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Report (Qgc00001) to

Queensland Generators Group

Stanwell Corporation Limited
CS Energy Ltd
Tarong Energy Corporation Limited
InterGen (Australia) Pty Ltd
NewGen Power Pty Ltd

Investigation of Positive Flow Clamping

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VERSION HISTORY

Version History					
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1.0	30-11-2007	Matthew Holmes	Ben Vanderwaal	30-11-2007	Draft Report
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EXECUTIVE SUMMARY

ROAM Consulting's investigation of the Positive Flow Clamping (PFC) proposal in the AEMC's Draft Report on the Congestion Management Review has shown that a change to this method of Congestion Management has the potential to have significant impacts for many participants in the NEM. The 2-4-C market simulation model has been applied to provide a view of the possible changes in NEM dispatch and pricing as a result of the PFC proposal. The market simulations show that as the clamping limit implemented with PFC increases, NEM dispatch and pricing outcomes are increasingly distorted.

Analysis of historic market outcomes shows that Negative Settlement Residues (NSRs) do not occur often nor with severity on interconnectors other than the QNI between the New South Wales and Queensland regions. This is due to increased generation volumes in the South-West Queensland (SWQ) region increasing more rapidly than the intra-regional transmission capability between the South-West of the Region and the Regional Reference Node near Brisbane. This historic analysis coupled with forecast market simulations for the 2010-11 year shows that the PFC proposal may discriminate against the generation located in the SWQ corner of the Queensland region. Modelling shows that implementation of PFC on the QNI will result in a downturn in generation dispatch from the SWQ generators equal to the PFC setting. This will have flow on effects with respect to the risk factors and capability for the SWQ generators to contract at the Regional Reference Node within their own region.

Many of the SWQ generators are amongst the lowest cost generators in the NEM, based on the publicly available ACIL Tasman *2007 Fuel resource, New Entry and Generation costs in the NEM* document. It follows that implementation of PFC on the QNI results in a reduction in market efficiency, measured as a function of total production cost. This is due to the requirement for higher cost generators to meet the reduction in SWQ generation. Increasing the Clamping level of PFC results in a significantly non-linear increase in NEM costs.

The analysis shows that forcing PFC will result in an increase in transmission system losses associated with transferring power over long transmission lines from distant generators to meet demand in adjoining regions of the NEM. This in itself appears at odds with one of the key premises of the NEM design which is to provide energy supply in the most efficient manner practicable.

The 2-4-C modelling shows that PFC may also cause perverse market pool price outcomes due to the relationships between generation dispatch and network powerflows on other network limits. Outcomes from the modelling show that implementation of PFC will increase pool prices across all regions of the NEM, relative to the present practice of Zero Flow Clamping (ZFC). Whilst this would constitute a wealth transfer from consumers to producers, it again appears at odds with the NEM premise of providing energy supply for the least cost based on generator offers to supply energy into the market.

The NEM dispatch and operation is necessarily complex. Market modelling applying dynamic transmission system constraint equations and realistic generator trading behaviour and responses to congestion, shows that alternative Clamping approaches can lead to significant distortions in market outcomes. Analysis of history and forecast market simulation studies shows that application of PFC with increasing levels of positive flow Clamping will result in non-linear decreases in market efficiency as measured by total generation cost and transmission system losses. Furthermore, modelling of the NEM shows the PFC will not only decrease system efficiency, but also result in increased market pool price outcomes leading to higher prices for consumers. All of these impacts appear at odds with the key objectives of the NEM to achieve the highest practicable levels of efficiency in energy supply at the lower cost to consumers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1) BACKGROUND

The AEMC's Draft Report on the Congestion Management Review was released on the 27th of September. Amongst a number of key recommendations, it was proposed that a new strategy be implemented for managing the accumulation of Negative Settlement Residues on interconnectors during times of counter-price flow across those interconnectors. This new strategy is called Positive Flow Clamping.

Due to the potential significant impact Positive Flow Clamping may have for generators, and particularly those with assets in South-West Queensland, a group of Queensland Generators have asked ROAM Consulting (ROAM) to investigate Positive Flow Clamping (PFC) and assess the implications of a potential change to this Congestion Management strategy in terms of market efficiency, generator volumes and generator revenues.

2) OVERVIEW OF CONGESTION MANAGEMENT

2.1) *NEGATIVE SETTLEMENT RESIDUES*

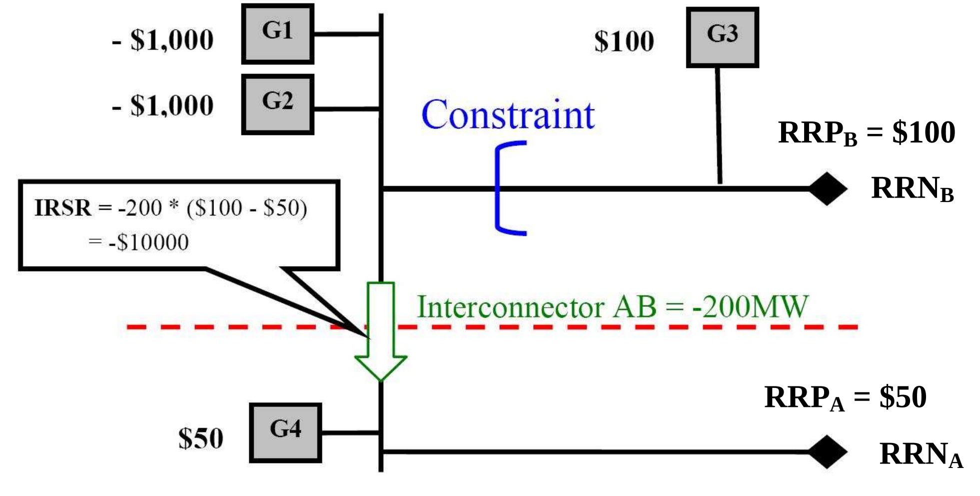
Settlement Residues apply to an interconnector and occur whenever power flows between regions along the interconnector. A Settlement Residue for a given interval is equal to the difference in pool price between the two regions, multiplied by the flow between the regions. For example, if the price in a Region 'A' was $10, the price in an adjacent Region 'B' was $20, and an interconnector between Regions 'A' and 'B' was flowing from Region 'A' to Region 'B' at 100MW, the Settlement Residue would be equal to *($20-$10) x 100MW*; that is $1000.

In the example of the previous paragraph, the interconnector was flowing from a lower priced region to a higher priced region. This is typically how the NEM functions; if lower cost generation in a different region is available, it is sent via the interconnectors to supply a higher priced region. The Settlement Residues resulting from such transfers are positive, and are therefore called Positive Settlement Residues (PSRs). However, it is also possible for Negative Settlement Residues to arise. This occurs when power is transferred from a higher priced region to a lower priced region. Such interconnector flows are called *counter-price flows* and occur as a result of intra-regional congestion issues.

The following example, paraphrased from the AEMC's Draft Report on the Congestion Management Review, describes how an intra-regional congestion issue drives Negative Settlement Residues:

To demonstrate how intra-regional congestion can cause counter price flow, refer to Figure 2.1. Because the intra-regional constraint in region B has reached its limit, an incremental increase in load at the regional reference node (RRN) in region B must be met by the higher priced generator 3, rather than the lower priced generators 1 and 2. Generator 3 is therefore setting the RRP for region B at $100 (in this example).

Figure 2.1 – Counter Price Flow



Because generators 1 and 2 are now dislocated from the regional reference node by the intra-regional constraint, they cannot set the RRP, and can therefore bid at any price and will still receive the (high) RRP being set by generator 3. They now have an incentive to bid as low as possible to maximise their dispatch. They will typically bid at the price floor of -$1000.

In the following dispatch interval NEMDE will dispatch generators 1 and 2 as much as possible due to their very low bidding price, and will correspondingly reduce the dispatch of generator 4 in region A. This may induce a flow south on the interconnector (200 MW in this example). Assuming generators 1 and 2 are fully dispatched, an increment in demand in region A must still be met by generator 4, so the RRP in region A is still set by generator 4 (rather than by generators 1 and 2).

This set of circumstances has produced the counterintuitive result of power flow from a high priced region to a lower priced region – counter priced flow.

Note that because the dispatch of generators in region A has been reduced, this scenario may actually decrease the RRP in region A (by changing marginal generators to a less expensive bid), hence exacerbating the difference in RRPs even further.

