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Multi-terminal Extension of Embedded Point-to-Point VSC-HVDC Schemes

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The National HVDC Centre

Multi-terminal Extension of VSC- HVDC Systems

Introduction

- HVDC schemes based on voltage source converter (VSC) technology are suitable for connecting relatively weak AC systems into stronger grid areas/ external grids.
- VSC has improved control capabilities than line commutated converter (LCC) and do not require change in voltage polarity to change power flow direction.
- Multi-terminal VSC systems have greater flexibility and can change power flow direction provided one end maintains the voltage polarity.
- This presentation identifies that multi-terminal extension of VSC-HVDC system is technically feasible, outlines co-simulation options and testing requirements with project risks to be managed.

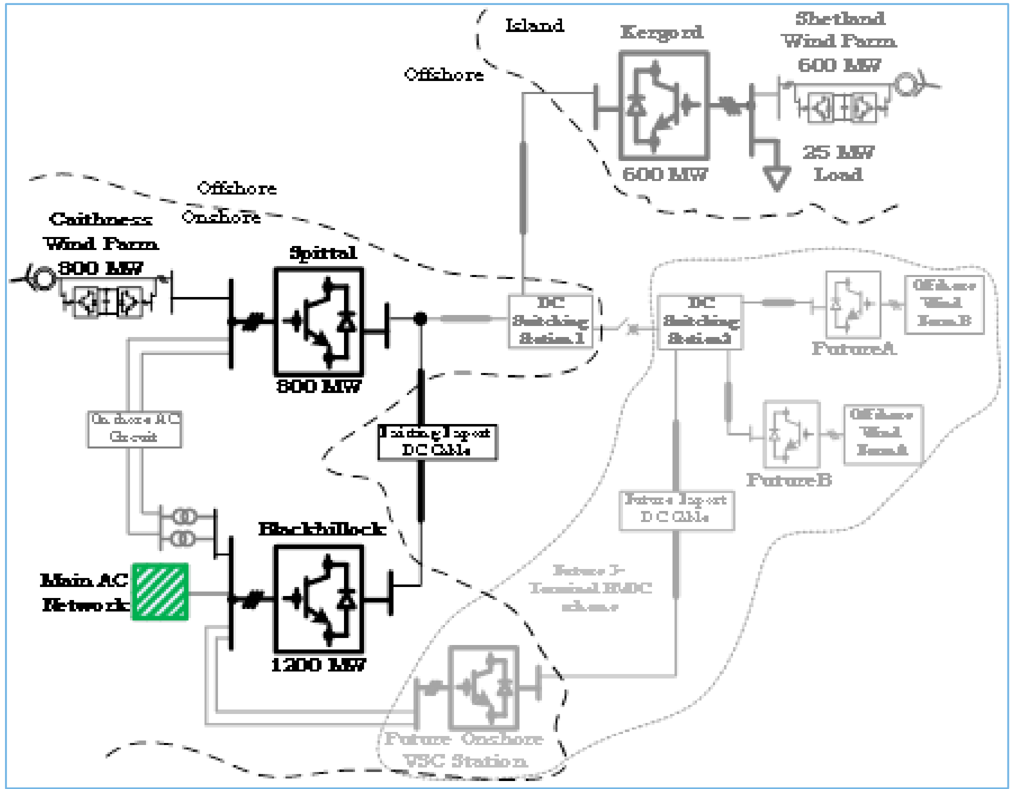

Fig.1: CMS Multi-terminal HVDC Design

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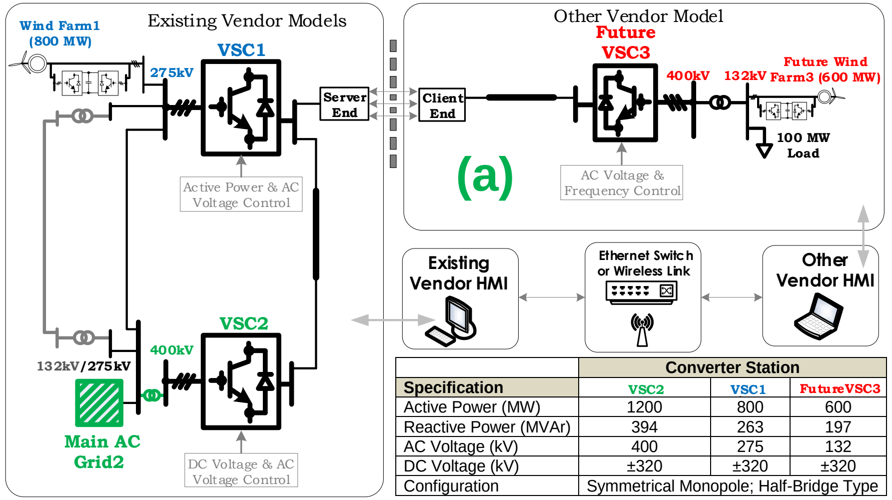
Co-simulation of Multi-Vendor VSC- HVDC Systems

