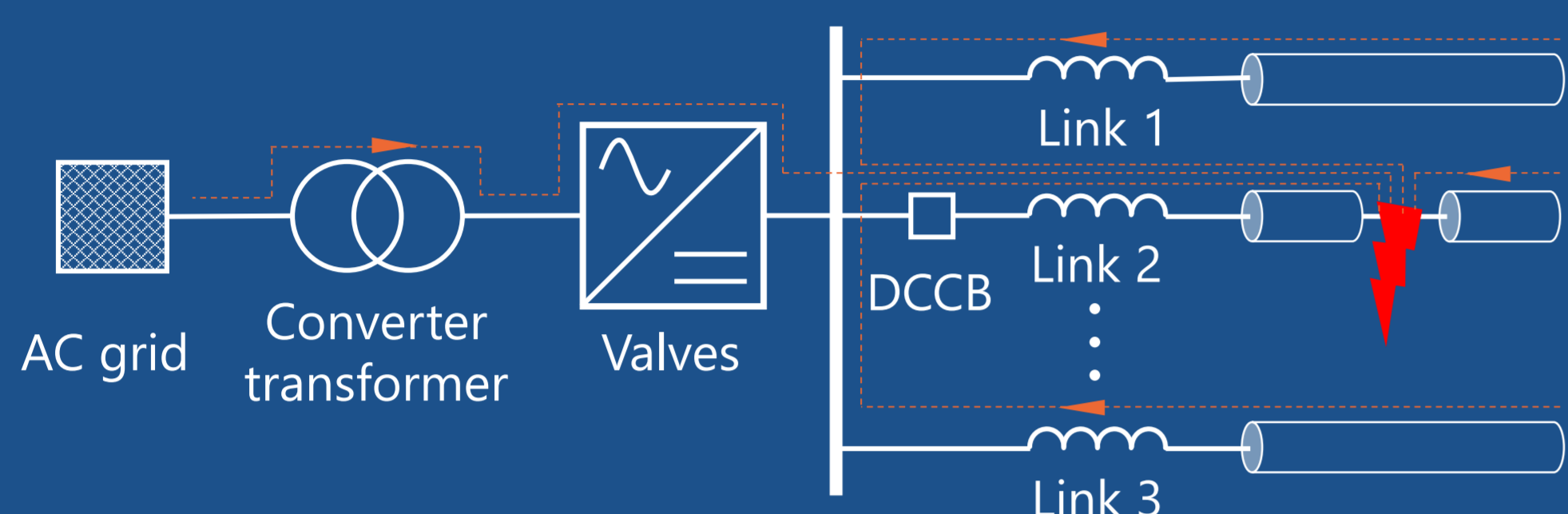
