Reserve in Electricity Markets

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INTRODUCTION

ABOUT ME

- University of Canterbury, BE(Hons) Chemical and Process Engineering
- University of Auckland, Year Three, Ph.D Eng. Sci and C&M
- Prior work at load aggregators
- HVDC Pole 3 Commissioning (Trading Team)
- Based at Transpower S.O. 2013
- Various Consulting Jobs

ROUGH AGENDA

- Reserve Constraints
- Assessment of Spot Prices
- Equilibrium Models of Reserve Participants
- Visualising Energy and Reserve Offers
- Using Bayesian Probability to assess Constraints
- Theoretical HVDC Transfer Capabilities
- Open Source and Open Data

Reserve Constraints

IT STARTS WITH A PICTURE

Figure : Haywards Nodal Spot Price (x axis) compared with the North Island FIR Price (y axis)

WHY DOES THIS MATTER?

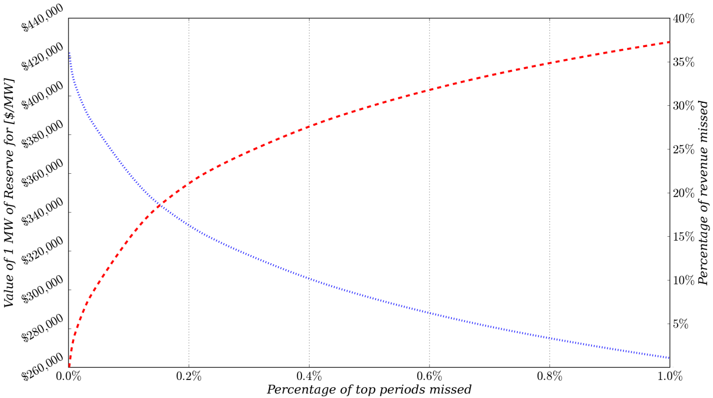

Figure : Revenue “lost” for missing highly priced trading periods

EFFECT ON INDIVIDUAL CONSUMERS

Table : Monthly Revenue “missed” by various IL producers

	NZST	PPAC	SKOG
2009	18-85%	2-92%	30-80%
2010	4-90%	0-90%	5-70%

In November 2010 NZST missed 90% of the monthly IR Revenue, SKOG missed 6%

SOME THEORY

$$
\begin{aligned}
[POPF]\ \min \quad & p_g^T g + p_r^T r \\
\text{st.} \quad & Mg + Af = d && [\pi] \\
& r + g \leq G && [\epsilon] \\
& r - Kg \leq 0 && [\kappa] \\
& Er - g \geq 0 && [\lambda^1] \\
& Hr - Bf \geq 0 && [\lambda^2] \\
& r \leq R && [\omega] \\
& |f| \leq F && [\tau^\pm] \\
& Lf = 0 && [\alpha] \\
& r, g \geq 0
\end{aligned}
$$

$$
\begin{aligned}
[DOPF]\ \max \quad & d^T + R^T\omega + G^T\epsilon + F^T(\tau^+ + \tau^-) \\
\text{st.} \quad & M^T\pi + \epsilon - K\kappa + \lambda^1 \leq p_g && [g] \\
& \omega + \epsilon + \kappa + E\lambda^1 \leq p_r && [r] \\
& A^T\pi + \tau^+ - \tau^- - B^T\lambda^2 + L^T\alpha = 0 && [f] \\
& \omega, \epsilon, \tau^\pm, \kappa \leq 0 \\
& \lambda^1, \lambda^2 \geq 0
\end{aligned}
$$

