MESHED OFFSHORE GRIDS
CHALLENGES AND SOLUTIONS

Experience from The Johan Sverdrup HVDC project

HVDC Centre – June 21st, 2022 – Operator Forum

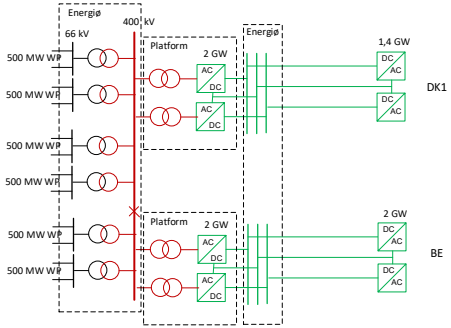
Sébastien DENNETIERE

EUROPEAN HVDC DEVELOPMENTS

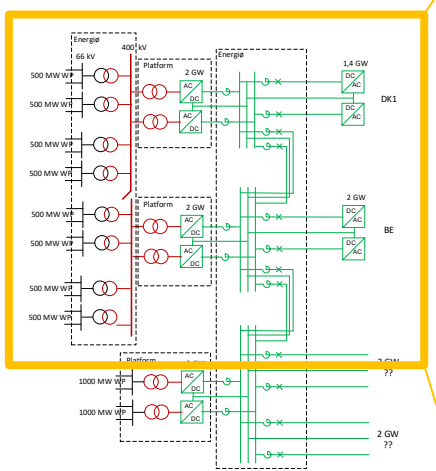
Large-scale offshore grids: NSWPH phase 2

GRADUAL AND MODULAR DEVELOPMENT

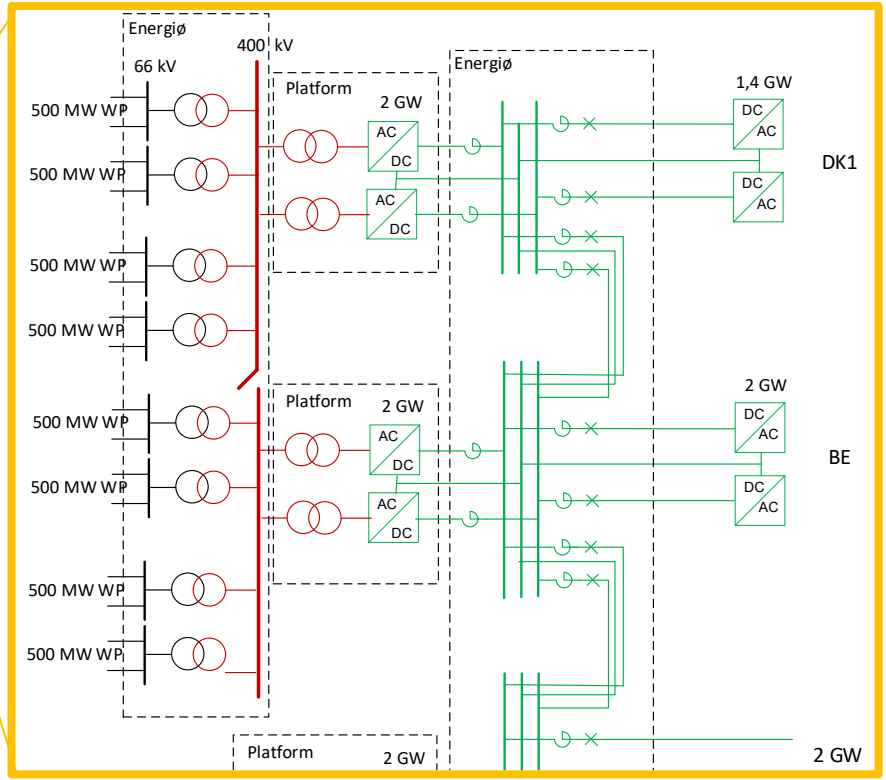
Phase 1



Phase 2



North Sea Wind Power Hub Programme



Source: North Sea Wind Power Hub Programme. Available: https://northseawindpowerhub.eu/

EUROPEAN HVDC DEVELOPMENTS

Large-scale offshore grids: further projects

Bornholm Energy Islands (Energinet DK, 50 Hertz)

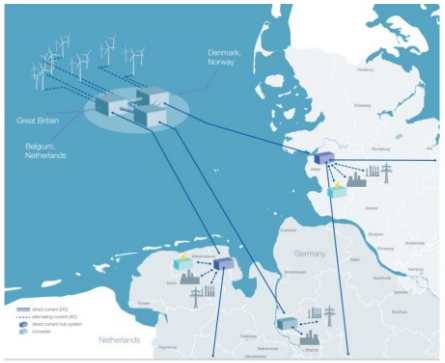
- 3 GW By 2030
- Cross-country, Cross-sector Interconnections
- Multi-vendor, Multi-technology Offshore Wind And HVDC Systems

Bornholm Energy Island: 50Hertz and Energinet sign cooperation agreement for offshore hub in Baltic Sea

50Hertz CEO Stefan Kapferer speaks at the signing of the contract at the windEurope conference. On the podium State Secretary Andreas Feicht, Thomas Egebo (Energinet) and Chris Peeters (Elia Group).

