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Stochastic optimization model for detailed long-term hydro thermal scheduling using scenario-tree simulation

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SOVN – New market simulator

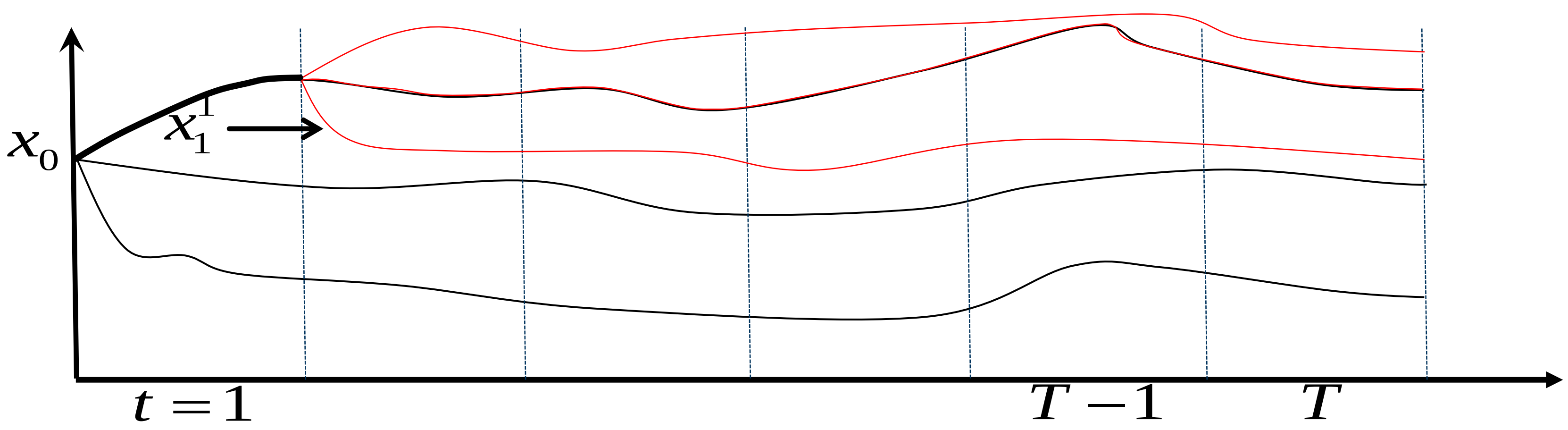
The aim is to develop a market simulator for the Northern European power market based on individual water values and power flow constraints.

