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Transmission System Capability and the Decision to Abolish the Snowy Region

By Andrew Campbell, Stephen Wallace and Stuart Thorncraft

Preamble

With the recent decision to abolish the Snowy region and the release of the AEMC Congestion Management Draft Report, the topic of congestion management in the Australian NEM is again at the fore.

In relation to the first of these, we observed what appeared to be modelling results that were either not explained or incorrect. Given the central role of modelling in the Final Decision to abolish the Snowy region and our observations of this modelling, we thought it timely to address in some detail the key issues of modelling the economic impact of a change in region boundaries.

Given the technical nature of this topic and the number of issues involved, this article is longer and more technical than those in previous issues of *Insider*. Consequently the article below is directed at those people with a particular interest in the Snowy region decision and the assessment/modelling of the economic impact presented in the Final Decision. However the broad issues discussed are also common to the modelling of congestion arrangements in other electricity markets.

While the conclusions of the article below suggest that the modelling undertaken in relation to the abolition of the Snowy region report may not be correct, the main objective is to present the technical issues that need to be understood, made transparent and addressed. We hope you find the article informative and interesting.

A Surprise Finding

On reading the Final Decision to abolish the Snowy region, we at IES were intrigued by a number of issues. However there was one conclusion in particular, which came out of the modelling presented, that attracted our attention. This was that abolishing the Snowy region would result in improved dispatch efficiency under the assumption that all generators bid their respective short run marginal costs (so called competitive bidding behaviour).

The reference to this is in Appendix B Section 3.2.4 of the Final Decision and is as follows:

'Figure B.8 shows the annual production cost savings if it is assumed that all market participants bid all capacity at SRMC (competitive bidding). Under this assumption, the level of contracting is immaterial. We observe that both the Abolition and SSR [Split Snowy

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Intelligent Energy Systems ABN 51 002 572 090

Head Office – Sydney Level 2 10-12 Clarke Street Crows Nest NSW 2065 Australia PO Box 931 Crows Nest NSW 1585
Telephone 61 2 9436 2555 Facsimile 61 2 9436 1218 Email ies@iesys.com.au Web www.iesys.com.au
Melbourne Level 8 45 William Street Melbourne VIC 3000 Australia PO Box 405 Collins St West Melbourne Vic 3000
Telephone 61 3 9614 6200 Facsimile 61 3 9614 6255 Email ies@iesys.com.au Web www.iesys.com.au

Region] scenarios yielded annual production cost savings of between $0.5m and $1.5m. The savings were positive in all years for these two scenarios and the Abolition scenario delivered at least $0.5m of additional savings over the SSR scenario.'

Detailed results of the annual production cost saving under SRMC bidding were presented in Figure B.8 of this appendix and are presented in the table below.

Annual Production cost saving under SRMC Bidding

Financial Year	2008	2009	2010
Abolition	$1.35	$0.99	$1.40
SSR	$0.66	$0.57	$0.89
SG -	-$0.01	$0.01	$0.09

The results above imply that the abolition of the Snowy region results in a more efficient dispatch than splitting the Snowy region (or maintaining the existing Snowy region) in all three years modelled.

A Dilemma

The modelling results above presented us with a dilemma, as we would have expected that both the Split Snowy Region option and the Southern Generators option (that maintained the existing Snowy region) should have resulted in a no less efficient dispatch than the abolition option, given that the bids and the physical transmission system were identical in both scenarios.

This article argues that an amalgamation of regions should result in a less efficient dispatch based on SRMC bidding if all of the following propositions are true:

1. The physical system (in particular the transmission system) does not change with changes to the pricing/settlement model (such as the elimination of a region) used in the dispatch and settlement process;
2. A pricing/settlement model that amalgamates regions has to result in an equivalent or less efficient model for the physical transmission system; and
3. A pricing/settlement model that amalgamates regions has to result in a less efficient model for losses.

We note that there is an additional issue that could result in changed market outcomes from a regional boundary change when assuming SRMC bidding. This is the need for NEMMCO to "clamp" the market to avoid the occurrence of counter price flows. However the need to do this is expected to be very small under the assumption of SRMC bidding.

