

Study Committee B4 DC systems and power electronics

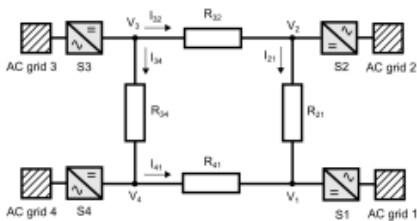
Paper ID_10896

Integration of power flow controllers in HVDC grids

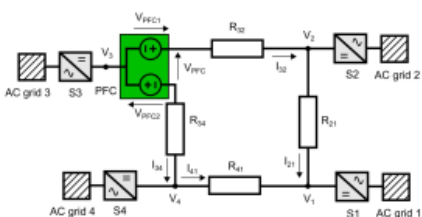
Florent MOREL, Joan SAU BASSOLS, Sellé TOURE, Serge POUILLAIN, Frank JACQUIER
Supergrid Institute

Motivation

- Not enough degrees of freedom to control all currents in dc grids



- Potential congestions, power curtailments, needs for grid reinforcement
- Control of current distribution in dc grids needs additional hardware → power flow controllers
- Interest of *interline power flow controllers*

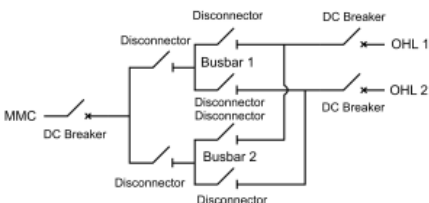


$$V_{FFC1} = V_{FFC2}$$

- How to integrate this converter in a dc switch yard?
 - Which busbar arrangement?
 - How to insert and bypass?

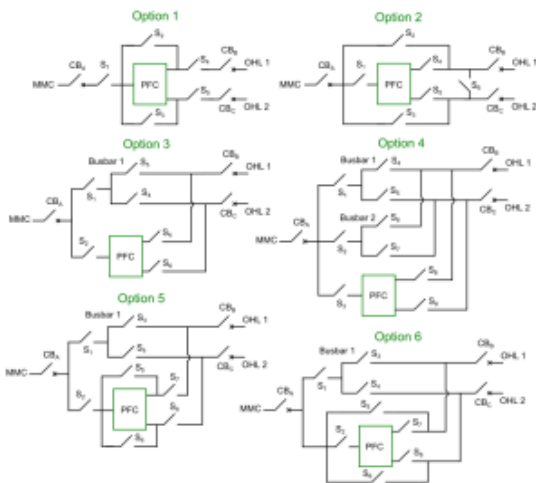
DC busbars

- Fault at a node → major consequences
- Dc busbar design related to targeted availability
- Different possible arrangements
- Example: Double busbar single breaker arrangement



Busbar arrangement with PFC

- PFC replaces a busbar or is added as an additional PFC-busbar
- Constraints
 - A fault in a terminal must be isolated
 - Single busbars: a fault in the busbar may stop the power transmission
 - Double busbars: a fault in a busbar can temporally stop the power transmission



- Switches "S_x" does not have current breaking capability
- For each option, assess if power transmission can be resumed after CB opening and reconfiguration.
- Example for option 2

Faults	Switches	Comments
MMC	S ₁ S ₂ S ₃ S ₄ S ₅ open / S ₆ closed	1 path
OHL 1	S ₁ S ₂ S ₄ S ₅ S ₆ open / S ₃ closed	1 path
OHL 2	S ₁ S ₃ S ₄ S ₅ S ₆ open / S ₂ closed	1 path
PFC	S ₁ S ₄ S ₅ open / S ₂ S ₆ closed / S ₃ DM S ₁ S ₄ S ₅ open / S ₃ S ₆ closed / S ₂ DM S ₁ S ₄ S ₅ open / S ₂ S ₃ closed / S ₆ DM	3 paths PPC

PPC: Possible power curtailment since the PFC cannot be used.
DM: Does not matter.

Study Committee B4 DC systems and power electronics

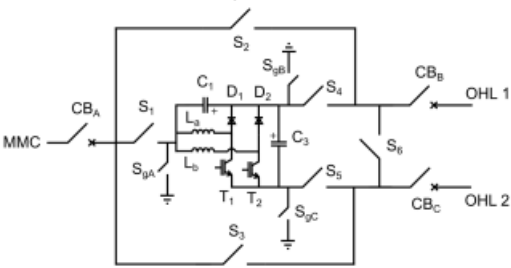
Paper ID_10896

Integration of power flow controllers in HVDC grids

Florent MOREL, Joan SAU BASSOLS, Sellé TOURE, Serge POUILLAIN, Frank JACQUIER

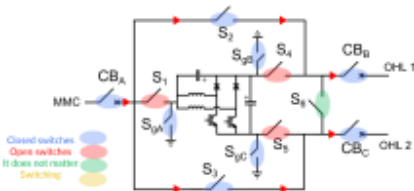
Supergrid Institute

Selected configuration

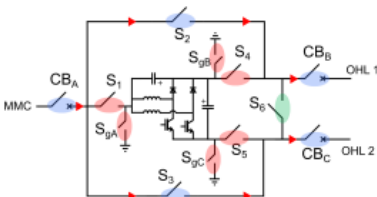


Sequence of operation for insertion

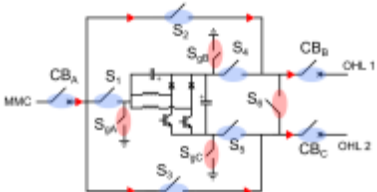
- Bypass and insertion while the dc grid is in operation
- A sequence among other possible