Dynamic Performance Studies (DPS)

- DPS is used to verify off-site performance of HVDC control and protection (C&P) systems in EMT-type software models prior to site delivery.
- Future VSC terminal DPS supplied by different vendor, would require co-simulation of EMT-type offline models from different suppliers.
- The Johan Sverdrup HVDC project in Norway represents a type of multi-vendor VSC scheme.
- Fig. 2 is an example 3-terminal HVDC system with 2 existing VSCs and a future terminal by another vendor, co-simulated using an offline EMT tool.

- Co-simulation can preserve IP arrangements of HVDC C&P systems from different manufacturers.



	Converter Station		
Specification	VSC2	VSC1	FutureVSC3
Active Power (MW)	1200	800	600
Reactive Power (MVAr)	394	263	197
AC Voltage (kV)	400	275	132
DC Voltage (kV)	±320	±320	±320
Configuration	Symmetrical Monopole; Half-Bridge Type		

Fig. 2: Co-simulation of 3-terminal HVDC Scheme (a) Schematic. (b) Set-up.

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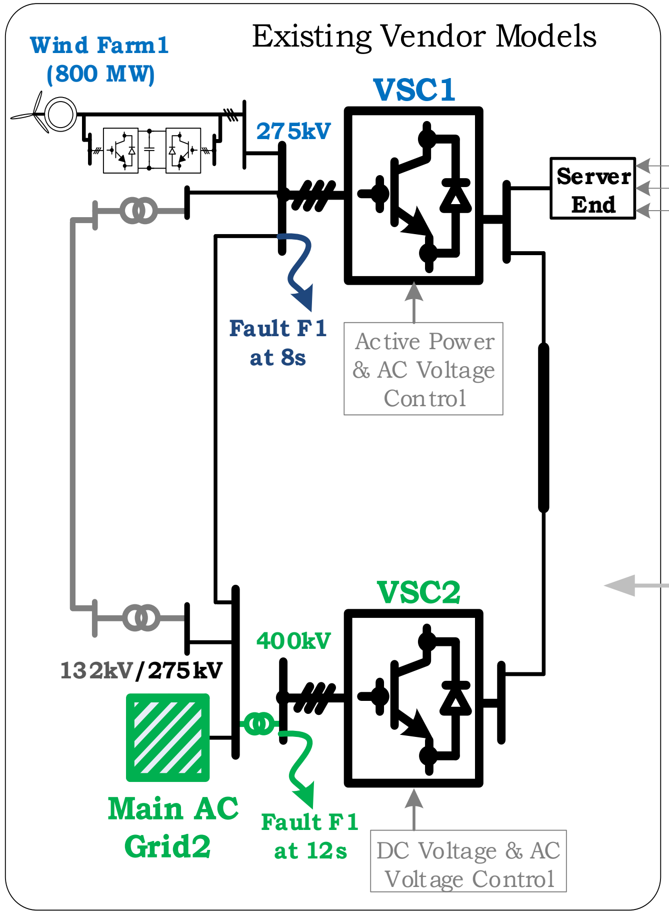
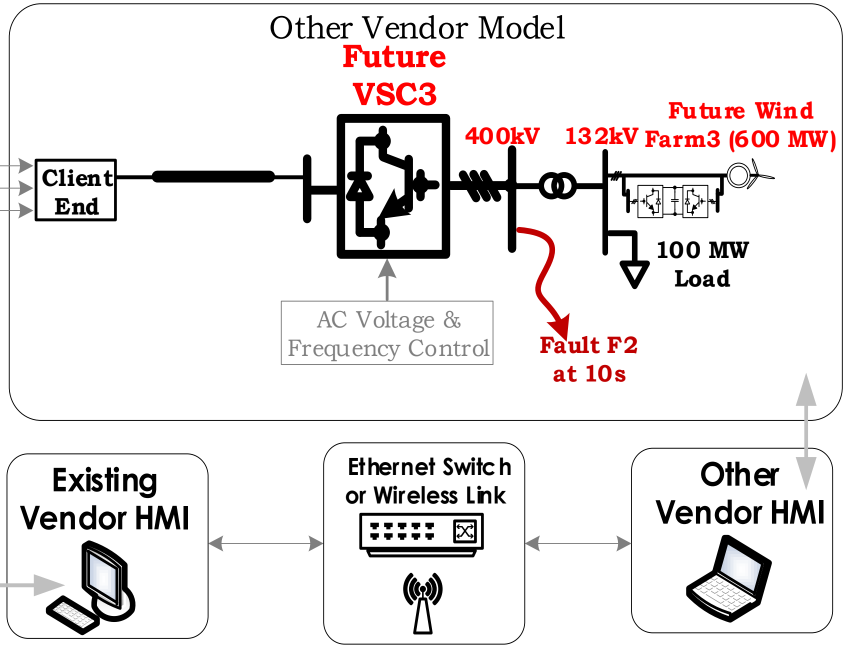
Co-simulation of Multi-Vendor VSC- HVDC Systems

