Optimal pricing of production changes in cascaded river systems with limited storage

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Outline

- Background and motivation
- Difference between linked river systems, and systems with sufficient reservoir capacity between power stations
- Problem description
  - Example of an existing method used for bidding in linked riversystems
  - Heuristics, Best Profit
- Case study
- Results and conclusion

Optimising hydro power is actually very easy …

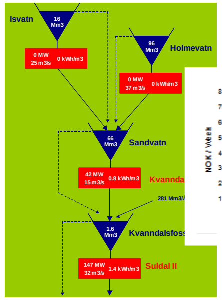
$$J(0) = \max E_p \left\{ \sum_{t=1}^{N} \sum_{d=1}^{7} [L(u_d(t), P(t), t)] + S(x(N), N) \right\}$$

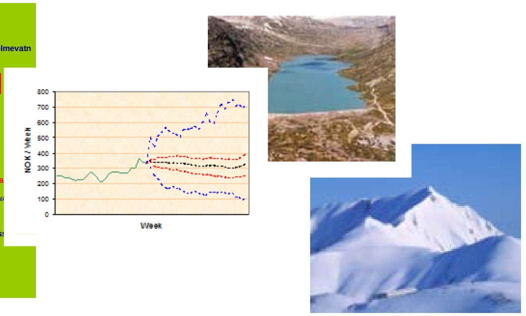
$$x(t) = x(t-1) - \sum_{d=1}^{7} u_d(t)$$

$$\underline{U}_d(t) \leq u_d(t) \leq \overline{U}_d(t)$$

$$\underline{X}(t) \leq x(t) \leq \overline{X}(t)$$

$$J(x(t-1), P(t-1), t-1) = \max E_p \left\{ \sum_{d=1}^{7} [L(x(t), u_d(t), P(t), t) + J(x(t), P(t), t)] \right\}$$





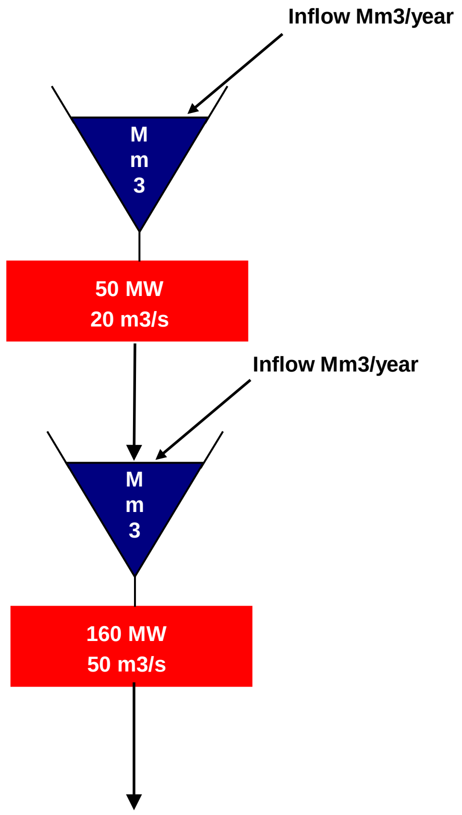
and decide whether to produce or not.

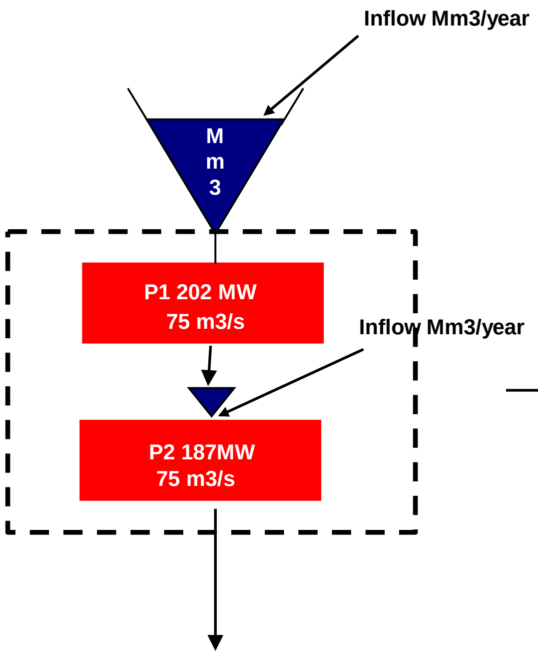
How much should we produce

.. and which generators should run

.. and at what is the price (mc) of production

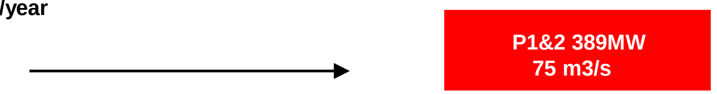
Cascaded river systems / linked riversystem

