A METHOD FOR MODELLING OF HYDRO STORAGE POWER PLANTS IN POWER PLANT DISPATCH MODELS WITH ROLLING HORIZON APPROACH

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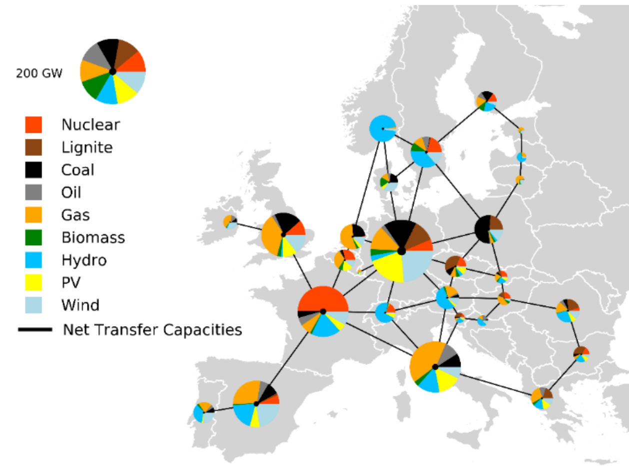
Restriction to storage power plants

Classification of hydropower plants:

- **Storage power plants:**
  - Flexible dispatch of hydropower
  - Very large storage capacity
  - Compensation of seasonal fluctuations possible
- **Run-of-river power plants:**
  - Very low storage capacity (pondage)
  - Base load power plant
- **Pumped storage power plants:**
  - Similar to storage power plants, with lower basin for high pumping
  - Compensation of intraday load fluctuations
  - Large storage capacity
- **Other (tidal power plants, wave power plants, ...)**

PERSEUS-EU Model

- Energy system optimization model PERSEUS-EU*
- **EU27 incl. UK, Switzerland, and Norway,**
  excl. Cyprus and Malta
- **Main decision variables:** energy production levels and cross-border electricity exchange levels
- **Objective:** Minimization of total system costs
- **Constraints:** Technical, ecological and political
- **Binary Variables**: E. g. Turning the power plants on and off
- One year in hourly resolution



* Program Package for Emission Reduction Strategies in Energy Use and Supply

Research Question: Need for long-term planning for storage power plants vs. model complexity

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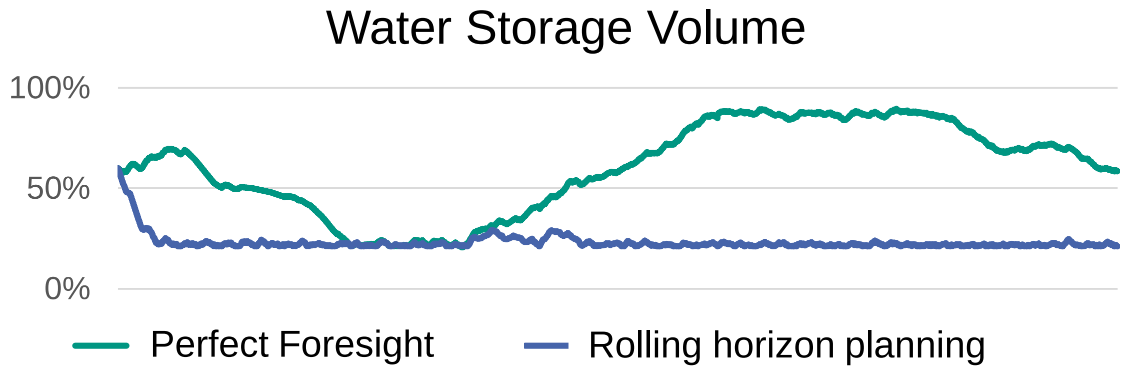
- The optimization problem across all regions and the several thousand power generation plants is too complex to be solved with perfect foresight for the whole year

  → Solution Approach: Rolling horizon planning

- **Problem:** Characteristics of storage power plants:
  - Seasonally varying inflow
  - Limited storage capacity

➢ Short-term rolling planning is not sufficient for the long-term optimization of water use in storage power plants.



