Old and new uncertainly in power system

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Old and new uncertainty in power systems

- Uncertainty, intermittency, probability
- Hosting capacity, grid overloading for sun and wind
- Voltage unbalance and uncertainty in phase and location
- Uncertainty during operation; prediction error
- Conclusion

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Uncertainty

- Uncertainty: the state of being uncertain
- Uncertain: not able to be relied on; not known or definite
- [Oxford Dictionary]

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Stochastic variables and probability

- Stochastic variable: a variable whose value is unknown
  - It is described through a probability distribution function
- Probability: a measure of the likelihood that an event can occur
  - Or, that a stochastic variable has a certain value or range of values
  - Defined as the outcome of an experiment that can be repeated many times

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Intermittent

- Occurring at irregular intervals; not continuous or steady
- Used typically to describe renewables like solar power and wind power
- Note: intermittency is not the same as uncertainty

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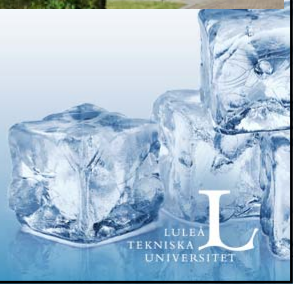
”stochastic intermittency”



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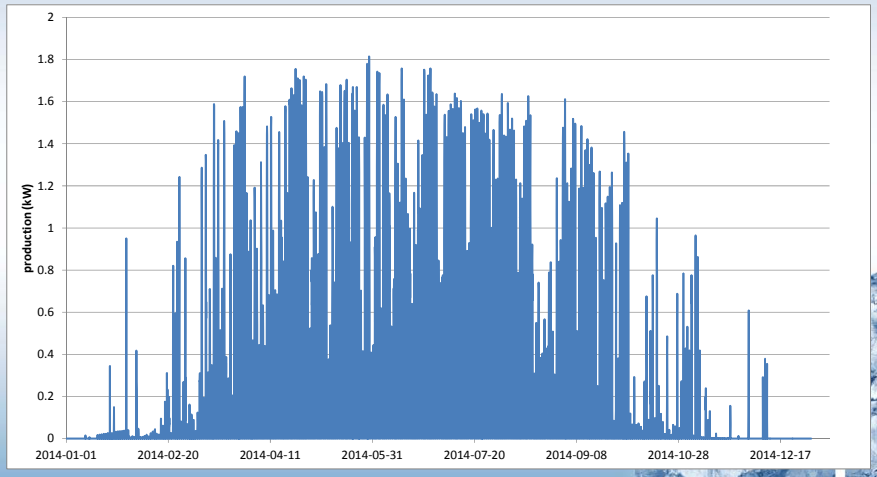
Intermittency of solar power



Calculated used: https://beta.renewables.ninja/

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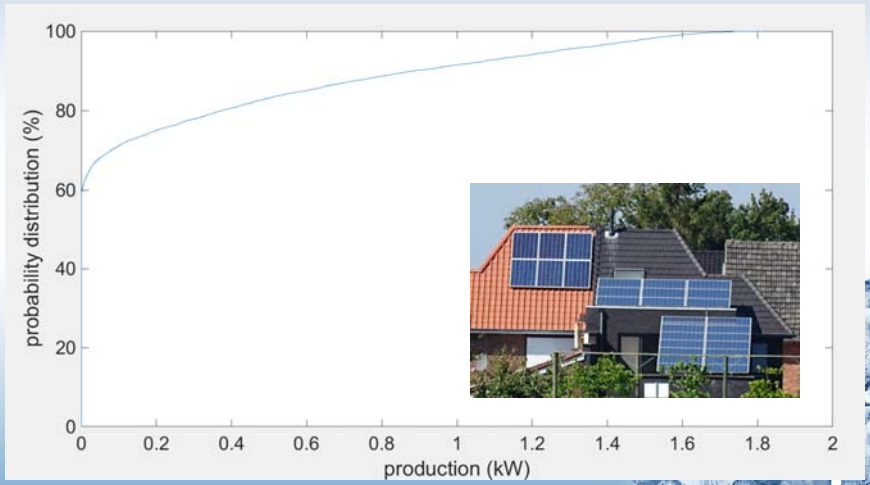
Probability distribution function



