Impact of Large Scale Wind Generation on Power System Planning and Operation

Markus Pöller/DIgSILENT GmbH

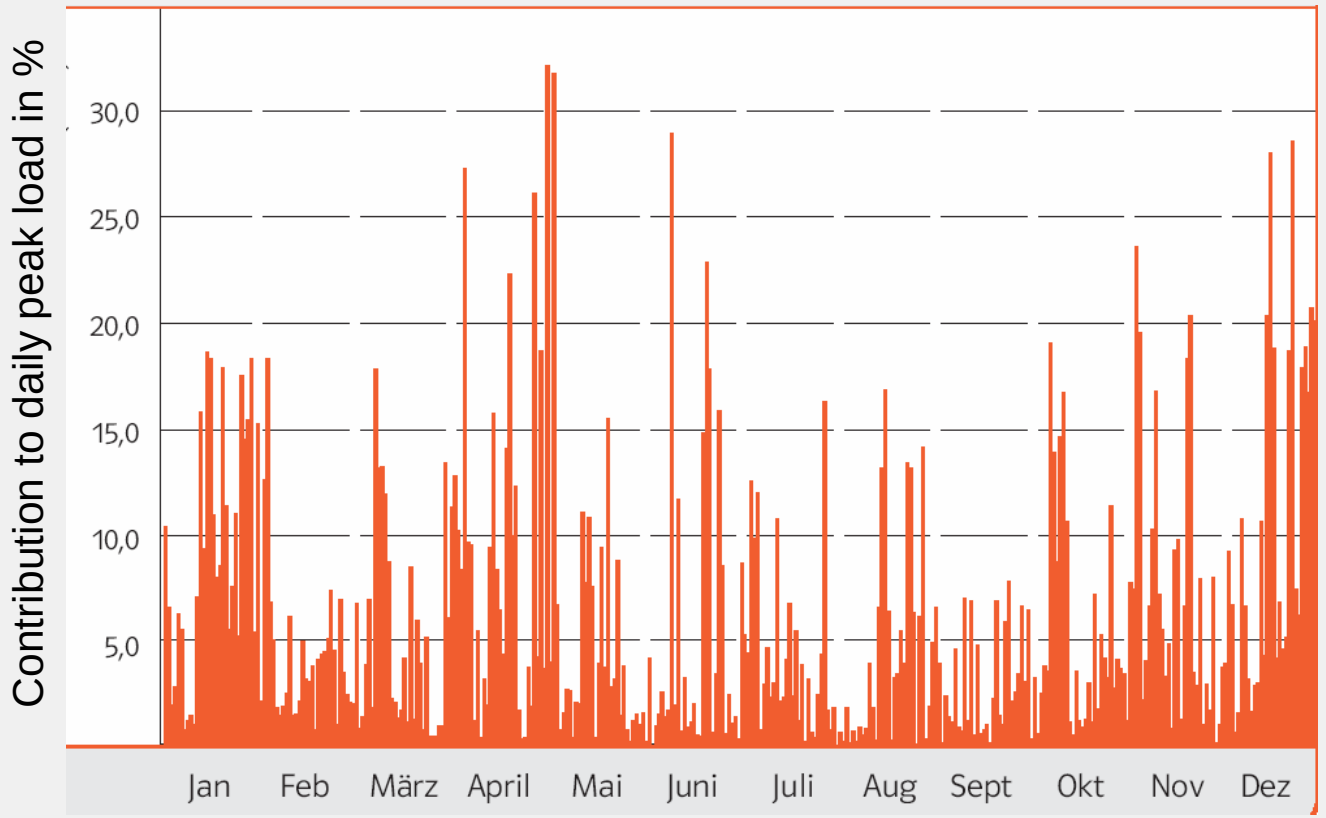
Impact of Large Scale Wind Generation

1. Availability – Impact on capacity planning
2. Variability – Impact on reserve allocation
3. Impact on frequency control
4. Impact on required transmission capacity
5. Impact on reactive power and voltage control

Availability – Impact on Capacity Planning

Availability – Impact on Capacity Planning

- Wind is a variable power source
- It is not permanently available
- Wind prediction error is considerable higher than load forecast error.



