HydrovSPD: a digital twin for the NZEM

Andy Philpott and Oliver Wilson

Electric Power Optimization Centre

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Monitoring markets

- The elements of market monitoring
- Are water values reasonable? Ask JADE.
- Is there exercise of hydroelectric market power in short term? [Bushnell, Operations Research, 2003]
- HydrovSPD can be used to look at this.

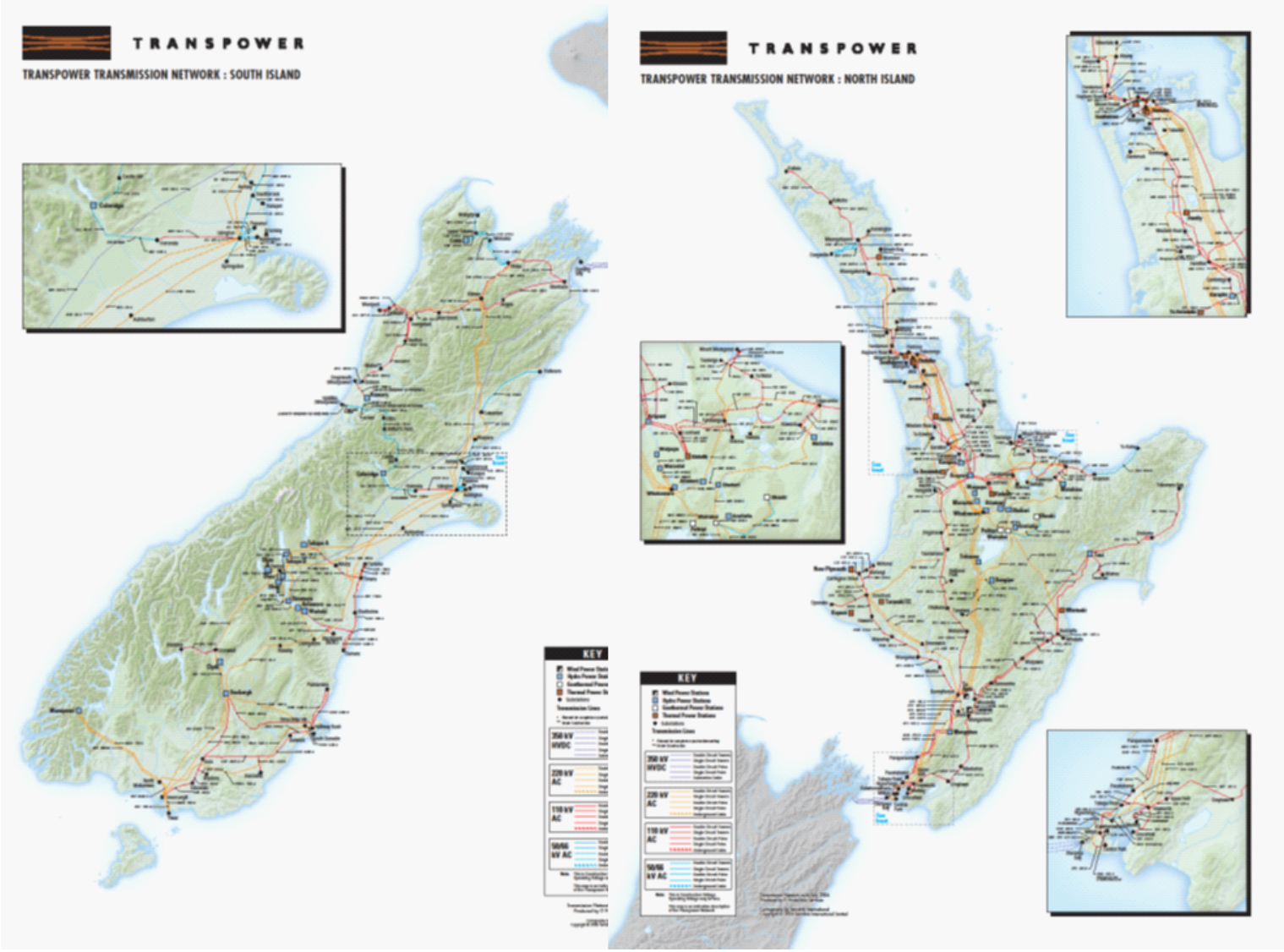
Summary

Summary

Modelling the New Zealand electricity system

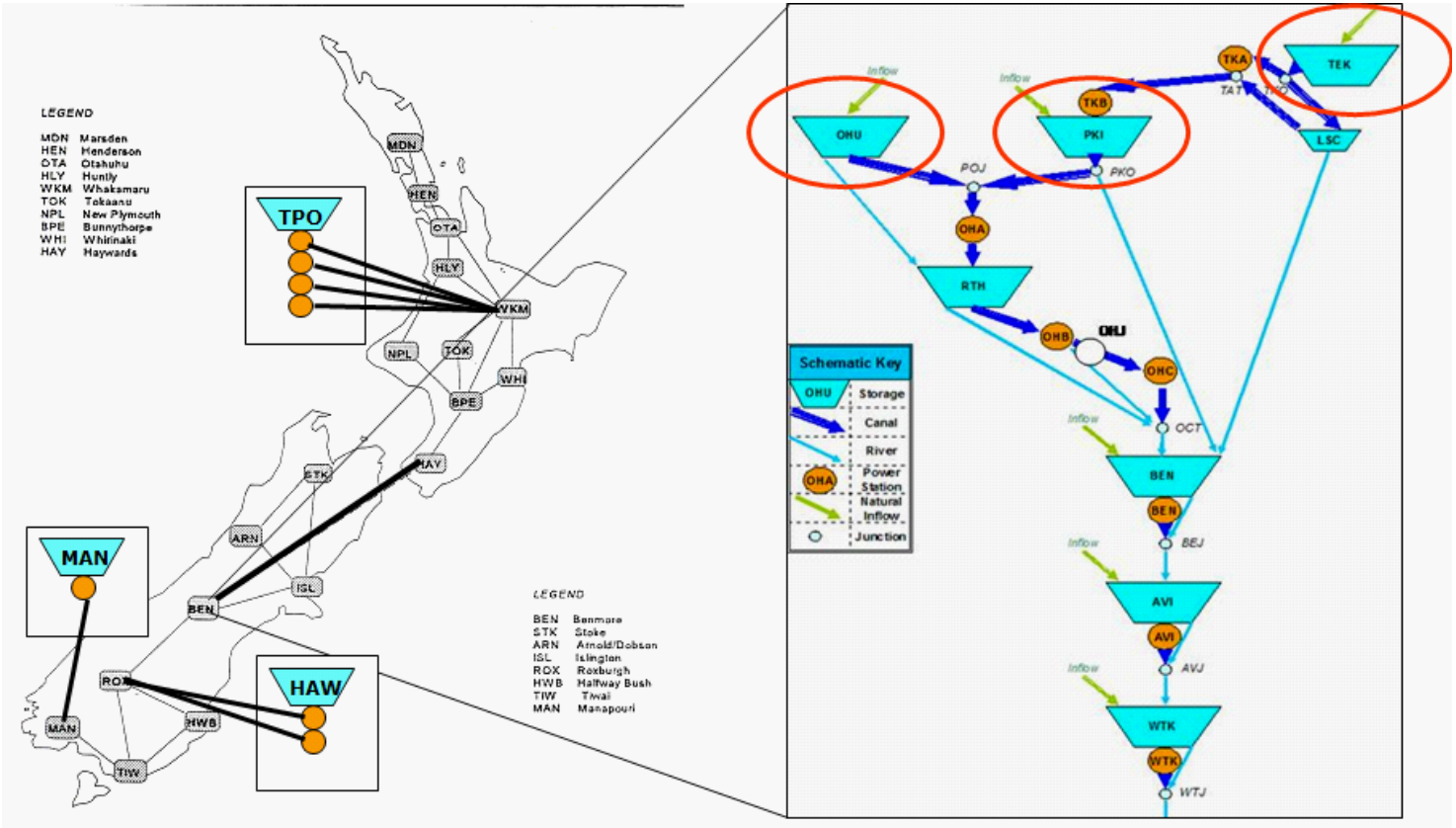
- NZ uses a standard nodal pricing market design with 250 nodes.
- Spinning reserve is co-optimized.
- Wholesale market is dispatched using software called SPD.
  - optimal generation levels and reserve levels allocated to every generator;
  - 250 locational marginal (nodal) prices;
- SPD inputs (offers of energy that are made by generators, network constraints and demand) are made public the day after the day of dispatch.
- vSPD is a GAMS/CPLEX model that replicates SPD output on public inputs.
- Enables market experiments for any previous day.

The SPD network



Network diagram of New Zealand transmission grid.