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Somewhat less stochastic

- The amount of radiation reaching a solar panel depends on two parameters
  - The position of the sun in the sky (deterministic)
  - The cloud cover (stochastic)
- The production also depends on the temperature (stochastic)

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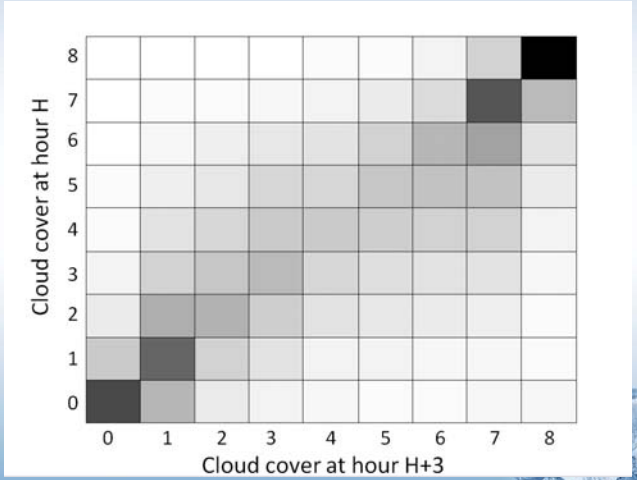
Changes in cloud cover



Gothenburg 1973-1999

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Hosting Capacity

- The amount of new production that can be connected to the grid without endangering the reliability or voltage quality of other customers

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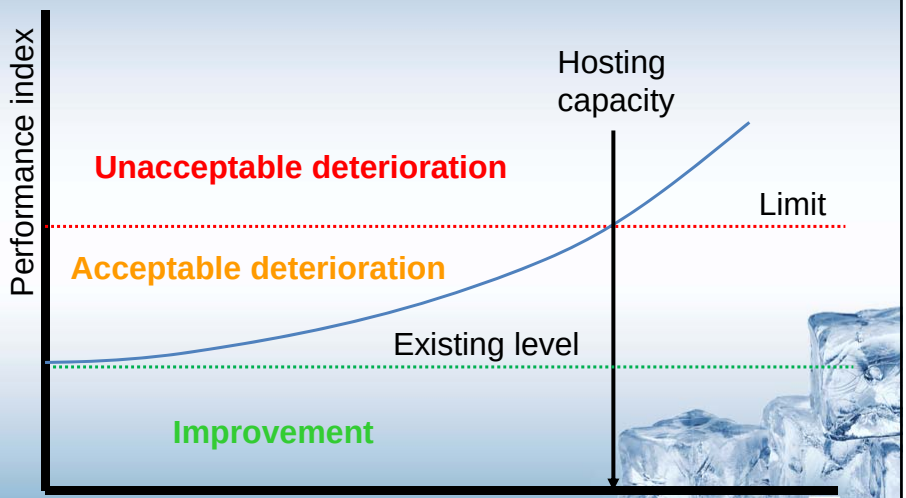
Hosting capacity



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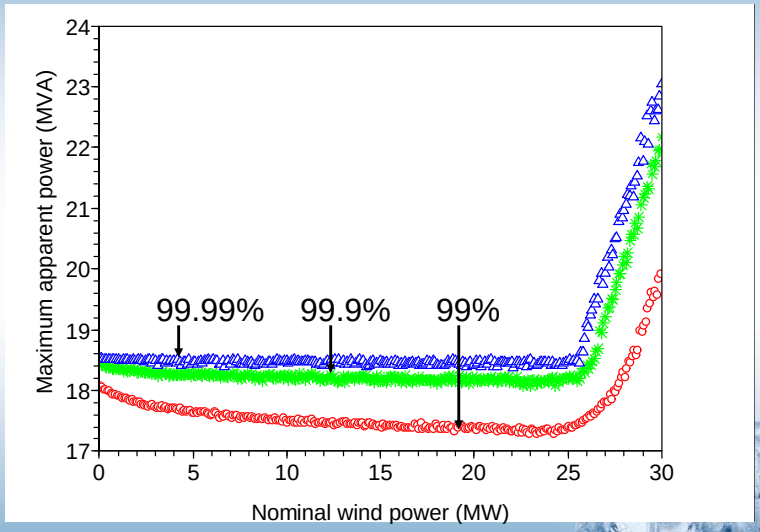
Loading of HV/MV transformer