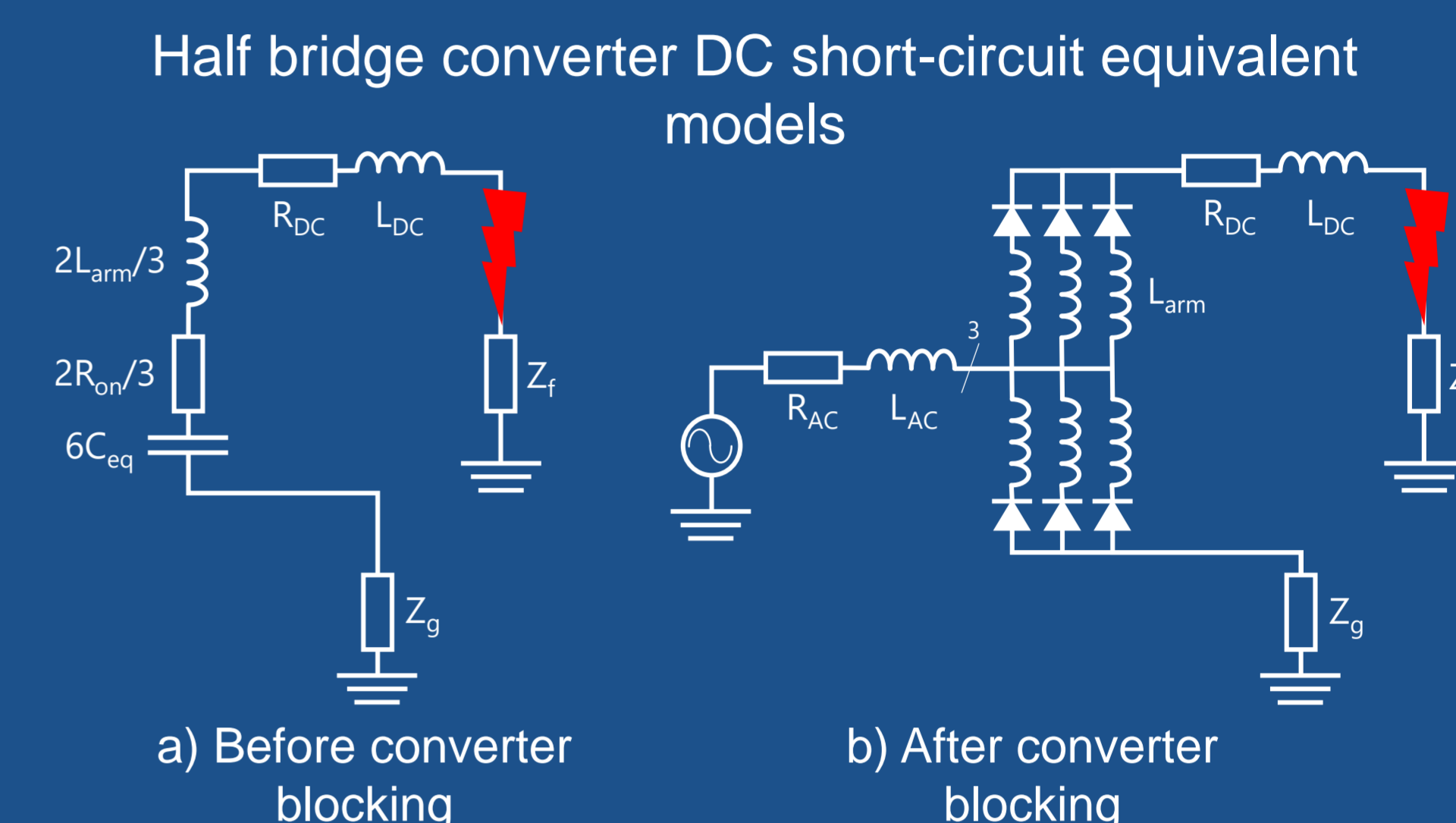