Modelled hydro river chains



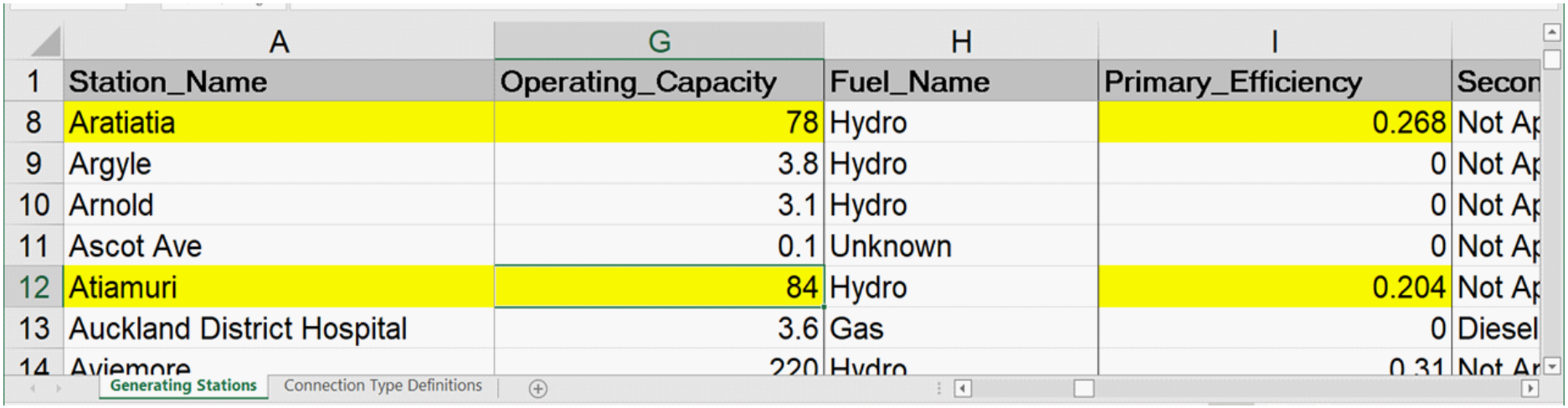
HydrovSPD: a digital twin

[N. Porter ME thesis, 2014, Z. Guan, 2021]

- HydrovSPD is a GAMS model based on vSPD over a single trading day.
  - 48 copies of vSPD are coupled by variables for water flow and reservoir levels.
  - all reservoirs and headponds have TP1 storage and TP48 storage set to historical water levels.
  - all plant capacities set to maximum offer quantity in TP.
  - thermal generation offers at fuel cost plus CO2 cost plus variable OM costs (SRMC).
  - Waikato and Waitaki (Meridian) are block dispatched: vSPD dispatch matches hydro generation at chain level.
- HydrovSPD includes spinning reserve (at zero cost) to meet historical reserve requirements.
- HydrovSPD is clairvoyant over 48 half-hours (perfect foresight of inflows and demand).

Calibration of hydro stations

- EMI gives linear efficiency for NZ hydro stations.



	A	G	H	I	
1	Station_Name	Operating_Capacity	Fuel_Name	Primary_Efficiency	Secon
8	Aratiatia	78	Hydro	0.268	Not Ap
9	Argyle	3.8	Hydro	0	Not Ap
10	Arnold	3.1	Hydro	0	Not Ap
11	Ascot Ave	0.1	Unknown	0	Not Ap
12	Atiamuri	84	Hydro	0.204	Not Ap
13	Auckland District Hospital	3.6	Gas	0	Diesel
14	Aviemore	220	Hydro	0.31	Not Ar

