



Johan Sverdrup world's first multivendor HVDC system in grid forming operation

EERA JP WIND WEBINAR
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Kamran Sharifabadi

Johan Sverdrup – first Multivendor HVDC system in grid forming operation

Technical challenges

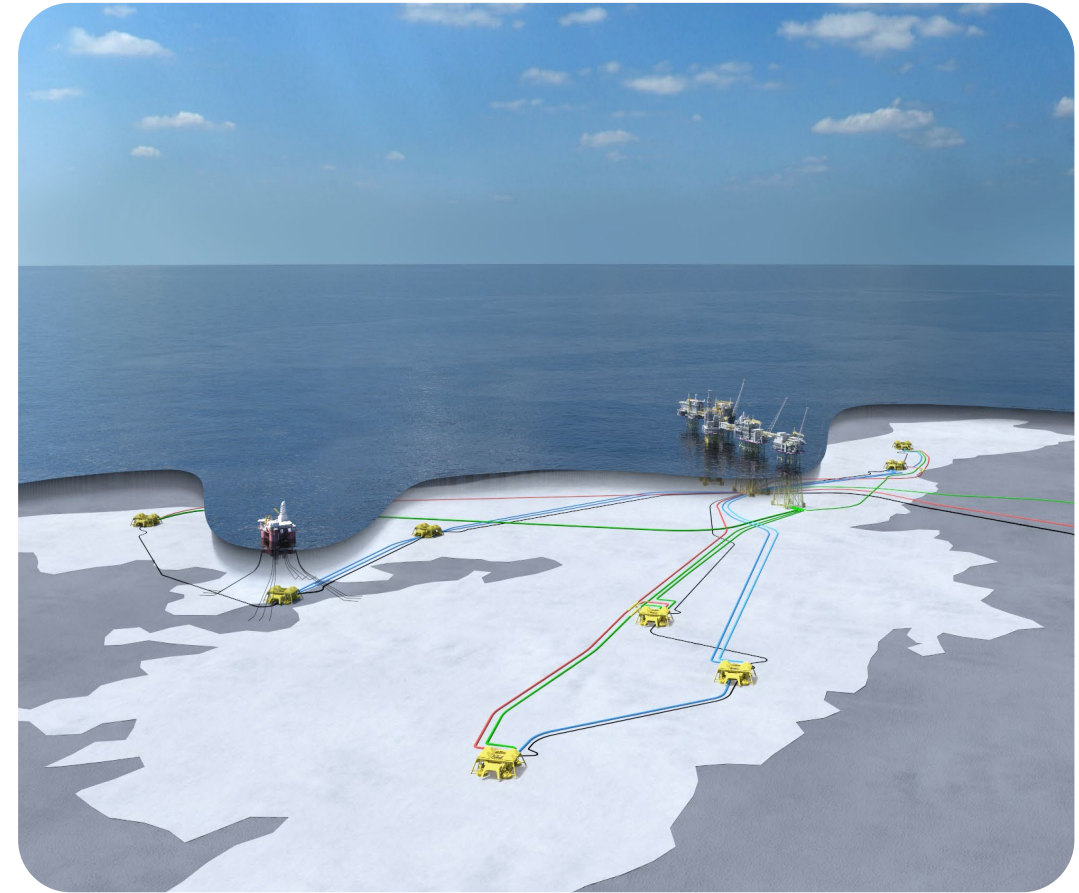
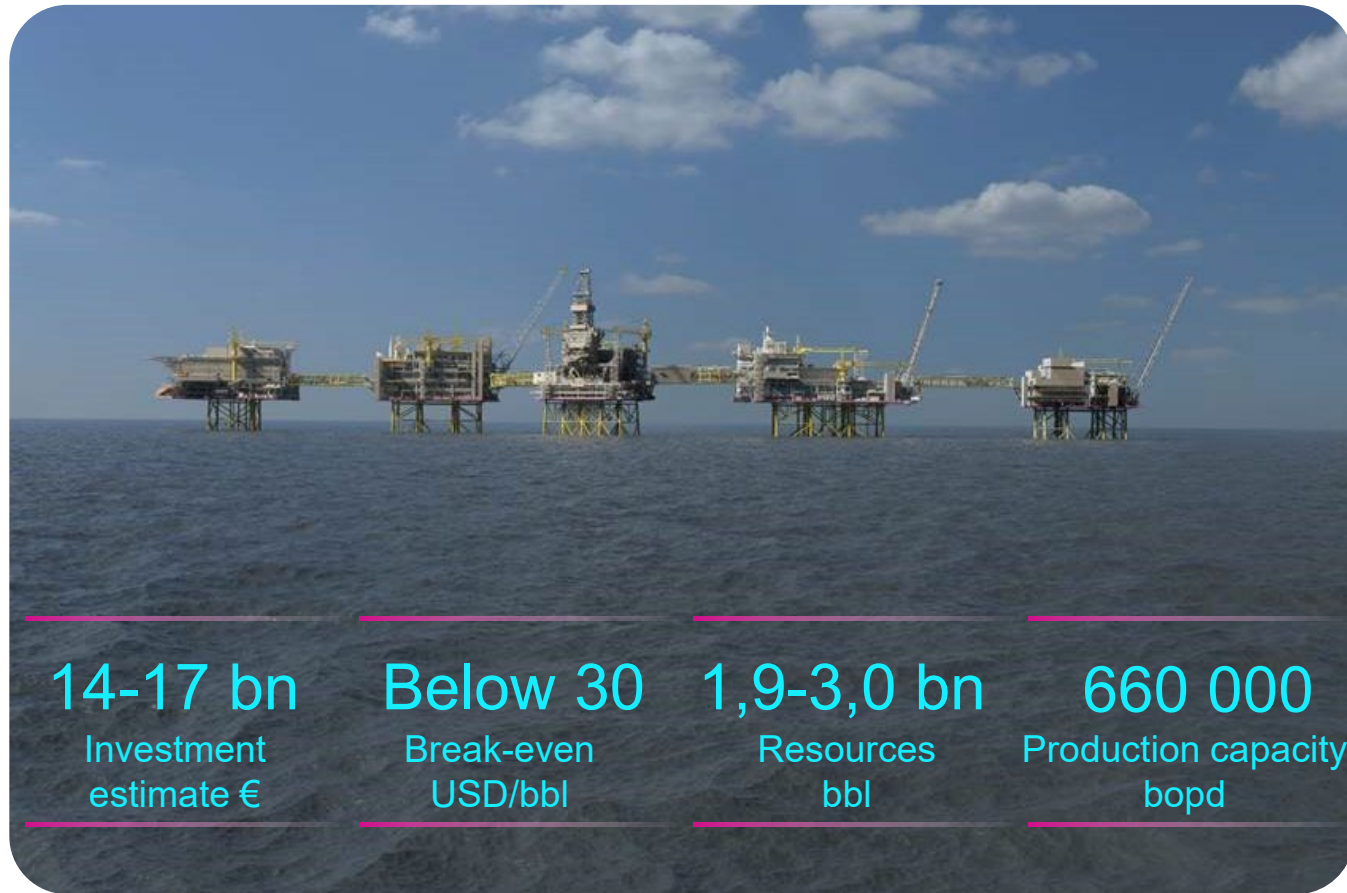
- Grid forming operation of 2 HVDC systems developed by 2 vendors in 2 different stages
- Coordination of the dynamic behavior is a challenge due to confidentiality restrictions between the vendors
- Coordination in steady state is achievable with a global controller
- Prediction of issues that may arise in future expansion of offshore transmission network

