REPORT

Constraint Support Pricing: Implementation of Snowy Proposal

Submitted to

NEMMCO

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CAVEAT

This report has been prepared on the basis of the original form of the Snowy Proposal document of November 2004, as interpreted by CRA. As noted in the report, alternative interpretations are possible, and there have been subsequent discussions between CRA and NEMMCO and, we understand, between NEMMCO and Snowy Hydro Limited. As a result of those discussions the formal submission to NECA for derogation to the National Electricity Code was varied to ensure an implementable interpretation of the original proposal. That submission partially reflects some of the proposals made in this report, however this report has not been systematically updated to relate to the final NEMMCO submission and may therefore contain some commentary that has been rendered redundant. The principles and issues, however, remain relevant to an informed consideration of the Snowy Proposal.

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1. SUMMARY OF CRA RESPONSES TO NEMMCO QUESTIONS

Snowy Hydro Limited has proposed (the Snowy Proposal) a pricing and contracting arrangement that that would amend the operation of the NEM in the Snowy area and in particular the settlement for Snowy Hydro Trading. A formal derogation to the National Electricity Code has been sought to facilitate its introduction. The Snowy Proposal is similar, but not identical, to the CSP/CSC regime presented as part of a report to the Ministerial Council on Energy by Charles River Associates (CRA).[1]

NEMMCO has requested advice from CRA on a number of specific matters concerning the implementation of the Snowy Proposal.

Some of NEMMCO's questions relate to both conceptual and implementation issues, and the discussion below combines conclusions from both parts of our report to deal with those questions, as presented by NEMMCO.

a(i) *Does the Snowy Proposal fully describe the range of settlement adjustments that need to be carried out to restore appropriate competitive price signals due to a binding constraint of the following form:*

$$\alpha * LT + \beta * UT + \gamma * V\text{-}Sn + \eta * Sn\text{-}NSW \leq RHS \ ?$$

The Snowy proposal is somewhat loosely described, and uses the terminology of the CRA proposal in a confusing way.[2] Thus further refinements would be appropriate to deal with issues such as:

- Rationale for allocation of CSCs;
- Treatment of transmission losses;
- Treatment of alternative constraint forms;
- Treatment of multiple simultaneous constraints binding
- Operation of the CSP/CSC regime when the Snowy regional reference node is shifted
- Implications of clamping the VIC-SNY interconnector

1 National Electricity Market: Regional Structure Review Consultation Paper, September 2004 (http://www.mce.gov.au/index.cfm?event=object.showIndexPage&objectID=FF2C944B-BCD6-81AC-1C9ECD7DB1FA1282) (CRA Region Boundary report)

2 Particularly by confusing CSP with PNP.

- Adjustment of CSCs when interconnector capacity is unavailable, e.g., during forced/planned outages;

- Treatment of any surplus/deficit arising from a mis-match between CSC allocation and constraint capacity.

In summary, although the situation that the Snowy Proposal seeks to address is relatively complex, it could be regarded in most respects as a relatively straightforward application of the CSP/CSC concept, with some complexity to be dealt with before the proposal could be considered final.

a(ii) In particular, would additional adjustments to/from the VIC-SNY residue be required to give a strictly correct result?

On the other hand, the Snowy Proposal clearly differs from the CRA proposal, in that it omits the VIC-SNY interconnector from the CSP/CSC regime entirely, while proposing that action is taken to limit any negative IRSS arising on that interconnector by shifting the SNY regional reference node, or by limiting counter-price flows. In our view, neither of these approaches is ideal, and the including the VIC-SNY interconnector in the CSP/CSC arrangement would provide a superior result, particularly in terms of dispatch optimality, and inter-regional hedging.

a(iii) If the current version of the Snowy Proposal produces only a partially correct adjustment, what are the implications of continuing with that partial approach, in the interests of simplicity, instead of altering the derogation to reflect an approach that is strictly correct? Use of NEMMCO's interim approach to managing negative residues is a key consideration in responding to this deliverable.

We consider that it would be preferable to include the VIC-SNY interconnector in the CSP/CSC arrangement. But, if that is not possible, the CSP/CSC arrangement can still work, and deliver value, with either of these alternative approaches applied to the VIC-SNY interconnector. The commercial implications of shifting the regional reference node are another matter, and outside the present scope. We note, though, that the PNPs applying to participants in the CSP/CSC regime are independent of the choice of regional reference node. [3]

b(i) What is the difference between PNP as used in Appendix B of CRA's report to jurisdictions, and the NP for a node?

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3 The implications of shifting the regional reference node are extensively discussed in our report. We also believe Snowy is correct in asserting that a negative IRSS on the SNY-NSW interconnector will not arise, given the basic constraint form we have studied. But we have not considered all variants and, if this situation did arise, the proposed action of suspending the CSP/CSC regime while the situation persisted should at least provide outcomes no worse than under the status quo.

There is a difference between NP and PNP which arises out of the way the term nodal price has traditionally been used in the literature. The strict definition of nodal spot price as used in the literature[4] defines spot price as the shadow price of the demand balance / nodal nett injection equation.

The conventional definition of nodal price did not include any reference to constraints that are outside the realm of limits on nodal generation and line flows. However, in the Australian NEM, and for that matter other real-life power systems, there are side constraints on generation and/or flows and/or ancillary services represented in the form of generic constraints that relate to voltage, angular stability, generator/line outage contingencies, and other considerations that go beyond the traditional definition of nodal prices.

We have used PNP to reflect a more complete definition of nodal price that, in principle, captures all these effects, but only in those constraints which are explicitly included in the CSP regime. The distinction however is somewhat artificial because a nodal dispatch model[5] with the so-called "non-NEO[6]" generic constraints can also be used to calculate PNP.[7] Nevertheless, we emphasize the fact that the CRA report to MCE and all of our discussion here with respect to prices specific to a generator node relates to PNP rather than the conventional definition of NP.

b(ii) What are the implications of using the NP or PNP in the context of the Snowy Proposal?

4 For example, F. Schweppe et al, *Spot Pricing of Electricity,* Kluwer Academic Publishers, 1988.

5 A nodal dispatch model would have nodal/bus-bar representation of demand and flow limits on lines connecting the physical bus-bars – hence this will obviate the need for any *intra-regional* flow limit constraints. However, various other voltage, stability and contingency constraints would still need to be reflected using generic constraints and hence PNP would still be relevant in a nodal dispatch model.

6 See CRA Region Boundary report

- "NEO", or "Nodal Energy Only" effects relate to the impact of nett nodal injections on the constraint. In principle, this means that generation and load would appear symmetrically in the constraint, and implies that the same "nodal price" should apply to both, as in the standard theory of nodal markets.
- "Non-NEO" effects relate to any other impact which generation or load may have on the constraint, including ancillary services, voltage support, inertia etc. These are participant-specific, and imply participant-specific pricing impacts which should not be reflected in nodal prices, and are not covered by the standard nodal market theory.

7 While it is true that shadow prices on generic constraints in a nodal model could be used to construct the PNP, the nodal prices in such a model should not reflect those constraints, unless its been mis-formulated so as to confuse nodal with participant-specific constraints.

As we have just discussed, PNP will be the appropriate price to be used for the Snowy Proposal because it should reflect all relevant intra-regional generic constraints including any non-NEO constraints that may apply. NP will not capture the latter impacts, if relevant, but would reflect the impact of any other constraints which happened to bind, but are not covered by the derogation, and hence should not be used[8].

b(iii) Is there a mechanical means of determining the NP and the PNP at a node other than the reference node, using only data that is available from central dispatch in the current NEM systems? What would be the specific process for determining NP and PNP for the Tumut node?

Both NP and PNP can be calculated using a simple adjustment to the RRP price, using the generic constraint shadow price and generator coefficient as discussed before:[9][10]

$$PNP_p = RRP - \sum_k CSP^k \cdot COEFF_p^k$$

Calculation of NP should exclude the constraints or components of coefficients that pertain to non-NEO effects. Calculation of PNP should only include those constraints which are explicitly included in the CSP regime. Sections 3.2.2, 4.2.1 and Appendix B provide further commentary on the theoretical underpinnings and numerical examples.

b(iv) If additional information would be required to determine a NP or PNP, what is that information, and what process would it be used in?

Our understanding of the information availability from NEMDE/MMS suggests that there are two potential sources of information gap, namely:

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8 In any case, the true nodal price could not be calculated from NEMDE unless the NEO and non-NEO components of all constraint coefficients were differentiated.

9 Note that the signs in this equation are consistent with assuming that the constraint is expressed as a < constraint in an LP which maximises the "value of trade". This means that a positive constraint coefficient for generation implies that generation makes congestion worse, and reduces the objective function value. Other sign conventions should be applied under other assumptions, but the end result must be that prices always reflect the basic economic logic that the PNP is less than the regional reference price in any situation where generation makes congestion worse.

10 This formula ignores losses. Since the NEM applies a loss adjustment to the regional reference price, this should also be applied in the above equation, although the outcome will only be as accurate as the loss adjustment itself. No loss adjustment should be applied to the CSP term because losses should have been accounted for in deriving COEFF.

- We understand that the sign of the NEMDE generic constraint shadow price is not stored. This implies if there are any *equality* generic constraints[11], we will not be able to calculate NP or PNP. However, the Snowy generic constraint set that we received from NEMMCO in December 2004, contains only inequalities and hence this may not pose a material concern as far as the current constraint set is concerned; and

- If we want to calculate NP, we also need to know the component of the generator coefficient that specifically applies to NEO constraints. We suspect that the NEO component cannot be separately identified for many existing generic constraint types. However, we are not sufficiently familiar with the details of the constraint derivation process to comment on the materiality of this issue for the Snowy constraints. But this is not a relevant issue here, because neither the CRA nor the Snowy Proposal requires NP to be calculated.

b(v) Can the process described in the Snowy Proposal be implemented in another way that does not require the determination of NPs or PNPs – for example, by making use of regional reference prices and flow data as considered in previous papers from CRA?

Firstly, the CSP/CSC concepts discussed in the previous CRA reports were based on RRP, generic constraint shadow price and generator coefficients in the constraints. Although *flows* will be related to the constraint shadow prices, and physical interpretations of the constraint pricing effects were drawn out for tutorial purposes, our derivation of NP and PNP do not use flows *per se* and rely only on the constraint shadow prices.

Second, the Snowy Proposal refers to the CSP where the PNP appears to be intended, and does not provide adequate level of details to make a *complete* connection between the CRA's CSP/CSC concepts and their specific implementation. Nevertheless, to the best of our understanding the proposed calculation will produce the same effect as the original calculations proposed by CRA, and discussed in this report. Other things being equal, we suggest that a direct calculation of CSP/CSC payments using the CSP is preferable to the differencing process implicit in the proposed Code amendments. But we note certain policy considerations which might require a need for heuristic price adjustments, such as capping of PNPs to VOLL, which might be more easily implemented using the Snowy Proposal approach.[12]

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11 Duals or shadow prices for $\geq$ constraints for a minimisation problem is always positive and that for a $\leq$ constraint is always negative. The reverse is true for a maximisation. The dual for equality constraints is however "unrestricted in sign".

12 Conversely, though, multiple simultaneous "bundled CSC" arrangements could more easily be implemented using the direct CRA approach, but it is not obvious how this could be done using the Snowy approach.

2. INTRODUCTION

2.1. BACKGROUND

Snowy Hydro Limited has proposed (the Snowy Proposal) a pricing and contracting arrangement that that would amend the operation of the NEM in the Snowy area and in particular the settlement for Snowy Hydro Trading. A formal derogation to the National Electricity Code has been sought to facilitate its introduction. The Snowy Proposal is similar, but not identical, to the CSP/CSC regime presented as part of a report to the Ministerial Council on Energy by Charles River Associates (CRA).[13]

NEMMCO has requested advice from CRA on a number of specific matters concerning implementation of the Snowy Proposal.

2.2. CRA'S CSP/CSC THEORY: REFERENCES

The CSP/CSC theory may be viewed as a specific compensation mechanism for constrained on/off payments that involves paying a consistent price to the generators irrespective of their actual costs. The approach can be adopted for a zonal or a nodal market alike and be used to compensate, or penalise, generators for their impact on all types of constraints including constraints that go beyond simple transmission limits. The theory is in similar spirit to that of the nodal pricing approach to managing congestion, but is more general. The theory was introduced originally for interconnector support pricing [3] and has been extended further in [4]-[5]. The major impetus for these developments was that:

- First, it provides a mechanism to deal with specific constraint situations, in a way which only affects those participants directly involved, rather than necessarily pursuing increased regionalisation in the NEM; and

- Second, this approach is generalised to deal with situations which are not covered by the standard Locational Marginal Price (LMP) and Financial Transmission Right (FTR) theory, and thus it provides a possible complement to increased regionalisation, or even to a fully nodal approach.

A complete discussion of the theory is contained in the following reports:

1. *Constraint Representation in the NEM*, CRA report to NEMMCO, January 2003;

2. *Constraint Orientation: Principles and Pricing Implications*, CRA report to NEMMCO, March 2003;

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13 CRA Region Boundary report

3. *Dealing with NEM Interconnector Congestion: A Conceptual Framework*, CRA report to NEMMCO, March 2003;

4. *NEM Interconnector Congestion: Dealing with Interconnector Interactions*, CRA report to NEMMCO, June 2003; and

5. *NEM Regional Boundary Issues: Theoretical Framework*, CRA Report to MCE, June 2004. We will refer to this report as the "CRA Theory Paper" in the remainder of this report.

