



HVDC grid connection of offshore wind power

Ir. Arjen A. van der Meer, Electrical Sustainable Energy

23-12-2009

Contents

- Present offshore wind parks
- Grid connection
- VSC-HVDC
- Future trends
- Conclusions

1st generation offshore wind parks

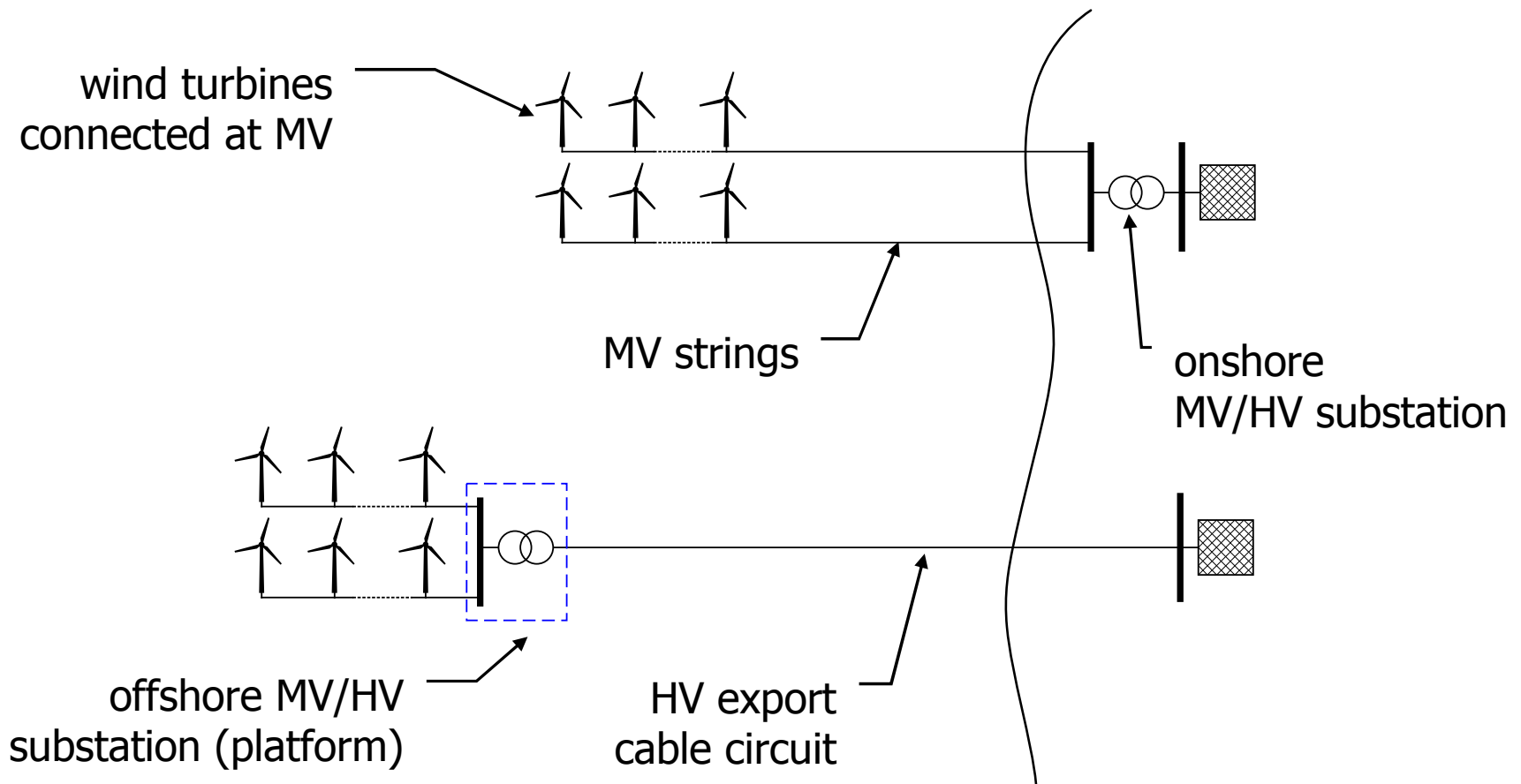
- Typical rating 100 – 200 MW
- Distance from the coast < 25 km
- Operation like a conventional power plant

Offshore wind parks in NL

- OWEZ:
 - 36 X 3 MW
 - Wind park directly connected to the mainland (33 kV)
 - ± 12 km from the shore
- Prinses Amaliawindpark:
 - 60 X 2MW
 - MV/HV transformer located offshore
 - Grid connection through 150 kV cable
 - ± 25 km from the shore



