Principal technology issues related to varying degrees of renewable energy penetration – the case of wind energy

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From a recent conversation with an old school electric power engineer:

"Oh wind power – that must be a pain for the power system.."

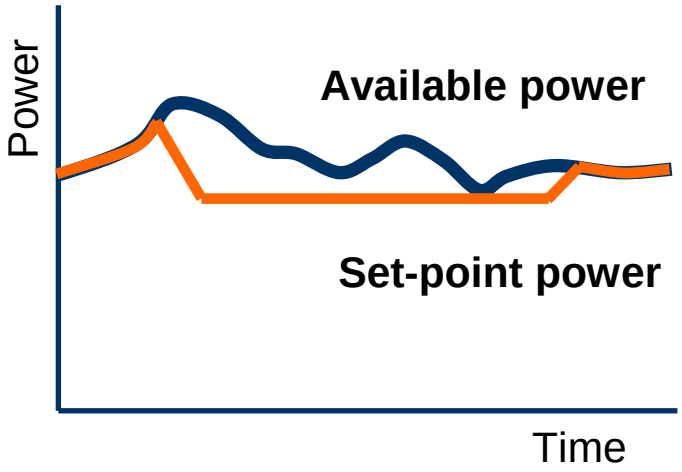
My suggestions

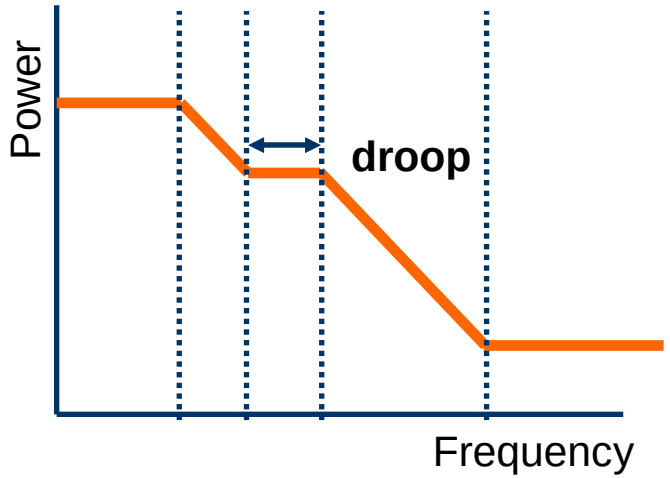
- The main issue is not the technology – it is the establishment opposing changes
- Wind (or any other renewable energy technology) does not by virtue be a technical problem – rather it is a solution for sustainable electricity supply
- No single generation technology is best for the power system – reliable operation requires a mix