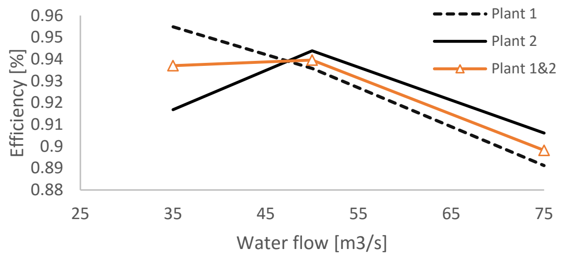




Multistation equivalent or

Single Plant Model





Existing method used for calculating marginal cost for linked power plants

$$mc_{ij} = \frac{\Delta Q_{ij}}{\Delta P_{ij}} * \alpha * WV^*$$

α is fixed to a value such that mc is equal to WV*

Plant 1 P [MW]	Plant 1 Q [m3/s]	P/Q	$\frac{\Delta Q_{ij}}{\Delta P_{ij}}$	mc_{ij}
70	25	2.80		
100	**35 (Q*)**	**2.86**	**0.33**	**30.0**
140	50	2.80	0.38	33.8
200	75	2.67	0.42	37.5

Example:

Highest P relative to Q at 100 MW and 35 m3/s => **α** = (100-70) MWh / (35-25) m3/s = 3 MWs/m3

MC moving from 100 MW production to 140 MW = ((50-35)m3/s / (140-100) MWh) * 3 MWhs/m3 * 30 EUR/MW

= 33,8 EUR/MWh

For the singles plant model. Production for identical waterflows are added together, and similar calculations as illustrated above are made

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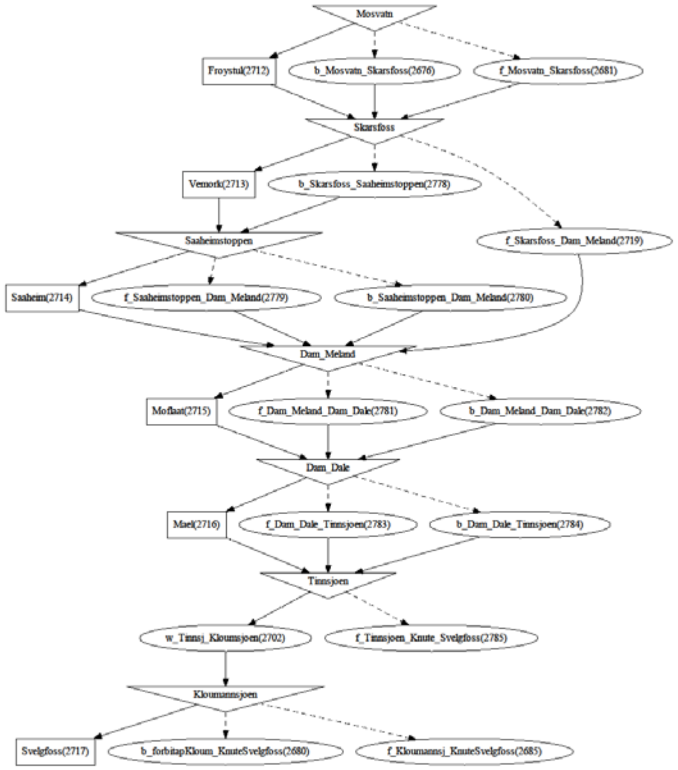
Weakness with existing method

- Static representation of the physical conditions and availability in the river-system
  - One plant could consist of several generators where some are shut down for maintenance.
  - There could also be temporary load restrictions, concessional requirements, or local inflow effecting operations.
  - Non-convexities when creating a common production-waterflow curve will create problems