Independent 3rd party is required to limit the risk of adverse interactions

- Perform tests and propose solutions to vendors to be adapted in C&P settings

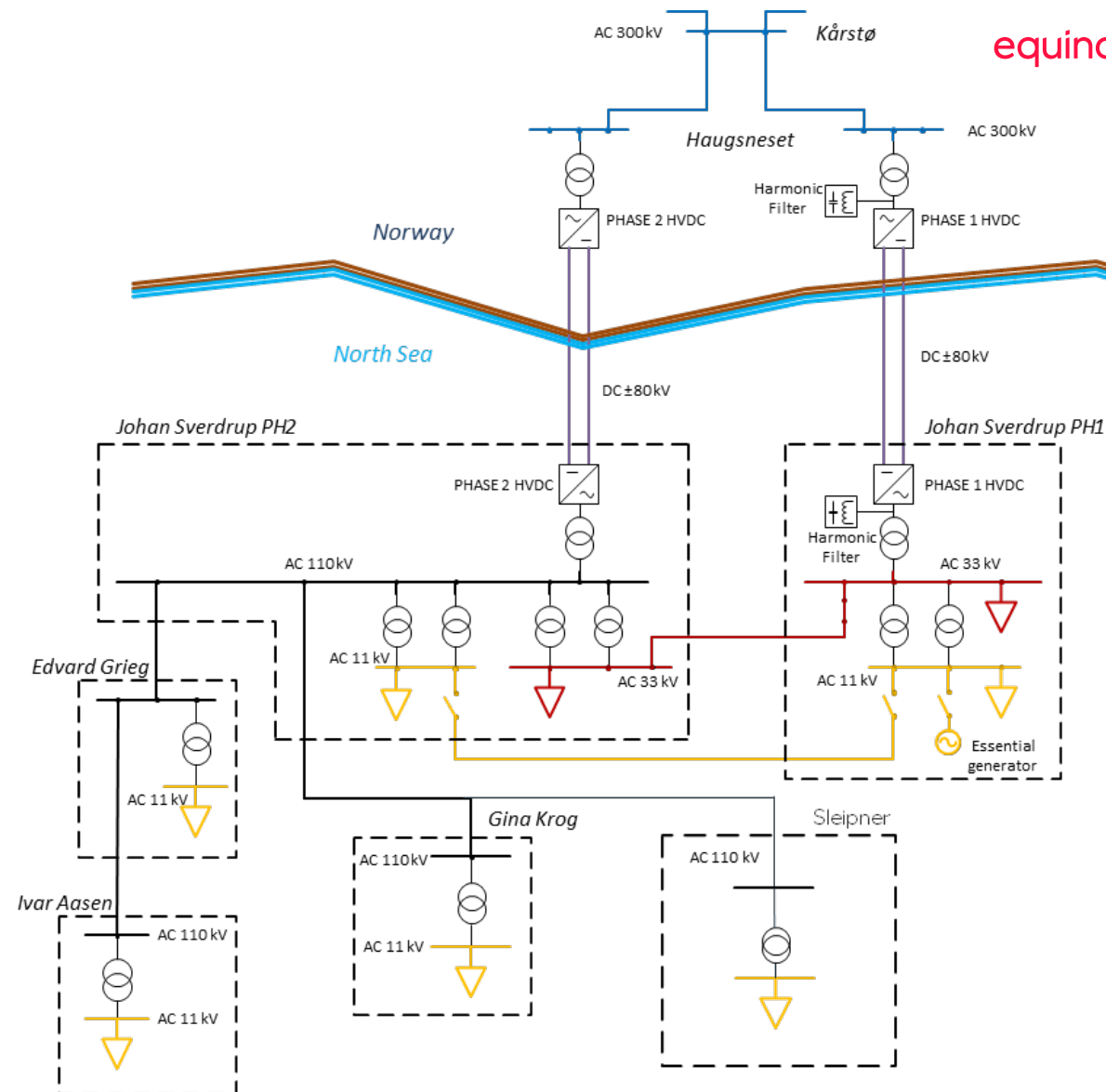
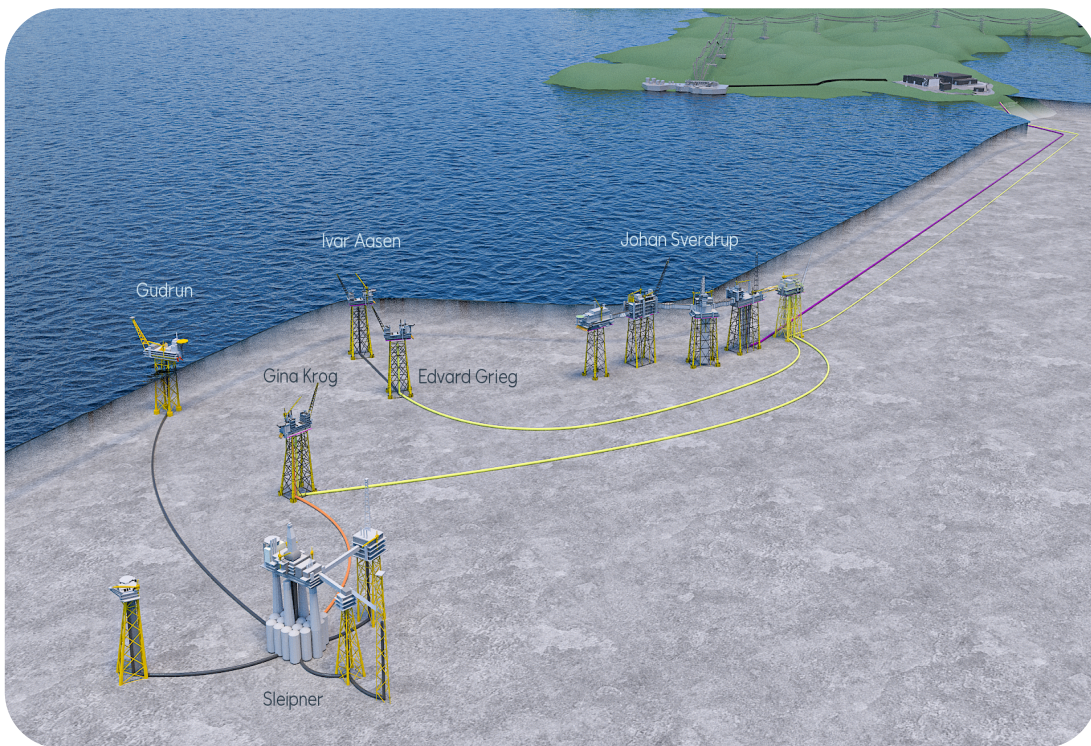
INTRODUCTION

- Johan Sverdrup largest north sea O&G field
- JS will produce O&G for next 50 years



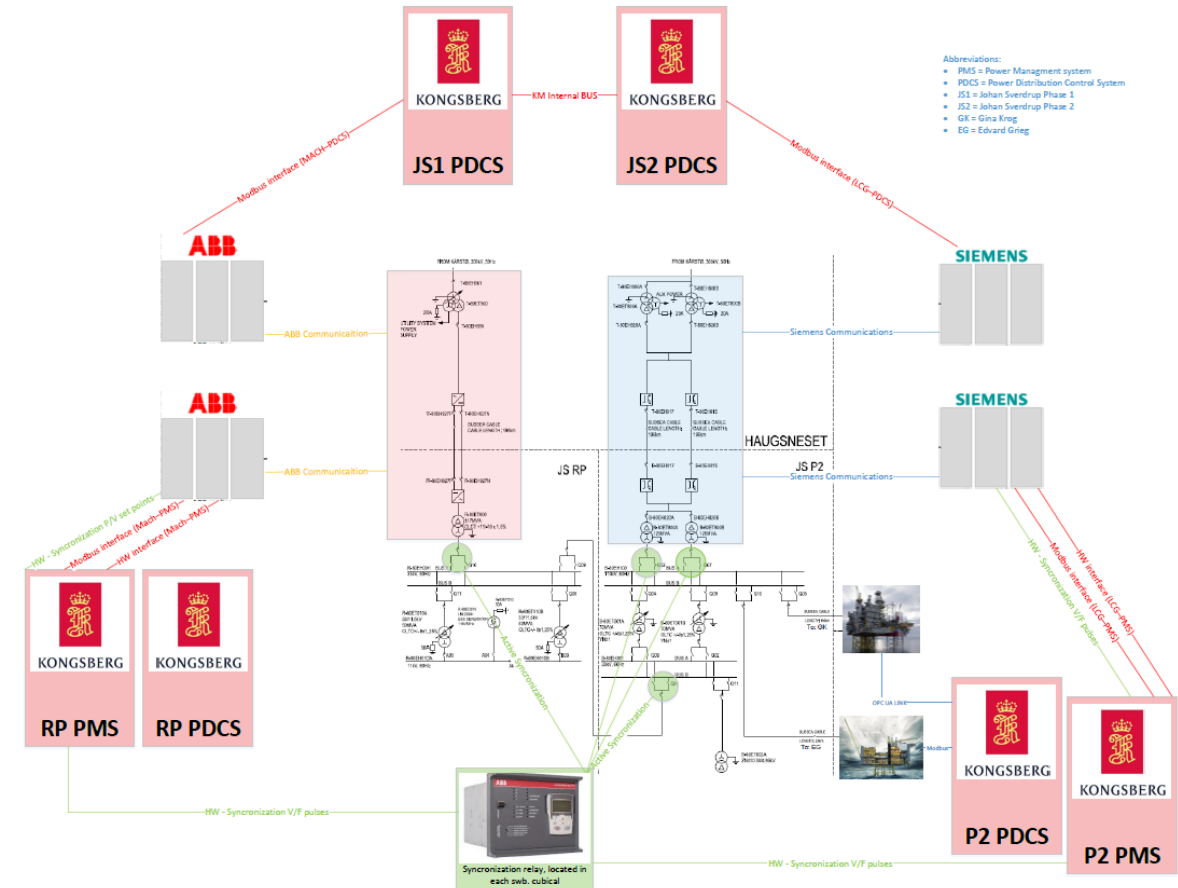
Simplified SLD

- SLD phase-1 & 2



Four neighbouring platforms will be connected to JS via long 110 kV subsea cables

- Load Sharing between the two HVDCs (Offshore)
- Reactive power support to onshore grid
- Gradual Load shedding system (Active power)
- Synchronization logic to synchronize the two HVDCs.



