Quantitative Analysis of Decision Parameters - Short-term Hydropower Scheduling

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Problem Outline

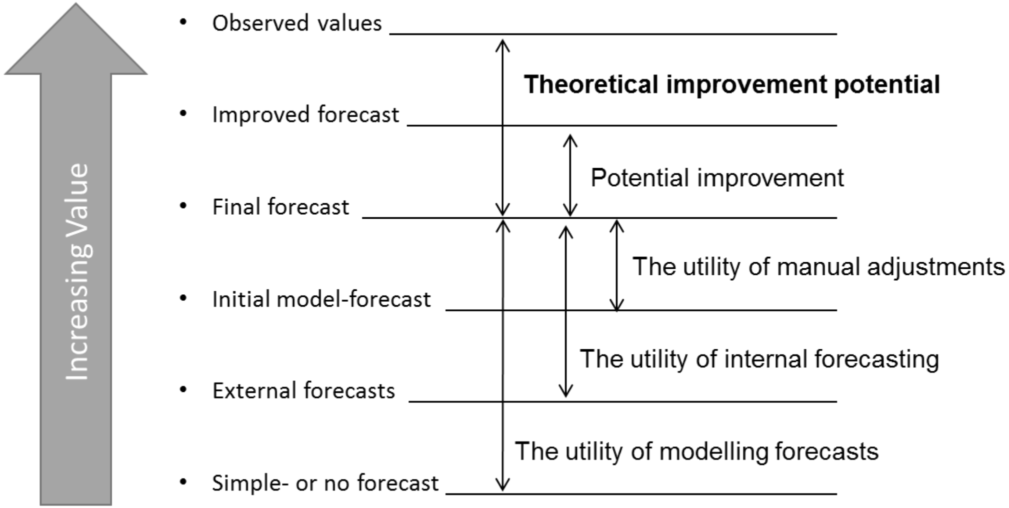
- Background
  - What is the **value of using a stochastic optmization model** for ST hydropower scheduling?
  - Earlier studies shows an imporvement potential in the range of **0.5 – 7 %** on total profits/income

- Methodology
  - Use a deterministic model (SHOP*)
  - Quantify the **maximum theoretical value** of having perfect information about decision variables (e.g. price and inflow)

- Expectations
  - Eariler studies use too naive benchmarks in terms of level of detail and flexibility

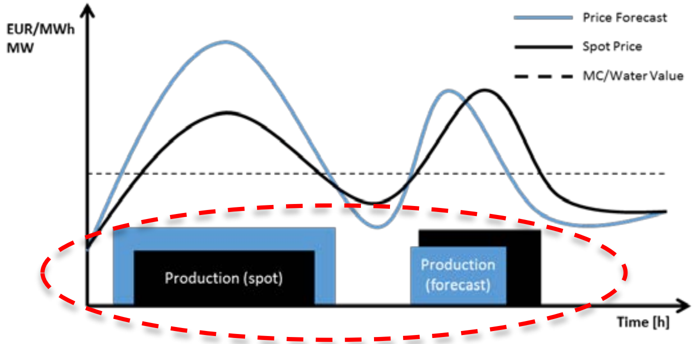
*SHOP = Short-term Hydropower Optimization Program

