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PS3 New Technologies and Concepts of DC and FACTS enabling Energy Transition

11116_2024

Assessment of Operational Challenges of HVDC Multi-Purpose Interconnectors in Connection to a Weak Grid

Asif KHAN*[1], Nikhil SHARMA[1], Wasim AHMAD[1], Ben GOMERSALL[1], Benjamin MARSHALL[1], and Dr Richard POOLE[2]

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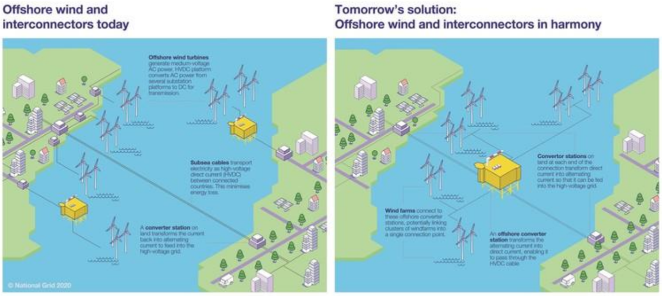
Introduction

- Increased offshore windfarm connections
- Interconnectors plays a vital role
- New generation interconnector: MPI
  - Efficient use of transmission assets
  - Maximum utilisation of wind resources



Source: https://www.nationalgrid.com/national-grid-and-tennet-jointly-develop-vision-link-offshore-wind-farms-britain-and-netherlands

Objectives

Investigate the performance and operational challenges of an MPI

To achieve this

A representative MPI network is developed in Real time simulator considering -

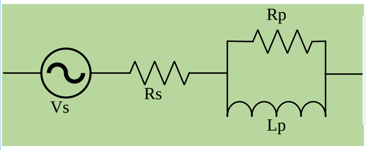
- Each component should have realistic behaviours as vendors' model, and
- The models characteristics validated by disturbance scenarios

A comprehensive list of simulation scenarios were performed including

- AC and DC faults at different location
- Converter blocking
- Windfarm disconnection
- Energisation

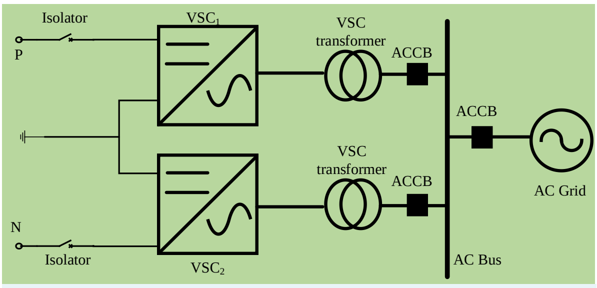
Only the key findings of few simulation scenarios are discussed here

Onshore AC Network Model



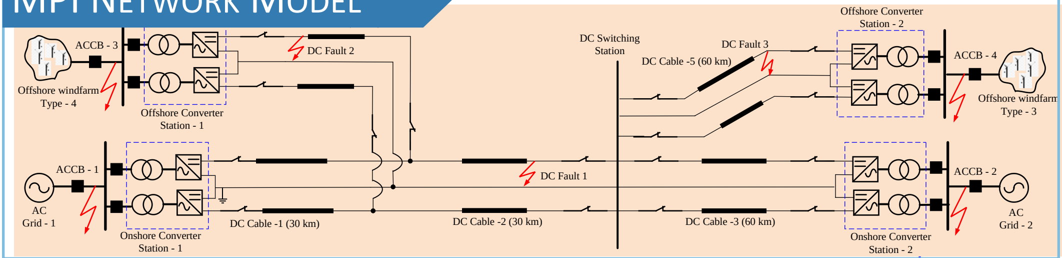
- Thevenin Equivalent: Ideal AC Source (400 kV) with series impedance
- Variable fault level

HVDC Converter Station



Both onshore and offshore stations are based on Bipole configuration.

