5th International Workshop on Hydro Scheduling in Competitive Electricity Markets

Modelling Minimum Pressure Height in Short-Term Hydropower Production Planning

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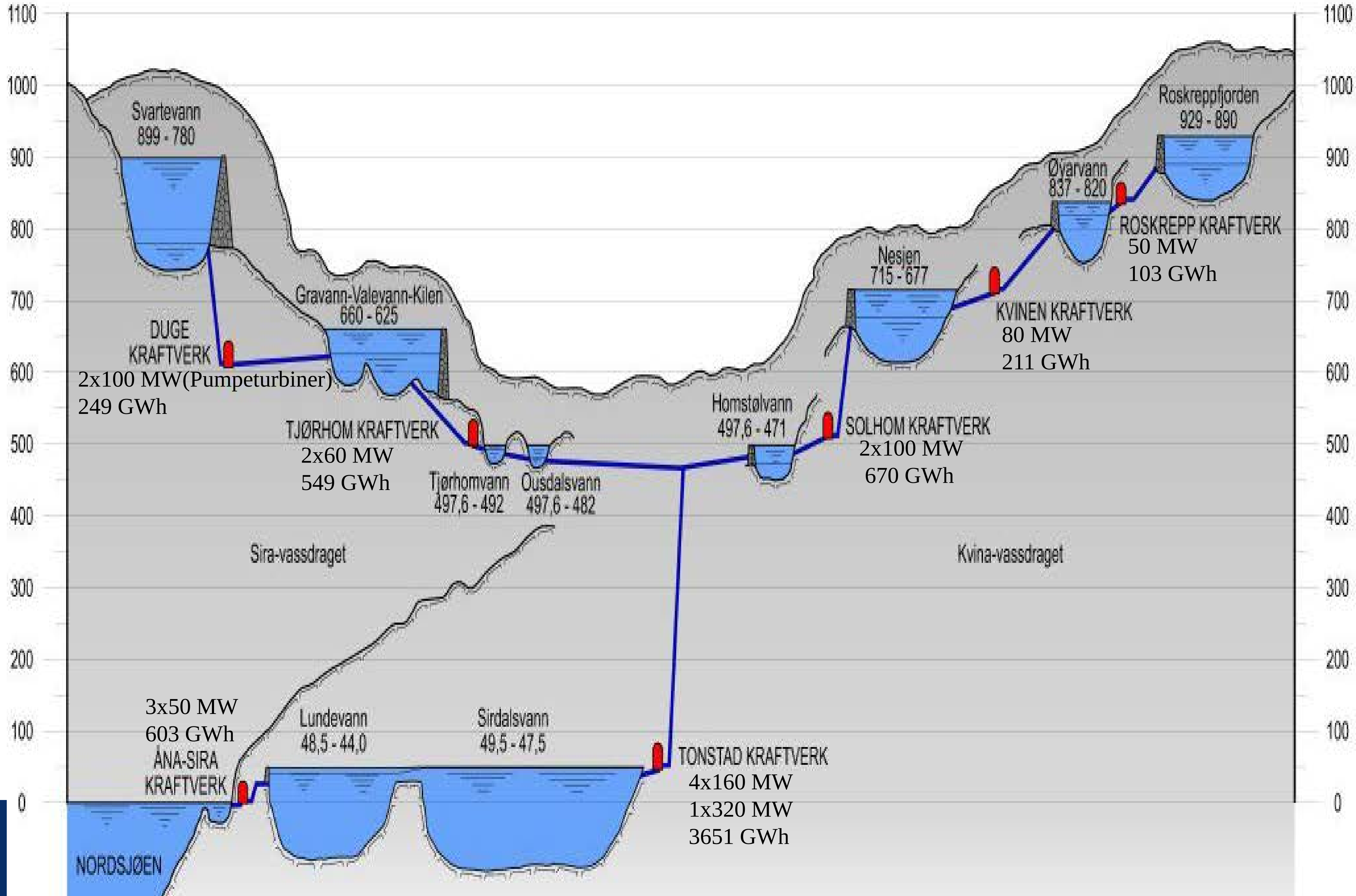
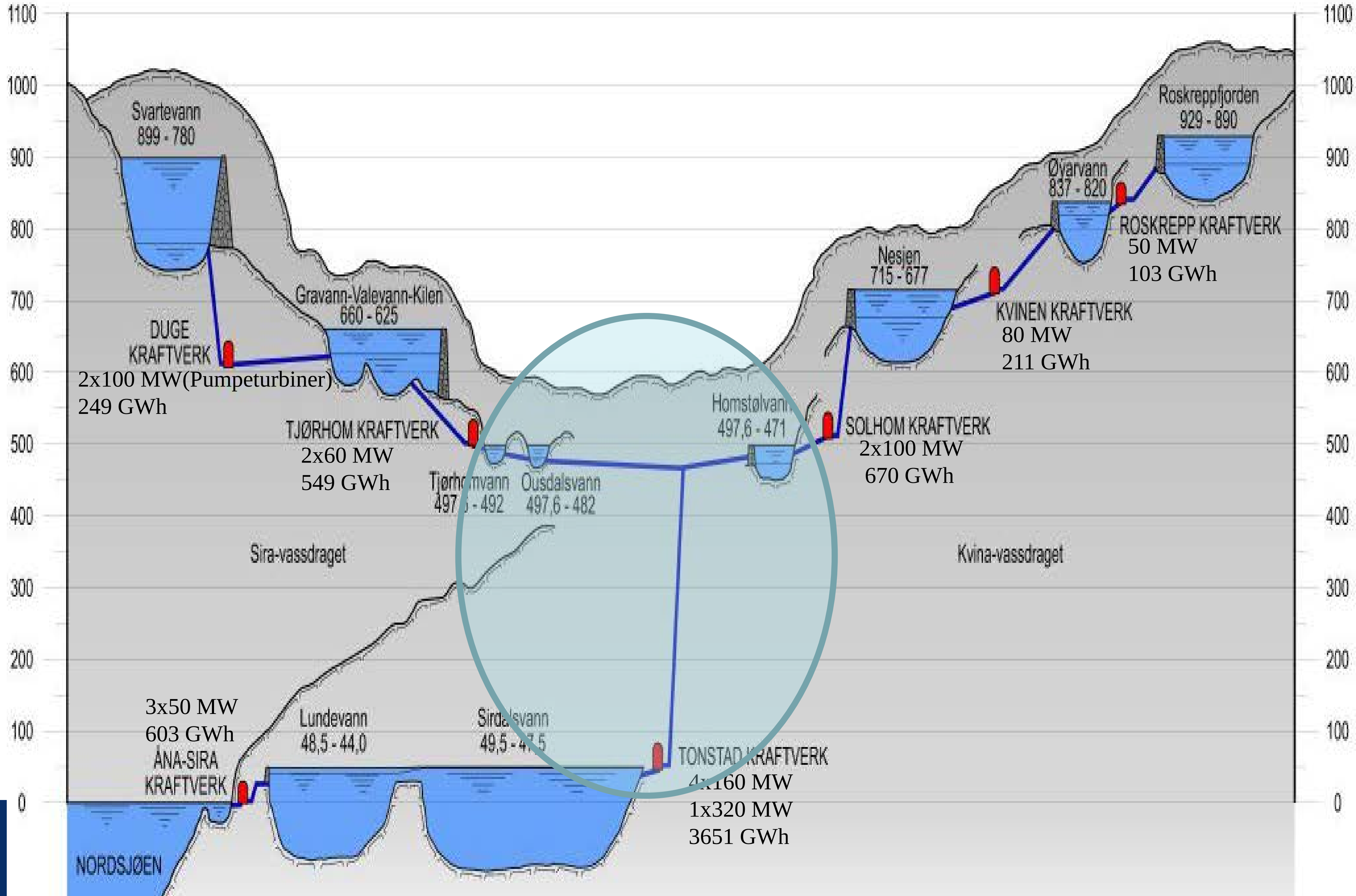
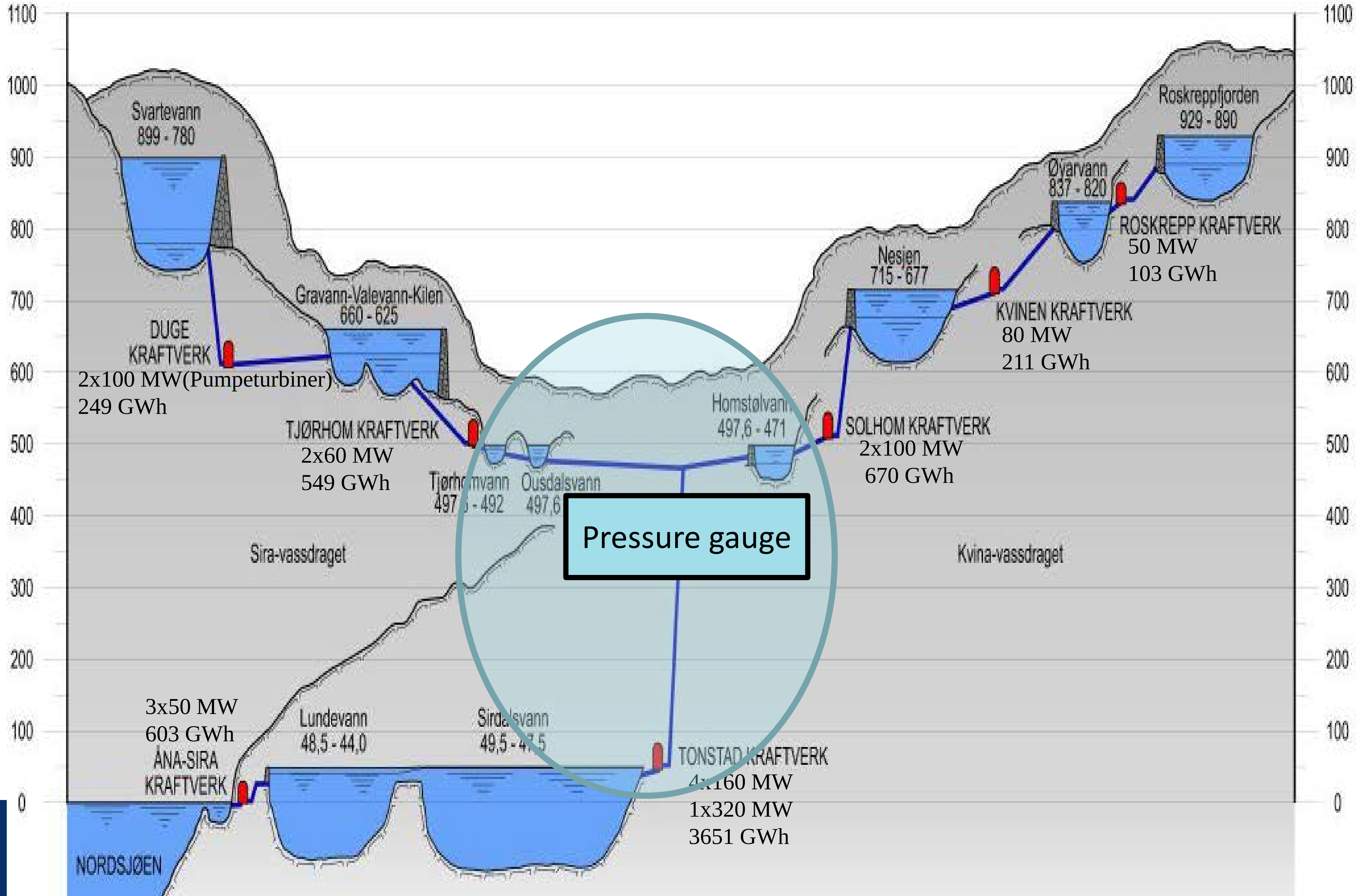
Sira-Kvina water system