E.ON, 2003

Availability – Impact on Capacity Planning

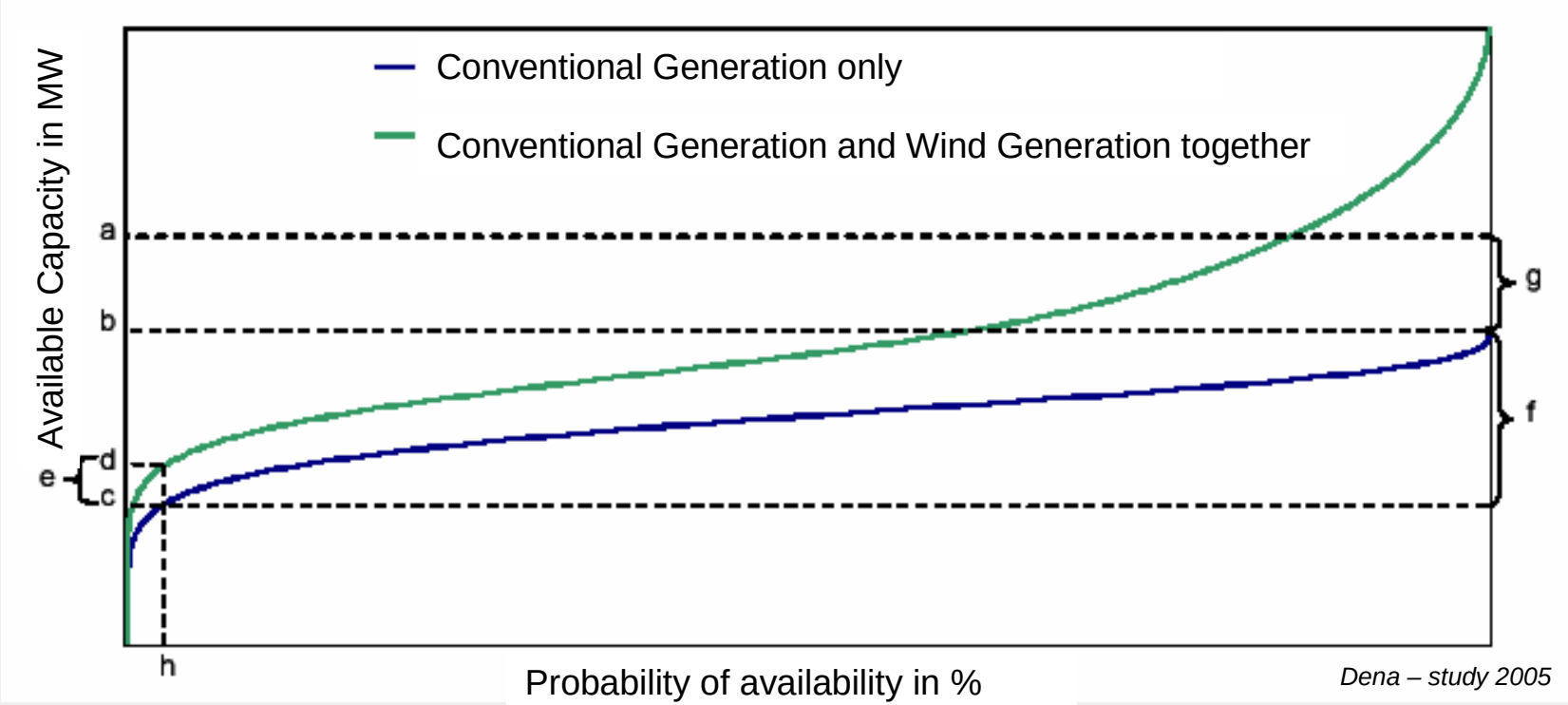
- The *Capacity Credit* of a power plant describes its contribution to the firm capacity in the system.
- Nonlinear relationship: Can only be determined for all conventional and wind power plants together.
- Based on probabilistic criteria for generation adequacy assessment (LOLP-loss of load probability/LOLE-loss of load expectancy)
- LOLP/yearly peak load: Probability that peak load can't be met by generation capacity (e.g. 10% -> once in ten years)
- LOLE: Expected number of hours per year that capacity doesn't cover load, e.g. 10h/year -> 0,11% (can be one event of 10h per year or 10 events of 1h per year)

Availability – Impact on Capacity Planning

- Equivalent Firm Capacity (EFC):
  - Increase in firm capacity resulting in the same LOLP/LOLE reduction as the actual additional wind capacity

