SPD Bolt Ons

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SPD

- Scheduling, Pricing and Dispatch
- EGRs do not appear to specify precisely how prices should be calculated
  - Part G, Schedule G6
    - Price at reference point
    - Marginal location factors
    - GIP/GXP Price = Reference price * marginal location factors
    - Consistent with transmission system power flows and losses
    - Infer intersection of supply and demand
  - In practice nodal prices are the values of the dual variables associated with the nodal energy balance constraints

Bolt On List

- Frequency Keeping
- Quadratic Loss Modelling (proposed)
- *Reserve Requirements (RMT)*
  - *Circular function between RMT and SPD*
- *Security Constraints*
  - *Thermal limits*
  - *Voltage*
  - *Usually conservative and not often relaxed in real time*
- *Must Run Dispatch Auction*
  - *In lieu of Negative offers*
  - *Incorrectly results in minimisation of losses*
- *Circulating Branch Flows*
  - *Binary variables for direction*
  - *Recent paper in EJOR (O'Neill, Rothkopf et al) validates the approach*

Frequency Keeper Function

- Frequency target is 50 Hz
- Frequency Keeper must maintain system frequency between 49.8 and 50.2 Hz by varying output
- Frequency Keeper is not bound by dispatch instructions (unlike all other generators - except for wind)

Frequency Keeping Market

- Two markets
  - NI and SI
- Each market has two competitors
- Simple auction
  - Lowest priced offer wins FK rights

Frequency Keeping Offers

- FK offers are submitted for each half hour trading period via COMIT
- FK offers include the following parameters set by the ancillary service agent:
- Control Max & Control Min
  - The upper and lower limits (MW) within which the ancillary services agent is offering the FK service
- Band [1-5] Power
  - Must add up to the FK bandwidth (50 MW)
- Band [1-5] Price
  - NZ dollars ($)

Source: Transpower

Selection of Frequency Keepers

- Two hours before the beginning of the trading period, the System Operator selects the FK offer(s) with the cheapest band price(s) that meets its SO Bandwidth requirement (currently +/-50 MW) for each island.
- The selection of FK offers results in the creation of the following frequency keeping constraints in SPD:
  - EnergyCleared>= Control Min + SO Bandwidth
  - EnergyCleared<= Control Max -SO Bandwidth
  - EnergyCleared+ Reserve6sCleared <= Control Max -SO Bandwidth
  - EnergyCleared+ Reserve60sCleared <= Control Max -SO Bandwidth

Source: Transpower

What do FK Control Min Constraints do to SPD solutions?

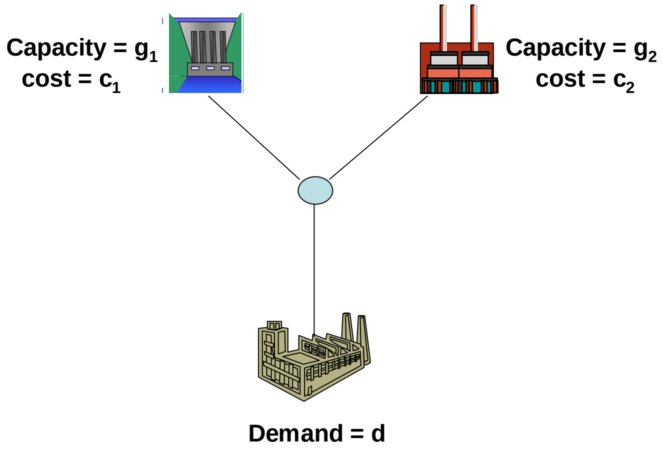
- Increase the optimal objective value (i.e. cost of supply).
  - Generation will possibly be dispatched out of merit order
- Decrease nodal prices

Simple SPD model

$$\begin{aligned} \min \quad & c^T x \\ s.t. \quad & Ax = d \\ & 0 \leq x \leq g \end{aligned}$$