Expansion to include storage power plants

- **Formula for the storage level:**

$$ReservoirL\_V_t^{unit} = ReservoirL\_V_{t-1}^{unit} + Inflow\_V_t^{unit} - ProcL\_V_t^{unit}$$

- **Limitation of the storage level upwards and downwards:**

$$ReservoirL\_V_t^{unit} \leq ReservoirL\_P^{unit}{}_{max}$$

$$ReservoirL\_V_t^{unit} \geq ReservoirL\_P^{unit}{}_{min}$$

- **Setting an initial storage level for each reservoir:**

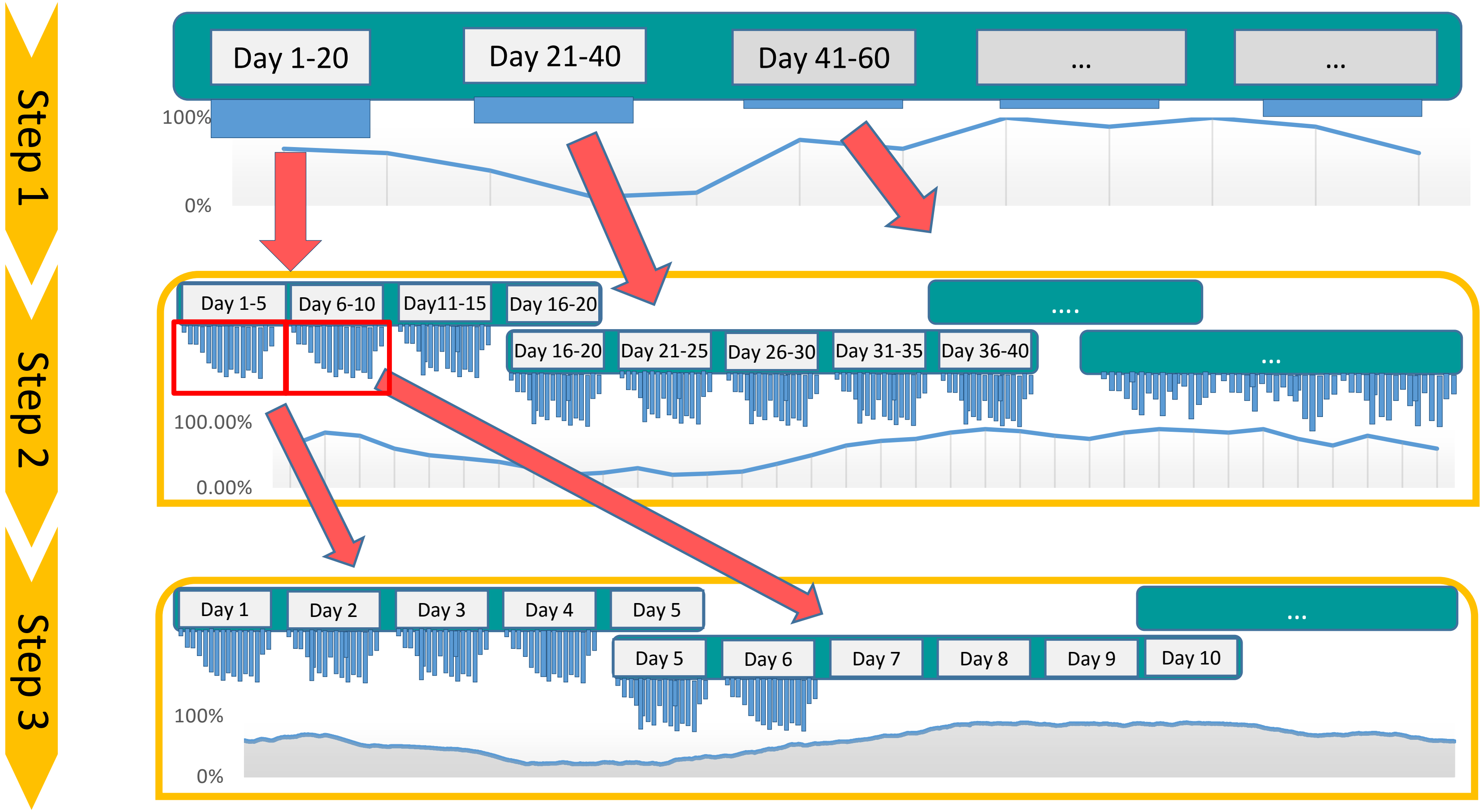
$$ReservoirL\_V_t^{unit} = ReservoirL\_P^{unit}{}_{Start} \quad for\ t = 0$$

- **Maximum water consumption over the period X:**

$$MaxHydro\_V_X^{unit} = ReservoirL\_P^{unit}{}_{Start} - ReservoirL\_P^{unit}{}_{End} + \sum_{t=1}^{8760} Inf\_V_t^{unit}$$

