Study Committee B4

DC SYSTEMS & POWER ELECTRONICS

10110

Test Systems and Models for DC/DC converters intended for DC transmission grid applications

D. JOVCIC, A. DARBANDI, P. DWORAKOWSKI (WG B4.76, TB 827)

University of Aberdeen, UK, Manitoba Hydro International, Canada, SuperGrid Institute, France

Introduction

DC transmission grids represent significant technical advance over AC transmission systems.

It is expected that a need will arise for DC-DC converters: isolated and non-isolated.

Functionalities of DC-DC converters include: voltage stepping, galvanic isolation, power flow regulation and fault blocking.

Models of isolated and non-isolated DC-DC converters are developed (available at e-cigre) and incorporated in the CIGRE test DC grid.

Topology of Isolated DC-DC

Ratings: ±400 kV / ±200 kV, 600 MW,

Advantages

- galvanic isolation facilitates flexible grounding options and safe isolation for severe disturbances on one DC system.
- wide range of stepping ratios with good utilisation of MMC bridge ratings.

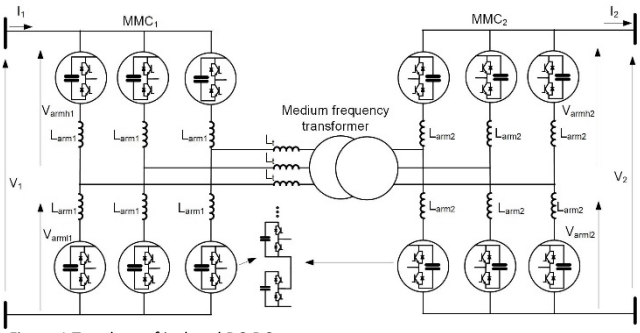


Figure 1 Topology of isolated DC-DC

Topology of Non isolated DC-DC

Ratings: 400 kV / 398 kV 600 MW

Advantages

- low cost/size/weight when compared to the isolated DC-DC which is the result of partial power processing.
- Low losses.

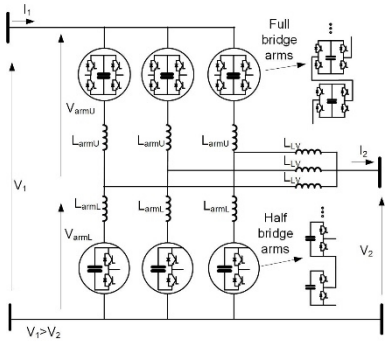


Figure 2. Topology of Non-isolated DC-DC

Isolated DC-DC

CIGRE type 4 MMC model.

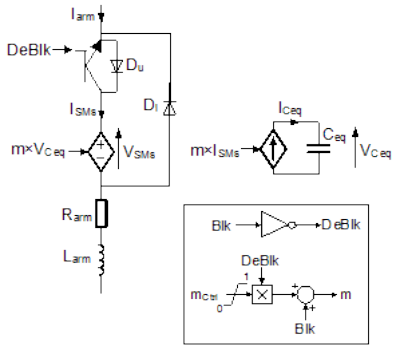


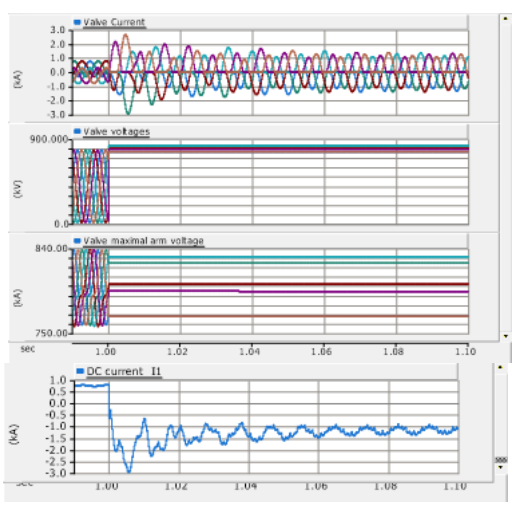
Figure 3. Model of half bridge arm

Table I Parameters of the 600 MW isolated DC-DC test system.

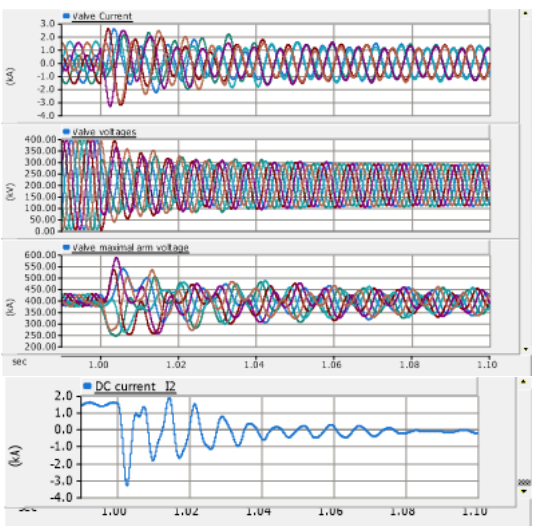
	Ratings	Arms	Cells	IGBT stress
MMC1	V_1=800 kV (±400 kV) I_1=0.75 kA, 150 Hz	L_{arm1}=36 mH (0.11pu)	C_{SM1}=2.4 mF, E_{MMC1}=9.6MJ V_{SM1}=1.6 kV, N_{SM1}=500	V_{IGBT1}=1.68 kV I_{IGBT1}=0.8 kA
MMC2	V_2=400 kV (±200 kV) I_2=1.5 kA, 150 Hz	L_{arm1}=15 mH (0.18pu)	C_{SM2}=3.8 mF, E_{MMC2}=7.2MJ V_{SM2}=1.6 kV, N_{SM2}=250	V_{IGBT2}=1.68 kV I_{IGBT2}=1.6 kA
AC circuit	V_{1ac}=440 kV, V_{2ac}=220 kV (line to line, RMS), Y-D, Turns ratio=1.15, 150 Hz			

