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MODELLING TUNNEL NETWORK FLOW AND MINIMUM PRESSURE HEIGHT IN SHORT-TERM HYDROPOWER SCHEDULING

Per Aaslid / Sigri Scott Bale

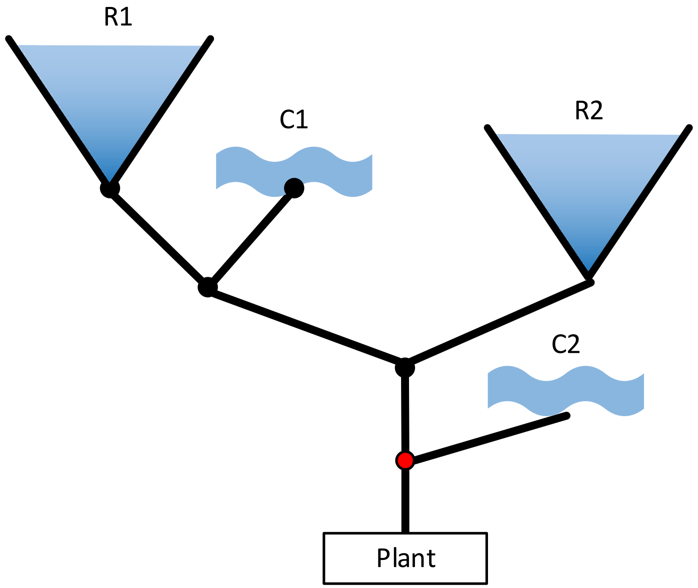
SINTEF Energy Research / Hydro Energi

Outline of the presentation

1. Motivation and relation to other functionality
2. Method
3. Real-world test cases
4. Conclusions and further work

Motivation

- Multiple reservoirs and creek connected through a tunnel network
- New operating patterns and capacity expansion
- Operational constraints due to pressure restrictions in tunnels (caused by surge chambers, sedimentation basins)



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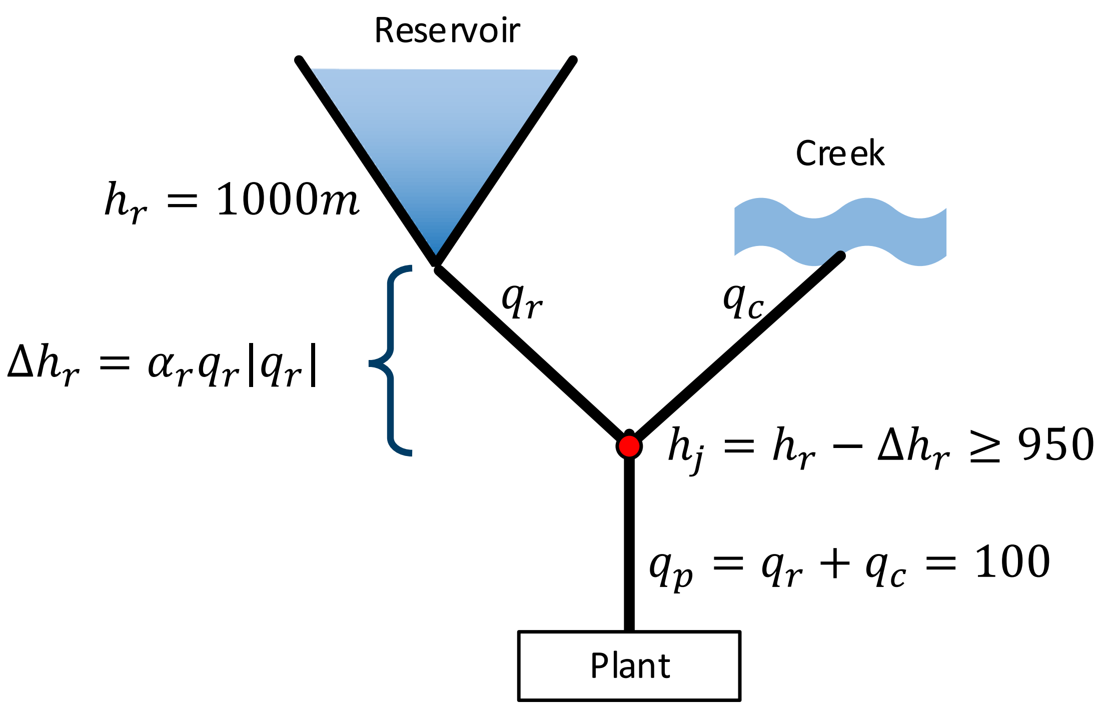
Example

Case	q_r	q_c	Δh_r	h_j
Low creek inflow	100	0	100	900
Medium creek inflow	50	50	25	975
High creek inflow	0	100	0	1000



Why is this important for hydro scheduling?