Because the power is being purchased at a low price in region A, but sold at a high price in region B, this produces a negative settlement residue equal to the difference in RRPs, multiplied by the flow on the interconnector (-$10,000 in this example). This will accumulate until the dispatch is changed such that the constraint no longer binds (probably by a reduction in the load at the RRN_B*).*

2.2) ZERO FLOW CLAMPING

Zero Flow Clamping (ZFC) is the strategy currently in use to manage Negative Settlement Residues. Currently, should NSR's accumulate to a threshold or *trigger* value of $6000 or greater on a given interconnector, NEMMCO responds by adding another system constraint that forces that interconnector's limit to a value of zero; the interconnector is artificially *clamped* to zero flow. Since the value of Settlement Residues is proportional to the flow, if the interconnector is clamped to zero, NSRs cannot result (note that Positive Settlement Residues cannot accumulate either).

It should be noted that the reason for the practice of Zero Flow Clamping is primarily to reduce NEMMCO's exposure to their inherent risk. NEMMCO does not possess the means to fund Negative Settlement Residues, so this clamping strategy has the effect of preventing significant accumulation of these amounts under most circumstances.

2.3) POSITIVE FLOW CLAMPING

The AEMC's Draft Report on the Congestion Management Review puts forward the concept of Positive Flow Clamping (PFC) as a substitute for Zero Flow Clamping (ZFC). This proposal has been put forward on the premise that PFC delivers Positive Settlement Residues, in comparison with Zero Flow Clamping, which prevents the accumulation of either Negative or Positive Settlement Residues.

PFC in practice works in a similar fashion to ZFC in that it is triggered by the accumulation of Negative Settlement Residues up to a specified amount. However, instead of the interconnector flow limit being clamped to zero, the flow limit would be clamped to a particular value representing a *positive flow*; that is, a flow from the lower-priced region to the higher-priced region.

PFC will have significant impacts on the dispatch of generation and has the potential to have run-on effects in terms of pool prices and system losses. The impacts of PFC for generators and particularly QLD generators are explored in Section 5).

2.4) CONGESTION AND NEGATIVE SETTLEMENT RESIDUES IN THE NEM

It is intra-regional congestion that causes counter-price flows in the NEM and hence Negative Settlement Residues.

ROAM conducted analysis of historical NEM trading data from the last few years to gain an understanding of how and when Negative Settlement Residues have appeared. Note that the following analysis was performed on Trading Interval records and not 5 minute Dispatch Intervals. Therefore only Trading Intervals for which Negative Settlement Residues exceeded $1500[2] were included in the analysis. Although this does not correspond exactly with detecting series of 5 minute Dispatch Intervals for which NSRs reached the current Clamping trigger value of

$6000, it provides sufficient detail to draw conclusions as to the frequency and severity of intra–regional congestion in the NEM.

Table 2.1 summarises the conclusions of this analysis of historic NEM data. It shows the occurrence of Negative Settlement Residues across the NEM and the severity of these events:

Table 2.1 – Summary of Negative Settlement Residues in the NEM

Time Period: 25/11/2005 to 25/11/2007

	NSW->QLD	QLD->NSW	SA->VIC	SNO->NSW	SNO->VIC	TAS->VIC	VIC->SA	VIC->SNO	VIC->TAS
Max	$ 8,629	$ 2,228,839	$ 78,301	$ 1,333,691	$ 567,052	$1,090,618	$ 488,255	$ 783,581	$ 473,904
Min	$ 2,501	$ 1,524	$ 1,628	$ 1,511	$ 1,551	$ 1,503	$ 1,502	$ 1,517	$ 1,501
Avg	$ 5,215	$ 145,364	$ 6,649	$ 58,057	$ 22,795	$ 15,315	$ 28,446	$ 69,280	$ 6,297
Median	$ 4,864	$ 5,565	$ 2,637	$ 4,560	$ 3,284	$ 3,027	$ 3,638	$ 6,410	$ 2,419
# Periods	4	143	22	134	46	380	69	39	453
Total Value	$ 20,859	**$20,787,064**	$146,280	$ 7,779,572	$ 1,048,590	$5,819,666	$1,962,787	$ 2,701,918	$2,852,669

The summary above shows that Negative Settlement Residues occur across all interconnectors in the NEM. Discounting NSRs between Victoria and Tasmania, which are different due to Basslink's status as an MNSP, it can be seen that NSRs occur most frequently on the Queensland to NSW interconnector, and on Snowy to New South Wales.

In addition to the high frequency of NSRs on the Queensland to NSW interconnector, the value of these NSRs has also been significantly higher than on the other NEM interconnectors. In comparison, NSRs in the reverse direction, that is, from NSW to Queensland, have been rare in the NEM and also much lower in value.

Of interest is the fact that only a handful of these NSR periods occurred over the Queensland to NSW interconnector prior to December 2006. After this time, the frequency of NSRs has increased markedly. This increase coincides with the commissioning of the Braemar Stage 1 power station in South-West Queensland. With several new power stations committed and a further number proposed for the South-West Queensland area, it appears that the degree of congestion in this area, and associated counter-price flow, is likely to increase significantly over the coming years unless major new transmission capacity is built.

For intra-regional congestion to cause counter-price flows between regions, there are some pre-conditions that must be satisfied. These are:

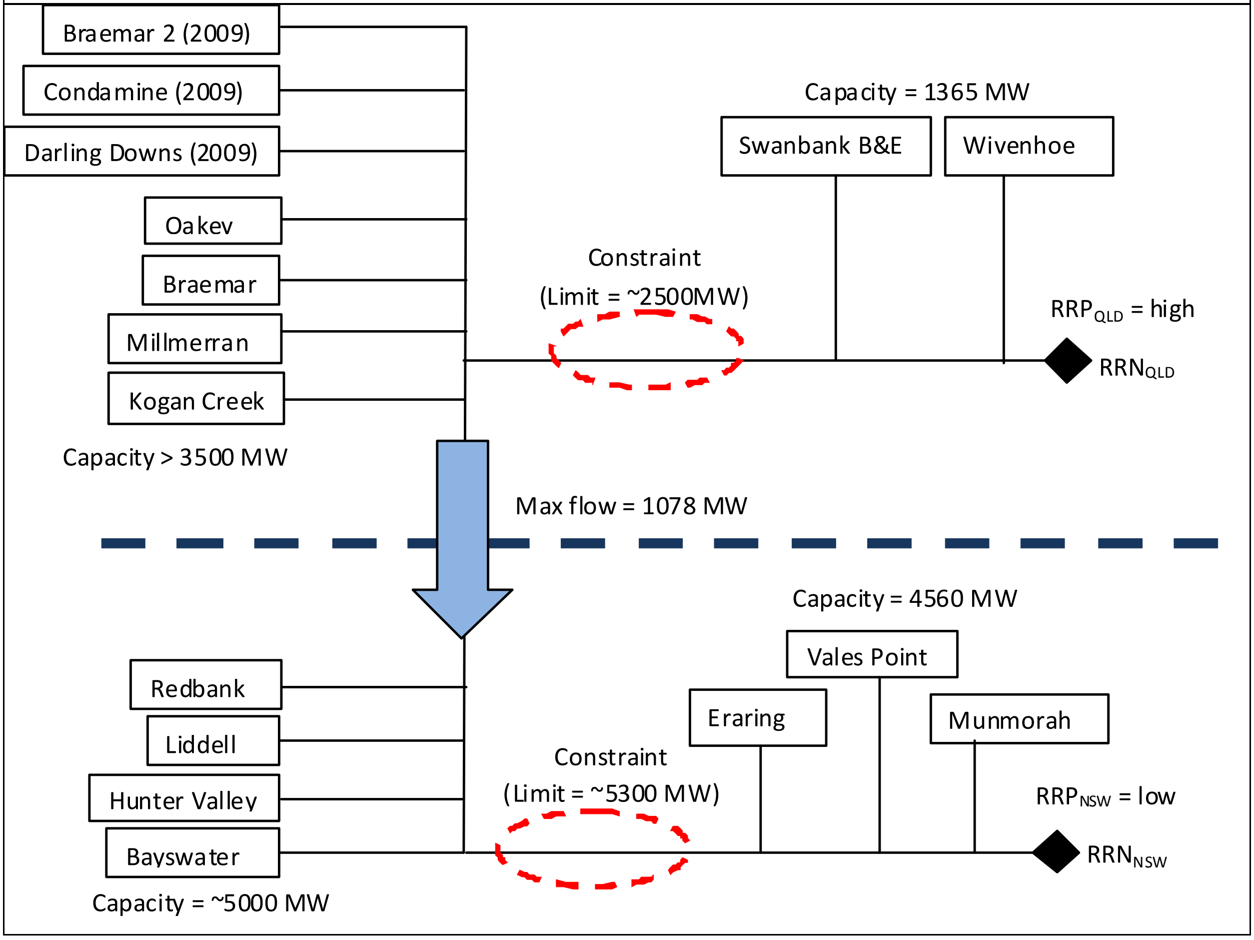
- A large pool of generation separated from the Regional Reference Node by an intra-regional transmission system that can be constrained. The total capacity of the generation pool must exceed the capability of the transmission system leading to the Reference Node.