Open

Coordination of the 2 HVDC links

- Power Management System (PMS)

A global controller to coordinate operation of the overall system

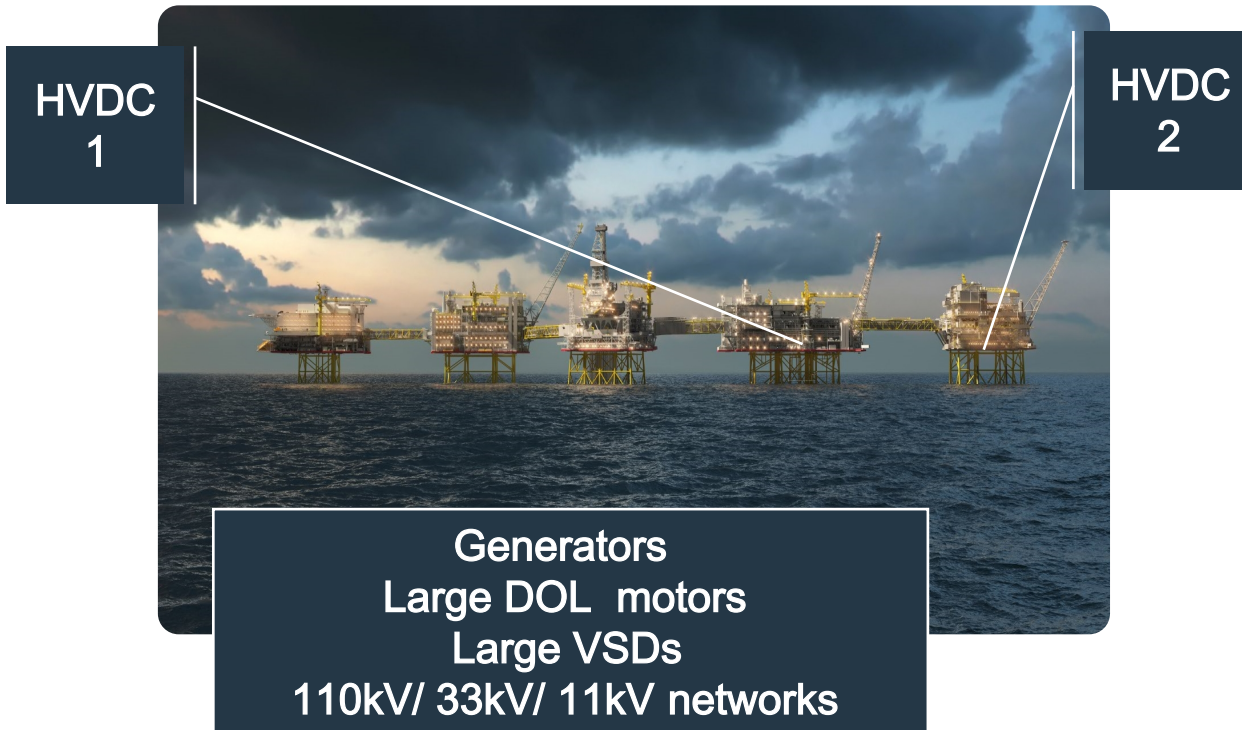
- Control offshore load sharing between the 2 HVDC links
- Secondary offshore frequency and voltage control
- Prepare suitable conditions for coupling and de-coupling the 2 HVDC offshore converters
- Load shedding activation in case of critical overload conditions

Integrated in the Power Distribution and Control System (PDCS)

- Control System that handles all the automation processes in the JSFC
- Designed and manufactured by Kongsberg Maritime

Johan Sverdrup Phase 2 HVDC

• Interactions



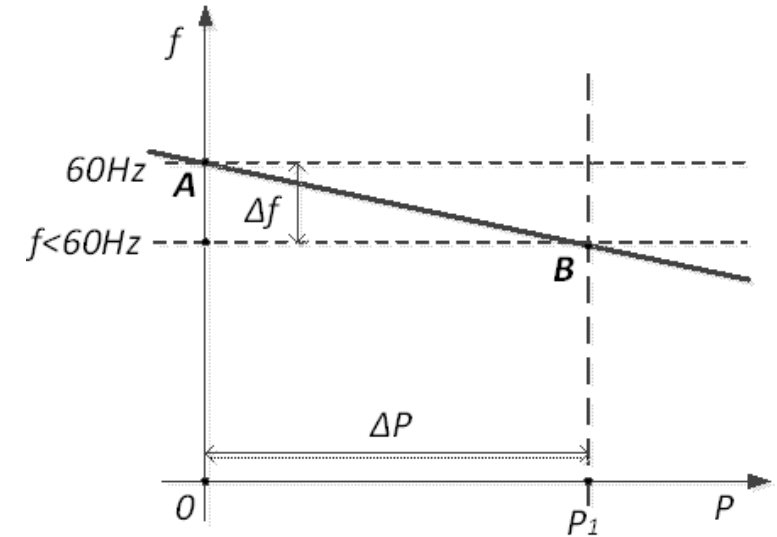
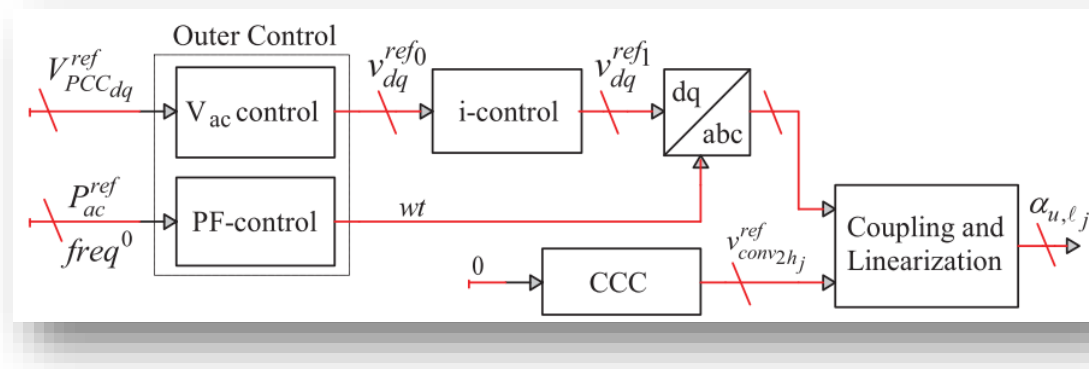
Two HVDCs of different suppliers in very close vicinity, Low SCR network

Frequency ↑	Super-synchronous	Controller interactions
	Sub-synchronous	Power oscillations/ controller interaction <ul style="list-style-type: none"> • Load steps • Fault recovery Torsional interactions with Turbine Generators
	Steady state	Active / reactive Power sharing Statics