Wind power – Weibull distribution
Consumption - measured



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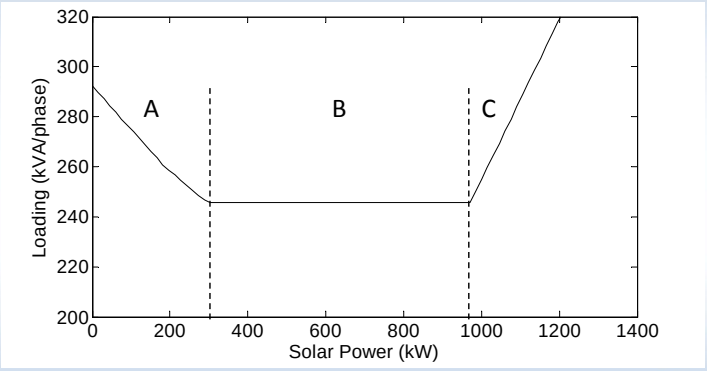
Hotel with solar power



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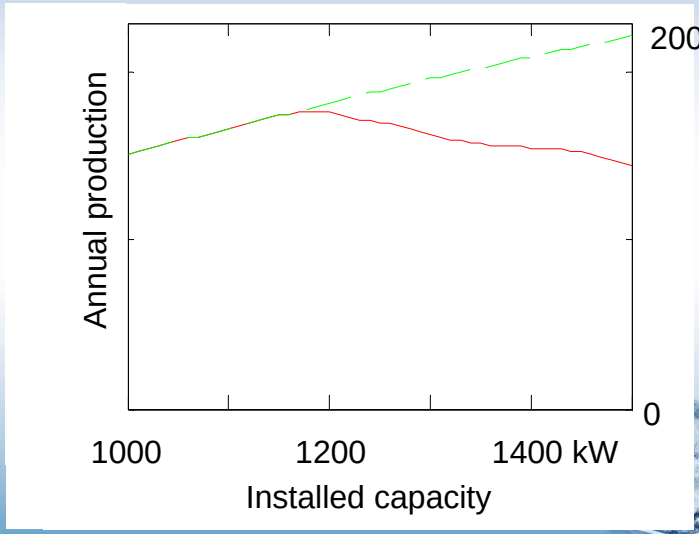
Impact of curtailment on production



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Assumptions made here

- This is a stationary process
  - Probability distribution does not change
- Position in the sky
  - Ok!
- Cloud cover
  - We need a long measurement period
  - Climate change can have some impact
- Consumption
  - This is the most uncertain factor

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Another level of uncertainty

- What if we don't know the where, when and what of the PV installations?

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Uncertainties

- Percentage of customers with PV?
- Average installed capacity per customer?
- Which specific customes will have PV and how big will there installation be?
- Three-phase or single-phase connection?
  - With single-phase: in which phase
- Direction and tilt of the panels
- Fixed, single-axis or double-axis?
- Type of inverter?
- On-site storage or not?
- Voltage / reactive power control or not?

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Low-voltage network with 6 customers

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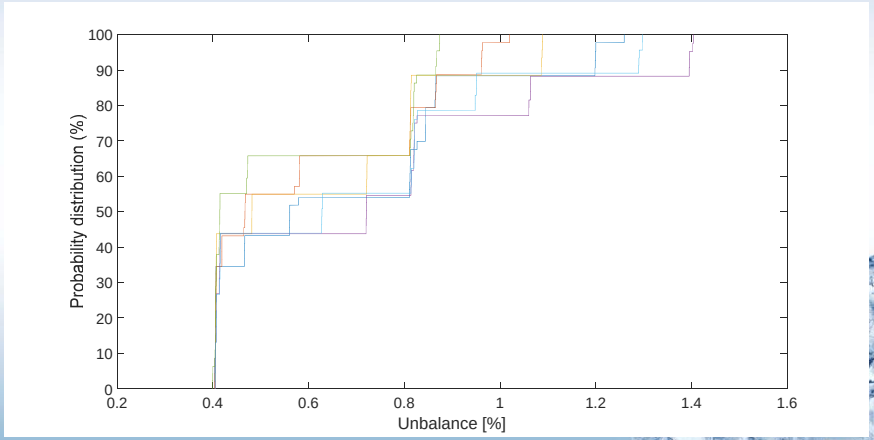
2 customers with PV