- Ignore reserves, transmission and losses

One node, two generators



No transmission losses, infinite transmission capacity, no reserves

Primal and Dual

P1: $\min \; c_1 x_1 + c_2 x_2$

$$\begin{aligned} s.t. \quad x_1 + x_2 &= d \\ x_1 &\le g_1 \\ x_2 &\le g_2 \\ x_1, x_2 &\ge 0 \end{aligned}$$

D1: $\max \; d\pi + g_1 \lambda + g_2 \mu$

$$\begin{aligned} s.t. \quad \pi + \lambda &\le c_1 \\ \pi + \mu &\le c_2 \\ \pi & \;\; \textit{unrestricted} \\ \lambda, \mu &\le 0 \end{aligned}$$

Solution to the Dual

D1: $\max \; d\pi + g_1 \lambda + g_2 \mu$

$$\begin{aligned} s.t. \quad \pi + \lambda &\le c_1 \\ \pi + \mu &\le c_2 \\ \pi & \;\; \textit{unrestricted} \\ \lambda, \mu &\le 0 \end{aligned}$$

Now if $c_1 > c_2$ and $d \ge g_1$ and $d \ge g_2$ then the optimal solution to D1 is:

$$\begin{aligned} D1^* &= c_1 d + g_2 (c_2 - c_1) \\ \pi &= c_1 \\ \mu &= c_2 - c_1 \\ \lambda &= 0 \end{aligned}$$

Now add Frequency Keeping Constraint: $x_1 \geq m$

P2: $\min \; c_1 x_1 + c_2 x_2$

$$
\begin{aligned}
s.t. \quad x_1 + x_2 &= d \\
x_1 &\leq g_1 \\
x_2 &\leq g_2 \\
x_1 &\geq m \\
x_1, x_2 &\geq 0
\end{aligned}
$$

Assume g_1 capacity and demand is greater than the fk instruction and the remaining demand can be met by g_2

Choose $g_2 \geq d - m, \; g_1 > m$ and $m < d$

The optimal solution to P2 is:

$$
\begin{aligned}
P2^* &= c_1 m + c_2(d - m) \\
x_1 &= m \\
x_2 &= d - m
\end{aligned}
$$

The constraints $x_1 \leq g_1$ and $x_2 \leq g_2$ are not binding and consequently the dual variables $\lambda, \mu = 0$.

Dual Problem with FK Constraint

D2: $\max \; d\pi + m\varphi$

$$
\begin{aligned}
s.t. \quad \pi + \varphi &\leq c_1 \\
\pi &\leq c_2 \\
\pi &\; unrestricted \\
\varphi &\geq 0
\end{aligned}
$$

Recall that $c_1 > c_2$.

The optimal solution to D2 is:

$$
\begin{aligned}
D2^* &= c_2 d + m(c_1 - c_2) \\
\pi &= c_2 \\
\varphi &= c_1 - c_2
\end{aligned}
$$

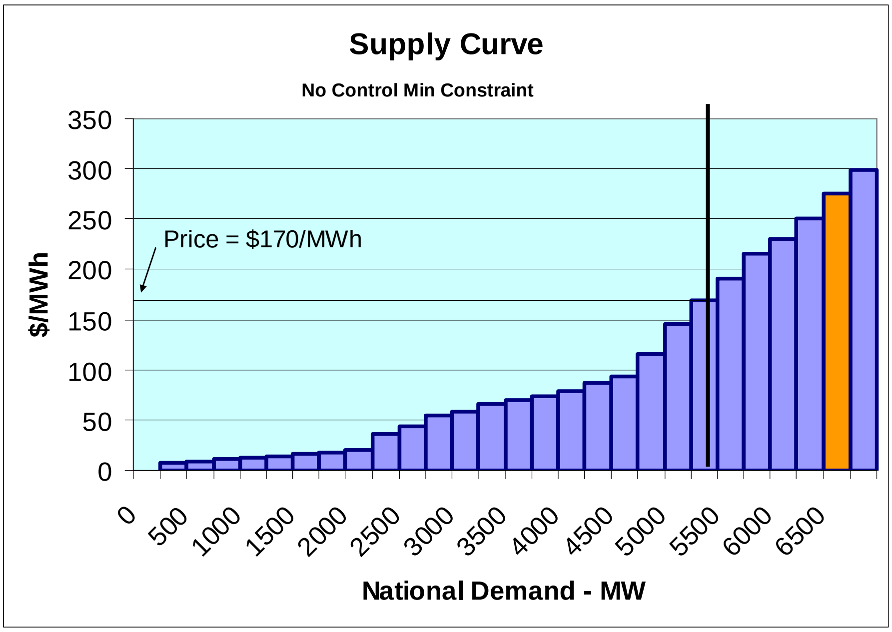
The value of π from *D2** is smaller than the value of π from *D1**