Objective and challenges

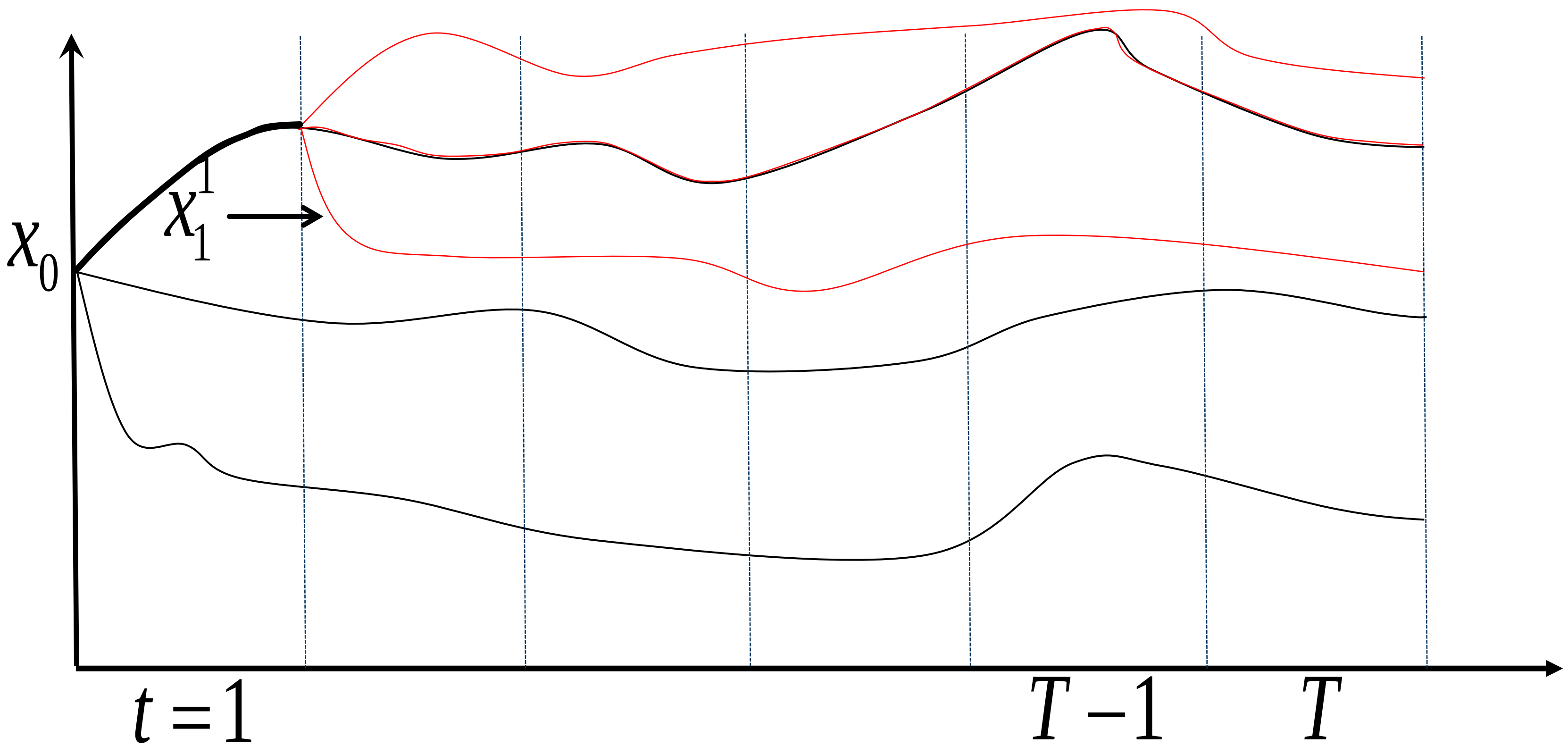
- Fundamental based market model including all relevant physical constraints (demand, transmission and production)
  - Stochastic dynamic optimization formulation
- Challenges problem size:
  - About 1000-1500 states (reservoirs)
  - Typically 100 -200 different stochastic inputs
    - Inflows to reservoirs
    - Temperatures
    - Wind and solar power production
    - Exogenous prices
  - Multi-period planning problem (3-5 years ahead , down to hourly resolution)
