Study Committee B4

DC Systems & power electronics

897_2022

Parallel operation of a multi-vendor HVDC scheme between France and UK – IFA2000 and Eleclink interaction studies

Marco SCHUDEL, Julien MICHEL, Sébastien DENNETIERE, Hani SAAD

Rte, France

Two HVDCs links connected at same AC substation

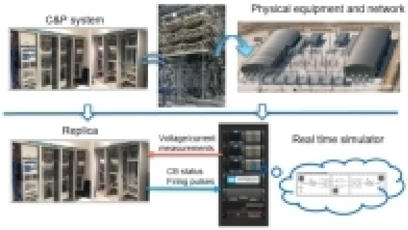
- IFA2000 link constructed in 1986 and refurbished in 2012 by GE – LCC technology – 2x1000MW, 270 kV DC
- Eleclink commissioned in 2022 – VSC MMC technology by Siemens Energy – 1000 MW, 320 kV DC

High interaction risk between HVDCs in close proximity

- Risk of undesired control interactions
- IP limitation for model sharing with different vendors
- Outdated LCC model (e.g.: protections)
- Studies performed to:
  - Prepare the commissioning
  - Prepare insertion into AC network
  - Verify absence of interactions between the two HVDCs

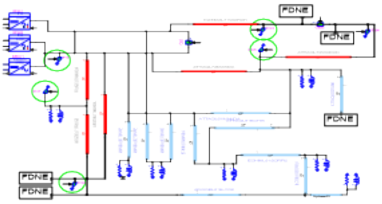
Hardware In the Loop setup

- Replicas of both C&P systems are connected to a Real Time Simulator, where AC network and converters are modelled



Test scenarios on several operating points of the HVDC scheme

- Faults, power ramps, start-up/shutdown, etc.



- No identified C&P interactions on strong networks
- Operation of both links lead however to different network steady state conditions, that are potentially less robust for the LCC link (e.g.: firing angle, tap changer position, etc.)
- On weak networks, LCC link may have a negative influence on the VSC link as network is more sensitive to LCC link behavior (see below)

Example of fault cases leading to trips

- 3 phase-to-ground fault at AC substation – 60 or 250 ms fault
  - VSC trips due to converter transformer saturation of LCC link
  - VSC link alone does not trip

Conclusion

- Connection of two C&P replicas from different vendors successfully achieved to overcome limitations:
  - In information exchange among vendors
  - Due to outdated and/or simplified offline models
- Adverse control interactions of both links are limited as in the majority of the cases in normal network situations
- On specific weak AC network cases, the scheme becomes even more sensitive to faults as the loss of active power can be higher when both links are connected

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Replica setup, interface with simulator

Voltage/current measurements at different points

Analog outputs: 76 + 158

Digital outputs: 191

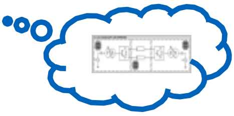
CB status
Firing pulses

Digital inputs: 21 + 96

Analog inputs: 47

Eleclink + IFA2000

Real time simulator



Examples of AO:

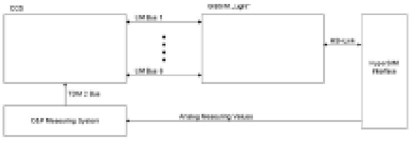
- Primary and secondary voltages of transformers
- Primary and secondary currents of transformers
- DC current, voltage

Examples of DI:

- Circuit breaker position
- Transformer tap changer position

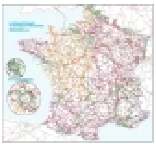
Interface between simulator and valve control

- Additional High Speed Interface (HSI) was developed in collaboration with converter vendor and RTS supplier to exchange the firing pulses through optical connections



Network model

- Thevenin source used for extremely weak network situations
- Detailed network model for real situations, using a frequency dependent network model at the boundaries

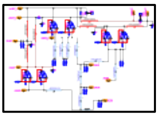


French detailed network
+ European network

reduction

French 400kV +
local 225/90kV network

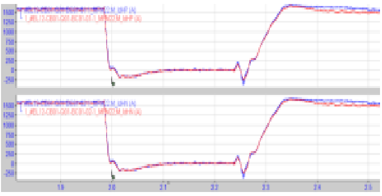
FDNE



Nearby substations and lines

Replica validation

- Behavior validated against FAT of real cubicles of the VSC Link



DC current after solid AC fault on network

- Model of LCC link validated against real events with on-site measurements (e.g.: pole to ground fault)

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Fault scenarios on detailed network