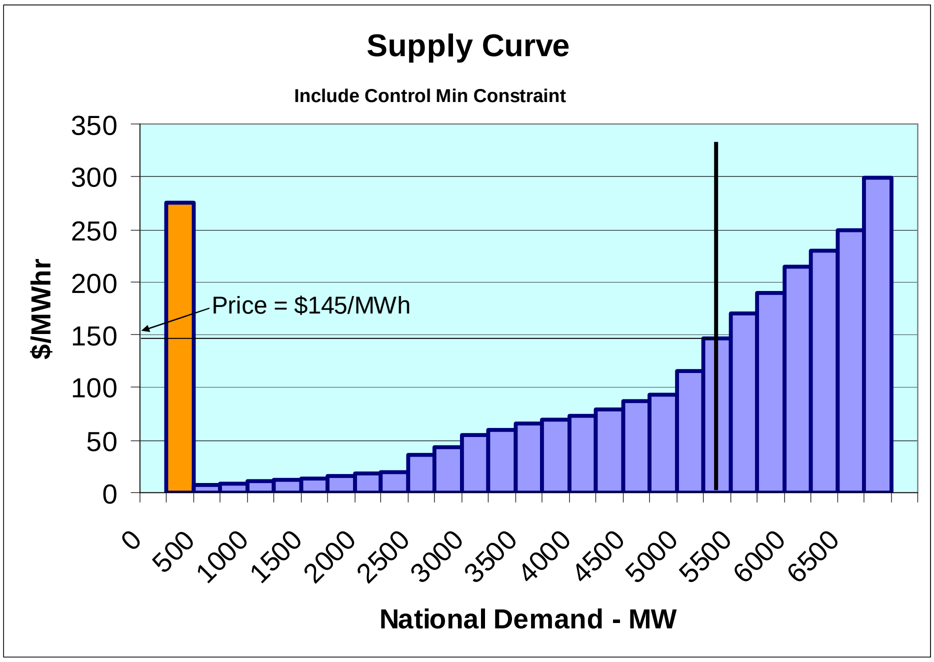
$$\pi(D1^*) = c_1$$
$$\pi(D2^*) = c_2$$

$$\begin{aligned} D2^* - D1^* &= dc_2 + (c_1 - c_2)m - [c_1 d + g_2(c_2 - c_1)] \\ &= (c_1 - c_2)(g_2 + m - d) \end{aligned}$$

Recall that $g_2 \geq d - m \Rightarrow D2^* \geq D1^*$

Here demand (*d*) can be met from the cheaper generator (x_2) and the constrained on volume from the Frequency Keeper (*m*) and the more expensive generation tranche is not required and the nodal price is reduced.





Effect of Network, reserves etc

- In our example we assumed that all network, reserve, security constraints were not binding
- In practice some of these constraints will be binding
  - FK constraints may cause constraints to bind
- Values of dual variables may increase at some nodes, and decrease at others

Effect of FK Control Min constraint

- Nodal prices may be reduced
  - Lower revenue for generators
- Marginal generation tranche may not be dispatched
  - Lower revenue for the previously marginal generator
- Need some method of compensating the Frequency Keeper

Constrained On Payments

- Constrained On payments are made to a generator as compensation for producing electricity above the level determined by the final pricing run of SPD
  - Either by virtue of being the Frequency Keeper
  - Or due to ramp rates
  - Or possibly due to an instruction for voltage support
- The total cost of Constrained On payments are pro-rated on a monthly basis amongst all purchasers regardless of location and time of use.