  - **Statistical properties in time and space is important, especially for inflows (simulation using weather years)**

Simulator Scheme

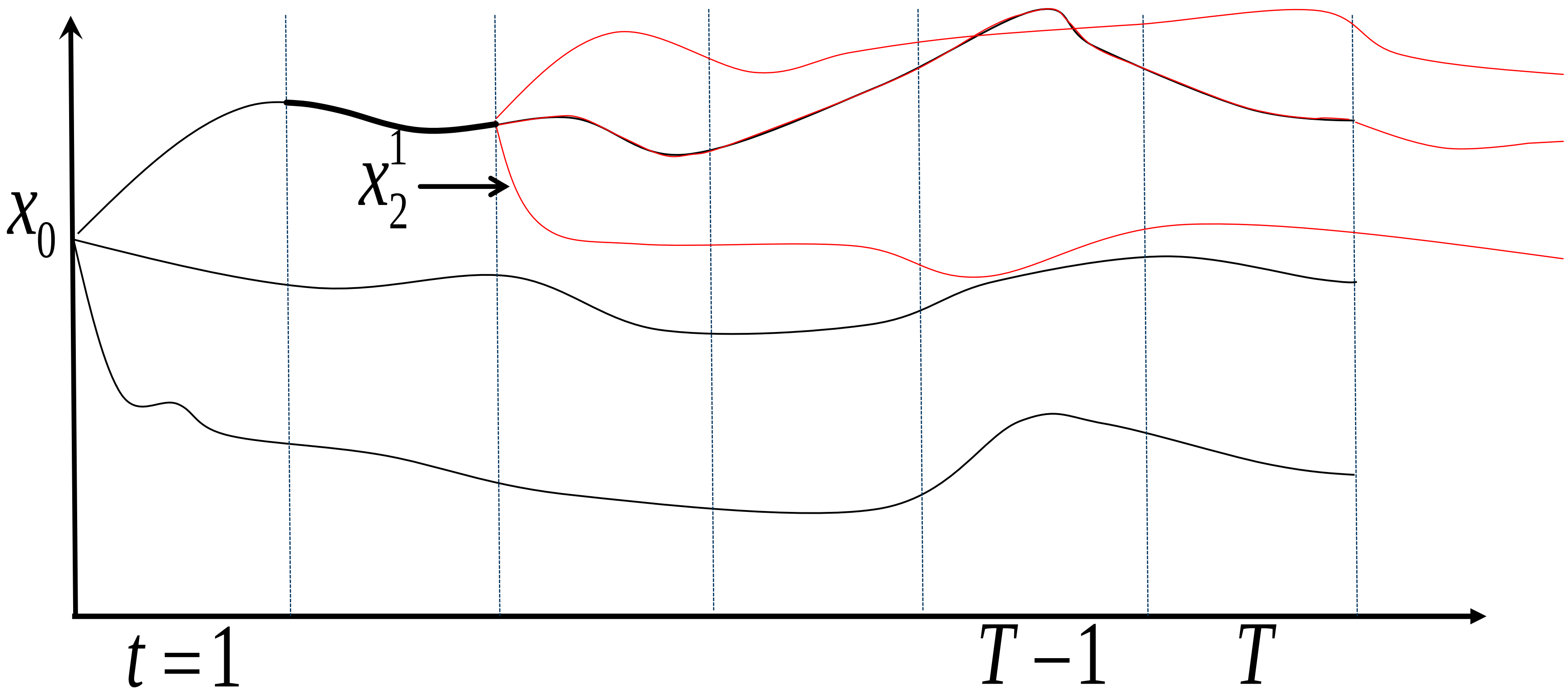
- Simulation along observed *weather scenarios* by solving a sequence of stochastic optimization problems
  - Two-stage stochastic problems
  - Inflows known in the first-stage (week)
  - All uncertainty is resolved in the second stage
  - First-stage decision is implemented and state variables are updated
  - Rolling horizon, fixed problem size