MPI Network Model



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CABLE PARAMETERS

525 kV DC Cable Parameters

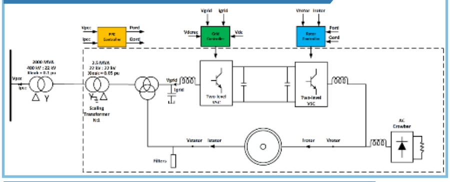
Parameter name	Values	Unit
Conductor outer radius	30	mm
Conductor resistivity	1.72×10^{-8}	Ωm
Insulator 1 outer radius	64.5	mm
Insulators (both) permittivity	2.5	
Sheath (earthed) outer radius	67.5	mm
Sheath resistivity	2.83×10^{-8}	Ωm
Insulator 2 outer radius	81	mm

- Library model
- Frequency dependent
- Generic value or AC and DC cables

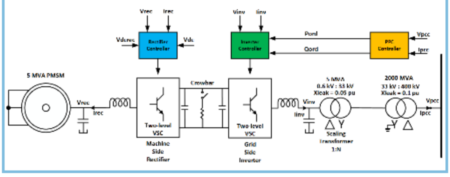
400 kV AC Cable Parameters

Parameter name	Values	Unit
Inner conductor outer radius	18	mm
Inner conductor resistivity	3.62×10^{-8}	Ωm
Insulator 1 outer radius	46.45	mm
Insulator 1 permittivity	2.7536	
Sheath outer radius	62.87	mm
Sheath resistivity	2.49×10^{-9}	Ωm
Insulator 2 outer radius	81.29	mm
Insulator 2 permittivity	3	
Armour outer radius	99.71	mm
Armour resistivity	1.8×10^{-7}	Ωm
Armour relative permeability	400	
Insulator 3 outer radius	166.71	mm
Insulator 3 permittivity	1	
Outer conductor outer radius	243.21	mm
Outer conductor resistivity	1.8×10^{-7}	Ωm
Outer conductor permeability	400	
Insulator 4 outer radius	333.21	mm
Insulator 4 permittivity	1	

TYPE – 3 WF



TYPE – 4 WF

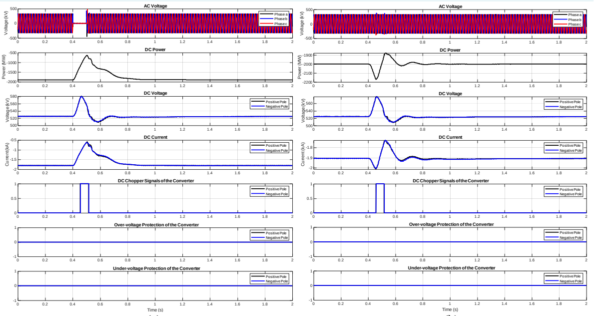


SIMULATION CASES

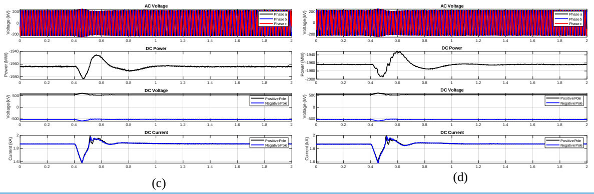
- Various types of faults at different locations
  - Offshore AC faults, Onshore AC faults and DC faults
- HVDC Converter blocking
  - One pole disconnection to observe the performance during unbalanced operation

OBSERVATION 1: AC FAULT

- Onshore AC faults lead to offshore AC disturbances
- AC voltage at the onshore AC grid 1 decreases severely and DC voltage increases
- AC voltages of both offshore terminals increases due to variation in DC voltage at the VSC GFMs
- No grid code defined to access the performance of the offshore network based on the fault or disturbances across different nations' onshore AC networks

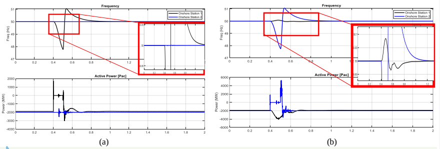


(a) (b)



(c) (d)

OBSERVATION 2: AC FAULT



(a) (b)

- Fault at AC Grid 2 causes disturbances at AC grid 1
- No impact on AC grid 2 due to a fault at AC grid 1
- Minor impact on the AC grid 1 frequency due to fault at ac grid 2
- During fault active power at AC grid 2 decreases, and due to the full capacity operation (4 GW in total) of offshore windfarms, the excess power is consumed by onshore station 1 and the DC choppers transiently. This additional power causes AC grid 1 frequency increase.

