Liaison HVDC
France-Espagne

Comportement dynamique des convertisseurs de type VSC-MMC
Conventional 2-Level Converter

Two voltage sources on the d.c. side are switched to the a.c. side

- High level of harmonic distortion and steep front voltages resulting in HF noise and stress of component insulation
- Intermediate energy storage in d.c. side capacitors
Modular Multilevel Converter

Six voltage sources in the converter arms create a.c. and d.c. voltage

- Low level of harmonic distortion and small steep front voltages resulting in low HF noise and low switching losses
- Intermediate energy storage in converter arm capacitors
Energisation from AC Side (1st Converter)

a.c. network close CB a.c. network

adjacent tap-change actively charge converter

close by-pass DEBLOCK

B close CB

A actively charge converter

Converter_IDLE Converter_OPERATIONAL

Note:
All AC Voltages shown are idealized values based on 400kV busbar voltages.

Voltage Chart:
- 403kV
- 411kV
- 293kV
- 333kV
- 884V
- 896V
- 450V
- 1.2kV
- 1.4kV
- 702V

SP4050 (1.5 to 2 min)
SP4040 (15 sec)
SP4060 (10 sec)
SP4070 (10 sec)

T=2 min

ST_A: SP5000: COUPLED
Energisation from AC Side (2nd Converter)

a.c. network

1. DEBLOCK
   - actively charge converter

2. adjust tap-change
   - close CB

3. close by-pass

Note:
All AC Voltages shown are idealized values based on 400kV busbar voltages.

- SP4040 (15 sec)
- SP4060 (10 sec)
- SP4070 (10 sec)

- ST_B: SP5000: COUPLED

- 285kV
- 333kV
- 640kV

Converter_IDLE
Converter_OPERATIONAL

- 504V
- 1.4 → 1.6kV

TC 15 min
702V (40%)
Energisation from DC Side (2\textsuperscript{nd} converter)

- Auxiliary power demand must be supplied by local generators.
- Converter must de-block from lower capacitor energy level.
- Transformer must be energized by the converter.
- Use of tertiary winding for aux. supply requires “stable” network conditions.

Note:
All AC Voltages shown are idealized values based on 400kV busbar voltages.

Command:
- AUX Supply Change-Over to Tertiary Supply.
Steady State Operation under Network Unbalances

- **P/Q-Mode**: converter acts as a (PPS) current source
- **U/f-Mode**: converter acts as a (PPS) voltage source

### Network
- \( Z_N^{(1)} \)
- \( Z_N^{(2)} \)
- \( Z_N^{(0)} \)

### Transformer
- \( Z_T^{(1)} \)
- \( Z_T^{(2)} \)
- \( Z_T^{(0)} \)

### Converter
- \( Z_C^{(1)} \)
- \( Z_C^{(2)} \)
- \( Z_C^{(0)} \)

- **P/Q**: \( U = 0 \) (short circuit)
- **U/f**: \( I = 0 \) (open circuit)
- **U50Hz = 0**
Behaviour on AC Faults (external 3-phase fault, 0%)

- Voltage collapses to zero in all phases.
- Reactive (pps) current is fed into the fault.
- Converter module energies are subject to a large disturbance (unbalance).
- Active power transfer collapses and must be recovered after fault clearing.
Behaviour on AC Faults (external 1-phase fault, 0%)

Voltage collapses to zero in one phase.

Converter currents (pps) are superimposed by network currents (zps).

Positive phase current (pps) is fed by the converter on the secondary side.

Active power transfer is only slightly reduced and is recovered after fault clearing.
Behaviour on DC Faults (internal faults)

HVDC system is isolated from ground

1-phase ground fault on secondary side

2-phase fault (with or w/o ground) on d.c. side

1-phase ground fault on d.c. side
Behaviour on DC Faults (1-phase grd. fault, secondary side)

unsymmetrical fault in an isolated system

no fault currents – over-voltage conditions in the d.c. circuit
Behaviour on DC Faults (1-phase ground fault, d.c. side)

unsymmetrical fault in an isolated system

no fault currents – over-voltage conditions in the d.c. circuit
Behaviour on DC Faults (2-phase ground fault, d.c. side)

- **Symmetrical fault with high fault currents**

- **Free-wheeling currents after disconnection from a.c. network**