Lanwin Hub (TenneT, 50 Hertz)

- 6 GW by 2032
- Multi-vendor, multi-technology offshore wind and HVDC systems



LanWin hub: Image: TenneT

References
https://www.50hertz.com/en/News/FullarticleNewsof50Hertz/11599/bornholm-energy-island-50hertz-and-energinet-sign-cooperation-agreement-for-offshore-hub-in-baltic-sea
https://www.offshorewind.biz/2021/11/02/tennet-presents-6-gw-offshore-wind-grid-solution-for-germany/

EUROPEAN HVDC DEVELOPMENTS

Novelties and challenges

Require development and increases risk:

-Functional requirements and tuning of parallel grid-forming converters connected on the ac side

-Detecting and mitigating adverse control interactions between power electronics

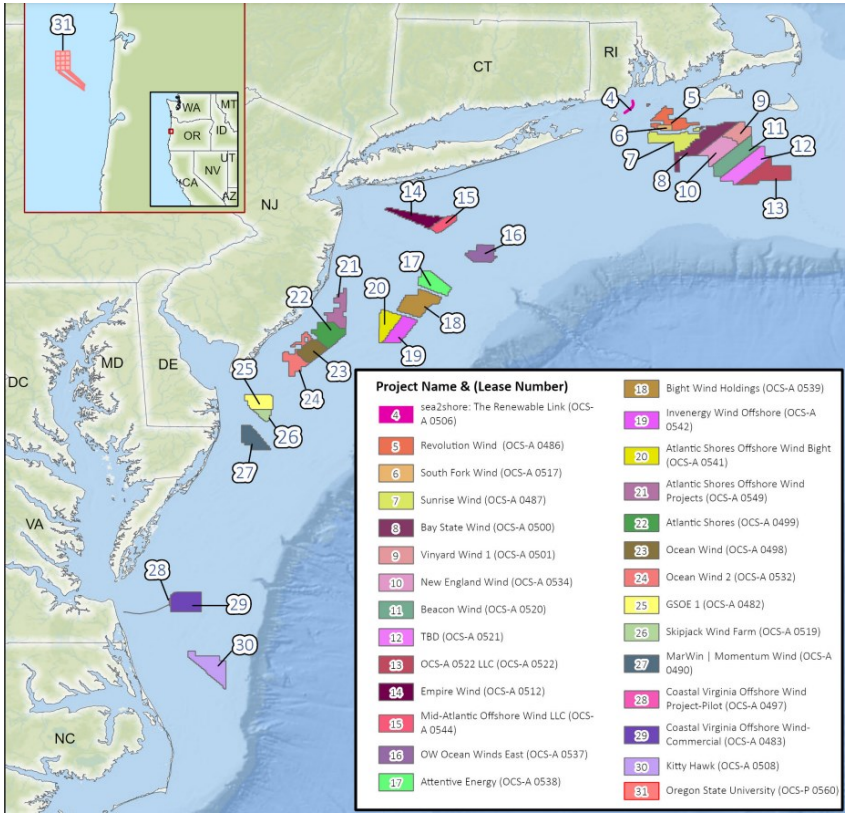
-Control and protection of multi-terminal HVDC grids

-Multi-vendor interoperability, including: Aligning and sharing IP protected models and data between developers, vendors and TSO

Source: North Sea Wind Power Hub Programme. Available: https://northseawindpowerhub.eu/
Energinet: Webinar: Webinar How to de-risk large-scale multi-vendor HVDC systems, lessons from the North Sea Wind Power Hub project

OFFSHORE DEVELOPMENTS IN US

Commercial and research leases issued by Bureau Of Ocean Energy Management

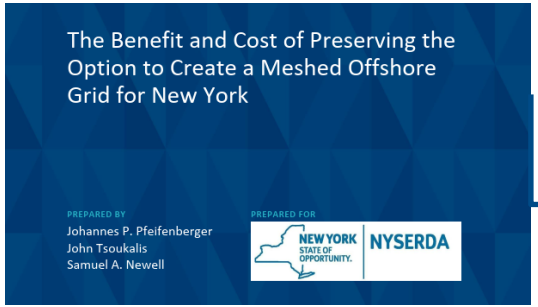


Source: https://www.boem.gov/renewable-energy/lease-and-grant-information

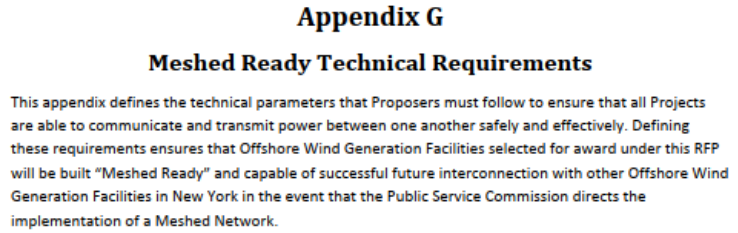
HVDC DEVELOPMENTS IN US

Development in New York State

Documents issued by the New York State Energy Research and Development Authority (NYSERDA)



The most attractive meshed grid design would link each OSW plant with two nearby OSW plants using three 66kV HVAC cables **with a combined capability of 300 MW per link**. The cost of creating a **"mesh ready"** offshore substation that can accommodate two such 300 MW links is estimated **to add approximately $15 million** (less than 0.4%) to the total cost of a 1,000 MW OSW plant. The additional cost of implementing a link between mesh-ready offshore substations (at some point in the future) would be approximately **$120-240 million per link**.



Appendix G

Meshed Ready Technical Requirements

This appendix defines the technical parameters that Proposers must follow to ensure that all Projects are able to communicate and transmit power between one another safely and effectively. Defining these requirements ensures that Offshore Wind Generation Facilities selected for award under this RFP will be built "Meshed Ready" and capable of successful future interconnection with other Offshore Wind Generation Facilities in New York in the event that the Public Service Commission directs the implementation of a Meshed Network.