Coordination of the 2 HVDC links

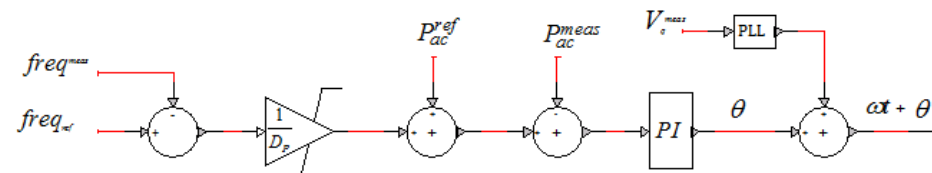
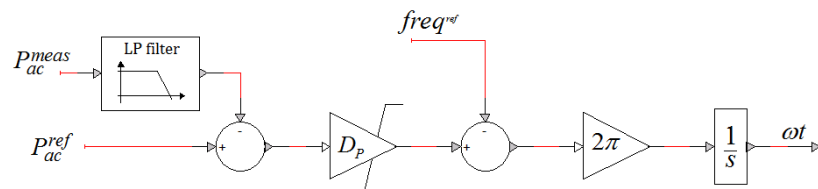
- HVDC1 and 2 primary controls

Generic structure of VF control (grid forming)



P/f control

- To regulate active power and frequency
- Several generic approaches to illustrate the P/f control:

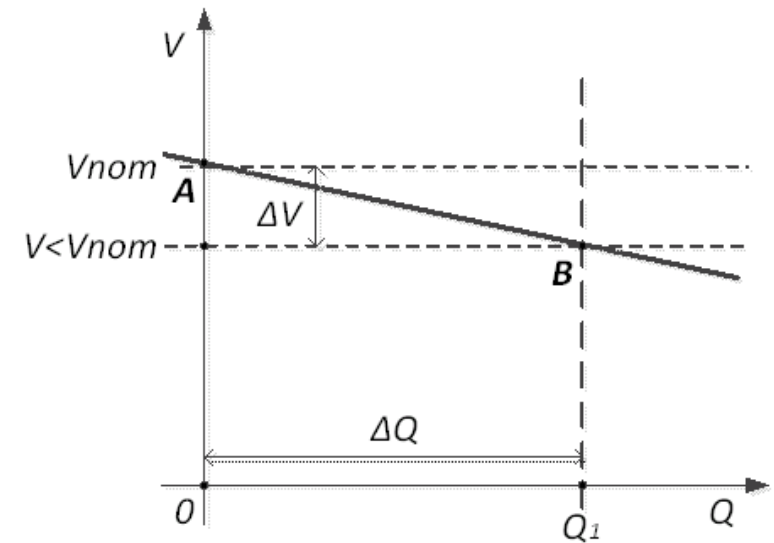
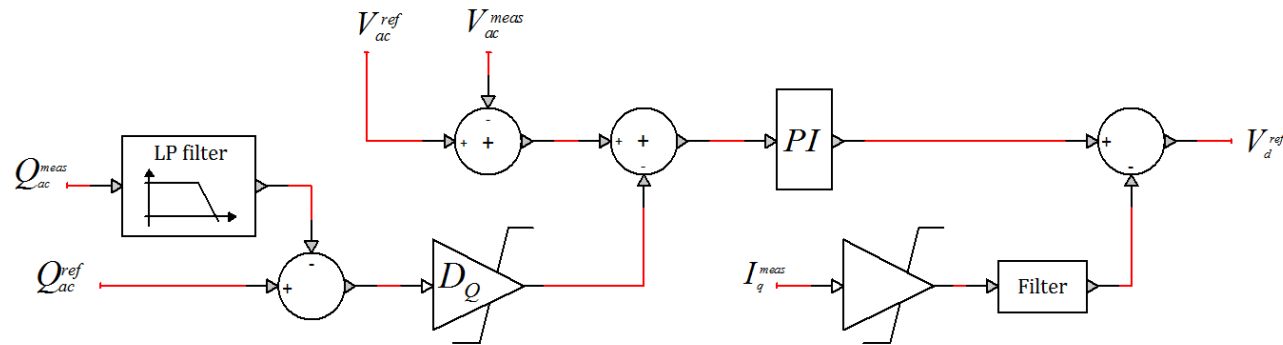


Coordination of the 2 HVDC links

- HVDC1 &2 primary controls

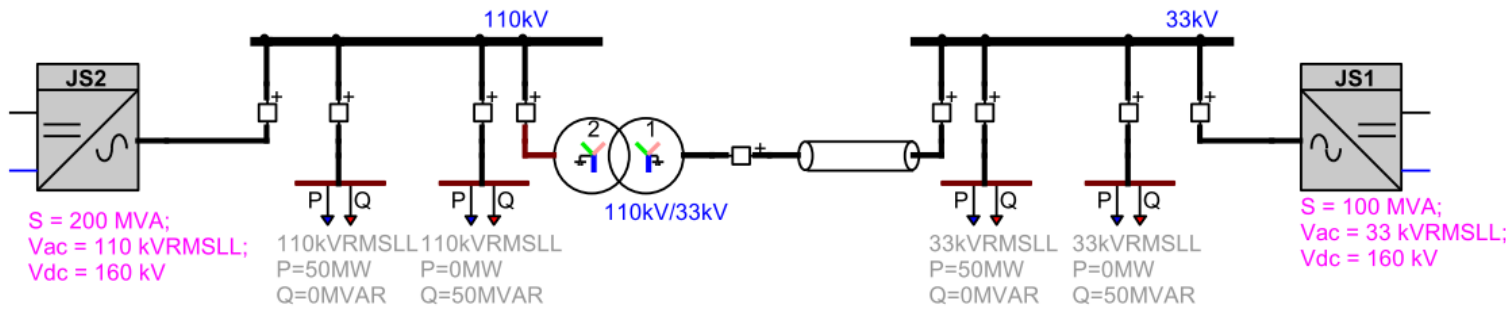
Vac control

- To regulate the AC voltage at Point of Common Coupling (PCC)
- 1 generic example to illustrate the Vac control:



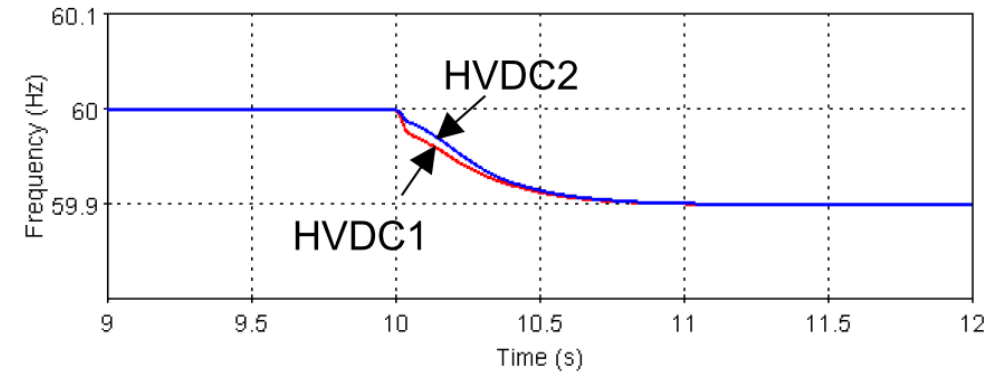
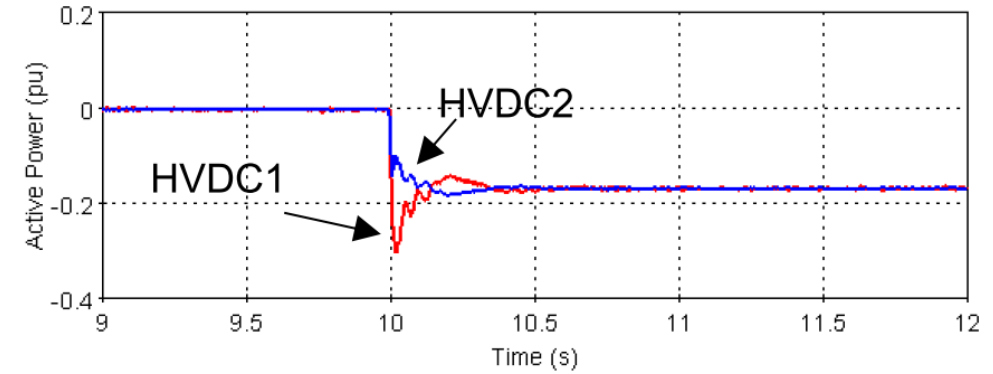
Coordination of the 2 HVDC links