2.3. An Overview of the Snowy Proposal

Although the Snowy Proposal rests on the same fundamental principles developed by CRA, it is important to recognise in the present context that the Snowy Proposal is a specific form of implementing the theory with its unique attributes that we will discuss at length in the remainder of this report. On the other hand, the nature of the constraints that apply to Snowy generators exclusively may not encompass all of the complexities associated with the more general theory. The specific claims that the Snowy Proposal make are:

- *"The CSP/CSC proposal will reduce the potential variability of settlement residues on the Snowy-NSW interconnector, and should therefore remove perverse commercial incentives on the operation of Snowy Hydro plant and associated interactions with the broader market;*

- *The pilot will remove uncertainty associated with Snowy Hydro plant operations for the net overall benefit of the market;*

- *The only directly affected participant is Snowy Hydro (who is willing to trade off perverse upside and perverse downside of the current arrangements) to gain certainty (rather than the current perversely generated uncertainty);*

- *The pilot will increase inter-regional trade/SRA unit values; and*

- *NEMMCO may (subject to confirmation) implement the Snowy Region CSP/CSC via a simple spreadsheet settlement systems adjustment and no changes to the NEMDE dispatch are required."*

2.4. SCOPE OF THE WORK

NEMMCO has sought advice to address specific questions in two broad areas:

(a) Adjustments to the Residue of the V-SN Interconnector:

i. *Does the Snowy Proposal fully describe the range of settlement adjustments that need to be carried out to restore appropriate competitive price signals due to a binding constraint of the following form:*

$$\alpha * LT + \beta * UT + \gamma * V\text{-}Sn + \eta * Sn\text{-}NSW \leq RHS \ ?$$

ii. *In particular, would additional adjustments to/from the V-Sn residue be required to give a strictly correct result?*

iii. *If the current version of the Snowy Proposal produces only a partially correct adjustment, what are the implications of continuing with that partial approach, in the interests of simplicity, instead of altering the derogation to reflect an approach that is strictly correct? Use of NEMMCO's interim approach to managing negative residues is a key consideration in responding to this deliverable.*

(b) Derivation of Pseudo Nodal Prices:

i. *What is the difference between PNP as used in Appendix B of CRA's report to jurisdictions, and the NP for a node?*

ii. *What are the implications of using the NP or PNP in the context of the Snowy Proposal?*

iii. *Is there a mechanical means of determining the NP and the PNP at a node other than the reference node, using only data that is available from central dispatch in the current NEM systems? What would be the specific process for determining NP and PNP for the Tumut node?*

iv. *If additional information would be required to determine a NP or PNP, what is that information, and what process would it be used in?*

v. *Can the process described in the Snowy Proposal be implemented in another way that does not require the determination of NPs or PNPs – for example, by making use of regional reference prices and flow data as considered in previous papers from CRA?*

2.5. STRUCTURE OF THE REPORT

In Part A of the report we focus on the conceptual issues and primarily addresses whether and how the Snowy Proposal aligns with the CRA CSP/CSC proposal, and whether the Snowy Proposal document accurately reflects the market implications of the proposal.

Part B address practical implementation issues.

3. PART A: CONCEPTUAL ISSUES

There are three key issues here:

- Does the Snowy Proposal document accurately represent, and align with the CRA CSP/CSC proposal?
- What implications arise from any mis-alignment?
- Does the Snowy Proposal document accurately represent the market implications of its proposal?

3.1. THE SNOWY PROPOSAL VS THE CRA CSP/CSC PROPOSAL

3.1.1. Statement of Proposal

The Snowy Proposal clearly relates to the CRA CSP/CSC proposal. But while the proposal document discusses the intended implications of the proposal, and provides some illustrative examples of its intended workings, it actually provides surprisingly little detail as to what is actually proposed. For example, it is not clear how the proposal is intended to deal with[14]:

- Treatment of terms which shift from the LHS to the RHS of a constraint;
- Shortfalls and surpluses in the constraint rental account;
- Allocation of CSCs when the constraint RHS varies due to load variation, maintenance etc;
- Different coefficients applicable to upper and lower Tumut generation; and
- Operation of the regime when prices are adjusted to reflect VoLL caps.

This makes it difficult for us to comment conclusively, or for the industry to judge the merits of the proposal, and leads us to recommend that some party be tasked with preparing a more detailed implementation plan, covering such issues.

14 This list is illustrative, not exhaustive.

Nomenclature and Notation

The Snowy Proposal repeatedly refers to the nett marginal price signal applying to a generator as the "shadow price", or CSP, for that generator. This terminology is loose, because a "shadow price" is a very general concept, applying to every constraint in an LP formulation, and the price referred to here is not actually a shadow price on any constraint in the NEMDE formulation[15]. The terminology is also confusing in that this "shadow price" is identified with the constraint shadow price, or "support price", referred to as CSP in the CRA documents. But the price referred to is actually the "Pseudo-Nodal Price" (*PNP).*

The CRA reports introduce two key prices:

- The "Constraint Support Price" (CSP^k for constraint k) which is, in fact, just the shadow price on the relevant constraint in the current NEMDE formulation; and

- The "Pseudo-Nodal Price" (PNP_p for participant p) which, if CSPs are applied to constraints $k = 1, \ldots K,$ can be determined by[16]:

$$PNP_p = RRP - \sum_k CSP^k \cdot COEFF_p^k$$

As discussed in the CRA theory paper[17], the PNP_p for participant p will be the same as the nodal price for its node if, and only if:

- *CSPs* are applied to ALL constraints affecting p, and

- All coefficients for p relate to "NEO" effects[18], reflecting the impact which nett nodal energy injections have on the constrained quantity[19].

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15 Nor would it be a shadow price on any constraint in a nodal market model, except under the special conditions when the nodal price equals the PNP, as explained below.

16 Note that the signs in this equation are consistent with assuming that the constraint is expressed as a < constraint in an LP which maximises the "value of trade". This means that a positive constraint coefficient for generation implies that generation makes congestion worse, and reduces the objective function value. Other sign conventions should be applied under other assumptions, but the end result must be that prices always reflect the basic economic logic that the PNP is less than the regional reference price in any situation where generation makes congestion worse.

17 *NEM Regional Boundary: Theoretical Framework*

18 As defined in CRA Region Boundary report, "NEO", or "Nodal Energy Only" effects relate to the impact of nett nodal injections on the constraint. In principle, this means that generation and load would appear symmetrically in the constraint, and implies that the same "nodal price" should apply to both, as in the standard theory of nodal markets.

19 Most commonly, their indirect impacts on energy flow over a constrained line, or set of lines.

Stating this another way, the nodal price applying to *p* in a properly formulated nodal model would be the price for nett energy injection at the node where *p* is connected, and would thus apply symmetrically to generation and load. And it accounts for all binding constraints to the extent that they are impacted by such injections. But the *PNP* differs from this in that:

- It can reflect additional "non-NEO" effects, which may be specific to a participant, rather than any other generation, or load, at that node; and
- It will only reflect impacts on constraints that are included in the CSP regime.

The CRA proposal relates only to *PNPs*, not nodal prices, and the implications of using the *PNP* in the context of the Snowy Proposal are that:

- The signals faced by participants will reflect any non-NEO[20] effects which may be implicit in the constraint coefficients; and
- The signals faced by participants will not reflect any effects arising out of constraints which may be binding, but which are not explicitly covered by the proposal.

3.1.2. Treatment of Assumed Constraint Form

It is understood that there are several constraints, of varying forms, which may apply around the Snowy region, but that this proposal relates only to a set of constraints of the general form[21]:

$$\alpha * LT + \beta * UT + \gamma * V\text{-}Sn + \eta * Sn\text{-}NSW \leq RHS$$

Application of CRA Proposal

Ignoring any CSCs, the direct application of CRA CSP proposal would require payments to/from all affected participants/interconnectors, for each binding constraint *k* in the constraint set to which the regime applies, equal to:

$$CSP_k * MWGEN_p * COEFF_{kp}$$

Where, $MWGEN_p$ is the generation by participant *p*.

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20 "Non-NEO" effects relate to any other impact which generation or load may have on the constraint, including ancillary services, voltage support, inertia etc. These are participant-specific, and imply participant-specific pricing impacts which should not be reflected in nodal prices, and are not covered by the standard nodal market theory.

21 Here the UT and LT terms refer to upper and lower Tumut, and the other two terms to interconnector flows. Generation at or around the Murray node is not directly constrained by this constraint form, although the indirect implications of combining this constraint with the regional energy balance constraint do affect Murray.

That is, if all coefficients were positive, payments would be required to the constraint rental fund equal to *CSP* times:

- $\alpha * LT$ from Lower Tumut;
- $\beta * UT$ from Upper Tumut;
- $\gamma * V\text{-}Sn$ from the VIC-SNY interconnector[22]; and
- $\eta * Sn\text{-}NSW$ from the SNY-NSW interconnector.

The same mathematical relationship applies if coefficients are negative, except that payments will then be in the reverse direction, ie from the fund to the participant, or interconnector. This applies to both generation and interconnector flows. However, care is required with respect to interconnector flows, where variables should be interpreted as a (positive or negative) nett flow in a specified direction.

In many cases, the constraint itself may also be reversed, typically to represent a line limit binding in the opposite direction.[23] Thus we may have:

$$-reverselimit \leq \alpha * LT + \beta * UT + \gamma * V\text{-}Sn + \eta * Sn\text{-}NSW \leq forwardlimit$$

This should be interpreted for CSP purposes in the same way as it will be implemented in an LP formulation, that is as two separate constraints:

$$\alpha * LT + \beta * UT + \gamma * V\text{-}Sn + \eta * Sn\text{-}NSW \leq forwardlimit$$

$$-\alpha * LT - \beta * UT - \gamma * V\text{-}Sn - \eta * Sn\text{-}NSW \leq reverselimit$$

It would be quite consistent to apply a CSP regime to one, without the other, but if the regime is applied to both, each will have its own CSP, at most one of which will be positive at any time. And each may have its own allocation of CSCs, too[24].

On the other hand, the CRA reports propose the application of a "Bundled CSC" (BCSC) concept where there are several alternative constraints, or constraint forms, having similar effects. We understand this is likely to be the case here, and note that:

22 That is to the IRSS fund for that interconnector.

23 For convenience we will refer to "line" limits etc, although we understand that this constraint actually relates to a congested "cut-set" between Murray and Tumut.

24 Noting that the desirable/acceptable level of generation may be quite different when the constraint applies in the reverse direction.

- If all constraint forms have the same coefficients, but differ on the RHS, then the CSP regime will actually apply identically in all cases, with the difference being evident in terms of the ability of rents to support CSC allocations. Thus, if they are included in the same BSCS, that arrangement may need to include rules to scale CSC allocations to match the RHS capacity;

- If constraint forms have coefficients which are different, but broadly similar, with (much) the same RHS, then the same CSCs may be applicable in all cases. These could be defined in terms of RHS shares, with coefficients from the constraint form which actually applies being used to scale both CSP and CSC payments. But, if basically the same behaviour, and protections, are considered desirable no matter which of several constraint forms applies, then it may be more appropriate to define the CSC in terms of that implied generation level for all these constraint forms;

- If constraint forms have significantly different coefficients, and/or imply substantially different desirable behaviour, they should probably be covered by different BCSCs;

- In the limit, if some participant or interconnector term has a zero coefficient in the constraint, this actually implies zero participation in both CSC and CSP arrangements, which seems appropriate because an element with a zero coefficient is actually connected direct to the regional reference node;

- This may also be appropriate if the element is dis-connected, and it has been decided to offer no firm CSCs to cover this situation. Thus it would face the regional reference price as a marginal production signal, but be unable to generate anyway. And any CSC would be ineffective because this element's constraint coefficient is zero[25]; and

- But if the constraint forms differ because terms have been shifted from the LHS to the RHS, the participant(s) involved could still be involved in a CSP/CSC regime, with the nett payment still determined by the CSP times the difference between their actual generation and the applicable CSC under the BCSC arrangement.[26]

25 Still, it may be useful to define a CSC for such generation, even if a zero coefficient is applied, so as to provide for situations where the regional reference node is shifted, as discussed later.

26 Either of these could equal the assumed RHS value, but if both equal that value there will be no difference, and no nett payout.

The primary implication of all this is simply that, in principle, a different CSC may apply for each different constraint form, while CSC allocations may also need to vary if the RHS of a constraint varies. For example, all CSCs could be scaled in proportion, or one participant or interconnector might retain a fixed allocation while others vary. Thus some process will be required to determine these allocations, or allocation rules, and processes may also be required to apply those allocations within the settlement system. But all of these processes lie outside the present scope. We do note, though, that the principles outlined above may greatly simplify the task, by allowing a single CSC to apply to several constraint forms, for example.

The secondary implication is equally important, namely that if the nett CSC allocation in any interval does not match the effective network capacity, as represented by the RHS of the constraint there will be a surplus or deficit in the constraint support account[27]. Thus, unless processes are defined to deal with this by scaling CSCs, processes will be required to deal with these surplus/deficit situations, eg by smoothing deficits and surpluses on a rolling basis from period to period, as in some FTR markets. Again, the definition of such processes has both policy and pragmatic implications beyond the present scope.