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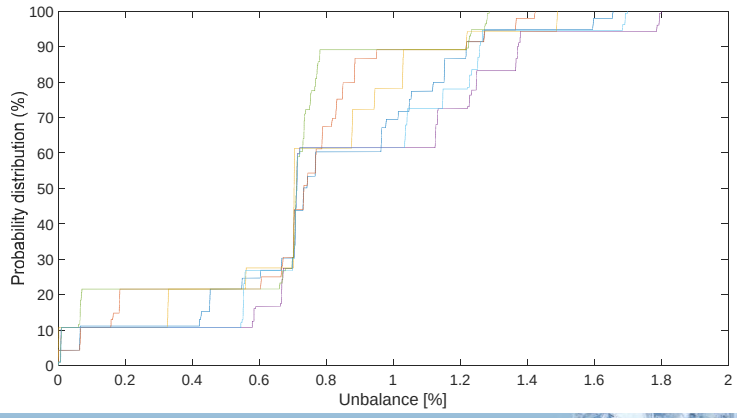
3 customers with PV



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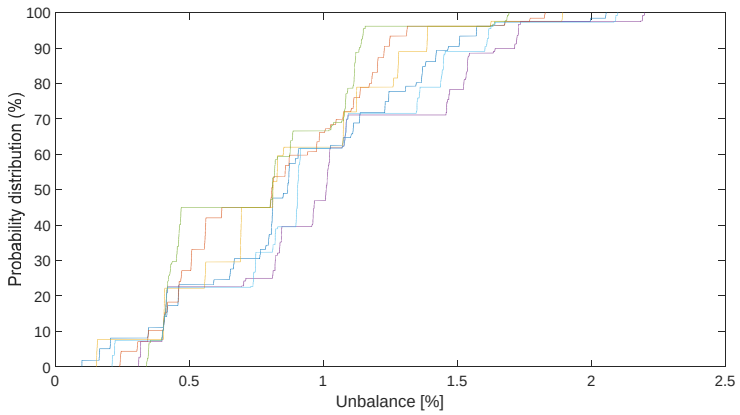
4 customers with PV



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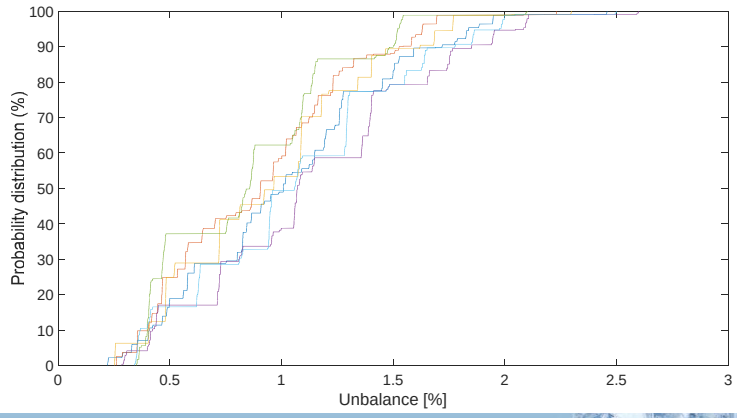
5 customers with PV