- Plant production is limited by current reservoir level and creek inflow
- Can we reduce the production in the hours where the minimum pressure constraint is violated?

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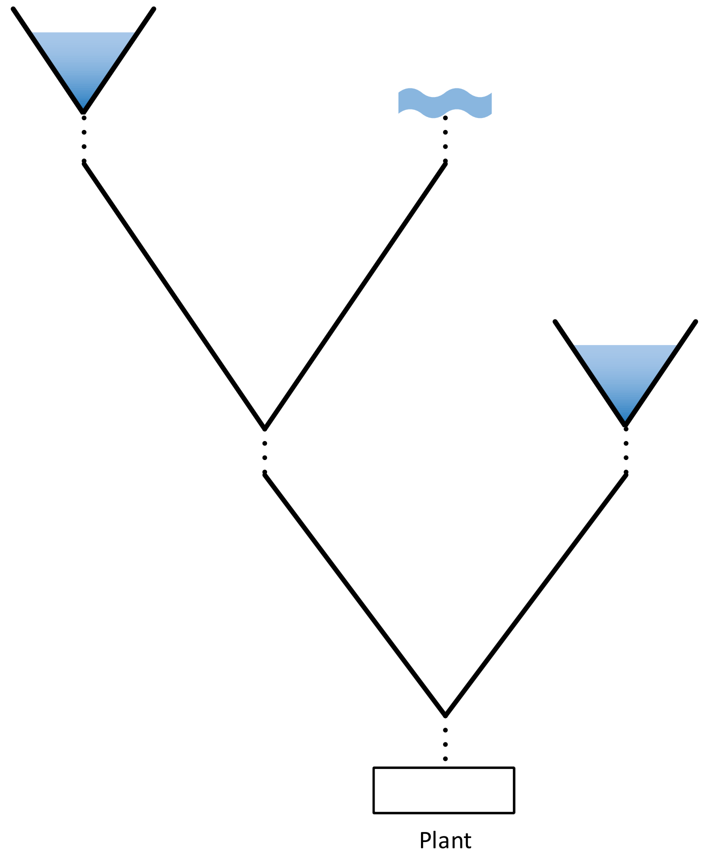
Goal

- Develop a *flexible* method for detailed modelling of complex hydropower tunnel networks in SHOP (Short-term Hydropower Optimization Program)
- Incorporate modelling of general pressure constraints in the tunnel networks



Junction flow physics

- Mass balance:

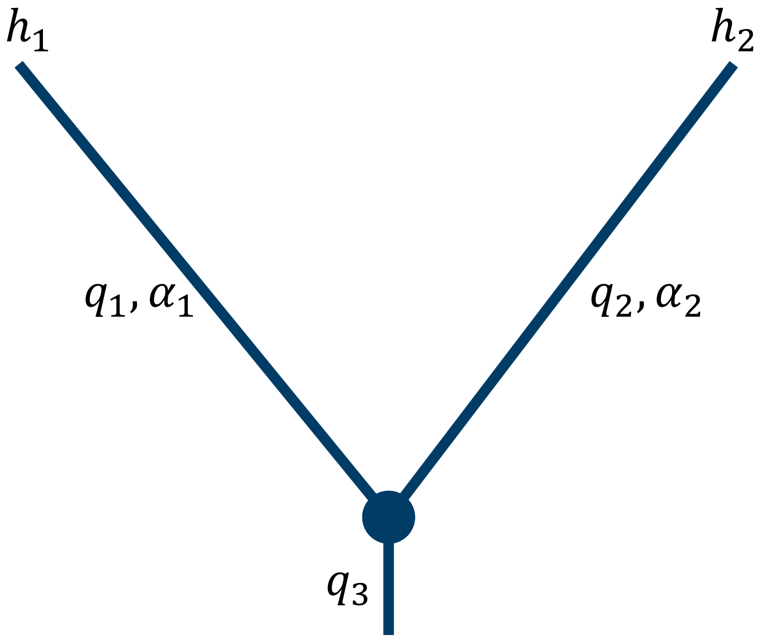
$$q_1 + q_2 = q_3$$

- Tunnel loss:

$$\Delta h = \alpha q|q|$$

- Pressure balance:

$$h_1 - \alpha_1 q_1|q_1| = h_2 - \alpha_2 q_2|q_2|$$

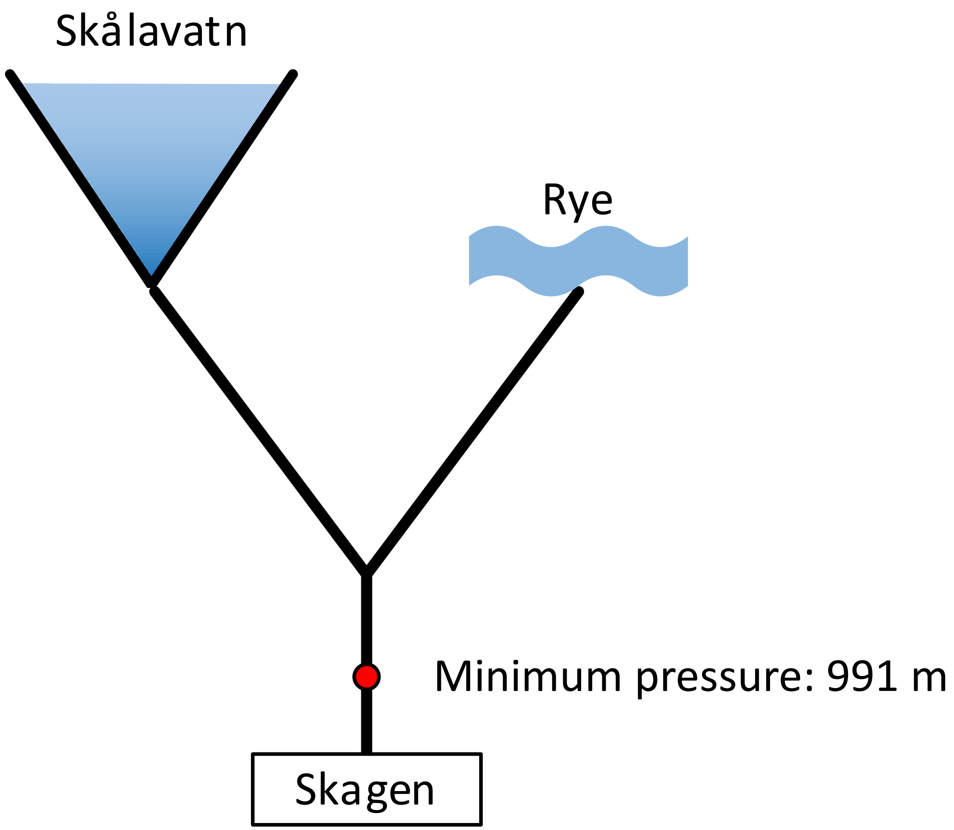


Methodology characteristics

- Two inputs to each junction, but allow junctions to be stacked
- Linearization around working point from previous iteration
- Implemented without use of binary variables

Test case: Skagen – Hydro Energy

- Maximum production: 270 MW
- LRL/HRL: 988 m / 1013 m
- Volume: 21.5 Mm3
- Low inflow from creek intake in this case