- HVDC1 and 2 primary power sharing



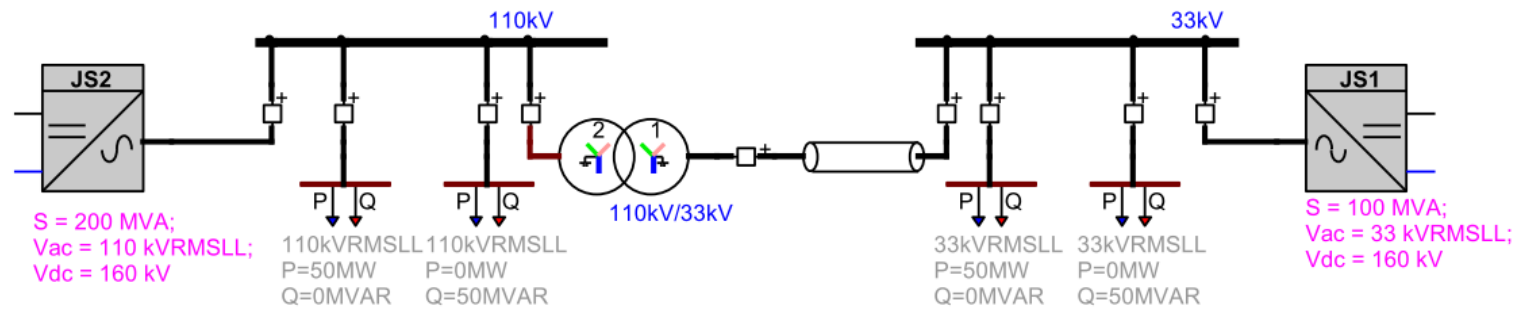
Simplified layout of the offshore parallel operation