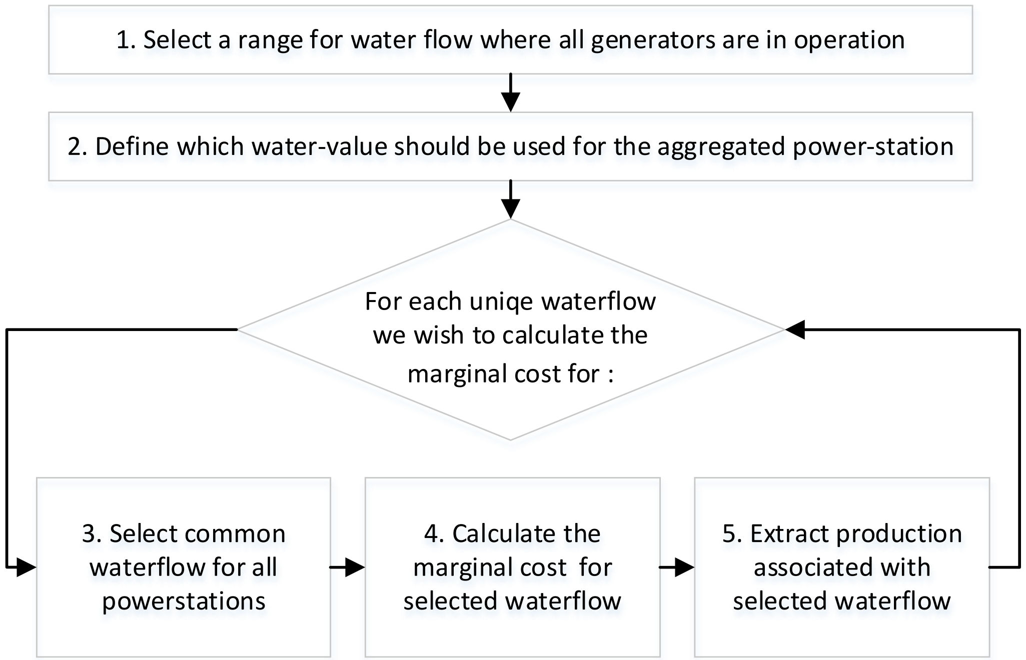
- Alternatives related to continuing with existing method
  - continuous update of the combined production-waterflow curve.
  - maintenance of a model which is not representing the physical power system.
  - distributing load requirements, a separate model or optimization must be run to allocate production to the correct generators.

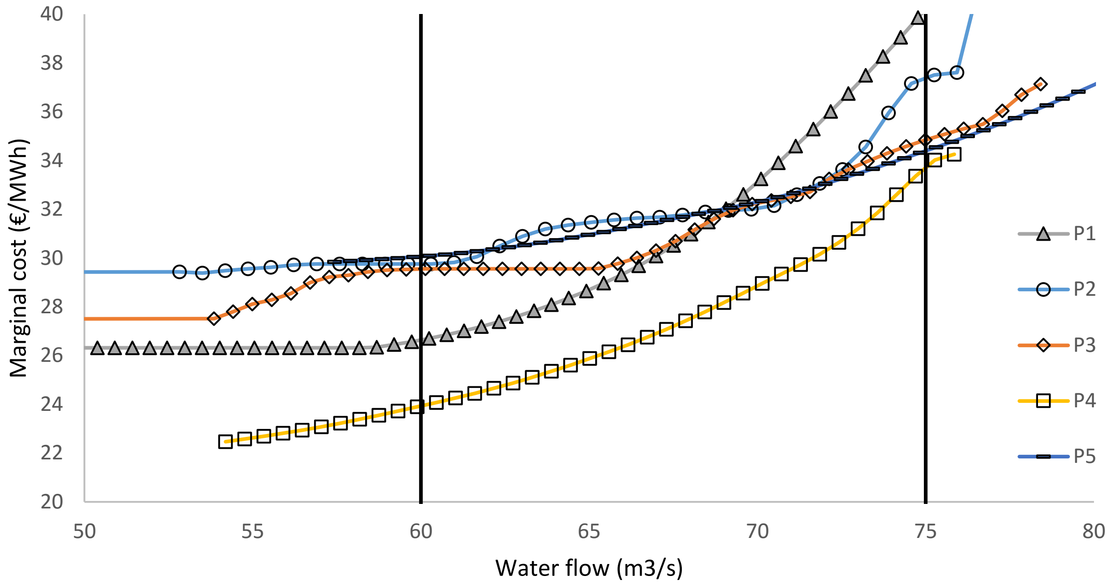
Best Profit

- Detailed physical representation of entire river system modeled in SHOP
- SHOP is run with water-values or cuts from a seasonal model
- transformation from the flow discharge to the power generation is implicitly done by the functionality in SHOP.
- marginal cost for a large number of combinations of flows in the running units is calculated using the best profit heuristics
- For each production level, the optimal distribution is the one resulting in the lowest discharge. This ensures that the most efficient units will always be used first.
- Best profit curves generally contain information about the marginal cost of each production level, the optimal production distribution between the running units and at what price it is optimal to switch between unit combinations.