Sira-Kvina water system



Sira-Kvina water system



Short-term hydropower scheduling

Short-term hydropower scheduling

Long-term Scheduling (1 - 5 years)
Aggregated system description
Stochastic models (inflow, price)

↓

Medium-term Scheduling (6 - 52 weeks)
Detailed system description
Inflow and price scenarios
Deterministic/stochastic models

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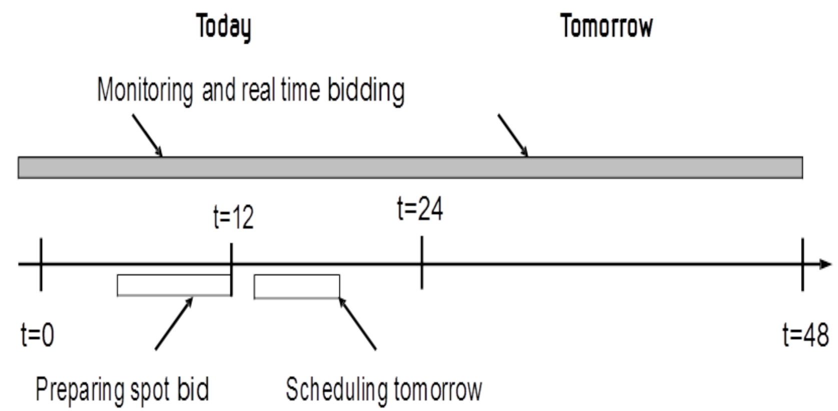
Short-term Scheduling (1 - 14 days)
Detailed system description with non-linearities
Deteministic models

Short-term hydropower scheduling

Long-term planning → Mid-term planning → Short-term planning



Short-term hydropower scheduling

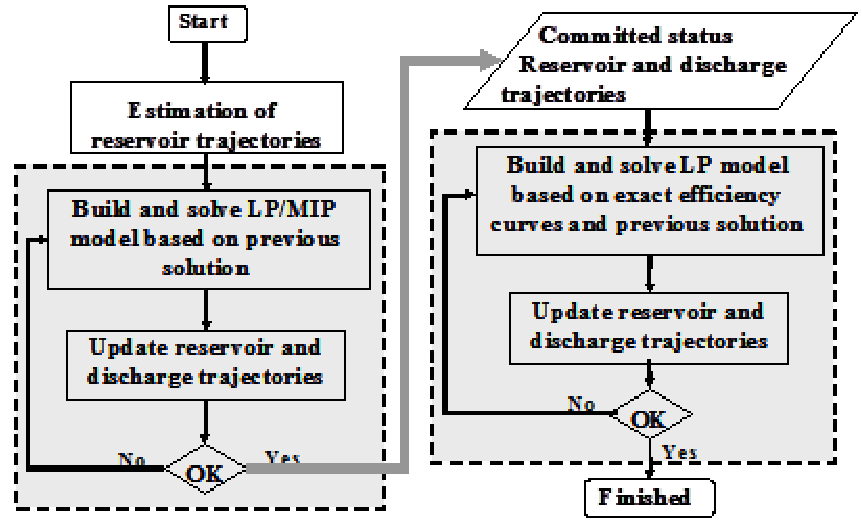
- Maximize income if market is present or minimize the cost for covering a load obligation ;
- Optimal generation schedules for the generation assets in the system;
- Find the exact balance between efficiency of the hydropower plants and the resource cost including the optimal unit commitment sequence.

Short-term hydropower scheduling

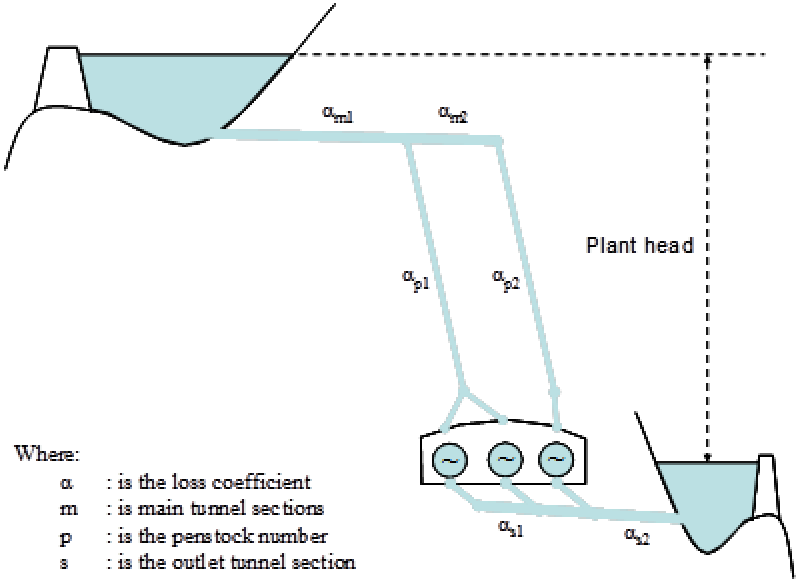
- Nonlinear problem with state dependency introduced by the relation between the reservoir levels and the decision variables;
- Linear programming, mixed integer programming.