Typical AC grid connection

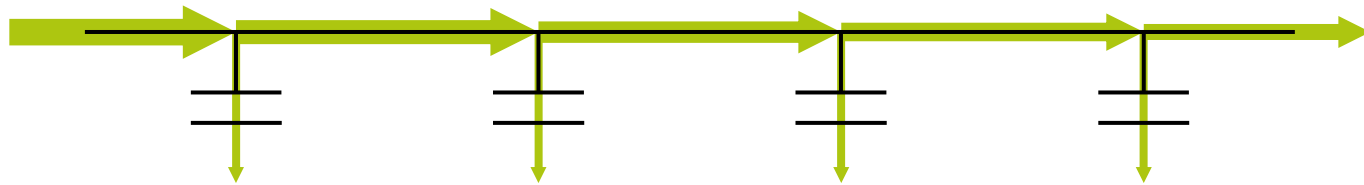


2nd & 3rd generation wind parks

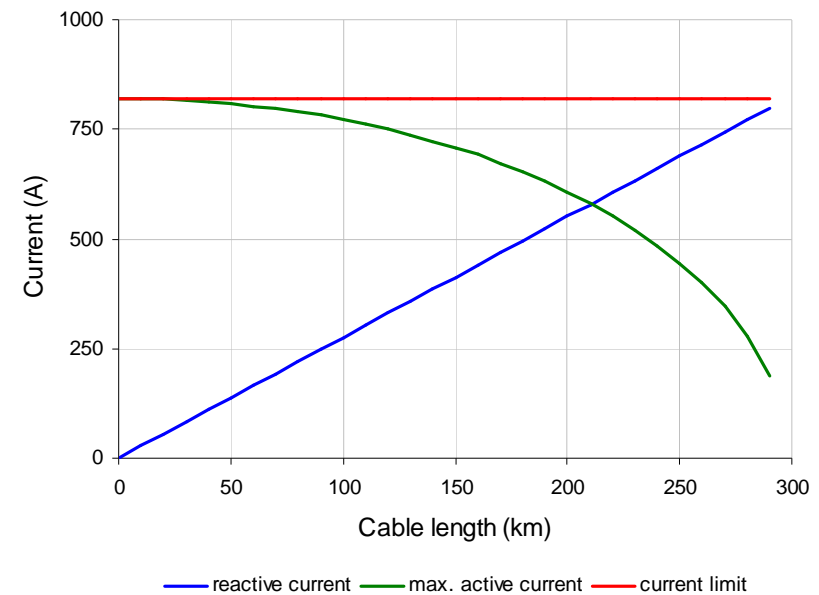
- Will have larger power rating (>500 MW)
- Will be located further from the shore (>>25 km)
- Will be clustered together
- Will show behavior like a large power plant

- In some countries, the TSOs are responsible for grid connection

Limitations of AC transmission



cable is a 'distributed capacitor'
at AC voltage, a charging current
must be provided to keep voltage
thermal limit determines maximum
current
maximum possible active current
reduces with cable length

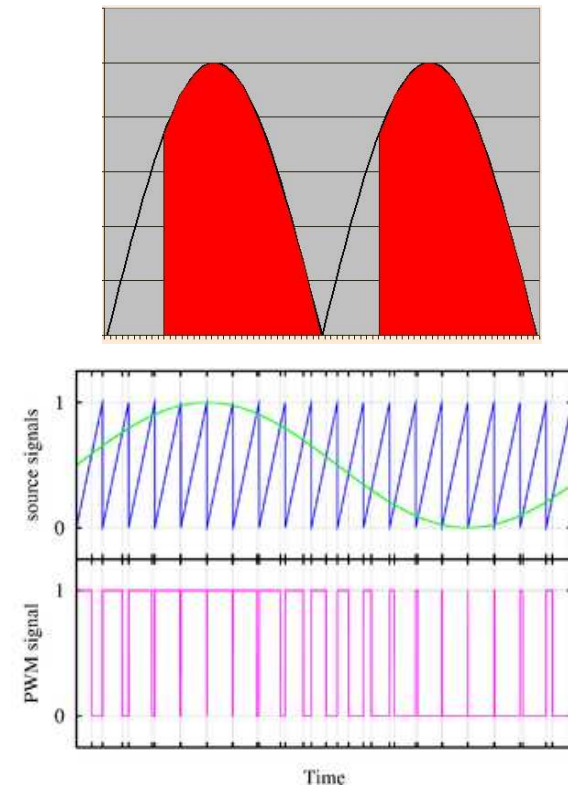


DC transmission

- Solves most problems
 - Only resistive losses, unlimited connection distance
 - No reactive current compensation needed, more power per cable
- But, at the cost of
 - Higher losses
 - Higher investment costs
 - More maintenance