Simulator Scheme



Simulator Scheme

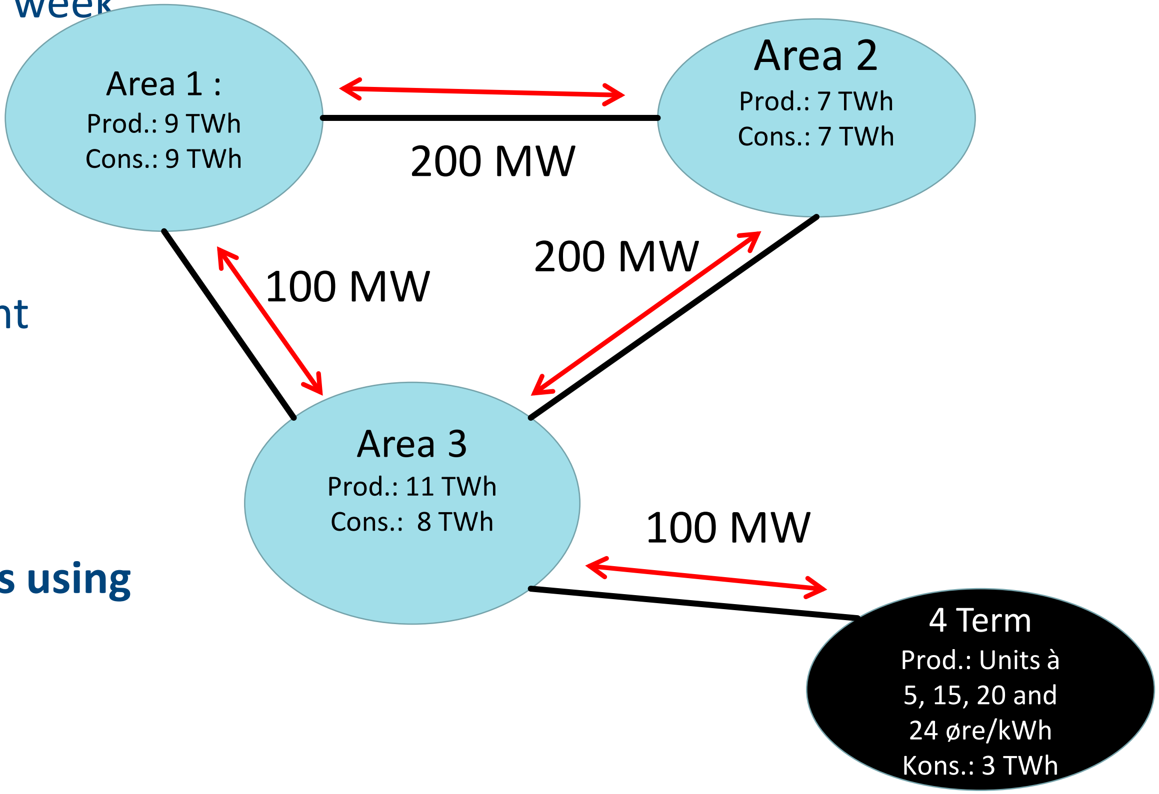


Simulator – pros and cons

- Pros
  - Based in formal optimization
  - Direct use of historical "weather scenarios" in second-stage forecast
  - Easy to build, extend and parallelize
    - Efficient use of computational resources
- Cons
  - Model users wants results quickly but this model has long computation times
  - Examples:
    - 950 modules, 52 week scenario fan, 4 load steps:
      - Observed: appr. 17 minutes per weekly decision problem (CPLEX)
      - Estimate 260 week simulation horizon: 74 hours (~3 days)

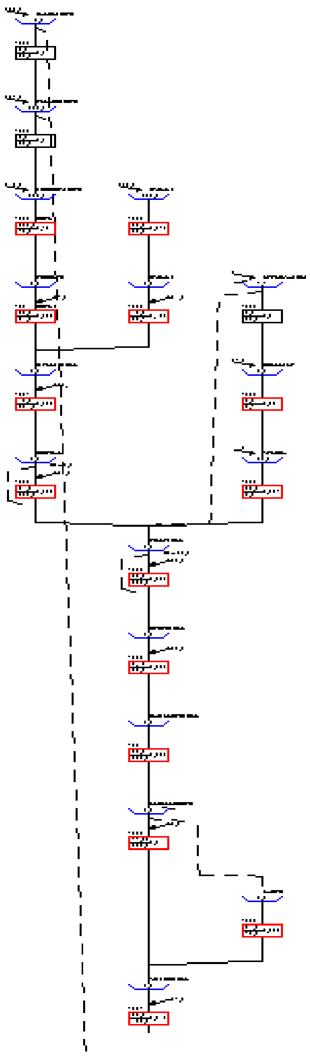
Test case: SOVN vs EMPS

- Four areas: 3 with hydro and one with only thermal units
- 38 years, 4 time periods within week
- Parallel simulation with 156 weeks
- Calc. time EMPS: 1 min
  Calc. time SOVN: 1 hour
  with 52 weeks scenario horisont
  using 79 cores