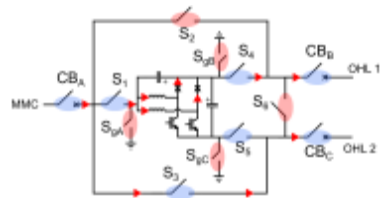
- PFC bypassed and grounded



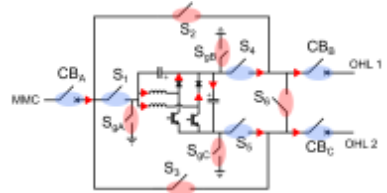
- PFC ungrounded



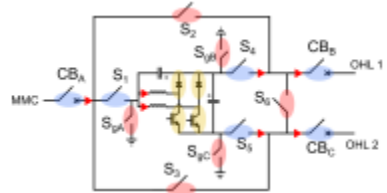
- S₂, S₄ and S₅ closed, S₆ open



- S₂ open



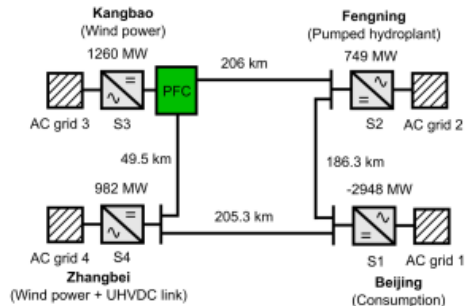
- S₃ open



- PFC in operation

Case study and models

- Case study based on Zhangbei HVDC grid
- Arc behavior modeled when opening bypass switches



Study Committee B4

DC systems and power electronics

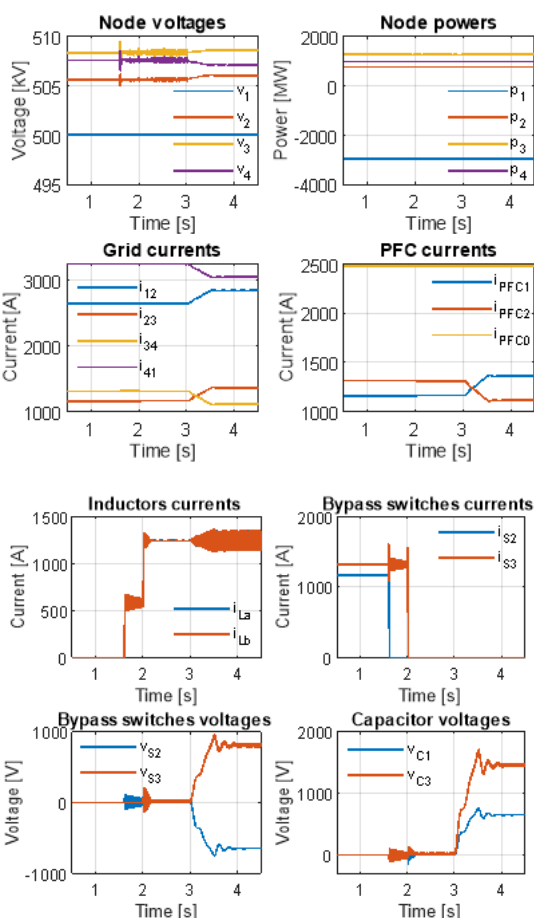
Paper ID_10896

Integration of power flow controllers in HVDC grids

Florent MOREL, Joan SAU BASSOLS, Sellé TOURE, Serge POUILLAIN, Frank JACQUIER

Supergrid Institute

Results for insertion

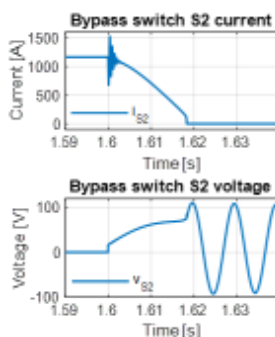


Bypass

- See paper for sequence of operation for bypass and corresponding simulation results

Requirements for switches

- Example of S_2



Conclusions

- Investigation of different busbar arrangements with PFC
- Selection of a circuit with good availability and moderate number of switches
- PFC can be inserted, bypassed and grounded without disturbing power transmission in the dc grid
- Requirements for S_2 and S_3
 - in transfer line switches and transfer busbar switches
 - Metallic return transfer breaker (MRTB) are in operation and have higher specifications → bypass switches are feasible
- Other switches can be disconnectors (opening when the current is very low or even zero).