# WP5 – HVDC circuit breaker test environment

## Analysis of stresses on HVDC circuit breakers

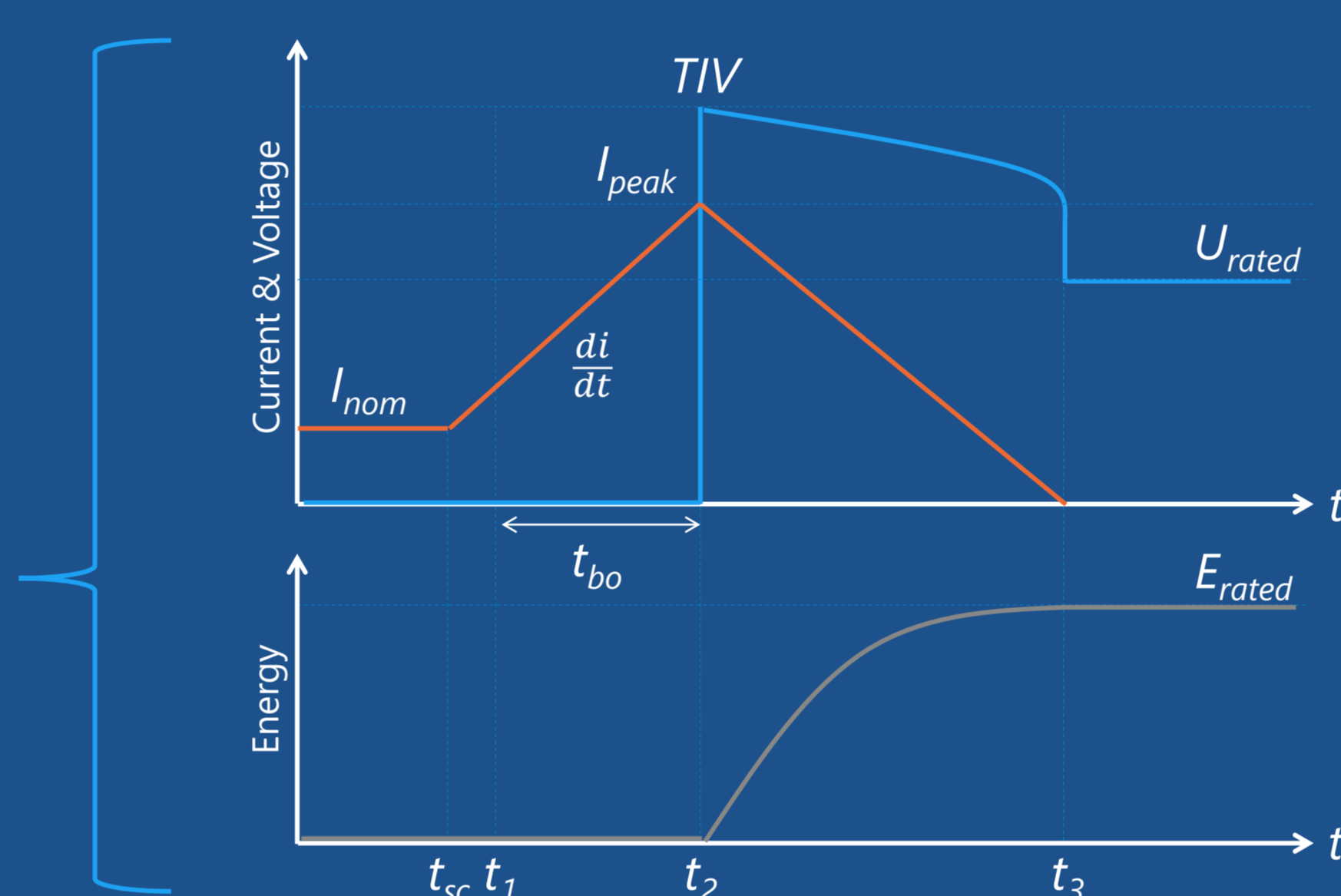


- Fault current contributions by:
  - Discharging capacitances of neighbouring cables
  - Discharging capacitances half bridge converters
  - AC grid infeed
- Converter blocking reduces current & energy stress
- Series reactors delay converter blocking but increase energy stress
- Fault current contributions can be modelled with passive equivalent sources