CASE STUDIES

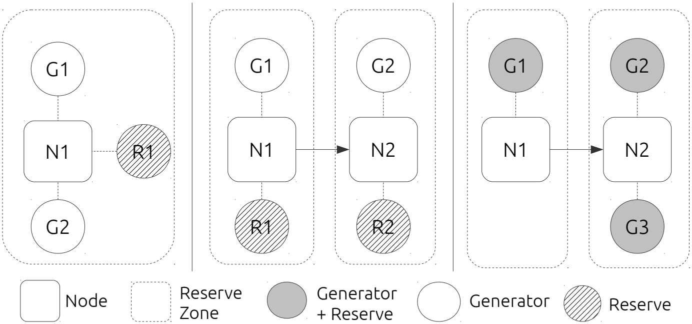

Figure : Some Case Studies to illustrate different mechanisms of binding constraints occurring

Case Study Results

Marginal Risk Setting Generator

$$\pi = p_{g,marginal} - \lambda \tag{1}$$

Risk Constrained Transmission Line

$$\pi_2 = \pi_1 - \lambda_2 \tag{2}$$

Bathtub Constrained Transmission

$$\pi_2 = \frac{1}{1 + k_{g,2}} p_{g,2} + \frac{k_{g,2}}{1 + k_{g,2}} (\pi_1 + \lambda_2) \tag{3}$$