3-terminal HVDC System Control and Test Cases





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- Control Modes:
  - **VSC1** regulates active power and reactive power.
  - **VSC2** controls DC voltage for power balancing and regulates reactive power.
  - **VSC3** creates offshore AC voltage with fixed frequency, magnitude and phase angle.

- Test cases:
  - 0.2p.u. active power ramp on **VSC3** at 2.5s and 4.5s.
  - 0.4p.u. active power ramp on **VSC1** at 5.5s; and
  - 100ms 3-phase to ground AC faults on **VSC1** at 8s, **VSC3** at 10s and **VSC2** at 12s.

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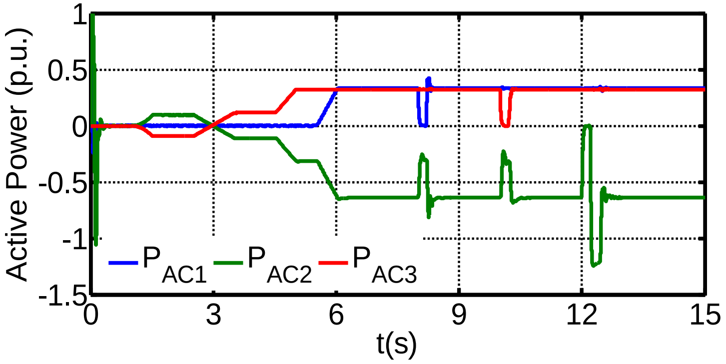
Co-simulation of Multi-Vendor VSC- HVDC Systems

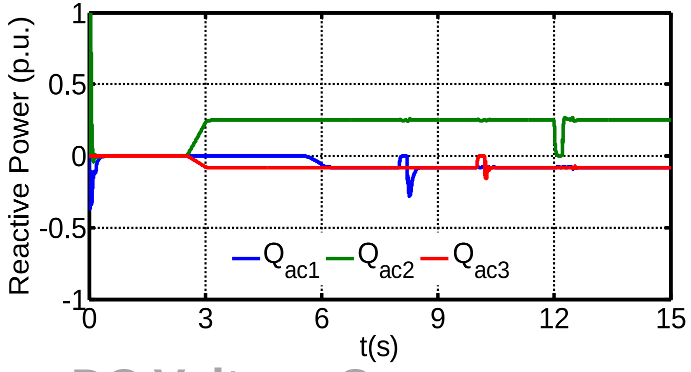
DPS Results and Discussions – Offline Co-simulation

- The co-simulated 3-Terminal HVDC system is stable across the test cases investigated.

