Technology Considerations

Lawrence H. Mott
Project Leader/Owners Engineer

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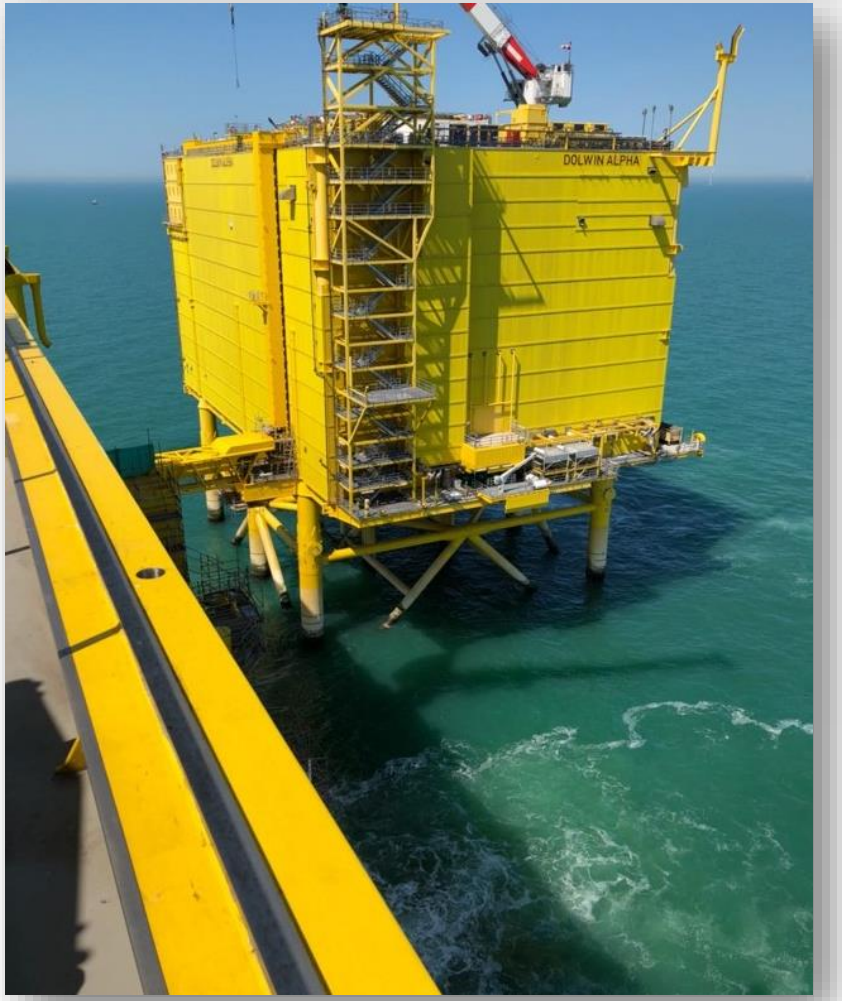
Planning and building the right offshore network for the onshore grid

Begin at the End: What is needed to reach goals?

- Onshore upgrades/implementation more difficult than offshore.
- Use the offshore network to support/upgrade the onshore grid.
- Ultimate goals – Generation/Timing/Flexibility/Cost/Competition

To build a suitable grid:

- Identify robust onshore POIs and maximize/build new.
- Upgrade ability to move wind energy to where it's most needed.
- Consider integration of battery storage to minimize curtailments.
- Design to:
  - *Minimize offshore cables/landings.*
  - *Maximize utilization of wind resources.*
  - *Minimize seabed impact by reducing number of cables.*
  - *Enhance redundancy, resiliency and reliability.*