TESTING THESE, MARGINAL GENERATOR

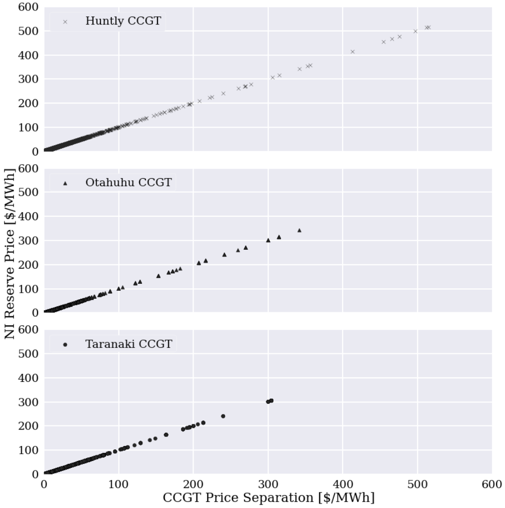

Figure : Reserve Constraints binding upon major CCGT Units

TESTING THESE, MARGINAL TRANSMISSION, NI

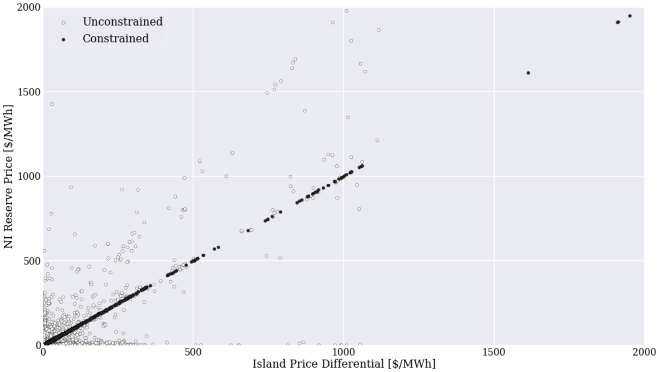

Figure : Reserve Constraints Binding upon Northward HVDC Transmission

TESTING THESE, MARGINAL TRANSMISSION, SI

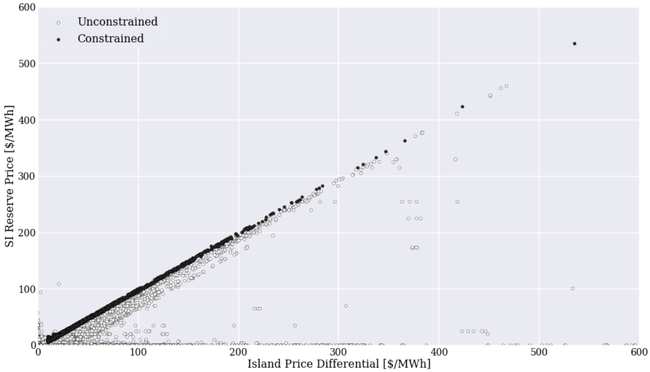

Figure : Reserve Constraints Binding upon Southward HVDC Transmission

TESTING THESE, BATHTUB CONSTRAINTS

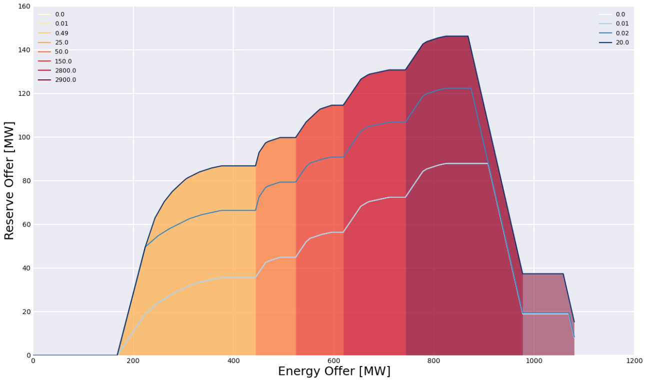

Figure : Mighty River Fan Curve, TP 19, October 3 2013.

Spot Market Prices

Scarcity, Constraints or Both?

- How do we understand Price?
- Moving up a merit order stack?
- High Demand = High Price?
- Hydrology? Price = f(Inverse Hydro)
- Constraints?

Average Price at Different Demand

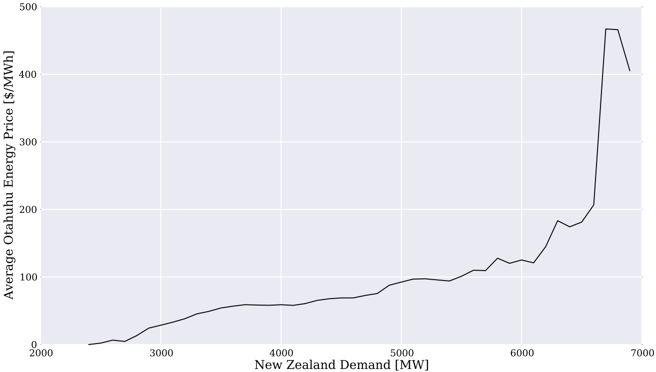

Figure : The higher the demand, the higher the energy price, we're moving up the stack.

AVERAGE PRICE AT DIFFERENT HYDROLOGY

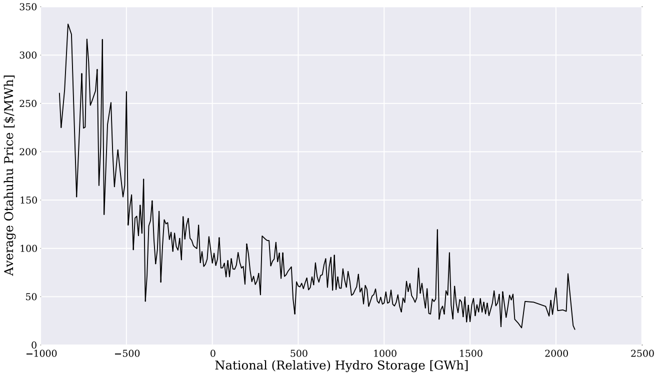

Figure : As expected, the less water we have (relative to the lower decile for the time of year) the higher the average price

AVERAGE DEMAND AT DIFFERENT PRICE POINTS

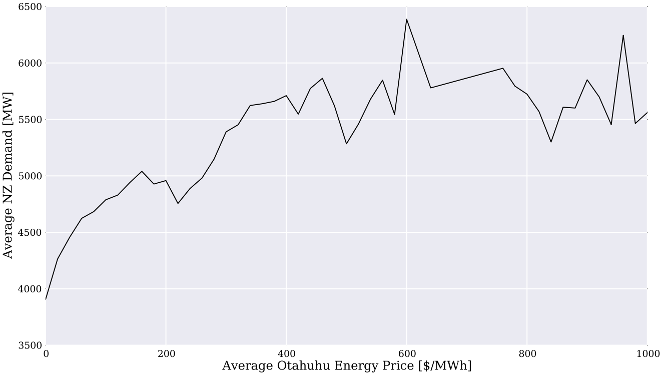

Figure : The relationship between high demand and high prices isn't so clear when the reverse situation occurs