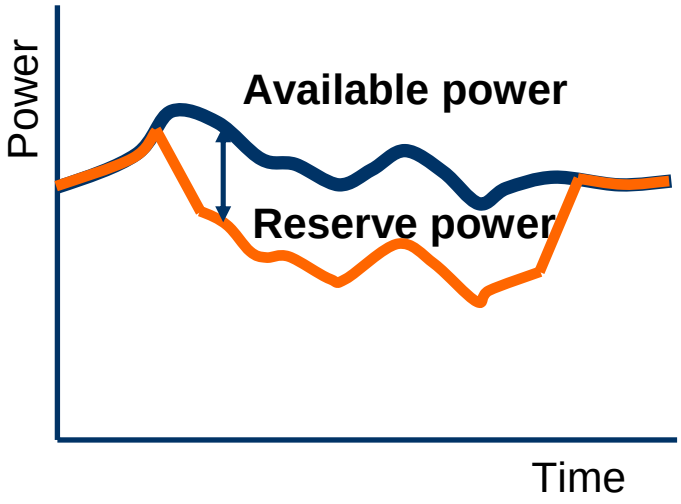
From wind turbines to wind power plants

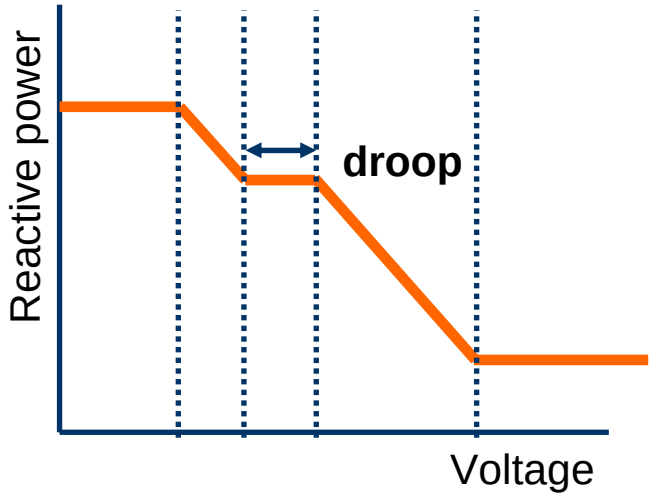
- **In the beginning (1980's)**
  - single wind turbines / small wind farms
  - connected to distribution grids applying simple rule of thumbs
- **Distributed generation (1990's)**
  - impact on voltage quality becomes an issue
  - IEC 61400-21: Measurement and assessment of power quality characteristics of grid connected wind turbines (2001)
  - rule of thumbs may be replaced by more accurate calculations
- **Large scale generation (now)**
  - impact on power system stability must be assessed
  - dynamic wind farm models is being developed (IEA ++)
  - wind farms must comply with TSO grid codes
  - wind farms may have an impact on power system operation
  - **the issues are the same for any generation technology**