Constrained On Formula

- Constrained On Payment = $(Q_{actual} – Q_{dispatch}) * (P_{offer} – P_{final})$

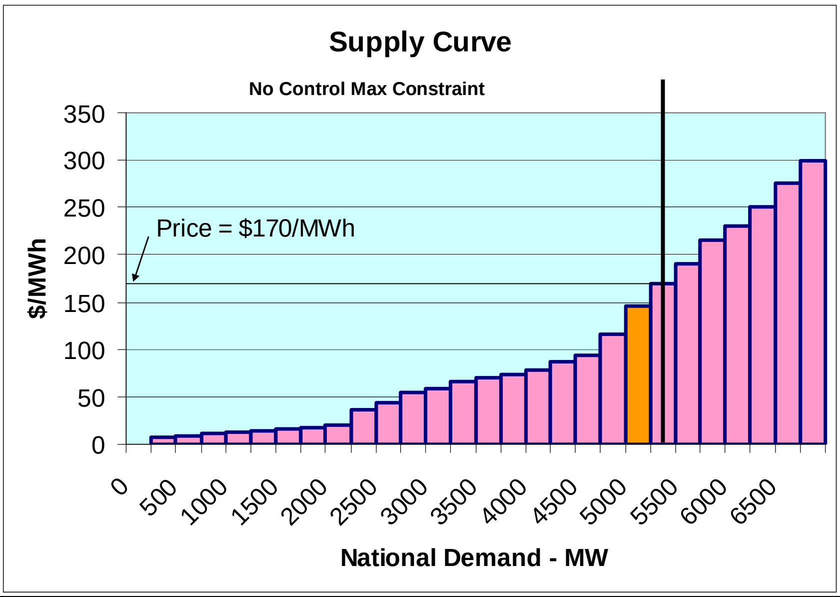
Example

- Actual generation = 70 MW for half an hour
- Dispatch Instruction = 20 MW
- P_{final}=$50/MWh, P_{offer} = $2050/MWh
- CO Payment = (35 – 10) * (2050-50) = $50,000

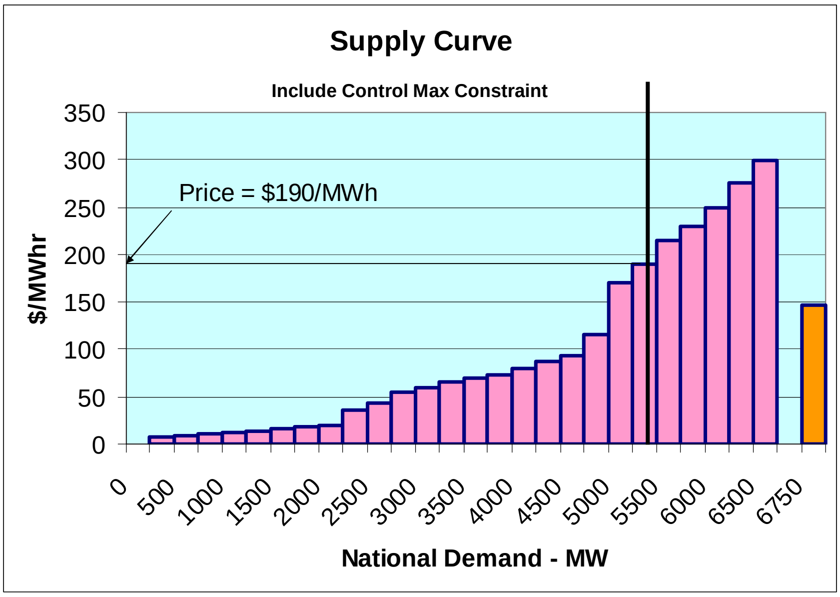
Opportunity for exercise of market power