VSC-HVDC versus LCC-HVDC

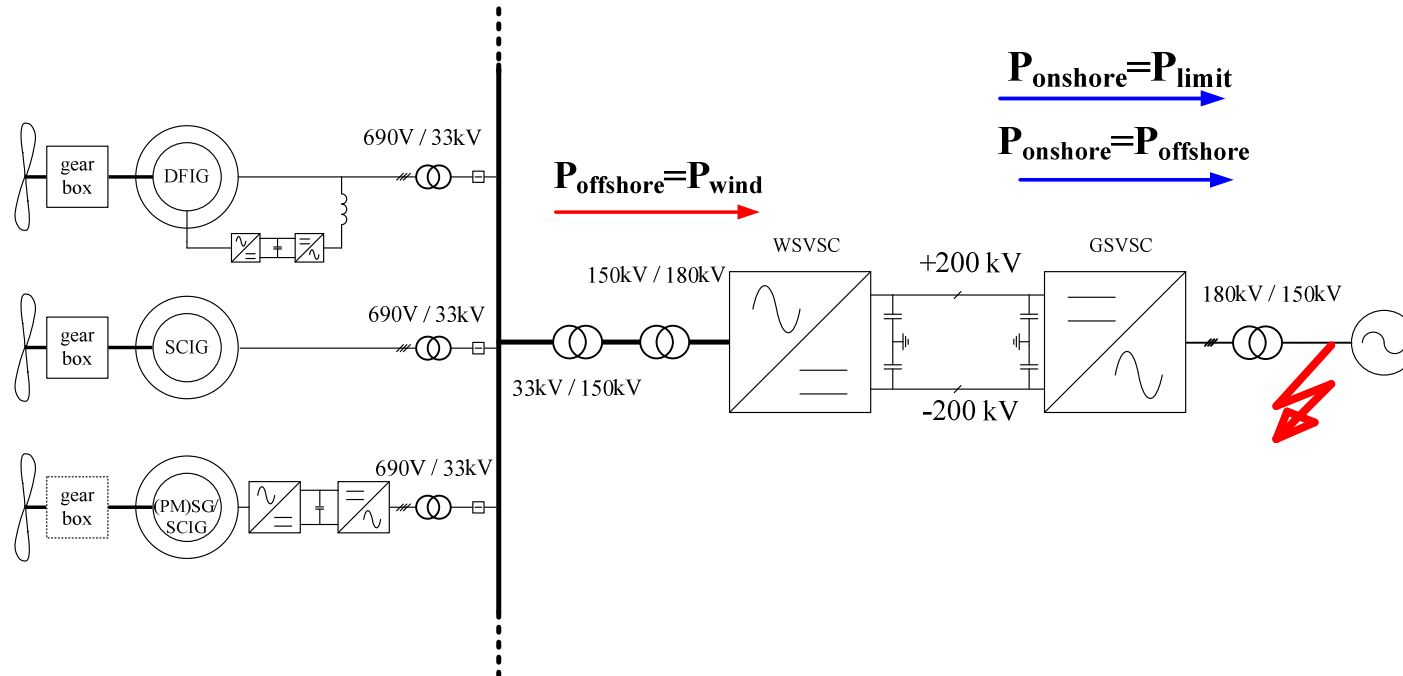
- LCC-HVDC
 - Operated through thyristors
 - Dedicated for bulk power transfer
 - Needs a strong grid to commutate against
- VSC-HVDC
 - Operated through IGBTs
 - Offers black-start capability
 - Good controllability
 - Feasible for systems ≤ 800 MW
 - Smaller footprint



Consequences of VSC-HVDC

- Modern wind parks are required to behave as a conventional power plant
- VSC-HVDC creates an electrical barrier between 2 grids
- Control system now determines grid interaction
 - Disadvantage: fault ride-through behaviour
 - Grid support during disturbances

