Modelling reserve scarcity under RTP

EPOC Winter Workshop 2018

7th September 2018

COMPETITION • RELIABILITY • EFFICIENCY

Current dispatch and pricing schedule

- Real time dispatch schedule used to dispatch energy and reserve.
- Real time pricing schedule produces indicative prices every five minute.
- Half-hourly based final price schedule define the settlement prices.
- Scarcity prices might be resolved during final prices.

Real time pricing

- Final pricing schedule cease to exist.

- Prices are defined according to real time dispatch.

- Half-hourly settlement prices defined by these “five-minute” prices

- Scarcity prices will remain and define the settlement prices.

Real time pricing – energy scarcity modelling

- 5% at $10,000/MWh
- 15% at 15,000/MWh
- 80% at 20,000/MWh

Real time pricing – reserve scarcity modelling

- Current CVP for 6s (FIR) and 60s (SIR) reserve are $100k/MWh
- Under scarcity situation, load shedding instead of reserve may occur while energy is used to provide reserve.

→ What are the right values of reserve CVPs?

Simplified risk/reserve modelling

HVDC risk :

$$IslandRisk_{i,c,rc} = HVDCRec_i - RiskOffset_{i,c,rc}$$

$$\forall c \in RESERVECLASSES\ \forall i \in ISLANDS\ \forall rc \in \{DCCEi, DCECEi\}$$

Generation risk :

$$IslandRisk_{i,c,rc} = Generation_g - RiskOffset_{i,c,rc} + Reserver_{g,c}$$

$$\forall g \in ISLANDRISKGENERATORS_i\ \forall c \in RESERVECLASSES$$

$$\forall i \in ISLANDS\ \forall rc \in \{ACCERISKSi, AECERISKSi\}$$

Simplified risk/reserve modelling

Matching of requirements and availability:

$$IslandRisk_{i,c,rc} \leq IslandReserve_{i,c} + \boldsymbol{ReserveDeficit_{i,c}}$$

$$\forall i \in ISLANDS \ \ \forall c \in RESERVECLASSES \ \ \forall rc \in RISKCLASSES$$

Total cleared reserve:

$$IslandReserve_{i,c} = \sum\nolimits_{r \in RESERVEOFFERS_{i,c}} Reserve_r$$

$$\forall c \in RESERVECLASS \ \ \forall i \in ISLANDS$$

Simplified risk/reserve modelling

Objective function:

$$
\begin{aligned}
&Net\ Benefit \\
&\qquad = DemandBenefit\ - GenerationCosts\ - ReserveCost \\
&\qquad - EnergyShortageCost\ - ReserveDeficitCost \\
&\qquad - OtherViolationCost
\end{aligned}
$$

COMPETITION • RELIABILITY • EFFICIENCY

ELECTRICITY AUTHORITY
TE MANA HIKO

Simplified risk/reserve modelling

$$EnergyShortageCost = \sum\nolimits_{i,j} EnergyShortage_{i,j} \times EnergyCVP_j$$

$$ReserveDeficitCost = \sum\nolimits_{i,c} ReserveDeficit_{i,c} \times ReserveCVP_c$$

$$\forall i \in ISLANDS \;\; \forall j \in ENERGYSHORTAGEBLOCKS \; \forall c \in RESERVECLASSES$$

SPD Energy and Reserve Price Basics

- Energy price: the marginal cost to supply the next 1 MW of demand.
- Reserve price: the benefit of 1 MW of “free” reserve to the system.
- Under normal situation, the definition of energy and reserve price is straight-forward.
- Under tight supply situation, the energy cost may impact reserve price and the reserve cost may impact energy price.

Potential issues with current reserve scarcity modelling

Case Study 1

Skip example

- One risk setter and both reserve classes constrained.
- The next 1 MW of demand supplied by a risk setting plant (or HVDC)

$$Price_{energy} = Cost_{energy} + Cost_{FIR} + Cost_{SIR}$$

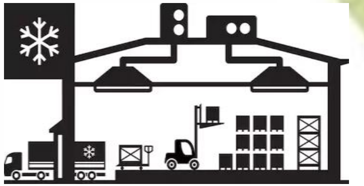
- If scarcity occurs in both reserve market, virtual marginal cost of FIR and SIR is reserve CVP.