Conceptual Illustration

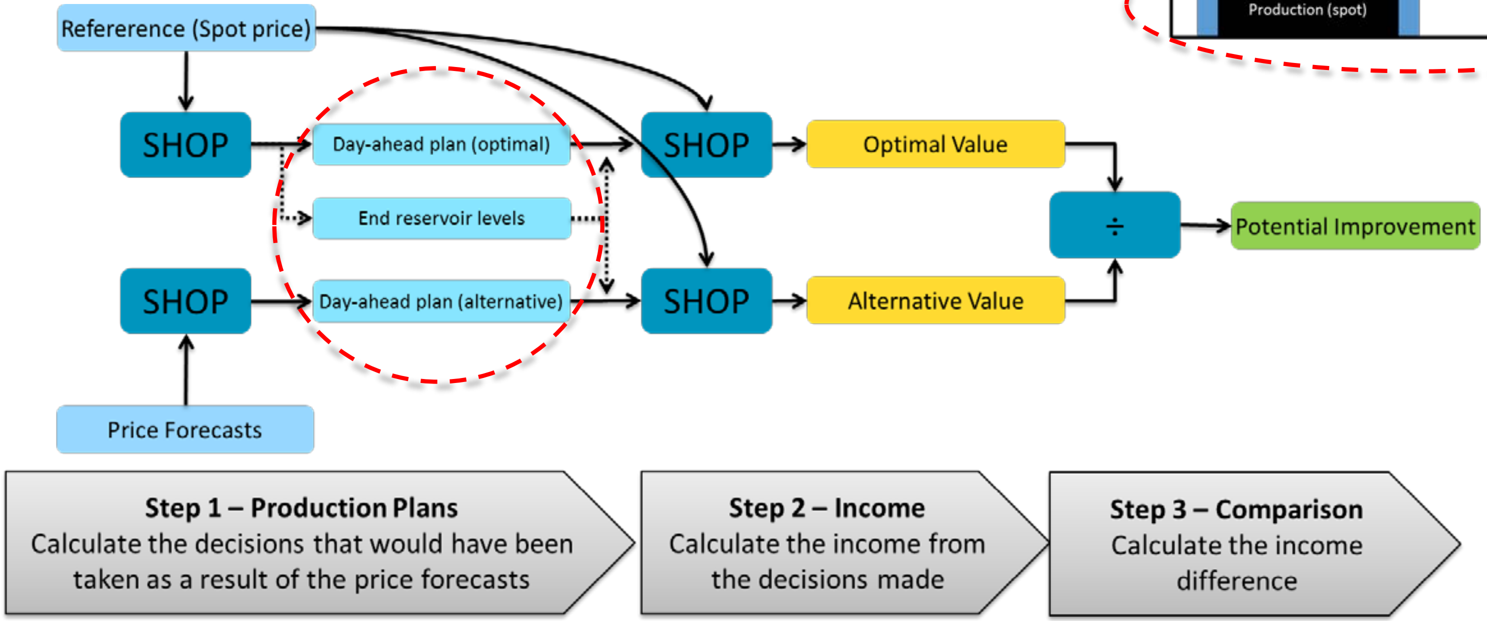


Improvement potential?

Approach



EUR/MWh
MW
Price Forecast
Spot Price
MC/Water Value
Production (spot)
Production (forecast)
Time [h]



Refererence (Spot price)
SHOP
Day-ahead plan (optimal)
End reservoir levels
Day-ahead plan (alternative)
SHOP
SHOP
SHOP
Optimal Value
Alternative Value
÷
Potential Improvement
Price Forecasts
Step 1 – Production Plans
Calculate the decisions that would have been taken as a result of the price forecasts
Step 2 – Income
Calculate the income from the decisions made
Step 3 – Comparison
Calculate the income difference

Case Study

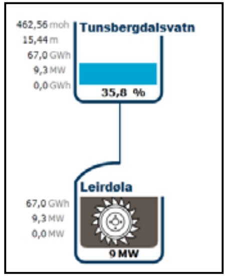
Considering different…

- System descriptions (degree of regulation, capacity)
  - With distincive properties in terms of flexibility and available capacity
  - E.g. a medium river system or a price area