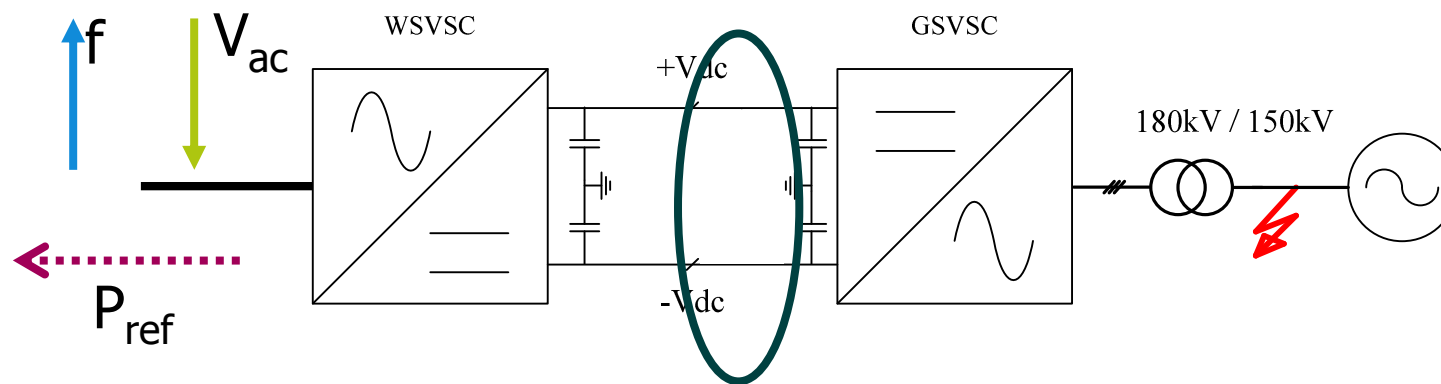
Low voltage ride-through



- Onshore converter has maximum current rating;
- Direct voltage quickly rises due to the power imbalance;
- Only few milliseconds are available for active power reduction;

fast power reduction

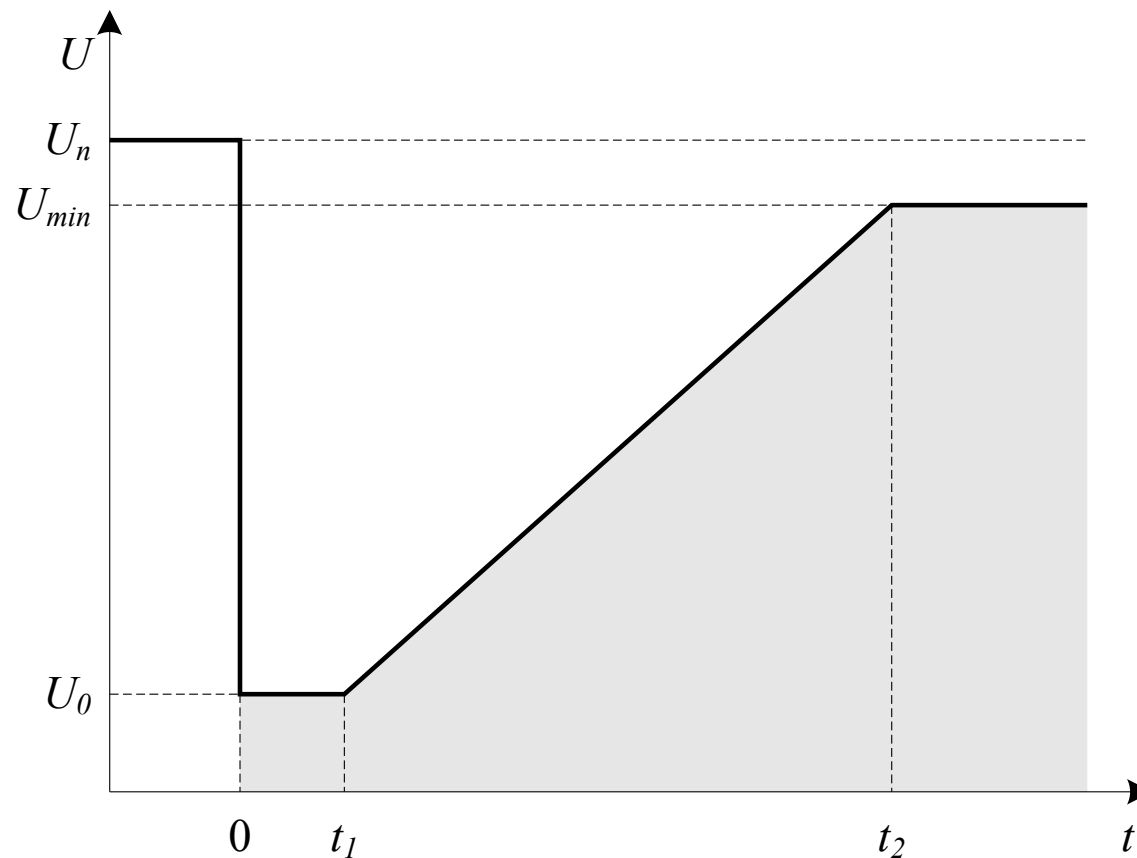
- Increase of offshore frequency;
- Reduction of offshore network voltage;
- power reduction signal to wind turbines;
- Dissipation of excess energy in dynamic braking resistor