Comparison with the Snowy proposal

The Snowy Proposal is not stated in sufficient detail to be certain of its intentions and implications in several areas. Given this lack of detail we are restricted, in some respects, to considering whether it is "*not inconsistent with the CRA proposal*", and to assuming and/or recommending that where ambiguity exists the implementation should be in accordance with the CRA proposal.

In particular, the Snowy Proposal document discusses the situation as if there were only one "Snowy constraint" involved, whereas we understand that there are up to 112 variants of this general constraint type, 52 of which could occur when constraints are oriented toward a regional reference node at Murray, and the remainder when constraints are oriented to a regional reference node at Dederang. Leaving this latter case for later discussion, inspection reveals that there are at least 10 distinct constraint classes in this first set, each of which may be applied in either a Northward or Southward direction. Within each such constraint class, there are (relatively) minor variations with respect to the constraint coefficients, and possibly major variations with respect to the RHS. But between classes the variation in constraint coefficients can be very large, to the extent that some terms are simply omitted in some constraint forms.[28]

27 See example B in the MCE forum presentation related to CRA Region Boundary report, where there is a 10MW discrepancy between the nett CSC allocation and the constraint capacity.

28 Most frequently the VIC-SNY interconnector is missing, but there are also variants in which the SNY-NSW interconnector, or one of the Tumut generation terms is missing too.

Still, although it is not stated in sufficient detail to be certain, the Snowy Proposal appears to broadly compatible with the CRA CSP/CSC proposal, and seems inherently capable of dealing with most of the above issues:

- Although the examples treat all Tumut generation as interchangeable, the application of differing coefficients involves no change in principle, and we assume that is the intent;
- Although no mention is made of which constraints this proposal is supposed to apply to, we presume that what is intended is a BCSC approach to a collection of basically similar constraints;
- Although the proposal recognises that CSC allocation can, and should, be different when flows are reversed, it makes no proposal with respect to the adjustment of CSCs to reflect variations in effective constraint capacity, or the allocation of CSCs when terms are shifted from the LHS to the RHS, for example. We presume that it would be intended to treat this latter aspect as a refinement at the implementation stage; and
- Although the proposal describes an indirect computational approach, in which the *CSP * COEFFp* is effectively inferred from the difference between what is referred to as a "shadow price" and the RRP, we presume that there is no objection to implementing a more direct computational approach which gives the same result.[29]

There are some further complexities involved in implementing the proposal, but those complexities are not fatal. Basically, the CSP regime can be introduced on as many constraints as may seem appropriate, with additive effects should more than one constraint bind simultaneously. Thus we may allow the prices to be computed, and the incidence of such prices to lie where it falls. Procedures must be developed to adjust CSC allocations to apply in cases where the constraint RHS, or coefficients, vary significantly, and/or to deal with surplus/deficit situations in the constraint rental account. But that may be seen as a matter for policy discussion, and implementational development, rather than one of principle.

29 Assuming the "shadow price" is actually *PNPp*, as above, the Snowy approach gives the correct result, and is used illustratively in some of the CRA examples. But a more direct approach may be preferable computationally, for reasons discussed below.

In summary, then, the Snowy Proposal could be regarded in most respects as a relatively straightforward application of the CSP/CSC concept, with some complexity to be dealt with before the proposal could be considered final. On the other hand, the Snowy Proposal clearly differs from the CRA proposal, in that it omits the VIC-SNY interconnector from the CSP/CSC regime entirely, while proposing what we understand to be a variation on current practice, whereby action is taken to limit any negative IRSS arising on that interconnector by shifting the SNY regional reference node, or by limiting counter-price flows. The implications of these alternatives are examined below.

3.1.3. Treatment of Other Market Features

Losses

The implication of varying loss treatments is discussed in section 2.6 of CRA's theory paper. In principle we would expect that loss effects would have to be accounted for in deriving generic constraints, assuming likely power flows at the time when such constraints are expected to apply, since this is the only way in which physical accuracy can be even approximately ensured. This sits a little awkwardly with the NEM practice of applying a loss adjustment to final prices, assuming averaged marginal loss factors. Although this point is not highlighted in earlier CRA reports, those averaged loss factors should really be accounted for, as an adjustment to the RRP in all PNP calculations. This will happen automatically through the NEMDE based settlement systems, and no further adjustment is required to the CSP payments if those are to be based directly on NEMDE shadow prices, as we recommend. But any implicit loss adjustment to RRP should be accounted for if CSPs are to be inferred from the difference between RRP and PNP, for example.[30] This does imply some inaccuracy in price signalling, but that approximation is accepted as inevitable, given the current market design and systems, in the CRA proposal.

30 The PNP equation assumes no loss adjustment is applied to the regional reference price, but a loss adjustment should really be implicit in the CSP component. An internally consistent result would arise if the loss factor assumed in the settlement system was also used in constraint derivation, and the same coefficient was applied to adjust the regional reference price in the PNP equation. But different loss factors may have been assumed in constraint derivation, perhaps relating to system conditions when such constraints are likely to bind. This presumably aligns the CSP component more closely with the marginal loss calculations implicit in a nodal model, but implies some discrepancy between that component and the loss adjusted regional reference price faced in the energy market. But this basic inaccuracy is no greater than that arising with respect to existing market arrangements, and no consideration has been given to developing more accurate adjustments when calculating CSP/CSC payments.

To be clear, the basic PNP formula ignores losses, but the NEM applies a loss adjustment (TLF) to the regional reference price, and this should also be applied in the PNP equation to give:[31]

$$PNP_p = TLF * RRP - \sum_k CSP^k \cdot COEFF_p^k$$

Simultaneously Binding Constraints

The CSP based PNP formula implicitly and correctly reflects the impact of simultaneously binding constraints. That is:

- It explicitly includes the impact of all simultaneously binding constraints covered by the CSP arrangement; and
- It explicitly excludes the impact of all simultaneously binding constraints not covered by the CSP arrangement.

Thus, no matter how many constraints are binding at any time, this formula can be applied independently for each binding constraint, using that constraint's CSP and, if desired, a CSC specific to that constraint. This approach can work, and imply desirable dispatch incentives, even when conflicting constraints bind, as explained in CRA's MCE forum presentation.[32]

VoLL Price Capping

It should be recognised that that this proposal, and the CRA proposal on which it is based, rests on the assumption that prices are being derived from NEMDE solutions. But this may not be the case when VoLL price caps are reached in one or more regions. The pricing heuristics applied in such cases may not give prices which strictly comply with theoretical understandings about how prices should relate to dispatch optimisation, or between regions. Thus there may be a similar mis-match between energy prices and CSPs, for example. The implications of this have not been considered, but heuristic rules might have to be developed to apply in such circumstances.

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31 Obviously, the resultant PNP will only be as accurate as the loss adjustment itself. As noted above, no loss adjustment should be applied to the CSP term because losses should have been accounted for in deriving COEFF. But if a PNP had been calculated, by whatever process, the CSP term could be inferred, by taking the difference between that PNP and the loss-adjusted RRP.

32 See slides on "constraint management" presented to public forums in relation to CRA Region Boundary report. But note that the indirect PNP based settlement process proposed by Snowy breaks down if we wish to apply different CSCs to constraints which may bind simultaneously. While the use of a PNP to effect the aggregate of all CSP transactions remains valid, the CSCs would have to be applied to each constraint (group) separately, using only the CSP for that constraint (group).

Similar issues occur with respect to the possible capping of PNPs. The PNP, as defined in the CRA papers, was not truncated, and nor did those papers discuss the possibility that the regional reference price might itself be truncated. Such truncations are really in the realm of policy rather than pure theory, so we would not want to be dogmatic with respect to the "best" option. To be consistent with a capped nodal price market, though, one would need to interpret the "regional reference price" in our price equations as the raw shadow price on the regional energy balance constraint, before any truncation was applied, then apply the CSP adjustment, and then truncate. This would also be consistent with a market regime which limits participant offers to lay between the market price floor/cap. But it may not be consistent with the heuristics currently applied to preserve inter-regional price relativities under VoLL pricing. This raises policy issues which are beyond the present scope. [33]

Similar comments apply with respect to the application of price caps to 5 minute vs 30 minute prices. Again, consistency should be sought between the CSP regime and other market arrangements, and it would not seem appropriate to pursue "accuracy" further with respect to CSP settlements than with respect to energy or FCAS settlements.

FCAS

No consideration has been given, in the Snowy Proposal, to the implications of FCAS terms appearing in any constraints which may be involved. Nor has any consideration been given, in the CRA papers, to the implications of FCAS co-optimisation on participant positions etc. Broadly, we expect that these will have similar implications to any other constraints which may be binding at the same time as those involved in the CSP arrangement, but not themselves covered by that arrangement. In fact they are covered by their own market pricing arrangement, which could be thought of as a specific application of the CSP concept. Thus the situation is similar to that discussed in the CRA papers and presentations[34], in which two CSP arrangements can be simultaneously active, and operate independently without creating any inconsistency. This suggests that the likelihood that CSP/CSC arrangements will have to operate in parallel with, but independently of, FCAS arrangements should not be a cause of theoretical concern, although the implications do need to be understood better. We have not, however, pursued any theoretical analysis on this issue.

33 Practically, though, if it is desired to cap PNPs, it will be necessary to explicitly calculate the PNP, by summing the CSP effects for individual constraints, rather than simply performing a CSP transaction independently for each binding constraint. This may imply a preference for adopting the relatively indirect PNP based calculation approach proposed by SNY, rather than the direct approach proposed originally by CRA. But see comments elsewhere with respect to the implications of differing CSC allocations for different constraints.

34 CRA's recent papers and presentations all assume that CSP/CSC arrangements can, if desired, be applied independently when multiple constraints bind simultaneously, but the issue is first discussed in Section 2.2 of: *NEM Interconnector Congestion: Dealing with Interconnector Interactions*, CRA report to NEMMCO, June 2003

3.2. Implications of Deviations From CRA Proposal

By omitting the VIC-SNY interconnector, the current version of the Snowy Proposal produces only a partial implementation of the CRA proposal, we must consider the implications of continuing with that partial approach, in the interests of simplicity, instead of altering the derogation to reflect an approach that is strictly correct. There are three possible implications, depending on how the situation is handled.

Implications of Simply Ignoring the VIC-SNY Interconnector

First, the CRA proposal assumes, for the most part, that all participants who are represented on the constraint LHS will be involved in any CSP regime, and shows that, under that assumption, both intra-regional and inter-regional settlement surpluses can be made as firm as the RHS. Thus, if all generator and ancillary service terms are included in the regime, the settlement surplus will be as firm as the underlying transmission system, after adjustment for the impact of local load variations. But if any term is omitted from the CSP regime, then the settlement surplus will be that much less firm, rendering it to be equivalent to the settlement surplus arising if that term had been placed on the RHS of the constraint[35].

In this case, it means that the VIC-SNY interconnector, and hence implicitly the participants using that interconnector[36], are not subject to any market discipline arising out of the CSP/CSC arrangement. We note, however, that even under the CSP arrangement, they would be setting their generation levels in response to regional price signals, which are unaffected by these arrangements.[37] Thus the real difference lies in the ability of the rental streams to jointly support CSCs within the SNY region, and CSCs to firm up VIC-SNY and SNY-NSW hedging:

- If the CSP/CSC arrangement motivates SNY generation to behave in ways which tend to stabilise the constraint rental pool, this will have some impact on both IRSS pools;

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35 At whatever value the NEMDE determines it to be.

36 Clearly this includes generators in Victoria and South Australia but also Murray, which is not directly involved in the constraint.

37 This is correct, provided these trans-regional constraints are properly represented and oriented, the CSP effects will already be implicit in their respective RRPs.

- If the VIC-SNY interconnector is excluded from both CSP and CSC arrangements, its own IRSS pool would be unaffected, except inasmuch as the SNY participants may be motivated to behave in ways which tend to stabilise the nett effective transfer capacity available on that interconnector. Thus, implicitly, we can think of the VIC-SNY as being involved in the CSP/CSC arrangement, but dynamically assigned CSCs to cover whatever its flow turns out to be in each market interval, so that the CSP and CSC effects exactly cancel, leaving it unaffected;

- If the SNY-NSW interconnector had firm (CSC-defined) access to the constraint rental pool, it would be able to provide firm inter-regional hedging on that basis;

- But these arrangements are incompatible, in that the nett effective hedging capacity available to support the SNY and SNY-NSW CSCs will depend dynamically on the VIC-SNY flow. Thus, unless we are prepared to contemplate surpluses and shortfalls in the constraint rental pool, the CSCs allocated to SNY and SNY-NSW will have to be scaled to match the remaining settlement surplus pool, after the VIC-SNY interconnector has implicitly been allocated a share to match its dispatch; and

- Thus, while SNY and (users of) the SNY-NSW interconnector would both receive some protection against deviations by the other from their agreed proportional shares of constraint capacity utilisation, they would both still be subject to risk arising out of the dispatch of the VIC-SNY interconnector. And, conversely, (users of) the VIC-SNY interconnector would still be subject to risk arising out of the dispatch of the SNY generation, and SNY-NSW interconnector.

Overall, while the IRSS for the VIC-SNY interconnector would still not be able to support firm inter-regional hedging, it seems that this arrangement probably offers some advantages to (the users of) that interconnector, at the expense of SNY generation, and (users of) the SNY-NSW interconnector. Conversely, while SNY generation, and (users of) the SNY-NSW interconnector stand to gain significant mutual advantage out of their cooperative involvement in this arrangement, that advantage is somewhat eroded by the exclusion of the VIC-SNY interconnector.