Average Hydrology at Different Price Points

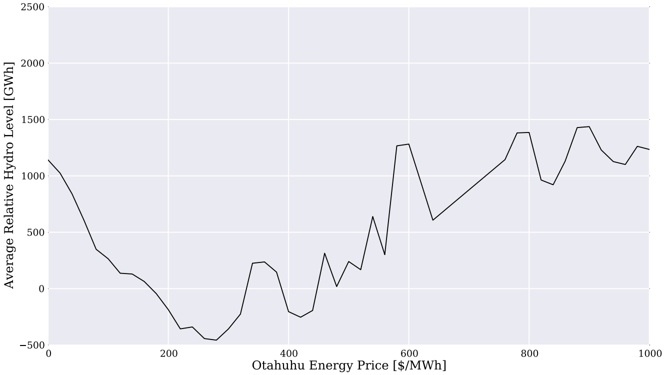

Figure : The Paradox of Hydrology, the highest price trading periods are associated with large quantities of water

Constraints at different price levels

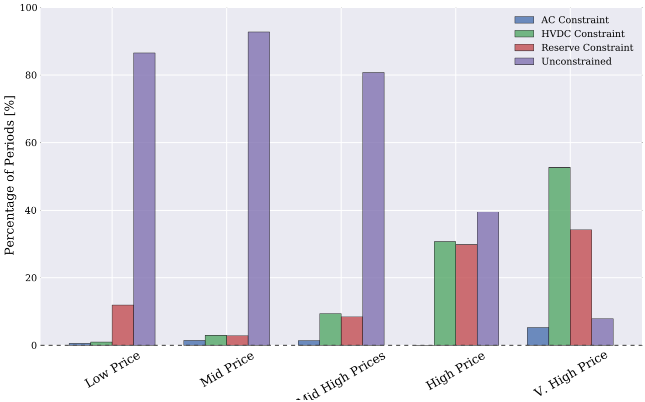

Figure : Aggregate assessment of constraints in the New Zealand Market

Specific Constraints

Table : Constraints binding during the top 155 priced trading periods

	Occurences	Mean	Min	Max
Waikato Block SIR Constraint	41	768	0	4948
Waikato Block FIR Constraint	40	491	2	3834
Tokaanu SIR Constraint	26	417	2	1010
Waikato Block Dispatch	21	1409	13	4653
Tokaanu FIR Constraint	13	1009	0	4409

CONTEXTUALISING THE CONSTRAINTS

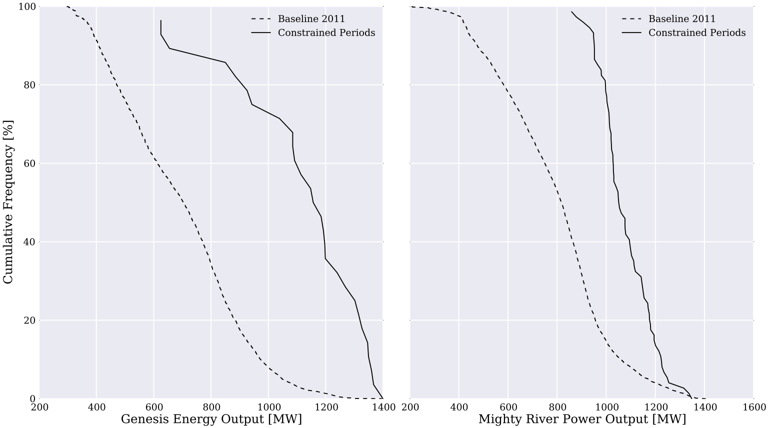

Figure : Dispatch (CDF) of Genesis and Mighty River during Constraints Periods (Genesis for Tokaanu Constraints, Mighty River for Waikato Constraints) compared with the overall CDF for the providers

FRAME 1