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Study Committee B4

DC SYSTEM AND POWER ELECTRONICS

Paper B4-10322_2022

Operation Mode and Post-fault Recovery of a Bipolar VSC-HVDC System with Offshore Wind Farms Connection

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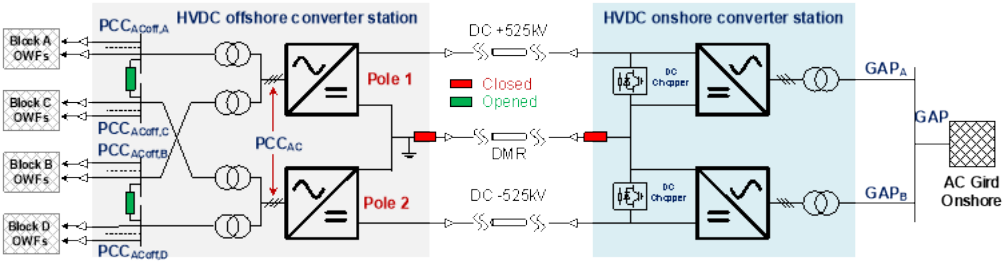
Motivation

- A single offshore VSC-HVDC system with the DC voltage up to +/-525kV and the transmission capacity of 2000MW will be the trend.
- The bipolar topology with flexible operation modes will be a viable solution for such high-power rating.
- There will be challenges on the operation and control of the bipolar offshore VSC-HVDC system.

Objective

- The configuration to enhance the flexible operation of the VSC-HVDC system is introduced and the possible operation modes and transitions are analysed.
- The controls for HVDC converters and a bipole power control are proposed.
- The dynamic behaviours in case of onshore AC grid faults and the post fault recovery for offshore grid faults are presented.

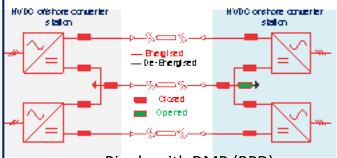
Configurations of a Bipolar Offshore HVDC System

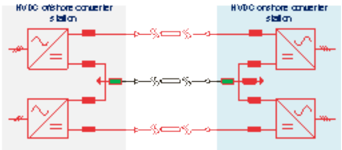


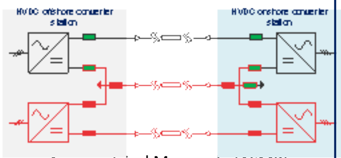
- Bipolar topology with dedicated metallic return (DMR) cable.
- DC circuit grounding point during normal operation is configured at the offshore converter station.
- The 66kV wind turbines (WTs) are connected to $PCC_{ACoff,x}$ of the HVDC offshore converter station (platform) directly.
- Two offshore converter transformers at each HVDC pole.
- A 66kV GIS with double busbars used at each HVDC pole.
- Cross-connection in the 66kV areas between the two HVDC poles.
- DC chopper equipped at onshore each HVDC pole.

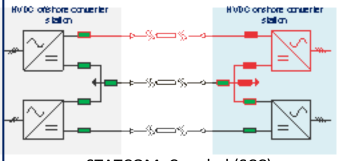
Operation Modes

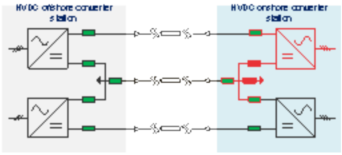
- 6 basic operation modes and can be expanded to various operation modes.

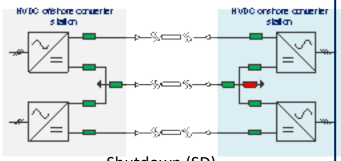

Bipole with DMR (BPD)


Bipole without DMR (BPND)


Asymmetrical Monopole (ASMP)


STATCOM, Coupled (SCC)


STATCOM, Decoupled (SCDC)


Shutdown (SD)

- **During the BPND operation, the continuous ground current of the VSC-HVDC system should be limited to an allowable value (e.g. 1% rated DC current).**

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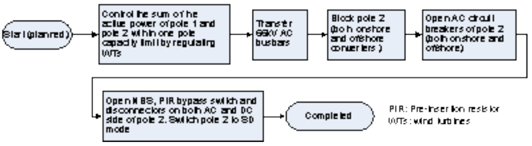
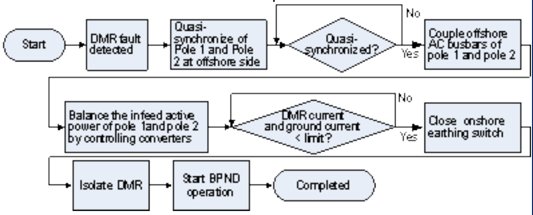
Transition of Operation Modes

- All transitions implemented in both automatically and manually.
- Minimal power reduction in targeted mode after transitions.
- Smoothly transitions with the minimal power interruption.
- Healthy pole not affected by transitions at faulted pole if DMR used.
- Maximized utilization of AC and DC equipment.
- The quantities and types of switchgears considered for flexibility of transition and platform occupation.