For clarity, the focus of this article will be on comparing the Split Snowy Region scenario with the Abolition of the Snowy region scenario.

The Propositions

Let's begin by briefly considering in turn each of the three propositions above.

The Actual Transmission System

It is self evident that the actual physical system does not change with changes to the pricing and settlement model used in the dispatch and settlement process. In this case the elimination of the Snowy region does not change the physical

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transmission system or its capability to transport power. Similarly, when comparing the Snowy Split Region scenario with the Abolition scenario they both have the same underlying physical transmission system.

Amalgamation of Regions and Efficient Use of the Transmission System

Under Clause 3.8.1 b[i] of the Market Rules NEMMCO is obliged to manage the central dispatch process to maximize the value of spot market trade considering power system security constraints, intra-regional network constraints and losses, and inter-regional network constraints and losses. The reference to network constraints in this clause is to the more general meaning of constraints as referring to the physical network limitations, and not to specific interconnector constraints and generic constraints used in the dispatch process.

So what does this require NEMMCO to do? Firstly maximizing the value of spot market trade means for a given set of generator offers and demand bids, maximising the sum of consumer and producer surplus. In the simple case where there are no demand side bids, this means meeting demand at the lowest cost. This requires NEMMCO to utilise the full capability of the physical transmission system and optimally allocate resources subject to (among other things) the participant offers, participant bids and the present state of the transmission system.

NEMMCO currently does this via a regional market model which models notional interconnectors and uses fixed marginal loss factors to adjust generator prices. Overlaid on this market model are a large number of generic constraints which manage the dispatch of generators and interconnectors to ensure that the physical power system remains in a secure operating state. These generic constraints are linear equations that involve generator and interconnector decision variables and may include system state data such as the current flows on specific transmission lines.

The Market Rules do not specify how NEMMCO is to achieve Clause 3.8.1 b. This was a deliberate decision aimed at giving NEMMCO the flexibility to model the power system in the most appropriate manner, and not to impose on NEMMCO an approach that may compromise its ability to maximize the value of spot market trade.

This means NEMMCO can model and hence optimize the use of the network anyway it likes. In principle NEMMCO could use a network model that explicitly models all of the transmission lines, transformers etc of the network, so long as it

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[i] Clause 3.8.1 b states: 'The *central dispatch* process should aim to maximise the value of *spot market* trading i.e. to maximise the value of *dispatched load* based on *dispatch bids* less the combined cost of *dispatched generation* based on *generation dispatch offers*, *dispatched network services* based on *network dispatch offers*, and *dispatched market ancillary services* based on *market ancillary service offers* subject to:

(1) *dispatch offers*, *dispatch bids* and *market ancillary service offers*;
(2) *constraints* due to availability and *commitment*;
(3) *non-scheduled load* requirements in each *region*;
(4) *power system security* requirements determined as described in Chapter 4and the *power system security and reliability standards*;
(5) *intra-regional network constraints* and *intra-regional losses*;
(6) *inter-regional network constraints* and *inter-regional losses*;
(7) *constraints* consistent with *registered bid and offer* data;
(8) current levels of *dispatched generation, load* and *market network services*;
(9) *constraints* imposed by *ancillary services* requirements;
(10) arrangements designed to ensure pro-rata loading of tied *registered bid and offer data*; and
(11) ensuring that as far as reasonably practical, in relation to a *direction* or *dispatch* of *plant* under a *reserve contract*:
    (A) the number of *Affected Participants* is minimised; and
    (B) the effect on *interconnector flows* is minimised. '

conformed to the requirement of the Market Rules to use fixed marginal loss factors for generators and customers and dynamic marginal loss factors for interconnectors.

Consequently, for any regional arrangement the dispatch should be able to make full use of the physical transmission system other than any minor reduction in accuracy owing to imposed approximation in the loss model used. This is clearly the case if an explicit network model is used to model the full transmission system because all regional pricing arrangements would still have the same explicit network model. On the other hand if the current NEM approach is used then this may not always be the case, though one would expect that NEMMCO, via creating a suitable suite of generic constraints, should be able to dispatch plant in such a way that the capability of the physical network can be fully utilized or very close to it.