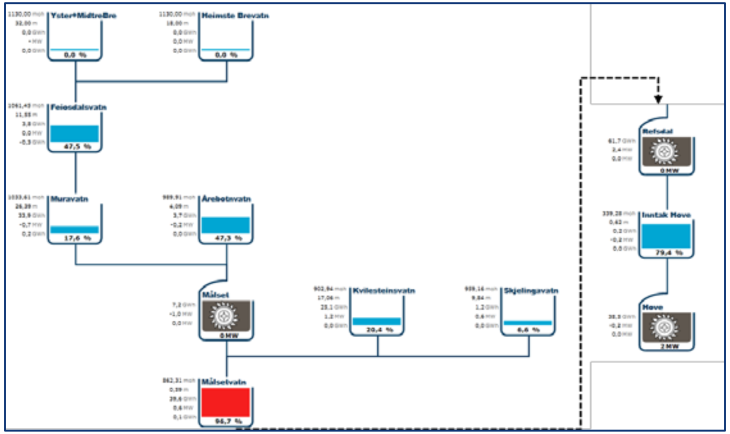
- Market situations (energy/effect deficit/surplus)
  - Price level and volatility
  - Price deviations
  - High wind/solar production
  - Holidays (red calendar)

Case study

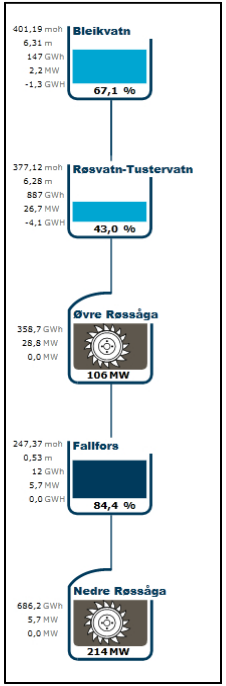
Name: **Leirdøla**
Capacity: 184 GWh
Degree of reg.: 0.4