Implications of Shifting the Regional Reference Node[38]

We do not see any basis for the claim, in the Snowy Proposal document, that CRA has not considered loop flow effects or counter-price flows. In fact such considerations have been integral to our analysis, and have lead to our recommendation that these effects be dealt with by a consistent application of the CSP/CSC concept, as in the above discussion.[39]

Nevertheless, for whatever reason, the Snowy Proposal calls for a partial implementation of the concept, and we agree that, as a consequence, a negative IRSS could arise on the VIC-SNY interconnector. Thus, the Snowy Proposal actually calls for the RRN to be shifted[40] whenever a negative IRSS would otherwise occur on the VIC-SNY interconnector. We will not comment further on the effectiveness or desirability of this practice, except to repeat our recommendation that a consistent CSP/CSC implementation seems preferable. We also note that a proposal to shift the Snowy RRN to Dederang whenever these constraints bind may not be very different to shifting the regional reference node permanently, if inter-regional price differentials are largely created by these constraints.

Although the policy implications of such a shift lie outside our present scope, we note that, in the absence of any CSP regime, such a shift would imply an overall shift in prices paid to Snowy generation. Importantly, this is actually not true under a CSP regime which, in this case would involve all generation in the region facing their PNP, which does not change with the location of the regional reference node. Thus the policy issue may be thought of more in terms of the CSC allocation which would be appropriate under each alternative. [41]

38 This analysis goes beyond the theory developed in the MCE papers, and should be regarded as preliminary and tentative.

39 For an illustration, see the "Tarong" example in our MCE forum presentation.

40 From Murray to Dederang.

41 But there are commercial implications, because those CSCs give access to a different regional reference price. Under the status quo, all generators in a region would get implicit access to the alternative regional reference node, and experience a corresponding shift in income. If CSP/CSC arrangements are in place, that income shift would only apply to the CSC MW levels of those participants involved in the regime. In principle it would also apply to all truly non-involved participants, since they may be thought of has having access to the regional reference price for whatever generation is dispatched). But see the note below with respect to constraint coefficients, and note that there may be no participants who actually have unlimited access to both old and new regional reference nodes in situations where those nodes are involved in binding constraints.

Since all of the above discussion assumes that the SNY regional reference node would remain unchanged, no matter what IRSS arose on the VIC-SNY interconnector, we do need to consider the implications of adopting this approach in conjunction with a CSP/CSC regime. The implications of shifting the regional reference node in a CSP/CSC regime have not been analysed in previous CRA reports. Unfortunately, we do not believe the discussion in the Snowy Proposal is entirely clear either. In fact, it should be recognised that, when the regional reference node is shifted:

1. All constraints involving Snowy generation or interconnector terms must be re-oriented to the new regional reference node;
2. Thus all constraint coefficients will change, with the effect that:
   - The constraint coefficient for the new regional reference node will be subtracted from the constraint coefficient for each (potential) term in the constraint expression[42];
   - Any term relating to the new regional reference node will disappear[43]; while
   - A term will now appear for any generation at the old regional reference node[44].
3. The CSP on the constraint will be unaffected.[45]
4. The PNP for each participant will remain unaffected[46], but it will now be made up by:
   - A different regional reference price; plus
   - A different constraint coefficient times; and
   - The same CSP.
5. The RHS of the constraint will be affected as discussed below, and we must consider whether this will affect the supportable CSC allocation.

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42 Including those potential terms which had a zero coefficient in the original constraint form.

43 In this case, the VIC-SNY interconnector term will disappear, if it feeds into the Snowy region via Dederang.

44 I.e., Murray, in this case.

45 Because the economic cost of congestion remains the same.

46 Because it is still equivalent to a nodal price, at least in this simple case.

An example is included in Appendix A, based on one of the examples in the earlier CRA paper. It will be observed that in this case there is an overall settlement surplus deficit arising, and the notes suggest that this is because the RRP has changed. This issue is taken up in the discussion of load and revenue adequacy issues in the expanded version of CRA's forum presentation[47], where it is argued that, since a consistent CSP application will produce prices equivalent to nodal prices:

- The settlement surplus should be just enough to cover nett FTR hedging requirement between (notional) generation and load hubs, or CSCs/FTRs from generation nodes to load hub, where the two hub prices are defined by generation and load-weighted averages, respectively; and

- But setting the regional reference price above, or below, the load hub price will create a nett hedging problem for CSCs on a zonal market or FTRs in an LMP generation market.

On further consideration, though, the problem identified in this last point seems to be overstated.[48] It is true that there will always be a nett settlement surplus issue arising out of the CSP regime alone, if the regional reference price for loads is not set to the generation hub price, that is to the average of generator nodal prices. And setting the load price to be the load hub price does create just sufficient nett settlement surplus sufficient to support FTRs to that hub in an LMP market, or CSCs to that hub in a zonal market. But:

- We could form a regional reference price by adding an arbitrary (positive or negative) "uplift" to that load hub price, and collect a corresponding extra rent, equal to the uplift times the total load.

- This "uplift rent" would then be available to support FTRs or CSCs from the generator nodes to the notional regional reference node, at which this regional reference price was deemed to apply.

- In particular, we could just assign the uplift rent to each generator, in proportion to generation, which is equivalent to performing the CSP/CSC calculations with respect to the load hub, and then adding an uplift on to all prices.[49]

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47 See third diagram in Appendix A.

48 This analysis should be considered cautiously, as it is tentative and has not been thoroughly tested.

49 This might be conceptualised in terms of an augmented network diagram, with notional arcs leading from each load node to the load hub, and from the load hub to the notional node at which the regional reference price is deemed to apply.

The real situation differs from the above in that the regional reference price is set to correspond to delivery at a specified regional reference node. Arguably, this does produce prices that are offset by an essentially arbitrary amount with respect to the load hub price. But the form of CSC allocation we have assumed has a distinct physical meaning, and does not correspond to the form implied by the above discussion. [50] On the other hand, it should be recognised that actually any assignment of the uplift rent should be feasible, provided it is assigned to generation and interconnector flows in such a way that the total MW assignment matches the total MW load. Here we re-consider the revenue adequacy issue in terms of the number of CSCs which can be allocated for transfer to any particular regional reference node, and derive a physically meaningful formula which re-allocates CSCs to achieve essentially the same outcome, irrespective of the choice of regional reference node[51].

Taking the example in the Appendix A, we note that, irrespective of the regional reference price, a revenue discrepancy is surely to be expected if there is no adjustment to the CSC allocation when the regional reference node shifts. After all, the proportion of any flow from each generator to the (new) regional reference node which passes over the congested line is now different. In particular, it may now be appropriate to allocate a CSC to any generation at the old regional reference node, and to remove any CSC protection from any generation at the new regional reference node.[52]

But how should the CSC allocation change?[53] Consider, first, the RHS of the constraint, which ultimately determines the supportable CSC allocation. Since the underlying physical capacity remains the same, it might be thought that this will be unaffected by a change in the regional reference node, and this would be the case if load was modelled on the LHS of the constraint. But the RHS actually includes possibly quite a large component reflecting the nett effect of "local" loads in terms of increasing the effective transfer capacity to the regional reference node, at which all regional load is notionally considered to reside. Thus, this term must be adjusted if the regional reference node shifts. In fact:

- The adjustment required corresponds to the change in notional flow across the congested line engendered by a notional transfer of the entire regional load from the old regional reference node to the new;

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50 That is it does not take the form of a firm allocation of CSCs to the load hub to all generation involved in the constraint, supported by the natural network rents, plus a dynamic allocation of the uplift to all generation, irrespective of location. Equivalently, it does not take the form of a CSC allocation which shifts dynamically as the uplift changes, with the proportion of "physical" vs "uplift" rent varying from interval to interval.

51 In this case, a constraint form which explicitly includes Murray may have some cosmetic advantage.

52 Where such protection is irrelevant anyway.

53 This issue did not arise in the earlier examples only because all load was assumed to be concentrated at the regional reference node.

- But the generation (and import/export) pattern required to meet the load does not change, and the system is still just as capable of supporting that generation (and import/export) pattern;

- Thus, if we think of CSC quantities being defined primarily in terms of MW of congestion (CCON), those quantities must adjust so that, when multiplied by the new constraint coefficients, they still give access to the same MW quantity generated (CGEN);

- This can be achieved by multiplying the CCON for each participant by that participant's new coefficient, divided by the old one[54];

- We believe it can be shown that, if the CSC allocation was complete and sustainable in the first place, in the sense that all relevant generation terms were included, and their sum matched the RHS, then the aggregate change to CSC allocation matches the change to the RHS[55];

- The key is that, since shifting the regional reference node makes no difference to the physical situation, it should make no difference to the desirable dispatch pattern, or to the network's ability to support that pattern. Thus it seems reasonable to think of the CSC allocation being the same, provided that CSC allocation is thought of as being defined in terms of CGEN, the implied MW generation level for each participant. The mathematics here just transforms that allocation into a CCON value, which will be different depending on the choice of regional reference node, because it relates to the congestion caused by a flow from the participant to the regional reference node;

- But two special cases deserve consideration:

  - First, since any generation at the old regional reference node had a zero coefficient in the original constraint, it will receive an infinite, or more exactly "undefined" CSC allocation when the regional reference node is shifted. This is a technically correct reflection of the infinite access it effectively enjoys to the original regional reference node. But a finite value should obviously be specified to apply in such cases, and we can think in terms of employing a finite value, with a zero coefficient; and

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54 That is, given the nature of this transformation ($COEFF_i$ – $COEFF_n$) / $COEFF_i$ where n is the new regional reference node. Note that this could reverse the sign of the coefficient, so that a generator which received a positively valued CSC with respect to one regional reference node may receive a negatively valued CSC with respect to the other.

55 This arises because generation in accordance with the CSC implies a feasible dispatch (in terms of transmission capacity, if not generation capacity), in which the sum of generation equals the sum of load.

- Second, since any generation at the new regional reference node has a zero coefficient in the new constraint, it will receive a zero CSC allocation when the regional reference node is shifted. This is a technically correct reflection of the fact that it no longer needs a CSC to get (infinite) access to the new regional reference node. But it may be better to think in terms of employing a finite value, with a zero coefficient.

The relevance of some of this discussion to the Snowy case may be moot, because there is little local load anyway. But the general principles must still be established and applied. Thus, even if the RHS changes very little, it is still true that constraint coefficients will change in the CSP and CSC calculations, and that CSC allocations will need adjustment, too.

In view of the above discussion, it may be best to think of CSC allocations, first, in terms of a desirable, or at least acceptable, level of generation from all potentially relevant sources, including those with a zero constraint coefficient, under the specified constraint situation. If the assumed load pattern can actually be met, it should be possible to achieve a feasible CSC allocation corresponding to any feasible generation pattern. This allocation can then be transformed so as to correspond to any regional reference node, as above. The effect should be to maintain access for a constant amount of generation, no matter what regional reference node is chosen. [56]

Implications of Blocking Counter-price Flows[57]

On the other hand, NEMMCO have asked for comment on the implications of continuing the current practice with respect to counter-price flow situations. We understand that practice to be that the regional reference node is shifted to Dederang in the case of a negative IRSS arising in the SNY-VIC direction, but the interconnector flow is "clamped" to eliminate counter-price flows in the case of a negative IRSS arising in the VIC-SNY direction[58]. Again, we will not comment on the effectiveness or desirability of this practice, except to repeat our recommendation that a consistent CSP/CSC implementation seems preferable.

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56 So, if we think of CSCs being defined in such terms, no transformation is actually necessary, except perhaps to facilitate calculations within the settlement system.

57 This analysis goes beyond the theory developed in the MCE papers, and should be regarded as preliminary and tentative.

58 Counter-price flows will be eliminated if the flow is clamped to zero, but a less drastic clamping will suffice if the SNY price rises to match the Victorian price. Given the discussion below it appears that this will only happen if VIC-SNY flows are relieved sufficiently that the original "Snowy" trans-regional constraint no longer binds at all, in which case the CSP/CSC regime will become irrelevant.

Mathematically, the situation when an interconnector flow is clamped is no different from that applying when a physical transfer limit binds. Thus an additional shadow price will arise, and presumably it will equal the incremental gain which could be made for the system as a whole as a result of allowing one unit of counter-price flow, assuming the specified generator offers. Given that flow from a higher to a lower priced regional reference node has been blocked, the price in the lower priced (receiving) region will typically be higher than it would otherwise be, while that in the higher priced (sending) region will typically be lower[59].

Thus restricting counter-price flows from Victoria to Snowy has the primary effect of reducing transfer capacity from Victoria to Snowy and NSW, thus inducing a requirement for more generation in one, or both, while reducing generation in Victoria. Physically, substituting generation in NSW or Tumut for generation in Victoria will reduce pressure on the congested cut-set, but substituting generation at Murray will actually increase congestion. Thus, while blocking flows from Victoria to Snowy will typically imply higher prices in NSW and/or Snowy than would have otherwise applied, it is less clear whether the constraint shadow price, and hence the Snowy/NSW price differential, will typically rise or fall. [60]

Looking at the situation in detail[61]:

- Before the VIC-SNY flow bound is applied, any 2 of the 5 terms involved in the equation can provide the marginal supply, giving 10 possible combinations;
- Once that bound is applied, there must be 3 marginal suppliers, but one of them must be in Victoria, which is now isolated from the SNY/NSW market;

59 The direction of price movement is as one would expect, but the implication is that the magnitude of the (negative) inter-regional price differential is reduced, rather than increased, as we would normally have expected. This reflects the nature of this trans-regional constraint which causes counter-price flows in the first place.