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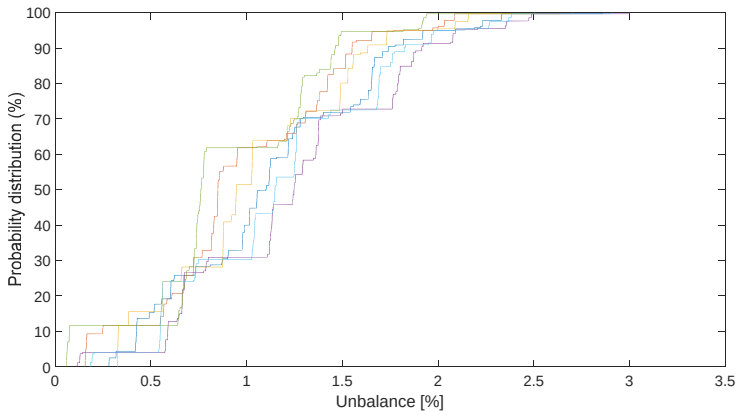
6 customers with PV



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Assumptions made here

- Number of customers with PV is known
  - Need the probability that a given number of customers will install PV
- All panels produce maximum power at the same time
  - Need information (deterministic or stochastic) on tilt angle and direction of the panels
- All installations are of the same size
  - Need probability distribution of size of the installation
- Background unbalance is neglected
  - Need long measurement series

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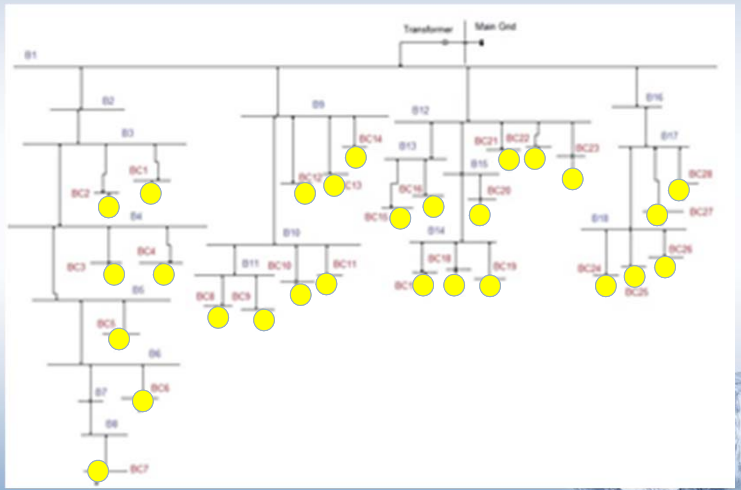
Low-voltage network with 28 customers



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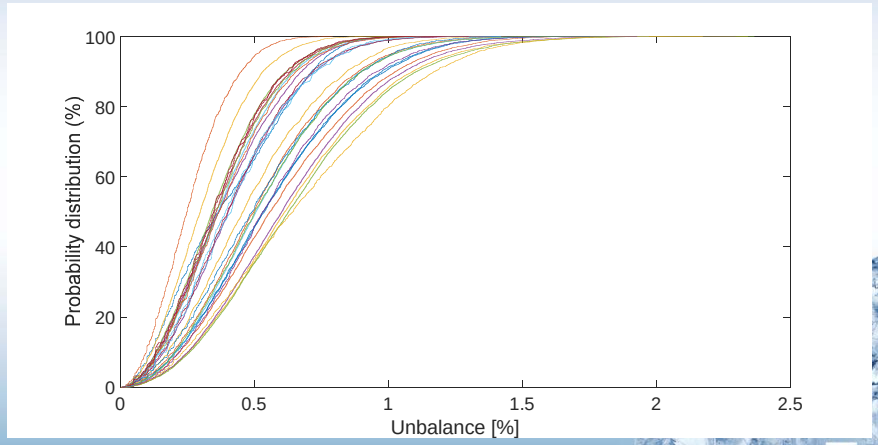
Random distribution of PV