Short-term hydropower scheduling

Full model <-> Incremental model



Short term hydro power scheduling



Short term hydro power scheduling

The optimal discharge from the plant depends on the plant efficiency.

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The efficiency depends on the net plant head.

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The net plant head depends on reservoir content up and downstream.

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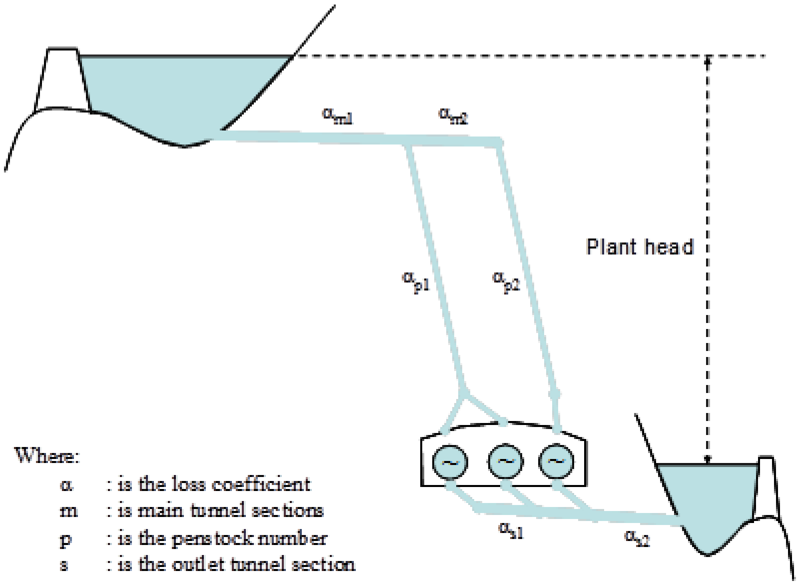
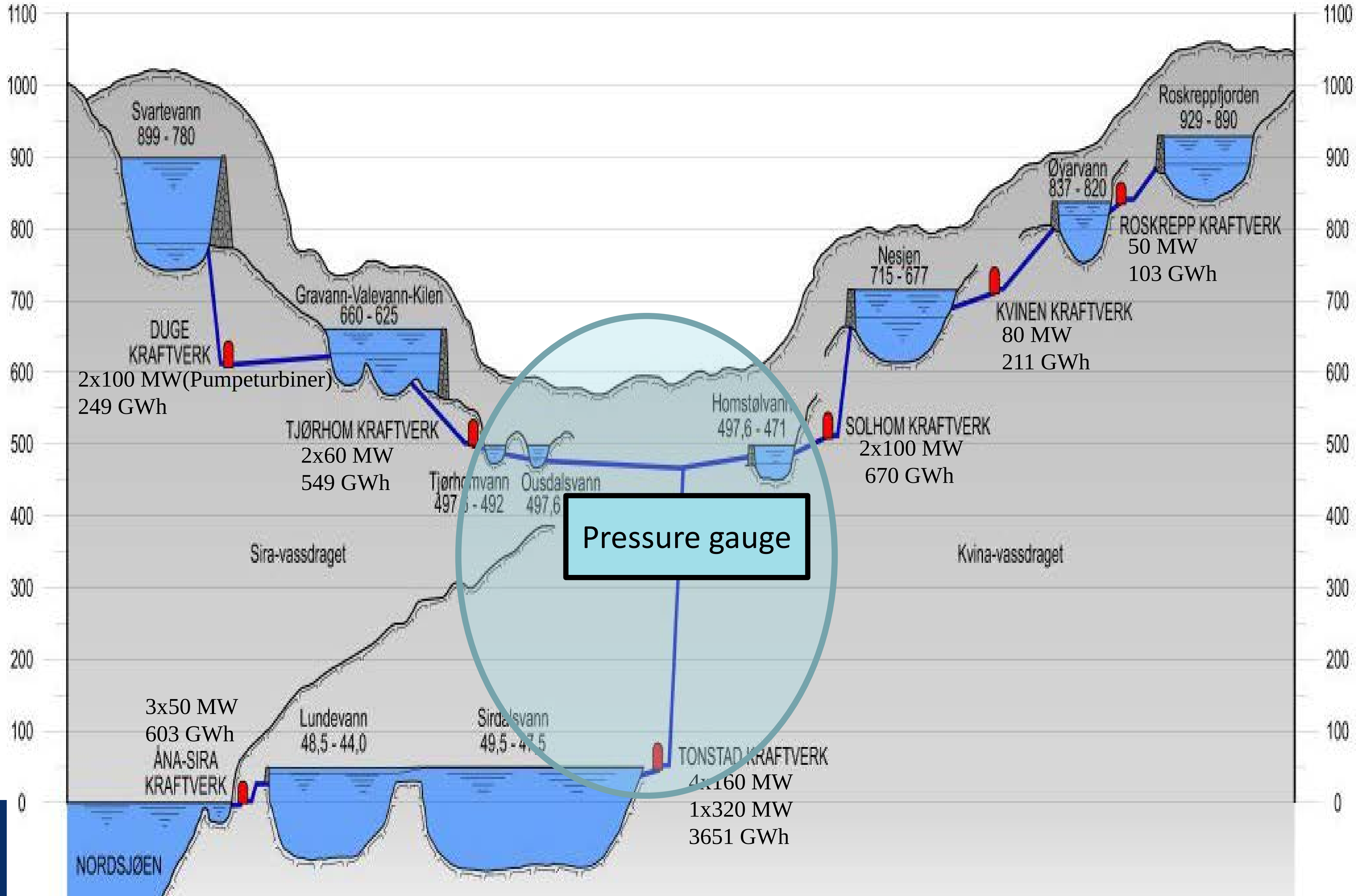
Reservoir content depends on the value of the decision variables (discharge).