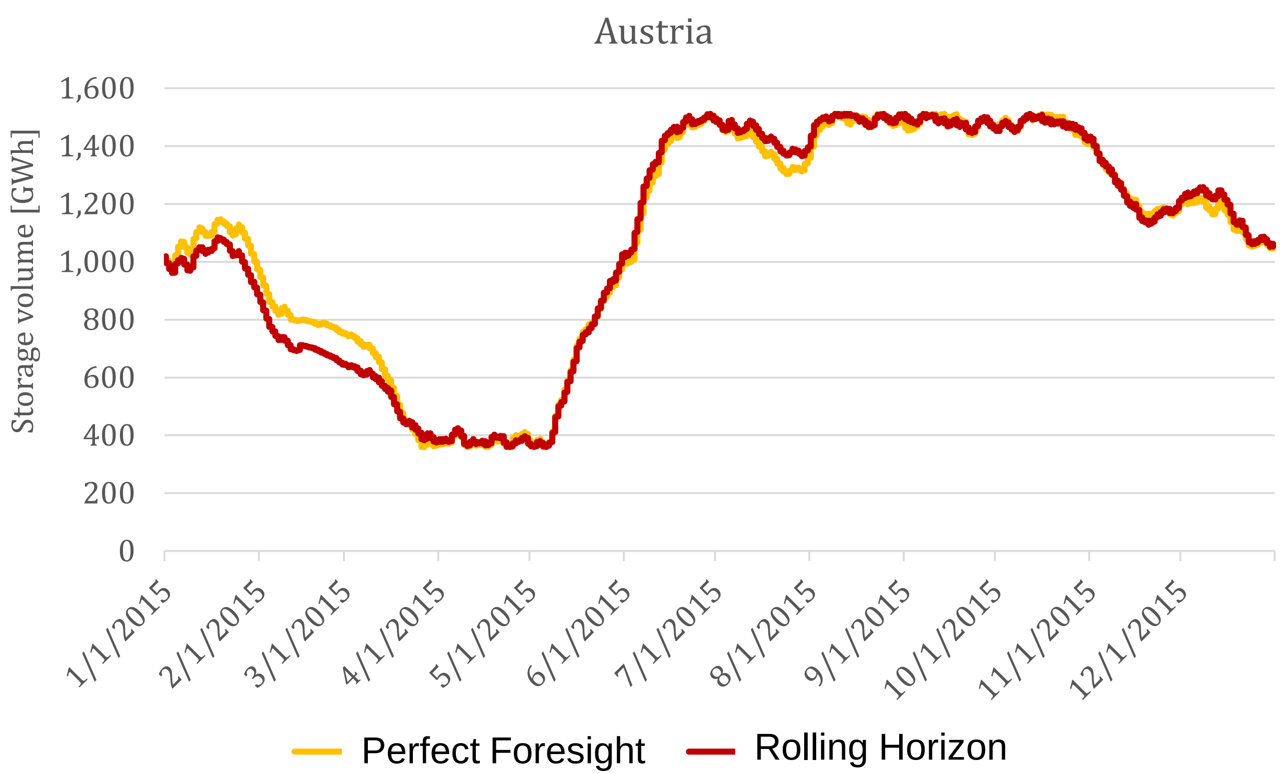
$$\sum_{t\, \in TIME} ProcL\_V_t^{unit} \leq MaxHydro\_V_X^{unit}$$

Developed heuristic



- Step 1: Perfect foresight over 365 time slots (each Day aggregated to one time unit)
- Step 2: Rolling planning over 20 days each, given water quantity from Step 1
- Step 3: Rolling planning over 5 days each, given water volume from Step 2