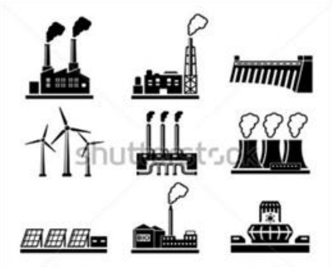
$$Price_{energy} = Cost_{energy} + CVP_{FIR} + CVP_{SIR}$$

- Assuming CVP_{FIR} and CVP_{SIR} = \$10,000/MWh
- → $Price_{energy}$ > \$20k/MWh → Load shedding is better option (Or is it?)

Case Study 1 example

North Island
Demand : 1650 MW





Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

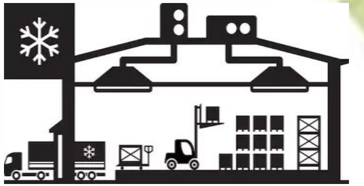
Energy CVP = 10k
FIR CVP = 10k
SIR CVP = 10k

South Island
Demand : 1000 MW

Case Study 1 example

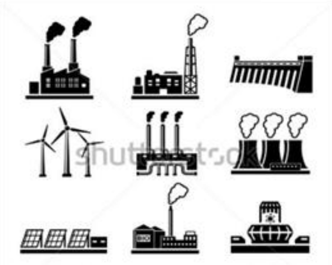
North Island

Demand : 1650 MW



IL FIR : 100 MW @ 100 $/MWh

IL SIR : 100 MW @ 200 $/MWh



ENRG: 1500MW @ 100$/MWh

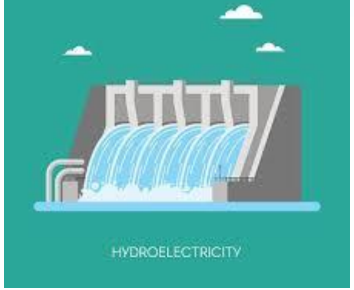
FIR : 200MW @ 20 $/MWh

SIR : 250MW @ 30 $/MWh

South Island

Demand : 1000 MW

ENRG: 3000MW @ 0.01$/MWh

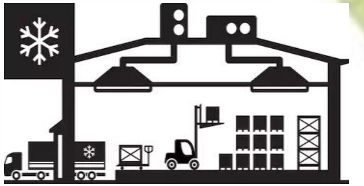


Case Study 1 example

North Island
Demand : 1650 MW

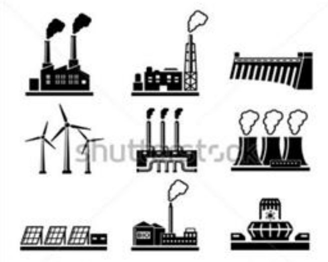
HVDC
NI ← SI
300 MW

South Island
Demand : 1000 MW



IL FIR : 100 MW @ 100 $/MWh
IL SIR : 100 MW @ 200 $/MWh

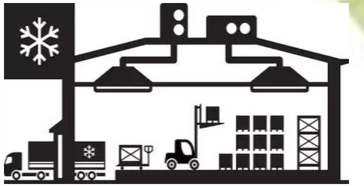
ENRG: 1300MW @ 0.01$/MWh



ENRG: 1300MW @ 100$/MWh
FIR : 200MW @ 20 $/MWh
SIR : 200MW @ 30 $/MWh

Case Study 1 example

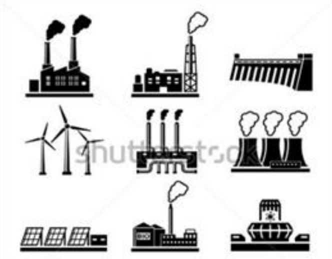
North Island
Demand : 1650 MW
50 MW energy shortage



Energy price: $10k/MWh

IL FIR : 100 MW @ 100 $/MWh
IL SIR : 100 MW @ 200 $/MWh

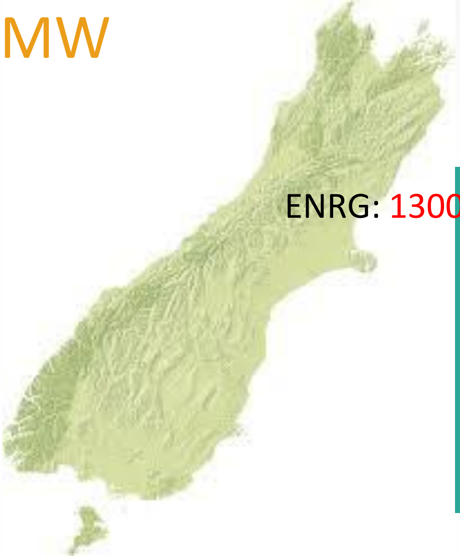
FIR price: $100/MWh
SIR price: $9899.99/MWh