Planned transition sequence from BPD to ASMP+SD



Fault-related transition sequence from BPD to BPND

Control for HVDC Converters

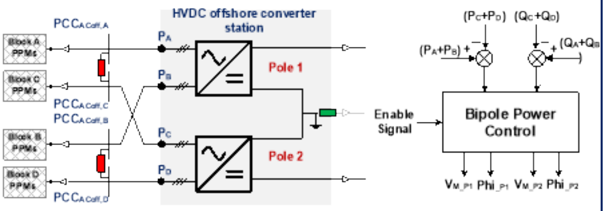
- Onshore: DC voltage control & reactive power control
- Offshore: AC voltage and frequency control

DC Ground Current Mitigation

- Two offshore converters operating in frequency droop control.
- One in stiff frequency control and the other one in frequency droop control.
- One in stiff frequency control and the other one in constant power control.

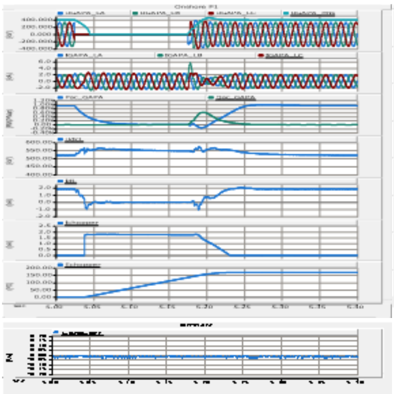
Proposed Bipole Power Control

- **Couple two HVDC poles at the 66kV busbars if DMR outage.**

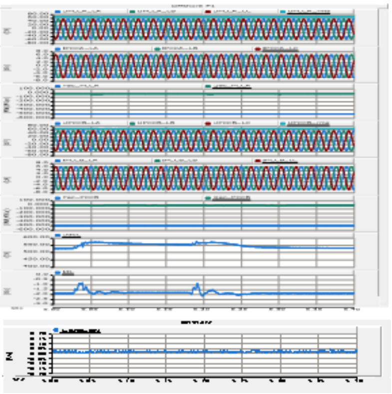


- **The two offshore converters regulate the output voltage magnitudes and phase angles dynamically to keep balanced power allocation.**

Onshore AC Fault-ride-through



Pole 1 onshore



Pole 1 offshore

- Bipole without MDR.
- Solid GAP three-phase to ground fault.
- Full power at each pole.

DC ground current

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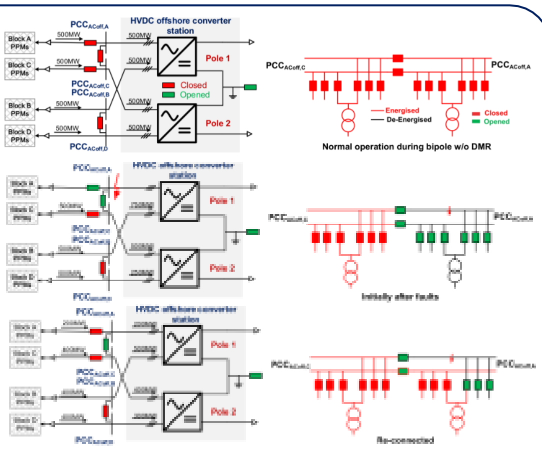
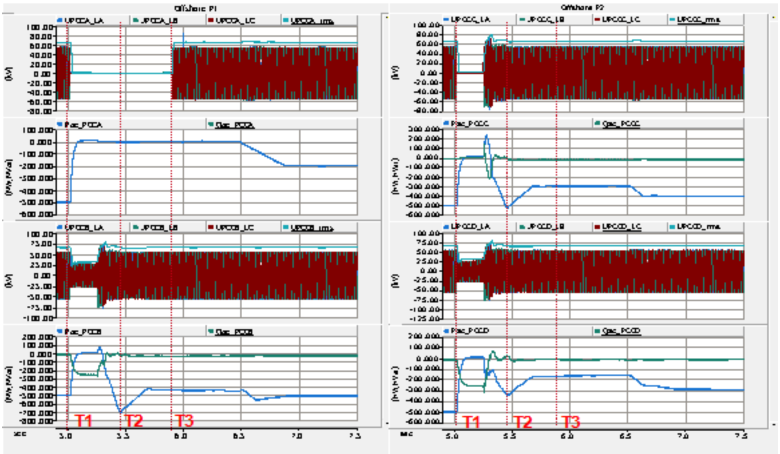
Offshore Fault-ride-through and Post Fault Recovery

- Solid faults at $PCC_{ACoff,x}$ at full power in bipole without MDR.
- Protection result in the loss of infeed power up to maximum 25% of full power (500MW).
- Converter transformer overload led by bipole power control.

Power recovery using double busbars in 66kV GIS.

- Regulate the active power generation to a lower value (avoid transformer overload).
- Reconnected partial offshore wind farms to healthy busbars.
- Increase active power generation from all offshore wind farms. (e.g. 1400MW, no overload component)





- T1: Initially after faults.
- T2: Active power reduction.
- T3: Partial offshore wind farms reconnected to the 66kV busbar at $PCC_{ACoff,A}$.

DC ground current

Pole 1 offshore

Pole 2 offshore

Conclusion

- A typical configuration of a ±525kV/2000MW bipolar VSC-HVDC system for offshore wind farms connection is presented.
- The bipolar offshore VSC-HVDC system introduces many possible operation modes and the transition principles as well as typical procedures are presented.
- A bipole power control strategy is proposed to mitigate the DC ground current effectively during bipole operation without DMR.
- A proposed post fault recovery strategy using 66kV GIS busbars can restore the active power without overloaded components.