Interim results



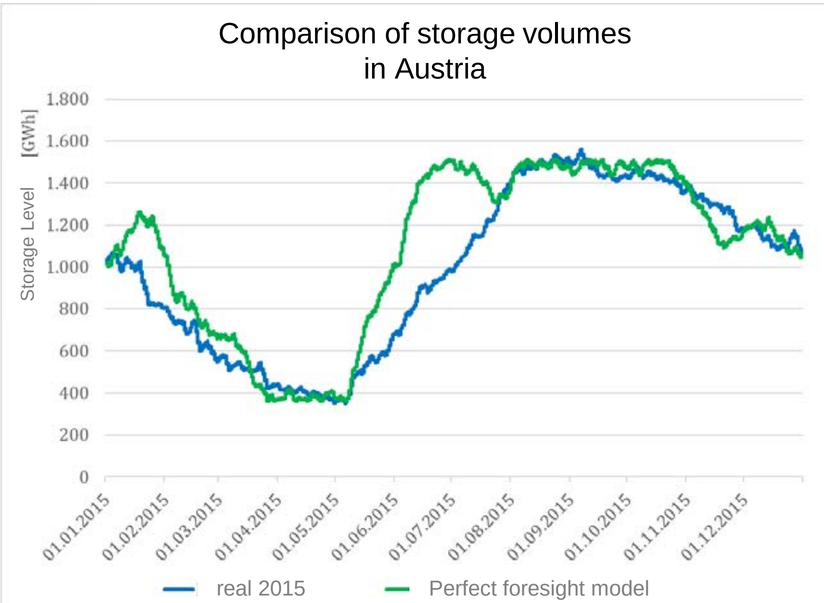
Correlation: 0,995

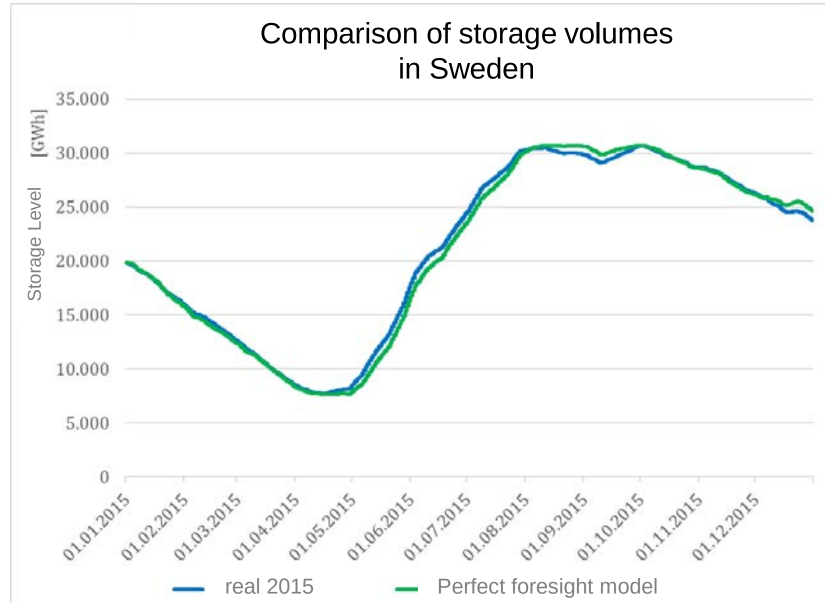
Correlation without trend: 0,953

⇒ Despite aggregation, the results of rolling planning almost correspond to those from the Perfect Foresight model

Results with perfect foresight

Consideration of each country individually:





Correlation: 0.90

Correlation without trend: 0.50

Correlation: 0.998

Correlation without trend: 0.961

⇒ the larger the available reservoir, the higher the correlation

Extension by minimum water flow

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- **Minimum water flow for step 1:** 0.05-quantile of all possible historical consumptions over 7 consecutive days.

$$MinHydroFlow_t^{Unit} = Quantil(0{,}05)\left\{\sum_{t=1}^{168} P_t^{Unit} * 1h\,;\sum_{t=2}^{169} P_t^{Unit} * 1h\,;\dots;\sum_{t=8593}^{8760} P_t^{Unit} * 1h\right\}\Big/7$$

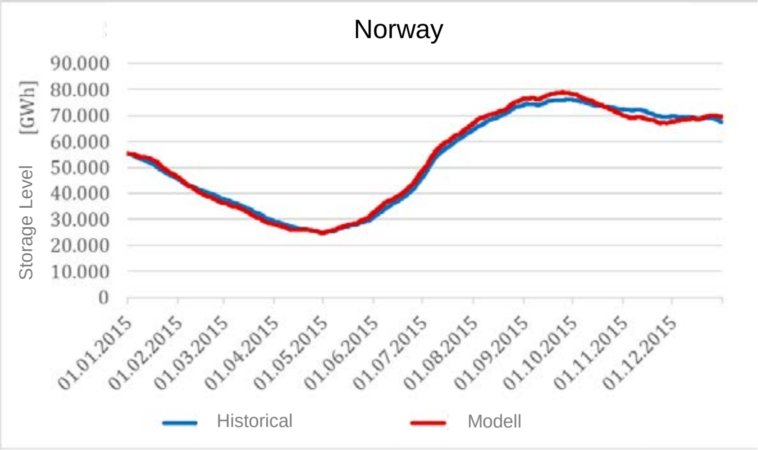
- **Minimum water flow for step 2 and 3:**
  0.01-quantile of all historical hourly consumptions over a 30-day period

$$MinHydroFlow_t^{Unit} = Q(0{,}01)\{P_1^{Unit}; P_2^{Unit}; \dots;\ P_{720}^{Unit}\}$$