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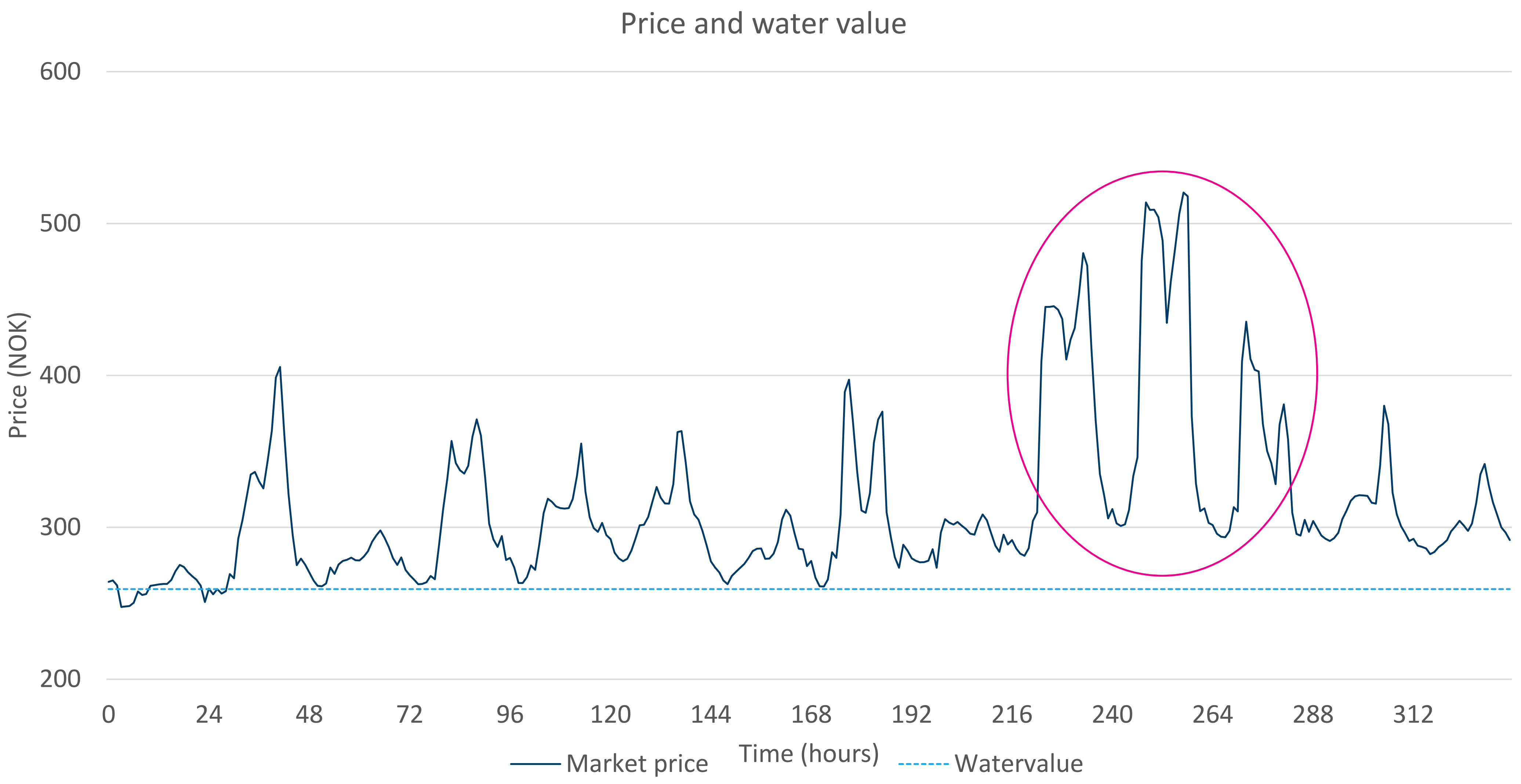