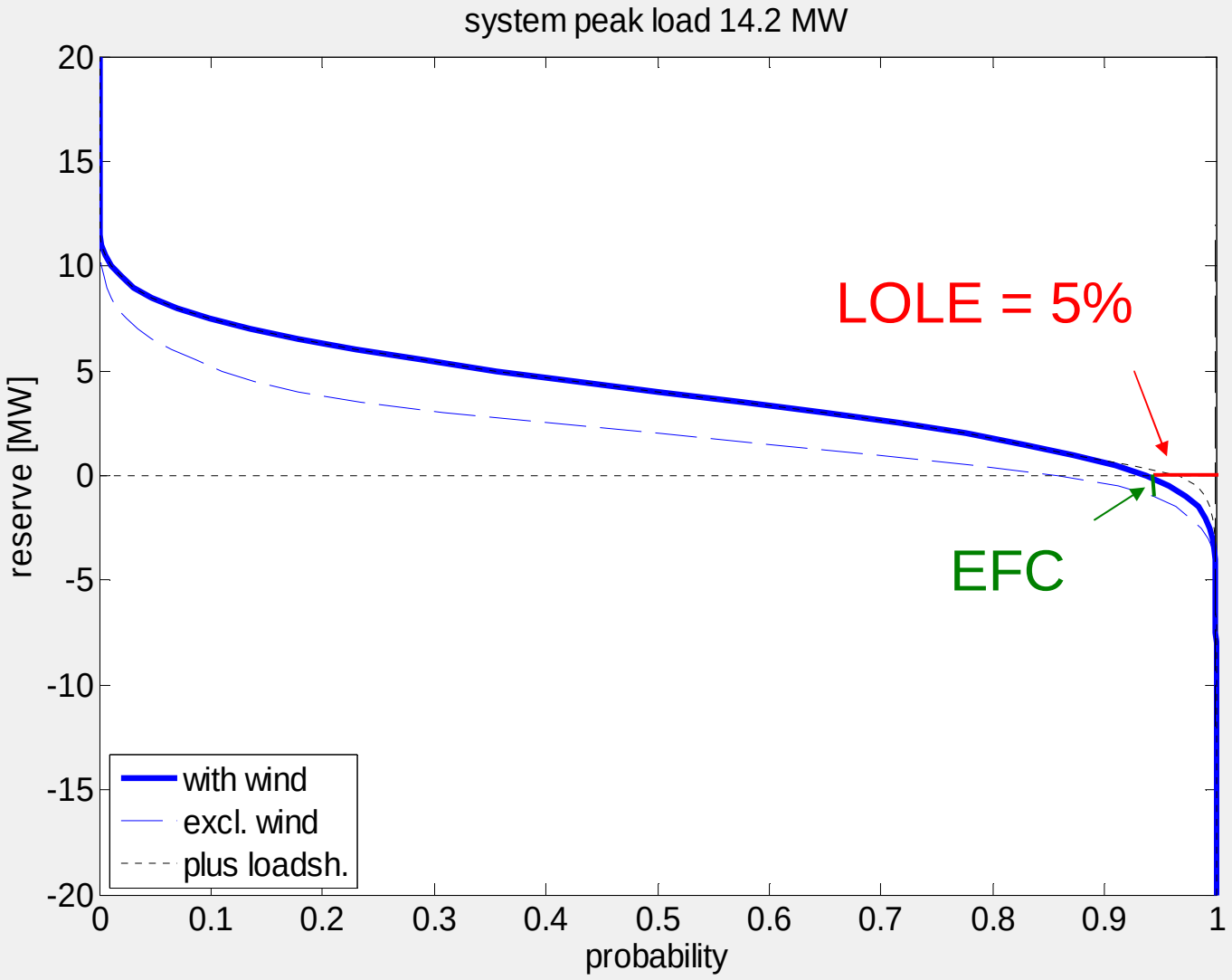
- Effective Load Carrying Capability (ELCC):
  - ELCC is the amount by which the load may be increased in the presence of non-firm capacity while the original LOLP/LOLE remains constant

Capacity Credit based on LOLP (yearly peak load) and ELCC



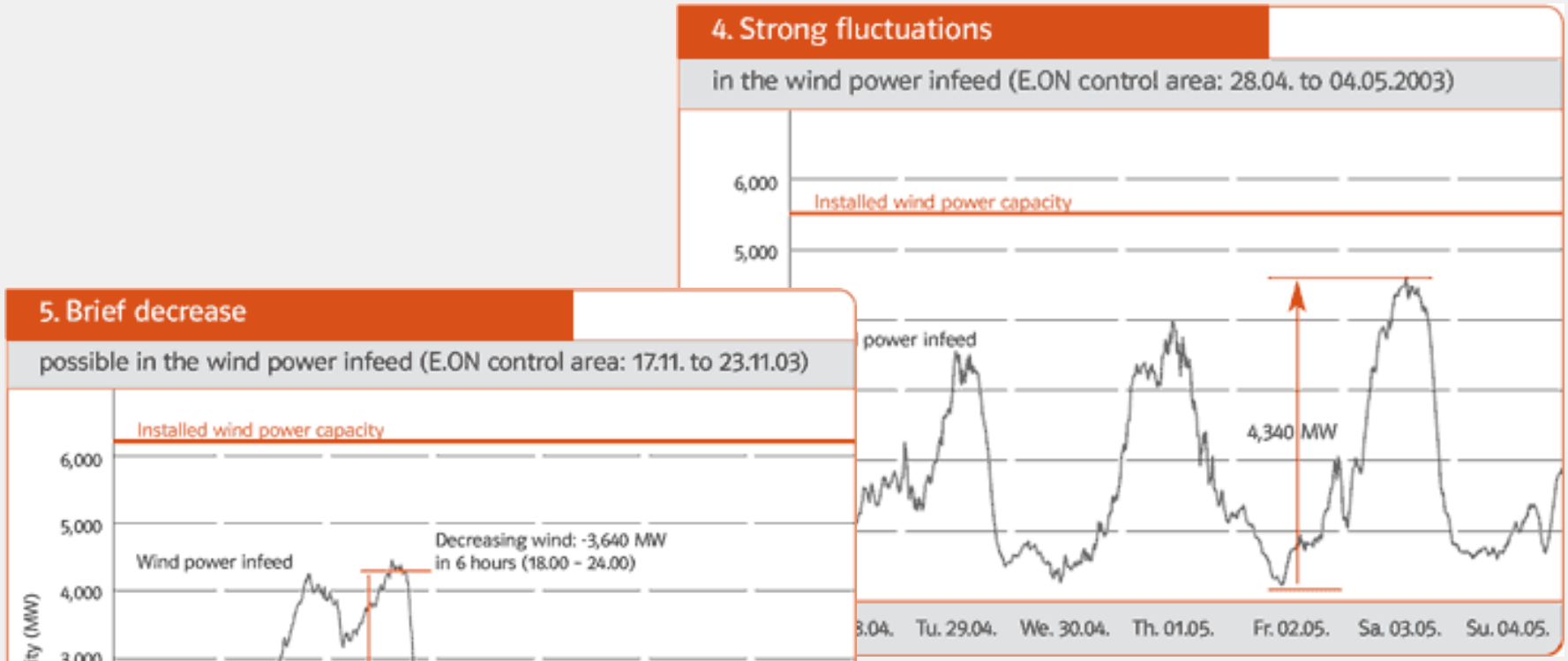
- h: LOLP, e.g. 1..10%
- c: firm capacity of conventional power plants
- d: firm capacity of conventional + wind power plants
- d-c: ELCC