Offshore transmission technology is dynamic

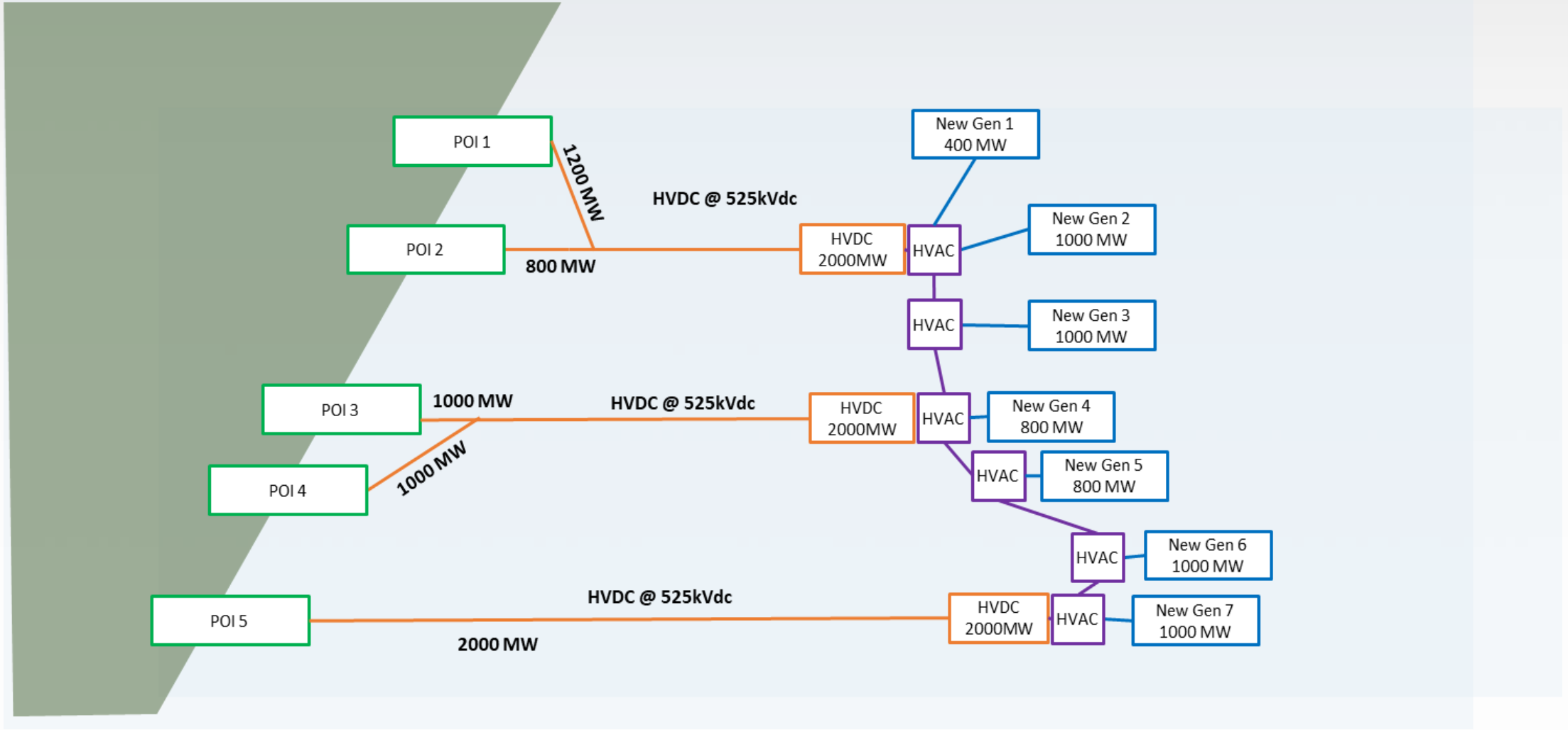
- Dutch-German offshore grid operator TenneT TSO: two 2 GW offshore HVDC grid connections for integrating IJmuiden Ver wind farms

- Equinor: 3.6 GW Dogger Bank Project: Three 1.2 GW HVDC systems

- WTG voltages going up
- Cable voltages going up
- Innovation: Fabrication/Modular/Foundations/Install

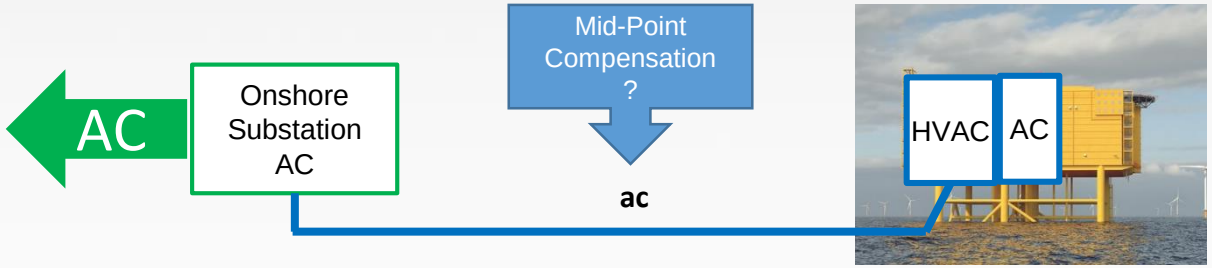
Source: Illustration from Tennet
www.tennet.eu/nl/ons-hoogspanningsnet/net-op-zee-projecten-nl/net-op-zee-ijmuiden-ver-alpha/

Offshore Network: Overall concept 6000MW



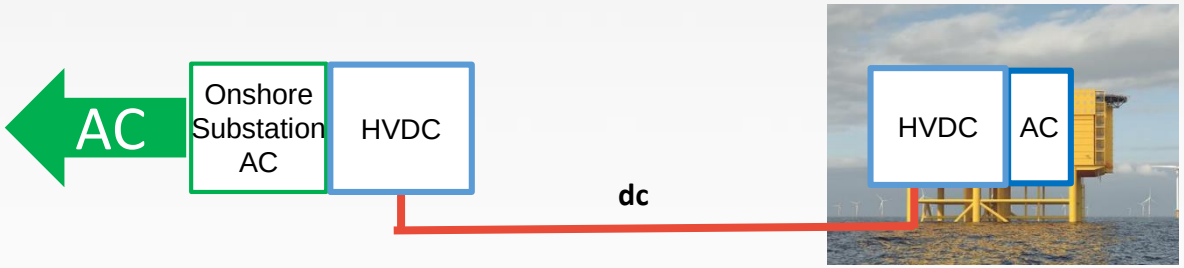
HVAC & HVDC offshore technology

HVAC (High Voltage Alternating Current)



- Competitive for close shore project
- Higher Losses
- Power quality limitations at POI
- Smaller platform/substation than HVDC
- If close to or beyond distance limit, additional platform needed at midpoint
- More cables, space impacts

HVDC (High Voltage Direct Current)



- Competitive for far shore project
- Lower overall losses
- Controllable operations asset
- Larger platforms/substation
- System stability by inherent HVDC equipment capability
- Fewer cables