60 It might be thought that the CSP will inevitably rise because, at the specified offers, the constraint is a more serious economic impediment to the system when counter-price flows are not allowed to relieve the constraint. But, while the situation is definitely worse, economically, with a tighter constraint, that economic cost is increasingly reflected by a high shadow price on the (artificial) VIC-SNY interconnector bound, making it unclear whether the CSP on the original constraint will rise or fall. In fact, as the flow bound is tightened, the original trans-regional constraint could become progressively less significant until it ceases to bind at all, and NSW/SNY share a common price, at which point there will be no more counter-price flow, and hence no incentive to tighten the bound further.

61 These hypotheses have not been rigorously tested, but appear to be confirmed by limited tests performed in the CRA spreadsheet model.

- In 6 of the original cases Victoria was not marginal, in which case the imposition of a flow bound will immediately lower the Victorian price, but not initially affect SNY/NSW prices;
- But Victoria was already marginal in the other 4 original cases, in which case the Victorian price is not initially affected, but the SNY and/or NSW prices will be. Imposing a bound to back off VIC-SNY flow will effectively raise the price at the VIC-SNY injection point, but affect other prices around the loop differently[62];
- Specifically, the supplier which was marginal before the bound was imposed will remain so, initially, and another will become marginal:
  - If NSW was marginal, then the NSW price will be unaffected, but the SNY price must rise until one of NLTS, NUTS or Murray becomes marginal. Thus the SNY-NSW differential, and the CSP, falls;
  - If NUTS was marginal, then the SNY price must rise, and the NSW price must also rise (to a lesser extent) until one of Murray, NLTS or NSW becomes marginal. Thus the SNY-NSW differential, and the CSP, falls;
  - If Murray was marginal, then the SNY price will be unaffected, but the NSW price must rise until one of NLTS, NUTS or NSW becomes marginal. Thus the SNY-NSW differential, and the CSP, **rises**; and
  - If NLTS was marginal, then the SNY price must rise, and the NSW price must **fall** (to a lesser extent) until one of Murray, NUTS or NSW becomes marginal. Thus the SNY-NSW differential, and the CSP, falls.

Thus we can conclude that, initially, ie for the first increment of VIC-SNY flow reduction:

- The Victorian price does not rise, although in 40% of cases it remains constant[63];
- The SNY prices does not fall, although in 70% of cases it remains constant;
- The NSW price also remains constant in 70% of cases, rises in 20% and falls in 10%; and
- The CSP remains constant in 60% of cases, rises in 10%, and falls in 30%.

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62 That price now corresponding to the Victorian price, plus the shadow price on the bound.

63 Ie in 4 out of the 10 logically possible cases… although some of those cases may, themselves, be improbable in practice.

As the VIC-SNY flow bound becomes progressively tighter, though, there must eventually be some adjustment in NSW and/or SNY, and we can expect an irregular sequence of changes of any of the final four types. Thus:

- The Victorian price tends to fall;
- The SNY price tends to rise;
- The NSW price is most likely to rise, but could fall if NLTS tends to make up for any reduction in VIC-SNY flow; and
- The CSP is most likely to fall, but could rise if Murray tends to make up for any reduction in VIC-SNY flow.

Thus clamping the VIC-SNY interconnector flow could induce a response in either NSW or SNY. Given the relative size of NSW and the SNY generation options, it may be that, eventually, adjustment will have to occur in NSW, thus raising NSW pries and the CSP. But this is unclear because what really matters is the amount of spare capacity available to economically take up the adjustment, and this may often be greater in SNY. If the SNY/NSW differential typically falls, the change in incentives may also be greater for SNY than for NSW. But this depends on the commercial arrangements:

- Under a CSP regime, Tumut would get roughly the same incentives as NSW, rather than the same as Murray, and would typically be generating more in the initial counter-price flow scenario than under the status quo. [64] Thus clamping VIC-SNY flows is more likely to have the effect of increasing Murray generation, which most directly substitutes for VIC-SNY flow. This means that, before flow clamping occurred, the CSP would typically be lower than under the status quo[65], but could tend to rise, once clamping commenced[66]; and

64 Which probably means that these scenarios are less likely in the first place, since increased Tumut generation will improve the supply situation in the combined SNY/NSW region, and tend to back off Victorian generation, and hence VIC-SNY flow, while also relieving the trans-regional constraint which causes the price differential to arise.

65 And quite possibly zero, in which case the trans-regional constraint is not binding and no clamping is required.

66 Because increasing Murray generation to back off VIC-SNY flow actually increases congestion within SNY.

- But, under the status quo, all SNY generation gets the same incentives. In this case that means that Tumut generation will have been artificially suppressed by low SNY prices[67]. Thus Tumut generation is just as likely to increase as Murray generation, if SNY prices rise as VIC-SNY flows are backed off. This means that, before flow clamping occurred, the CSP would typically be higher than under a CSP regime, but is more likely to fall, once clamping commences[68].

By assumption, the VIC-SNY interconnector is excluded from the CSP/CSC regime and, in this case, would receive an IRSS corresponding to the MW flow to which it has been clamped[69]. It would thus only be able to support hedges to that level in this situation, as for the status quo. But the CSP/SC regime will still work between Snowy generation and the SNY-NSW interconnector. In particular, CSCs could be allocated to match the nett effective constraint capacity, after accounting for the impact of VIC-SNY interconnector flows which in this case will be at their clamped level.[70] Thus the imposition of a transfer limit in this extreme case may be argued to reduce the general impact of the uncertainty created by excluding that interconnector from the CSP/CSC regime.

3.3. Market Implications

The Snowy Proposal is not presented in sufficient detail to be certain of its intentions and implications in several areas. Given this lack of detail we are restricted, in some respects, to considering whether it is "not inconsistent with the CRA proposal", and to assuming and/or recommending that where ambiguity exists the implementation should be in accordance with the CRA proposal.

It has been proposed that the CSC allocations should differ, depending on the direction of flow over the constrained line, with[71]:

67 Which may be one reason why these counter-price flow scenarios occur in the first place, since reduced Tumut generation will worsen the supply situation in the combined SNY/NSW region, and tend to bring on Victorian generation, and hence VIC-SNY flow, while also creating pressure on the trans-regional constraint which causes the price differential to arise.

68 Because increasing Murray generation to back off VIC-SNY flow actually increases congestion within SNY.

69 As noted above, this may be non-zero, since a less severe flow restriction is often sufficient to eliminate a negative IRSS, presumably by equalising, or reversing, the inter-regional price differential.

70 Except that, if clamping the VIC-SNY flow means that the inter-regional price differential disappears because the constraint no longer binds, the CSP/CSC regime will also be irrelevant.

71 These characterisations summarise the effect of the proposal when applied to the whole spectrum of situations which might arise in practice, rather than just to the simplified examples accompanying the proposal itself.

- Zero MW allocated to Tumut, so that the entire constraint capacity (typically 1350 MW before accounting for the impact of factors such as VIC-SNY flow) is allocated to the SNY-NSW interconnector in the case of Northward flow; and

- 550 MW allocated to Tumut, so that the remaining constraint capacity (typically 800 MW before accounting for the impact of factors such as VIC-SNY flow) is allocated to the SNY-NSW interconnector in the case of Southward flow.

The proposal implicitly assigns no CSC to the VIC-SNY interconnector, and does not say what allocation might be proposed for Murray, which will require an allocation if the regional reference node is shifted to Dederang. It does not say how allocations might be scaled if 1350MW of capacity is *not* available, or how the impact of other factors such as VIC-SNY flows or binding interconnector limits are to be accounted for.[72]

Ignoring those issues, though, this allocation may well be appropriate, but the implications deserve consideration, both in terms of hedging and operational incentives[73].

First, in the case of Northward flow[74]:

72 Although we understand that, in the absence of any discussion of such topics, the proposal may be, and has been, interpreted as implying that a fixed allocation factor is to apply irrespective of such considerations.

73 This discussion is based on partial and preliminary analysis, and should NOT be taken as a reliable, exhaustive or definitive analysis of the variety of strategic situation which could be faced.

74 This discussion takes no account of the possibility that VIC-SNY interconnector flow may be clamped to prevent counter-price flows. If flows are clamped to zero, the fact that the VIC-SNY interconnector is excluded from the CSP/CSC regime becomes irrelevant, because it generates no IRSS anyway, while a non-zero clamping level should only be adopted in cases where the CSP/CSC regime itself becomes irrelevant. And we have argued that clamping would probably occur less often, and be less severe, under a CSP regime than under the status quo. We have also noted that if, instead, the regional reference node is shifted to Dederang, the PNPs would actually be unaffected. Thus, of itself, such a shift should make no difference to participant incentives, although it may have some indirect impact via the second order incentives implied by contract arrangements (cfds, CSCs or SRA based hedges) which relate to the regional reference price. But note that our discussion has assumed that the CSCs, at least, would be automatically adjusted so as to make the choice of regional reference node irrelevant in terms of implied incentives for generation behaviour. (The commercial implications of a different regional reference price remain, but apply only to contract quantities, not marginal generation incentives.)

- The allocation of zero MW to Tumut represents a significant change from the status quo, under which Tumut may be thought of as being implicitly assigned a negatively-valued CSC giving it forced "access" to the regional reference node at Murray for everything it generates. Thus, assigning a zero MW CSC to Tumut will actually remove rent from the IRSS, leaving the SNY-NSW interconnector with firm access to 1,350 MW, rather than to an uncertain MW transfer level (ie approximately: 1350 + Tumut generation + that portion of VIC-SNY flow which by-passes the congestion) as at present. [75] Conversely, Tumut would gain essentially unlimited access to the NSW market[76], without having to purchase hedges via the SRA process.

- With respect to incentives, under this regime, Tumut would effectively face the higher NSW price on the margin, and compete on a level playing field with NSW generation. Murray would still face the lower Snowy regional reference price, linked to the Victorian price. Thus, relative to the status quo, Snowy will definitely have (first order) incentives to increase generation at Tumut to its economic level[77]. It may also have (second order)[78] incentives to reduce generation at Murray and/or increase Tumut generation further so as to actually relieve the constraint, and so obtain the NSW price for any remaining Murray generation[79]. But, unless another constraint binds, this implies that the Victorian price will also come into line with the NSW price, and generation in all three regions will be competing on a level playing field, apart from loss adjustments. Thus this strategy will only work if SNY can increase Tumut generation without depressing the NSW price and/or decrease Murray generation sufficiently to raise the Victorian price.

75 Unless the interconnector constraint itself binds.

76 Again, unless the interconnector constraint itself binds.

77 I.e., up to the point where its marginal cost equals the NSW price, ignoring any potential for it to exercise market power in the NSW market.

78 First order incentives relate to purely competitive responses to market prices, while second order incentives arise as a result of a participant's ability to profitably manipulate market prices.

79 Swapping generation between Tumut and Murray seems a viable self-contained strategy. Otherwise, increasing generation at Tumut will only help relieve the constraint if this backs off generation in Victoria, which is possible. Decreasing generation at Murray will help most if this brings on generation in NSW, but will also assist if it brings on more generation from Victoria, since this partially bypasses the constraint.

- While either is possible, the key thing to note is that the CSP means that both Tumut and Murray are effectively competing in larger more competitive markets[80] and thus have considerably reduced second order incentives. And what second order incentives remain will be further reduced if a realistic CSC allocation can be achieved[81].

- Overall, this situation is a distinct improvement over the status quo, under which all Snowy generation receives the lower Snowy regional reference price and Snowy Hydro does not have appropriate economic incentives to relieve congestion.

Second, in the case of Southward flow:

- The allocation of 550 MW to Tumut effectively gives Tumut access to the higher priced Snowy regional reference price at Murray, irrespective of its generation level. Thus Tumut would only receive its PNP for any generation above that level, as noted in the text. But Tumut would also receive rent corresponding to the difference between its PNP and the regional reference price, even when it is not generating. This may be thought of as a payment from those participants who are using the constrained capacity for their use of that part of the capacity which has been assigned to Tumut via its CSC. Conversely, the SNY-NSW interconnector would implicitly receive a CSC allocation corresponding to the remaining constraint capacity. With respect to incentives, under this regime, Tumut would again face the lower NSW price on the margin, and compete on a level playing field with NSW generation. Murray would still face the higher Snowy regional reference price, linked to the Victorian price.

80 Simplistically, they compete in NSW and Victoria respectively. In reality the NLTS and NUTS coefficients are not identical to that for NSW, and the Murray coefficient is not the same as that for Victoria, implying that they are all interacting with both NSW and Victoria. But the 'level playing field' comment still applies, with respect to their involvement in both markets. Thus, to be successful, a second order strategy has to be able to shift the price in one or both of these relatively competitive markets.

81 The importance of these second order effects also depends very much on the level of energy contracting underlying the CSP arrangement. Thus if Murray generation is contracted via a CfD (contract for difference) defined with respect to the Snowy regional reference price, or a CfD defined with respect to some other regional reference price with effective hedging to the Snow regional reference price,[81] then it is only the difference between its generation and that contract generation level which will be exposed to the Snowy regional reference price. Thus any second order incentives apply only to that difference, and will be quite small if the contracts applying when these congested situations occur are close to the generation levels which would induce such congestion.