Minimum pressure restriction above Tonstad



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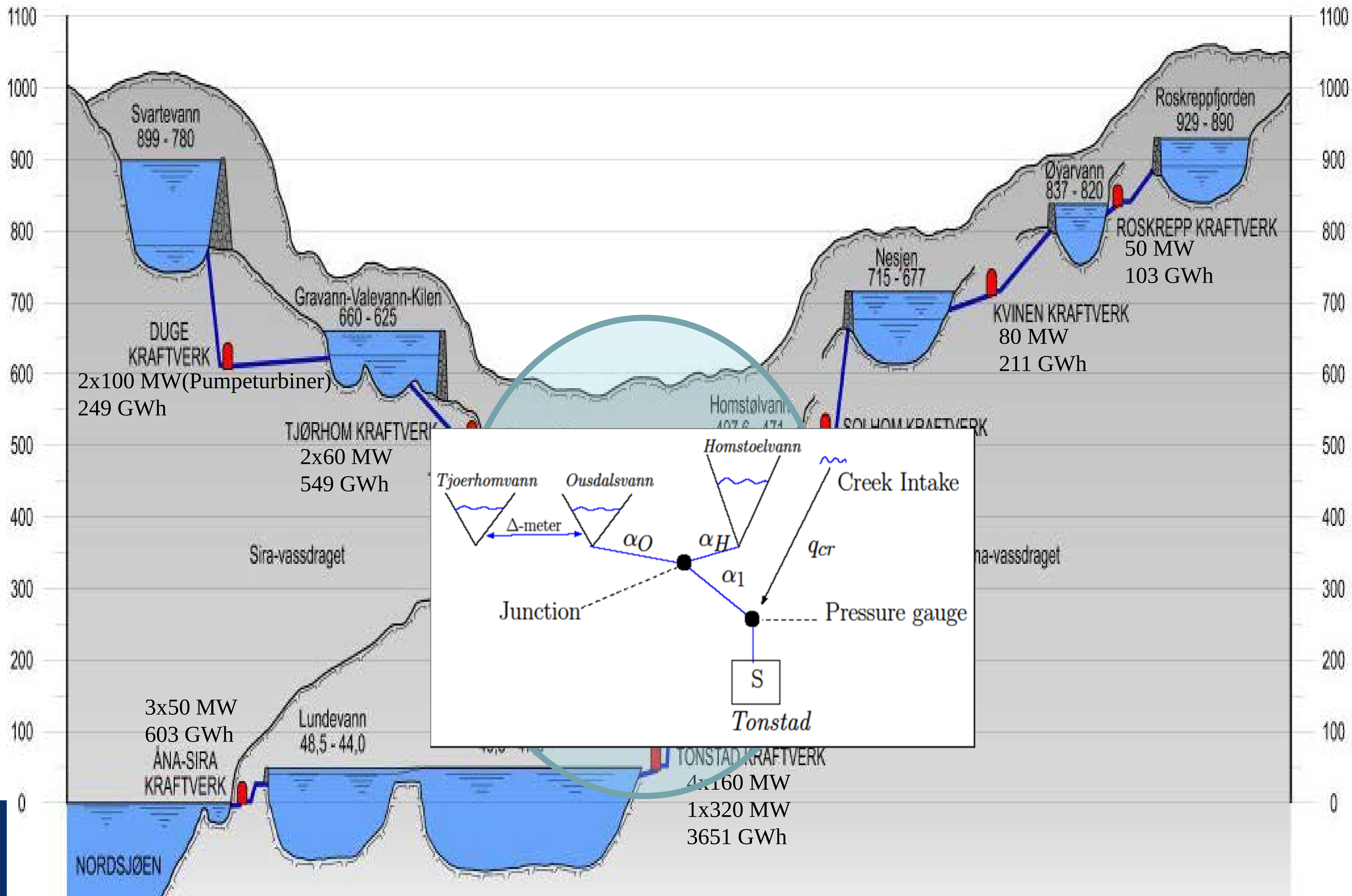
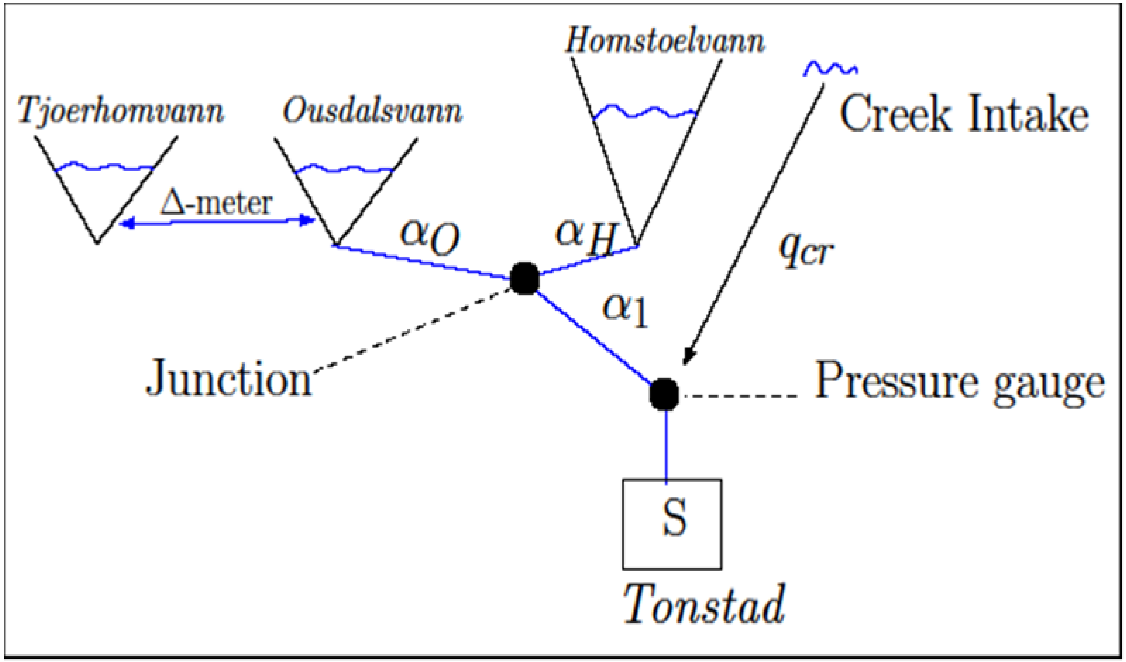
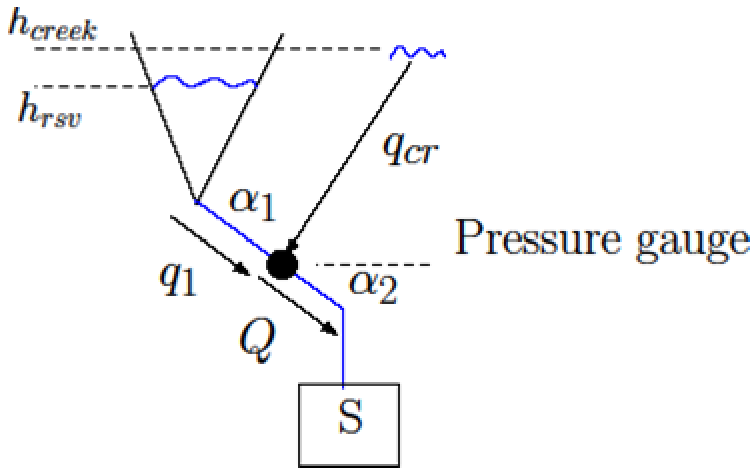


Minimum pressure restriction above Tonstad



Phase I : pressure gauge

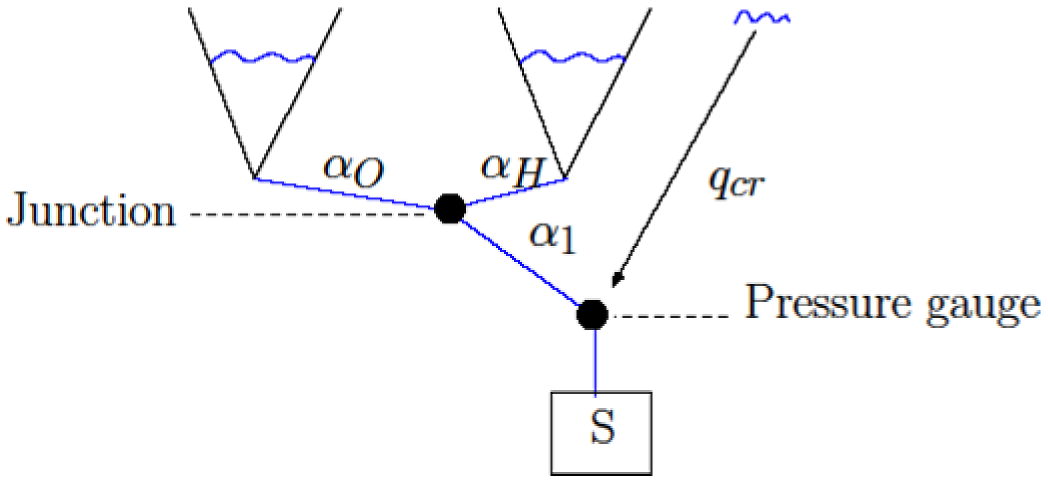


In the LP-model the following equation is linearized:

$$H_{min} \leq h_{rsv} - \alpha_1 \cdot (Q - q_{cr}) \cdot |Q - q_{cr}|$$

- q_cr is handled as fix inflow per time-step in the model .
- only the MIP model is implemented.
- The head loss is added to the busbar equation.

Phase II – Junction and pressure point



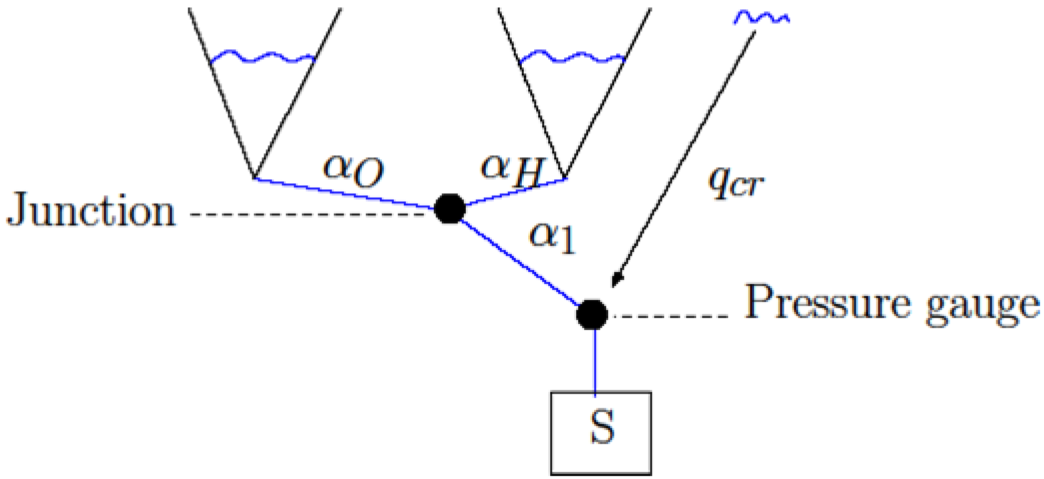
Junction:

$$h_O - \alpha_O \cdot Q_O \left|Q_O\right| = h_H - \alpha_H \cdot Q_H \left|Q_H\right|$$