Generating Stations | Connection Type Definitions

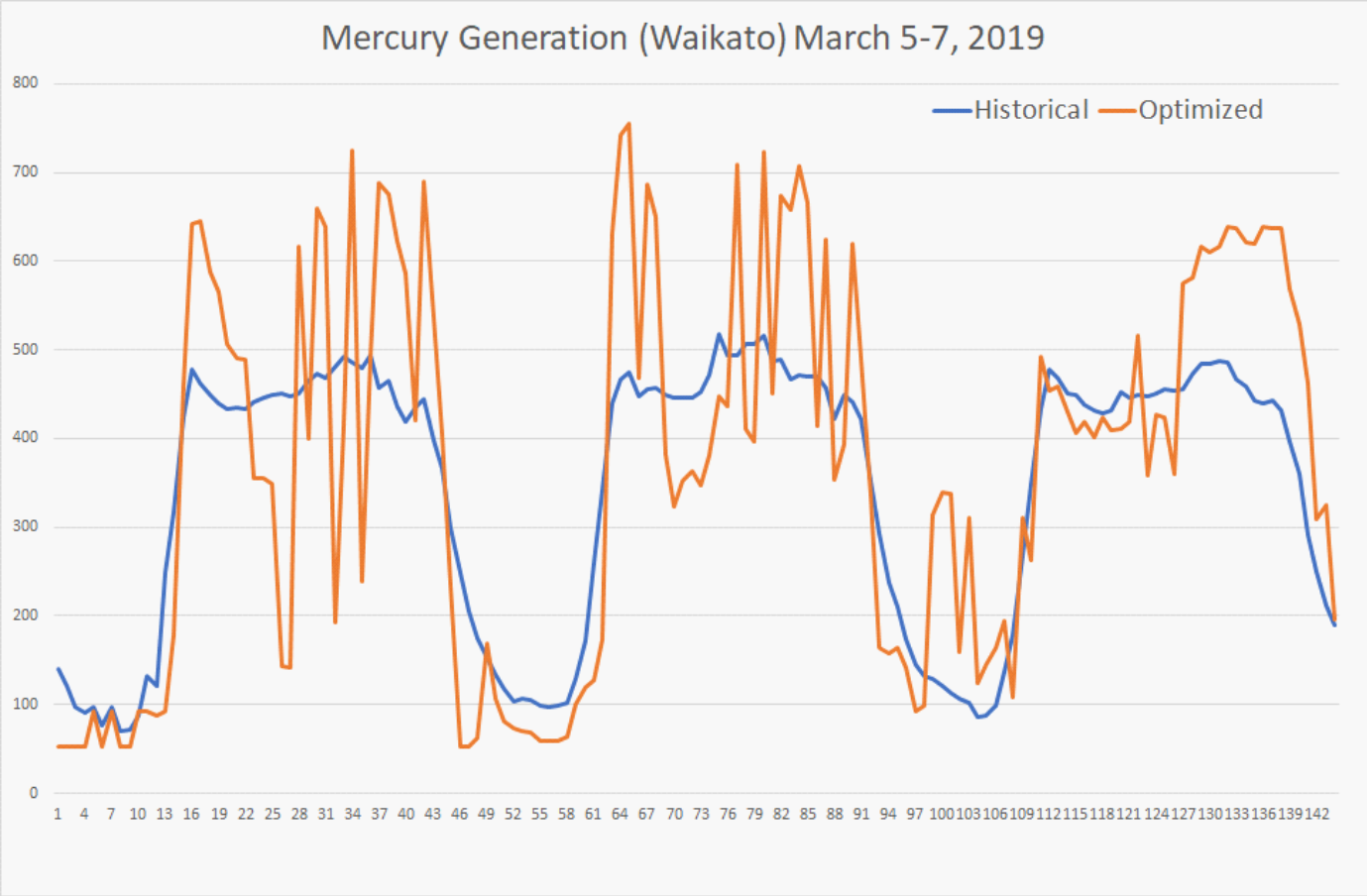
- These can vary with operating conditions e.g., if some turbines operating in TWD mode.
- EMI gives historical metered generation, daily inflows, daily spill
- For each day, calibrate efficiencies to match historical water transfers. These are sometimes smaller than EMI values.

Experimental setup

- If missing data then assume plant parameters to produce synthetic headpond volumes from historical dispatch.
- Historical solution: HydrovSPD with historical offer prices and block dispatch should be able to replicate synthetic headpond volumes (since historical dispatch did).
- Optimized solution: HydrovSPD with target headpond levels=synthetic headpond volumes, and SRMC for thermal plant.
- Compare historical dispatch with optimized dispatch