- Different fault types and durations performed at several operating points and substations

o: trip of one link, x: no trip	Both		IFA2000		Eleclink	
Case	24	25	24	25	24	25
IFA2000 Active power (pu), FR to UK positive	-1	1	-1	1	-1	1
Eleclink Active power (pu), FR to UK positive	-1	1	-1	1	-1	1
Eleclink Reactive Power	Voltage control mode					
Scenario						
AC Grid fault						
1phG fault, Manda, 0%, 60ms	o	x	o	x	x	x
1phG fault, Argoe, 0%, 60ms	x	x	x	x	x	x
1phG fault, Attaq, 0%, 60ms	x	x	o	x	x	x
1phG fault, Fruge, 0%, 60ms	x	x	x	x	x	x
1phG fault, Waran, 0%, 60ms	x	x	x	x	x	x
2phG fault, Manda, 0%, 60ms	o	x	o	x	x	x
2phG fault, Argoe, 0%, 60ms	x	x	x	x	x	x
2phG fault, Attaq, 0%, 60ms	o	x	x	x	x	x
2phG fault, Fruge, 0%, 60ms	x	x	x	x	x	x
2phG fault, Waran, 0%, 60ms	x	x	x	x	x	x
3phG fault, Manda, 0%, 60ms	o	x	o	x	x	x
3phG fault, Argoe, 0%, 60ms	x	x	x	x	x	x
3phG fault, Attaq, 0%, 60ms	x	x	o	x	x	x
3phG fault, Fruge, 0%, 60ms	x	x	x	x	x	x
3phG fault, Waran, 0%, 60ms	x	x	x	x	x	x
2ph fault, Manda, 0%, 60ms	x	x	x	x	x	x
2ph fault, Argoe, 0%, 60ms	x	x	x	x	x	x
2ph fault, Attaq, 0%, 60ms	x	x	x	x	x	x
2ph fault, Fruge, 0%, 60ms	x	x	x	x	x	x
2ph fault, Waran, 0%, 60ms	x	x	x	x	x	x

- Initial conditions are changed by the presence of both links (e.g.: firing angles, tap changer positions, etc.)
- In some cases, these conditions are less stable for the LCC link, leading to a trip in case of a fault
- No positive impact of the VSC voltage support capabilities on the LCC reliability

Additional events

- Faults during power reversals (160MW/min)
- Starting/stop sequences of LCC or VSC link with ramping
- Load steps
- VSC link trip (DC faults, secondary busbar solid fault) on minimum SCL and real network
- Reactive power ramps
- Temporary fault of interstation communication (with and without ramping)

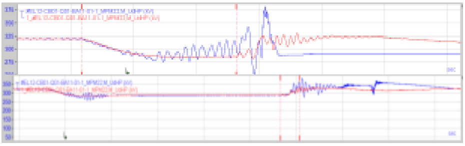
⇒ No negative control interactions identified on the selected cases

Fault scenarios on weak networks

- VSC link withstand all scenarios alone but not with the LCC link: the scheme is weakened

o: trip of one link, x: no trip	Both		
Case	2	4	11
IFA2000-1 Active power (pu), FR to UK positive	-1	1	-1
IFA2000-2 Active power (pu), FR to UK positive	-1	1	-1
Eleclink Active power (pu), FR to UK positive	-1	1	-1
Eleclink Reactive Power (equal for FR and UK), from converter to grid (pu)	-1	-1	0
U network (equal for FR and UK) (1 pu = 400 kV)	1.05	1.05	1
Scenario			
AC Grid disturbances			
1 - 1phG fault, Mandarins, 0%, 60ms	x	x	x
2 - 1phG fault, Mandarins, 0%, 250ms	o	x	o
3 - 2ph fault, Mandarins, 60ms	x	x	x
4 - 2ph fault, Mandarins, 250ms	x	o	x
5 - 2phG fault, Mandarins, 0%, 60ms	x	x	x
6 - 2phG fault, Mandarins, 0%, 250ms	x	o	x
7 - 3phG fault, Mandarins, 0%, 60ms	x	o	x
8 - 3phG fault, Mandarins, 0%, 250ms	x	o	x

- With the LCC link, VSC link trips because of an induced high DC voltage or arm current imbalances on some specific cases



DC voltage for the VSC link with (top) and without (bottom) the LCC link

- A fault can be even more critical with the two links in a parallel operation as it implies a higher amount of power loss

Conclusion

- Connection of two C&P replicas from different vendors successfully achieved to overcome limitations:
    - In information exchange among vendors
    - Due to outdated and/or simplified offline models
- Adverse control interactions of both links are limited as in the majority of the cases in normal network situations
- On specific weak AC network cases, the scheme becomes even more sensitive to faults as the loss of active power can be higher when both links are connected
- Risk mitigation solutions are to be further analysed with the replica on dedicated situations