Modern wind farm control possibilities





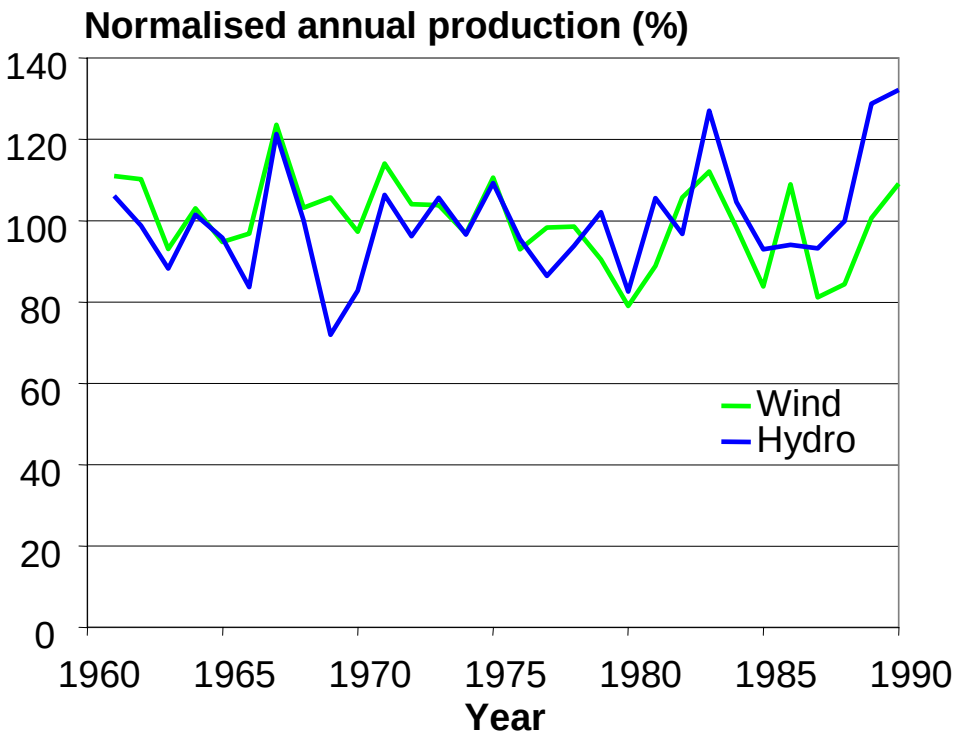


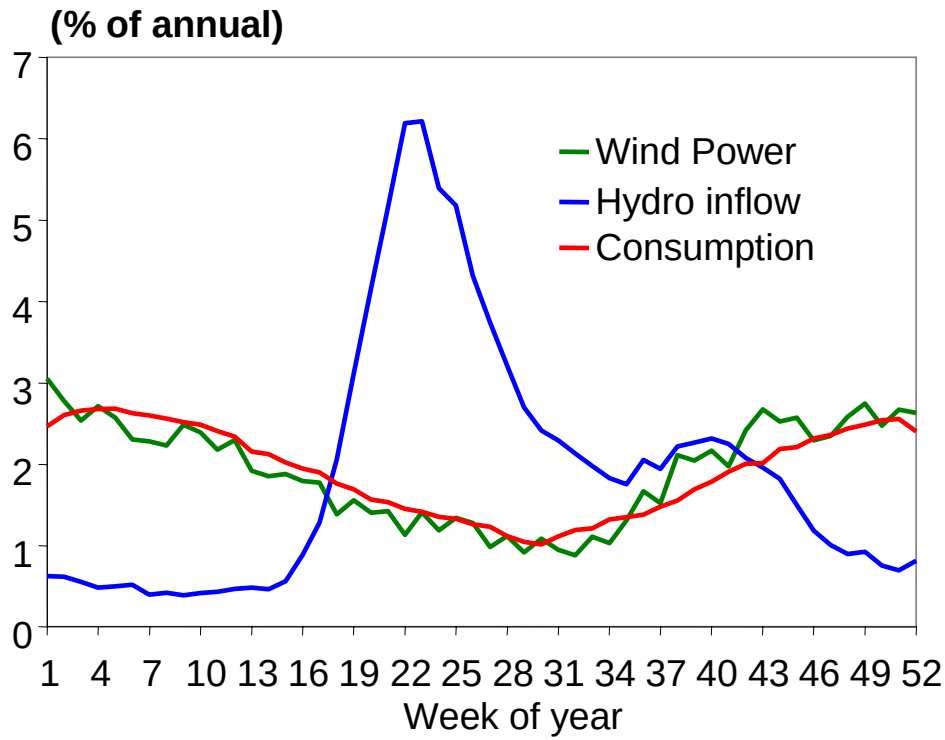


Grid connection of wind power plants

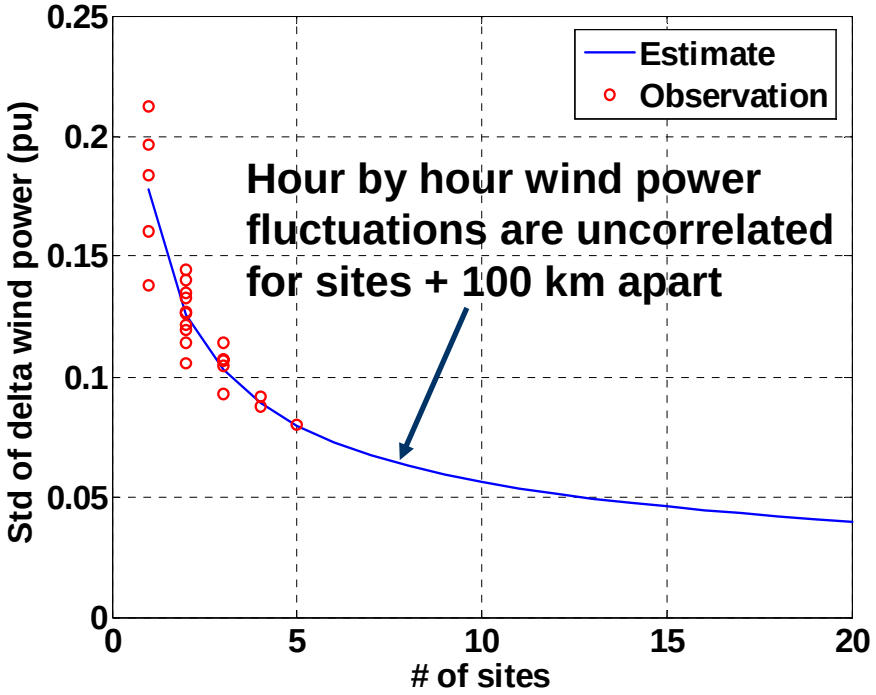
- Grid reinforcements may be needed for handling larger power flows and maintaining a stable voltage, and is commonly needed if new generation is installed in weak grids far from load centers.
- This is true for any generation technology, be it e.g. a nuclear power plant or a modern wind farm
- Given the same location the cost of connection is the same per MW, but may differ per MWh depending on the number of full load hours of the generation technology
- Grid reinforcements should in general be held up against the option of curtailing generation or altering system operation, and these latter options may in some cases prove to be very cost efficient.