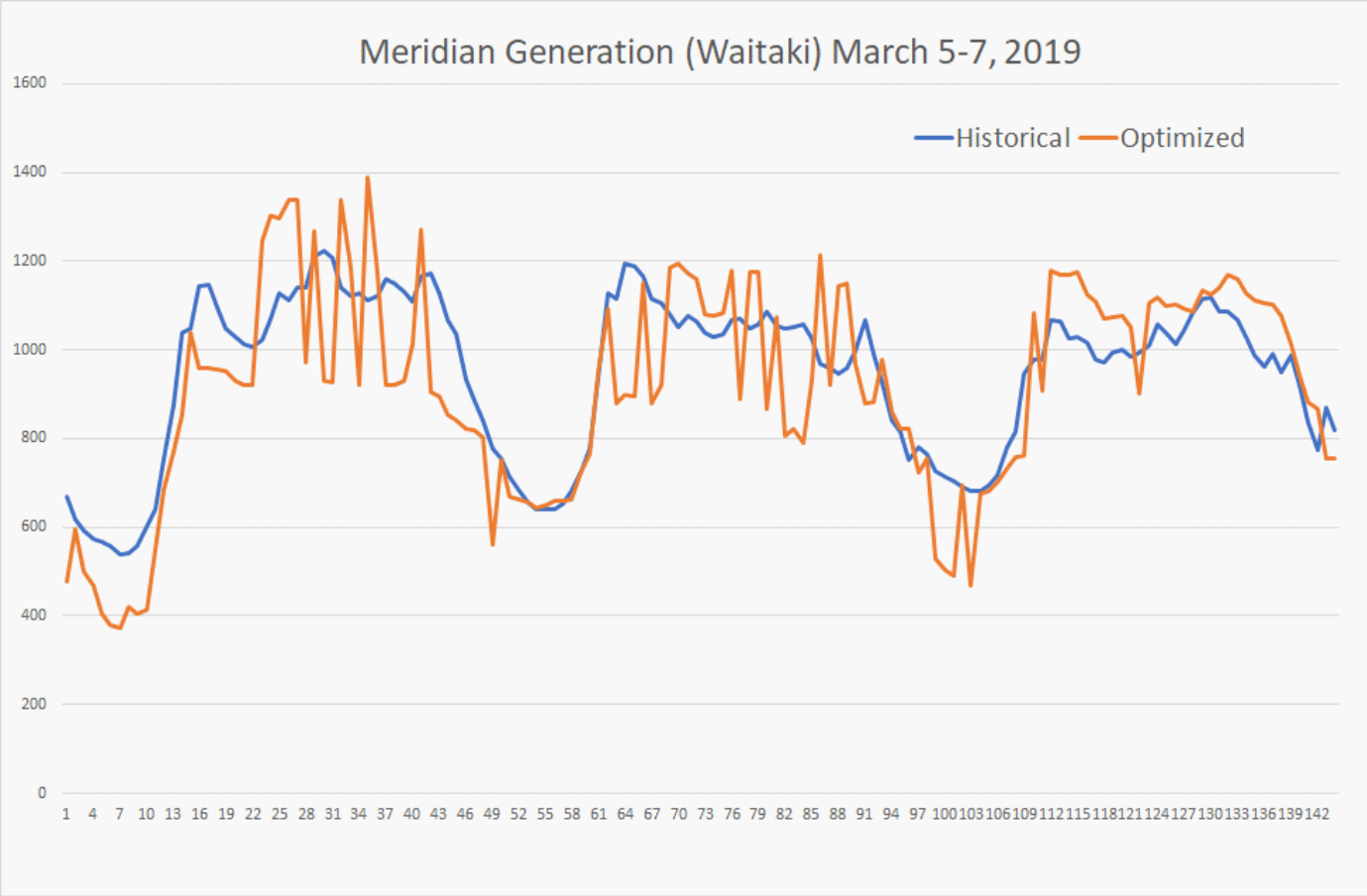
Summary

Hydro generation



Historical and optimized generation for Waikato river.

Hydro generation



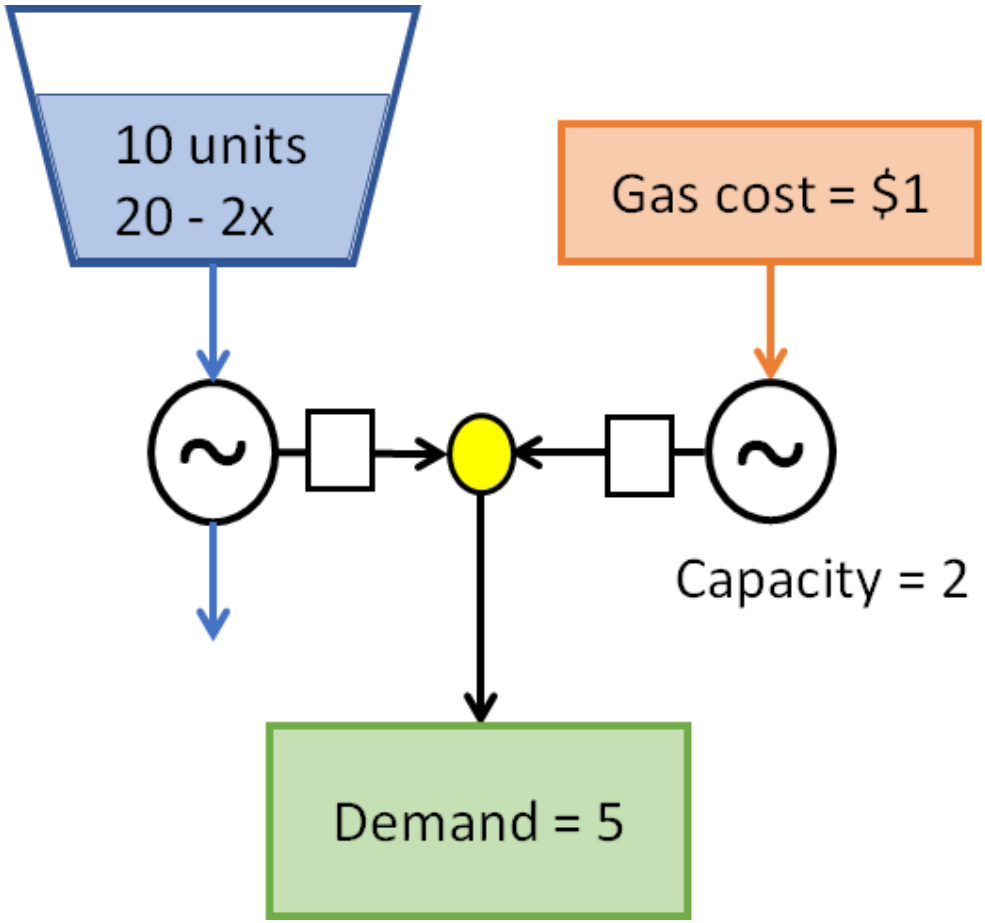
Historical and optimized generation for Meridian stations in Waitaki system