Pressure point:

$$H_{min} \leq h_O - \alpha_O \cdot Q_O \left|Q_O\right| - \alpha_1 \cdot (Q - q_{cr}) \cdot \left|Q - q_{cr}\right|$$

Phase II – Junction and pressure point



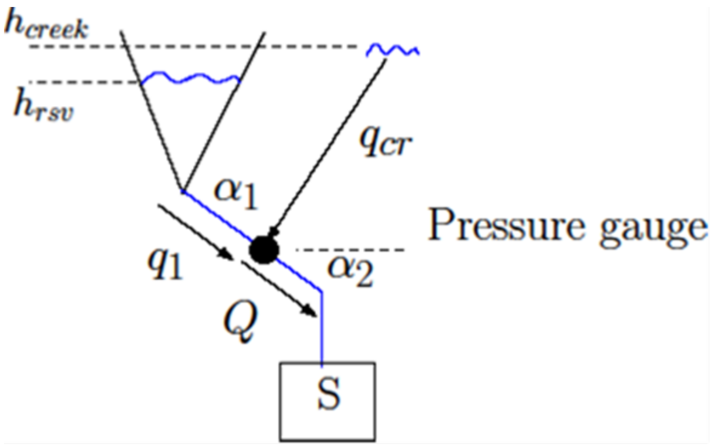
Pressure point:

$$H_{min} \le h_O - \alpha_O \cdot Q_O |Q_O| - \alpha_1 \cdot (Q - q_{cr}) \cdot |Q - q_{cr}| \quad (1)$$

$$H_{min} \le h_H - \alpha_H \cdot Q_H |Q_H| - \alpha_1 \cdot (Q - q_{cr}) \cdot |Q - q_{cr}| \quad (2)$$

Test results

Case I: Fulfilling pressure constraint



- Water value 66 NOK/MWh.
- Minimum pressure height 479 m.
- Installed capacity 960 MW (4x160MW + 1x320MW)

Test results

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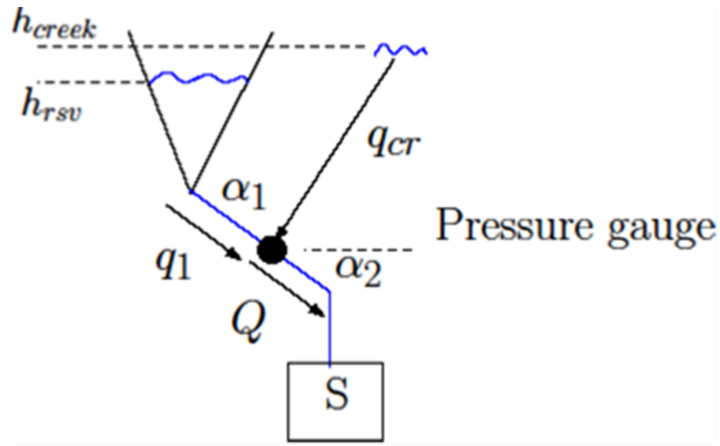

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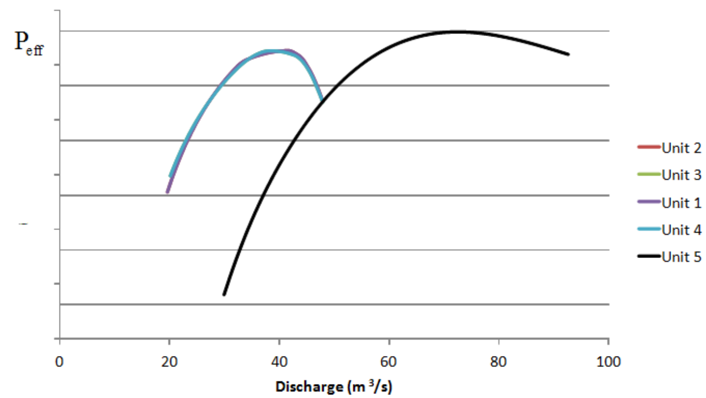

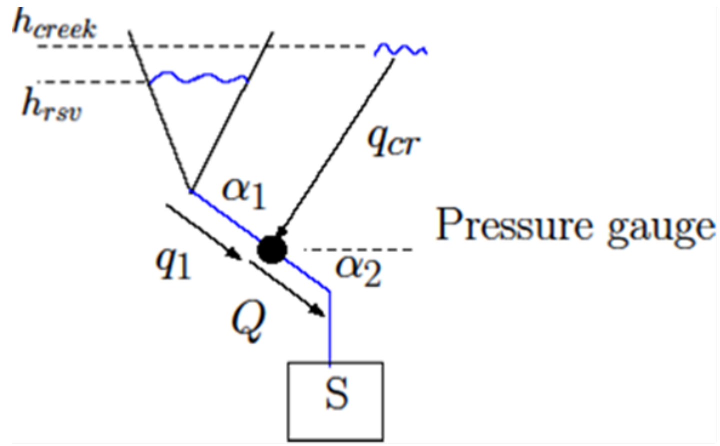

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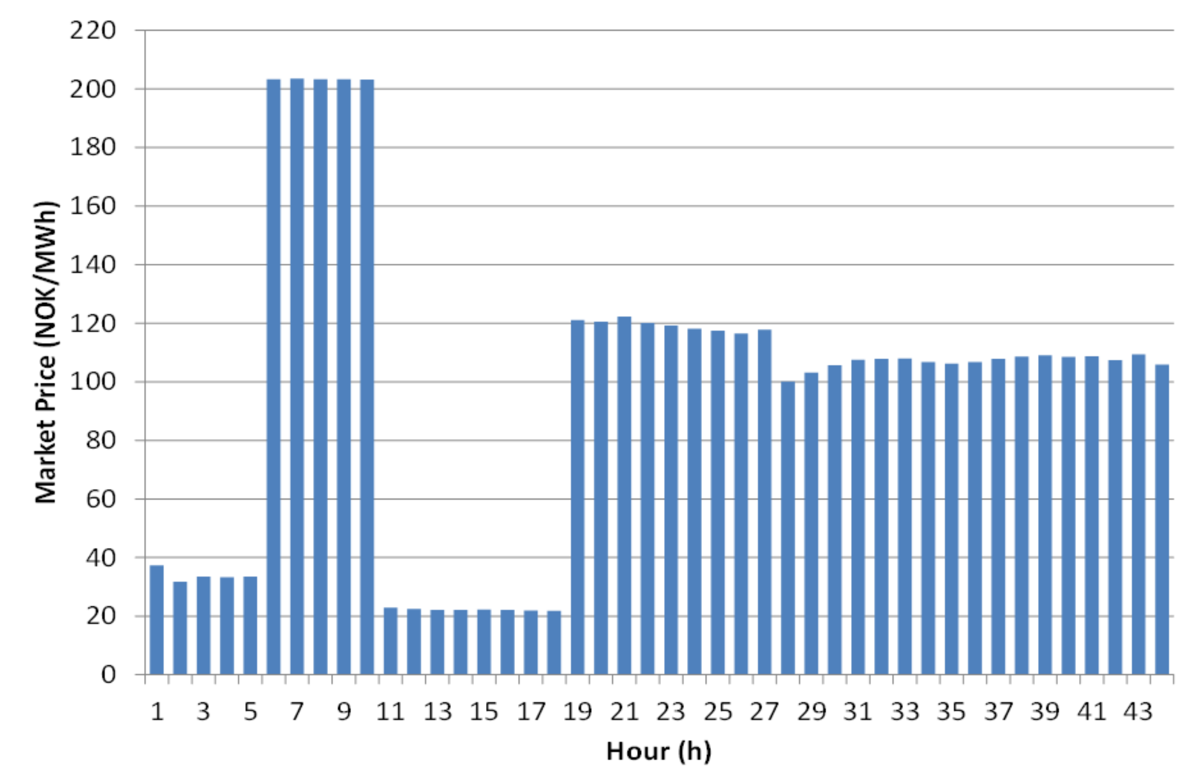

