A Study of the Balancing Capability of Hydro Power Systems

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Agenda

- Background
- Model of the Swedish hydro power system
- Balancing capability of a river system
- Future challenges

Background

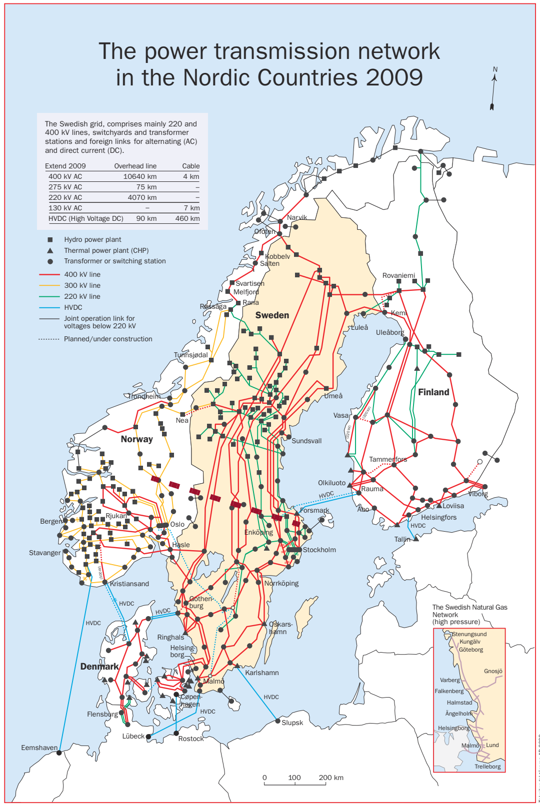
Wind and hydro power in Sweden

- Swedish planning target for 2020: possibility to have 30 TWh wind power
  - Parliament decision from 2009.
  - Wind power generation in Sweden:
    2.5 TWh (2009)
    11.6 TWh (2014)
- A large-scale development of nondispatchable generation will need more balancing resources.
- 30 TWh wind power equals about 12 000 MW installed capacity.
  - Sweden has around 16 600 MW hydro power.

Background

Research questions

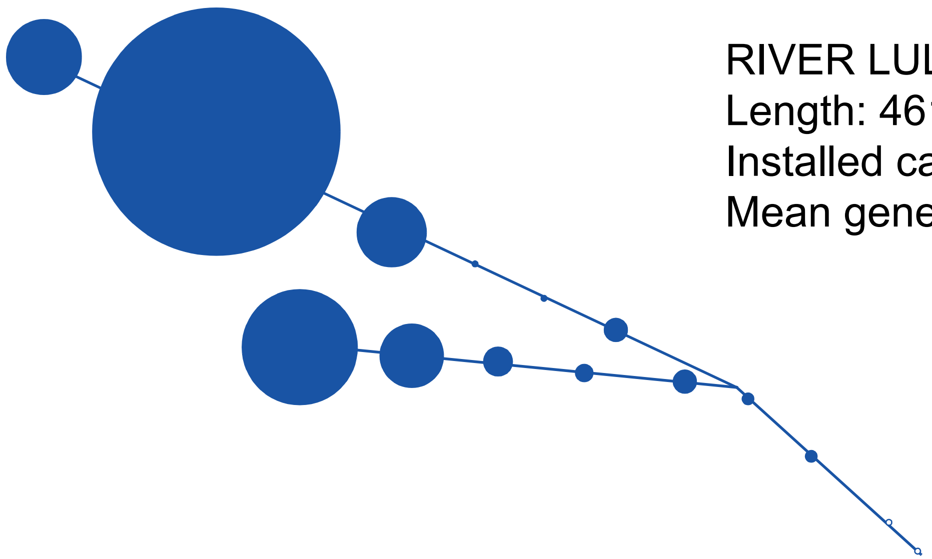
- At which level of wind power expansion is it motivated to strengthen the transmission capability from Northern to Southern Sweden?
- What is the balancing capability of the Swedish hydro power north of cut 2?
- What is the balancing capability of the entire Swedish hydro system?



Background

Flexibility of a river system

- Each individual hydro power plant is very flexible.
- Operation of a river system needs to take into account hydrology and court decisions.



RIVER LULE ÄLV
Length: 461 km
Installed capacity: 4 345 MW
Mean generation: 14 TWh/yr

Model of the Swedish hydro power system

Main characteristics

- The model includes 256 hydro power plants with a total installed capacity of 15 640 MW.
- Linear optimisation model.
- Sweden divided in four areas.
- Perfect information.
- Time period: 1 week, divided in 168 hours.
- Decision variables: Hydro generation, reservoir levels, spillage, transmission.
- Data: Wind power and thermal generation, demand, transmission limits.
- Installed wind power varied between 0 and 12 000 MW.

