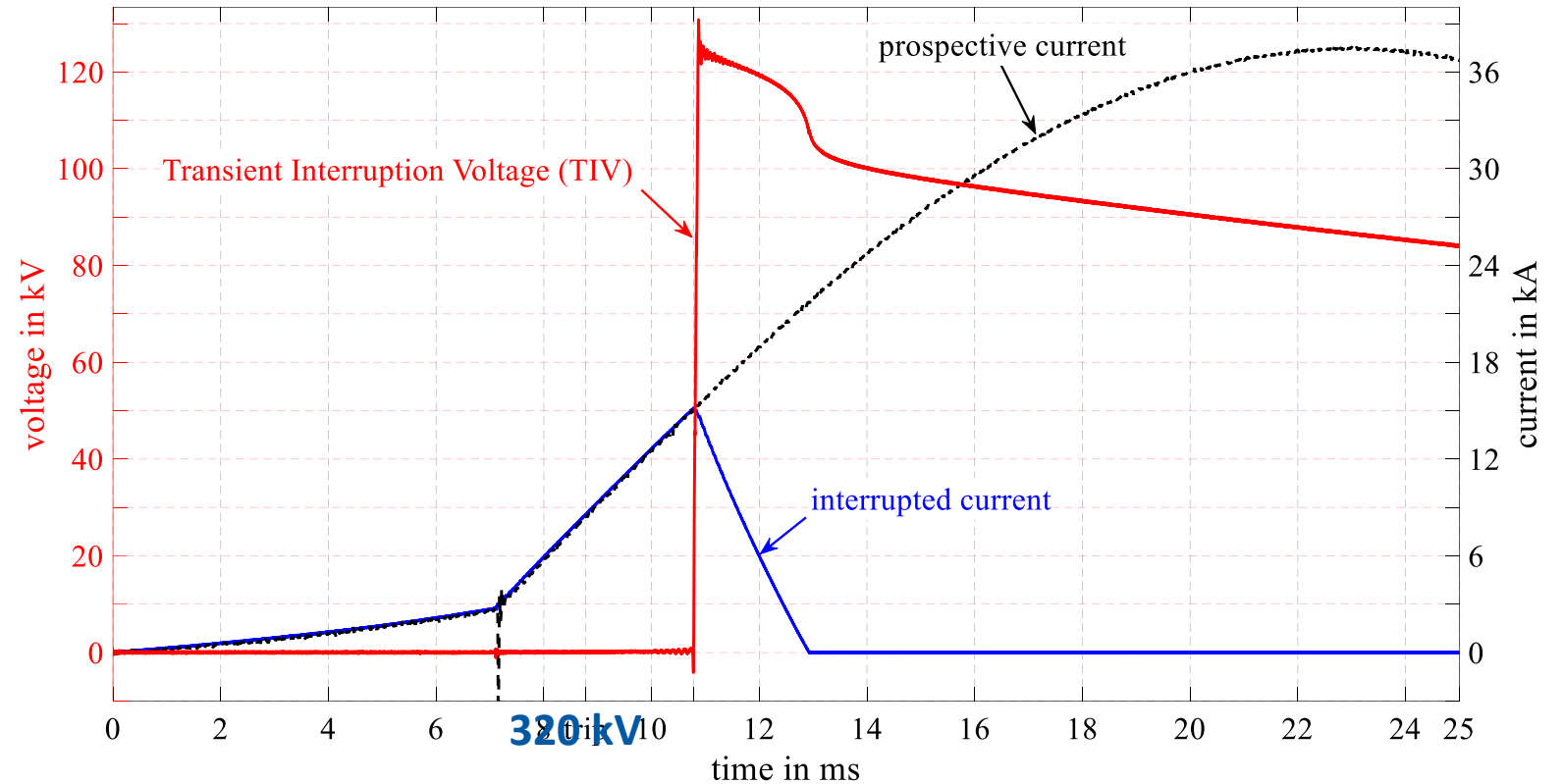


- 350 kV, 20 kA, 3 ms operation
- 10 MJ energy absorption
- 480 kV - TIV peak

80 kV, 12/15 kA → SCiBreak



Test Result



- 80 kV, 12/15 kA, ≤ 2 ms operation
- 3 independent modules
- Energy 3 MJ, > 120 kV TIV

Summary

- HVDC Switchgear are essential for Multi-terminal HVDC Grid development
 - **Disconnect switches, (High-Speed)Earthing switches, Transfer Switches and Circuit Breakers**
- Thorough testing of all HVDC switchgear is essential before installation
 - **Standards are being developed**
- A lot of focus on HVDC Circuit Breakers → Led to prototype development
 - **Test methods have been developed and test circuits are designed and readily available**
 - **Full-power short-circuit breaking tests have been demonstrated**
 - **Many other part of type test program including dielectric and other operational and as well as functional tests need to be performed**



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