- Demand in and around the Regional Reference Node must be sufficient to allow high power transfers from the large generation pool to the Reference Node (ie. High demand periods);
- The generation pool must be located between an interconnector and the Regional Reference Node.

These conditions must be in place for counter-price flows to occur under normal market operation. Naturally, transmission de-ratings due to maintenance or events such as lightning or bushfires have the potential to create an increased likelihood of counter-price flows. These events are not covered in the modelling, which assumes System Normal conditions. It is noted however that the transmission system in and around South-West Queensland has been prone to de-rating due to lightning in the area.

Figure 2.2 shows the area in the NEM responsible for the vast majority of congestion leading to Negative Settlement Residues between Queensland and New South Wales. This configuration is consistent with the study period, being between 2009-10 and 2010-11.

Figure 2.2 – QLD and NSW Generation and Transmission



The diagram shows that by 2009, the ~3500MW of capacity located within South-West Queensland will exceed a ~2500MW constraint limit towards the Regional Reference Node. This constraint is known as the SWQ constraint and is described in detail in Appendix B.4). This indicates that there exists a high possibility of constraining this flow path, and since the generation pool is located next to QNI, there is a corresponding potential for counter-price flow from Queensland to New South Wales. It is noted here that the Tarong and Tarong North generators are 'upstream' of the SWQ constraint and as such they are not affected by this limitation. There is no guarantee however that if/when the SWQ limit is alleviated that the next limitation will be across the larger set of transmission lines from Tarong into Brisbane. In that possible future situation the Tarong generators would be faced with a similar situation to the SWQ generators shown in this analysis.

In the opposite direction, however, the likelihood of counter-price flows is much lower. The ~5000MW of capacity located in the Hunter Valley is not sufficient to exceed the ~5300MW notional limit towards the NSW Regional Reference Node under normal circumstances. Therefore, the probability of counter-price flow from New South Wales to Queensland is low. Planned upgrades to the Sydney ring transmission corridor will bolster the capabilities of the NSW network, further reducing the possibility of such flows. ROAM's Monte-Carlo simulation of 2010-11 found no occurrences of counter-price flow from New South Wales to Queensland.

2.5) FACTORS CONTRIBUTING TO NEGATIVE SETTLEMENT RESIDUES

Primarily, it is a situation with a regional generation and network configuration as described in Figure 2.2 that provides the potential for counter-price flow across interconnectors and hence Negative Settlement Residues. However, there are several factors which can contribute to and/or lengthen periods of counter-price flow. These factors include:

- Unit outages – typically, even at times of high demand, very large transfers are not drawn from the key generation 'pool'. However, if some baseload units elsewhere in the network have failed, then flows from the pool may increase sufficiently to cause congestion;
- Sustained high demand at/around the RRN – continuing high demand allows flows to remain high and therefore prolong congestion;
- Manipulation of ramp rates – ramp *down* rates particularly may cause or lengthen periods of counter-price flow as generation dispatch outcomes leading to counter-price flows may not be quickly resolved;
- 'Disorderly' bidding - if the pool bids at the price floor, that is, bidding in a way not reflective of real costs, the dispatched capacity from the pool may cause congestion and hence counter-price flow, and;
- Transmission de-ratings – de-ratings may be due to maintenance or other unplanned transmission outages, however all have the effect of reducing the network capability and hence increasing the potential for congestion.

3) KEY ASSUMPTIONS

The following sections describe the key assumptions upon which the outcomes described in Section 5) depend. More detailed modelling information is provided in the Appendices.

3.1) *DEMAND AND ENERGY*

The demand and energy forecasts used in this study have been assembled by ROAM to be fully consistent with the 2007 NEMMCO energy and demand projections located in the 2007 SOO. These forecasts correspond with the Medium Economic Growth energy, 50% Probability Of Exceedence (POE) demand forecasts for all NEM regions. The 50% POE demand forecast corresponds with average weather conditions leading to power demands expected to be exceeded one year out of every two.

The regional load trace forecasts (that is, the half-hourly load data) have been developed using the actual recorded 2006-07 financial year load traces for each region as the reference year.

Note that if a 10% POE forecast was to be used, extreme demands would be higher and more frequent in Queensland (and particularly, South-East Queensland). This would have the potential to result in a higher incidence of binding on the SWQ constraint, which in turn may lead to increased occurrences of Negative Settlement Residues. The 50% POE forecast represents a more likely level of demand and hence is presented here. The nature of the findings would be equally valid for 10% POE conditions.

Due to the similarity between the forecast 50% POE peak demand for 2010-11 and the forecast 10% POE peak demand for 2009-10, it is reasonable to assume that the modelling presented (50% POE 2010-11) may provide similar outcomes to those which would be seen in a 10% POE case for 2009-10.

3.2) *NEW PLANT SCHEDULE*

The new plant schedule shown in Table 3.1 was assumed in the modelling. The plan was developed in light of the information provided in the 2007 SOO along with public announcements from possible developers which were used to flag plant that became committed after the publication of the SOO and also to identify those projects most likely to proceed. Only the years up to and including 2010-11 are important in this assessment given that this covers the timeframe of the modelling work. Note that all results shown in Section 5) assume this same plant schedule.

Adding the assumed new entry generation schedule into the 2007 Supply-Demand Calculator results in the Supply-Demand balance charts presented in Appendix A.1). These charts show that the assumed new entry generation schedule will satisfy the NEM Minimum Reserve Level criterion up to the year 2012-13.

Table 3.1 – Assumed New Entry Generation Schedule

	Station Name	Station Type	Capacity*	Timing	Status
QLD	**Braemar 2**	OCGT	450	2009/10	Proposed
	Condamine	CCGT	135	2009/10	Committed
	Darling Downs	CCGT	630	2009/10	Committed
	AGL Townsville	CCGT	400	2011/12	Proposed
	Swanbank F	CCGT	385	2012/13	Proposed
NSW	**Tallawarra**	CCGT	422	2008/09	Committed
	Uranquinty (Stage 1)	OCGT	471	2008/09	Committed
	Uranquinty (Stage 2)	OCGT	157	2009/10	Committed
	Colongra	OCGT	668	2009/10	Committed
	Munmorah (retirement)	Coal-fired	-600	2012/13	Committed
	Tomago	OCGT	450	2012/13	Proposed
VIC	**Bogong**	Hydro	140	2009/10	Committed
	Mortlake	OCGT	450	2010/11	Proposed
SA	**Lake Bonney 2**	Wind	*13*	2007/08	Committed
	Hallett Windfarm	Wind	*8*	2008/09	Committed
	Quarantine	OCGT	121	2008/09	Committed
	Snowtown Windfarm	Wind	*7*	2008/09	Committed
	Hallett B	CCGT	250	2011/12	Proposed
TAS	**Tamar Valley**	CCGT	191	2009/10	Committed
	Tamar Valley	OCGT	40	2009/10	Committed
	Bell Bay (retirement)	CCGT	-240	2009/10	Committed

** Note: Windfarm capacities have been set to 8% of their respective maximum capabilities for supply-demand balance assessment in line with NEMMCO's assumptions. In the dispatch modelling these windfarms were modelled at their real capacities with dispatch based on a pseudo randomised wind scheduling tool developed by ROAM. These new developments are far from SWQ and therefore not likely to materially influence the focus of this assessment.*

4) METHODOLOGY

The following outlines at a high level the approach that was taken in assessing the impacts of Positive Flow Clamping, particularly for Queensland generators. More detail describing the modelling conducted and particularly the ***2-4-C*** model itself may be found in the Appendices.

1. The ***2-4-C*** Market Dispatch model was used to simulate the year 2010-11[1] several times with different Clamping methodologies implemented:
    i. Without any form of Clamping;
    ii. With Zero Flow Clamping implemented at an NSR trigger threshold of $1500 per Trading Interval[2];
    iii. With Positive Flow Clamping implemented at an NSR trigger threshold of $1500 per Trading Interval and with QNI clamped to 250MW (250MW represents a typical QNI import limit at time of extreme demand in Queensland), and;
    iv. As for (iii) above but with QNI clamped to 500MW (500MW being the nominal import limit of QNI and therefore the maximum value at which it could potentially be Clamped).
2. From the 'No Clamping' case, Trading Intervals with Negative Settlement Residues exceeding $1500 were identified, and the full dispatch information (generation, flows, prices, etc) of all cases (Clamping and No Clamping) for these periods was exported from the results set for detailed analysis.
3. An analysis tool was constructed that summarises the key information, such as SWQ generation volumes, pool prices and inter-regional transfers and also allows the comparison of these outcomes between two cases simultaneously.
4. Of all the analysed periods, a subset was selected featuring interesting outcomes. These same periods from the different Clamping cases were then compared with the analysis tool to highlight the impacts of the Clamping strategy.
5. A cost estimate was performed based on Short-Run Marginal Costs sourced from ACIL Tasman's *2007 Fuel resource, New Entry and Generation costs in the NEM* report and the generation volumes determined by the ***2-4-C*** simulations to identify the change in system cost or efficiency between the different Clamping strategies.