Low voltage ride-through: results

- Power reduction methods:
 - Reliability is an issue
 - Additional control systems needed in wind turbines
- Braking resistor: robust but expensive

Grid support during disturbances



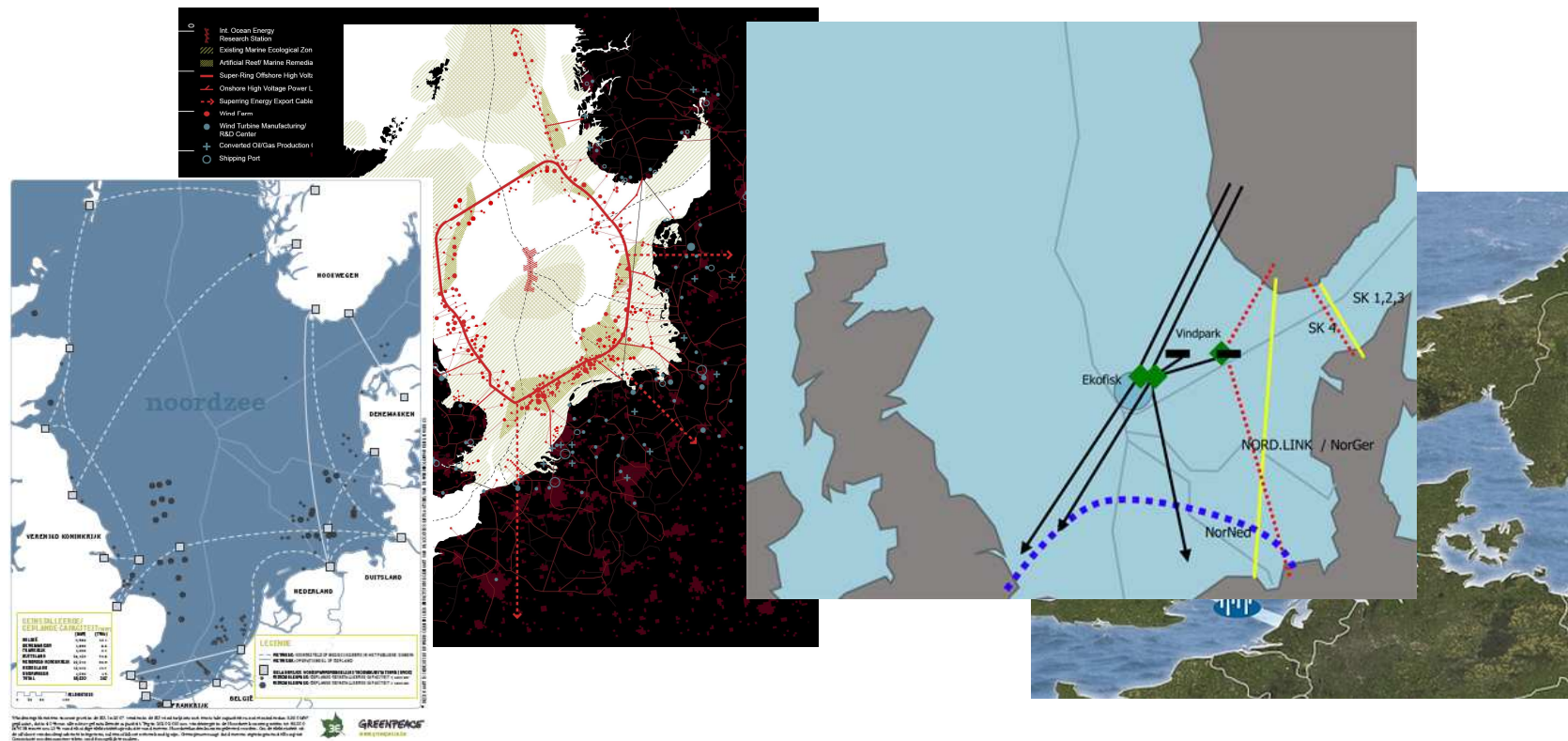
Grid support during disturbances

- Reactive current injection to support voltage restoration
 - Minimize geographical impact of the fault
 - Wind turbines/ VSCs are able to inject reactive power any time
- Different grid codes require different behaviour
- Common variants:
 - No reactive power support
 - Reactive power boosting
 - Continuous voltage control