- Generator offers a low price into FK market and wins the rights to FK
- Generator offers a high price into the energy market and stipulates a high control min
- Generator is paid a Constrained On payment at the high offer price for the control min amount
- Further opportunities are available by anticipating times when constrained on instructions are likely (when system demand is ramping up)
  - manipulating frequency from other stations

Effect of Control Max Constraint

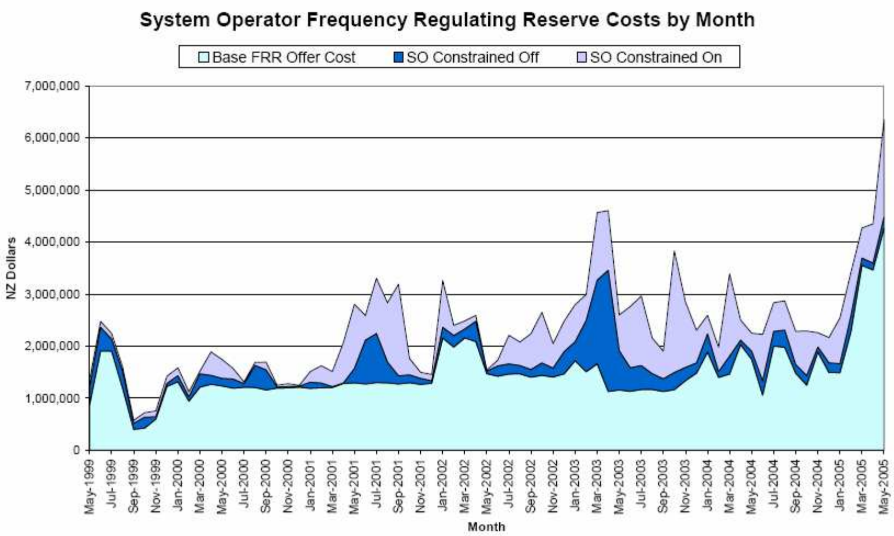


Control Max Tranche excluded, price goes up

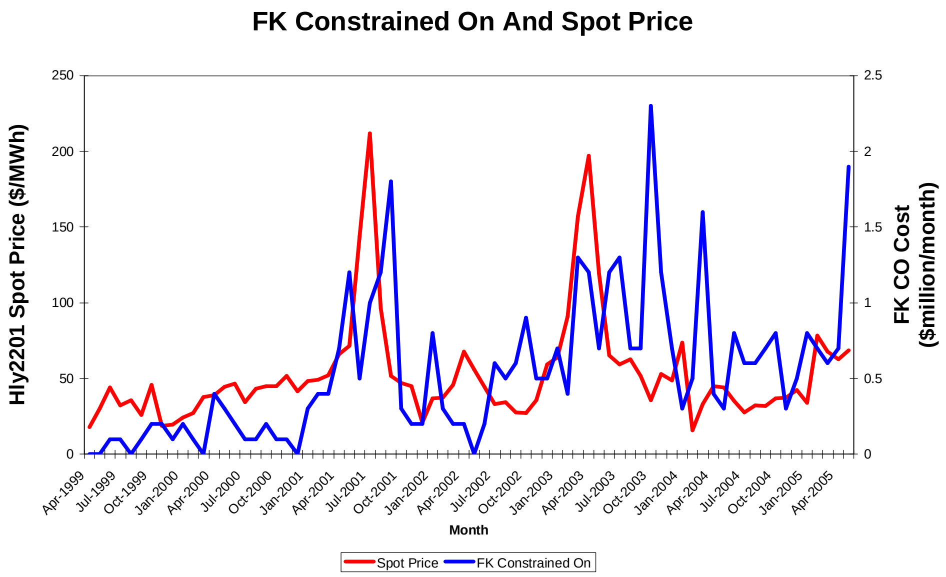


Materiality

- Control Max constraints seem unlikely to be material
  - Generators probably set high values for control max.
  - If control max constraints bind prices are likely to be high anyway.
  - No apparent opportunities to exploit control max
- Control Min Constraints seem likely to be material much more often than control max constraints.
  - Generators may be attempting to conserve fuel
  - Opportunities to exploit control min appear to exist