- Thus Snowy Hydro will definitely have (first order) incentives to decrease generation at Tumut, relative to the status quo, to its economic level[82], and potential (second order) incentives to increase generation at Murray and/or decrease Tumut generation further, so far as to relieve the constraint, and so obtain the higher Victorian price for remaining Tumut generation[83]. But, unless another constraint binds, this implies that the Victorian price will also come into line with the NSW price, and generation in all three regions will be competing on a level playing field, apart from loss adjustments. As discussed for the previous case, such second order effects will only arise if Snowy Hydro can shift the price in Victoria and/or NSW, and the importance of such second order effects is moot anyway, given the likely contracting situation.

- Overall, this situation is a distinct improvement over the status quo, under which all Snowy generation receives the higher Snowy regional reference price and does not have appropriate economic incentives to relieve congestion.

Thus, while a complete analysis has not been attempted, and does not seem warranted in this context, we agree with the proposal in concluding that the CSP regime, with or without CSCs will substantially improve both first and second order incentives for generation from all Snowy plant.

82 I.e. up to the point where its marginal cost equals the NSW price, ignoring any potential for it to exercise market power in the NSW market.

83 Swapping generation between Tumut and Murray again seems a viable self-contained strategy. Otherwise, increasing generation at Murray will help relieve the constraint most if this backs off generation in NSW, but will also assist somewhat if it backs off generation in Victoria, either of which is possible. Decreasing generation at Tumut will only help relieve the constraint is this brings on generation in Victoria, which is also possible.

4. PART B: IMPLEMENTATION ISSUES

4.1. CONTEXT FOR IMPLEMENTATION

Snowy Hydro's CSP/CSC proposal focuses on the *trans*-regional constraint that has the effect of separating its two major generators in Murray and Tumut. The current regional pricing mechanism without a proper compensation arrangement such as the CRA's CSP/CSC mechanism implies that if the constraint is binding in either direction Tumut generation ends up facing the "wrong" price and hence has a perverse incentive to increase/decrease generation from its efficient level.

The Snowy Proposal summarises the key issues as follows:

"*For the southerly flow scenario, when an intra-regional constraint binds between Tumut and Murray network nodes Tumut generation receives the higher Snowy price. This means that there is no commercial discipline on Tumut generation to offer efficient (cost reflective) prices since it would be guaranteed the higher Snowy price irrespective of output. Hence the commercial incentive is for Tumut to generate as heavily as possible and possibly drive counter-price flow back towards the NSW region.*

For the northerly flow scenario, when the intra-regional constraint between Murray and Tumut network nodes binds all Tumut generation is electrically in the NSW Region. However, under the current regional boundary definitions Tumut generation receives the Snowy price, which in this scenario is lower than that of NSW. Effectively, the Tumut generator while competing with NSW and Queensland generators for dispatch is penalised by receiving the lower Snowy price. As a consequence, the difference between the NSW Price and the Snowy Price multiplied by the Tumut output is paid into the Settlements Residue fund and distributed to the Snowy to NSW SRA units. This transfer in value from Tumut generation to the SRA Unit holders results in an incentive to make Tumut generation unavailable at precisely the time where there may be a tight supply demand in NSW. Most participants are aware that Tumut plant is energy constrained and thus must prevent constrained-on generation without adequate compensation. This perverse incentive may be further compounded by the pumping capability of Lower Tumut plant."

The Snowy Proposal asserts that an application of CSP/CSC regime will subject both sets of generators to the correct (nodal) price and therefore restore the desired commercial discipline. In particular, the Snowy Proposal states:

"*The CSP will have the following effect:*

1. *When one or more of a defined list of constraints bind, Tumut generators will be paid the Trading period shadow price at the network nodes; and*

2. *In all other periods Tumut Generators will receive or pay the Snowy Regional Reference Price adjusted for losses.*"

4.2. Implementation of the CRA Proposal

4.2.1. Relevant NEMDE Input/Outputs and Processing

Prior to the discussion on implementation issues, we reiterate some of the points raised in Part A, that will aid the subsequent discussion in this section, namely that:

1. There is a nomenclature issue with regard to the usage of CSP vs PNP – again, we will refer to CSP as the relevant generic constraint shadow price and PNP as the pseudo-nodal price calculated as RRN price, *less* the CSP times the relevant coefficient of the generator; and

2. The VIC-SNY interconnector is effectively ignored in the proposal and hence its impact on IRSS etc will also be ignored.

CRA's derivation of PNP as discussed in the CRA reports to the MCE dated June 2004 relies on a fairly simple transformation as described in Table 1. Let us consider a hypothetical example for a constraint form:

$$0.8*\text{Generator-1} - 2*\text{Generator-2} \geq 200$$

For any given NEMDE solution, the calculation of PNP requires three parameters:

1. Applicable regional reference node price, i.e., the RRN to which the constraint is oriented;

2. Shadow price (value and sign), or marginal value as these are referred to in NEMDE market clearing engine outputs, of the relevant generic constraint; and

3. Input coefficient (value and sign) of the participant in the generic constraint.

We understand that information (1)-(3) is available from NEMDE. The only exception is the sign of the shadow price, which we understand is not available in NEMDE. The basic LP theory provides standard rules that should enable deriving the sign for inequality constraints. However, the sign of the shadow price for equality constraints can go both ways and this poses a potential information gap issue[84].

[84] Our understanding, based on an examination of the currently applicable 52 Snowy related constraints suggest that they are all inequalities, so there should not be a problem in this case.

The other potential data gap issue arises if one wished to calculate the conventional nodal price (NP) as opposed to the pseudo-nodal price (PNP). As discussed earlier, the CRA proposal used PNP rather than NP. The procedure to calculate NP is fundamentally no different from that of PNP – the former will also require exactly the same transformation with the only exception being the relevant generation coefficients should *exclude* those that relate to non-NEO effects. In other words, the relevant generation coefficients should strictly be related to intra-regional flow limits because these are the only constraints that will appear in a conventional nodal dispatch model. Our understanding is that NEMMCO's constraint database *does* distinguish between constraint *types*, in terms of the power system phenomena that dictate the constraint on generation/flow. However, it is not entirely clear whether a clear distinction can be made between NEO and non-NEO effects or constraints, e.g., a voltage stability constraint may alternatively be expressed as a limit on generation, or on intra-regional flow limit, or some combination of both. The generator coefficient will vary depending on the representation adopted and it may or may not be possible in all cases to identify the component of the coefficient that may be attributed to a pure intra-regional thermal flow limits and the counterpart that is attributable to non-NEO effects.

Finally, there is a 5-minute vs 30-minute issue in calculating PNP – presumably, the RRP and generic constraint shadow prices will continue to be available on a 5-minute basis, but the settlement will be on a 30-minute basis. We have not undertaken any in-depth analysis of the implications of an averaging of 5-minute constraint shadow prices. However, we see no major technical problems with such averaging – there is obviously a potential inaccuracy issue in that *if* both generation and constraint shadow price and RRP were used in settlement on a 5-minute basis, the generator revenue etc may be different from the average of shadow prices multiplied by the average of half-hourly dispatch MW. Nevertheless, we do not have any particular reason to believe that such inaccuracies will be exacerbated significantly if averaging is applied to generic constraint shadow prices as well as to RRPs. Such averaging may not seem very accurate if a constraint only binds for some 5-minute intervals, or a different constraint form applies in different intervals[85]. But the impact of these constraints is already reflected in the regional reference prices, where it is also averaged. Since the CSP combines with the regional reference price to form a PNP for each node in each 5 minute interval, and since these effects are all linear[86], the effect of averaging is effectively similar to averaging 5 minute nodal prices, which may be considered an acceptable practice.[87]

85 We suggest that this be handled by determining the PNP, or nodal CSP adjustment, for each participant in 5 minute interval, then averaging these, rather than averaging coefficients and CSPs separately, then multiplying.

86 Given the above recommendation.

87 As discussed earlier, additional issues may arise with respect to choices which have to be made if PNPs must be capped to VoLL, at either the 5 or 30 minute level.

Fundamentally, we consider that, while greater accuracy may be possible, there is no point in pursuing accuracy with respect to CSP/CSC adjustments beyond that which has been deemed appropriate with respect to energy transactions, or FCAS. On that basis, the relevant information is all available:

- Prices from 5 minute NEMDE dispatch solutions; and
- Quantities from half hourly meter data.

4.2.2. Examples of PNP Calculation

Let us consider a hypothetical example for a constraint of the form:

$$0.8*\text{Generator-1} - 2*\text{Generator-2} \geq 200$$

Table 1 shows how, PNP for participant generators can be derived using RRN price and constraint coefficient/shadow price.

Table 1: Derivation of Pseudo Nodal Prices (PNP) – hypothetical example

Participant (*p*)	**RRN price (λ)**	**CSP or Shadow price of intra-regional constraint (π)**	**K (Coefficient of π)**	**PNP (Pseudo Nodal Price) ($=\lambda+K\pi$)**[88]
Generator 1	50	30	0.8	74
Generator 2			-2	-10
Generator 3			0	50

Let us consider a hypothetical example for a constraint of the form:

$$0.8*\text{Generator-1} - 2*\text{Generator-2} \geq 200$$

Table 1 shows how, PNP for participant generators can be derived using RRN price and constraint coefficient/shadow price.

Table 1 We have reproduced three examples in the Appendix B to this report that we had presented in our reports to MCE in June 2004. These examples may be helpful in developing insights on:

- How physical intra-regional flow constraints can be re-expressed in terms of generic constraints – see example B.1;

88 We have assumed a ≥ constraint and hence the CSP is +ve

- How constraints are oriented towards the reference node – again see example B.1;

- How correct PNPs may be derived even if the constraint is *not* oriented towards the reference node – see example B.3;

- How loop flows can be accounted for in such a transformation and the transformed constraint preserves the appropriate loop flow effect – see example B.1;

- What happens if the intra-regional constraint has an impact on an adjoining regional price – see example A.2; and finally

- What is the impact of a cut-set constraint that links two inter-regional flows – see example B.3;

The CRA report to the MCE also includes an analysis of historic generic constraints[89] that used 5-minute historic constraint shadow prices, RRP and constraint coefficients to calculate PNPs for all significant binding instances over Jan 1, 2003 – April 27, 2004.

4.3. Comparison with Snowy Proposal

It is not entirely clear, from the examples in the Snowy proposal, how the price derivation process, and related calculations, have been applied, or might apply in a more general context. But it seems that the prices referred to there have not actually been derived by a process similar to that described in Section 4.2.1, but by the alternative process implied by the wording of the proposed derogation[90]. As we understand it, that approach involves determining compensation payments based on the difference between a "derogated" and an "un-derogated" price, where:

- The "un-derogated" price appears to be the price which would apply under the status quo, thus roughly corresponding to the regional reference price (adjusted for losses) in our discussions; and

- The "derogated" price appears roughly correspond to the PNP in our discussions.

89 Charles River Associates, *NEM Regional Boundary: Modelling Report*, Section 3 titled "Analysis of historic generic constraint shadow prices', June 2004.

90 See part (g).

Thus the necessary CSP adjustment can be inferred by differencing these two prices, because the PNP is just the regional reference price plus the CSP adjustment. In principle, it seems that this differencing approach could work, and it does have certain advantages. In particular:

- Reference to the un-derogated price, rather than the regional reference price allows for processes such as loss adjustment and truncation to VOLL to be applied as appropriate;

- Explicit calculation of the PNP would allow heuristic process such as truncation to be applied to that composite price, too, if that is deemed to be appropriate; and

- It may be considered acceptable to work such processes through to determine half hourly prices, of both types, then work with differences between them.[91]

On the other hand, the CRA CSP/CSC approach seems simpler and more direct because:

- Appropriate adjustments can be made to the regional reference price under either approach;

- The CSP adjustments for all relevant constraints must be calculated in order to determine the PNP in the first place; and

- It is unclear how CSCs could be applied if adjustments are based on differencing aggregate prices in situations where several constraints, to which different CSCs apply, bind simultaneously.

Arguably, though, the implementation is not too difficult in either case, and the choice between these methods may finally rest on policy decisions as to whether PNPs are to be capped, on the one hand, or differing CSC allocations allowed to apply to different constraint groups, on the other.

Further consideration seems desirable, but if both features are required to be implemented, it may ultimately be necessary to implement aspects of both approaches, for different aspects of the calculation.[92] Under these circumstances consideration should also be given as to whether the wording of any derogation should be intended, or interpreted, as specifying the **process** to be followed, or the **outcome** to be achieved. We might suggest that the latter approach could allow a more focussed policy debate, always subject to the caveat that a process can be found to implement the desired outcomes.

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91 Although this is probably less accurate than determining adjustments for each 5 minute interval, then averaging, as proposed above.

92 For example in applying a direct CSP adjustment, a cumulative total could be kept, and the process truncated when the cumulative total implies a PNP in excess of VOLL.

4.4. ALTERNATIVE COMPUTATIONAL APPROACHES

NEMMCO has asked a number of questions in relation to possible variations on the computational approaches proposed by CRA and/or Snowy Hydro. Since conceptual aspects of some of those questions have already been addressed, here we restrict ourselves to addressing computational aspects.

b(i) What is the difference between PNP as used in Appendix B of CRA's report to jurisdictions, and the NP for a node?

b(ii) What are the implications of using the NP or PNP in the context of the Snowy Proposal?