Summary

Transpower solves a sequence of dispatch problems

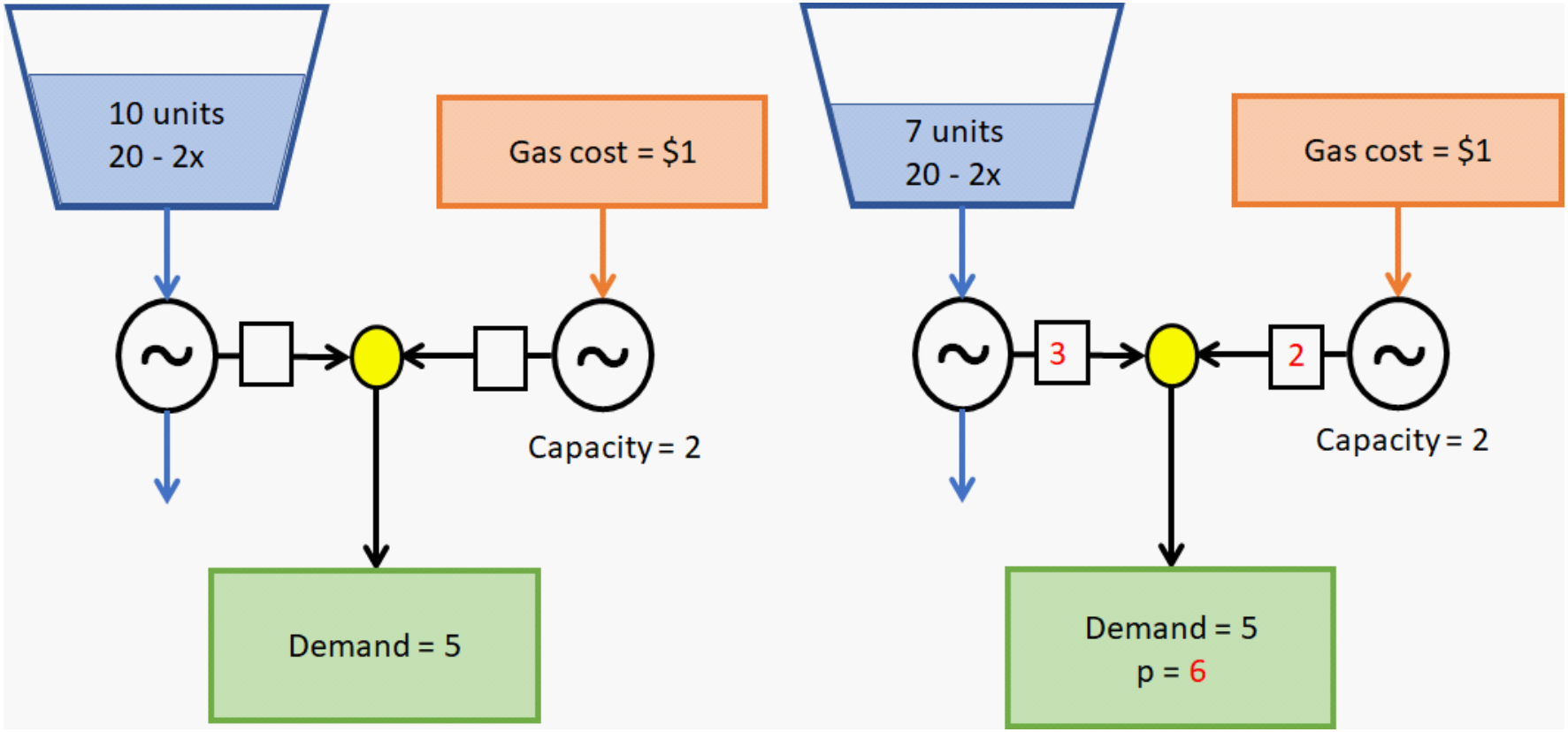
- Gate closure: offers are fixed for next g periods.
- At period t generators submit offers for periods $t+g, t+g+1, t+g+2, \ldots$
- Observe SPD pre-dispatch and provisional prices.
- Plan future generation and offers using provisional prices.
- Update future offer stacks until gate closure.