Source: www.electricitycommission.govt.nz (CQAG meeting papers)



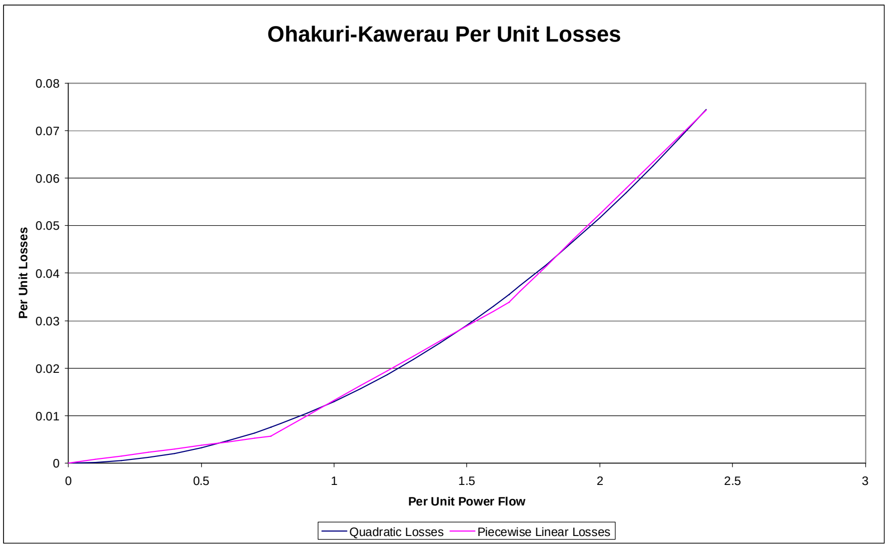
Risk of Rogue Trader

- MEUG alleged the rules around FK and Constrained on represented an Undesirable Trading Situation as the potential liability was unlimited.
  - Once appointed FK, generator has no competition
  - Purchasers see no signals of high FK/CO costs and have no way to avoid them
  - Suppose a trader offers energy at $\$1.0\ e^{20}$
  - All purchasers bankrupted
- The Electricity Commission said that no UTS existed as there was no recent evidence of any patterns of undesirable behaviour related to FK and CO charges.

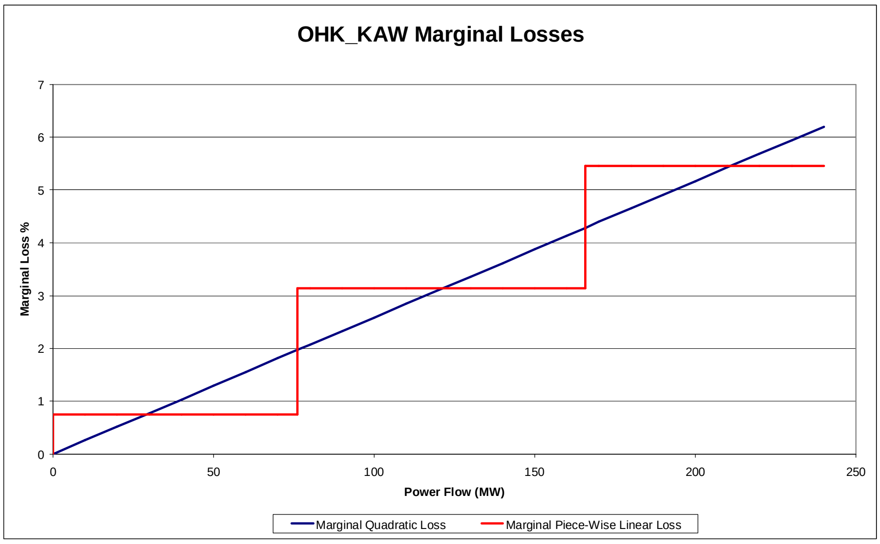
Solution

- Remove Constrained On Payments to the Frequency Keeper
  - This removes the unlimited liability
  - Provides some competition
- Allow multiple frequency providers
- But the problem of nodal price interference/suppression still remains
  - Add the cost of procuring Frequency to the SPD objective function?