Model of the Swedish hydro power system

Optimisation problem

maximise hydro power generation

subject to

- load balance per area
- hydrological balance per reservoir
- operational limitations for hydro power
- reservoir level per reservoir at the end of the week

Model of the Swedish hydro power system

Conclusions

- Some spillage cannot be avoided due to operational limits and is therefore not depending on wind power level.
- Some spillage has a small correlation to wind power level, but can be avoided by changing final reservoir levels.
    - More water can be stored during winter weeks and used later when there is free transmission capacity.
- Some spillage is caused by transmission limits.
- No clear limitation has been observed in the balancing capability of the hydro system.

Balancing capability of a river system

Problem description

- How large variations in load and wind power generation can be balanced by a single river system?
- Which factors are influencing the balancing capability?
  - Reservoir size.
  - Water delay time.
  - Operational limitations.
- Is it possible to define an index which describes the balancing capability of a river system?

Balancing capability of a river system

Model

- River system with total installed capacity 1 000 MW.
- Load and wind power data series (maximal net load 1 000 MW).

Optimisation problem:

minimise spillage + unserved load + unused wind power

subject to

load balance

hydrological balance per reservoir

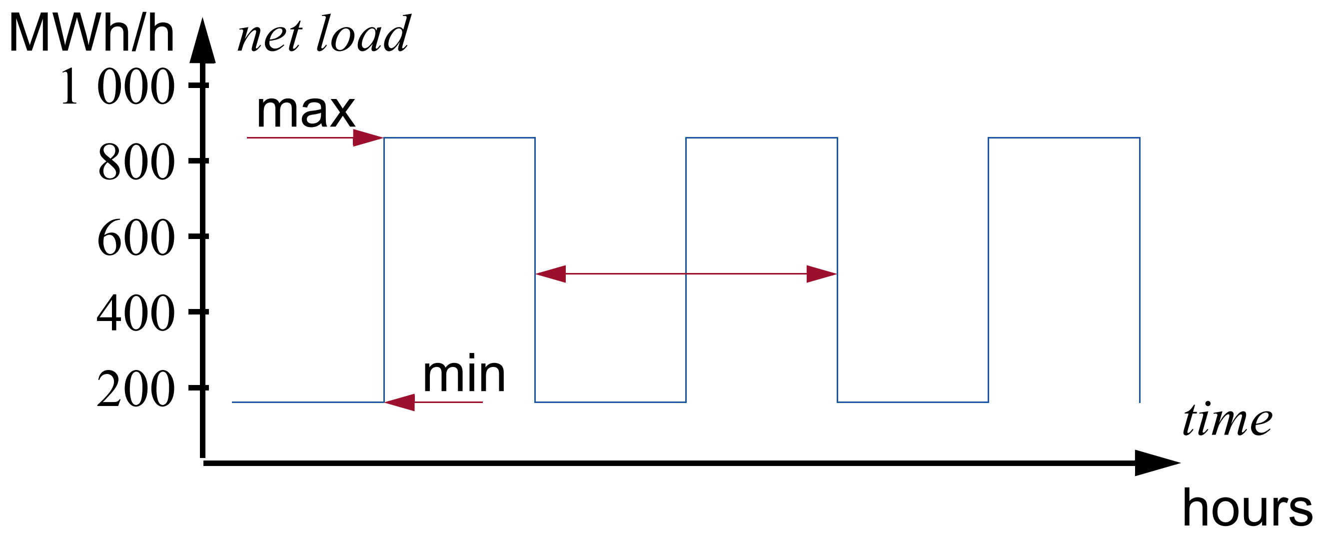
operational limitations for hydro power

minimal final reservoir levels

Balancing capability of a river system

Testing

- Real load and wind power profiles ⇒ increasing wind power level does not cause spillage but unused wind power (when wind power > load).
- Net load as square wave.



Balancing capability of a river system

Preliminary results

Increase the amplitude of the square wave until the hydro power cannot follow the variations (either resulting in spillage or unserved power).

Test river	T [h]	Max [MWh/h	Min [MWh/h]
"Lule"	2	950	100
"Lule"	8	900	100
"Skellefte"	2	850	50
"Skellefte"	8	750	50

Future challenges

- Daily hydro power scheduling under uncertainty
  - Bidding strategies for day-ahead, intraday and real-time markets.
  - Rules that encourage technical balancing capability to be offered to the market.
- Links between daily, weekly and seasonal planning of hydro power.