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10 February 2006

Dr John Tamblyn
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Australian Energy Market Commission
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Dear John

Rule Change – Management of Negative Settlement Residues in the Snowy Region

The Australian Energy Regulator (AER) welcomes the opportunity to comment on the proposed Rule change concerning the management of negative settlement residues in the Snowy region.

The AER has invited Dr. Darryl Biggar to analyse the proposed Rule change. Dr. Biggar has an excellent understanding of the issues surrounding the current proposal, given that he analysed these issues extensively during the Australian Competition and Consumer Commission's assessment of the CSP/CSC trial in the Snowy region.

Dr. Biggar's analysis of the proposed Rule change is attached. Dr. Biggar's paper indicates that the Rule Change proposal is an adequate "band aid" solution to the immediate problem of negative settlement residues in the Snowy region. However, Dr. Biggar suggests that a longer term solution to the broader problem of negative settlement residues across the National Electricity Market (NEM) is required. The AER endorses Dr. Biggar's analysis and supports the proposed Rule change. It also encourages the AEMC to consider the broader issue of management of negative settlement residues across the NEM.

The AER notes that there are a number of Rule Change proposals which impact on the treatment of constraints in and around the Snowy region. In addition to this current proposal, there are region boundary change proposals from both Snowy Hydro and Macquarie Generation, and a proposal from the Ministerial Council on Energy to reform the region boundary change process. The AER also notes that the upcoming Congestion Management Review will also consider related issues. The AER encourages the AEMC to consider the extent to which some (or all) of these processes can be combined. Such an approach would promote a more comprehensive consideration of issues with broad market impacts, such as the management of negative settlements residues, than the alternative of considering each of these processes separately.

We look forward to discussing this response with you and participating in the subsequent stages of the review.

Yours sincerely

Steve Edwell
Chairman

MANAGEMENT OF NEGATIVE SETTLEMENT RESIDUES IN THE SNOWY REGION:

COMMENTS ON THE PROPOSAL BY LYMMCO AND OTHER GENERATORS

9 February 2006

1. This note sets out my comments on the proposal by a group of generators to amend the current arrangements for managing negative settlement residues arising in the vicinity of the Snowy region.

2. The issue of how best to handle negative settlement residues has been around for some time. NEMMCO issued a consultation paper on this topic in May 2005.[1] I prepared a paper in response to that consultation which is directly relevant to the issues being considered by the AEMC. I have revised the paper slightly and am attaching that paper for your consideration.

3. The basic issue is as follows: NEMMCO, as the market/system operator, can be thought of as purchasing electricity from generators and selling electricity to consumers (electricity distributors and retailers). When there are constraints on the national transmission network, there arise differences in the prices charged for electricity in different regions. On average, NEMMCO purchases in low price regions and sells in high-price regions. This gives rise to a "trading surplus" for NEMMCO. Access to this trading surplus is useful to market participants as a device for hedging the risk of trading across different pricing regions, so the total surplus is divided up by NEMMCO into separate financial streams which are then sold by NEMMCO back to the market participants.

4. At present, the total trading surplus is divided up into streams known as "inter-regional settlement residues" which are linked with each notional interconnector. The inter-regional settlement residue for a given interconnector between two regions at a given point in time is equal to the price difference between those regions times the flow on the notional interconnector between those regions at that point in time.

5. This approach to dividing-up the total trading surplus works well as long as there are no intra-regional transmission constraints and as long as the overall transmission network is "linear" (that is, there are no loops between regions).

6. Unfortunately, neither of these assumptions holds for the NEM. On the one hand, there are a few significant intra-regional transmission constraints; on the other, there exists at least one loop between regions (and more such loops may arise in the future if the number of regions increases or new transmission links are constructed).

7. The problem of intra-regional transmission constraints is well-known. The AEMC is currently involved in reviewing both the grounds for changing region boundaries and the scope for congestion management arrangements within regions. I will not comment further on these issues here.