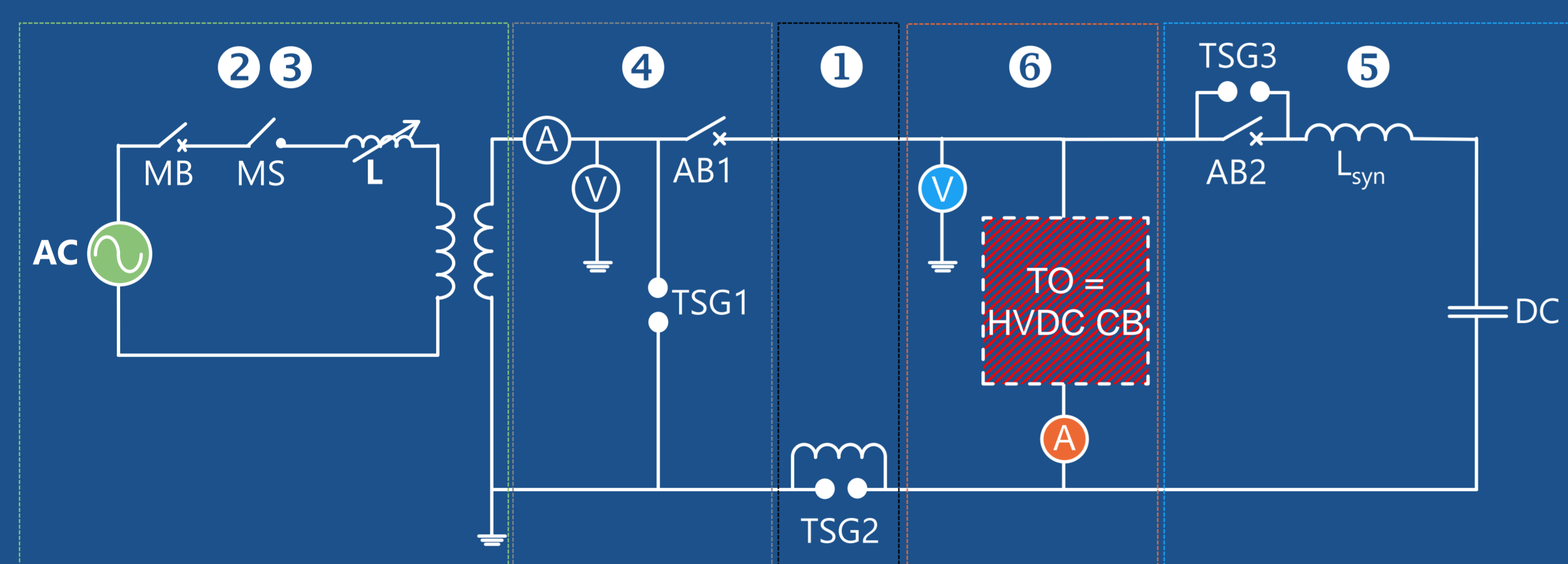
## Formulation of test requirements

<b>Dielectric tests</b>	<ul style="list-style-type: none"> <li>Between terminals / Support structure</li> <li>DC withstand / impulse / EMI</li> </ul>
<b>Operational testing</b>	<ul style="list-style-type: none"> <li>Loss / resistance measurement</li> <li>Temperature rise</li> <li>Current withstand</li> </ul>
<b>Current interruption testing</b>	<ul style="list-style-type: none"> <li>Breaking current</li> <li>Breaker operation time</li> <li>Energy absorption</li> <li>Transient interruption &amp; recovery voltage withstand</li> </ul>
<b>Special tests</b>	<ul style="list-style-type: none"> <li>Endurance tests</li> <li>Reclosing / Current limiting / Soft closing</li> </ul>