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[1] The years 2009-10 to 2010-11 were selected as the outlook period. Due to time constraints, modelling was restricted to the year 2010-11. The Queensland network configuration and generation portfolio is consistent over 2009-10 and 2010-11. Therefore the most significant change in the QLD grid over these two years is the increased demand in 2010-11. This increased demand will serve to increase the likelihood and severity of intra-regional congestion. Therefore it is considered that the outcomes presented here are valid for the 2009-10 year but would likely be less frequent due to the somewhat lower demand primarily in South-East Queensland.

[2] In the NEM, Clamping is currently triggered when the 5 minute pre-dispatch process forecasts an accumulation of $6000 in NSRs. The modelling for this study was however conducted on a Trading Interval basis. Therefore, the value of $1500 per Trading Interval was selected as it was deemed high enough to avoid Clamping NSRs situations due to outcomes of the IRLF equation, but lower than $6000, since the $6000 value may easily be reached within the six 5 minute dispatch outcomes making up a single Trading Interval.

6. With the assistance of an AC Powerflow model and the ***2-4-C*** dispatch outcomes, changes in system losses resulting from the dispatch alterations caused by the different Clamping strategies were assessed.

5) IMPACTS OF POSITIVE FLOW CLAMPING

A change from the current practise of Zero Flow Clamping to Positive Flow Clamping will have significant implications for all participants in the NEM, but particularly generators nearby the intra-regional issues that cause Negative Settlement Residues. The key impacts may be described in terms of:

- Dispatch and generator volume;
- Pool price and revenues;
- Market efficiency, and;
- System losses.

The following sections focus on each of these issues in detail and describe the modelling conducted by ROAM to quantify their impacts.

5.1) IMPACT ON POOL PRICES

By implementing Clamping on QNI, pool price outcomes will be affected. Depending on the degree by which the Clamping affects the dispatch, the modelling conducted has found that the difference in pool prices in both Queensland and New South Wales can be dramatic. To illustrate this effect, a Trading Day has been selected and the pool price trace for this day compared across the No Clamping, Zero Flow Clamping and Positive Flow Clamping cases. These pool price impacts are shown in Figure 5.1 and Figure 5.2.

As demonstrated in Figure 5.1, Positive Flow Clamping has two main effects on Queensland pool prices. The first effect is that Clamping to a positive flow increases the pool price relative to Zero Flow Clamping. Clamping to a higher value (500MW versus 250MW) exaggerates this price difference; in this Trading Day, the price in Queensland goes to the ceiling (VOLL, $10,000/MWh). The second effect is that Positive Flow Clamping extends the duration of the high prices. The combination of these two effects means that the average price across the Trading Day is increased significantly by Positive Flow Clamping.

Figure 5.1 – Queensland Pool Price Trace for 7/3/2011 with Clamping Cases

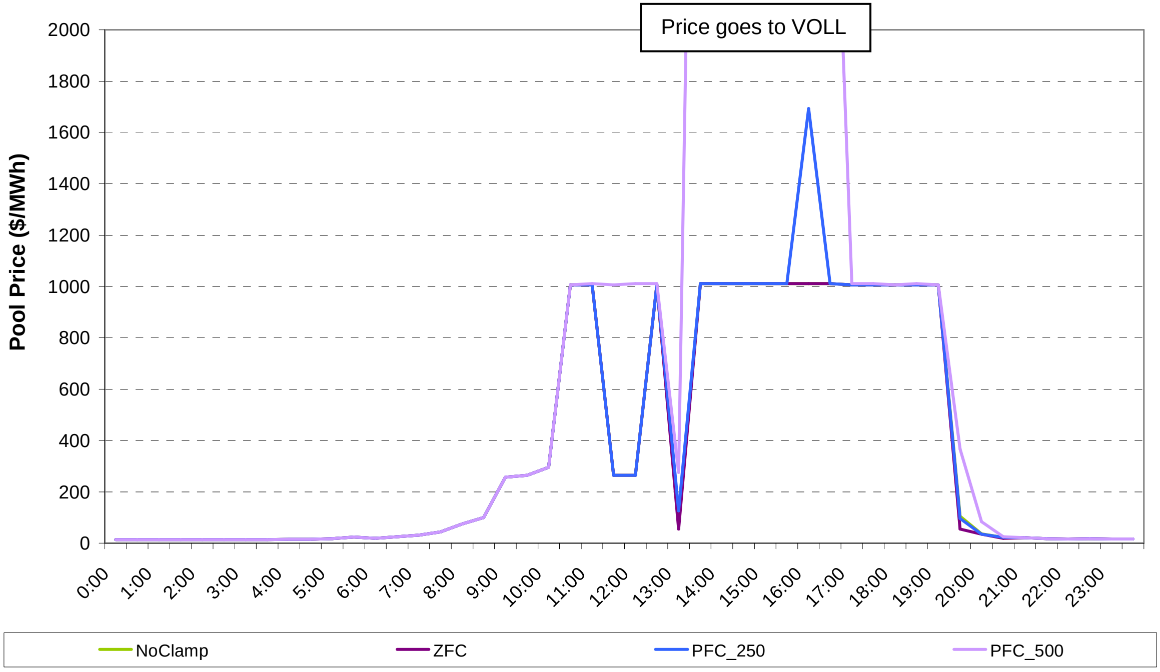
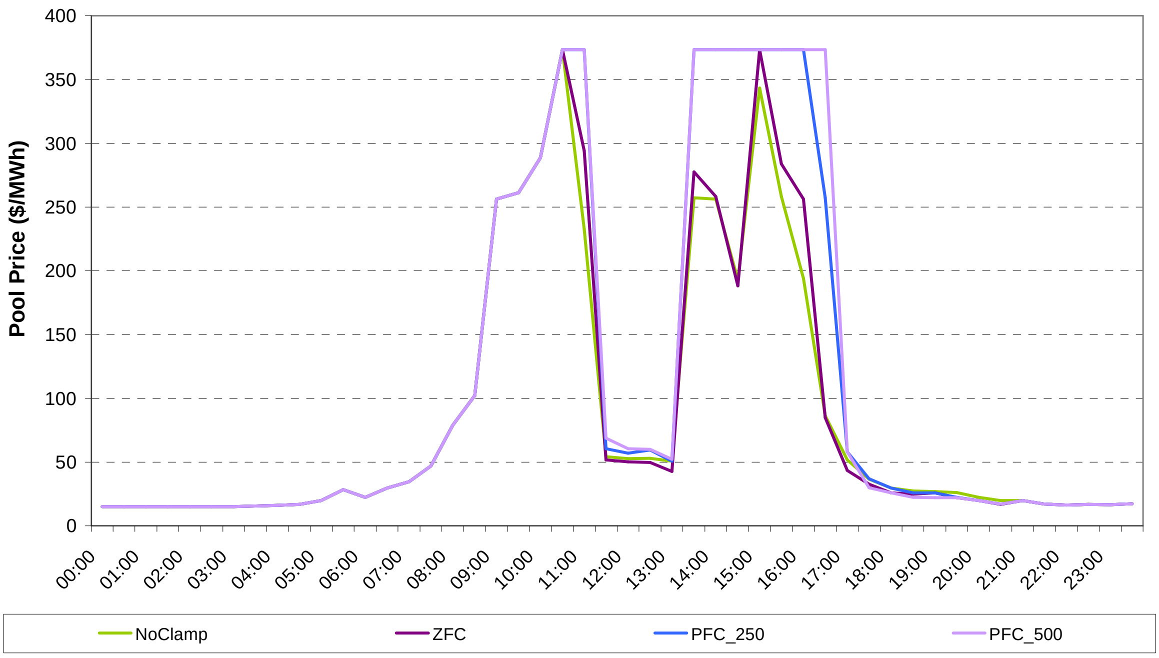


Figure 5.2 – New South Wales Pool Price Trace for 7/3/2011 with Clamping Cases



In Figure 5.2, it can be seen that the Clamping of QNI has similar price effects for New South Wales. However, the price increases are not as dramatic, which is expected due to the separation from the Queensland Regional Reference Node.