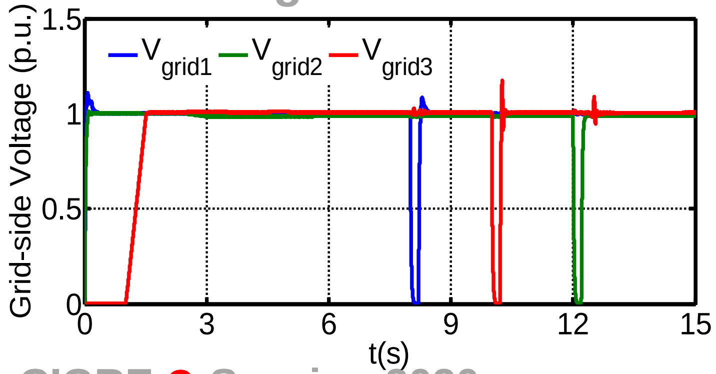
- **Active Power Curves**



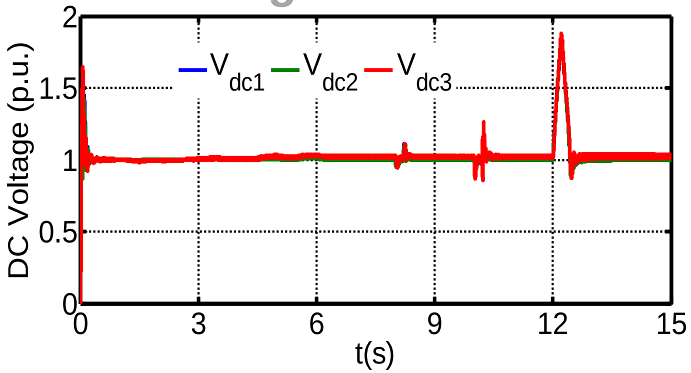
- **Reactive Power Curves**



- **AC Voltage Curves**



- **DC Voltage Curves**



- 1.8p.u. DC overvoltage observed for AC fault on inverter terminal VSC2 at 12s, and the system recovers within 500ms.
- DC choppers, fast adaptive HVDC droop control or power reduction schemes can be used to prevent DC overvoltage.
- Ethernet link between two separate computers minimised telecommunication delays compared to wireless option

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Testing VSC-HVDC Supplied by Different Manufacturers

Real Time Simulation with Hardware-in-the-Loop Replica HVDC C&P systems

- Used for de-risking multi-terminal HVDC C&P systems from different suppliers (Vendor A and B).
  - Two existing HVDC terminals (VSC_{11} & VSC_{12}) represented using hardware replica C&P system
  - Additional terminal (VSC_{13}) is modelled using an open-source modular multi-level converter models.

- Control Modes:
  - **VSC_{11}** regulates active power and AC voltage with reactive power droop control.
  - **VSC_{12}** controls DC voltage for power balance and regulates AC voltage with reactive power droop.
  - **VSC_{13}** creates offshore AC voltage with fixed frequency, magnitude and phase angle for connecting 100MW load and 300MW generation.