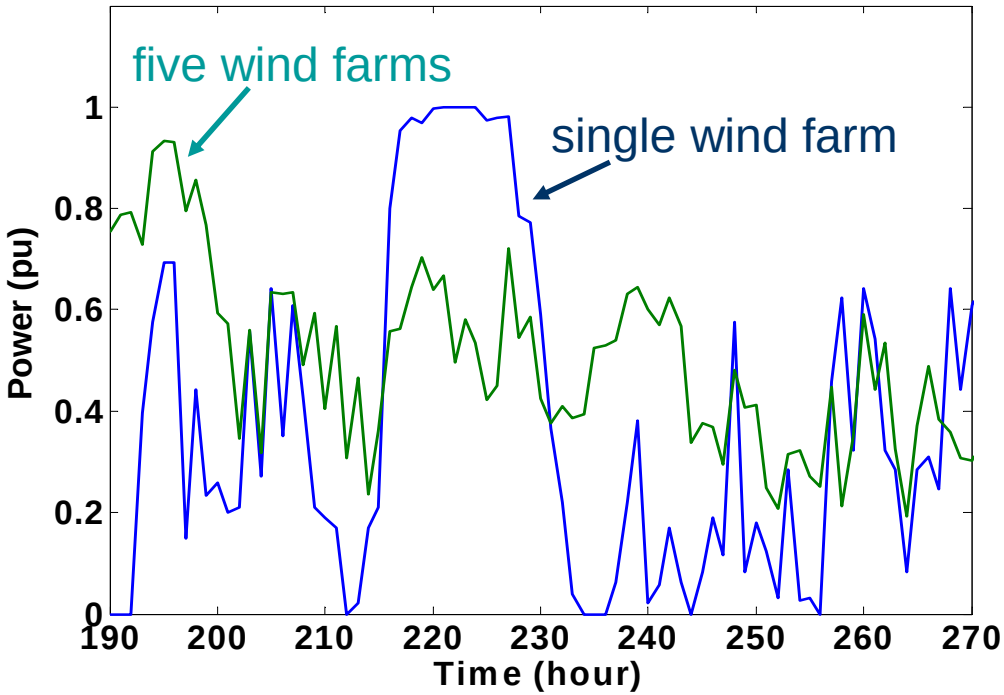
Wind and hydro is better than just hydro