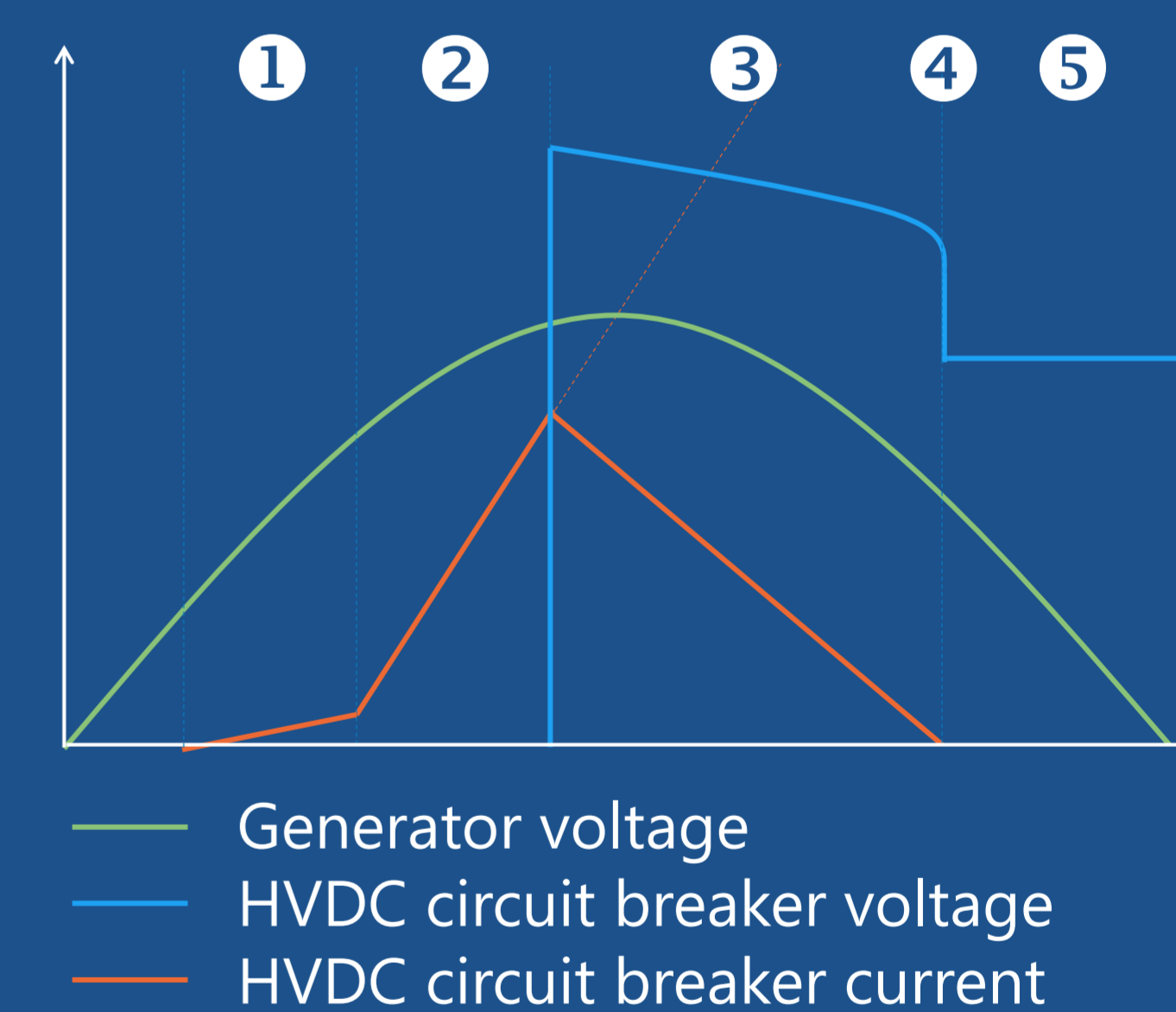


- Normal operation**
  - Operational & dielectric tests $t < t_{sc}$
- Relay time**
  - Supply range of di/dt
  - Bidirectional, different duties $t_{sc} < t < t_1$
- Breaker operation time**
  - Supply range of di/dt
  - Bidirectional, different duties $t_1 < t < t_2$
- Fault current suppression time**
  - Withstand Transient Interruption Voltage
  - Supply sufficient energy $t_2 < t < t_3$
- Isolation**
  - Apply DC voltage stress $t_3$
- Post suppression**
  - Apply DC voltage stress $t > t_3$

## Development of DC short-circuit current breaking test circuit



- Mimic effect of load current and delay operation of fast breakers
- Create current stresses di/dt &  $I_{peak}$
- Withstand TIV and create energy stresses  $E_{rated}$
- Isolate test object from the generator and protect it from over-current if it fails to clear
- Apply DC voltage stress  $U_{rated}$
- Take measurements



## Demonstration of test environment



**Mechanical HVDC circuit breaker with active current injection**



Rated voltage:	80 kV
Rated current:	2 kA
Rated short-circuit breaking current:	16 kA
Rated transient interruption voltage:	120 kV
Tested energy absorption:	4 MJ
Rated breaker operation time:	8 ms