Nonetheless, it can be seen that Positive Flow Clamping can result in increased New South Wales spot prices and can increase the duration of these high price periods. These effects may be considered as a significant price distortion in the market.

The reason why Positive Flow Clamping can increase pool prices significantly is that the generation removed from SWQ generators cannot fully be supplied via the forced increased supply from New South Wales via QNI. Therefore, other units in Queensland with available capacity may have to be dispatched due to subtle flow-on effects of the Constraint Equations. The units called upon in these situations will typically be high cost as at these high demand periods most low-cost generation will be running at full capacity. Therefore this supply may come from either switching on expensive peaking units, or by utilising very high 'opportunity' bids at the upper ends of baseload generators' bid stack.

In the modelling completed there are over 1300 Trading periods in 20 Monte Carlo simulations of the 2010-11 year where NSRs occur under normal conditions (i.e. in the absence of 'Disorderly' bidding). Analysis of the Pool Price outcomes during these Trading periods provides the following outcomes.

Table 5.1 – Average Pool Price During Clamping Intervals ($/MWh)

Clamping	Queensland	New South Wales	Victoria	South Australia
NoClamp	1387.33	148.24	128.70	76.92
ZFC	1282.85	201.50	163.28	87.06
PFC_250	1351.34	247.21	183.59	89.59
PFC_500	2468.17	283.49	193.02	89.45

This shows that ZFC may actually serve to reduce the Queensland pool price, relative to the pool price outcome under no Clamping. This is due to a few instances where the Queensland pool price goes to VOLL without clamping, however remains below VOLL after ZFC. This is an outcome of the transmission constraint equations under normal operating conditions. Except for this outcome and taking ZFC as the reference case, it can be seen that increasing Positive Flow Clamping serves to increase the pool price outcome across the whole NEM.

5.2) IMPACT ON GENERATION DISPATCH AND REVENUES

Clamping to zero or a positive flow on the QNI interconnector results in a forced reduction in generation dispatch for the generators between the interconnector and the intra-regional limitation. As described previously, the analysis completed for this assessment shows that it is the SWQ limit which is the most significant limitation in the Queensland intra-regional network. As such, Clamping of the QNI interconnector provides for a negative impact on the set of SWQ generators only, whilst allowing other generators in the Queensland region, and generators south of Queensland to increase generation due to the impact of the Clamping event.

Table 5.2 shows the average generation dispatch from the SWQ generators during the periods of Clamping as described in Section 5.1) above. This shows that the average southerly flow (counter-price flow) on QNI during periods of NSR is 400MW. Therefore, when ZFC is implemented the average total generation from the SWQ generators must reduce by 400MW in total. In these circumstances the generators will likely be bidding at the price floor and therefore will be subject to 'pain sharing' whereby their dispatch will be shared in proportion to the submitted available capacity offers. As shown by the difference in total SWQ generation dispatch with respect to the ZFC dispatch outcome, PFC_250 and PFC_500 result in a forced reduction in SWQ generation by 250MW and 500MW in total respectively. This may increase the risk associated with contracting at the reference node by these generators.

Table 5.2 – Average SWQ Generation Dispatch During Clamping Intervals (MW)

Clamping	Braemar Stage 1	Braemar Stage 2	Condamine	Darling Downs	Kogan Creek	Millmerran	Oakey GT	SWQ Tot Gen	Diff w.r.t ZFC
NoClamp	356	394	130	617	726	830	282	3335	402
ZFC	313	346	114	543	639	730	247	2933	-
PFC_250	286	317	105	497	585	668	226	2684	-248
PFC_500	259	287	95	450	530	605	205	2431	-502

As a result of the forced reduction in generation dispatch from the SWQ generators their revenue will also be affected. The following table illustrates the average annual pool revenue earned during periods of Clamping.

Table 5.3 – Average SWQ Revenue During Clamping Intervals (MW)

Clamping	Braemar Stage 1	Braemar Stage 2	Condamine	Darling Downs	Kogan Creek	Millmerran	Oakey GT	SWQ Tot Gen	Diff w.r.t ZFC
NoClamp	15	19	6	29	34	39	14	155	29
ZFC	12	15	5	23	27	32	11	126	-
PFC_250	12	15	5	23	26	30	11	122	-5
PFC_500	20	25	8	37	44	50	18	202	75

Table 5.3 shows that the SWQ generators will suffer on average a $29million reduction in annual revenue as a result of ZFC. Implementation of PFC_250 will cause a reduction in generation, but a relative uplift in Queensland pool price, resulting in a net reduction of $5million on average compared with ZFC. Increasing PFC to 500MW towards the north will result in a further downturn in net generation, but a significant increase in Queensland pool price. This results in a perverse outcome whereby the SWQ generators will actually experience a net gain of $75million per annum compared with ZFC. This analysis however does not consider the generators' contracting position and is a measure of pool revenue only.

5.3) IMPACT ON SYSTEM EFFICIENCY

In order to quantify the impact of PFC on system efficiency, ROAM has utilised the short-run marginal costs for all generators in the NEM from ACIL Tasman's *2007 Fuel resource, New Entry and Generation costs in the NEM* report. Using these assumed generation costs, and comparing the difference in dispatch between simulated cases featuring Zero Flow Clamping and Positive Flow Clamping respectively, a direct comparison can be drawn in terms of total system efficiency.

Figure 5.3 shows the difference in total NEM cost of supply between the different cases studied for each of the 20 discrete Monte-Carlo iterations (an average value is also given at the right hand side of the chart). The 'NoClamp' case shows the cost outcome should no Clamping be applied, whereas the 'ZFC', 'PFC_250' and 'PFC_500' cases show the outcome of Clamping QNI at 0MW, 250MW and 500MW respectively.

These simulations show that Clamping to alleviate Negative Settlement Residues typically increases the total NEM cost compared with not Clamping. Furthermore, of the Clamping options, Zero Flow Clamping was found to deliver the lowest increase in cost relative to no Clamping.

Of the Positive Flow Clamping cases, Clamping at 250MW was found to generally increase the system cost again relative to Zero Flow Clamping. Implementing Positive Flow Clamping at 500MW was found to significantly increase system costs relative to both Zero Flow Clamping and Positive Flow Clamping at 250MW.

From these results, it may be inferred that *any* level of Positive Flow Clamping will increase NEM system costs relative to the current strategy of Zero Flow Clamping, and furthermore, the higher the value at which the interconnector is Clamped, the greater the increase to system cost will be.

Figure 5.3 – System Cost Comparison between QNI Clamping Cases

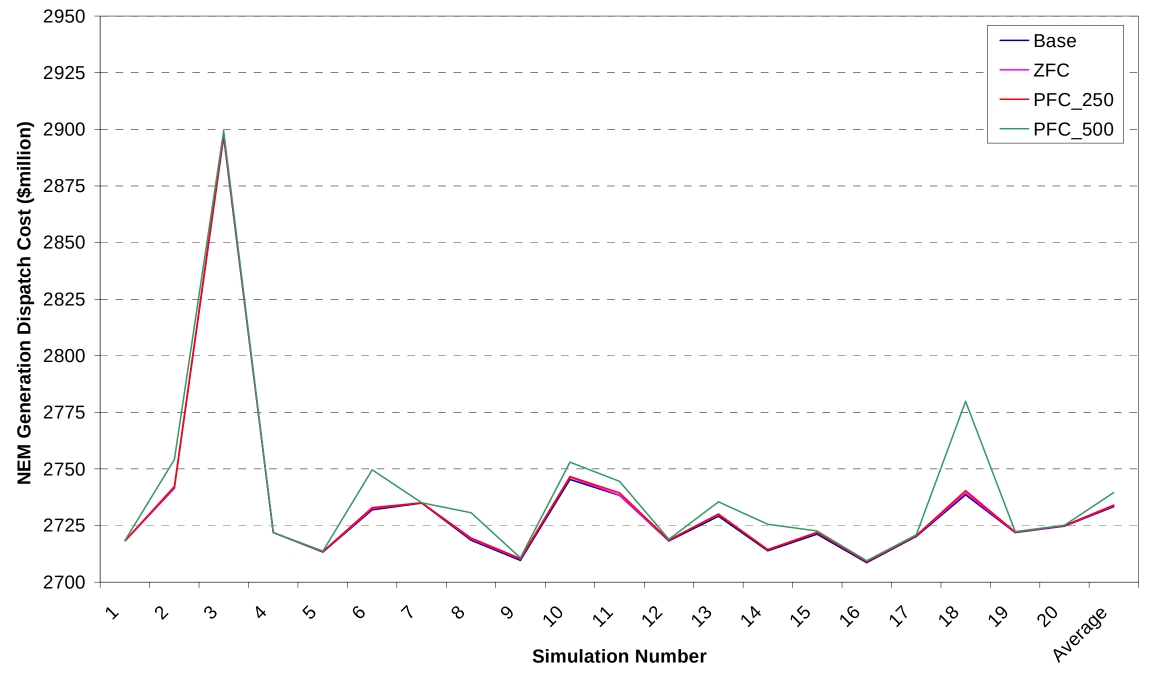


Table 5.4 shows the average annual cost differences resulting from the implementation of the different QNI Clamping strategies relative to not performing any Clamping on the interconnector.