Hour by hour variations of wind generation





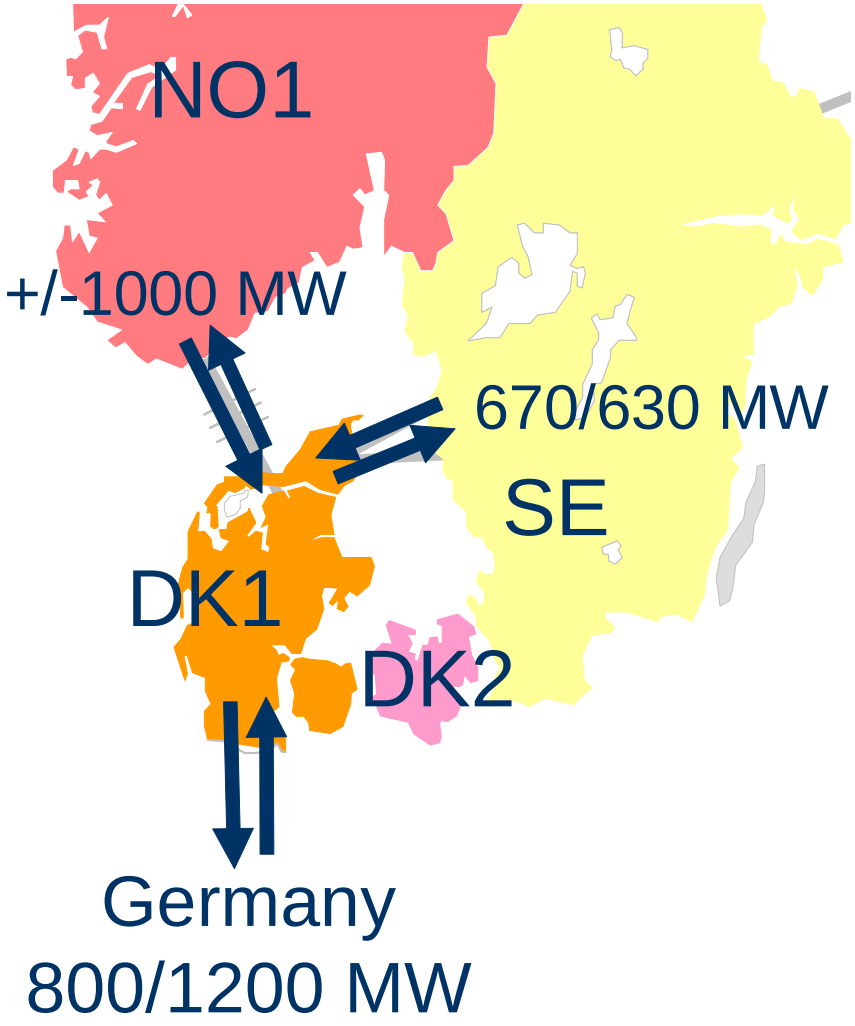
Wind impact on need for balancing power is small:

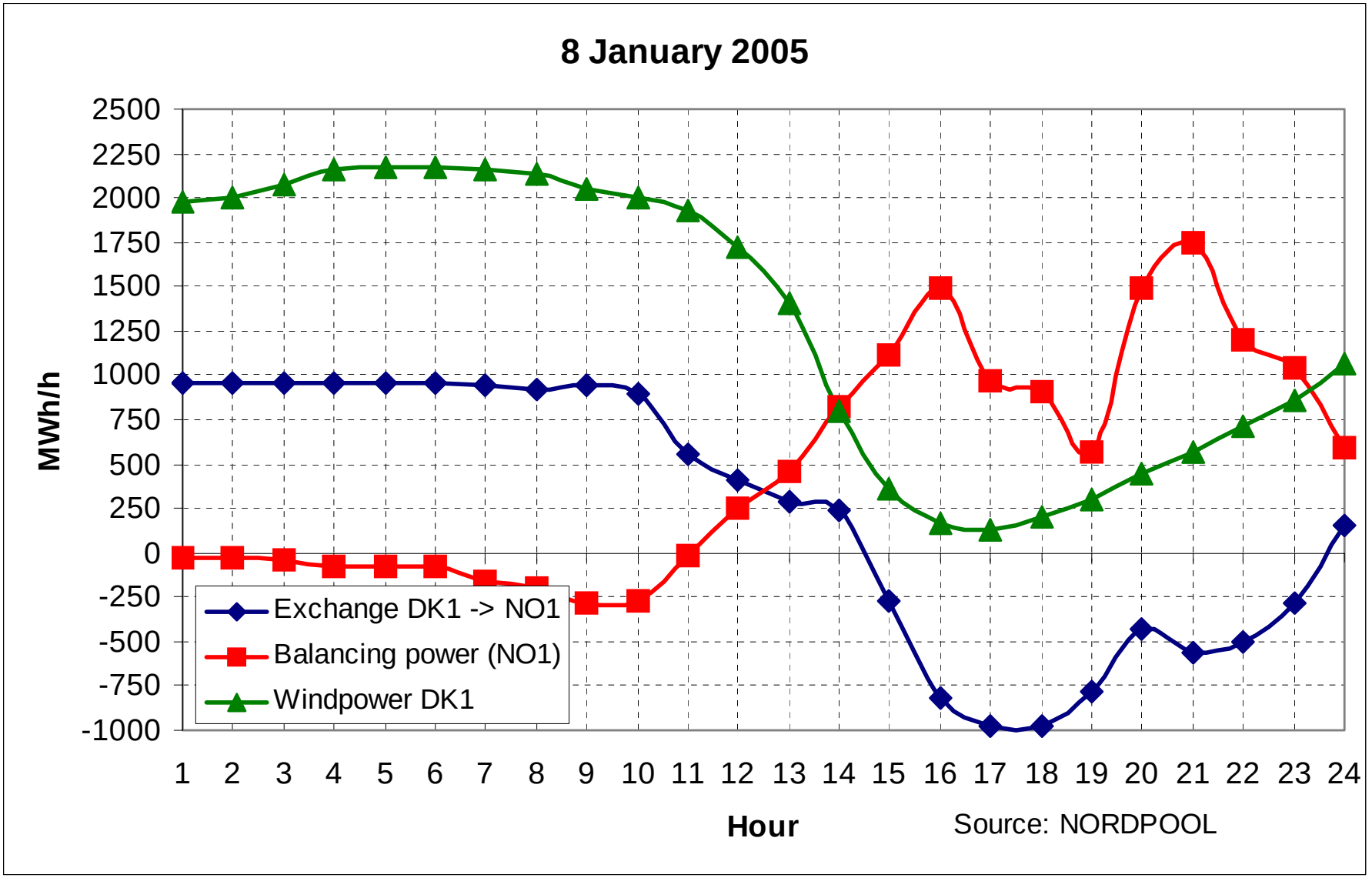
10 % wind energy supply of gross demand in the Nordic power system gives an extra balancing power of 1.5%-4% of the installed wind capacity, corresponding to a cost of about 0,8 øre per kWh wind, and about half if investment in new reserve capacity is not needed. [Holttinen 2005]