Capacity Credit based on LOLE and EFC



Variability – Impact on Reserve Allocation

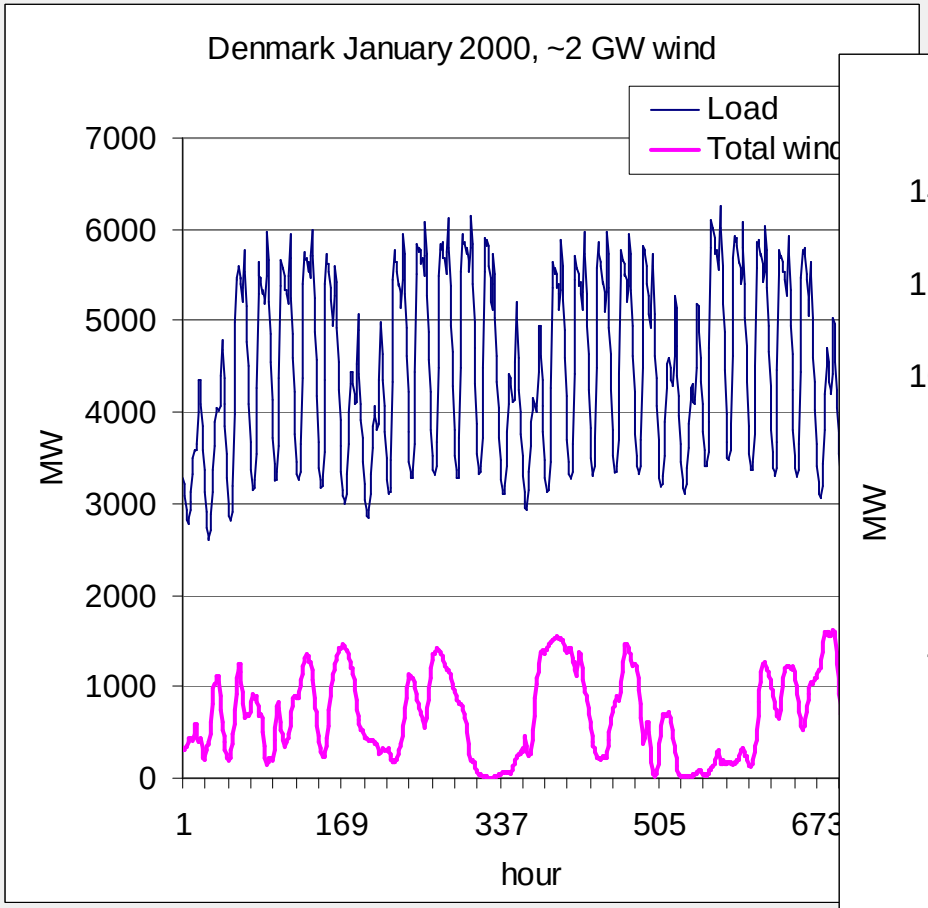
Variability/Wind fluctuations

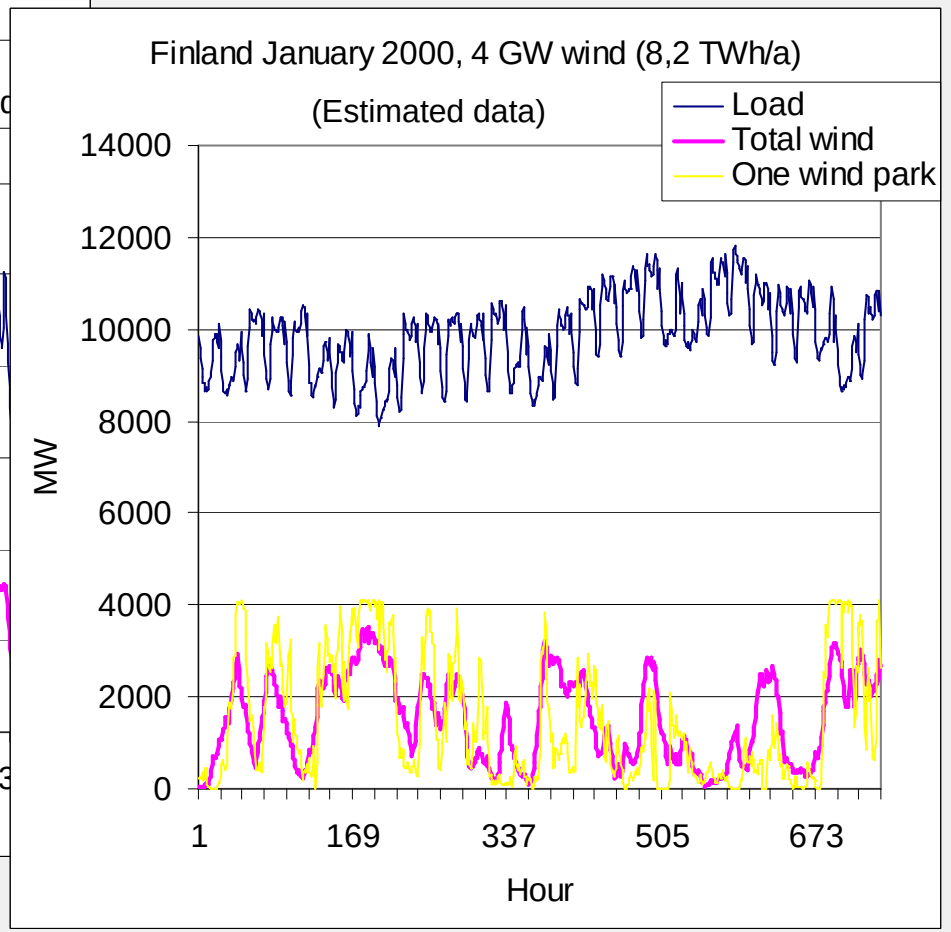


E.ON Wind energy report 2004

Variability/ Wind fluctuations