ENRG: 1300MW @ 100$/MWh
FIR : 200MW @ 20 $/MWh
SIR : 200MW @ 30 $/MWh

HVDC
NI ← SI
300 MW

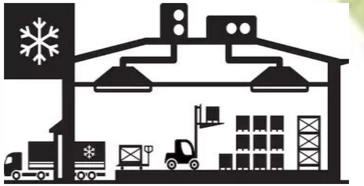
South Island
Demand : 1000 MW

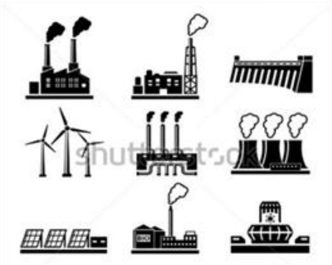


ENRG: 1300MW @ 0.01$/MWh

Case Study 1 example

North Island
Demand : 1650 MW





Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k
FIR CVP = 4.5k
SIR CVP = 4.5k

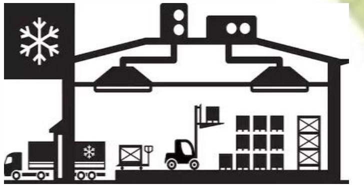
South Island
Demand : 1000 MW

Case Study 1 example

North Island
Demand : 1650 MW

HVDC
NI ← SI
350 MW

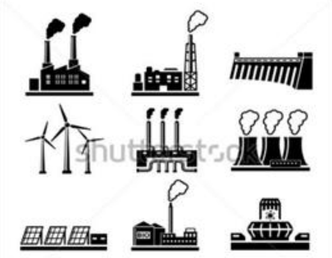
South Island
Demand : 1000 MW



Energy price: $9000.01/MWh

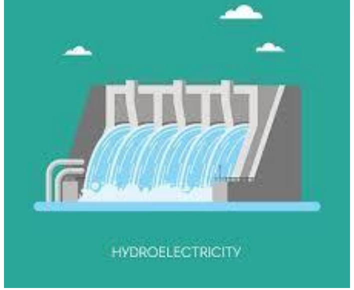
IL FIR : 100 MW @ 100 $/MWh
IL SIR : 100 MW @ 200 $/MWh

FIR price: $4.5k/MWh 50 MW FIR deficit
SIR price: $4.5k/MWh 50 MW SIR deficit



ENRG: 1300MW @ 100$/MWh
FIR : 200MW @ 20 $/MWh
SIR : 200MW @ 30 $/MWh

ENRG: 1350MW @ 0.01$/MWh



Case Study 2

Skip example

- Three supply sources (A, B, C) are constrained by either reserve class

$$Price_{energy} = \frac{1}{3}\left(Cost_{energyA} + Cost_{energyB} + Cost_{energyC} + Cost_{FIR} + Cost_{SIR}\right)$$

- Assuming FIR supply is constrained (scarce).

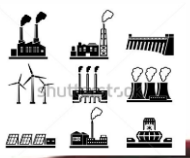
$$Price_{energy} = \frac{1}{3}\left(Cost_{energyA} + Cost_{energyB} + Cost_{energyC} + CVP_{FIR} + Cost_{SIR}\right)$$

- Assuming CVP_{FIR} = \$10,000/MWh, marginal energy cost at A, B and C is insignificant and marginal SIR price is very low → $Price_{energy} \approx 3333.33$

→ Energy supply source with marginal cost > 3333.33 will not be cleared but a reserve deficit is preferable by the model.

Case Study 2 example

North Island
Demand : 1510 MW



Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k
FIR CVP = 10k
SIR CVP = 10k

South Island
Demand : 1000 MW

Case Study 2 example

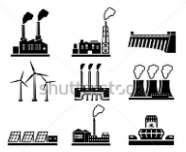
North Island

Demand : 1510 MW

ENRG: 350MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 350MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 100MW @ 5k$/MWh

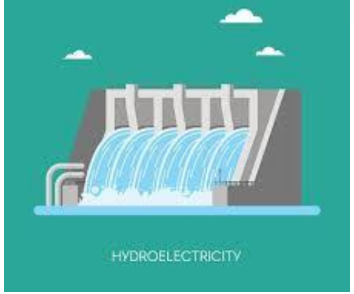


ENRG: 1000MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 300MW @ 3$/MWh

South Island

Demand : 1000 MW

ENRG: 3000MW @ 0.01$/MWh



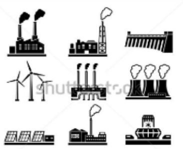
Case Study 2 example

North Island
Demand : 1510 MW

ENRG: 230MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 230MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 0MW @ 5k$/MWh