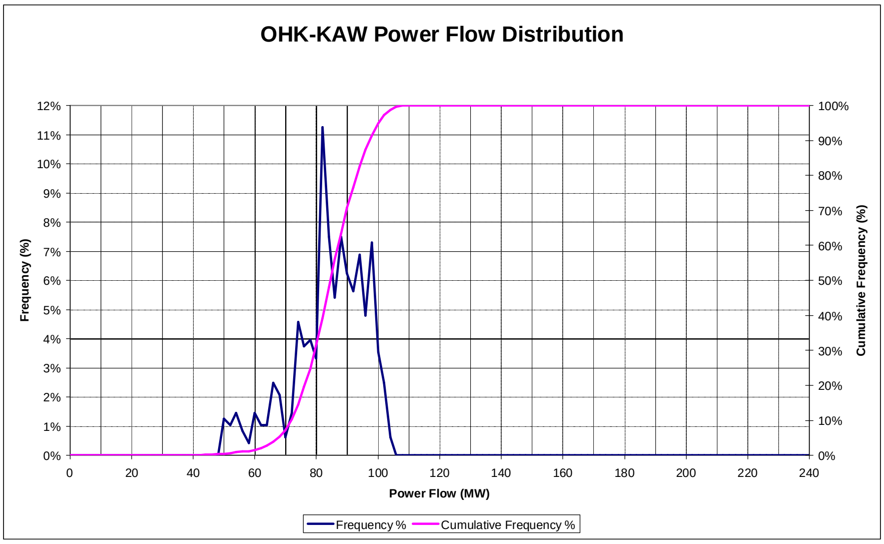
Loss Modelling



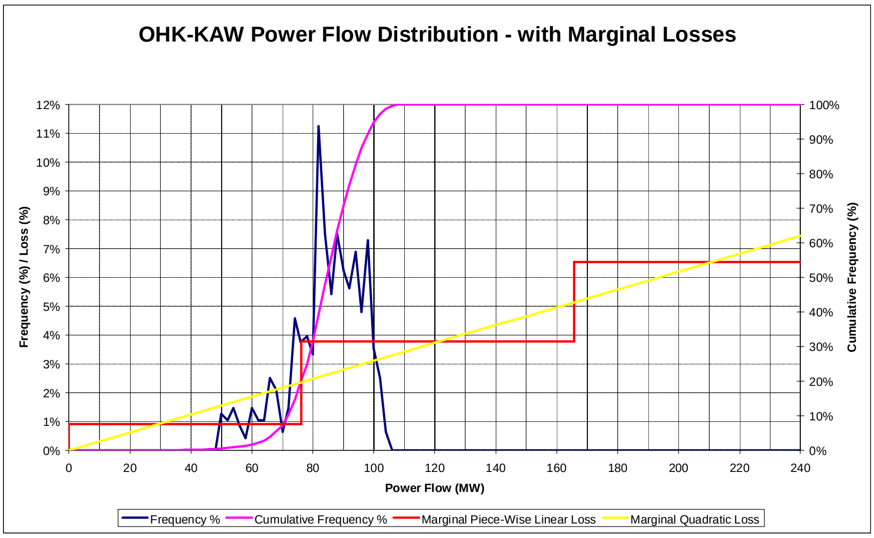
SPD has 3 marginal loss tranches per transmission line