14 out of 28 customers



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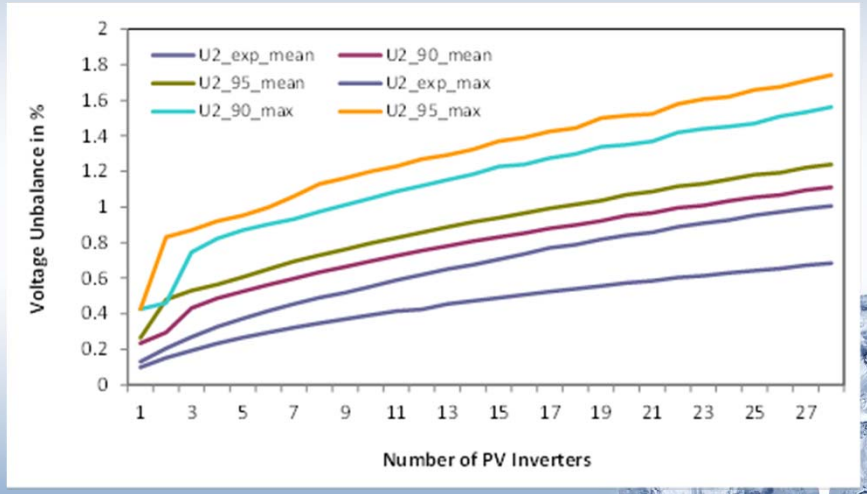
Increasing amount of PV



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Interpretation of the results

- Hosting capacity approach
  - We need a performance index
    - e.g. highest 95% probability over all customer
  - We need a limit
    - e.g. 2%
- What happens when the limit is exceeded?

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What happens when the limit is exceeded?

- Network operator has to make investments
- Network operator has to pay large fines
- Customer equipment trips
- Customer equipment gets damaged
- Customer equipment ages faster
- PV installations trip
- PV installations get damaged
- PV installations age faster
- Additional PV installations cannot be connected

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Uncertainty during operation

- The amount of wind of solar power deviates from the predicted value

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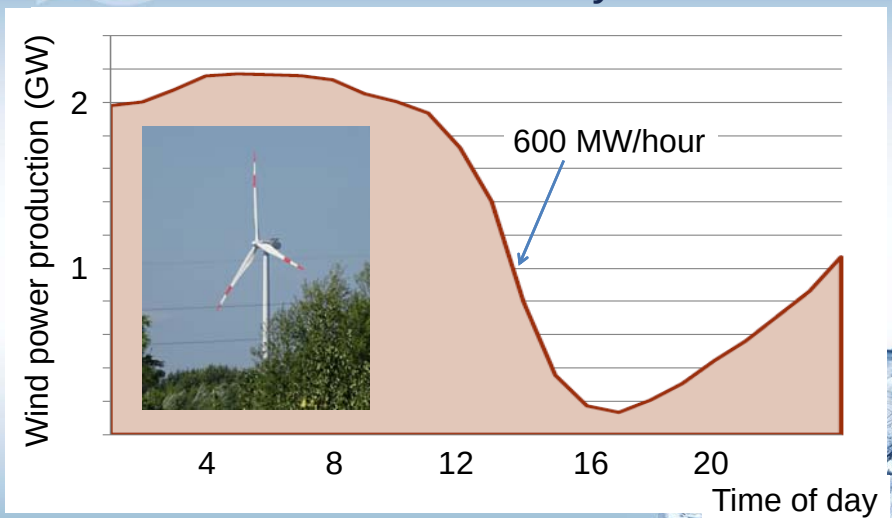
Denmark, 8 January 2005



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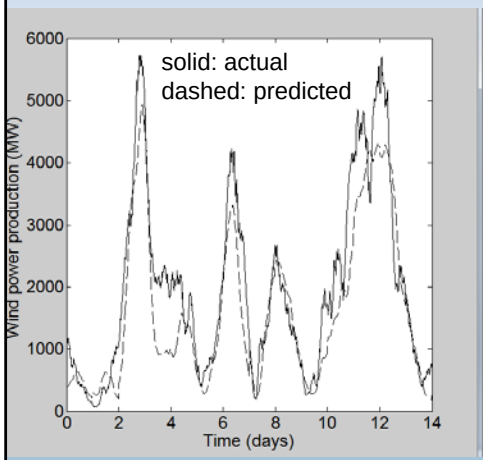
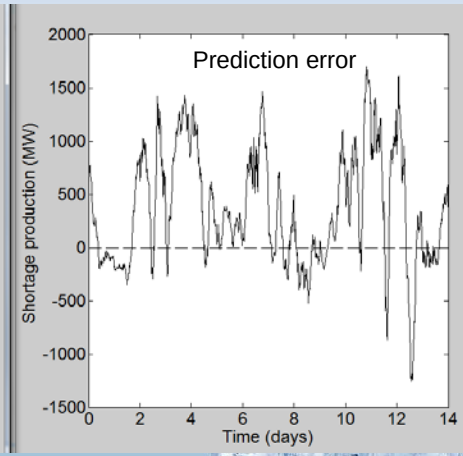
http://www.windpower.org