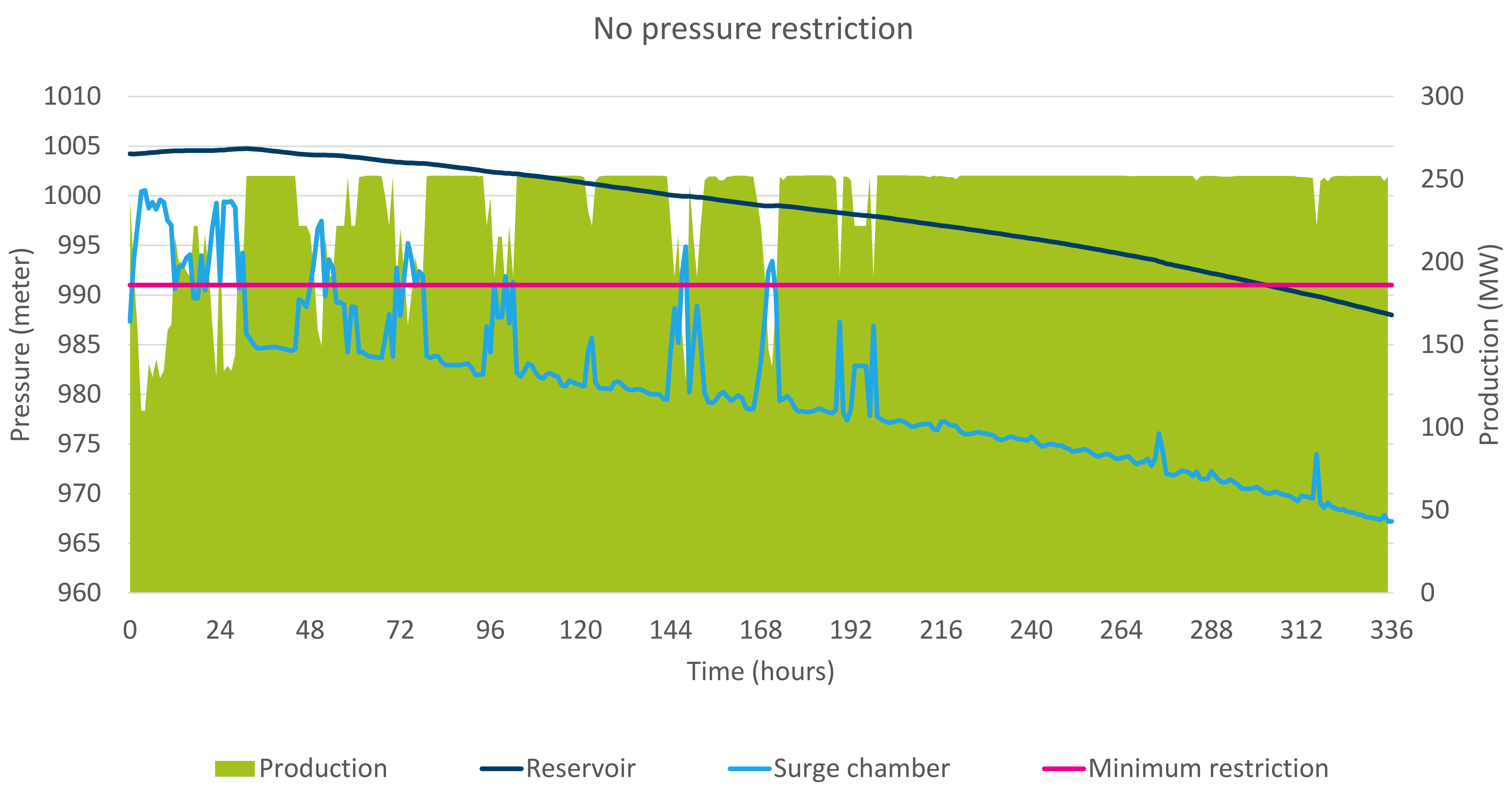
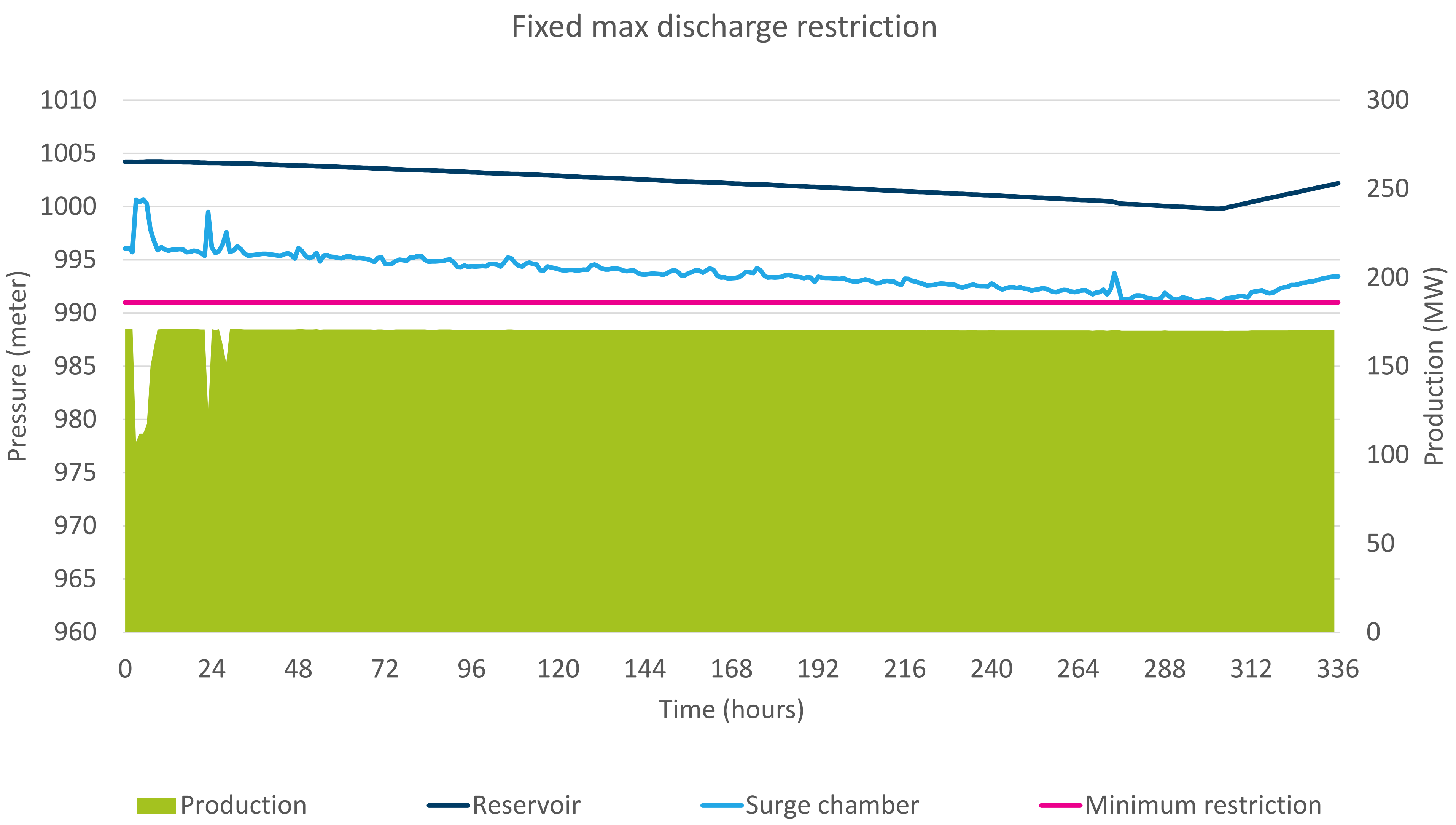
Comparison of methods