A simple hydrothermal model



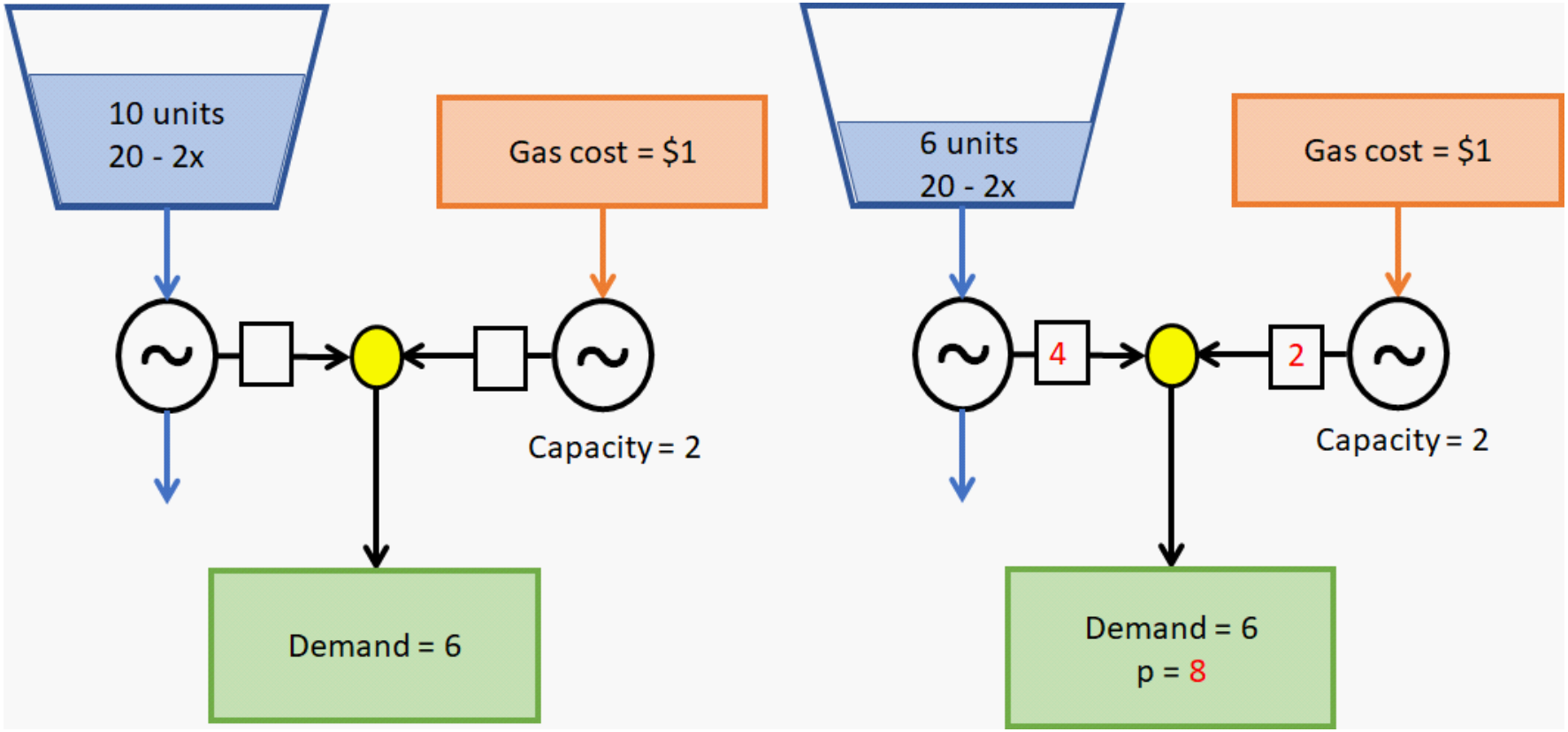
Example: Thermal capacity is $b = 2$, and water storage x has value $20x - x^2$. Marginal water value $= 20 - 2x$.

