Electrical grid integration

Overview and Results

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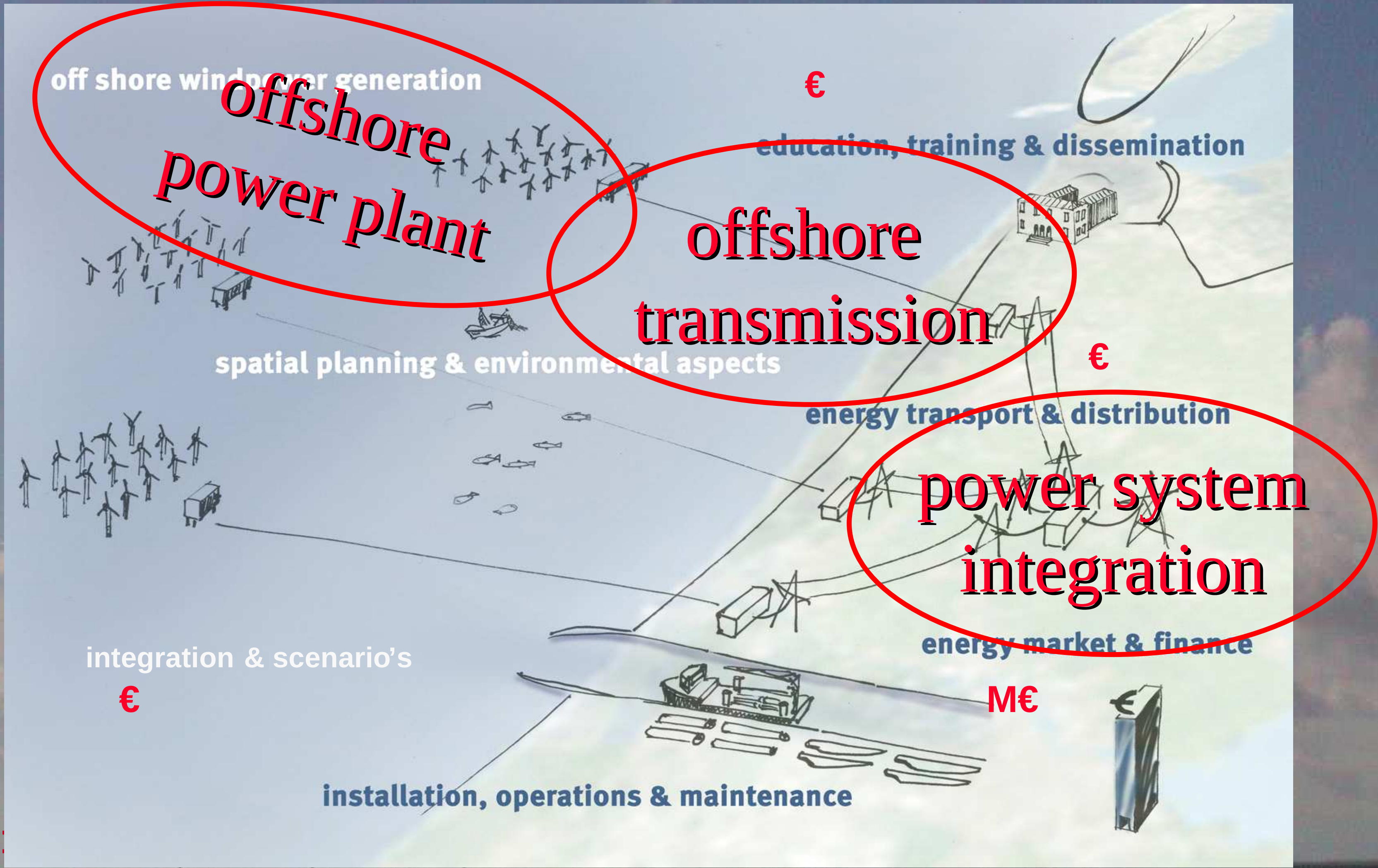
Scope of the research line 3



Power generation and grid integration

Topics	Scope	Projects
Wind farm as an electricity plant	Power plant aspects including the lay out of the wind farm grid	• WAP (ECN, JP) • EE Farm (ECN, JP)
Grid connection	Offshore connection and transmission	• Interconnectors (HV-DC, PhD RH)
System integration and balancing	System planning and operation with large offshore wind power in-feed	• System integration (PhD BU) • SI and balancing (Ecofys)

- TradeWind (FV)
- IEA Task 25

Projects

- 2004-009 Wind farm as power plant (ECN, TUD, Nuon, Kema)
- 2004-010 Electrical integration and balancing of large wind energy generation at sea (Ecofys)
- 2004-12 PhD@Sea   Interconnectors   (Y. Zhou TUD)
- 2004-12 PhD@Sea   Grid Stability   (Bart Ummels, TUD)
- 2004-026 DC Interconnector   PhD (Ralf Hendriks, TUD)
- 2007-010 EE Farm II (Jan Pierik, ECN)
- 2007-018a Dutch contribution to IEA Annex 25

Grid issues and R&D objectives (1)

Wind power plants:

- Techno-economic optimisation of electrical subsystem: need for adequate design tools
- Dynamic modeling of wind plant configurations for studying network impact and design of entire electrical subsystem including connection
- Control strategies for performance optimisation, provision of ancillary services as demanded by TSO and for fulfilling Grid Code requirements.