- Wind fluctuations must be set in relationship with load fluctuations:

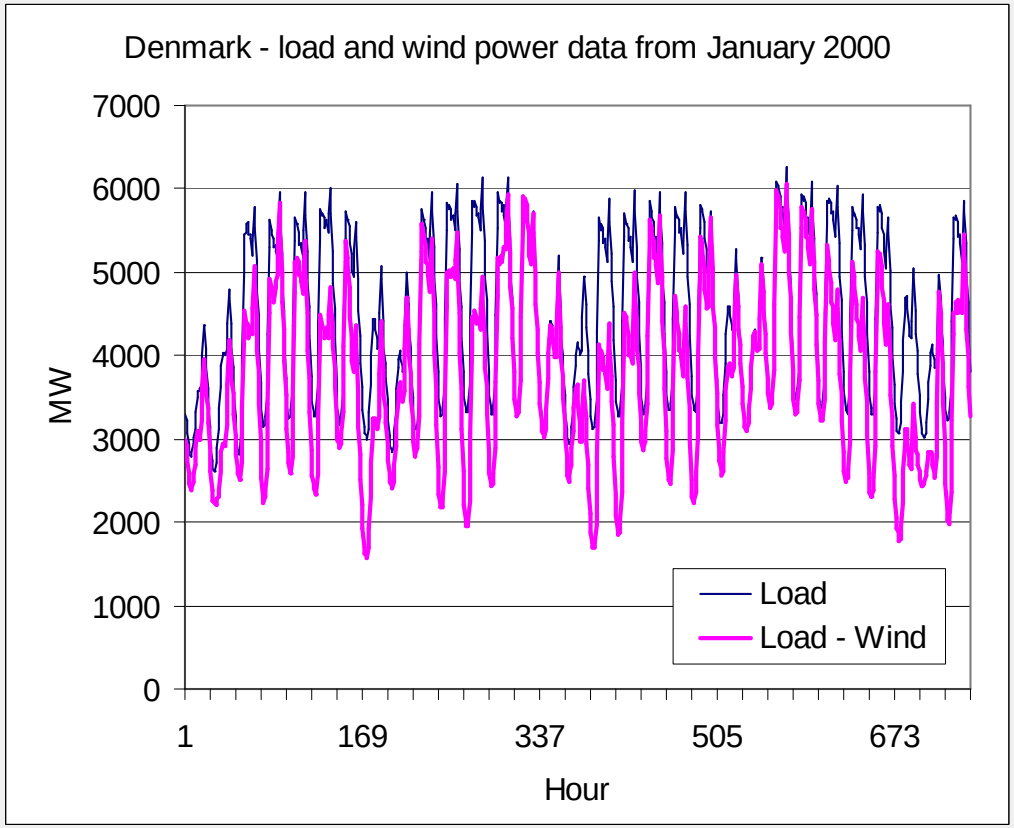




VTT-research institute: The impacts of hourly variations of large scale wind power production in the Nordic countries on the system regulation needs