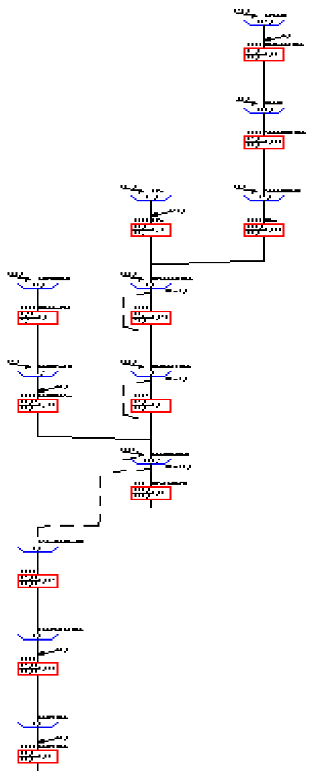


- **Case-study:**
  - **Compare simulated results using EMPS and SOVN**

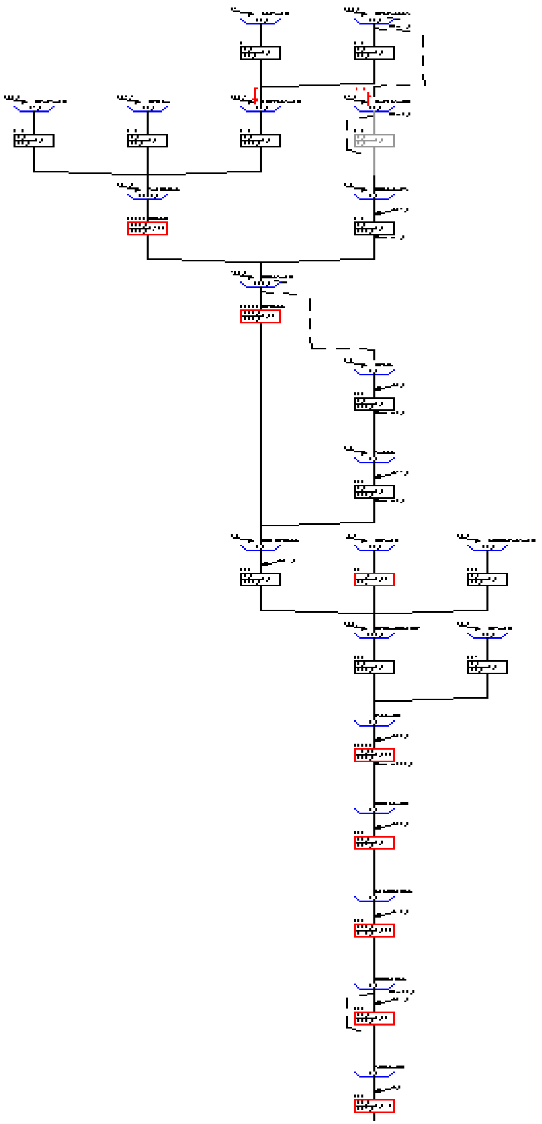
Area 1



Area 2

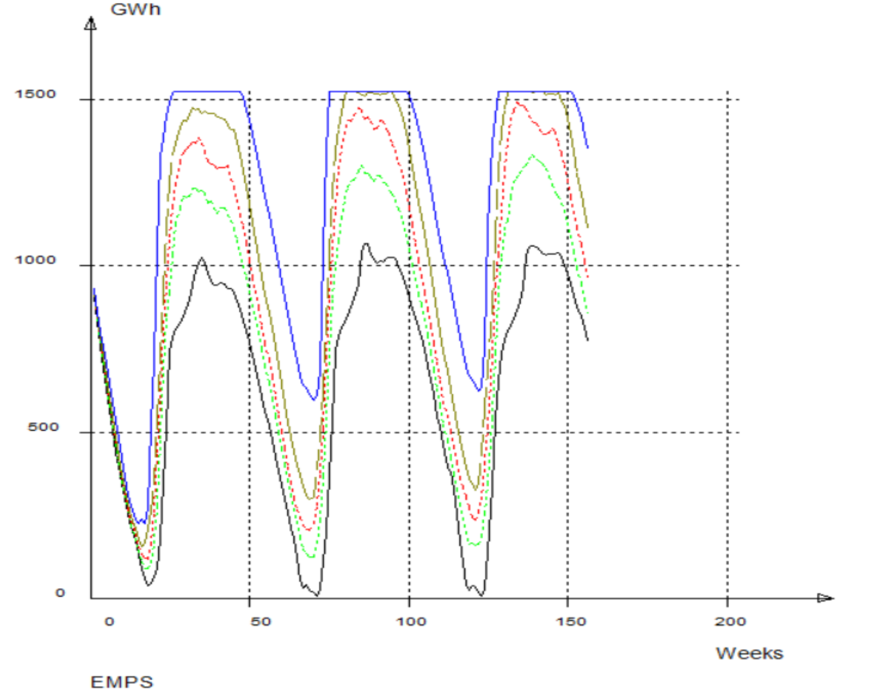


Area 3

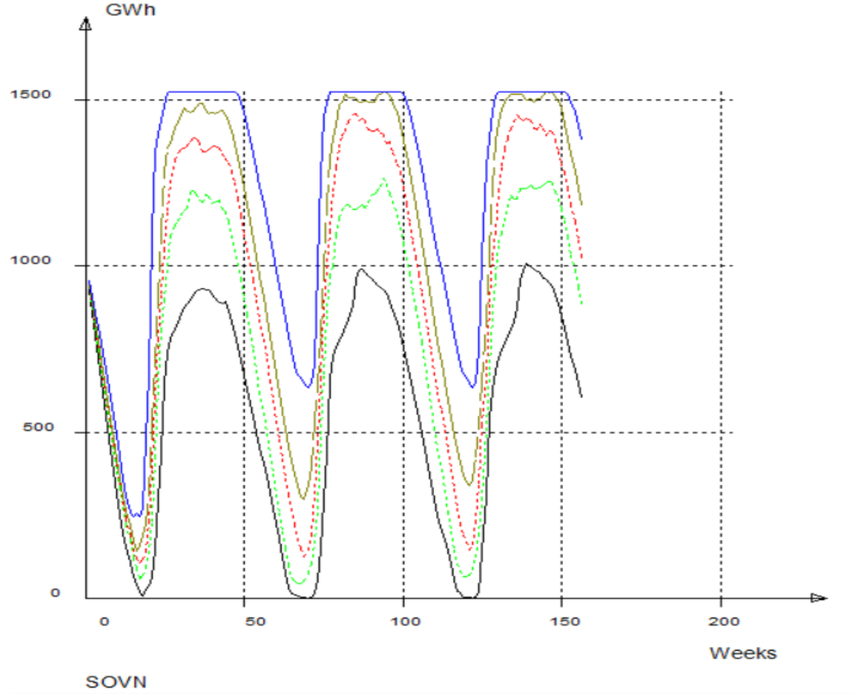


Results: Reservoir handling area 1 (0 – 100 % percentile)