Active power load step



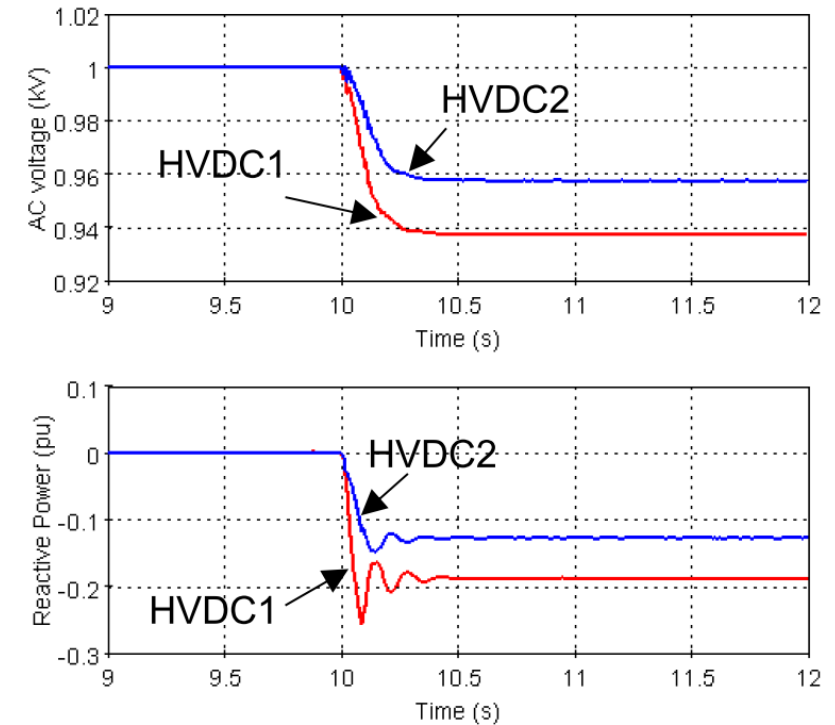
Coordination of the 2 HVDC links

- HVDC1 and 2 primary power sharing



Simplified layout of the offshore parallel operation

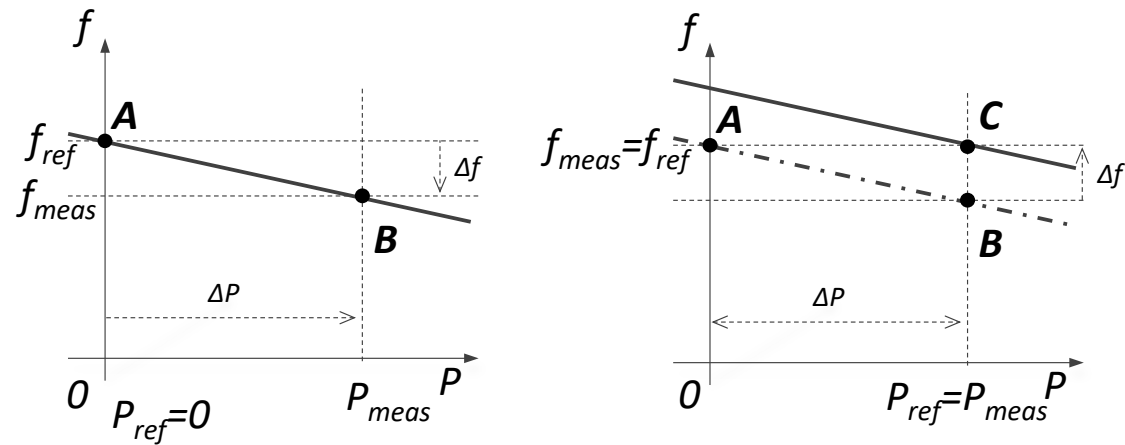
Reactive power load step



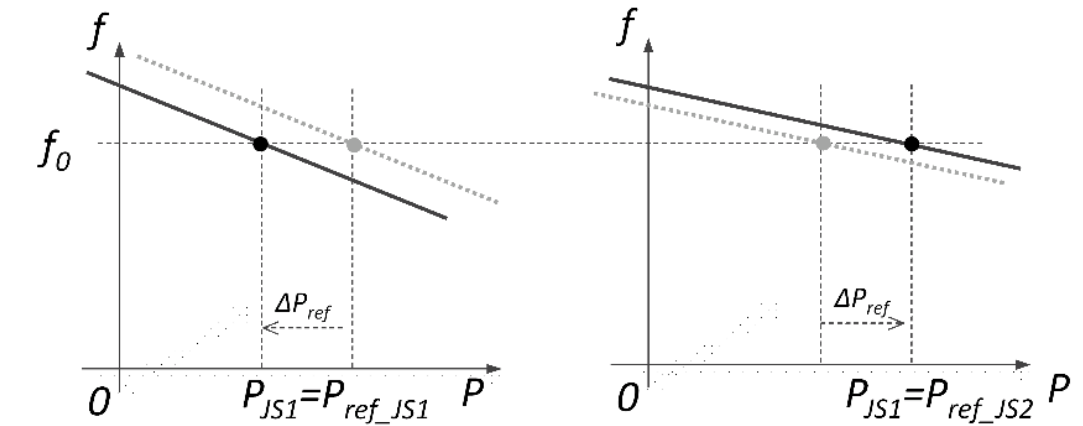
Coordination of the 2 HVDC links

- HVDC1 and 2 secondary control

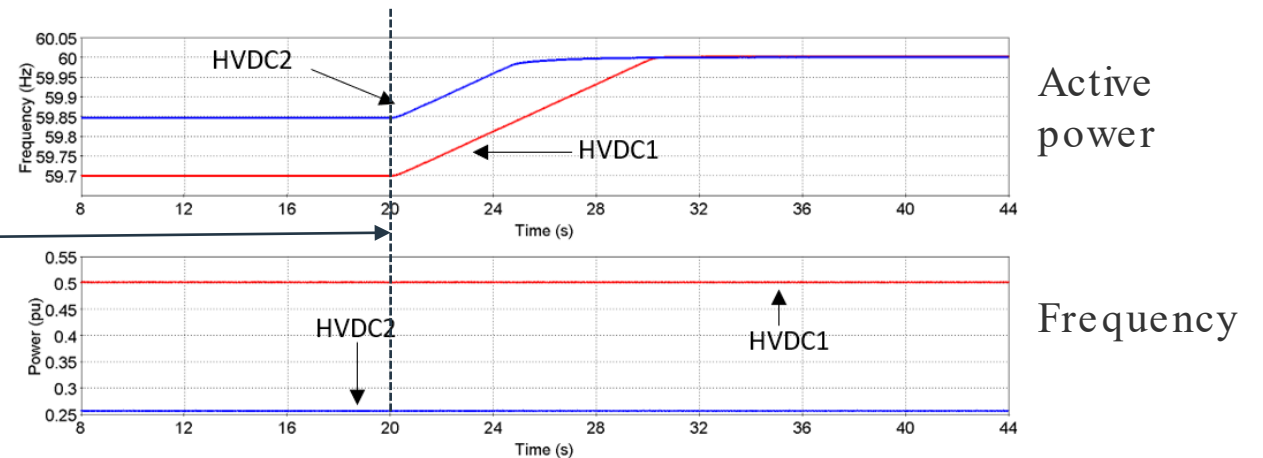
Secondary control for HVDCs



Secondary control to prepare for parallel operation



Secondary control activation



Coordination of the 2 HVDC links

- HVDC1 and 2 secondary voltage control

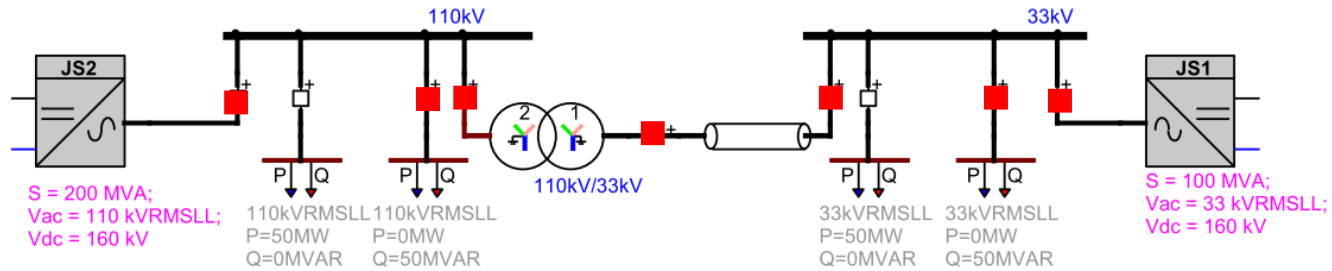
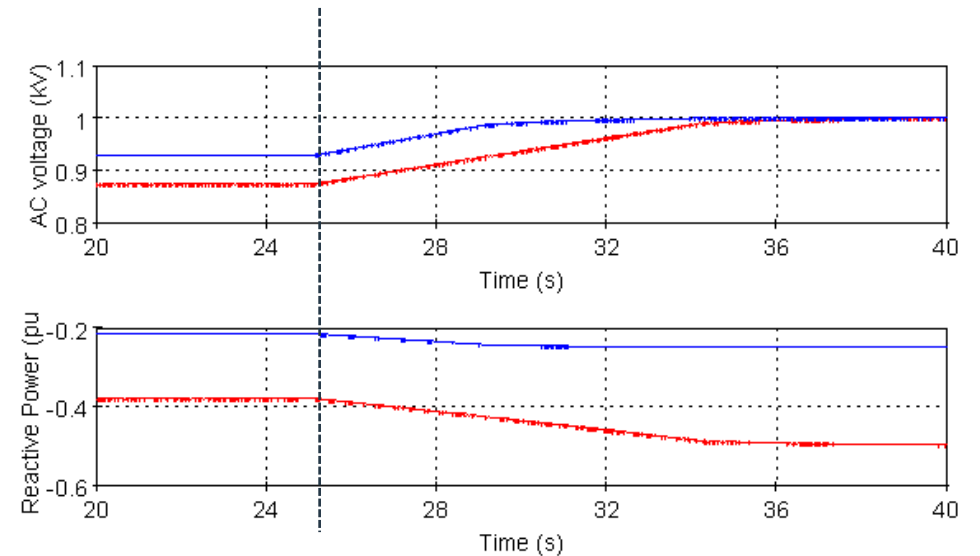


Illustration of the compensated droop control with PMS (Reactive Power)

Secondary control Activation



3rd PARTY (RTEi) SCOPE OF WORK

- Preserve the intellectual property, protecting both VSC technologies involved in this project (Siemens and ABB),
- Specify the functions of a global controller coordinating steady state operation of the overall system.
- Develop and define the methodology and scenarios required to assess the interoperability issues of the two HVDC links in all operation modes e.g. steady state, dynamic and transient conditions.
- Build the onshore and offshore grid PSCAD models. EQUINOR provides the developed PSCAD models of the phase-1 and phase-2 offshore AC grids, ABB and SIEMENS provide Black-Boxed models
- Establish the PSCAD simulation environment for preliminary offline analysis.
- Identify the attributes of the Power Management System to ensure the parallel converters operate efficiently within the operating range specified.
- Perform the offline Electro-Magnetic Transient (EMT) studies and real time simulations with replica of the HVDC C&P cubicles.

Parallel operation studies

- EMT studies are required to ensure secure power supply

HVDC systems developed with limited information of each other

- HVDC1 has been designed to be the main power source offshore
- HVDC2 is designed without detailed information on HVDC1

Studies are required to analyze interactions and coordination of the overall system

- EMT simulation is the most advanced simulation tool (vs phasor domain tools)
- Detailed electrical component models and detailed C&P representation

For the Johan Sverdrup project the following events were analyzed:

- Power sharing
- Energization processes
- Load shedding, load rejection
- Synchronization
- Fault ride-through

Parallel operation studies

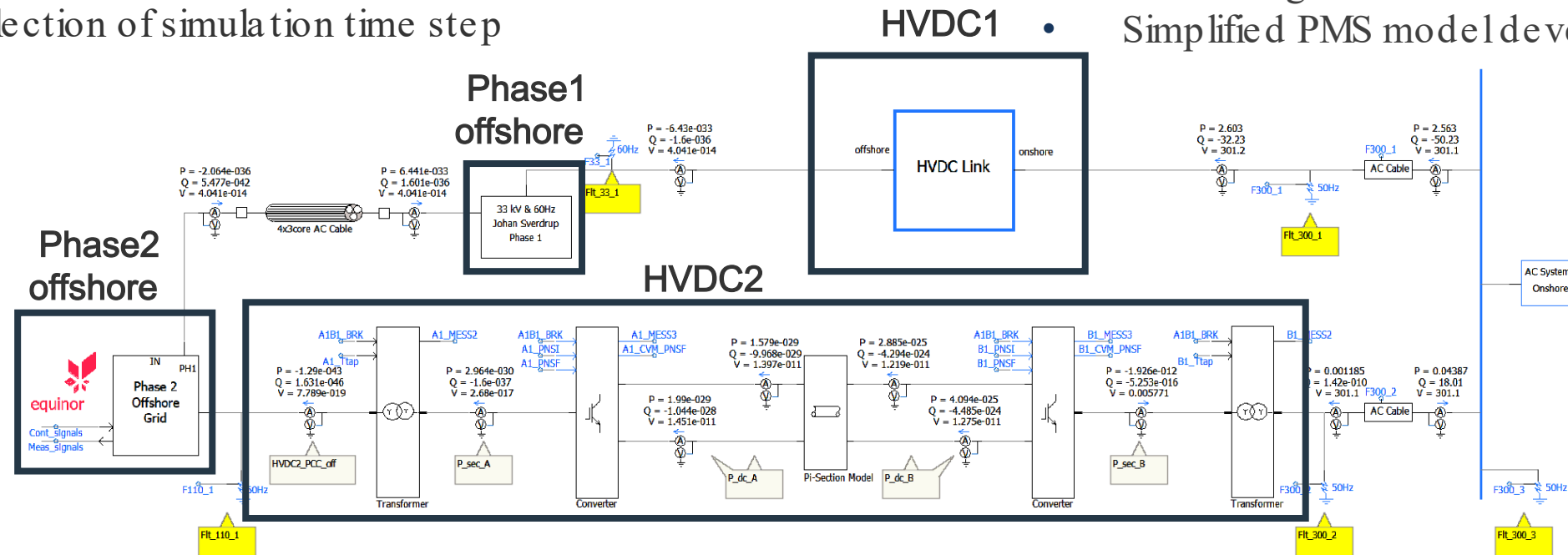
- Specification and delivery of Offline EMT model

Main requirements

- Functions to be included
- Accessible parameters (can change during project)
- Version of simulation tools and compilers
- Selection of simulation time step

Models delivered by vendors

- As built model for HVDC1
- Preliminary model for HVDC2
- Offshore grid model delivered by SIEMENS
- Simplified PMS model developed by RTEi