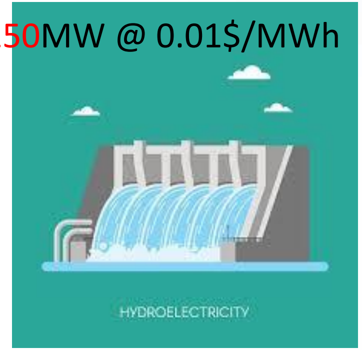


ENRG: 800MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 200MW @ 3$/MWh

HVDC
NI ← SI
250 MW

South Island
Demand : 1000 MW

ENRG: 1250MW @ 0.01$/MWh



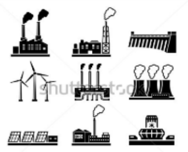
Case Study 2 example

North Island
Demand : 1510 MW

ENRG: 230MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 230MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 0MW @ 5k$/MWh



ENRG: 800MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 200MW @ 3$/MWh

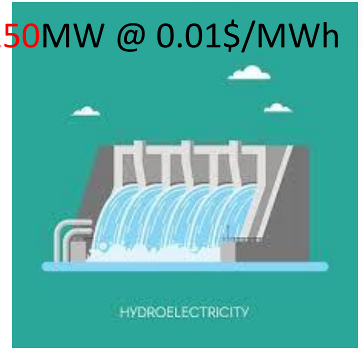
HVDC
NI ← SI
250 MW

Energy price: $3334.35/MWh
FIR price: $10k/MWh
SIR price: $3/MWh

10 MW of FIR deficit

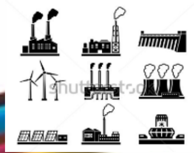
South Island
Demand : 1000 MW

ENRG: 1250MW @ 0.01$/MWh



Case Study 2 example

North Island
Demand :   1650 MW



Ignoring transmission losses, net free reserve, HVDC ramp up, HVDC capacity, reserve sharing and reserve requirement in SI

Energy CVP = 10k
FIR CVP   = 15k
SIR CVP   = 15k

South Island
Demand :   1000 MW

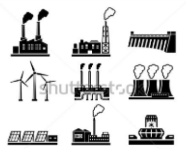
Case Study 2 example

North Island
Demand : 1510 MW

ENRG: 220MW @ 0.01$/MWh
FIR : 20MW @ 1$/MWh
SIR : 30MW @ 1$/MWh

ENRG: 220MW @ 0.02$/MWh
FIR : 20MW @ 2$/MWh
SIR : 30MW @ 2$/MWh

ENRG: 30MW @ 5k$/MWh

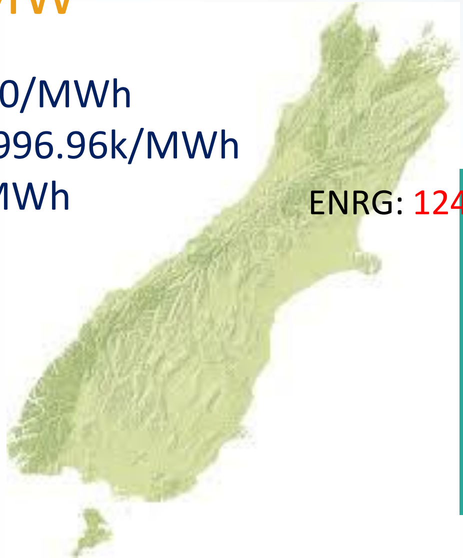


ENRG: 800MW @ 100$/MWh
FIR : 200MW @ 3$/MWh
SIR : 190MW @ 3$/MWh

HVDC
NI ← SI
240 MW

Energy price: $5000/MWh
FIR price: $14,996.96k/MWh
SIR price: $3/MWh

South Island
Demand : 1000 MW



ENRG: 1240MW @ 0.01$/MWh

Issues with current reserve scarcity modelling

- If reserve CVPs too low → available expensive supply may not be used but risk violation is preferred if there are multiple risk setters.
- If reserve CVPs too high → energy violation might be preferable by SPD model instead of violating reserve requirement and "keeping the lights on"

Desirable outcomes during scarcity in real time pricing

- Reserve/risk violation is preferable to load shedding.
- Reserve/risk violation should be limit at certain level.
- Reserve price reflecting the risk(s) that are covered.

- The current reserve scarcity modelling can’t achieve all of the above.