Grid support: results

- Reactive current injection by VSC-HVDC improves dynamic performance
- Some support methods are more efficient than others
- Voltage support is ineffective for wind parks connected through long AC-cables, VSC-HVDC can overcome this problem

What does the future hold?



Multi-terminal VSC-HVDC

- Increased need for cross-border interconnection capacity
- Utilization factor increases
- Reliability improves
- Synergies with other offshore applications

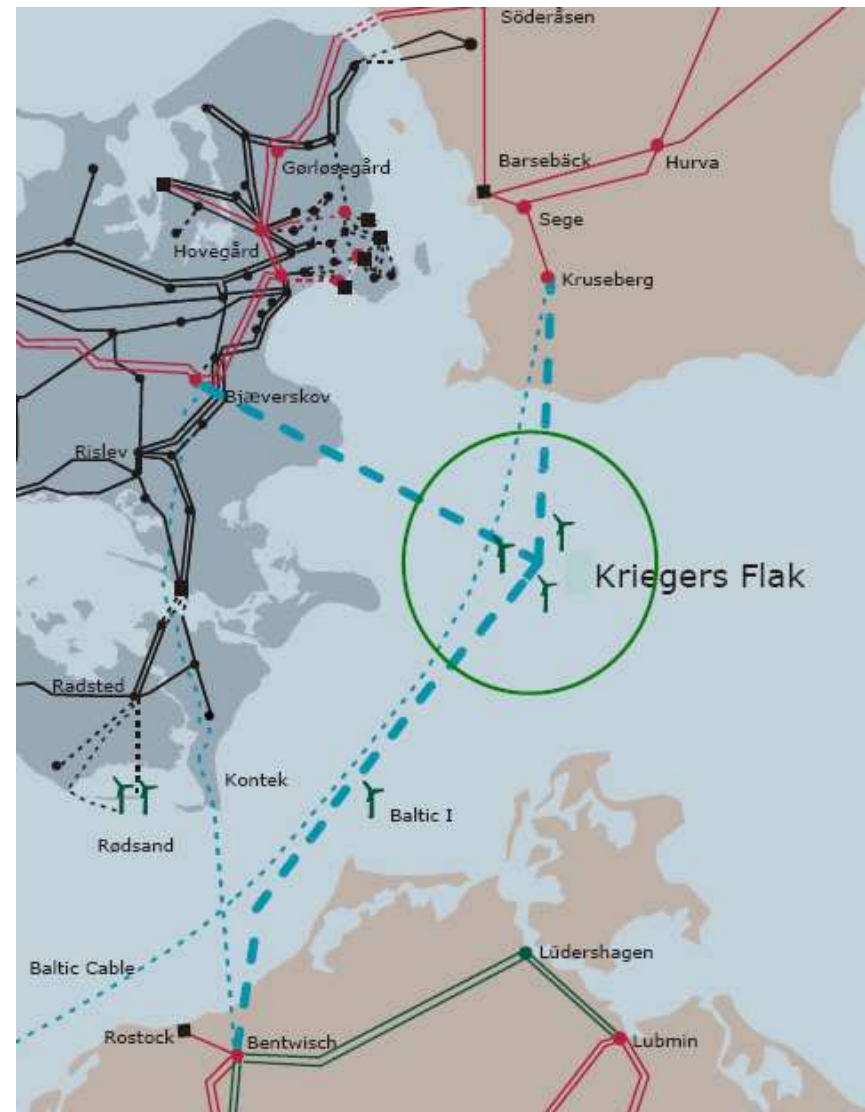
- Economic feasibility is an important prerequisite

Multi-terminal DC: challenges

- Wind power dispatch amongst connection points
- Implementation into market environment
(how to earn money with the additional applications)
- Availability of DC circuit-breakers

Kriegers flak

- 650 MW
- Planned between Germany, Denmark, and Sweden



Conclusions

- Next generation Wind Power Plants requires re-thinking of connection technologies
- VSC-HVDC offers major advantages above other technologies
- VSC interface needs to fulfill grid-code compliance