Northern Germany – January 2009





Source: Bollen och Hassan, 2011, Fig. 8.16

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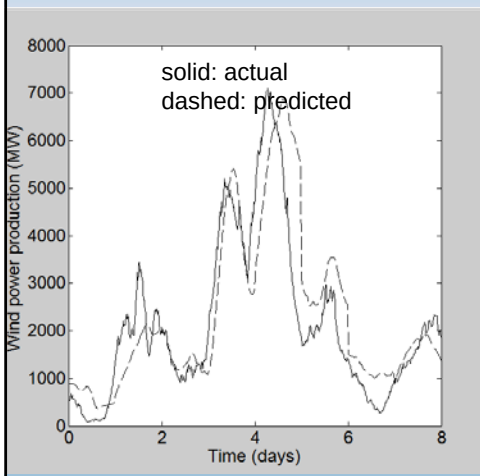
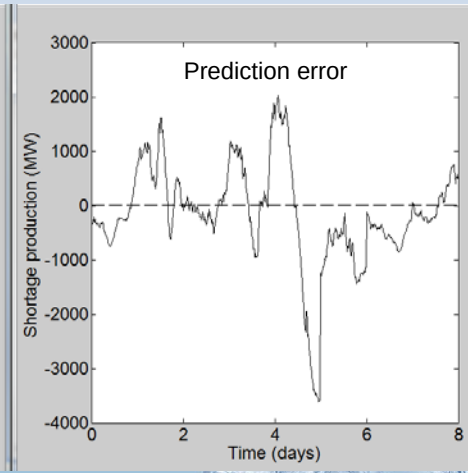
Northern Germany – Februari 2009





Source: Bollen och Hassan, 2011, Fig. 8.17

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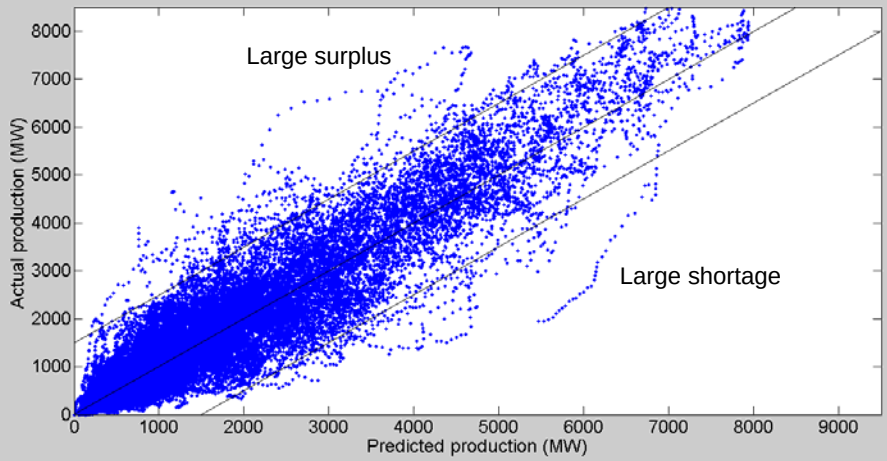
Prediction versus actual production



Source: Bollen and Hassan, 2011, Fig. 8.18

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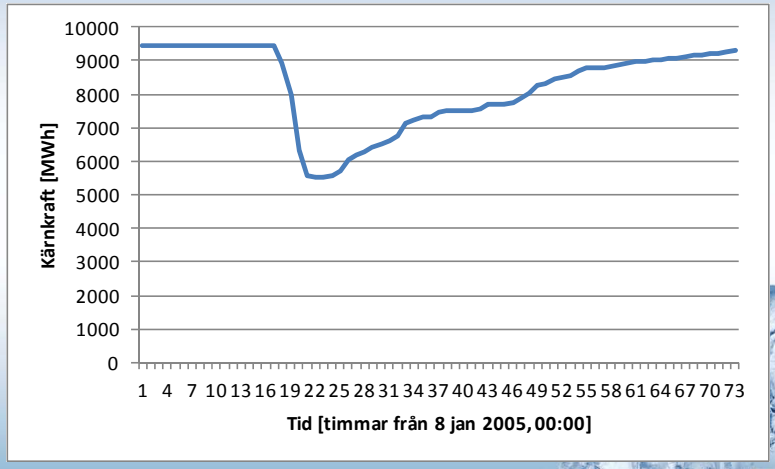
Nuclear power in Sweden – 8 January 2005