Simulation results

- DC fault at V_1 bus: MMC 1 is blocked. MMC2 continues operating with reduced AC voltage.
- DC fault at V_2 bus: MMC2 is blocked. MMC1 continues operating with reduced AC voltage.



a) MMC 1 response (V_1).



b) MMC 2 response (V_1).

Figure 4. Response of isolated DC-DC for a DC fault at 800kV bus (V_1).

NON-Isolated DC-DC

CIGRE type 4 MMC model.

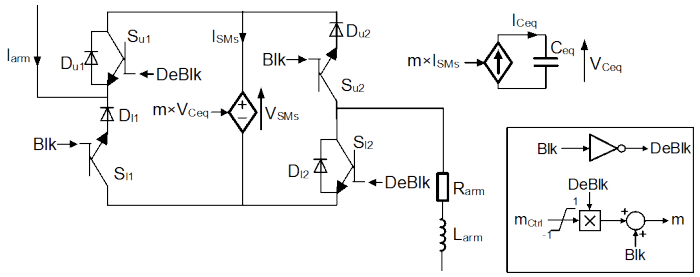


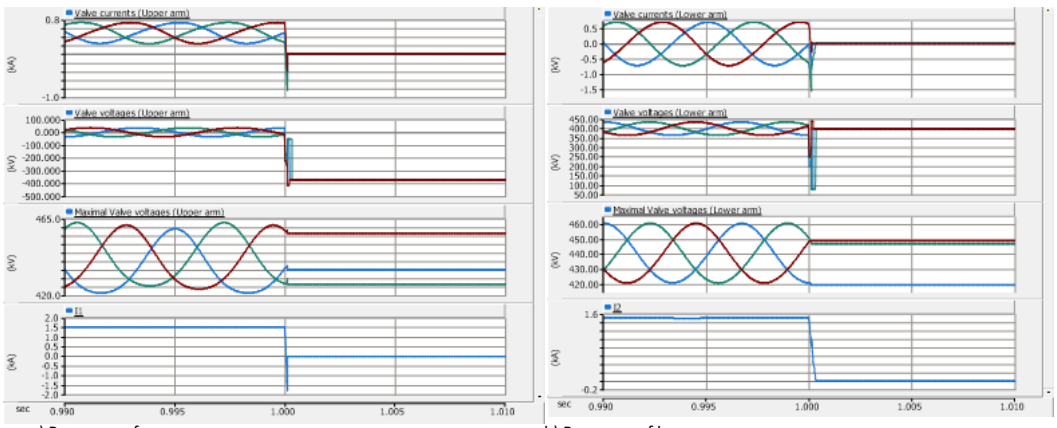
Figure 5. Model of full bridge arm

Table 2 Parameters of the 600 MW Non-isolated DC-DC test system.

	Ratings	Arms	Cells	IGBT stress
Upper arm	V_1=400 kV I_1=1.5 kA, 150 Hz	L_{armU}=20 mH	C_{smU}=0.4 mF V_{SMU}=2.0 kV, N_{SMU}=200	V_{IGBTU}=2.3 kV I_{IGBTU}=0.73 kA
Lower arm	V_2=398 kV I_2=1.51 kA, 150 Hz	L_{armL}=20 mH	C_{smL}=6.9 mF V_{SML}=2.0 kV, N_{SML}=200	V_{IGBTL}=2.3 kV I_{IGBTL}=0.73 kA
AC circuit	L_{LY}=80 mH			

Simulation results

- DC fault at V_1 bus: Upper and lower arms are blocked.
- DC fault at V_2 bus: Upper and lower arms are blocked.



a) Response of upper arms . b) Response of lower arms.

Figure 6. Response of Non-isolated DC-DC for a DC fault at 400kV bus (V_1).

Conclusions

- 600MW, ±400kV/ ±200kV Isolated DC-DC test system and model are presented,
- Simulation shows good responses for smalls signal inputs and DC faults.
- In case of DC faults, only fault-facing MMC is blocked.
- 600MW, 400kV/ 398kV Non-Isolated DC-DC test system and model are presented,
- Simulation shows good responses for smalls signal inputs and DC faults.
- In case of DC faults, upper and lower arms are blocked.