A simple hydrothermal model



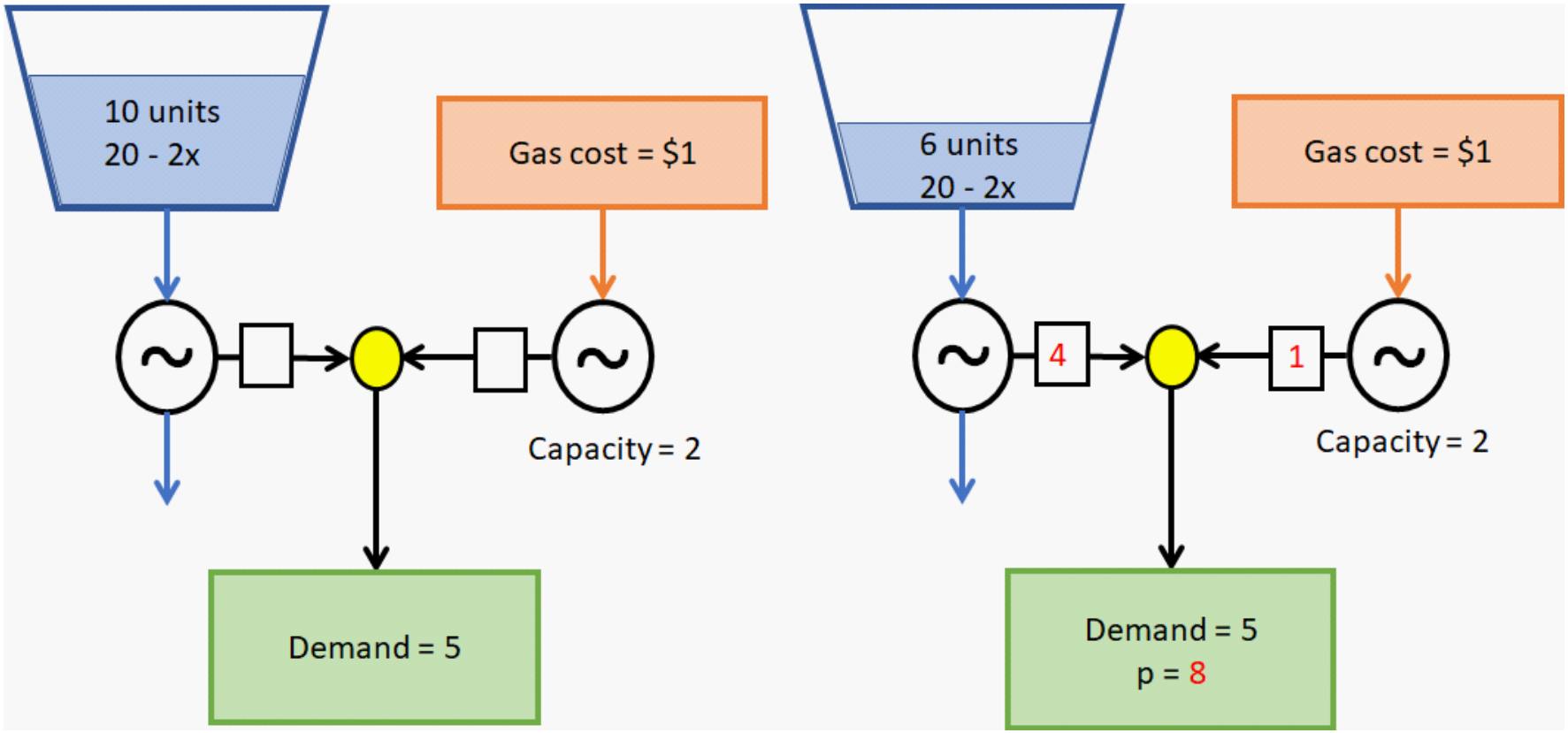
Least cost dispatch when demand is 5 giving hydro generation 3 and price equal to MWV=$6 (=20 - 2*7).

Forecast demand to be 6 not 5.



Least cost dispatch when demand is 6 giving hydro generation 4 and price equal to MWV=$8 (=20 - 2*6).

Thermal plant offers at $8 in actual demand (5)



Least cost dispatch when demand is 5 and gas offers at $8. Gas is now marginal and sets price at $8.

Summary

Will prices converge?

Model: Single thermal plant with capacity b bidding against a fixed supply function.

Assumption

Demand forecasts at iteration k satisfy $d_k > b$ and are accurate enough so that $|d_k - d_l| < b$ for every $k, l > 0$.

Theorem

Suppose the ISO solves a sequence of dispatch problems $P(k)$, $k = 1, 2, \ldots$, with forecast demand $d_k \to d$, each yielding clearing price $p(d_k)$. Assume the forecasts satisfy Assumption 1. If for $k = 0, 2, \ldots$, thermal plant offers b at price $p(d_k)$ to problem $P(k+1)$, where $p(d_0) = c_2$, then $p(d_k) \to p(d)$ if and only if $d_k \leq d$ for every k.

References

Bushnell, J., 2003. A mixed complementarity model of hydrothermal electricity competition in the Western United States. *Operations Research*, 51(1), pp.80-93.