Proposed risk/reserve modelling

HVDC risk :

$$IslandRisk_{i,c,rc} = HVDCRec_i - RiskOffset_{i,c,rc} - \boldsymbol{RiskViolation_{i,c,rc}}$$

$$\forall c \in RESERVECLASSES\ \forall i \in ISLANDS\ \forall rc \in \{DCCEi, DCECEi\}$$

Generation risk :

$$IslandRisk_{i,c,rc} = Generation_g - RiskOffset_{i,c,rc} + Reserver_{g,c} - \boldsymbol{RiskViolation_{i,c,rc}}$$

$$\forall g \in ISLANDRISKGENERATORS_i\ \forall c \in RESERVECLASSES$$

$$\forall i \in ISLANDS\ \forall rc \in \{ACCERISKSi, AECERISKSi\}$$

Proposed risk/reserve modelling

Matching of requirements and availability:

$$IslandRisk_{i,c,rc} \leq IslandReserve_{i,c} + \cancel{\boldsymbol{ReserveDeficit_{i,c}}}$$

$$\forall i \in ISLANDS \;\; \forall c \in RESERVECLASSES \;\; \forall rc \in RISKCLASSES$$

Total cleared reserve:

$$IslandReserve_{i,c} = \sum_{r \in RESERVEOFFERS_{i,c}} Reserve_r$$

$$\forall c \in RESERVECLASS \;\; \forall i \in ISLANDS$$

Proposed risk/reserve modelling

Matching of requirements and availability:

$$IslandRisk_{i,c,rc} \leq \sum_{r \in RESERVEOFFERS_{i,c}} Reserve_r + \cancel{\boldsymbol{ReserveDeficit_{i,c}}}$$

$$\forall i \in ISLANDS \;\; \forall c \in RESERVECLASSES \;\; \forall rc \in RISKCLASSES$$

Risk Violation Tranches Allocation:

$$RiskViolation_{i,c,rc} = \sum_{j \in VIOLATIONTRANCHES} RiskViolationTranches_{i,c,rc,j}$$

$$RiskViolationTranches_{i,c,rc,j} \leq RiskViolationTrancheLimits_{i,c,rc,j}$$

$$\forall i \in ISLANDS \;\; \forall c \in RESERVECLASSES \;\; \forall rc \in RISKCLASSES$$

Proposed risk/reserve modelling

Objective function:

$$
\begin{aligned}
&Net\ Benefit \\
&\qquad = DemandBenefit\ - GenerationCosts\ - ReserveCost \\
&\qquad - EnergyShortageCost\ - \cancel{ReserveDeficitCost} \\
&\qquad - \boldsymbol{RiskViolationCost}\ - OtherViolationCost
\end{aligned}
$$

Proposed risk/reserve modelling

$$EnergyShortageCost = \sum_{i,j} EnergyShortage_{i,j} \times EnergyCVP_j$$

$$\cancel{ReserveDeficitCost = \sum_{i,c} ReserveDeficit_{i,c} \times ReserveCVP_c}$$

$$RiskViolationCost = \sum_{i,c,rc,j} RiskViolationTranches_{i,c,rc,j} \times RiskCVP_{c,j}$$

$\forall i \in ISLANDS \quad \forall j \in VIOLATIONTRANCHES$
$\forall c \in RESERVECLASSES \quad \forall rc \in RISKCLASSES$

COMPETITION • RELIABILITY • EFFICIENCY

ELECTRICITY AUTHORITY
TE MANA HIKO

Example of Risk Violation Tranche Limits and CVPs

Violation limits (MW)	FIR CVP ($/MWh)	SIR CVP ($/MWh)
10 MW	4500	4000
10 MW	7500	7000
10 MW	9500	9000
20 MW	12000	11000
1000 MW	15000	15000

Case Study 1

- One risk setter and both reserve classes constrained.
- Assuming CVP_{engy} = \$10,000/MWh and the risk binding supply source is cheap enough

→ Can violate the risk up to 10 MW before load shedding occurs.

Case Study 2

- Three supply sources (A, B, C) are constrained by 6s reserve class (FIR)
- Assuming CVP_{engy} = $10,000/MWh and the risk binding supply sources are cheap enough
- Assuming the other non-risk setting supply sources are available at $5000/MWh

→ Risk violation up to 10 MW occurs at A, B, C in the order of energy cost and free up 30 MW of energy before the $5000/MWh supply is required.

CONCLUSION

- The multi-step risk violation model seems to do the tricks.
- Still have to decide on the limits and cost of risk violation tranches.