"Meshed Grid Coordinated Controller" (MGCC) necessary for the Meshed Network operability shall be considered in the Meshed Ready phase with the following functions:

- Active Power Flow Coordination Within Meshed Network
- Reactive Power Support
- Automatic Switching Sequences

Source:

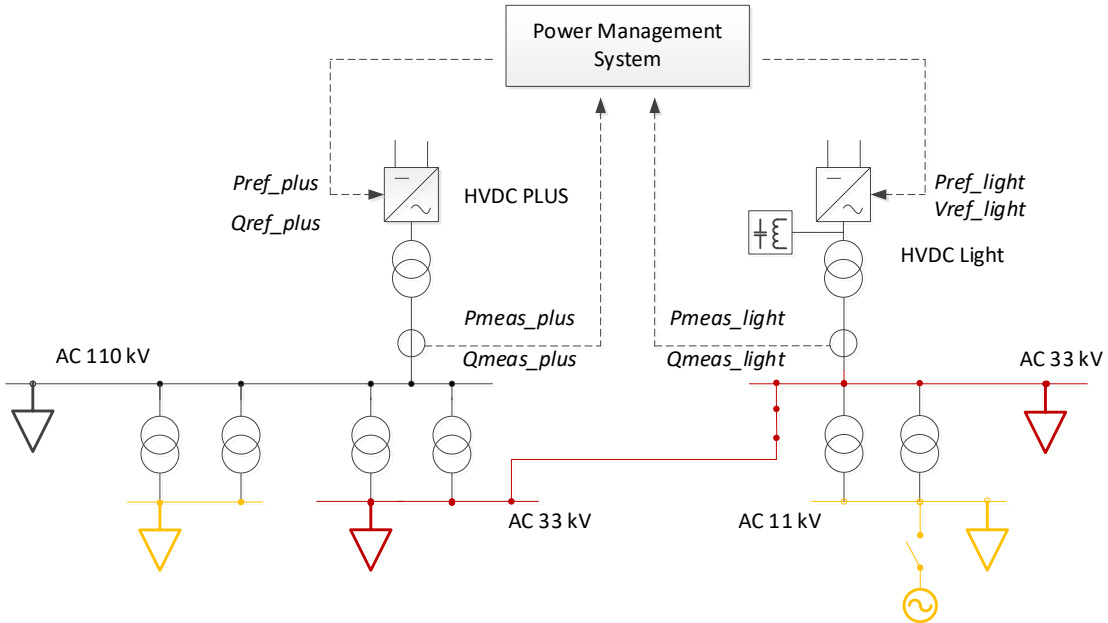
https://www.brattle.com/wp-content/uploads/2021/12/The-Benefit-and-Cost-of-Preserving-the-Option-to-Create-a-Meshed-Offshore-Grid-for-New-York.pdf

https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00P8z000000gjB1EAI#:~:text=The%20meshed%20connection%20would%20be,230%20kV%20AC%20cable%20technology.

COORDINATION OF 2 HVDC LINKS

Experience from the Johan Sverdrup project - PMS

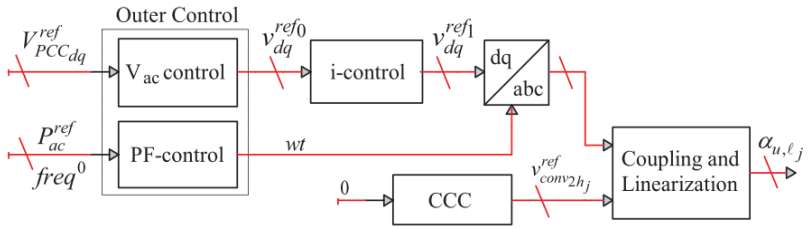
Load Sharing between the two HVDCs (Offshore)
Secondary frequency and voltage control (Offshore)
Reactive support interface to HVDC 2 (Onshore)
Gradual Load shedding system (Active power)
Synchronization logic to synchronize the two HVDCs.

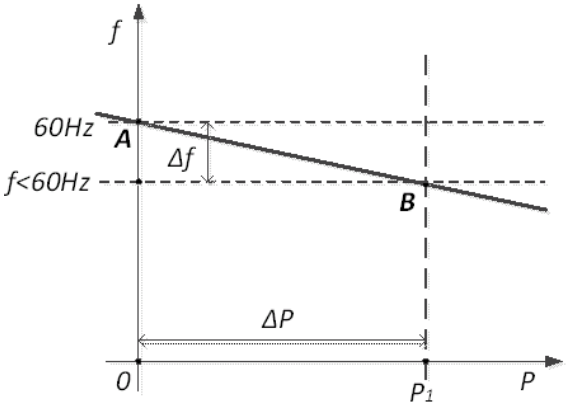


COORDINATION OF THE 2 HVDC LINKS

HVDC1 and 2 primary controls

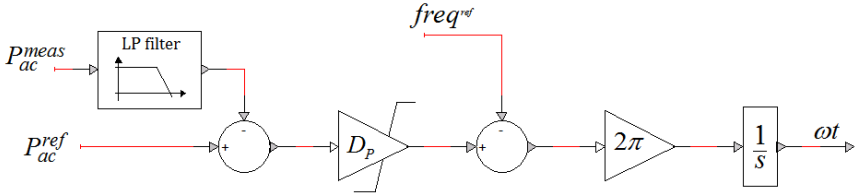
1. Generic structure of VF control (grid forming)