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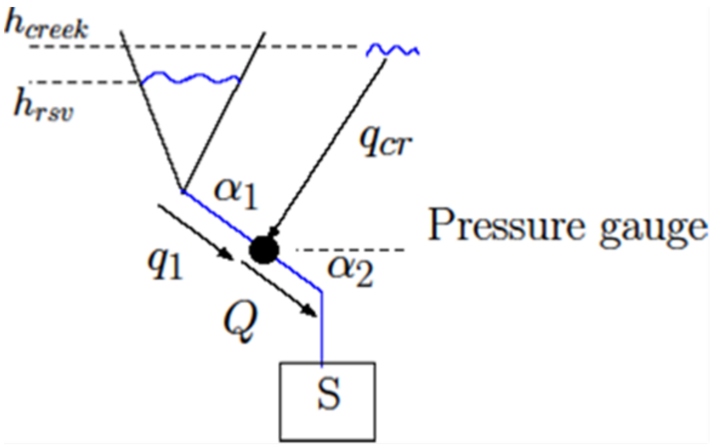

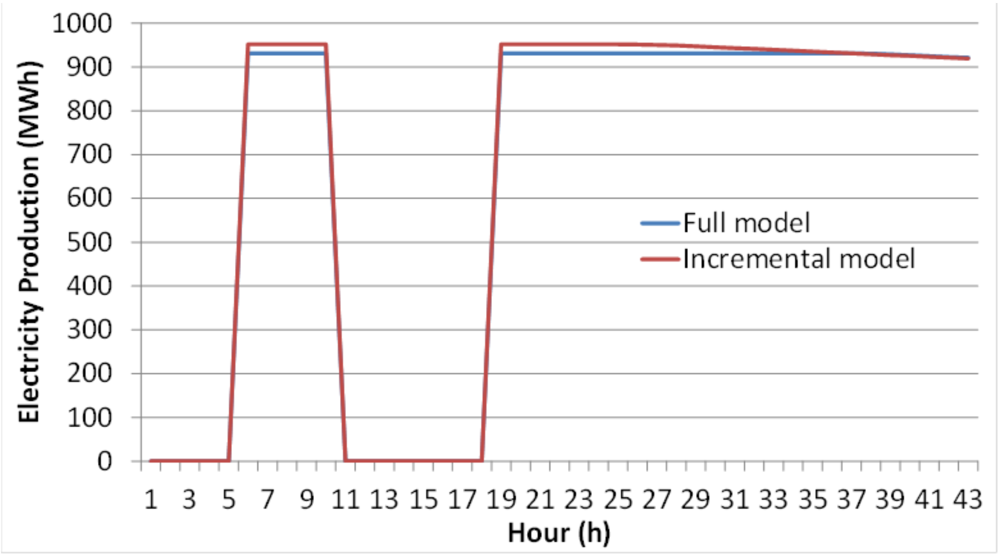

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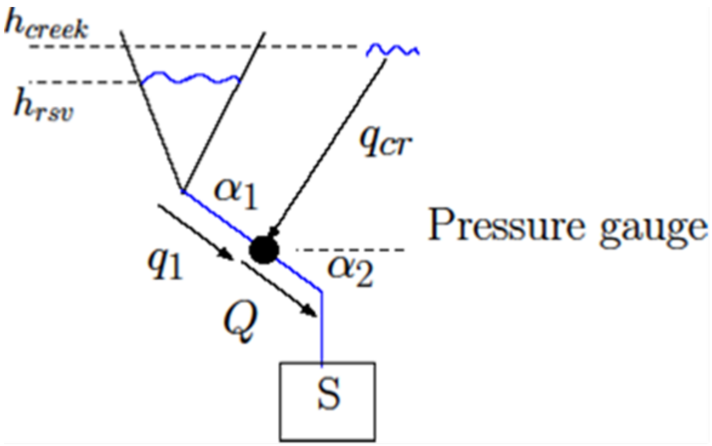
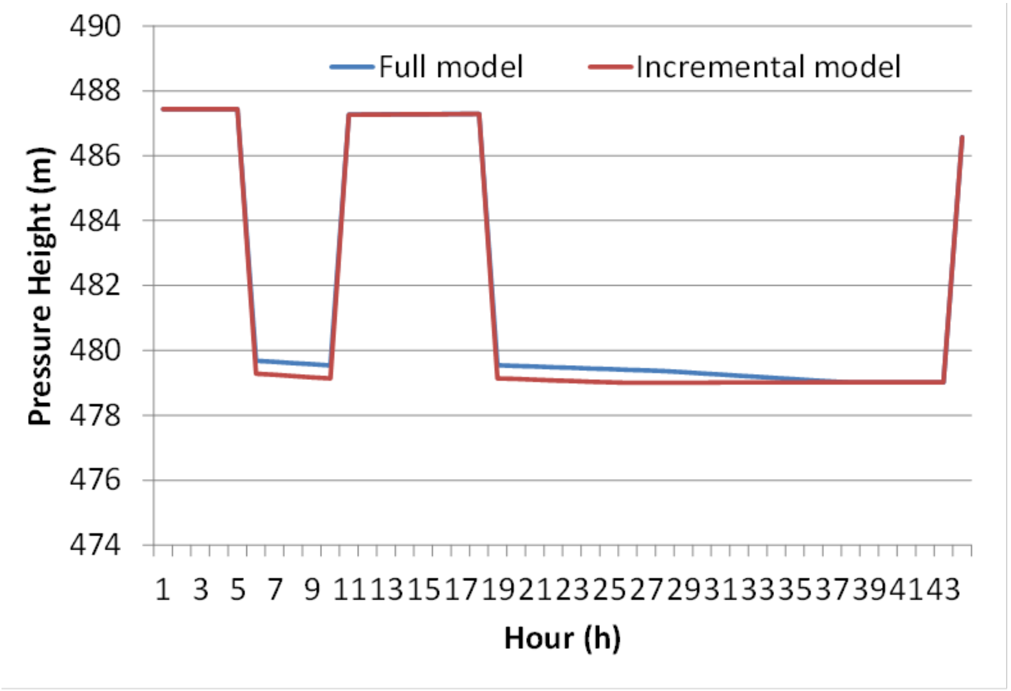
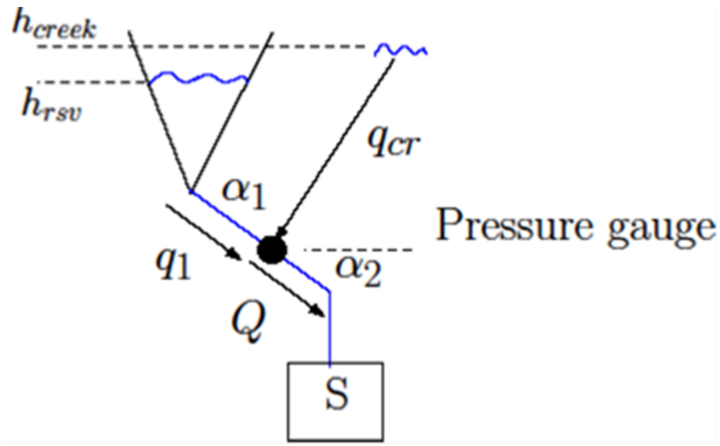