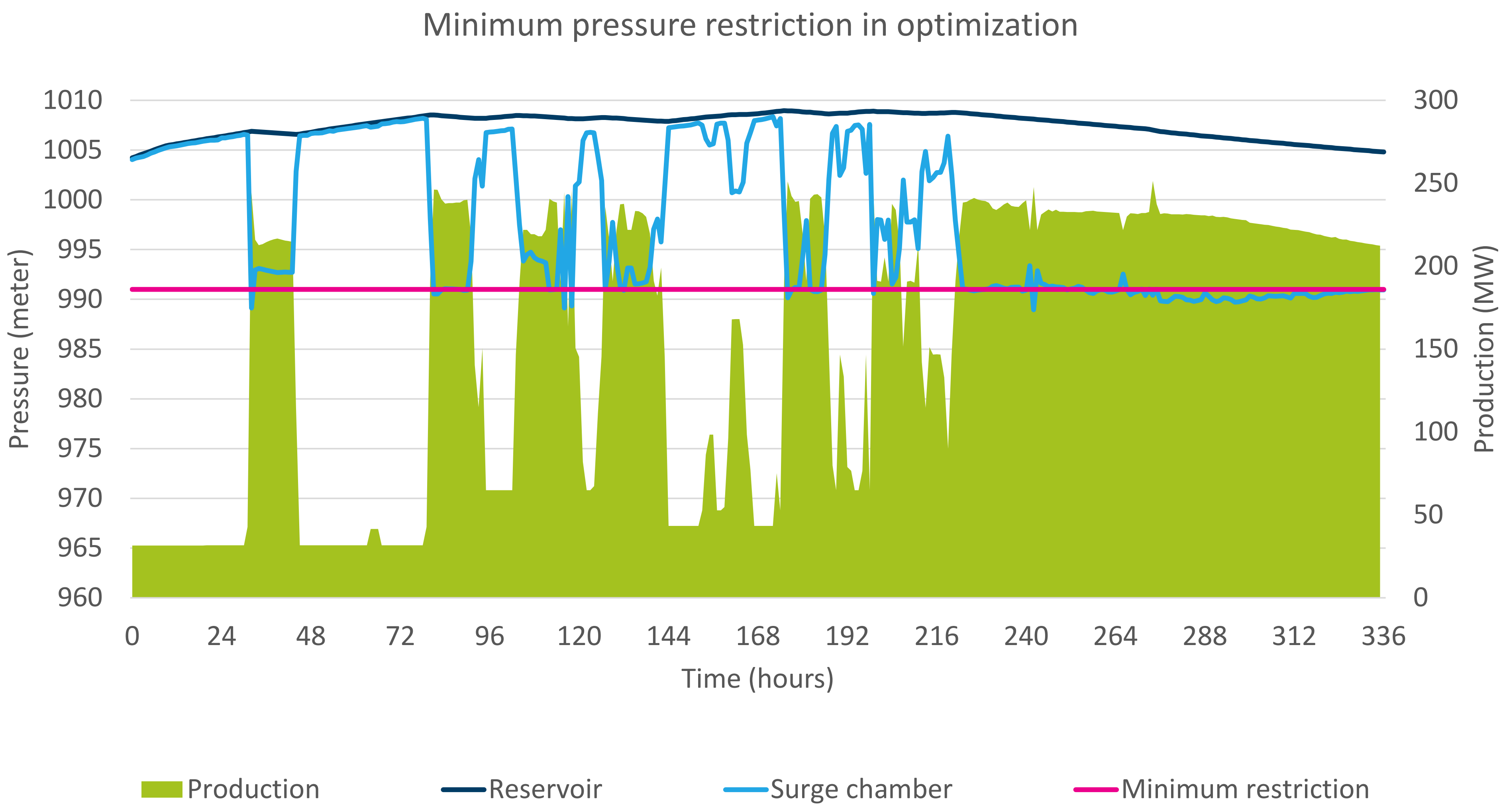
1. Optimization without pressure restriction
2. Optimization where max discharge restriction is applied to optimization if result is violating pressure restriction
3. Optimization with pressure restriction incorporated in SHOP