EMPS

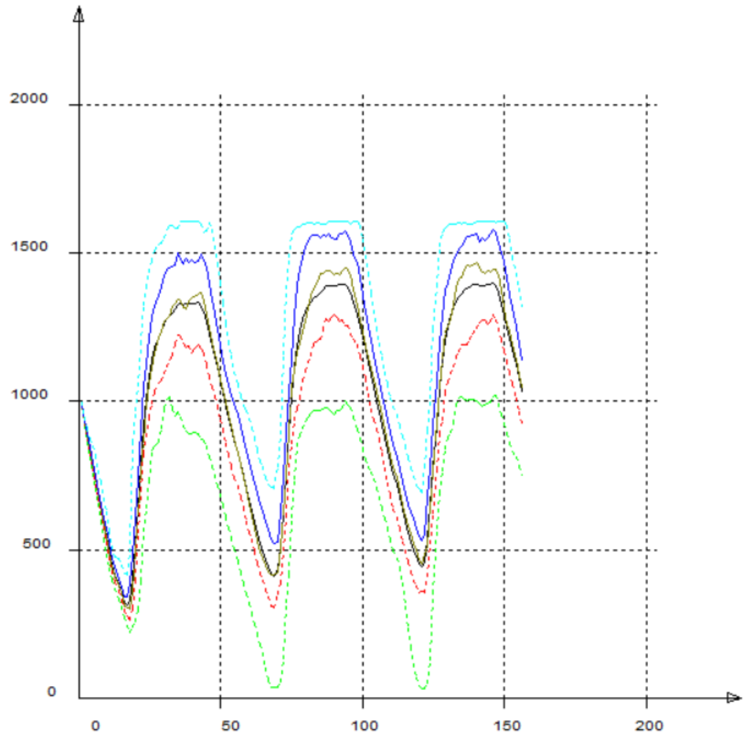


SOVN

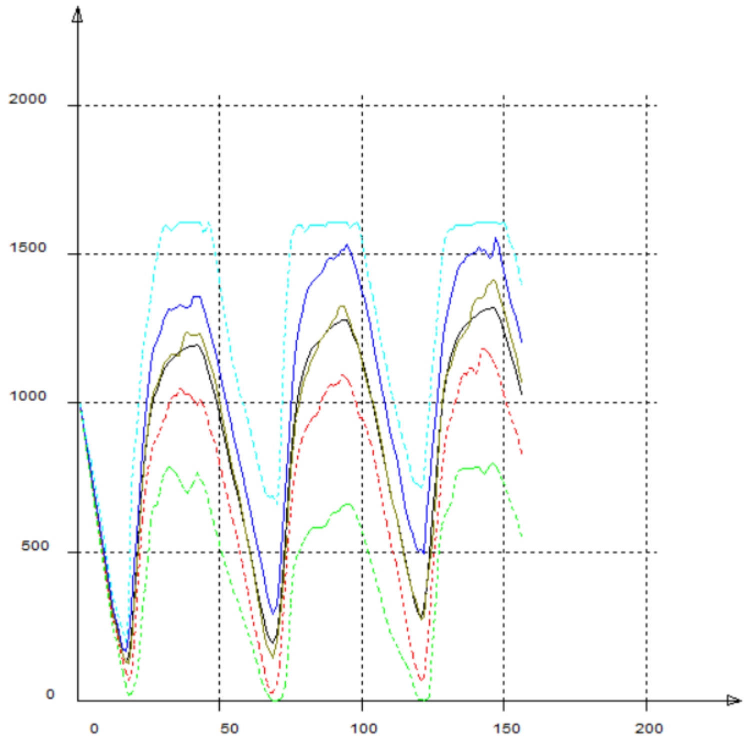


Results: Reservoir handling area 2 (0 – 100 % percentile)

