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

\[ x_0 \rightarrow x_1 \]

\( t = 1 \quad T - 1 \quad T \)
Simulator Scheme

\[ t = 1 \quad \quad T - 1 \quad \quad T \]

\[ x_0 \quad \quad x_2 \]
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 want 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 horizon using 79 cores

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

Area 1:
- Prod.: 9 TWh
- Cons.: 9 TWh

Area 2:
- Prod.: 7 TWh
- Cons.: 7 TWh

Area 3:
- Prod.: 11 TWh
- Cons.: 8 TWh

4 Term
- Prod.: Units à 5, 15, 20 and 24 øre/kWh
- Cons.: 3 TWh
Results: Reservoir handling area 1 (0 – 100 % percentile)
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

**Average prices area 1**

**Average prices area 2**

**Average prices area 3**

**Average prices area 4**
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.