Real life case – balance handling

- At 8 January 2005 a strong storm crossed over Denmark
- The wind farms of western Denmark at first produced close to rated power, but then started to cut out due to the excessive wind speed (+ 25 m/s) – the wind production were reduced from about 2200 MW to 200 MW in a matter of 10 hours

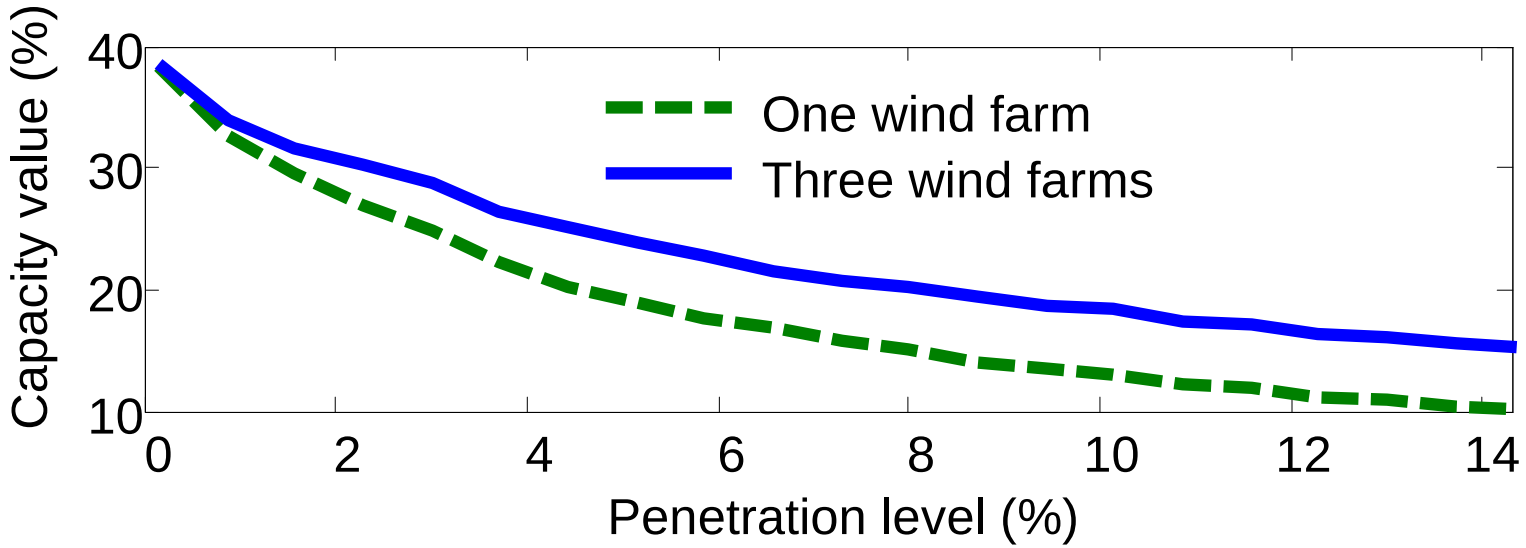
Data for DK1, west Denmark 2003	MW
Central power plants	3,516
Decentralised CHP units	1,567
Decentralised wind turbines	2,374
Offshore wind farm Horns Rev A	160
Maximum load	3,780
Minimum load	1,246