What we can say is that if the dispatch of two regional models were not equally efficient then the dispatch of a regional model that splits regions will always be at least as efficient as the dispatch for the un-split regional model. Specifically, the dispatch of the Snowy Split Region scenario has to always be at least as efficient as the Abolition scenario. The reason for this is that in the Snowy Split Region scenario, the dispatch optimisation has all the decision variables that were available in the Abolition scenario plus two extra interconnector variables for the flows between the Tumut and NSW regions and for the flows between the Murray and Victorian regions. Thus the same generic constraints that are used for the Abolition scenario could be used for the Split Snowy scenario if nothing better could be done. However, if some constraints could be better modelled using the extra interconnector terms then the Split Snowy Region would be more efficient. Thus the Split Snowy Region scenario can never be less efficient in terms of managing network constraints. The same applies to the current regional arrangement compared to the Abolition scenario.

Amalgamation of Regions and Losses

The Abolition of the Snowy region, when compared with the Snowy Split Region scenario, corresponds to amalgamating the Tumut region with the NSW region and amalgamating the Murray region with the Victorian region. In terms of the central dispatch process amalgamation of regions will always produce a less accurate model for losses because a dynamic loss model is replaced by static loss factors.

The use of static intra-regional losses in the NEM dispatch and pricing model was always understood to be an approximation and that it would cause some level of dispatch inefficiency. However, this approach was introduced as a trade-off between basis risk certainty within a region and a less accurate loss model.

An accurate modelling of losses in the dispatch process requires that these be dynamically determined on all transmission lines, as is done in a full nodal model. In a regional model such as that used in the NEM, any pricing and settlement model that breaks regions into smaller parts must result in a more accurate and hence more efficient model for losses, as static marginal loss factors are replaced, to some extent, by dynamic loss factors for the increased number of interconnectors. As a consequence the reverse is true. Specifically, the amalgamation of the 'Tumut region' with the NSW region and the 'Murray region' with the Victorian region must mean that losses are less accurately modelled when compared with the split of the Snowy region.

Conclusion from Review of Propositions

From our discussion so far we can unequivocally conclude that since the Abolition of the Snowy region and the status quo both correspond to amalgamations of the Split Snowy Region option their loss models and security constraint representations can not be better than the split Snowy Region option and hence have to have dispatch costs that are greater than or equal to the Split Snowy Region. However, this does not correspond to the modelling results. Therefore one of the propositions is wrong or there is something wrong with the conclusions regarding dispatch efficiencies of the various options.

Let's next examine how the modelling was done.

The Modelling Approach

The relevant part in the description of the modelling undertaken (in the Final Decision) is how the transmission system was modelled in each of the cases considered. To recap there were four scenarios considered – Base, Abolition, Split Snowy Region Case (SSR) and the Southern Generators (SG) scenarios. The important point for this article is that the SSR scenario had one additional region; the Abolition scenario had one less region, while the Base and SG scenarios had no change to the regions.

The report described the way in which the transmission system was modelled under each scenario. Appendix B describes that for the Abolition and SSR proposals, NEMMCO supplied revised loss factors and constraint equations. Also that revised interconnector limits were developed for these scenarios[ii].

The interpretation of the revised transmission models used in the report is of relevance to our discussion. The report suggests that the capability of the transmission system available to the market could change based on the regional pricing and settlement model used. Specifically, in the modelling report regarding the results from the game theoretic modelling it was stated that:

'The differences between the SG (Southern Generators) and Base scenarios were less than those between the Abolition and Base and SSR and Base scenarios. This reflects the fact that the only difference between the Base and SG scenarios was Snowy Hydro's financial incentives rather than a fundamentally different constraint formulation, as was the case with the region boundary change scenarios.'