Price and water value
600
500
400
300
200
Price (NOK)
0
24
48
72
96
120
144
168
192
216
240
264
288
312
Time (hours)
Market price
Watervalue


No pressure restriction
Pressure (meter)
1010
1005
1000
995
990
985
980
975
970
965
960
Production (MW)
300
250
200
150
100
50
0
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
Time (hours)
Production
Reservoir
Surge chamber
Minimum restriction



Fixed max discharge restriction
Pressure (meter)
1010
1005
1000
995
990
985
980
975
970
965
960
Production (MW)
300
250
200
150
100
50
0
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
Time (hours)
Production
Reservoir
Surge chamber
Minimum restriction


Minimum pressure restriction in optimization
Pressure (meter)
1010
1005
1000
995
990
985
980
975
970
965
960
Production (MW)
300
250
200
150
100
50
0
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
Time (hours)
Production
Reservoir
Surge chamber
Minimum restriction

Comparison of results case 2 and 3

- Increased value of total sale: 3,3%
  - Reduction in total sale, but increase in value of remaining water
- Value of higher production capacity at end of horizon is not taken into account
- Relatively low impact on calculation time

Conclusion

- A new method for modelling tunnel networks and pressure constraints has been implemented
- It is in operational status for real-world cases
- Higher flexibility, superior scheduling strategies and improved computational efficiency compared to previous methods

Possible future work

- Optimizing gates in junctions (ongoing)
- Include pressure constraint modelling in mid-term model
- Optimize with stochastic inflow and/or price and varying length of short-term model

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Questions?

Teknologi for et bedre samfunn