Grid issues and R&D objectives (2)

Offshore transmission for distances > 50 km

- Combined use of offshore cables for trade and WE transmission
- Design of multi-terminal HV-DC transmission: power balancing, voltage control
- Solution for voltage control of HV-DC transmission during network faults

Grid issues and R&D objectives (3)

Energy and power balancing in the Dutch power system

- Characterisation of wind power variability and predictability
- Wind power plant control for managing variability
- Development of power system UC-ED model
- Simulations and analysis to study integration solutions
- Market design for wind power

Grid issues and R&D objectives (4)

Power system dynamic stability

- Development of dynamic power system model for simulation of power-frequency control with high wind penetration
- How to handle the ‘worst cases’ for the Dutch power system
- Small signal stability with high wind power penetration
- Power market design consequences with high penetration

Wind power plants: the WAP project

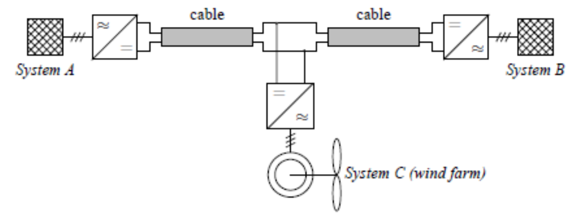
- Dynamic models developed for diversity of wind farm el conversion concepts, most popular are DFIG, PM, all variable speed.
- Connection options: AC (typical 200 MW, 100 km) and DC (LCC and VSC)
- New: development of models for the thyristor bridge of the HV DC classical link, and compared to Simulink modules
- Control concepts: new one developed for FCIG?
- The models are capable to describe dynamic behaviour: flicker production, behaviour during voltage dip (FRT), response to frequency dip:
- Next step: validation with measurements is the next step, as well as reference to grid codes and IEC 61400-21

Wind power plants: the EE-farm project

- EE-farm II: A software tool for techno-economic evaluation of electrical concepts of offshore wind plants
- Level of detail (up to individual components) permits accurate calculation of performance (WTs, generators, trafos, cables, splitters, converters, choppers, Statcoms)
- Inputs include technical specs, prices, wind conditions,
- Outputs: electrical parameter values, AEO, losses, generation costs
- Software tool tested by Vattenfall AB on offshore Lillgrund wind farm (110 MW): user satisfaction
- Re-evaluation of electrical concepts with the software show minimal price differences between AC and DC concepts

Offshore transmission: Multi-terminal HVDC VSC

- Advantages: separate controllability of active and reactive power, operate with weak grids, capacity up to 1 GW, black start capability, small footprint, solution for meshed grid (multi-terminal)
- Weakness: dealing with network faults – non-availability of high power DC circuit breakers, somewhat higher losses
- Main design challenges for multi-terminal HVDC identified
- Modeling and analysis: Integration of functions of interconnectors with offshore connection looks feasible and promising
- Condition: implementation of flexible trading mechanisms



HVDC VSC and network faults

- It will be important at high penetrations that wind farms can support the grid during network faults. This is a particular challenge when wind farms are connected through a HV DC VSC link
- Three strategies investigated to keep the direct voltage controllable during network faults (voltage dips):
  - over-dimensioning of the grid side VSC converter;
  - dissipation of the excess wind power during the fault;
  - fast reduction of the wind power production, for example by direct communication, voltage reduction and frequency increase.

NL System balancing with 6 GW offshore (1)

- System study performed into energy and power balancing with high wind penetration for Netherlands
- Wind speed time series variability on measured wind speed time series on and offshore for system studies developed
- Variations relevant for power system investigated (load less wind) for up to 12 GW. Demand variations dominate, wind power amplitudes comparable to demand exist but very rare, Day-ahead forecast errors around 8%
- Wind farm control strategies studied that can reduce fluctuations at high wind states
- Wind power affects minimum load levels, hence requires additional flexibility

NL System balancing with 6 GW offshore (2)

- A powerful UC-ED model developed for studying the Dutch power system
- Thermal generation can cope with balancing most of the time,
- Critical situations: low load high wind. More flexible international power exchange can avoid wasting wind.
- Wind significantly reduces operational cost of power generation, reduces power imports, increases exports: international exchange is key for integration
- Energy storage definitely not the most attractive balancing solution
- Rather: use of heat boilers at CHP sites and additional interconnection capacity with Norway

NL power system stability with large-scale wind

- Dynamic power system model developed for simulation of power-frequency control with high wind penetration
- Frequency stability only indirectly impacted through the changed operation of conventional generation. No problem thanks to strong ENTSO-E grid
- Modern wind plants capable to provide power-frequency control and to emulate inertia
- Adequate optimisation of UC-ED of PRPs allows to handle additional variations (=keeping ACE) in critical situations.
- Additional secondary reserves needed. Wind power and PAC nice partners in secondary control.

What did we learn and remaining issues

- RL3 produced progress in simulation tools in various fields: WPP, HV-DC, power system studies
- Multi-terminal HV-DC attractive; trade and wind power transmission should be combined. Speed-up in R&D here!
- 12 GW can be integrated in NL from balancing point of view, Its going to be easier if handled in international exchange
- Wind plants are nice devices for frequency control and secondary reserve
- Grid designs needed for the 6 GW and 12 GW perspectives, with European dimension – combined with trade
- Low involvement of TSO – actual transmission network consequences of 6-12 GW not brought into the picture

Thank you and questions?