Back to the Dilemma - The Modelling of Losses and the Physical System

Observations from the Modelling Approach Used

Of particular note is that the description of the modelling presented in the Final Decision did not contain any discussion or make any distinction between the actual

[ii] For the Base and SG cases no change was required. The constraints that are included in the Tumut CSP/CSC Trial for the Snowy region were taken from NEMMCO's document, Constraint List for the Tumut CSP/CSC trial, March 2006. In the Base and SG scenarios, the constraint equations for all other constraints were taken from the Constraint Spreadsheet provided with the Annual Transmission Statement (ANTS) data attached to the NEMMCO 2005 SOO. For the Abolition and SSR scenarios, NEMMCO provided altered versions of the 2005 ANTS constraint set which reflected the relevant change to region boundaries in each scenario. These constraints were implemented dynamically in the modelling for all scenarios in fully co-optimised form.
The revised region boundary structures under the Abolition and SSR scenarios meant that new static loss factors were required for the new regions and new dynamic marginal loss factor equations were required for the new interconnectors. NEMMCO provided the specific static loss factors and dynamic marginal loss factor equations for each of these scenarios

physical transmission system and the commercial model used in the dispatch engine.

Our interpretation of this is that there was an implicit assumption that the revised constraint equations and loss factors provided by NEMMCO for the modelling provided an adequate representation of the physical transmission system under each of the scenarios. The modelling was not done such that the dispatches from the different regional models were fed back into say an AC power flow model to check whether the flows on the transmission lines satisfied security limits or whether some constraints were excessively conservative, or more importantly whether the same demands were being met.

To be clear, if a revised loss model resulted in different demands being met then any difference in the resulting dispatch targets (from the output of the dispatch engine) cannot be used to assess the economic impact of a change in regional boundaries. This is because in the actual dispatch process the physical transmission system is the same regardless of the regional structure, and consequently actual losses are unchanged. Any change in the total level of dispatch targets resulting from a regional boundary change would be managed through the use of frequency regulation services where generation levels are adjusted to correct among other things load forecast errors that arise from issues such as the use of an approximate loss model.

As previously mentioned, while there was insufficient information to determine whether or not the constraint equations were the same for the various scenarios modelled, adding and removing regions does change the loss model used. In the commercial model a change to the loss model would impact the total demand required to be met as this is given by the (input) regional demand plus interconnector losses. This is explained in some detail below.

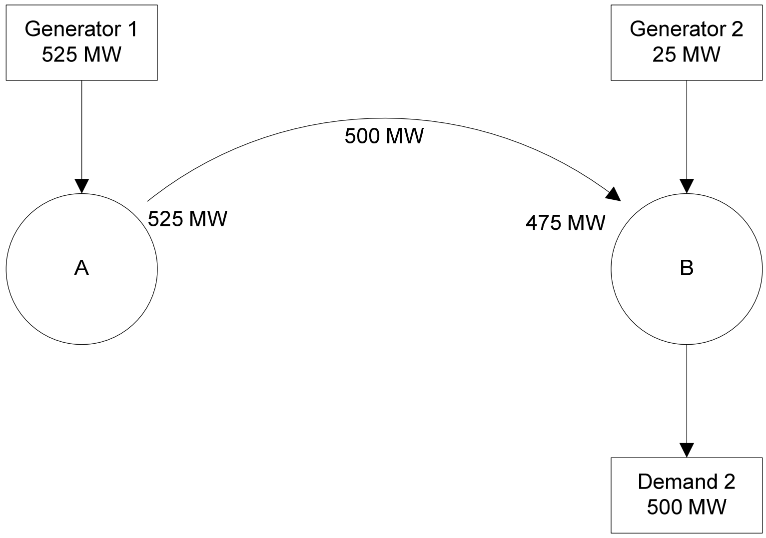
Modelling Losses

Getting the right results in terms of demands and losses is not as easy as it might seem. Interconnectors and generators are not treated in the same way when it comes to demand and supply balances in the NEM dispatch process. Losses within a region are not explicitly modelled but are included as part of the regional demands. The marginal loss factors of generators are used to adjust their offer prices to be effectively prices at the regional reference node. In contrast, inter-regional losses are explicitly modelled via the regional energy balance equations which are essentially as follows:

Regional demand	=	sum of scheduled generation in region
	-	sum of scheduled demands in region
	+	sum of interconnector flows into the region
	-	share of losses for interconnector flows into the region
	-	sum of interconnector flows out of the region
	-	share of losses for interconnector flows out of the region

The impact of this approach is that losses associated with interconnector imports and exports are explicitly accounted for in the energy balances while intra regional losses associated with generator dispatches are not explicitly accounted for. To illustrate how this could affect dispatch costs when a region is split we have constructed a very simple example illustrated in Figure 1.