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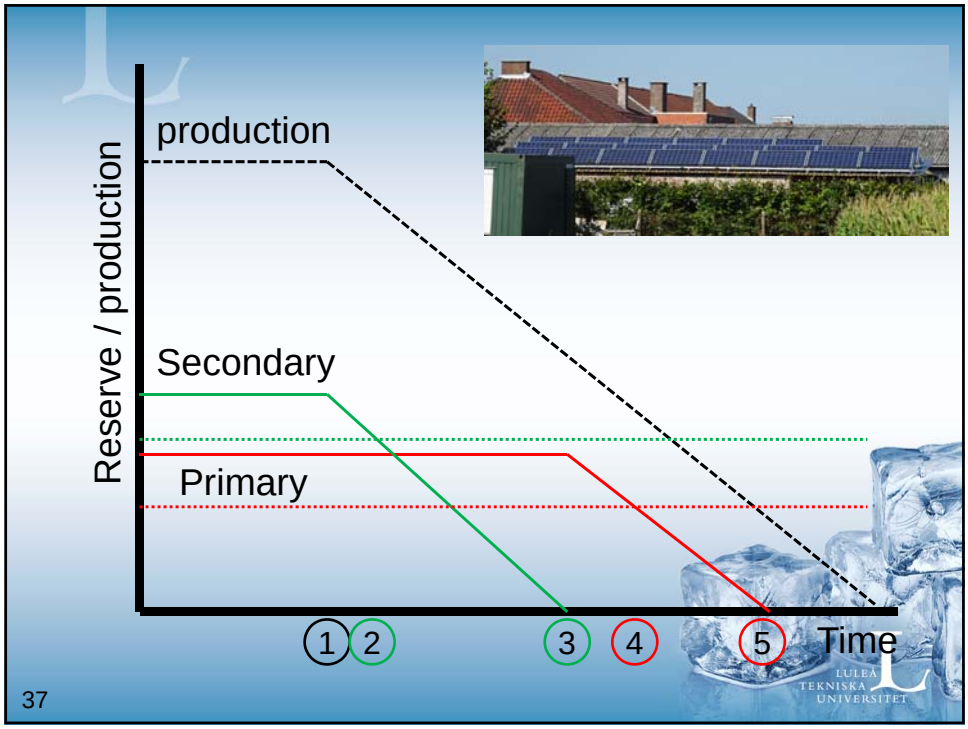

Conclusions

- ”The uncertainties we know about …
  - When probability distribution is known
  - .. assessment of risks and risk carriers is important
- and the uncertainties we don’t know about”
  - When the probability distribution is not known
  - … we need to be very careful.
  - Retreating to worst case is a low-risk solution but not always the best one.
- Data collection reduces the uncertainty and reduced uncertainty increases the hosting capacity without increasing the risks

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Disclaimer

- All the pictures of solar panels shown were made during a 30-minute walk through a small Belgium village (Uykhoven)

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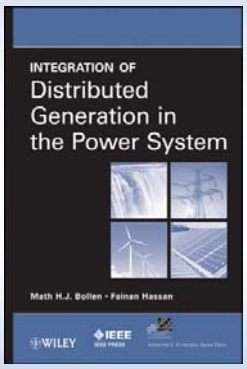
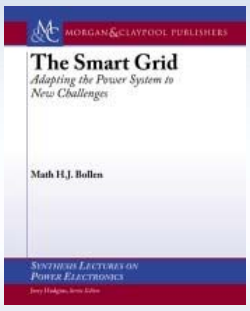
Want to read more?





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