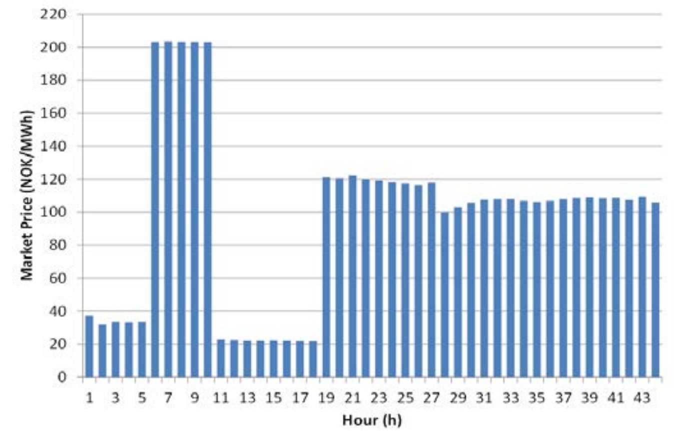


Test results

Case II: High production

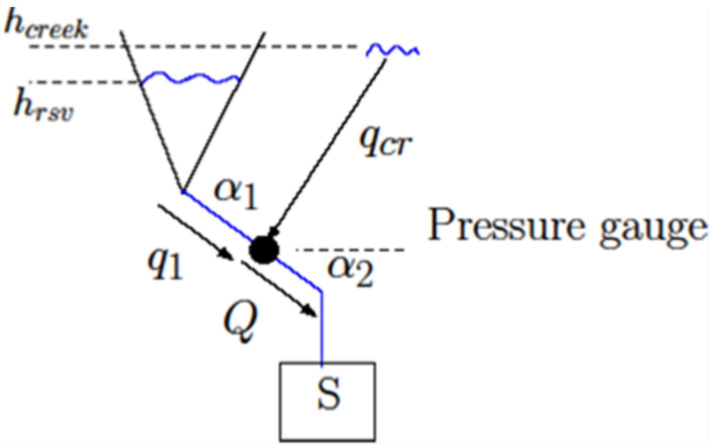


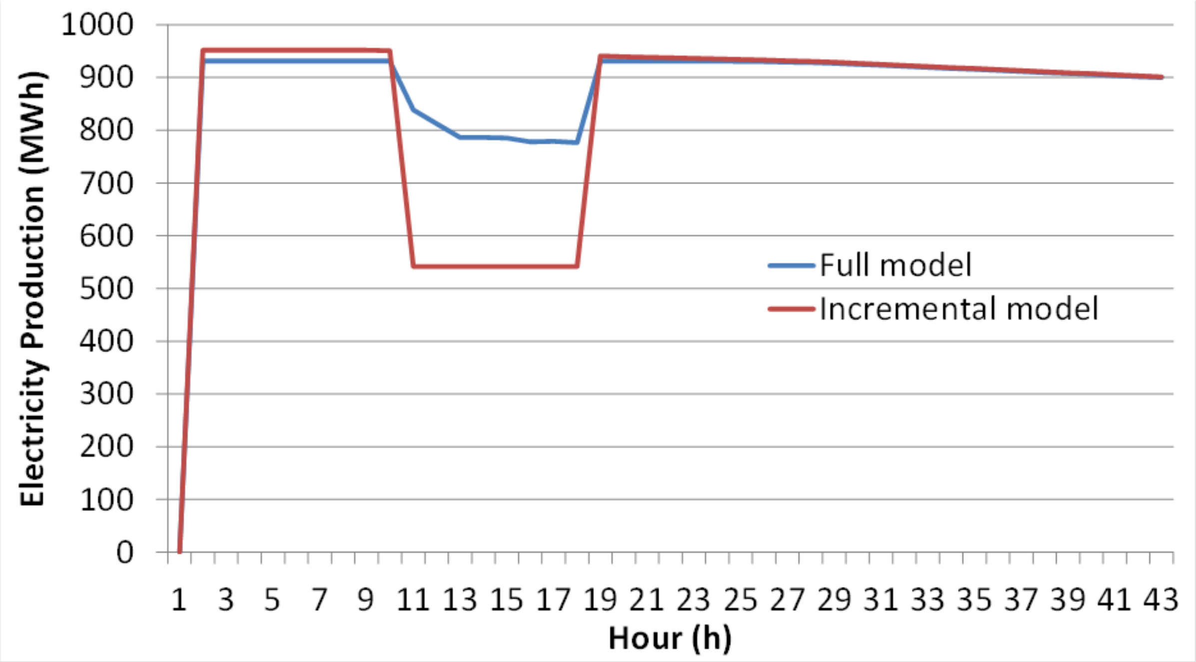
- Water value **20** NOK/MWh.
- Minimum pressure height 479 m.
- Installed capacity 960 MW (4x160MW + 1x320MW)



Test results

Case II: High production





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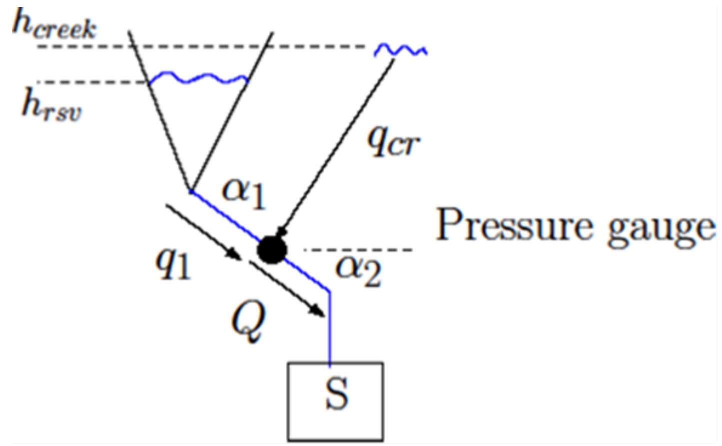
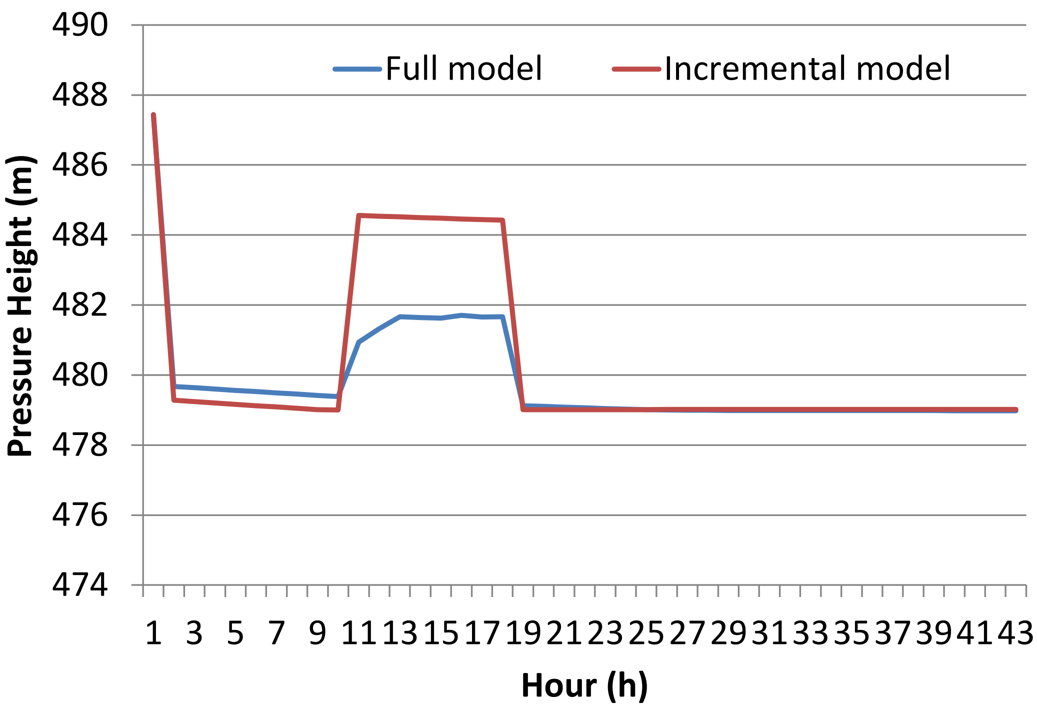
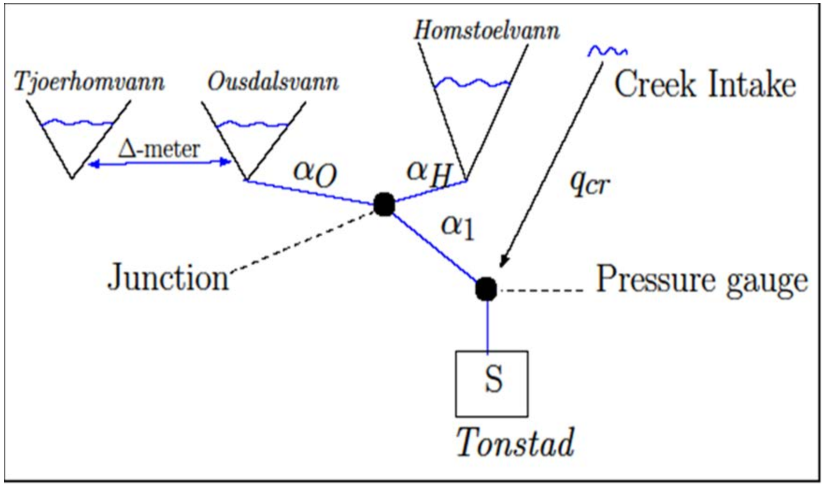
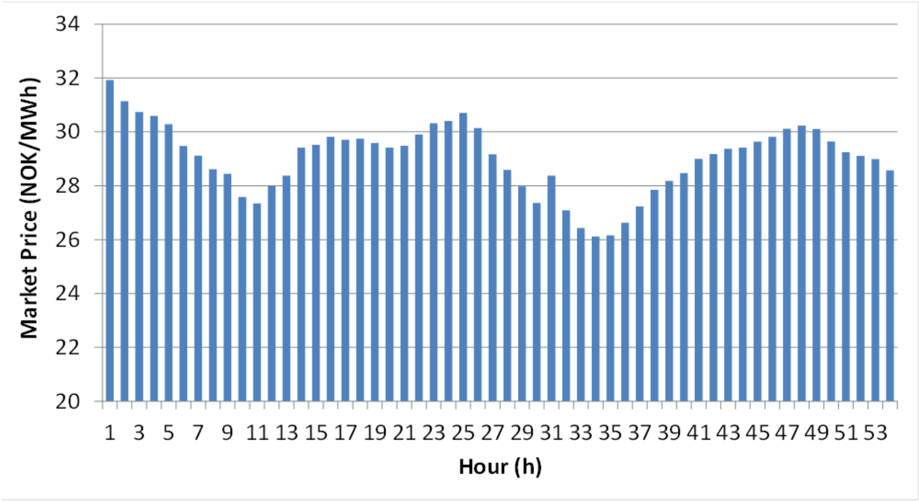