Table 5.4 – Average Cost Impact of Clamping Strategies for QNI

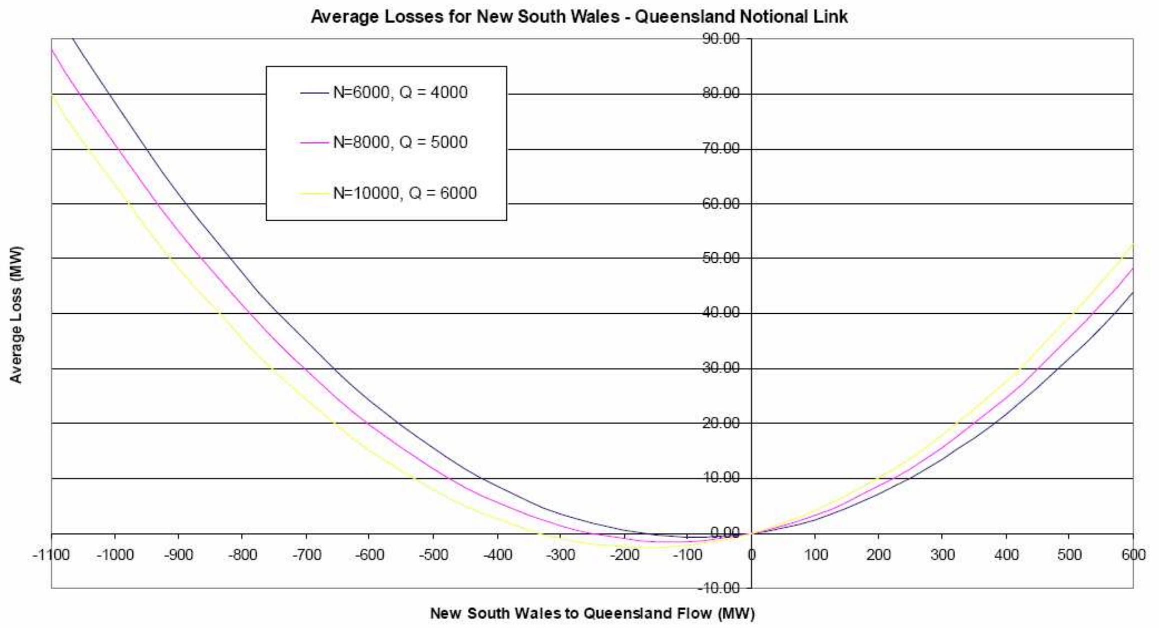
Clamping Strategy	Average Cost Increase for 2010-11
Zero Flow Clamping	$0.41m
Positive Flow Clamping at 250MW	$0.67m
Positive Flow Clamping at 500MW	$6.23m

5.4) *IMPACT ON SYSTEM LOSSES*

Altering interconnector flows via measures such as Clamping will have an impact on the magnitudes and directions of power flows in the transmission network. These flows will impact the amount of power lost across the network. By comparing the difference in interconnector flows resulting from the different Clamping strategies, the impact on system losses can be estimated.

A general aim of the NEM design is to minimise system losses where possible as high losses are indicative of an inefficient market. Should a Clamping strategy therefore act to increase losses, it may be argued that this strategy is not in keeping with the aims of the NEM.

Figure 5.4 – Notional Queensland to New South Wales Interconnector Loss Curve



As can be seen from Figure 5.4 above, forcing a higher flow to the North via Positive Flow Clamping will certainly increase system losses as measured by transmission flows on the notional Queensland to New South Wales Interconnector between the notional Queensland and New South Wales reference nodes. Increasing Clamping from zero to 250MW towards the north will result in a notional increase in system losses of around 10MW on average. Increasing Positive Flow Clamping to 500MW will more than double the estimated losses to in excess of 30MW, compared with Zero Flow Clamping.

Modelling of the year 2010-11 shows that there are on average around 70 Trading intervals across the year that may be Clamped due to forecast Negative Settlement Residues under normal operating conditions. Implementation of Positive Flow Clamping at the upper level of 500MW could increase total energy losses over the year by at least (30 * 70 / 2) 1,050MWh. In extreme instances up to 200 Trading intervals may result in Negative Settlement Residues. Implementation of the maximum 500MW PFC on the QNI interconnector would result in more than 3,000MWh of increased losses in the transmission network. The additional fuel required to generate the energy lost in the transmission network will have flow effects in terms of NEM efficiency and secondary outcomes such as increased CO_2 emissions.

6) SUMMARY OF FINDINGS

ROAM Consulting's investigation of the Positive Flow Clamping (PFC) proposal in the AEMC's Draft Report on the Congestion Management Review has shown that a change to this method of Congestion Management has the potential to have significant impacts for many participants in the NEM. The 2-4-C market simulation model has been applied to provide a view of the possible changes in NEM dispatch and pricing as a result of the PFC proposal. The market simulations show that as the clamping limit implemented with PFC increases, NEM dispatch and pricing outcomes are increasingly distorted.

Analysis of historic market outcomes shows that Negative Settlement Residues (NSRs) do not occur often nor with severity on interconnectors other than the QNI between the New South Wales and Queensland regions. This is due to increased generation volumes in the South-West Queensland (SWQ) region increasing more rapidly than the intra-regional transmission capability between the South-West of the Region and the Regional Reference Node near Brisbane. This historic analysis coupled with forecast market simulations for the 2010-11 year shows that the PFC proposal may discriminate against the generation located in the SWQ corner of the Queensland region. Modelling shows that implementation of PFC on the QNI will result in a downturn in generation dispatch from the SWQ generators equal to the PFC setting. This will have flow on effects with respect to the risk factors and capability for the SWQ generators to contract at the Regional Reference Node within their own region.

Many of the SWQ generators are amongst the lowest cost generators in the NEM, based on the publicly available ACIL Tasman *2007 Fuel resource, New Entry and Generation costs in the NEM* document. It follows that implementation of PFC on the QNI results in a reduction in market efficiency, measured as a function of total production cost. This is due to the requirement for higher cost generators to meet the reduction in SWQ generation. Increasing the Clamping level of PFC results in a significantly non-linear increase in NEM costs.

The analysis shows that forcing PFC will result in an increase in transmission system losses associated with transferring power over long transmission lines from distant generators to meet demand in adjoining regions of the NEM. This in itself appears at odds with one of the key premises of the NEM design which is to provide energy supply in the most efficient manner practicable.

The 2-4-C modelling shows that PFC may also cause perverse market pool price outcomes due to the relationships between generation dispatch and network powerflows on other network limits. Outcomes from the modelling show that implementation of PFC will increase pool prices across all regions of the NEM, relative to the present practice of Zero Flow Clamping (ZFC). Whilst this would constitute a wealth transfer from consumers to producers, it again appears at odds with the NEM premise of providing energy supply for the least cost based on generator offers to supply energy into the market.

The NEM dispatch and operation is necessarily complex. Market modelling applying dynamic transmission system constraint equations and realistic generator trading behaviour and responses to congestion, shows that alternative Clamping approaches can lead to significant distortions in market outcomes. Analysis of history and forecast market simulation studies shows that application of PFC with increasing levels of positive flow Clamping will result in non-linear decreases in market efficiency as measured by total generation cost and transmission system losses. Furthermore, modelling of the NEM shows the PFC will not only decrease system efficiency, but also result in increased market pool price outcomes leading to higher prices for consumers. All of these impacts appear at odds with the key objectives of the NEM to achieve the highest practicable levels of efficiency in energy supply at the lower cost to consumers.

Appendix A) Detailed Modelling Assumptions

A.1) Supply-Demand Balance

The new plant schedule detailed in Table 3.1 was implemented within the Supply-Demand Balance Calculator (SD Calculator) accompanying the 2007 NEMMCO Statement of Opportunities. This tool allows the assessment of the supply-demand balance over the next ten years, taking into account the 2007 ANTS constraints and available interconnector flows.

The Supply-Demand balance charts from the SD Calculator have been reproduced here in the following figures. These planting assumptions result in a positive supply-demand balance in all cases up to 2012-13 (beyond the scope of this Clamping study) except for the combined Vic-SA region in the year 2010-11, for which a small shortfall is determined. This shortfall is not however regarded to be material to this project.