EMPS



SOVN

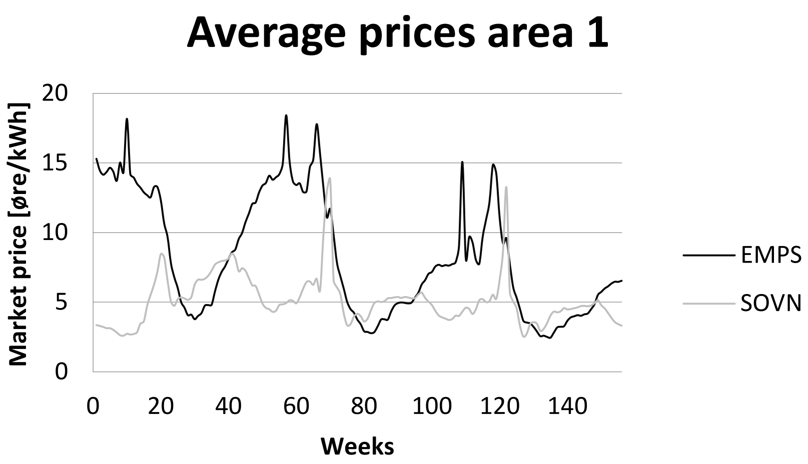


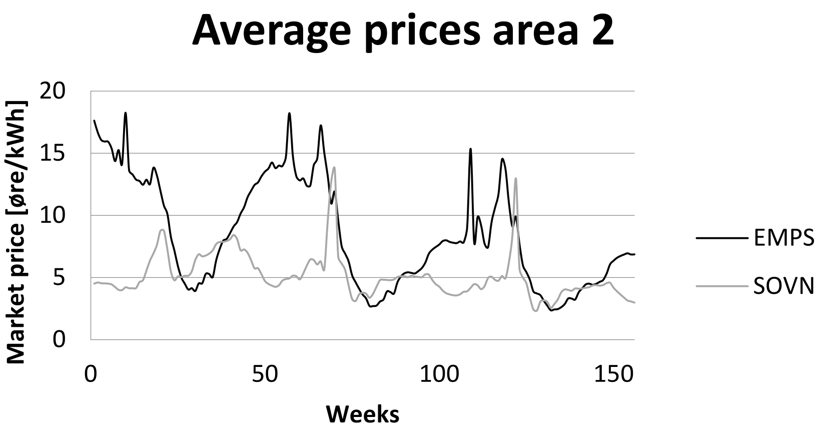
The SOVN model gives more optimal use of water

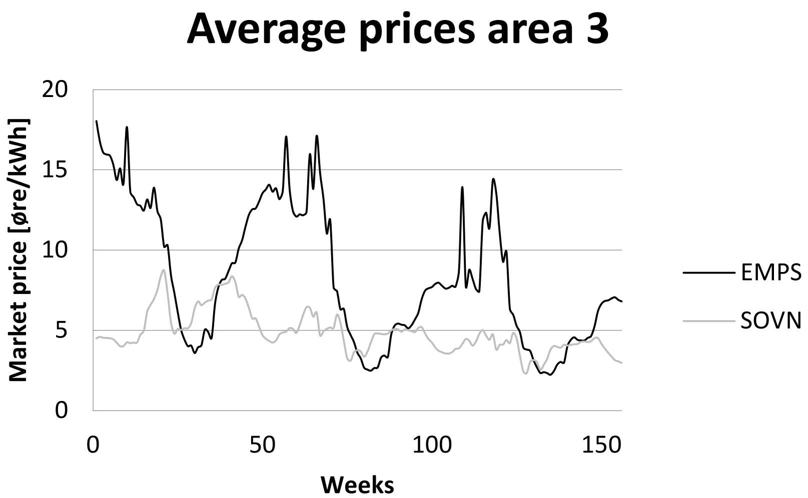
- More optimal use of the water in the reservoirs:
  - Less spillage (605 GWh)
  - Higher hydro production (787 GWh)
  - Replaces thermal production (672 GWh)