Case III: Minimum pressure below junction



- Water value 27.34 NOK/MWh in all the three reservoirs.
- Minimum pressure height **471** m.
- Installed capacity 960 MW (4x160MW + 1x320MW)



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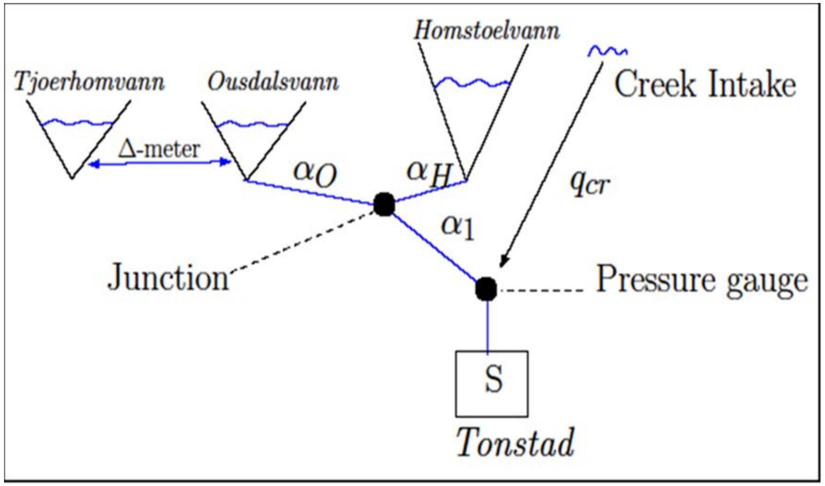

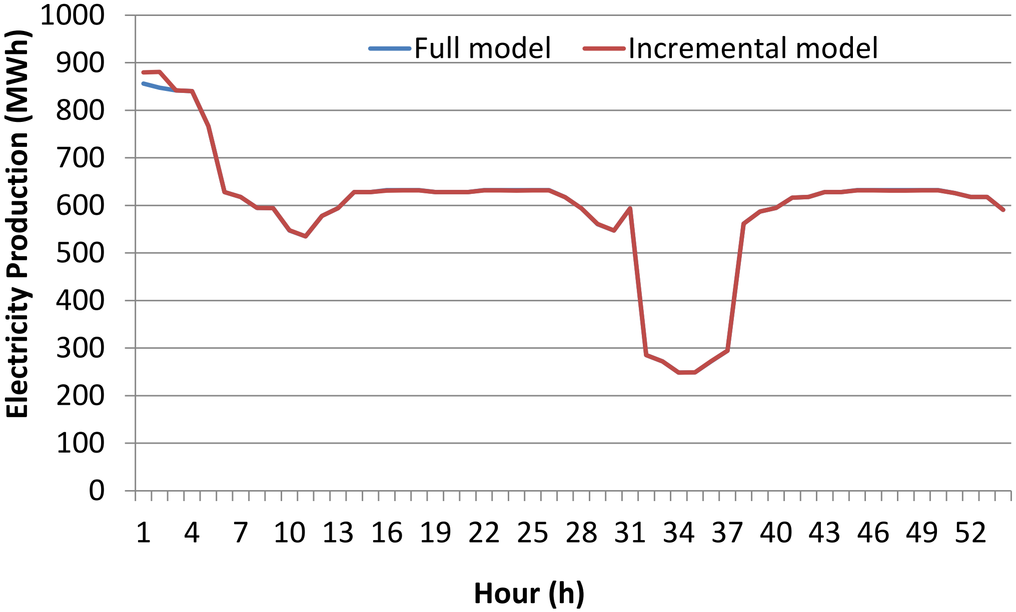

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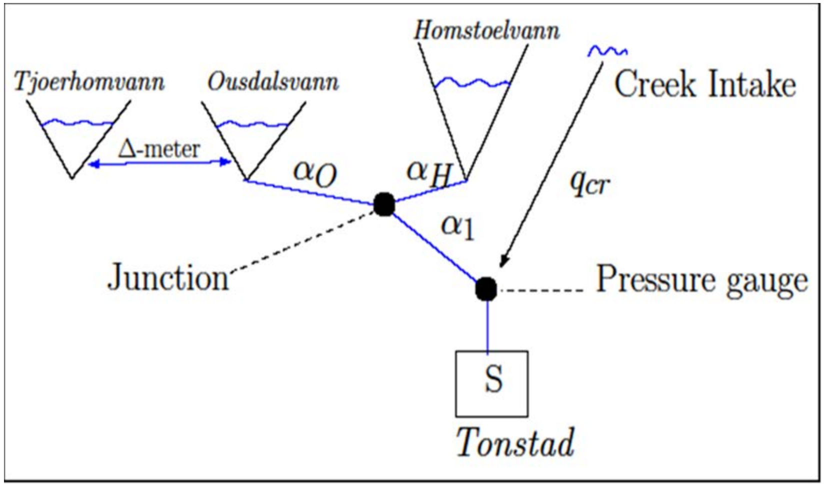

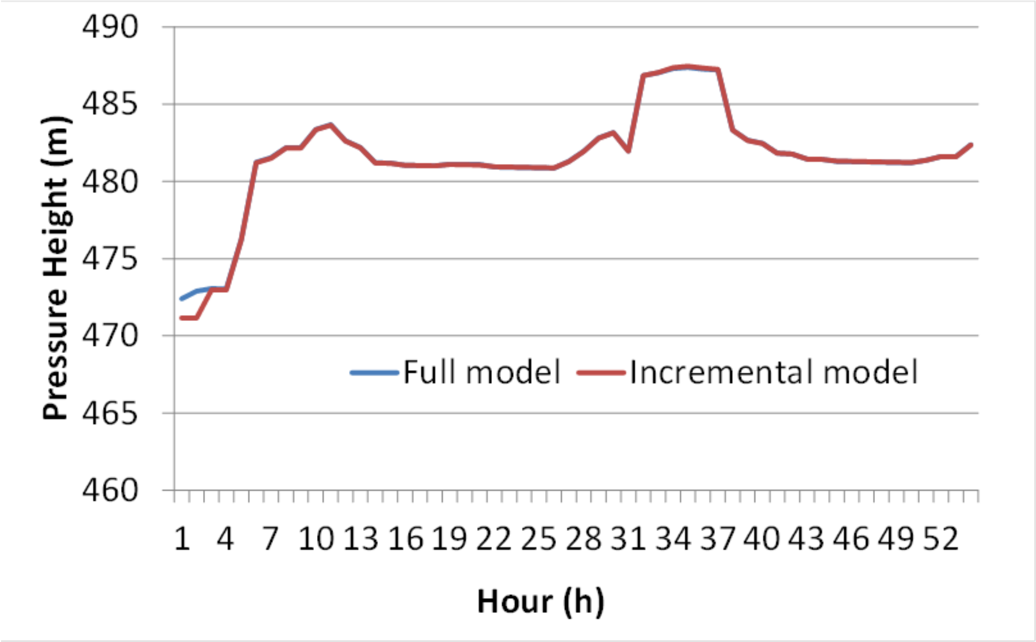

Summary

We presented a model with which one is able to calculate an optimal short-term production plan for minimum pressure restriction above a plant.

Future work: Optimizing balancing power under minimum restriction.

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