Figure A.1 – QLD Supply-Demand Chart

Figure A.2 – NSW Supply-Demand Chart

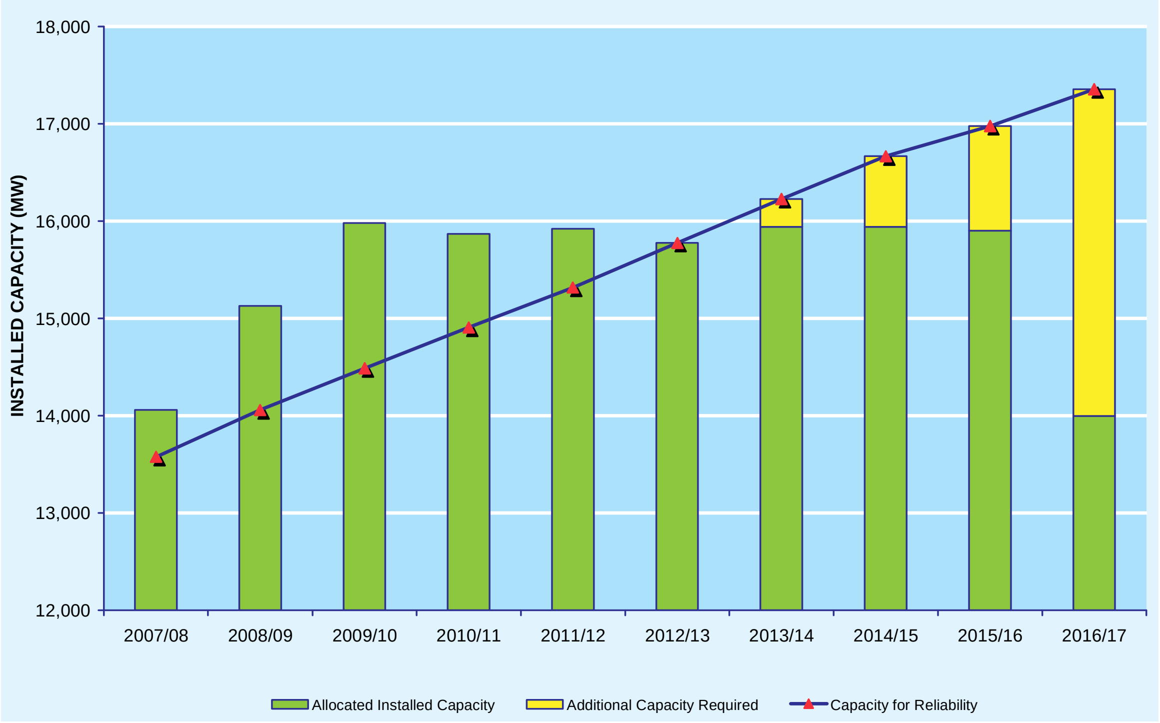


Figure A.3 – VIC/SA Supply-Demand Chart

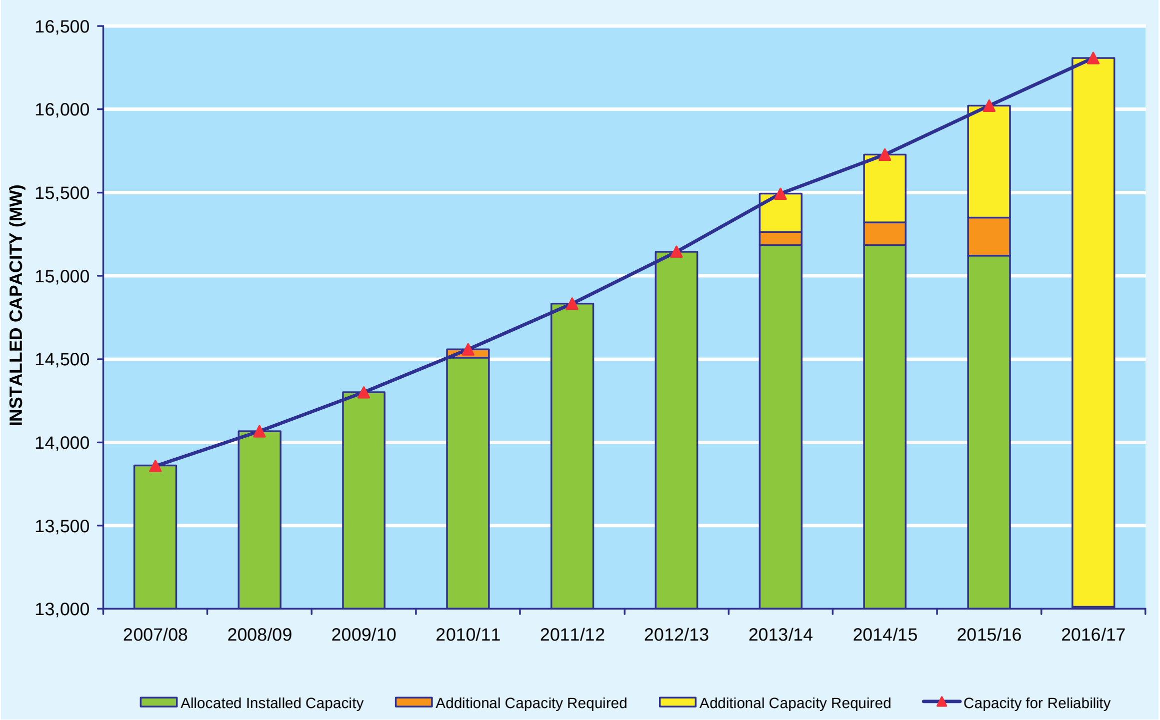
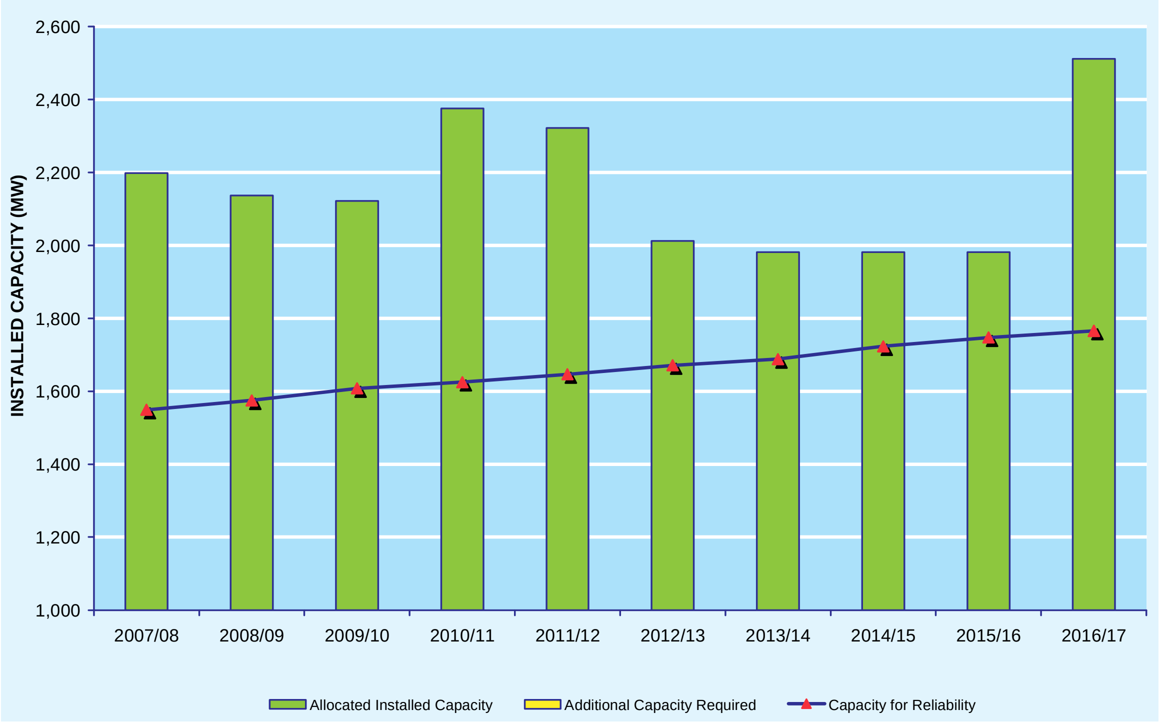


Figure A.4 – TAS Supply-Demand Chart



Appendix B) Model Detail and Assumptions

In conducting this project, ROAM employed a combination of software to produce highly detailed forecasts. This level of detail is essential for modelling the impacts of Positive Flow Clamping, as it would be invoked in response to typically rare but highly significant (i.e. high demand and high price) periods and depends heavily on interactions between constraint equations, bid strategies, unplanned forced outages and technical limitations on generation and transmission assets.