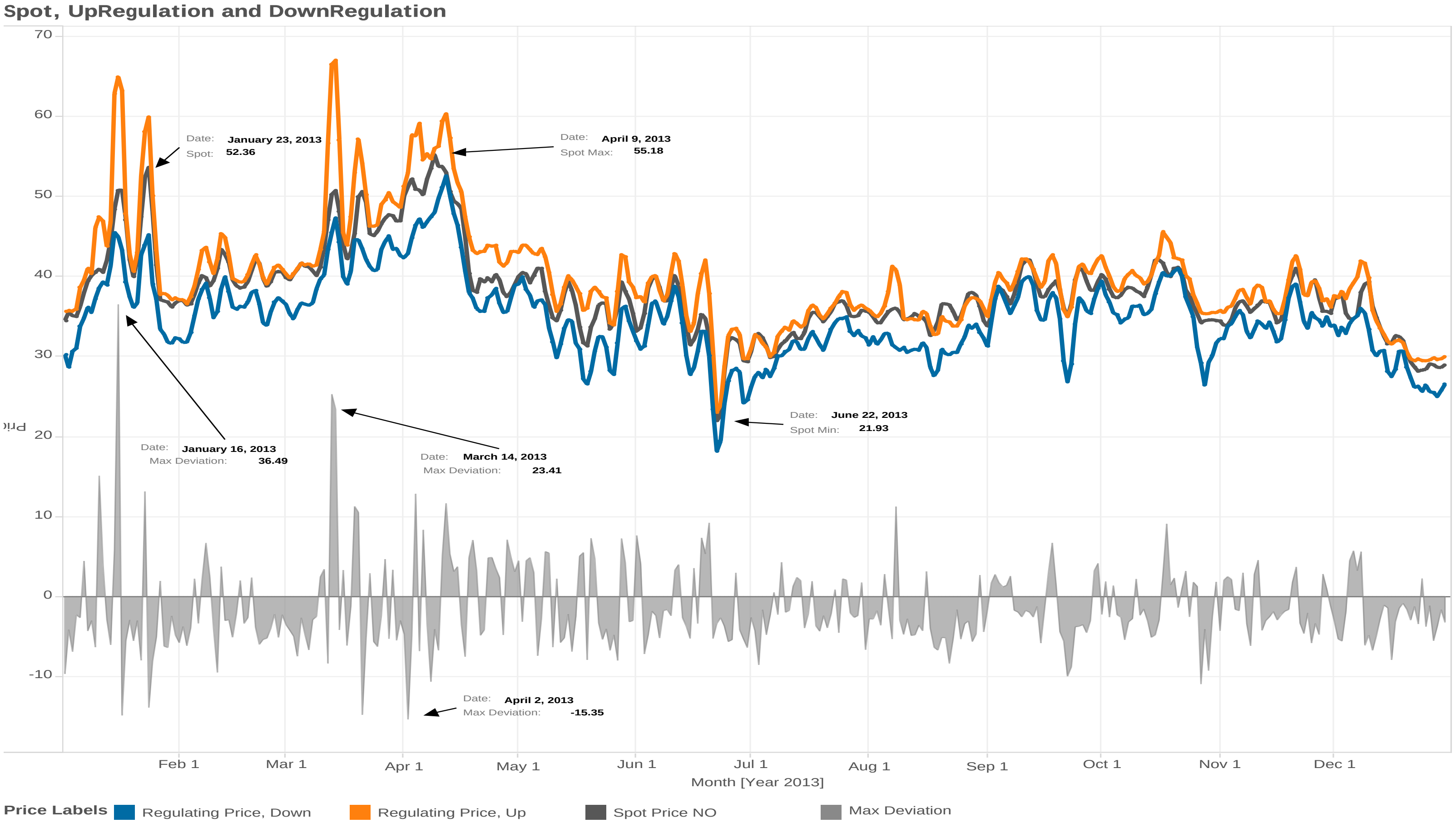


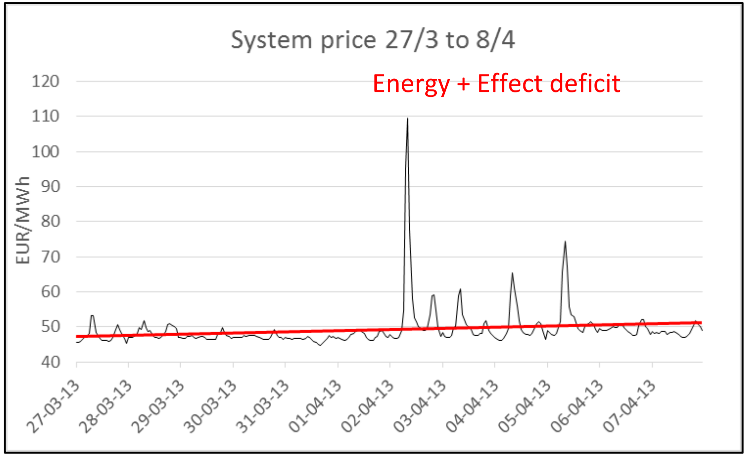
Name: **Vik**
Capacity: 413 GWh
Degree of reg.: 0 – 0.5