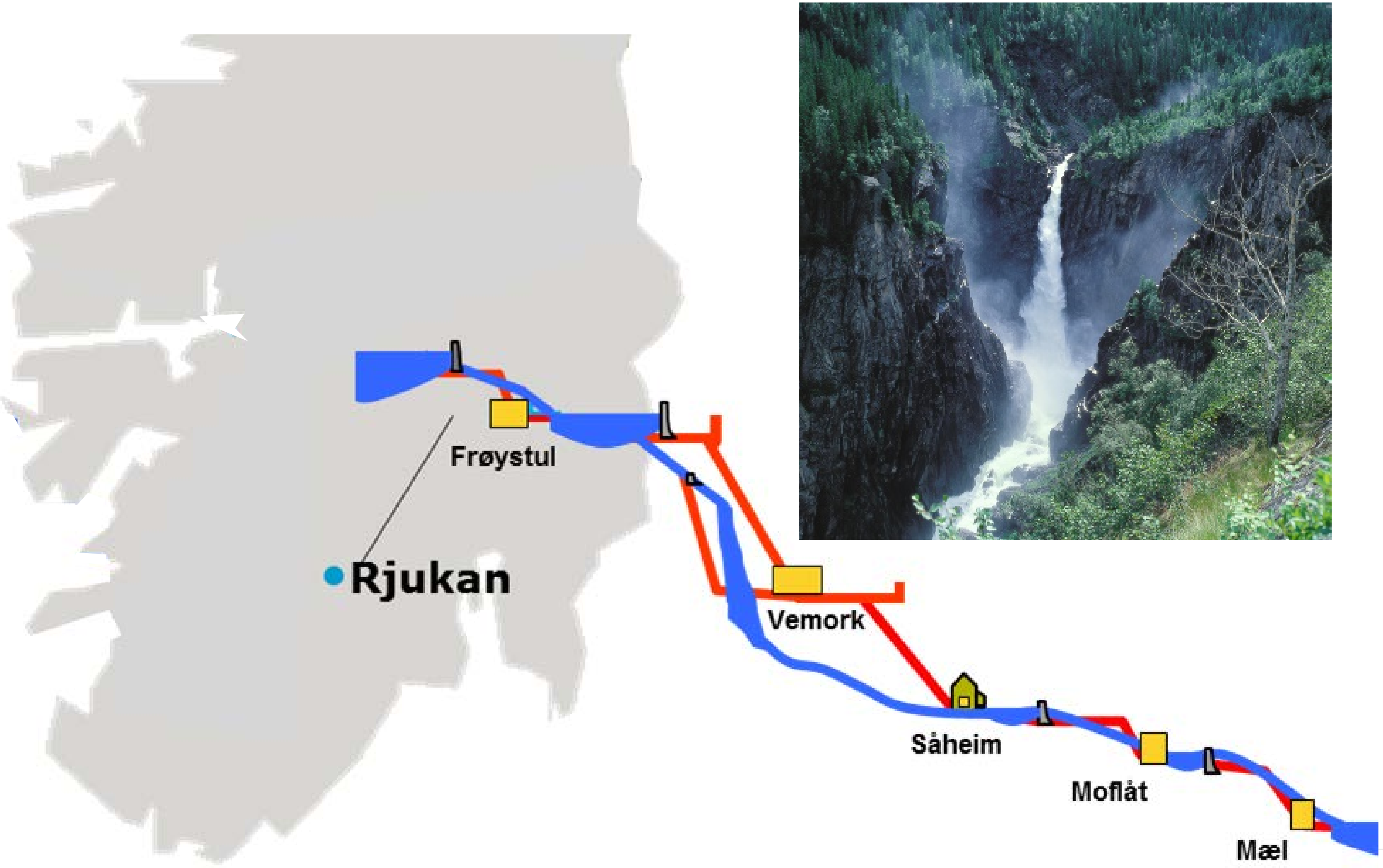


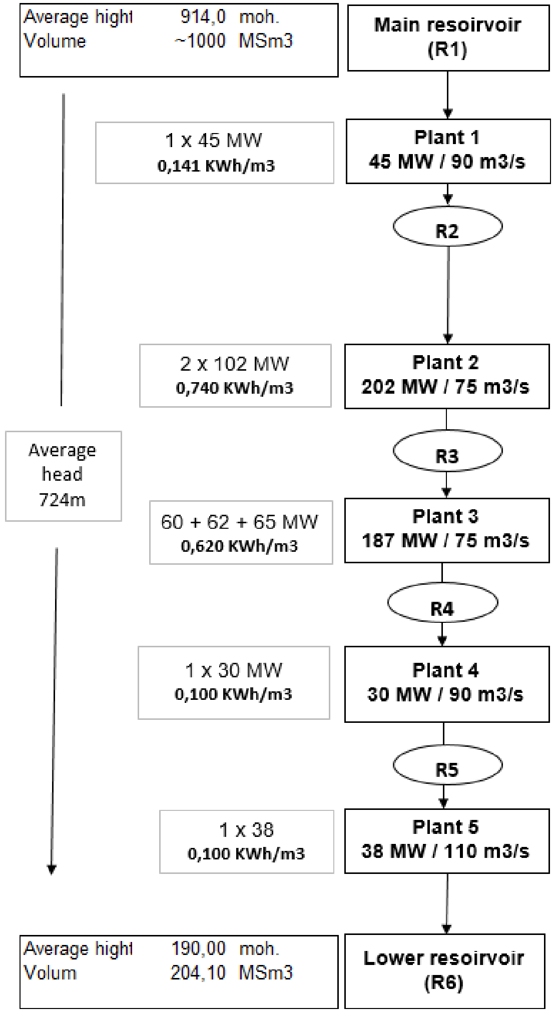
Best profit used for linked riversystem





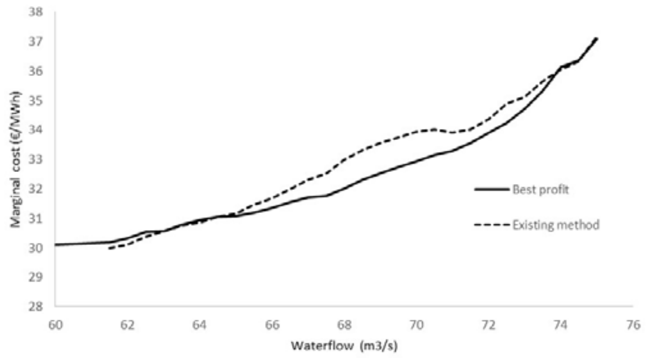
Case study – Rjukan

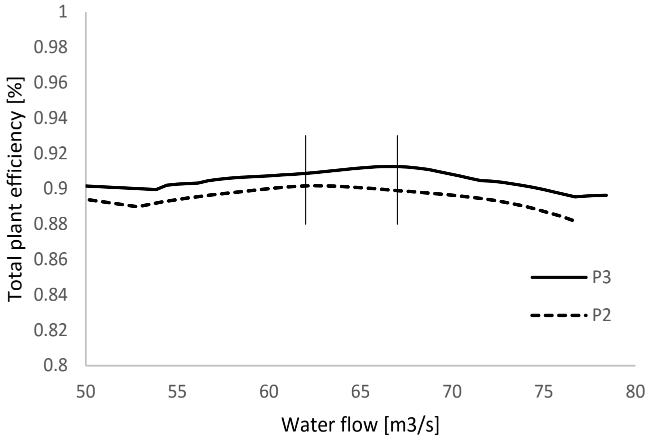




Results and conclusion

- It has been demonstrated that the best profit method can be used to generate real-time marginal cost curves for linked river systems.
- These results can readily be used for bidding to the spot-, balancing and/or intraday market.
- Results from the best profit give significant insight into how optimal load distribution for linked river system should be executed in daily operations.
- In this paper, we calculate the marginal cost for a linked river system where all generators are in operation. This is not a limitation that applies for the method in general. A relatively trivial expansion is to investigate the best profit value when one or more generators are out for maintenance. This can be done by investigating the best profit values for an area of operation where the available generators are running.





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