Variability/Fluctuations

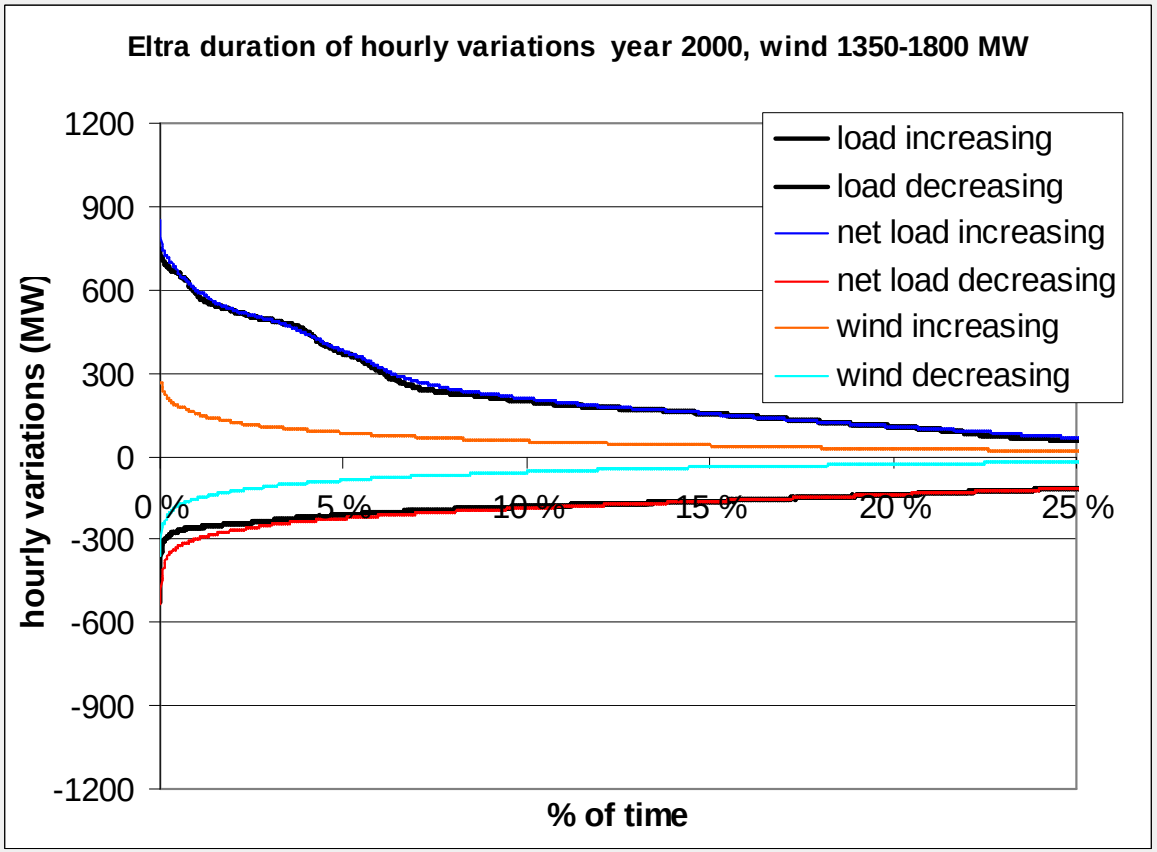
- Relevant figure: Residual load = Load – Wind generation



VTT-research institute: The impacts of hourly variations of large scale wind power production in the Nordic countries on the system regulation needs

Variability/Fluctuations

- Assessment of increase of load variations using duration curves.



VTT-research institute: The impacts of hourly variations of large scale wind power production in the Nordic countries on the system regulation needs

Variability/Fluctuations

- Assessment of wind penetration impact on residual (net) load variations allows the assessment of:
  - Relevance of wind generation on system operation
  - Technical requirements for conventional generators (up-/down- ramp speed etc.), required type of production (regulation power plants)
  - Estimate of increased start-ups and shut-downs.
  - Estimate of efficiency reduction of conventional power plants
  - Rough assessment of additionally required regulatory reserves.