We have already discussed the difference between NP and PNP in conceptual terms, and note that the NP does not need to be calculated under either the CRA or the Snowy Proposal. Computationally, NP could be calculated in a similar way to PNP. But, In order to calculate NP, one would need to know the component of each generator constraint coefficient that specifically applies to NEO effects. In practice, we suspect that this NEO component has not been identified separately for all constraint types. However, we are not sufficiently familiar with the details of the constraint derivation process to comment on the materiality of this issue.

b(iii) Is there a mechanical means of determining the NP and the PNP at a node other than the reference node, using only data that is available from central dispatch in the current NEM systems? What would be the specific process for determining NP and PNP for the Tumut node?

b(iv) If additional information would be required to determine a NP or PNP, what is that information, and what process would it be used in?

We have already discussed how both NP and PNP can be calculated using a simple adjustment of the RRP using the generic constraint shadow price and generator constraint coefficient. Calculation of NP should exclude the constraints or components of coefficients that pertain to non-NEO constraints. Calculation of PNP should only include those constraints which are explicitly included in the CSP regime. We have already noted two potential sources of information gap, neither of which seems material in this case:

- We understand that the sign of the NEMDE generic constraint shadow price is not stored. This implies if there is any equality generic constraints, we will not be able to calculate NP or PNP. However, the Snowy generic constraint set that we received from NEMMCO in December 2004, suggest that all of them are inequalities and hence this should not pose a material concern as far as the current constraint set is concerned; and

- If we wanted to calculate NP, we also need to know the component of the generator coefficient that specifically apply to NEO constraints. This may not be possible with respect to the current constraint set, simply because the information was not retained during the constraint derivation process. But, even if the relevant constraint set here did reflect some non-NEO effects, the issue is not material, because calculation of NP, as opposed to PNP, is not required.

b(v) Can the process described in the Snowy Proposal be implemented in another way that does not require the determination of NPs or PNPs – for example, by making use of regional reference prices and flow data as considered in previous papers from CRA?

Firstly, with respect to the relationship between the various CRA papers, the CSP/CSC concepts discussed in the previous CRA reports were based on the RRP, generic constraint shadow price, and generator coefficients in those constraints. Although *flows* will be related to the constraint shadow prices, and physical interpretations of the constraint pricing effects were drawn out for tutorial purposes, our derivations of NP and PNP do not use flows *per se* and rely only on the constraint shadow prices. We did not make a distinction between nodal price and pseudo-nodal price in our previous reports to NEMMCO because the distinction between NEO and non-NEO effects was not the focus there. However, the core CSP/CSC concepts discussed in the recent MCE report and all previous CRA reports are identical. And the NP derivation is only a minor variation on the PNP derivation, as explained above.

Secondly, with respect to the relationship between CRA's methodology and the Snowy Proposal the latter does not provide adequate level of details to make a complete connection between the CRA's CSP/CSC concepts and their specific implementation. But it seems clear that they propose to determine Settlements adjustments by utilising the difference between two price calculations. We suggest that a direct calculation of CSP/CSC payments using the CSP is preferable, from a computation perspective. As discussed above, we consider that this process can be used to deliver the same outcomes as the Snowy Proposal, and do not favour alternative methods, which may give correct results for simplified situations such as those considered in the Snowy Proposal examples, but can not readily be generalised. Still, some policy considerations remain, for example with respect to the desirability of truncating PNPs to VOLL, and these may imply a preference for an alternative methodology.

APPENDIX A: EXAMPLE OF RRP CHANGE EFFECTS

Figure 1: CSP/CSC Settlement

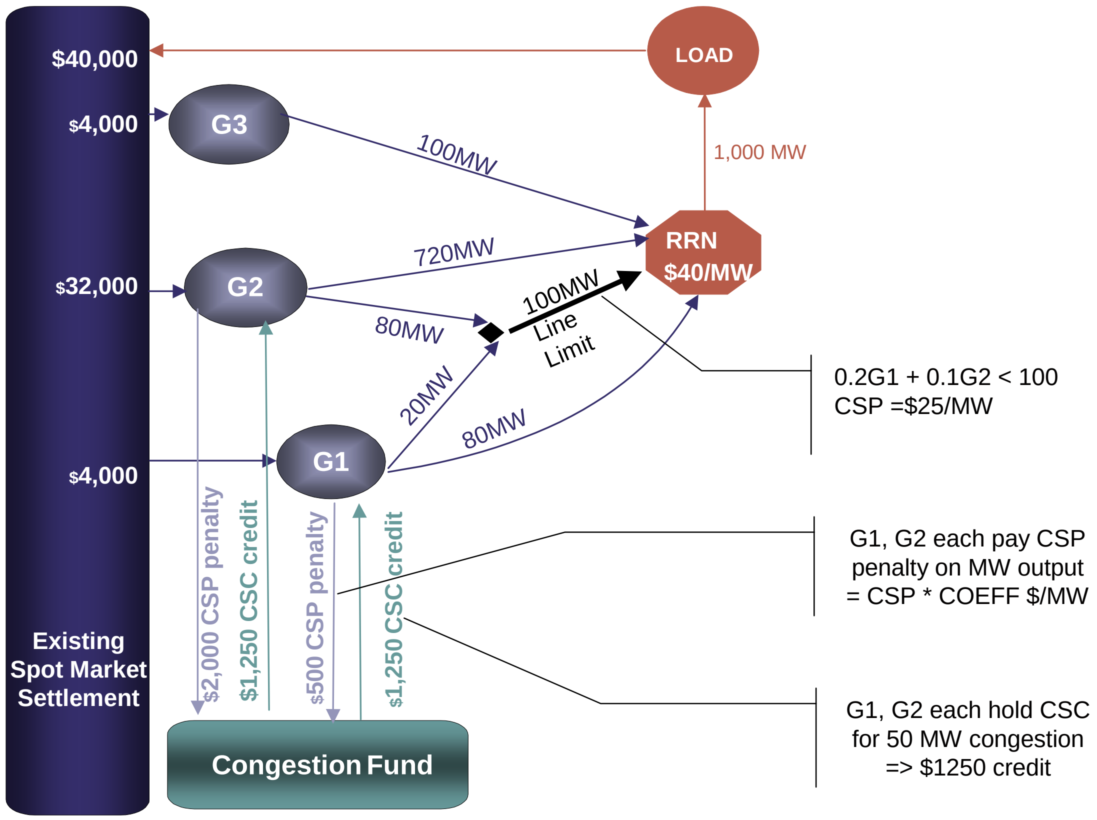


Figure 2: Scenario A with RRN shifted to G2

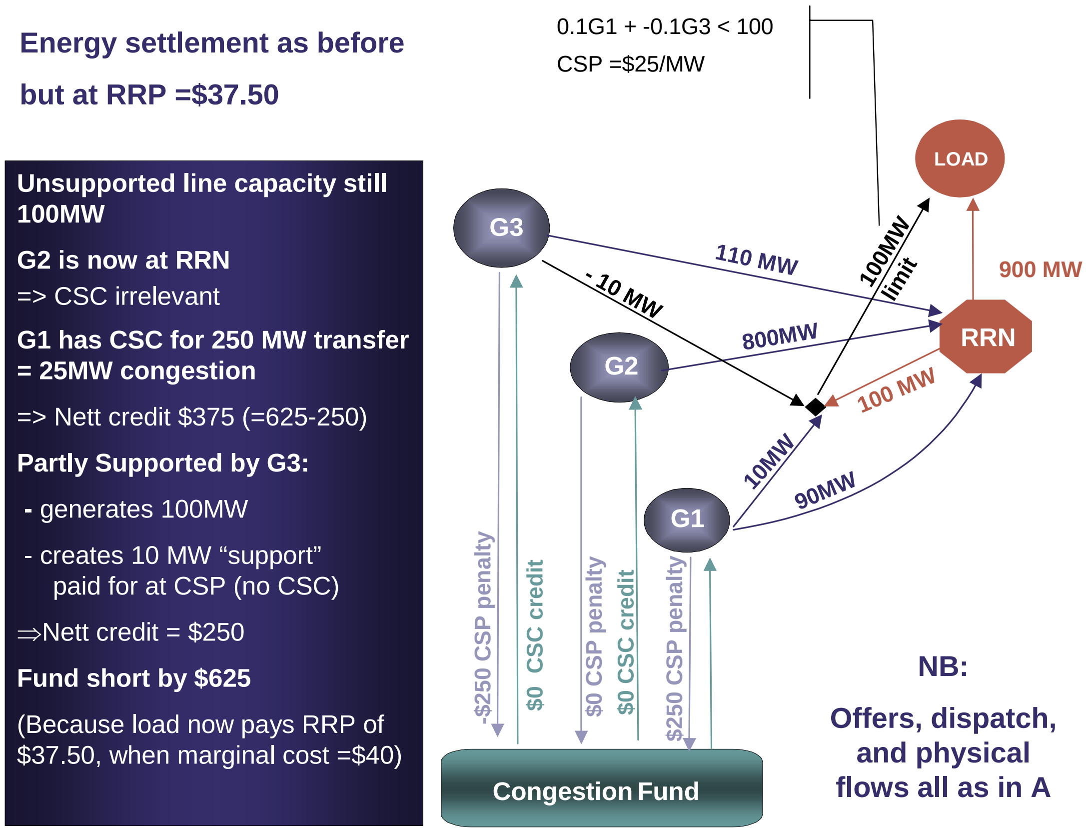
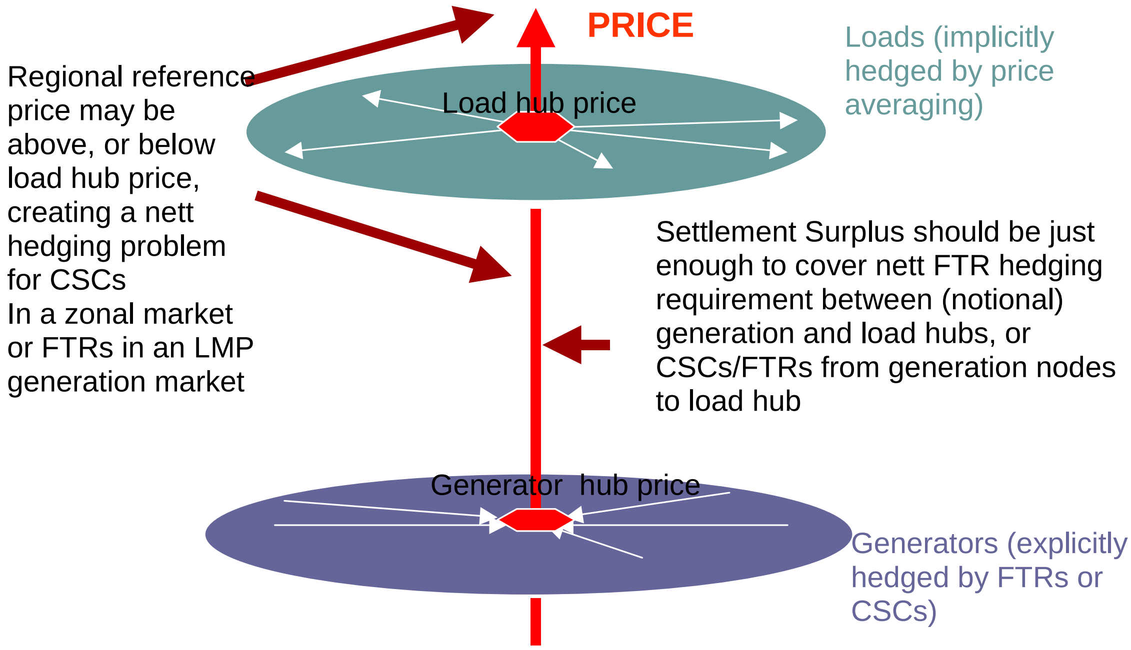


Figure 3: Hub Pricing and Hedging

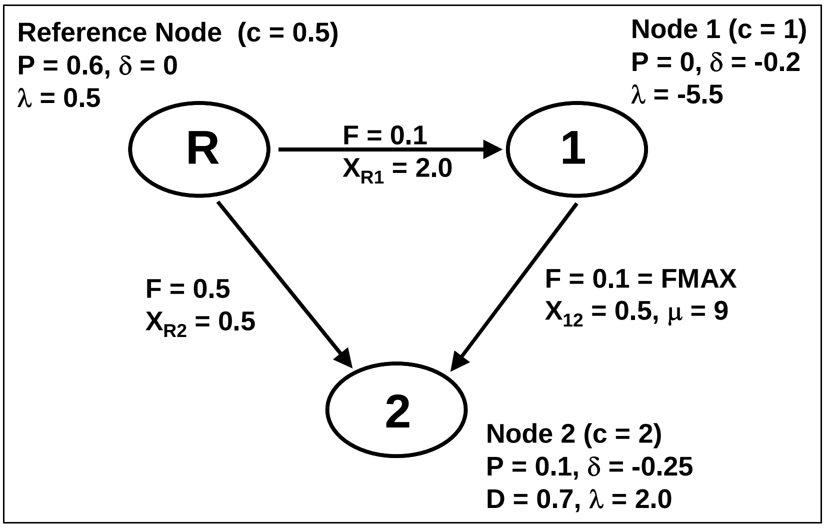


APPENDIX B: NODAL/ZONAL EQUIVALENCE: EXAMPLES[93]

B.1 WORKING OUT NODAL PRICE FOR A SINGLE REGION WITH 3 INTRA-REGIONAL NODES AND A BINDING INTRA-REGIONAL CONSTRAINT

We first demonstrate the simplest mathematical example[94] wherein the reference node is involved in a loop that comprises three intra-regional links including a constrained one. Figure 4 presents the generation dispatch (***P***:*Pr in reference node, P1 in node 1 and P2 in node 2*) and the associated flows (***F***) to meet a demand (***D***) of 0.7 at node 2, which will be the reference node.