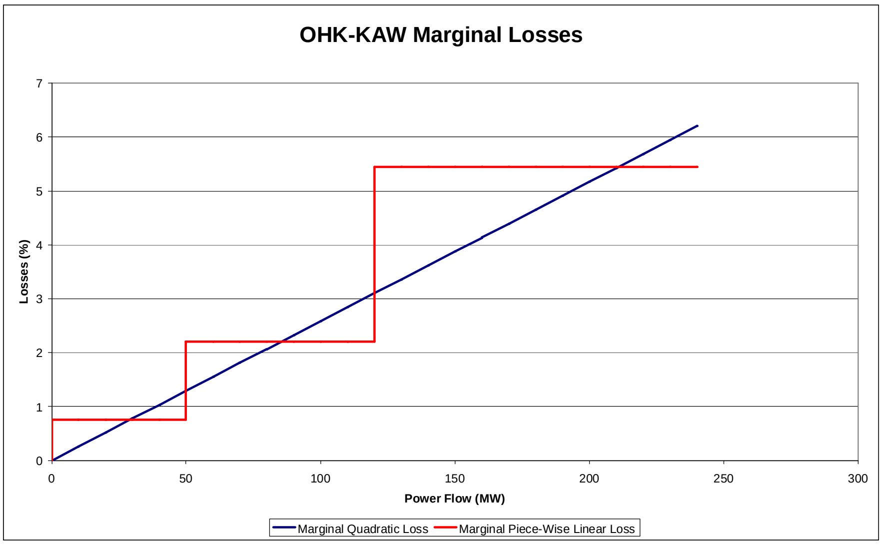
Actual flows



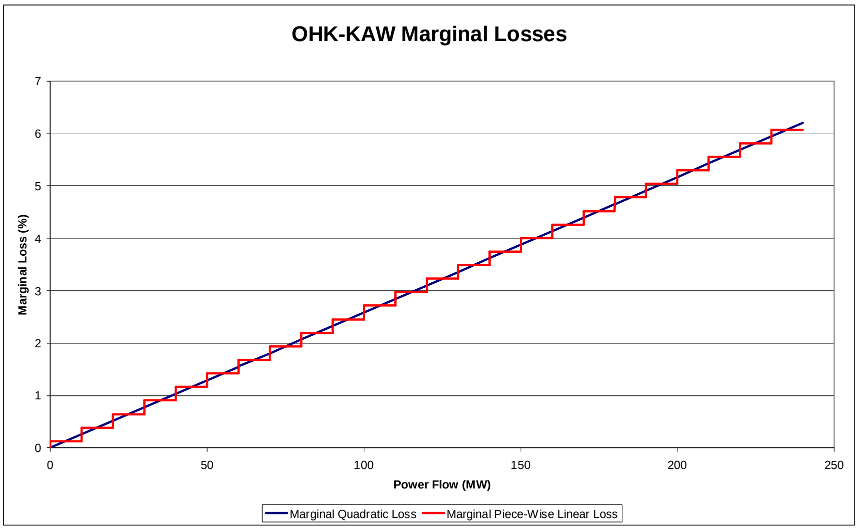
Flows on the "wrong" side of the break point



Shift the Break Point



More Sensible Solution is to increase the number of marginal loss tranches



WMAG (Electricity Commission) Paper

"The market administrator is aware that most suppliers of SPD type models now claim to be able to provide more accurate modelling of AC line flows (and losses) that can still interact with linear programming limitations.

Typically this involves the use of separate non-linear line flow and contingency analysis model that provides piecewise linear constraint information to the linear part of the model at each iteration."

Source: www.electricitycommission.govt.nz (WMAG meeting papers)

Non Convexity

- I am unable to find any references to SPD suppliers with hybrid algorithms
- Supply chain optimisation vendors have bundled heuristics (e.g. genetic algorithms) with Linear Programs to overcome non-convexity
- Not aware of any convergence theory that supports these kinds of approaches

Conclusion

- Bolt-ons to SPD can have unexpected (and unintended) consequences.
- There appears to be a strong case to remove bolt-ons from SPD.
- But the bolt-ons perform a necessary function so alternative methods would be required.

Is it time for a re:think?

- Why is it necessary to have 248 nodes?
  - Helpful for the system operator and grid owner
  - But probably does not promote liquidity in spot and hedge markets
- How about a 2 node market?
  - 248 node SD model can still be used for dispatch
  - Non-linear P model for pricing
    - Fixed losses
    - No spring washers
    - No ancillary services (paid for outside the market)
    - Only one FTR
    - Negative Offers
    - But…large increase in Constrained On instructions!
    - …..

Bolt On List

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End of Talk