Variability/Fluctuations/Impact on Reserve

- In systems with only conventional generation:
  - Reserve needed for compensating load forecast error (minute reserve, stand-by reserve, etc.)
- Systems with high wind power penetration:
  - Reserve needed for compensating the *residual load* forecast error (minute reserve, stand-by reserve, etc.)
- An assessment of the impact of wind power on residual load forecast error allows a cost estimation for additionally required regulatory reserve.
- Reserve power can be reduced with increased precision of wind forecast tools.

Availability and Variability - Summary

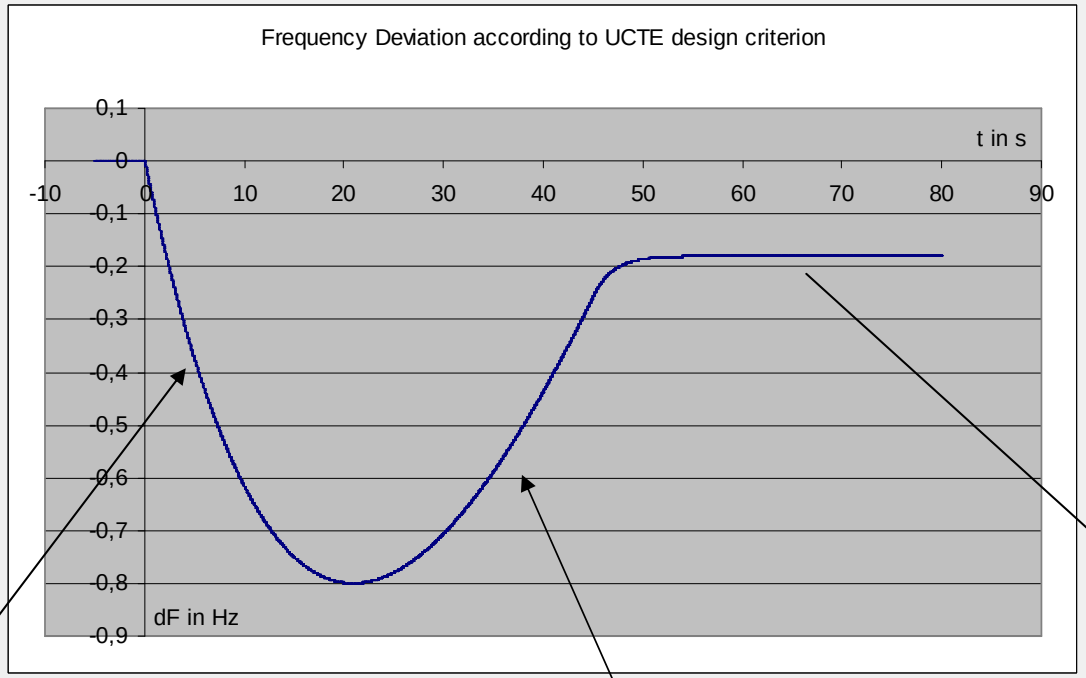
- Assessment of the capacity credit of wind generation for:
  - identifying the overall required installed capacity of the network.
  - Fuel cost savings.
  - Reduction of CO2-emissions.

- Assessment of impact on residual load variations:
  - Ramp rates
  - Prediction error

  Important for:
  - Identifying technical requirements for conventional power plants
  - Assessment of reserve requirements.
  - Assessment of efficiency reduction of conventional power plants.
  - Assessment of impact on CO2-emissions.

Impact on Frequency Control

Impact on Frequency Control



Rotor Inertia

Dynamic Governor Action

Secondary Control

Frequency Control

- Spinning reserve covers:
  - Generator outages (Primary and Secondary Reserve)
  - Load/Wind power prediction error (minute reserve)
- Primary reserve covers outages during first 15s…minutes (regulatory reserve)-> Very minor influence by wind fluctuations
- Secondary reserve covers outages during 5…15 minutes (AGC)
  -> Low influence by wind fluctuations
- Longer time frames (load following):
  Generator re-dispatch, use of long-term reserve.

Reserve Requirements and Fault Ride-Through Capability

- Wind turbines without FRT-capability can cause wide-area production losses in case of single line faults !

Dena-study 2005

Frequency Control - Summary

- Primary control/Secondary control:
  - If wind generators with fault ride-through capability are used:
    No considerable increase.
  - If wind generators without fault ride-through capability are used:
    Max. credible generation outage increases -> Compensation by additional reserve.
- However, required primary/secondary reserve must be distributed amongst a fewer number of conventional power plants.
- In case of systems with very high wind penetration, wind generators must contribute to frequency control (no other generators available)

Impact on Required Transmission Capacity

Impact on Transmission Lines

- Higher installed capacity for the same electricity production typically requires more transmission lines (wind farms and conventional power plants at different locations)
- Wind farms in areas with high wind ressources. Proximity to load centers can usually not be realised -> more transmission lines.
- Network must be able to accommodate increased flow of regulatory power.