Parallel operation studies

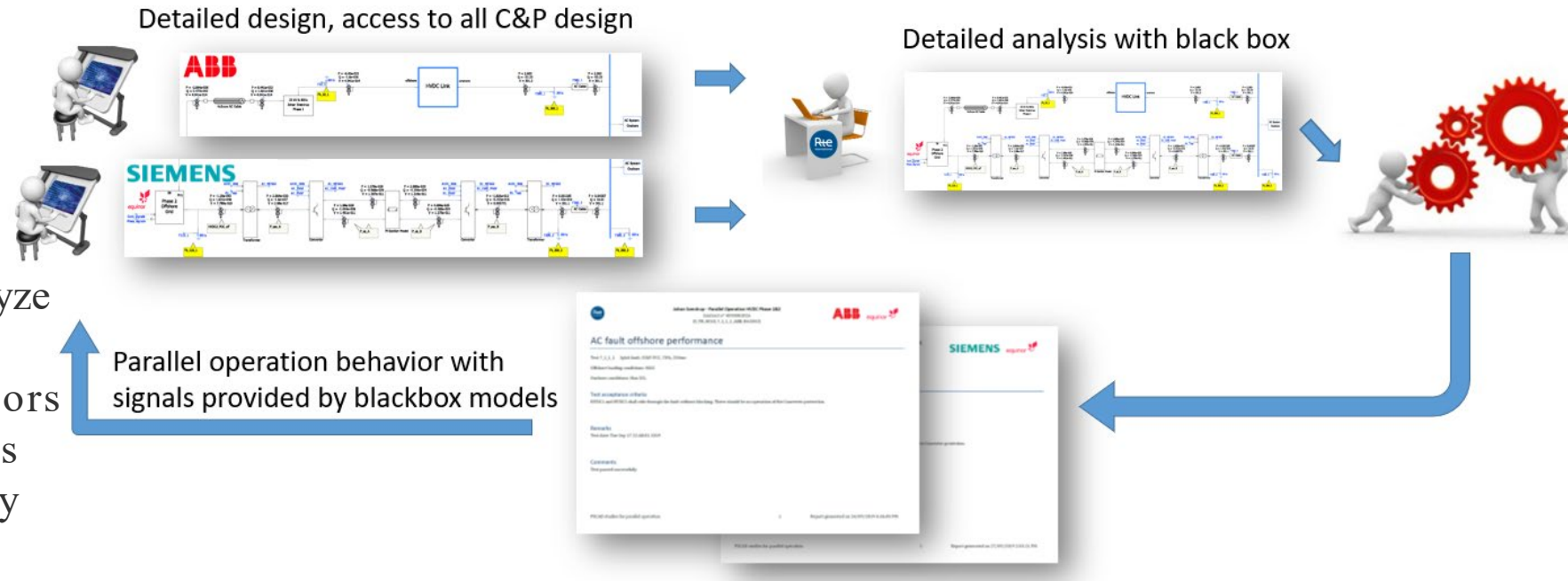
- Offline studies with multivendor models

Sharing information

- Each vendor needs minimum set of results to analyze system behavior
- They also need to limit information shared with the other vendor
- List of signals to be shared between ABB and SIEMENS has been agreed before starting simulations

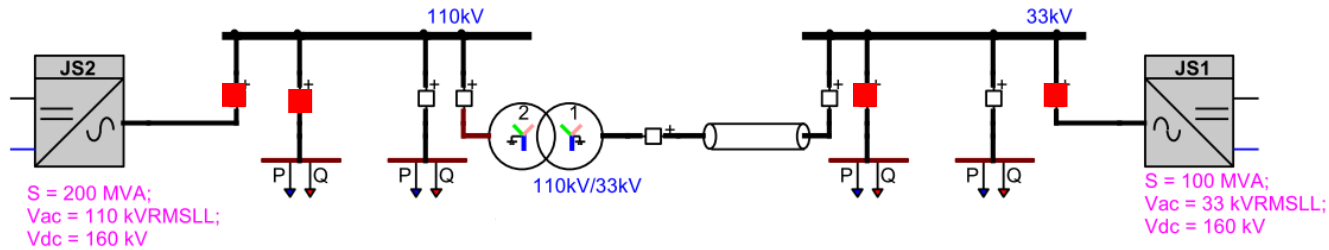
Iterative process

- Integrate updated models
- Run test cases
- Generate reports and analyze results
- Propose solutions with vendors
- Vendors implement solutions
- BB models are generated by vendors

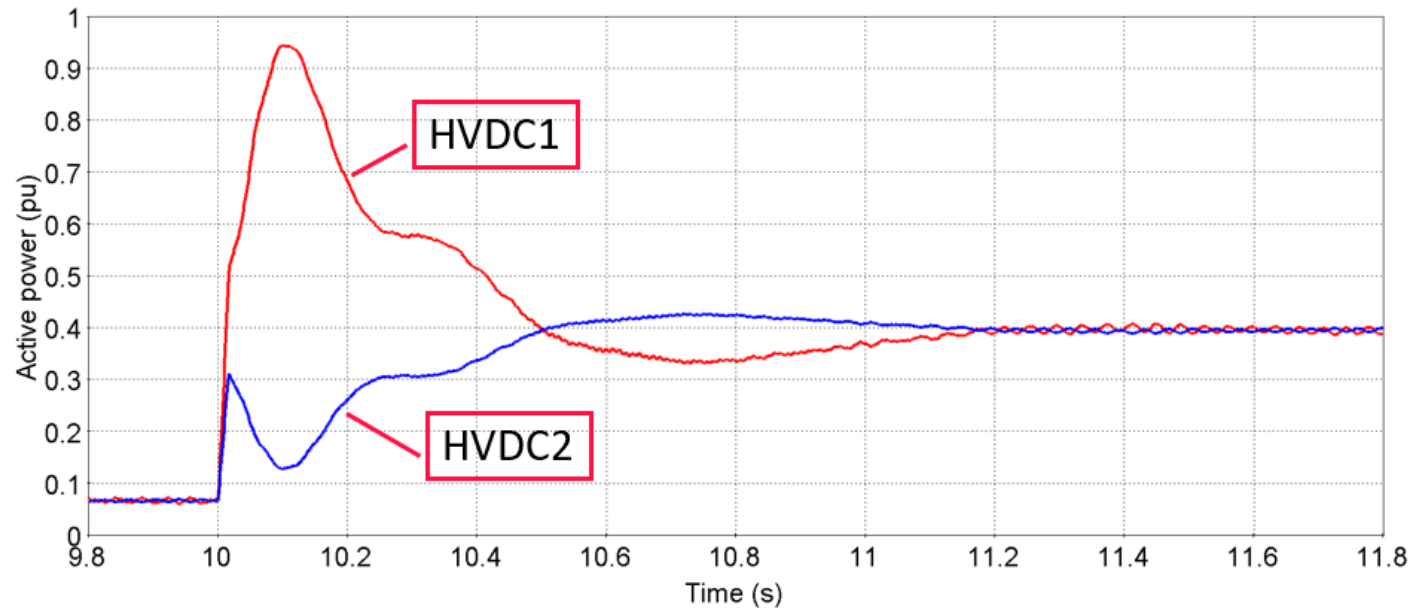


Parallel operation studies

- Illustration of interactions analyzed with offline simulation



Load step test with generic models (Rated power HVDC1: 100MVA, HVDC2: 200MVA)



Parallel operation studies

- Hardware In the Loop (HIL) simulations - justifications

Limitations of the EMToffline models

- Long and cumbersome iterative process to analyze interactions and fix issues
- Difficulties in solving issues for vendors (they do not have the full system)
- Offline EMT simulations are time consuming and within a limited time window
- EMT simulation is not suitable for dynamics of PMS
- Some non relevant functions are not included in the EMT models

Advantages of HIL simulation

- Reproduce conditions of tests similar to onsite conditions
- HVDC C&P systems can be updated remotely by ABB, SIEMENS and KM
- Manufacturers can instantaneously have access to parallel test records on their system