OBSERVATION 3: DC FAULT

- Total 27 DC fault (pole to earth) cases simulated by varying fault location and AC grid SCL value
- For all cases, the defective pole is disconnected from the network by blocking one pole converter at all stations and all the DC isolators are opened
- DC voltages and current of all terminals for other pole remains stable once fault is isolated

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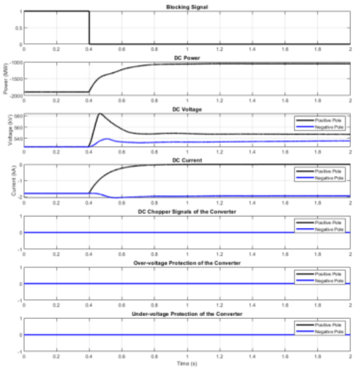
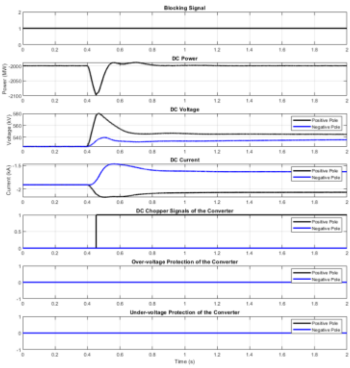
OBSERVATION 1: CONVERTER BLOCKING



(a)



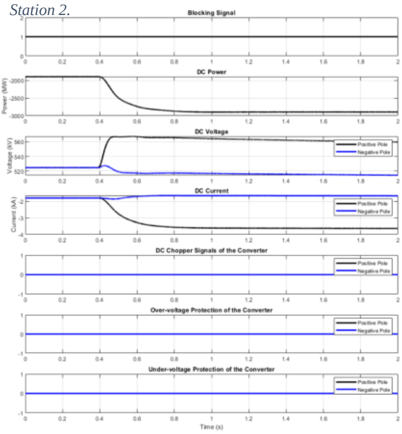
(b)

- The system regained stability after all simulation instances of converter blockages, except for the simulation related to the blocking of onshore converter station – 1
- This instability due to loss of DC voltage controlled HVDC converter
- When one pole of station – 1 is lost without reducing the power supplied by windfarms, it causes a significant imbalance in the network as well as an increase in DC voltage, triggering the DC choppers located at the positive pole of HVDC converter station – 2
- While not demonstrated in the simulation results, if these choppers are not deactivated after a certain duration, the positive pole of HVDC converter station 2 will be blocked. Consequently, both positive poles of the onshore HVDC stations will be lost, leading to the disconnection of the offshore stations.

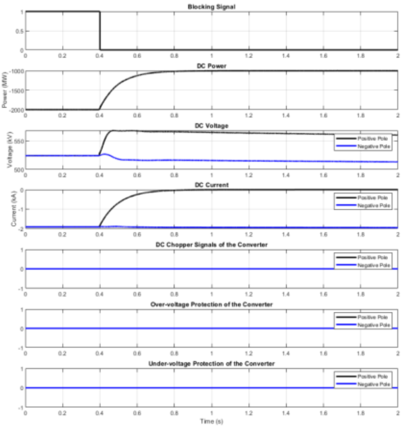
OBSERVATION 2: CONVERTER BLOCKING

- While results not shown, blocking of one pole of the offshore HVDC converter signifies a loss of 1 GW supply. To account for that loss, power consumed by one pole of onshore station – 1 drops to zero.
- However, in case of loss of one pole of onshore station – 2, causes power at the onshore station – 1 to increase from 1 GW to 2 GW (in one pole) – which causes current in the converter to saturate. Therefore, to match the power supplied by the windfarm, the DC voltage controller of the converter increases the DC voltage.

Behaviour of (a) Onshore Station 1, and (b) Onshore Station 2 during Positive Pole Blockage of Onshore Converter Station 2.



(a)



(b)

CONCLUSIONS AND FUTURE WORK

- A centralised coordinated control between HVDC converter stations is necessary.
- More than one DC-Voltage controlled terminal using droop-based control or mode switching option required.
- Several idealistic assumptions are made for the developed MPI network model considering the simulation resources, and in future, the models can be further improved.
- Appropriate controller is required to ride through additional power supplied by windfarms during one pole operation scenario.
- Employment (where appropriate) of DC-side circuit breakers in the MPI network
- The studies with fault ride through and blocking indicate value in a strategy of rating DC chopper infrastructure carefully to ensure there is not an excessive disturbance in over-rating individual DC choppers within it- allowing for a diversified strategy of operation and recovery.