Impact on Transmission Capacity - Methodology

- Additionally required transmission lines must be planned based on well defined scenarios, considering size and location of planned wind farms.
- Load flow studies required for combinations of:
  - Load level (High-/Low-load)
  - Wind speed level (High-/Medium-/Low wind)
- For avoiding investments in new transmission lines which are only required for a few hours per year, probabilities should be assigned to the studied cases.
- Assessment of potential of dynamic line rating recommended because of the good correlation of transmission line capacity and wind speed.

Impact on Reactive Power/Voltage Control

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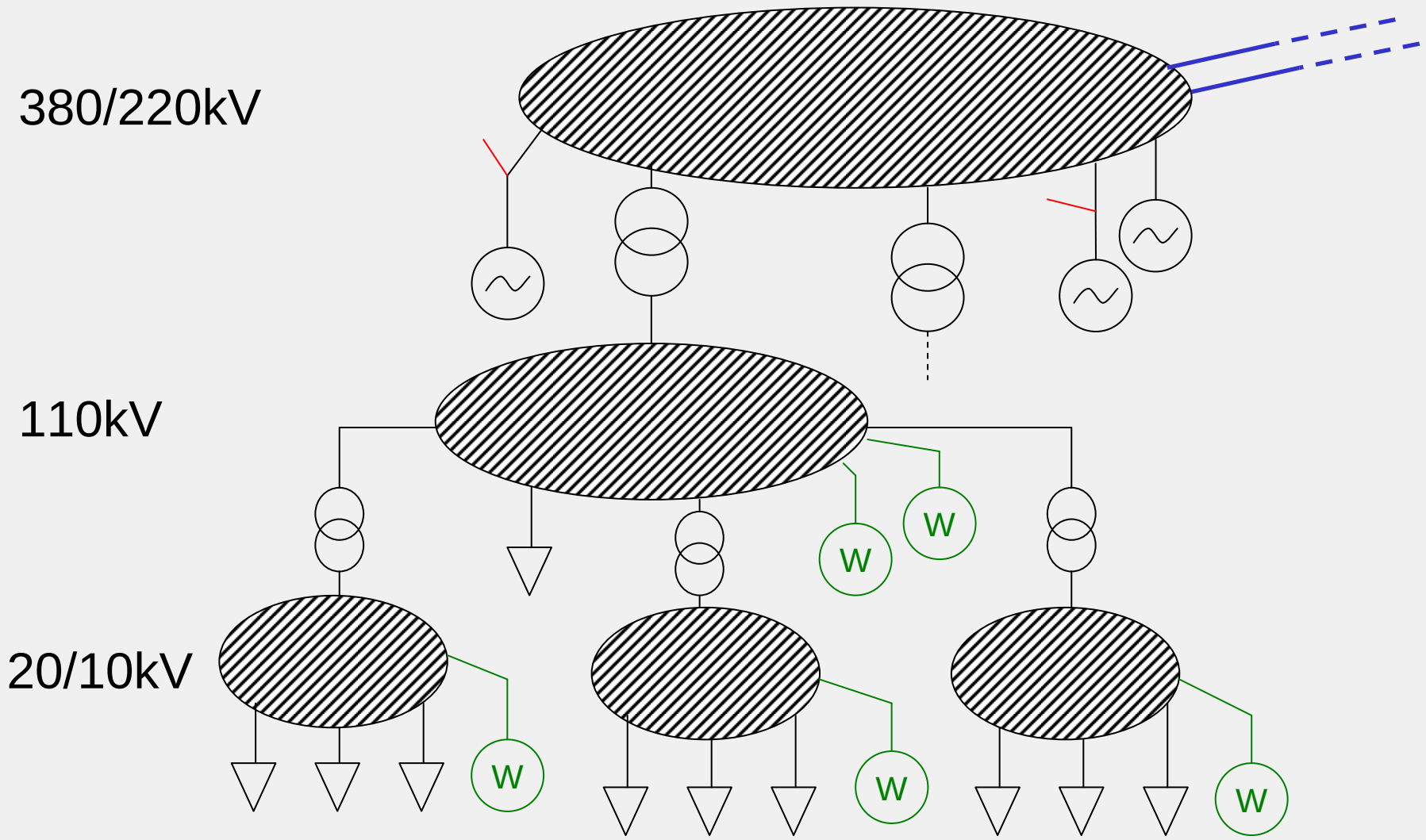

Reactive Power/Voltage Control

- Reactive power cannot be transported over long distances

  -> reactive power “production” must be on-site (where required)

- Disconnecting conventional power plants and dispatching wind power plants leads at the same time to reduced reactive power levels in the main transmission levels.

- Consequences:
  - Additional reactive power sources needed (capacitors, SVCs).
  - Large wind farms shall participate in voltage control, either using reactive control capabilities of the generators or by additional devices, such as SVCs or STATCOMs.

Thank You

Markus Pöller

mpoeller@digsilent.de

DIgSILENT GmbH

Heinrich-Hertz-Str. 9

72810 Gomaringen

www.digsilent.de