EMToffline simulation remain essential

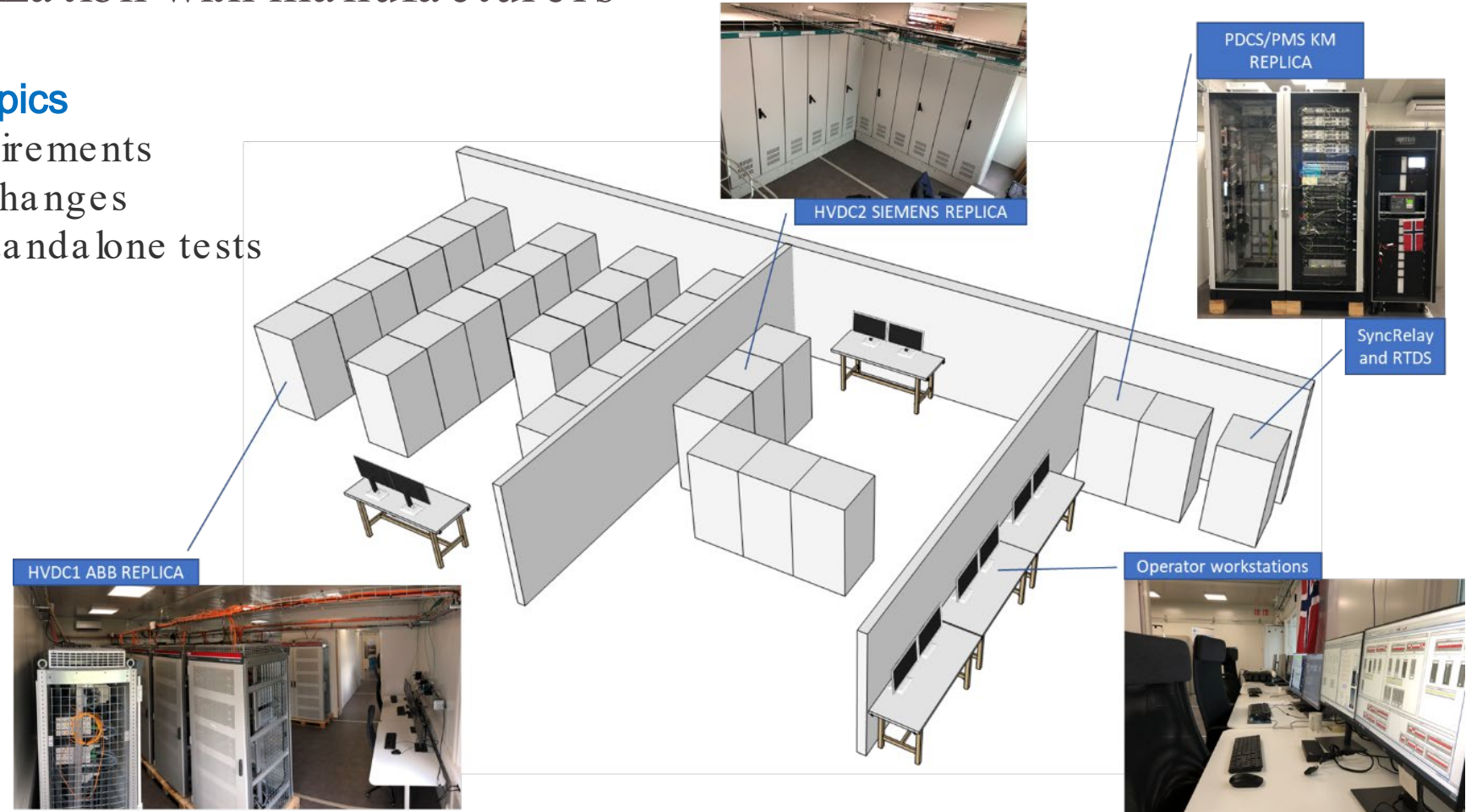
- More detailed and accurate representation of the electrical equipment and especially nonlinearities
- Possibility to run several simulations in parallel without any human actions

Parallel operation studies

- Test lab facility – organization with manufacturers

Special care to the following topics

- Respect confidentiality requirements
- Strict tracking of software changes
- Coordination with HVDC2 standalone tests



Dogger Bank Wind Farm

Dogger Bank Wind Farms consist of three offshore HVDC connected wind farm projects, Dogger Bank A and B and C, located between 125 and 290 km off the North East coast of England.

The projects are being delivered as part of a joint venture between SSE Renewables and Equinor. Once completed Dogger Bank will be the worlds largest offshore wind farm.



Each project will have:

- 1200 MW Installed Capacity
- GE Haliade X Wind Turbines
- One Offshore HVDC Platform
- Two 320 kV HVDC Export Cables (200 km+)
- Onshore HVDC Converter Station
- 400 kV HVAC Export Cables

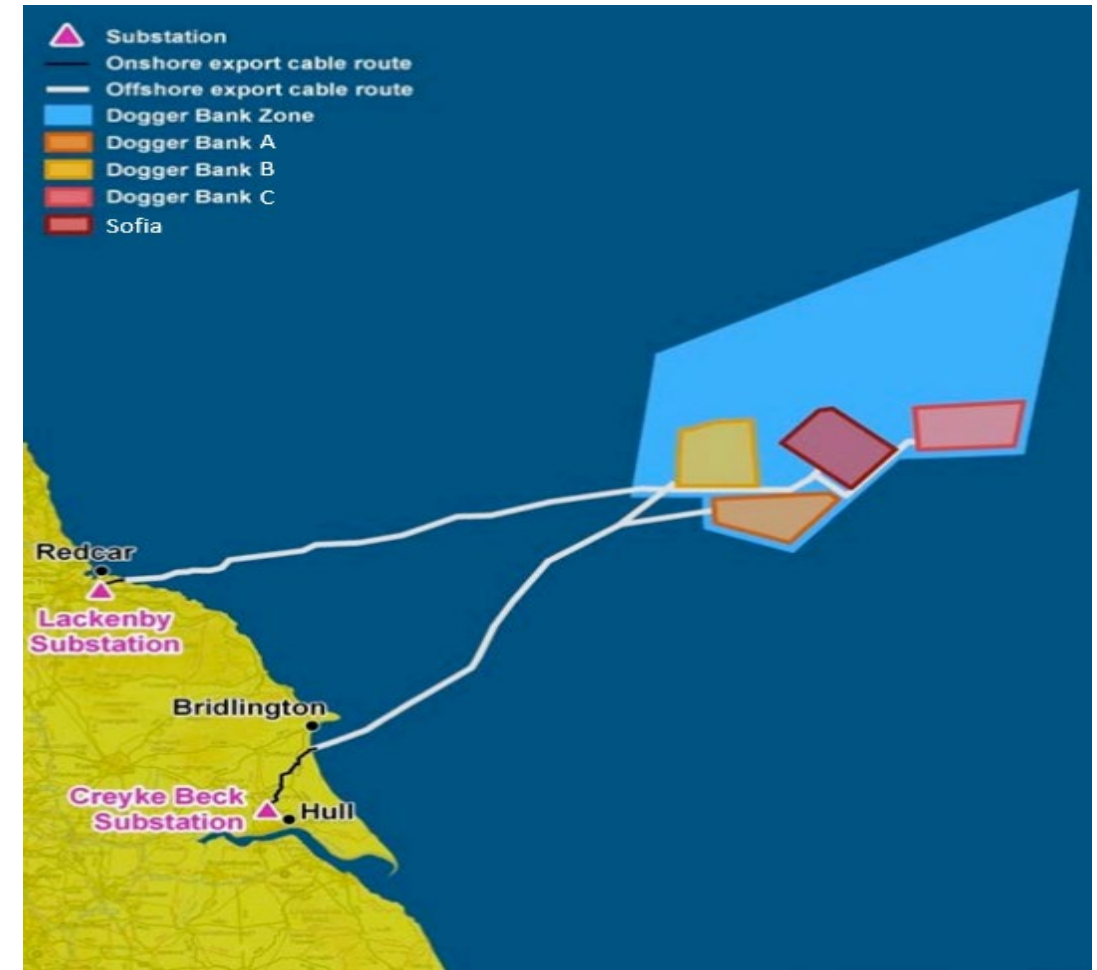
Dogger Bank Wind Farm

The Sofia Offshore Wind Farm is also being developed in the Dogger Bank region.

Sofia is also HVDC connected and is being delivered by Innogy.

Sofia connects to National Grids Lackenby Substation, the same connection point as Dogger Bank C.

The projects are being delivered by different HVDC suppliers. As a result the interaction between the two HVDC Systems needs to be studied to ensure compliance with the Grid Code.



- World's first Multivendor HVDC system in grid forming operation is a success
- Competent 3rd party to perform the offline EMT and HIL analysis is the key success factor due to confidentiality restrictions between the vendors
- System studies and analysis are time consuming processes, 10 000 scenarios have been tested with the replicas of the systems
- Detailed specification of system behavior is essential
- Balance of data and model confidentiality, with simultaneous open processes is necessary but challenging
- Commitment from all parties involved is the key success factor

Kamran Sharifbadi
Chief Engineer Electrical Power Systems & Renewables

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