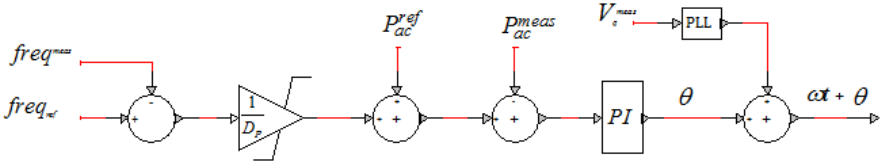




2. P/f control

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



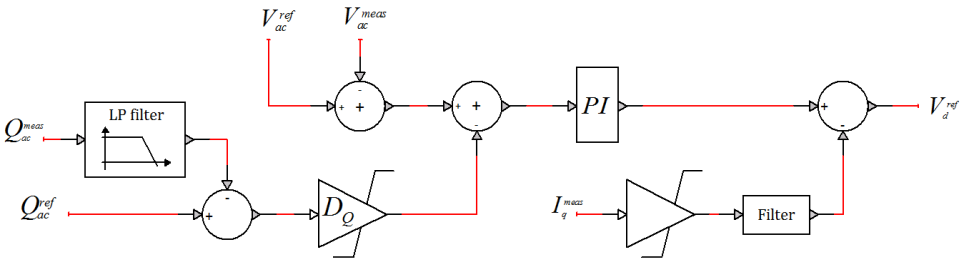


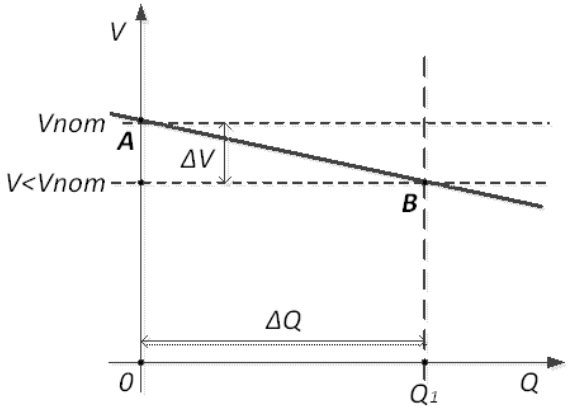
COORDINATION OF THE 2 HVDC LINKS

HVDC1 and 2 primary controls

1. Vac control

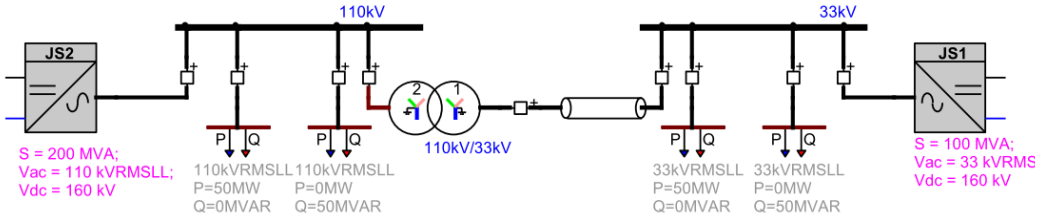
- To regulate the AC voltage at Point of Common Coupling (PCC)
- 1 generic example to illustrate the Vac control:

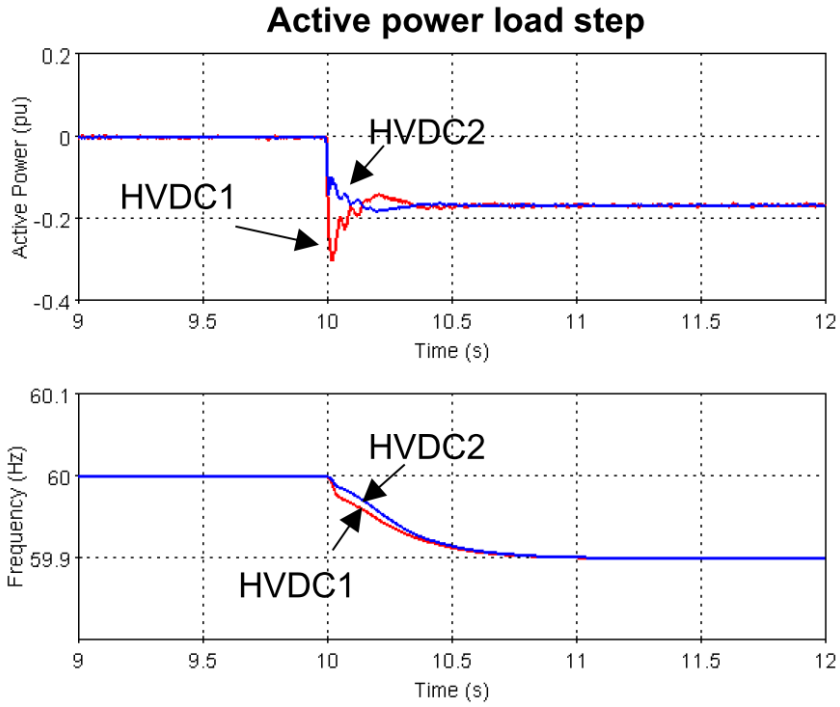




COORDINATION OF THE 2 HVDC LINKS

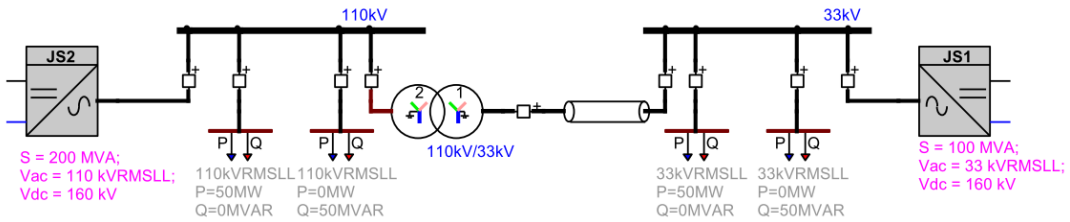
HVDC1 and 2 primary power sharing

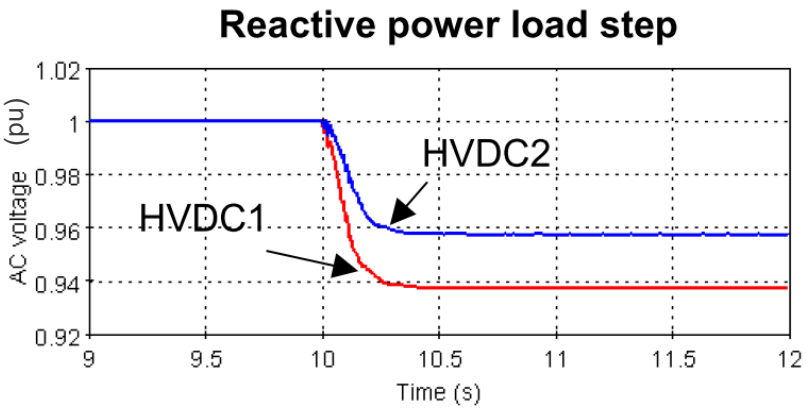


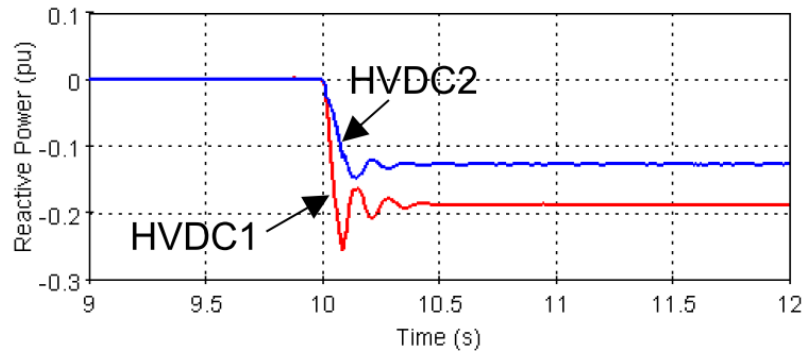


COORDINATION OF THE 2 HVDC LINKS

HVDC1 and 2 primary power sharing



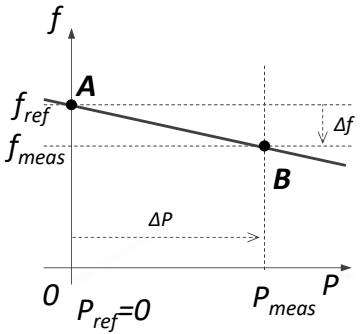


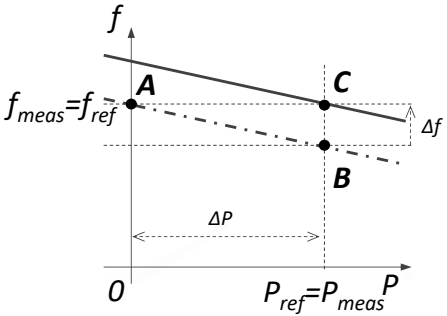


