Power swaps in Hydro

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Helping utilities work smarter

Powel Optimal Hydro

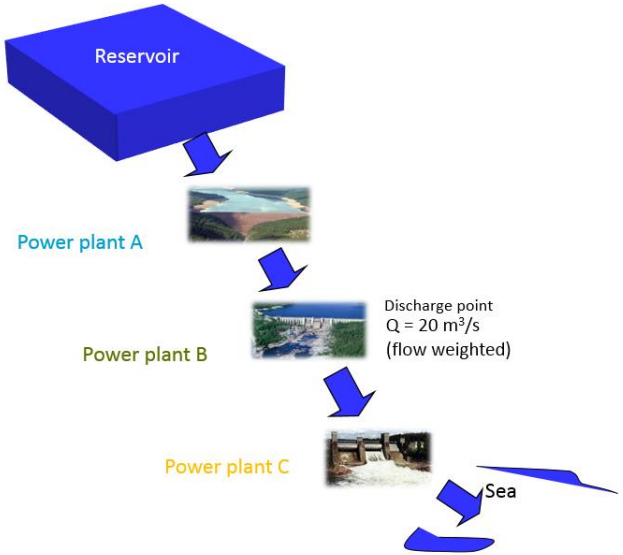
- Previously known as Hotshot
- An optimization model for short term hydro-electric production planning
- Similar to Sintef's Shop
  - Different way to handle head dependency of production
  - Different way to solve large problems (LP + DynP)
- Uses Cplex to solve LP/MIP

powel

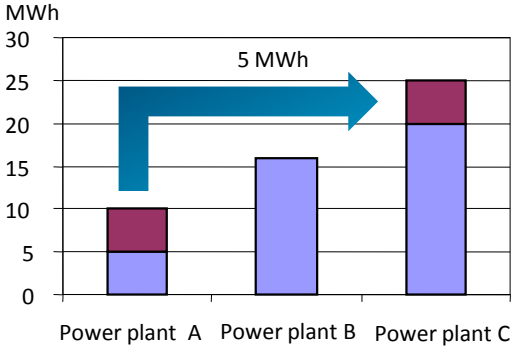
Power swaps

- Swedish way to handle rivers with mixed ownership. (”Kraftbyten”)
- Purpose: Each producer should be able to plan its production as if it was alone in the river.
- How:
  - Each producer bids for discharge.
  - Common authority adjust bids.
  - Compensation is made through *physical* power.
  - Authority keeps track of each producer’s water balance.

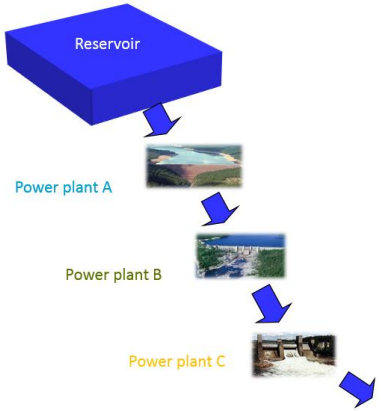
Power swaps



	A	B	C	Total
Equivalent (MW/(m3/s))	0,5	0,8	1	2,3
Nominated discharge (m3/s)	10	20	25	
Nominated prod (MW)	5	16	25	46
Weighted flow				20
Actual production (MW)	10	16	20	46
Power swap	-5	0	5	0

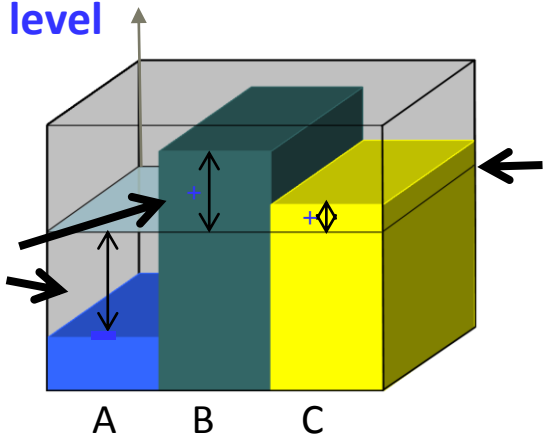


Reservoir management



Reservoir level

Water balance management (+ or -)



Recommendation from the River regulation authority

Nominations

- One point in the river called ”Release point” (*Swedish: Tappningspunkt*)
  - Total flow from one reservoir
- The nominations are typically for 6, 8 or 24 hours averages.
- The nomination can be made before and after spot trade
- The river regulation authority takes in all the nominations and calculate ”adjusted release”.

Issues with optimizer

- Should make the planning simpler *but* user's of Shop face:
    - After adjustment: Constraint on "average discharge".
    - Before nomination: My and the other's decisions on discharge levels introduce new constraints on the average discharge.
    - What discharge should I wish for?
    - What will the effect be on the power swap?
    - How does this effect my plan/spot bid?

Basic notation

- Each time period for nomination is denoted by t
- $T(t)$ is the set of ”hours” that belong to t

Introduce variables for nominations and adjusted release:

q_t^N and q_t^A

Actual flow in release point. Also to be determined by optimizer.

The adjusted release need to be kept by the short term optimizer:

$$q_t^A = \sum_{\tau \in T(t)} q_\tau / |T(t)|$$

Simple case

e^M = My equivalent
e^O = Other's equivalent
q_t^O = Other's nomination

$$\frac{(e^M q_t^N + e^O q_t^O)}{(e^M + e^O)} = q_t^A$$

q_t^O is educated guess, or given by previous nominations and adjusted release:

$$q_t^O = (q_t^{APrev} (e^M + e^O) - e^M q_t^{NPrev})/e^O$$

Power swap

$$p_t = e^M(q_t^N - q_t^A)$$

$p_t > 0$ means we receive power
$p_t < 0$ means we give away power

p_t accounted for in balance for all hours $\tau \in T(t)$.

Cost for nomination

- Two choices
  - The nomination is accounted for in ”artificial reservoir” using normal water value evaluation.
  - Cost of water.

In the objective you are charged a cost for requesting more than the adjusted release: $c_t(q_t^N - q_t^A)$.

All relations are linear!

- $q_t^A = (\sum_{\tau \in T(t)} q_\tau)/|T(t)|$
- $\frac{(e^M q_t^N + e^O q_t^O)}{(e^M + e^O)} = q_t^A$
- $p_t = e^M (q_t^N - q_t^A)$

No problem for optimizer!

Complications

- Spill
  If my nomination causes spill then my equivalent is reduced:

$$p_t = \begin{cases} e^M(q_t^N - q_t^A) \text{ if } q_t^A \leq q_t^{Ref} \\ e^M(q_t^N - q_t^A) - e^{Loss}\left(q_t^A - q_t^{Ref}\right) \text{ if } q_t^A \geq q_t^{Ref} \end{cases}$$

  q_t^{Ref} is called spill reference (parameter)
- Power swap may be accounted for at other time periods

Implementation in Powel Optimal Hydro

- Setup in Sim
- A reservoir is assigned to be release point.
- All parameters $e^M, e^O, e^{Loss}, c, q^{Ref}, q^M_{min}, q^M_{max}, \ldots$ are (breakpoint) time series associated with release point (reservoir).
- A special time series called ”Power Swap flag” determines the discretization.
- Results (nomination, adjusted release and power swap) are available as time series on the reservoir.

Summary

- Optimize your power swap nomination together with normal production planning.
- Optimal Hydro calculates optimal nomination, adjusted release and the power swap.
- Power swap accounted for in balance and priced accordingly.
- Flexible implementation.
- Also available in Powel Optimal SpotBid.