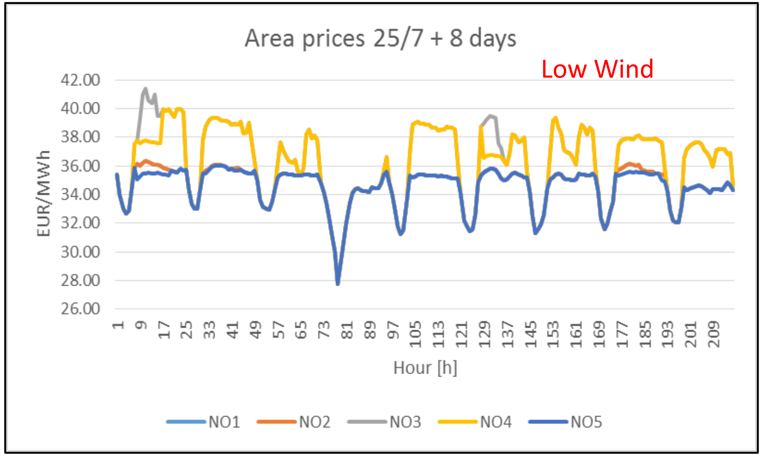


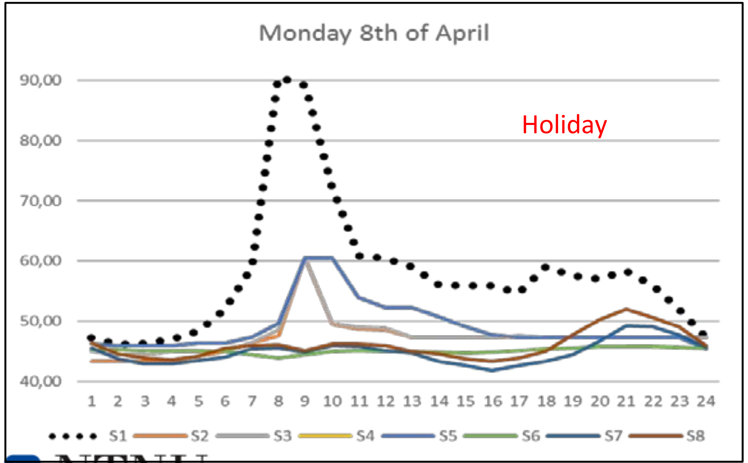
Name: **Røssåga**
Capacity: 2245 GWh
Degree of reg.: 0.7 – 1.4

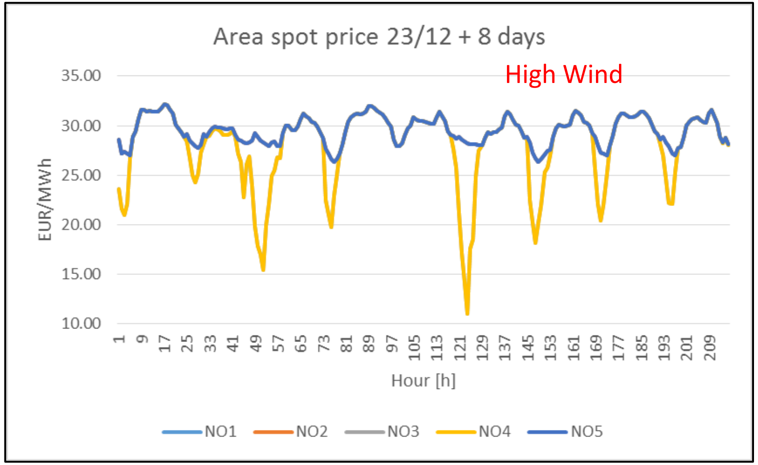



Spot, UpRegulation and DownRegulation
70
60
50
40
30
20
10
0
-10
Price
Date: January 23, 2013
Spot: 52.36
Date: April 9, 2013
Spot Max: 55.18
Date: June 22, 2013
Spot Min: 21.93
Date: January 16, 2013
Max Deviation: 36.49
Date: March 14, 2013
Max Deviation: 23.41
Date: April 2, 2013
Max Deviation: -15.35
Feb 1
Mar 1
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Month [Year 2013]
Price Labels
Regulating Price, Down
Regulating Price, Up
Spot Price NO
Max Deviation


System price 27/3 to 8/4
Energy + Effect deficit
EUR/MWh
120
110
100
90
80
70
60
50
40
27-03-13
28-03-13
29-03-13
30-03-13
31-03-13
01-04-13
02-04-13
03-04-13
04-04-13
05-04-13
06-04-13
07-04-13


Area prices 25/7 + 8 days
Low Wind
EUR/MWh
42.00
40.00
38.00
36.00
34.00
32.00
30.00
28.00
26.00
Hour [h]
NO1
NO2
NO3
NO4
NO5


Monday 8th of April
Holiday
90,00
80,00
70,00
60,00
50,00
40,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
S1
S2
S3
S4
S5
S6
S7
S8


Area spot price 23/12 + 8 days
High Wind
EUR/MWh
35.00
30.00
25.00
20.00
15.00
10.00
Hour [h]
NO1
NO2
NO3
NO4
NO5