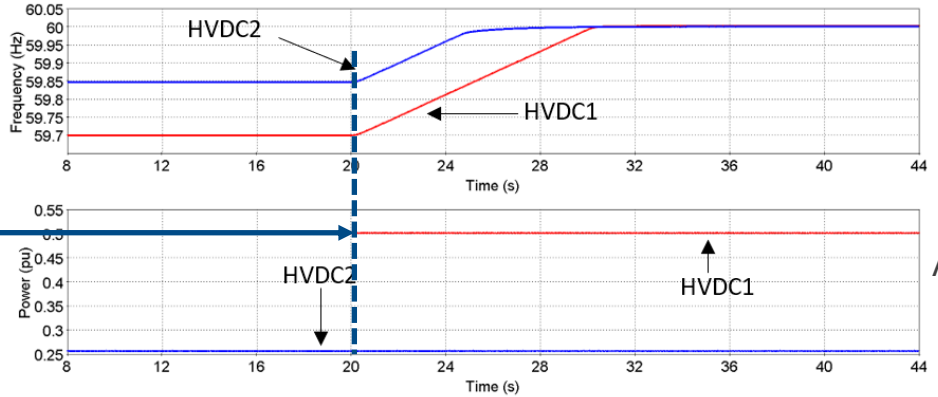
COORDINATION OF THE 2 HVDC LINKS

HVDC1 and 2 secondary control

1. Secondary control for 1 system



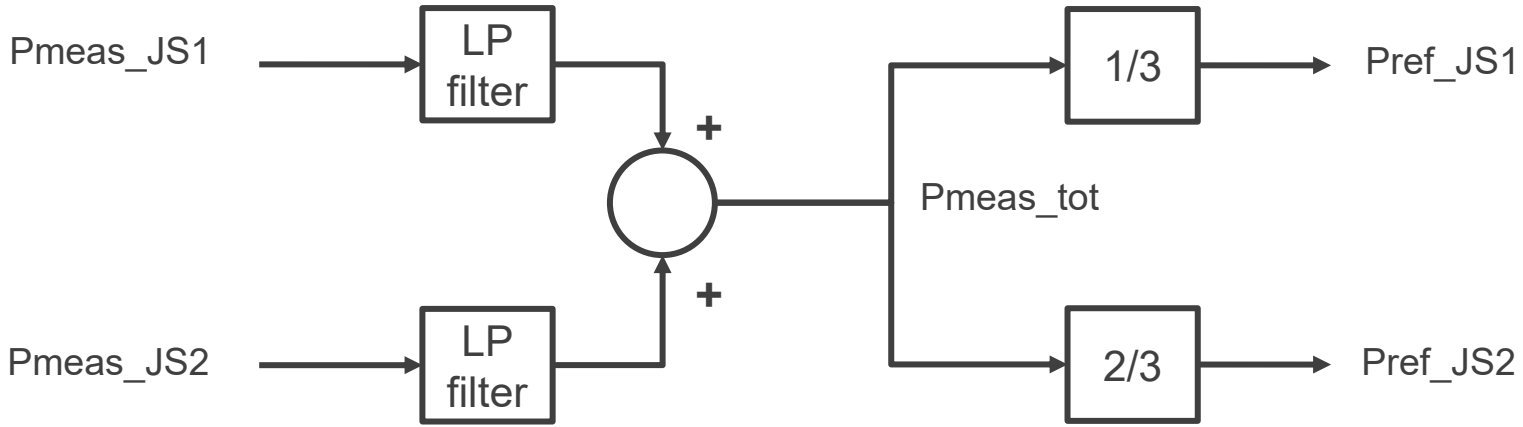




Secondary control activation

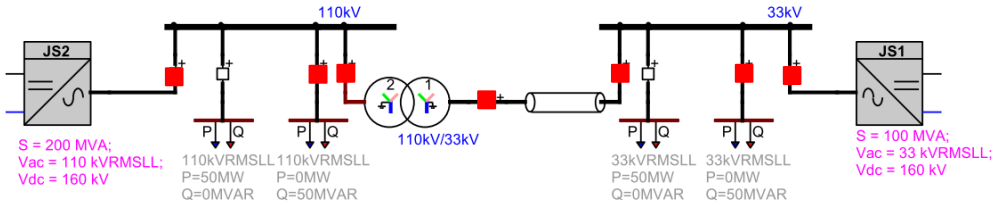
COORDINATION OF THE 2 HVDC LINKS

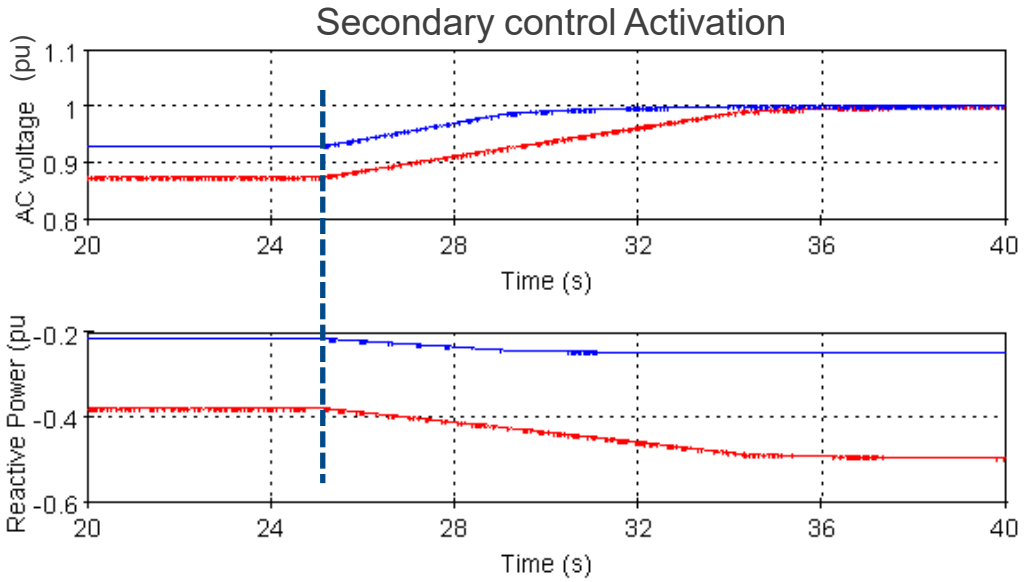
HVDC1 and 2 secondary frequency control and power sharing (simplified)