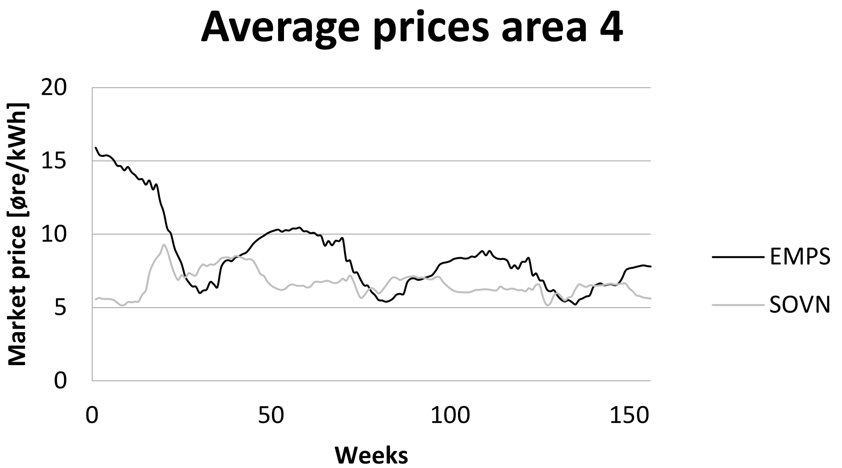
- Increased socio-economic surplus (+ 63 MNOK)

The SOVN model gives lower prices



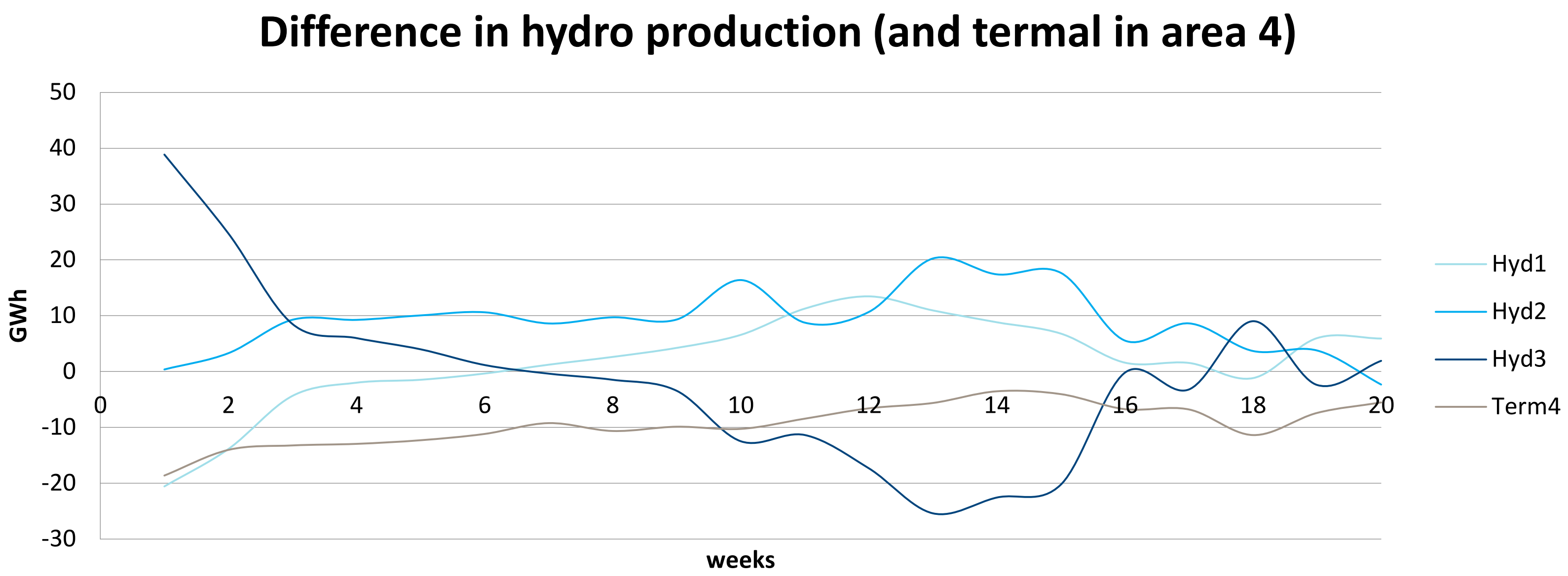






Why so much higher prices in EMPS in first weeks?

- First appr. 20 weeks:
  - More hydro, especially in area 2 and 3
  - Less thermal in area 4



Summary

- SOVN gives better results than EMPS
- Tested on a artificial system with limited flexibility

- To early to conclude
  - SOVN lacks some modelling features which are included in EMPS
  - Optimization problem in SOVN too flexible?
    - Needs to add more constraints (e.g. time delays, ramping)

Status/future work

- Prototype ready for testing by project participants June 2015

- Current model uses transport constraints.
  Detailed transmission constraints will be implemented using PTDF's.

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