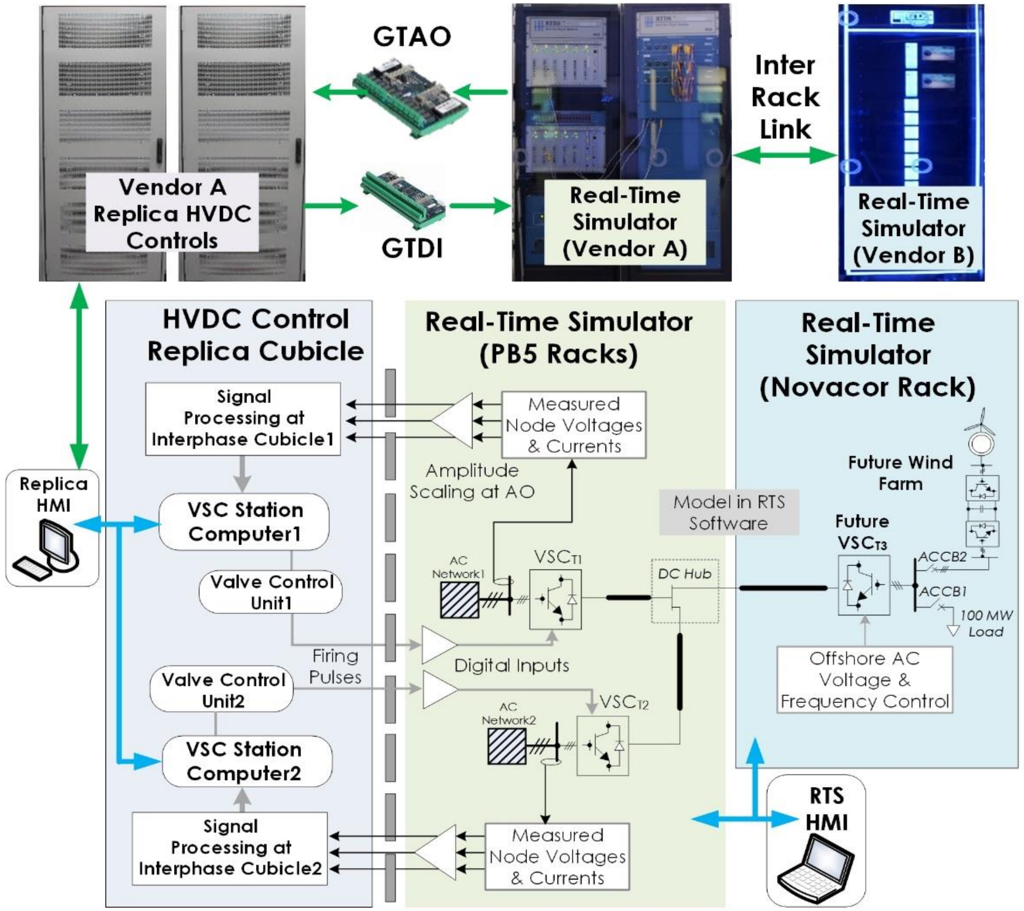

Fig. 3: Hardware in the loop set-up.

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Testing VSC-HVDC Systems from Different Suppliers

Experimental Demonstration Results

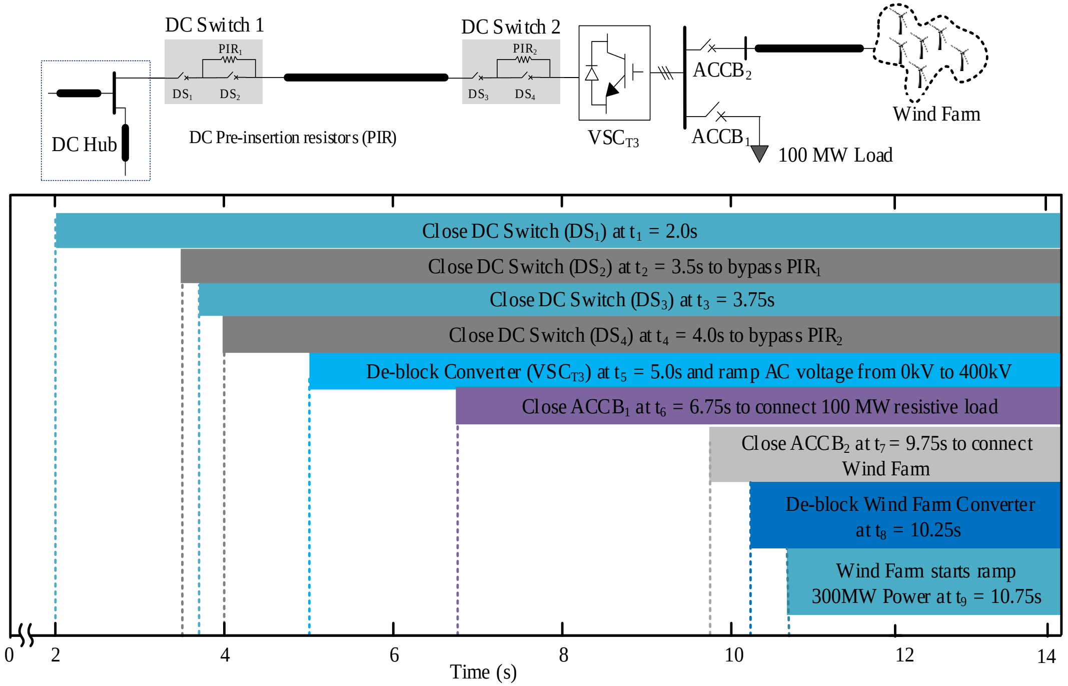
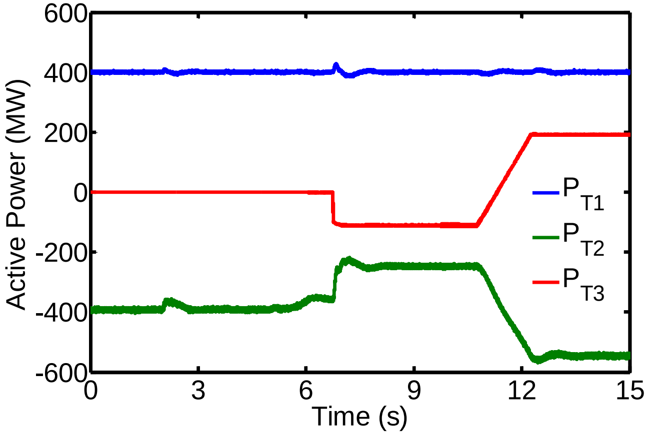