COORDINATION OF THE 2 HVDC LINKS

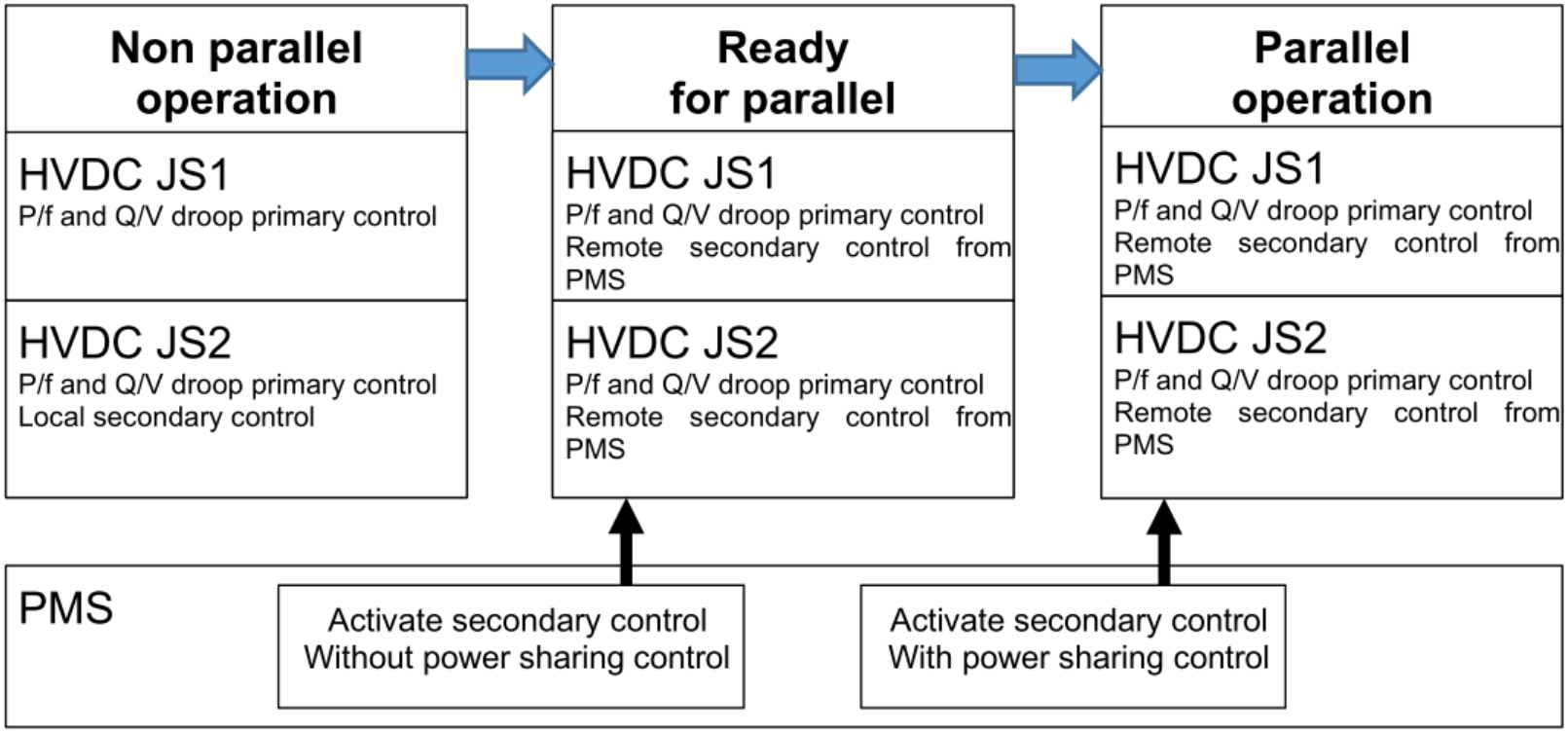
HVDC1 and 2 secondary voltage control





COORDINATION OF THE 2 HVDC LINKS

Transitions for Parallel operation (simplified description)