Figure 1 Example Dispatch and Losses



In this example there are two generators: one at node A generating 525 MW and the other at node B generating 25 MW. There is a demand of 500 MW at node B. If both node A and B are within the same region then the regional demand would be 550 MW = 500 MW demand + 50 MW intra regional losses. Now if the region were split into two regions: region A and region B, then the demand in region A would be zero MW and in region B it would be 500 MW not 550 MW.

Consequently, if the original regional demand of 550 MW were used for region B then an extra 50 MW would be required relative to what was physically required for the single region scenario. This in turn would result in apparently 'higher' dispatch costs. Similarly, if the same demand forecasts were used for the Split Snowy Region and the Abolition scenarios without some process to adjust for inter-regional losses then the dispatch cost comparisons would be biased to favour the Abolition scenario.

NEMMCO largely overcomes the different treatment of intra-regional and inter-regional losses by feeding back into the load forecasts the current inter-regional losses. After this adjustment, any residual mismatches are largely washed out in the real dispatch process because the load forecasts are updated based on the actual generation of units which balance demand and supply.

Dilemma Solved?

From the above, the apparent dilemma in the AEMC's Snowy region boundary SRMC modelling could be attributed to two possible causes.

- Firstly the generic constraints supplied by NEMMCO for the modelling are either not equally efficient at utilizing the actual physical network or they do not provide equal levels of security. However this should not be the case as the Split Snowy Region constraints can always be made to be at least as efficient

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at managing the physical network's capability as the Abolition constraints for the same level of system security.

- Secondly, it is likely that the apparently greater dispatch efficiency of the Abolition scenario is due to the treatment of losses in the commercial model which resulted in effectively different physical demands being met. If we assume that roughly 3% of Snowy's generation would be used in 'inter-regional' losses between Tumut and NSW and Murray and Victoria then the Abolition scenario may be underestimating intra-regional losses by about 3% of 4,500 GWh. If these losses were valued at the SRMC of black coal generation, say $10/MWh, then the Abolition scenario could be picking up $1.6M per annum in phantom benefits. This sort of figure is large enough to change all of the rankings of the scenarios based on SRMC bidding.

The two suggested reasons for the apparent dilemma are all examples of problems which can occur when the commercial model is also assumed to be the actual physical model. The most appropriate way to undertake such modelling, as required for reviews of regional boundaries, congestion management and issues where the actual physical network remains unchanged but the commercial model does change, is to:

- either use a NEMDE like dispatch model with sets of constraints that achieve exactly comparable network utilization and feed its results into a full network model which is used to feedback into the dispatch model:
  - adjusted demands to take account of actual losses; and
  - actual transmission flows which are subsequently used to update the parameter values in relevant generic constraints; or
- use a market dispatch model that overlays the regional boundary pricing model with an explicit model of the full network including nodal demands.

Any other approach that does not model the underlying physical network is likely to result in erroneous inferences.

Conclusions

The review of the modelling presented in the Final Decision to abolish the Snowy regions suggests that there was an implicit assumption made that the model of the transmission system used in the dispatch and pricing process also represented the capability and loss characteristic of the physical transmission system. Further that this assumption resulted in the counter intuitive results for the SRMC bidding scenarios.

Our analysis suggests that the correct answer for the production cost savings for SRMC based bidding would be for the Snowy Split Region scenario to have greater production cost savings benefits than for the Abolition scenario (and also that the SG scenario would have greater production cost savings benefits than for the Abolition scenario).

A corollary to this conclusion is that since the apparent error in the results for the SRMC based bidding is of the same order of magnitude as for the differences in benefits based on the game theoretic based bidding, then the general results which conclude that the Abolition of the Snowy region has greater production cost savings than the Split Snowy Region scenario must also be in question.

The discussion presented in this article also leads to the more general observation that a change to a congestion management regime (such as a regional boundary change) should not influence the capability of the transmission system available to the market, unless reasons are given to the contrary.

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