Results – Price Uncertainty

- Income potential for river systems with..
  - Low flexibility
    - 0 % for systems operating near limits (e.g. low/high reservoir levels)
  - Higher flexibility (**without forecast information**)
    - 0.75 % (low capacity) to..
    - 1.78 % (high capcity)
  - Higher flexibility (**with forecast information**)
    - 0.05 % (low capacity) to..
    - 0.24 % (high capcity)
    - ..also more dependent on price level and price volatility

- Income potential for price areas
  - Spans from 0.14 % (NO3) to 1.47 % (NO2)

Results – Inflow Uncertainty (Leirdøla)

- Zero value for day-ahead operations
  - ..as long as the system has enough capacity to store the expected inflow

- About 0.69 % income potential (maximum)
  - ..when the water level is near its higher limits (spillage risk)

- But how likely is actually «extreme» inflow scenarios (compared with «extreme» price scenarios)?
  - 40 % price deviations VS 100 m3/s @ Leirdøla

THANK YOU!

Future work

- Same analysis, but over a longer operational period
  - Capture positive and negative concidences over time
  - Ex: « A poor deciocion can turn out to be good, anyway..»

- Include intraday market (flexibility)

Use SHOP to evaluate LT strategies?

- With respect to water values during energy surplus/deficit
  - SHOP can calculate max/min contribution to the supply side in the market
  - Reveal forced production (not accounted for in LT models)
    - Increase water value when unforeseen forced production?
    - How does this then affect the price level in the nearest future? Increase? (producers will most likely increase their sell bids..)

Use MC from SHOP as water value?

- Upfront flood- and inflow seasons where LT guiding is sensititve to ST decisions and weather
  - Do a multi-scenario price optimizations and weight the MC
  - Indicate up- or downregulation of the LT water value

The river system's price sensitivity, defining the *feasible solution space for theoretical improvement potentials*. The average value is calculated between the maximum and minimum tangents.

Table 1 - The average theoretical improvement potential for the feasible solution space (between tangent values) in EUR and % of spot sales

Case	Leirdøla		Vik		Røssåga	
Feasible Solution Space	5,531	0.7480%	9,322	1.4670%	58,113	1.7825%

The river system's *seasonal variations and price forecast's improvement potential*. Average values of the price forecasts S2 to S8.

Table 2 - The average theoretical improvement potential for the seasonal variations, in EUR and % of spot sales

Case	Leirdøla		Vik		Røssåga	
High reservoir levels, January	353	0.0915%	453	0.0628%	414	0.0150%
Low reservoir levels, May	895	0.6738%	35	0.0187%	1,391	0.0582%
Medium reservoir levels, July	545	0.0823%	574	0.0993%	2,142	0.0927%
Average	**598**	**0.2826%**	**354**	**0.0603%**	**1,316**	**0.0553%**

The river systems analysed in the price volatility cases, representing *price forecast's improvement potential*. Calculated as average values of the price scenarios S2 to S8.

Table 1 - Summary of the price volatility cases, average theoretical improvement potential in EUR and % of spot sales

Case	Leirdøla		Vik		Røssåga	
Low volatility, low price	0	0.0000%	127	0.0175%	109.155	0.0044%
Low volatility, high price	0	0.0000%	776	0.0957%	677	0.0180%
High volatility, low price	115	0.0247%	592	0.5330%	2,311	0.1136%
High volatility, high price	1,388	0.1877%	1,985	0.3124%	4,492	0.1352%
Average	**376**	**0.0531%**	**870**	**0.2397%**	**1,897**	**0.0678%**

The price areas analysed in the wind power cases, representing *price forecast's improvement potential*. Calculated as average values from the price scenarios S2 to S8.

Table 2 - Summary of the wind production cases, average theoretical improvement potential in EUR and % of spot sales

Case	NO2		NO3		NO4	
Low wind production (26/7)	95,139	1.4382%	1,167	0.0318%	4,991	0.0515%
High wind production (24/12)	122,705	1.4989%	6,026	0.2491%	22,354	0.2748%
Average	**108,922**	**1.4685%**	**3,597**	**0.1404%**	**13,672**	**0.1632%**