COORDINATION OF THE 2 HVDC LINKS

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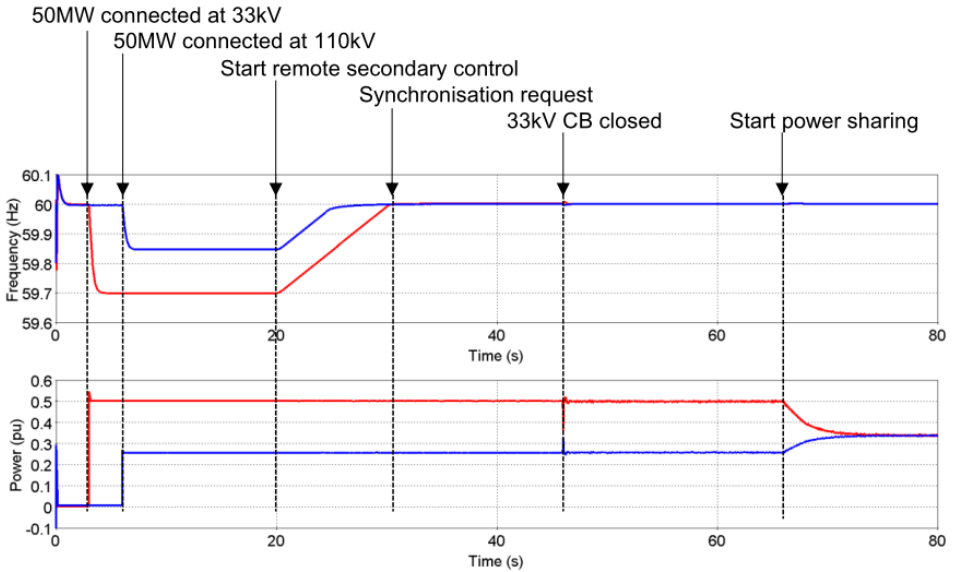
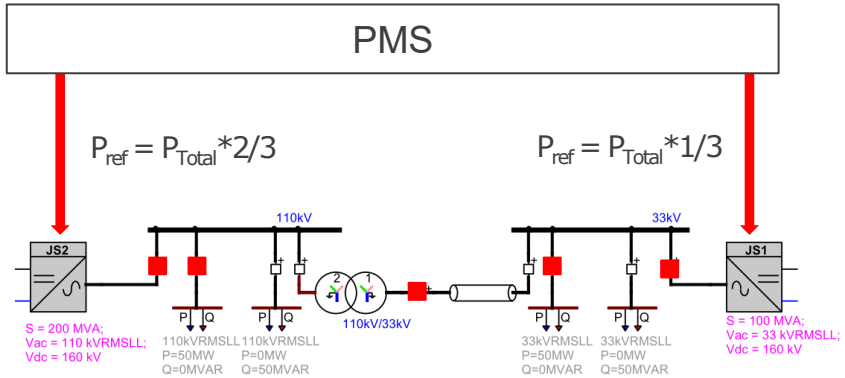
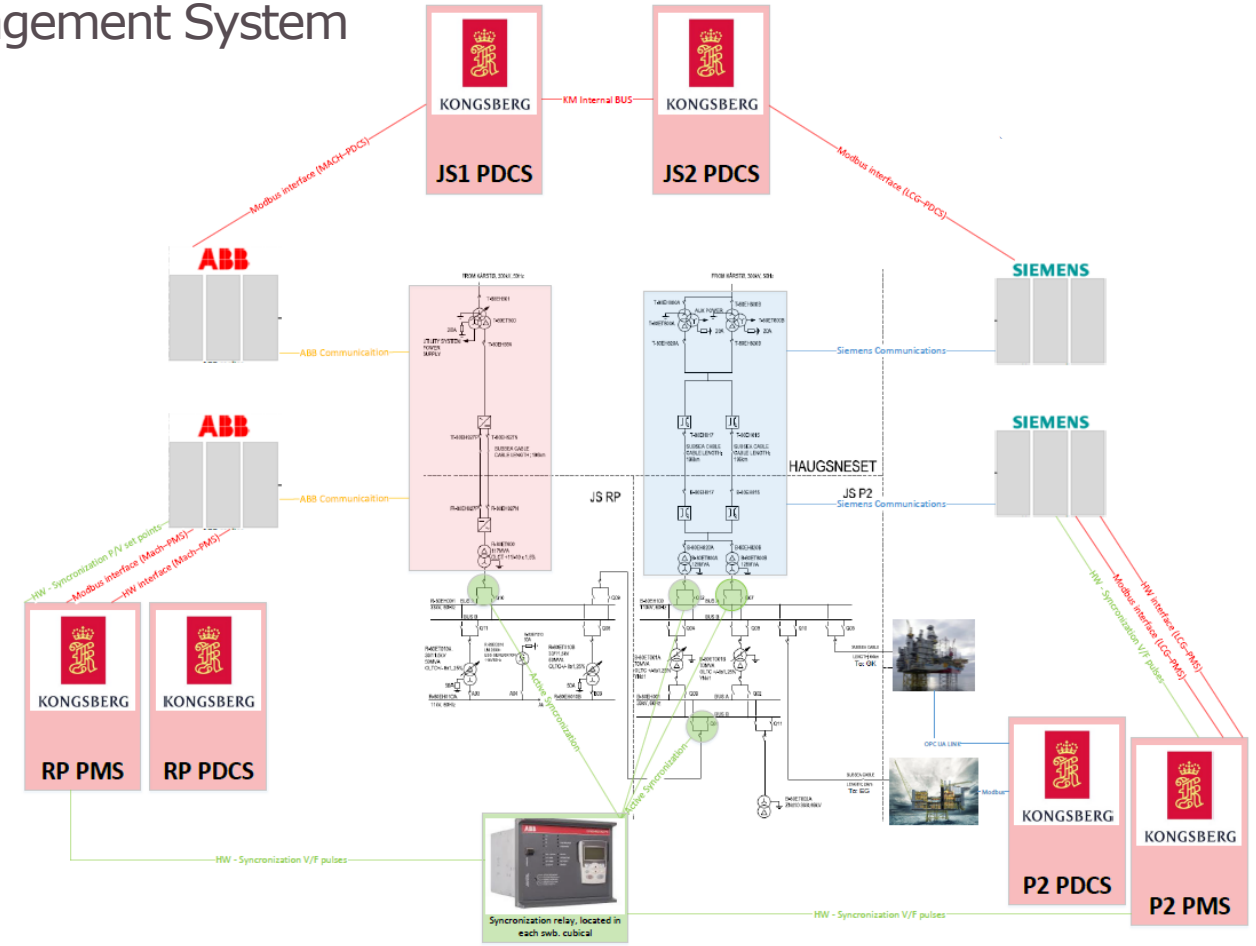




PMS – IMPLEMENTATION

Distributed Power Management System



CONCLUSION

Johan Sverdrup – First meshed offshore grid

1. Technical challenges and solutions

- Coordination in steady state is achievable with a global controller
- Coordination of the dynamic behavior is a challenge due to confidentiality restrictions
- Vendors were willing to adapt C&P settings and strategies in this project
- Keep changes as simple as possible!

2. Vision for the development of meshed offshore grids

- The approach used for JS project (control philosophy and derisking methodology) is applicable to meshed offshore grid for wind generation in Europe and USA
- On going initiatives to facilitate analysis of multi vendor systems with EMT models (IEEE/CIGRE WG)
- An independent 3rd party is usually required to:
  - handle sharing of confidentiality data
  - provide an independent assessment of the coordination between stakeholders

MESHED OFFSHORE GRIDS
CHALLENGES AND SOLUTIONS

Questions & Answers

Experience from The Johan Sverdrup HVDC project