Figure 4: Nodal model outcome: 3-bus System with Line 1 → 2 flowlimit = 0.1



Generation costs (***c***) for the generators at the three nodes are shown, and we assume there are no generation capacity constraints. Line reactances, X_{ij}, for the three lines are shown, and the flows have been calculated, using standard power flow techniques as being driven by "phase angles", via[95]:

$$F_{ij}=(\delta_i-\delta_j)/X_{ij}.$$

93 All the examples in this appendix are reproduced from CRA's report to MCE titled *NEM Regional Boundary: Theoretical Framework*, dated June 2004.

94 Wood and Wollenberg, 1995, 3 bus system for DC load flow, pp. 108.

95 See, for example, Wood and Wollenberg.

In order to eliminate the reference node from the flow calculation, we set the phase angle for this node (δ_2) to zero. The optimal dual variables (shadow prices) associated with this dispatch are also shown in Fig.2, namely the nodal prices (λ) corresponding to the demand constraint and congestion prices (μ) for the flow limit on link 1→2.

It is easy to show that the angle variables δ can be eliminated and the constrained flow (F_{12}) can be expressed in terms of the other two flows from the reference node as:

$$F_{12} = (F_{R2}.X_{R2} - F_{R1}.X_{R1})/\, X_{12}$$

We can further eliminate the flows from the reference node by substituting the net generation terms for them from the nodal balances to derive the following expression:

$$F_{12} = [(D_2\text{-}P_2)X_{R2} - (D_1\text{-}P_1)X_{R1}]/\,(X_{12} + X_{12} + X_{12}) \leq 0.1$$

Thus, we have now obtained an expression for the constrained flow that does not involve the reference node variables, as desired. The constraint in the present case is: 0.667P1 – 0.167P2 ≤ 0.1. The dispatch/pricing outcome is described in Figure 5.

Figure 5: Zonal model: All 3 generators in reference node and intra-regional constraint

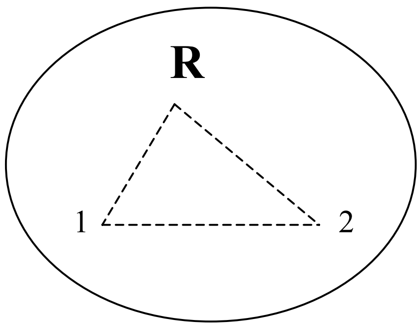
Single region with all 3 generators (c=0.5,1, and 2), Demand D=0.7, and intra-regional constraint:

-0.667P1 + 0.167P2 ≥ -0.1

Dispatch/pricing outcome:

P1=0.6,P3=0.1

λ=0.5 and shadow price of intra-regional constraint π = 9



Using dual analysis, we can demonstrate the underlying nodal prices can be derived as follows.

Table 2: Deriving Nodal Prices

Node	Zonal price (λ)	Shadow price of intra-regional constraint (π)	K (Coefficient of π)	Pseudo Nodal price (=λ+K π)
R	0.5	9	0	0.5
1			-0.667	-5.5[96]
2			+0.167	2.0

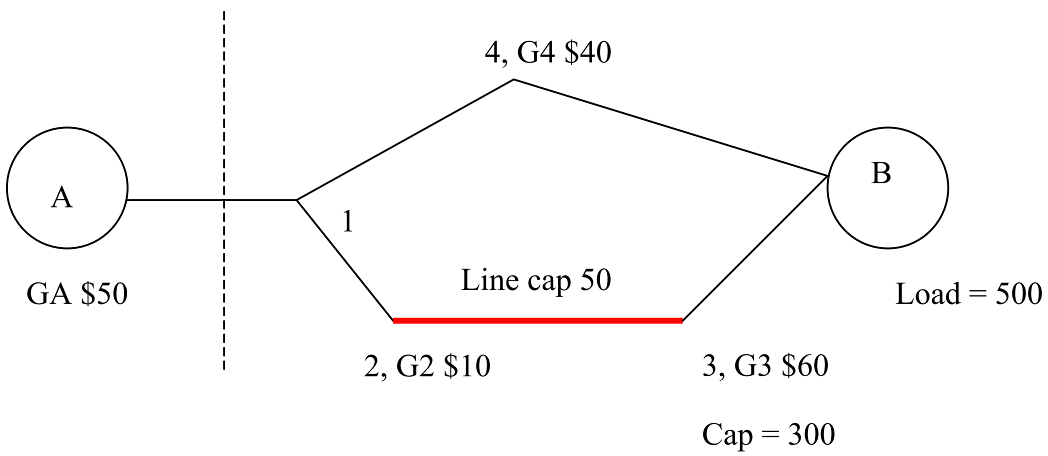
The derived nodal prices match the nodal model outcome shown in Figure 4.

B.2 Two Region Case with Load in the Reference Node of One Region

We construct a second case that is a bit more general in that:

- It has two regions;
- One of the regions has a loop that in fact affects the prices throughout the network including both regional reference node prices; and
- One of the reference nodes has a load and increasing the load has asymmetric impact on generation.

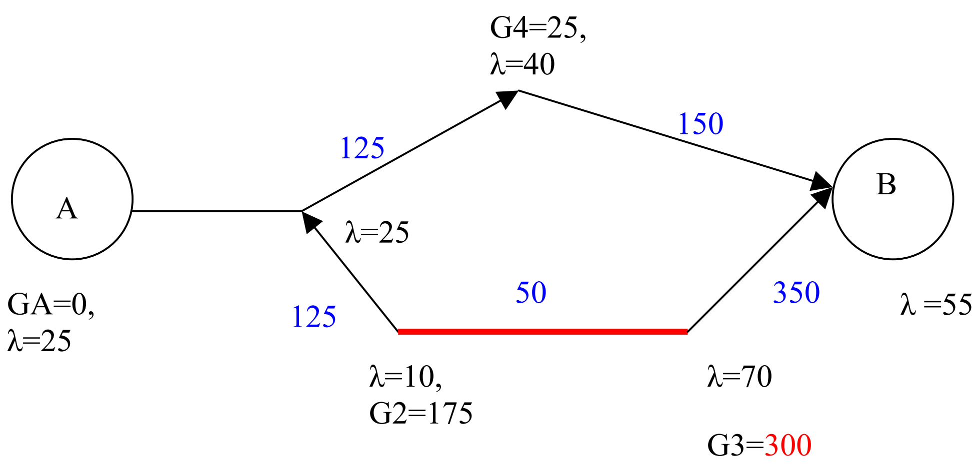
Figure 6: Two Region Case with Load in Reference Node in Region B



We assume all line reactances are 0.1 and line 2-3 has a limit (in both directions) of 50 MW (please note that we have not followed a per unit convention here).

96 Indicates strong loop flow effect that pushes the nodal price to negative i.e., an additional MW demand in node 1 would in fact reduce system cost by releasing cheaper generation from reference node.

Figure 7: Nodal Dispatch and Prices



Prices reflect a combination of binding generation limit, line flow limit and loop flow effects. In particular, reference node A price is also affected by the line flow limit and loop flow effect in region B. Also, reference node B price of $55 reflects the constrained line flow 2-3 in that every additional MW load in B is to be met by lowering G2 generation by 0.5 MW (i.e., a savings of $5) and increasing G4 generation by 1.5 MW (i.e., cost of 1.5*40=$60).

The nodal DC load flow constraints for region B nodes (reference node, angle=0) can be stated as:

$\delta_3 + \delta_4 = 50$	Ref node B
$-F_{A\rightarrow 1} + 20\,\delta_1 - 10\,\delta_2 - 10\,\delta_4 = 0$	Node 1
$-P_2 - 10\,\delta_1 + 20\,\delta_2 - 10\,\delta_3 = 0$	Node 2
$-P_3 - 10\,\delta_2 + 20\,\delta_3 = 0$	Node 3
$-P_4 - 10\,\delta_1 + 20\,\delta_4 = 0$	Node 4

We can also express the line capacity limit between nodes 2 and 3, as:

$(\delta_2 - \delta_3)/0.1 \leq 50$ Line flow limit of 50 MW

Since we have five equations that involve the four voltage angles, we can derive alternative expressions for the flow limit constraint. It is easy to show that depending upon the nodal equation that we do *not* use, the zonal model price will reflect the price for that node e.g., if we do not use equation for node 3, zonal price will reflect the nodal price for node 3 of \$70, etc. This is a round about way of restating the basic principle that since we are interested in preserving the regional reference node price, we must not use the nodal generation *and load* terms associated with the reference node B in which case we derive the following way to express the flow limit in the zonal model:

$-F_{A \rightarrow B} - 1.5\ P_2 + 0.5\ P_3 - 0.5\ P_4 \geq -125$ Line flow limit in zonal model

Table 3: Deriving Nodal Prices for Region B

Node	Zonal price (λ)	Shadow price of intra-regional constraint (π)	K (Coefficient of π)	Pseudo Nodal price (=λ+K π)
B	55	30	0	55
1			-1	25
2			-1.5	10
3			+0.5	70
4			-0.5	40

B.3 Three Region Case with Load in the Reference Node Of One Region and Cut-Set Constraint Linking Inter-Regional Flows

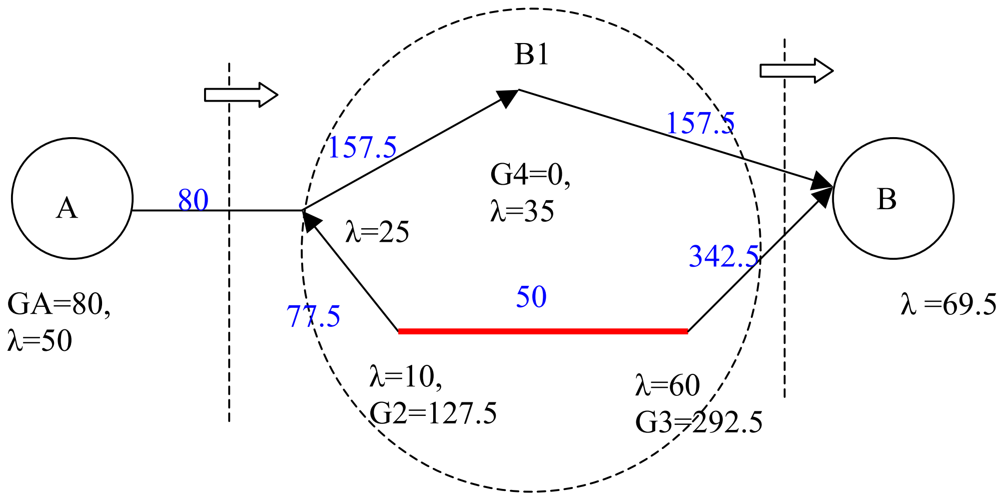
Finally, we demonstrate the equivalence of nodal and zonal prices for a case where inter-regional flows are linked. We have created an additional region B1 by isolating all the generators in region B which leaves the original zone B with a load alone.

We have also imposed a cut-set constraint as follows:

$-1.25\ F_{A \rightarrow B1} + F_{B1 \rightarrow B} \leq 400$

The nodal solution is presented in Figure 8.

Figure 8: Three Region Case with Load in Reference Node in Region B and Cut-Set Constraint Linking Flows From A→B1 And B1→B



The cut-set constraint has the impact of making flow from region A attractive in that it allows expanding the interconnection capacity into load region B – in fact, without any flow from region A, region B load of 500 cannot be met because the RHS limit is 400. It is therefore hardly surprising that generator GA produces 80 and flow A→B1 is also 80 to allow the interconnection B1→B to be expanded by 1.25*80=100. The additional generation of 80 displaces generation from all region B generators with the biggest impact being on G2

We have used the previous form of the intra-regional constraint which is oriented towards node B and hence includes the generation term for the new regional reference node B1:

$-F_{A\rightarrow 1} - 1.5\,P_2 + 0.5\,P_3 - 0.5\,P_4 \geq -125$ Line flow limit in zonal model

Although, the same physical dispatch results, as expected the regional reference node price for B1 will not match that of the nodal model, but it is worth noting that the shadow price adjustment would yield the correct price.

Table 4: Deriving Nodal Prices for Region B1

Node	Zonal price (λ)	Shadow price of intra-regional constraint (π)	K (Coefficient of π)	Pseudo Nodal price (=λ+K π)
B1	47.5	25		
1			-1	22.5
2			-1.5	10
3			+0.5	60
4			-0.5	**35**

Nevertheless, the desired procedure should be to restate the intra-regional constraint correctly oriented towards the new regional reference node for B1 (i.e., node 4 before) and eliminate the generation/load terms for the node as follows:

$F_{A \rightarrow B1} + 2\ P_2 - 2\ P_3 \leq -250$ Line flow limit in zonal model.