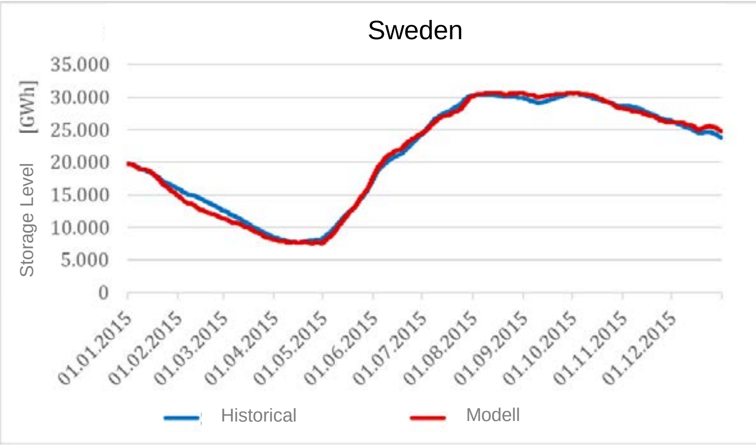
- Application of minimum water flow by extending the model:

$$WaterL_{t-L}^{Unit} - WaterL_t^{Unit} + \sum_{i=t-L}^{t} Inf_i^{Unit} \geq MinHydroFlow_t^{Unit}$$

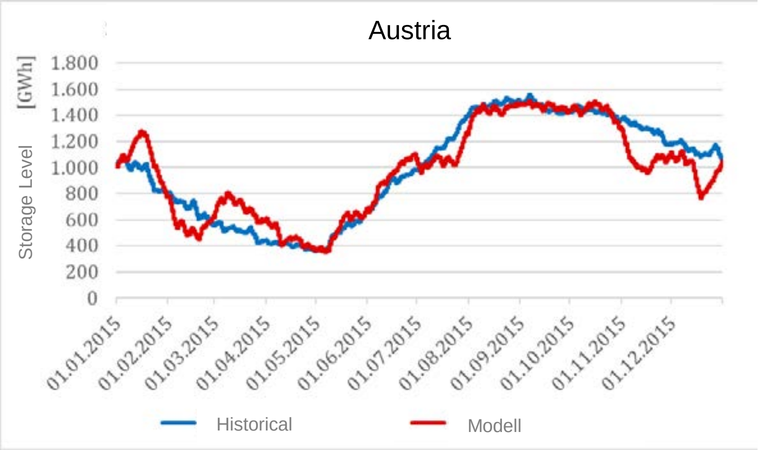
Final results



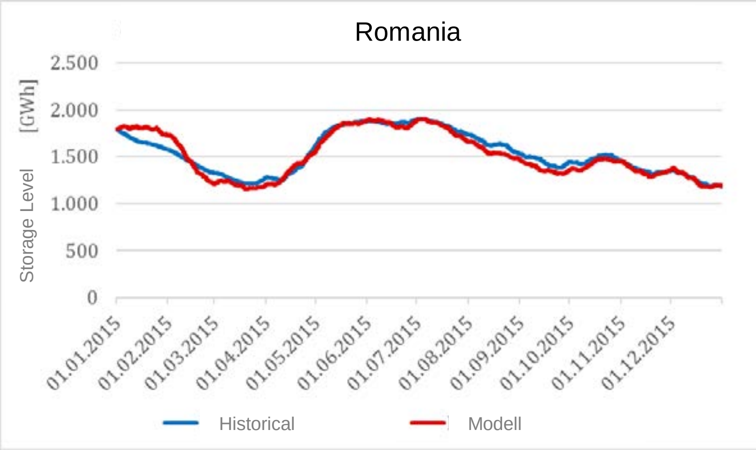
Correlation: 0,9962
Correlation without trend: 0,9179



Correlation: 0,9977
Correlation without trend: 0,9065



Correlation: 0,9401
Correlation without trend: 0,4695



Correlation: 0,9657
Correlation without trend: 0,5075

Conclusion

- The application of the presented method allows the modelling of storage power plants in power plant dispatch models with rolling horizon.

- A big advantage of the method is that only new model restrictions have to be added, and time resolution of the model have to be adapted.

  → The method can therefore be transferred relatively easily to other energy system models.

Critical reflection

- Difficulty to define values for minimum water flows

  → Analysis of further data

- Introduction of minimum flows reduces the flexibility potential of storage power plants (especially for countries with a large share of storage power plants)

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Thank you for your attention!

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