The case demonstrates that the existing marked based mechanisms can handle large variations in (wind) generation and demand

Wind capacity value – Mid-Norway case study



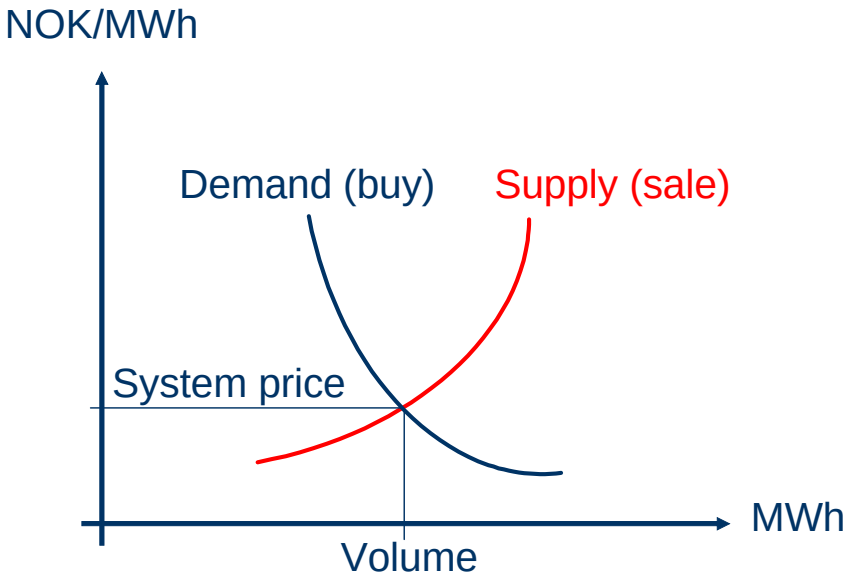
Wind capacity value = average generation at low penetration