B.1) The 2-4-C Dispatch Model

ROAM's proprietary market forecasting package ***2-4-C*** has been developed specifically to model the NEM on a half hourly basis. ***2-4-C*** closely matches the operation of the NEMMCO Market Dispatch Engine (NEMDE) used for real dispatch in the market. ***2-4-C*** bases dispatch decisions on generator bidding patterns and availabilities, including forced full and partial and planned outages for each generator, including renewable energy generators and inter-regional transmission capabilities and constraints.

Typically, ROAM constructs realistic 'market' bids for all generators in the NEM by analysing their past bid profiles and then taking into account any known factors that may influence existing or new generation, for example, water availability, changes in regulatory measures, or fuel availability. In practice, base load generators are generally bid at negative price levels up to their minimum operating levels (to avoid de-commitment) and then at marginal costs for the remainder of the capacity (with perhaps some capacity reserved at a high 'opportunity' price). These base load generators are referred to as 'price-takers' in the market. Intermediate plants, such as Combined Cycle Gas Turbine units, are typically bid as price-takers for the peak periods of the day and may be started at other periods in response to a high price signal. Peaking generators are generally bid at or above their marginal costs and start when prices reach these values due to low generator reserve margins caused by high demand intervals or periods of generator failures. Since prices may be set at different times by base, intermediate and peaking plant, depending on load levels and simulated failures of generating units, the simulation faithfully replicates the price variability in the real market. A Monte-Carlo random outage modelling capability is employed to account for forced outages for all generating units.

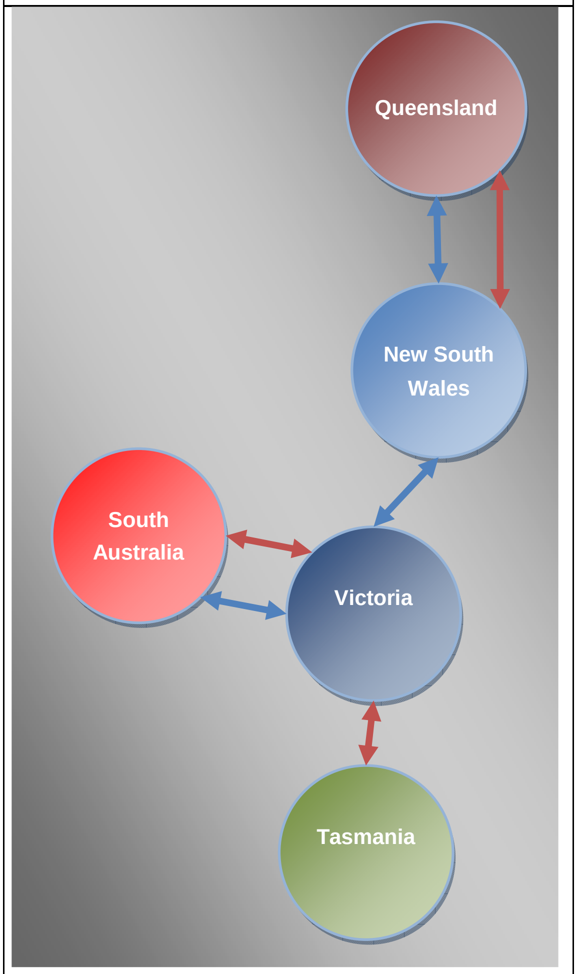
Experience in the Australian market over an 8-year period since market start has indicated that there is a strong relationship between actual bidding and marginal cost economic theory for the vast majority of the time. That is to say, generators are forced to bid at their marginal costs or at shadow prices reflecting the next most expensive generator in the bid stack to maintain market share. It is only during periods of impending shortfall of generation or transmission limitations that generators are able to exert substantial market power and re-bid their energy into the market to achieve prices at or close to the regulated maximum price (currently at $10,000/MWh for the Australian National Electricity Market and known as VoLL – the Value of Lost Load).

2-4-C has been used on behalf of NEMMCO since 2004 to estimate the level of reliability in the NEM and consequently set the official Minimum Reserve Levels for all regions of the NEM.

B.2) The 2-4-C Network Model

The multi-node model used to produce the forecasts in this report is shown in Figure B.1. This nodal arrangement with, featuring a single node per region is the same as that used in NEMDE.

Figure B.1 – *2-4-C* NEM Representation



Blue bi-directional arrows signify the AC interconnectors between the regions of the NEM, while the red arrows signify High-Voltage DC Links.

Note that this network representation precludes any explicit modelling of the intra-regional transmission system. This means that no visibility of intra-regional congestion issues exists. In order therefore to model these important aspects of the physical system, NEMMCO employs the use of Constraint Equations that in effect transpose intra-regional network issues to the visible parts of the network; that is, the inter-connectors between the regions. These Constraint Equations consist of several hundred mathematical expressions which define the interconnector limits in terms of generation, demand and flow relationships. ***2-4-C*** implements these Constraint Equations within its LP engine in fully co-optimised form. More detail on ROAM's modelling of the Constraint Equations is given in Section B.3).

Modelling major transmission lines, network augmentations and Constraint Equations delivers an outcome consistent with the real operation of the NEM under normal system conditions; indeed without this level of modelling detail, Negative Settlement Residues and hence Clamping cannot be captured. Additionally, the occurrence of congestion in the network is the factor that drives out-of-merit dispatch outcomes which would otherwise not be seen in a more simplistic model.

The network configuration within Queensland and Northern NSW will have a significant impact on dispatch and pricing outcomes in the study. This project focuses on the period approximately between 2009 and 2011. This will incorporate a grid configuration with the Middle Ridge to Greenbank line upgrade in service but prior to any other potential significant network upgrades, such as the Halys to Blackwall 500kV transmission between SWQ and SEQ, which is presently under investigation by Powerlink.

B.3) Modelling of Constraint Equations

ROAM's ***2-4-C*** dispatch model implements the full set of NEMMCO 2007 ANTS Constraints as supplied by NEMMCO with the 2007 Statement of Opportunities. These Constraint Equations define interconnector flow limits in terms of generation, demands and flows. A Constraint Equation for an interconnector is defined in a particular direction and will look similar to the following:

$$X * Flow_{InterconnectorA_{DirectionB}} + Y * Output_{GenA} \leq$$

$$Constant + Z * Demand_{RegionA} + P * Output_{GenA} + Q * Output_{GenB} + R * Flow_{InterconnectorB_{DirectionA}}$$

$where: X, Y, Z, P, Q$ are constants

Note that dispatchable terms (variables) exist on both the LHS and RHS of the equation. Linear Programming (LP) engines, which are used to dispatch the NEM at least cost, are not able to fully optimise dispatch outcomes with constraints in this form. They require all variables to be on the LHS of the equation only. Therefore, this re-formulation is performed prior to submitting the constraints to the LP. This linear formulation has been called 'co-optimised' format. Therefore, prior to entering these Constraint Equations into ***2-4-C***, they are converted into co-optimised form.

B.4) The 'SWQ' Constraint

The SWQ Constraint has been found in the modelling conducted to be by far the most significant constraint causing Negative Settlement Residues between Queensland and New South Wales. This Constraint is designated *Q>Q_SWQ* and due to its significant contribution to the outcomes discussed in this project, it is presented in detail in Table B.1 below.

Table B.1 – The SWQ Constraint (for Summer 2010-11)

LHS			**RHS**	
1.000	NSW->QLD (QNI)	**<=**	2525.000	Constant - Includes rating if applicable
			0.037	QLD1 (QLD Demand)
			-1.000	Millmerran
			-0.960	Kogan+Braemar2+SpringGully
			-0.960	Braemar
			-1.100	Oakey
			-1.000	SWQ New Entry

This equation refers an SWQ intra-regional constraint to QNI, since the six region model has no explicit visibility of intra-regional issues. The equation states that due to the SWQ intra-regional constraint, QNI flow in the Northerly direction must not exceed 2525MW, plus 3.7% of the QLD regional demand, minus the generation in SWQ (multiplied by various factors near 1.0). From this, it can be seen that increasing generation output in SWQ decreases the allowable limit on QNI on a nearly 1 for 1 basis, while increasing the Queensland regional demand increases the allowable limit slightly. The 'SWQ New Entry' term is used for forecasting; any new generation coming into the area is assumed to reduce the QNI limit by 1MW for each 1MW of generation output. In the studies conducted for this project, the 'SWQ New Entry' term includes the output of the Condamine and Darling Downs power stations (Note that Spring Gully is not included in the generation assumptions).