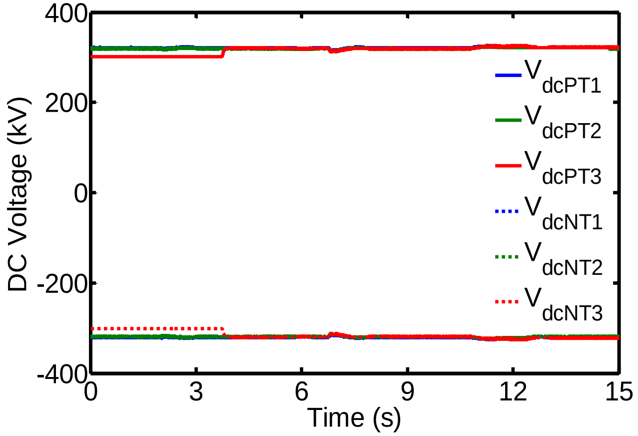
Fig. 4: VSC_{13} energisation and operation test sequence

- Stable system performance achieved for multi-vendor HVDC scheme & RTS with hardware replica C&P preserved IP of different suppliers.

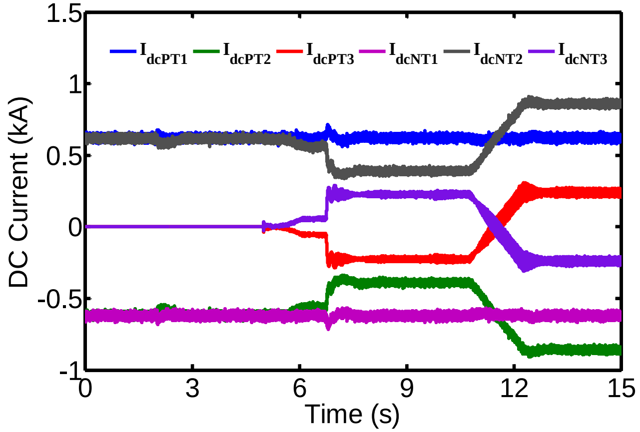
- Active Power Curves



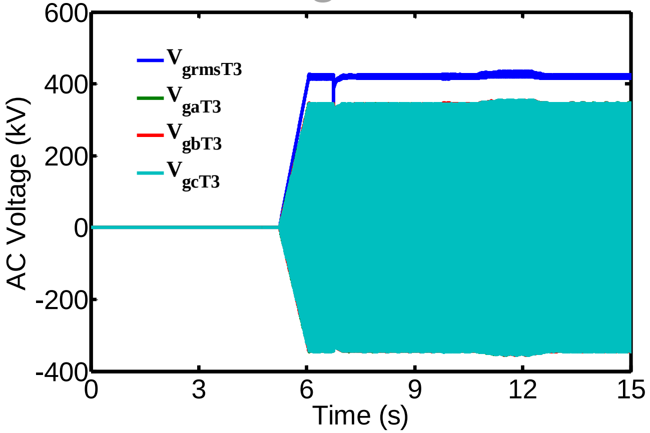
- DC Voltage Curves



- DC Current Curves



- AC Voltage Curves



Key Considerations and Project Risks

Role of independent test environment in multi-vendor HVDC schemes

- Additional time (estimated as12 months) may need to be managed for multi-vendor option compared to a single-vendor approach, mainly due to multi-vendor testing requirement.

Fig.4 Estimated Project timeline for additional HVDC terminal

- **Key considerations include:**
  - **Model Sharing:** manufacturers will need to shared detailed EMT-models, fit for intended purpose
  - **Replica C&P system:** future HVDC supplier must provide a replica C&P test for multi-vendor tests to track changes in development and or further changes in service.
  - **Procurement:** multi-vendor tests may result in dis-interest from other suppliers
  - **HVDC Grid Code:** standardisation of C&P specifications will reduce interoperability risk.

- **Vendor responsibility has to be assigned and better coordination between different vendors could streamline development timeframes.**

Summary

Multi-terminal extension of VSC-HVDC system is technically feasible

- There are no major technical barriers to multi-vendor HVDC systems with VSCs provided by different suppliers;
- Dynamic performance studies can be performed using EMT-type tools with co-simulation capabilities to de-risk HVDC schemes involving different vendors ;
- Factory testing of HVDC C&P systems of converter terminals being supplied by different equipment manufacturer can be performed at independent testing environment to demonstrate compatibility with replicas of existing HVDC scheme; and
- Multi-vendor HVDC option would incur an additional time (estimated as 12 months), but coordination of multi-vendor testing could streamline development timescales.