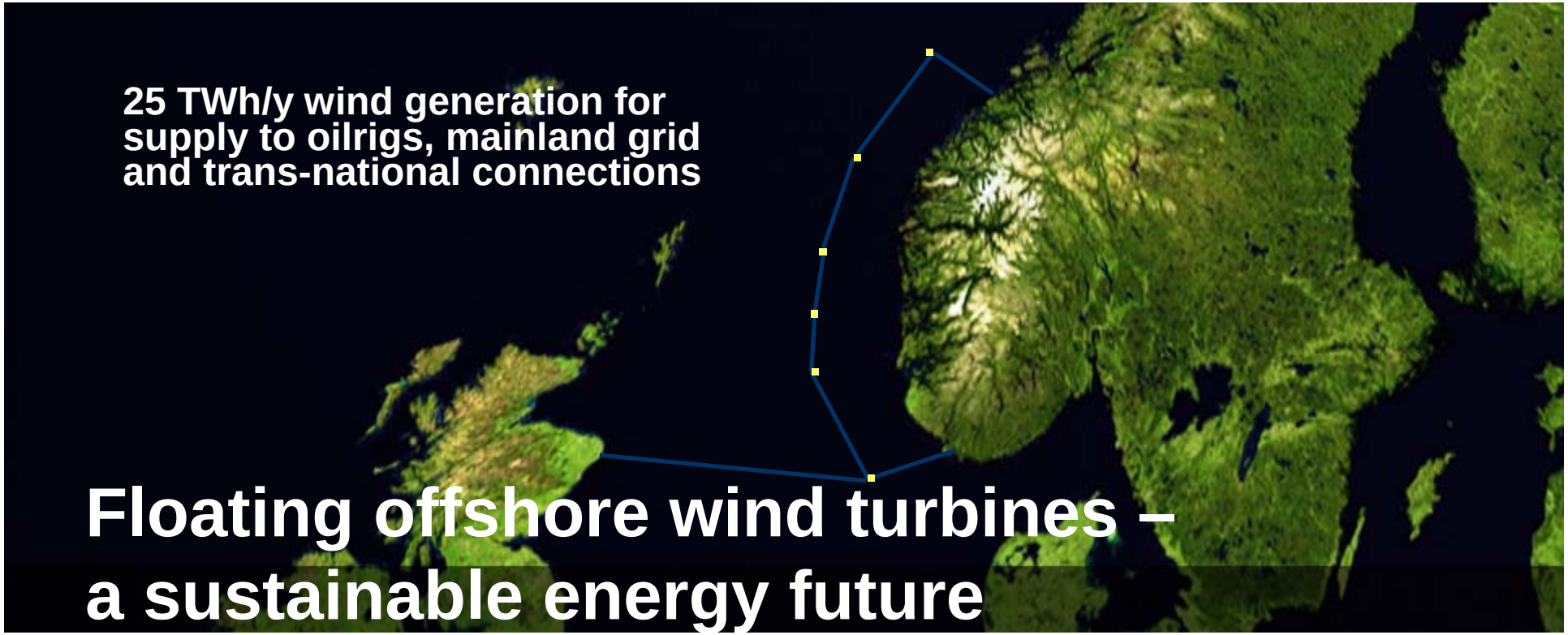
The smoothing effect of distributed wind is significant

PS: TSO requirement of Fault Ride Through is implicit an acknowledgement of wind capacity value

Wind generation impact on power system

- Wind will replace the generation with the highest operating cost, and reduce the average Nord Pool spot market price.
- 20 TWh/y wind generation will reduce the average system price with about 3 øre/kWh and CO2 emissions by 12-14 million tons per year for the case of replacing coal, and about 6 million tons per year for replacing natural gas.
- Replacing gas turbines on oilrigs with wind generation would give higher savings of CO2 and NOx emissions.





Floating offshore wind turbines – a sustainable energy future

- Use Norwegian oil and gas industry know-how.
- Large scale commercial use of floating offshore wind turbines is viable by year 2020.
- The market is global.

Summing up:

- Wind generation impact on power system operation and adequacy will be overall positive. Wind contributes with energy and capacity value.
- Combining wind and hydro provides for a more stable annual energy supply than hydro alone – in the same manner wind is a hedge against rising fuel prices.
- Wind impact on need for balancing power is small, i.e. the extra balancing cost is about 0,8 øre per kWh wind, and about half if investment in new reserve capacity is not needed.
- The real life example from 8 January 2005 demonstrates that existing marked based mechanisms can handle large amounts of wind power
- 20 TWh wind will reduce the average spot market price with about 3 øre/kWh and CO2 emissions by 12-14 million tons for the case of replacing coal, and about 6 million tons for replacing natural gas. Replacing gas turbines on oilrigs with wind generation would give higher savings.
- Wind generation is a cost-effective means to reduce emissions of greenhouse gasses

Impact of integrating wind power in the Norwegian power system

SINTEF Energy Research, April 2006, TR A6337. **www.sintef.no/wind**