8. Actions to improve the handling of intra-regional constraints, such as improvements in locational pricing (through changes to region boundaries or congestion management procedures) may help reduce the incidence of negative settlement residues but it will not

[1] NEMMCO, "Management of Negative Residues on the VIC-Snowy and Snowy to NSW Directional Interconnectors".

solve the problem. The problem of negative settlement residues would remain (and indeed, would worsen) if the NEM moved towards much finer geographic differentiation of prices. The reason, as noted above, is that negative inter-regional settlement residues will arise even under fully efficient nodal dispatch, when there are loops in the transmission network.

9. A problem of just this kind has arisen around the Snowy region of the NEM. At present, power from Victoria can flow to NSW either via the Snowy region or via an alternative path through Wagga Wagga. The presence of this alternative path gives rise to loop flow around the Snowy region. When the transmission lines between Murray and Tumut bind, this loop flow gives rise to negative settlement residues on the VIC-Snowy interconnector. This is explained further in the attached paper.

10. As I have emphasised above, negative settlement residues arising from loop flows between regions are not the consequence of any market flaw or inefficiency. However, under the current arrangements in the NEM, there is no mechanism for funding negative residues – either by NEMMCO or by market participants. As a result, NEMMCO is forced to take action to curb these negative residues when they arise. They do this by either limiting the flows on the interconnector, or by "re-orienting the constraint equations" to eliminate the price difference between the neighbouring regions. These interventions by NEMMCO have several undesirable consequences:[2]

(a) First, importantly, either intervention by NEMMCO reduces the efficiency of the market, by requiring higher-cost generation to produce when lower cost generation is physically available – thereby lowering the overall economic benefit of the market. Over time, the distorted price signals will have an impact on investment decisions, reducing the efficiency of investment.

(b) Second, and equally importantly, the current policy of limiting VIC exports has the consequence of reducing the value of the inter-regional settlement residues as a hedging instrument, thereby limiting the scope for inter-regional trade.

(c) Third, in the case of northwards flows, Snowy Hydro benefits (sometimes significantly) by NEMMCO's intervention. Therefore Snowy Hydro has an incentive to shift production from Tumut to Murray to encourage the Murray-Tumut constraint to bind, in order to induce NEMMCO to intervene. In other words, Snowy has an inefficient incentive to encourage, rather than alleviate, transmission constraints.

(d) Fourth, less importantly, when NEMMCO intervenes to limit exports, prices in Snowy tend to be extremely volatile – changing by a large amount in response to small changes in flows.[3]

11. The problem is not that there are not enough "residues" overall. It is easy to show that under efficient dispatch the overall trading surplus must be non-negative – therefore, it must always be the case that the positive residues on some interconnectors are sufficient to outweigh the losses on other interconnectors. The problem, rather, is in the allocation of these residues to the "inter-regional settlement residues" as they are currently defined.

[2] It is worth noting that Snowy Hydro (which is otherwise an opponent of this proposal) agrees that the current approaches to dealing with loop flows in the Snowy region have undesirable outcomes. In their draft submission they note that "Snowy Hydro believes that all current options to deal with loop flows in the Snowy region (interconnector truncation, re-orientation to Dederang) are unsatisfactory".

[3] For example, in the case of 2 February 2006 (described more fully in Appendix 1), the Snowy price which had been around $25 earlier in the day, dropped to zero at 1:00 pm and remained at zero until 2:30 pm, at which point it jumped up to $7440. It then dropped back to zero at 2:50 pm, returned to $7440 at 2:55 pm, dropped to zero at 3:45 pm, returned to above $6000 for the next 15 minutes, before dropping to under $100 for the rest of the day.

12. Put another way, the underlying problem with negative settlement residues is not a problem in the "real" or physical market, but primarily a problem with defining financial flows. This suggests that a better response to the problem of negative settlement residues is not to distort the real or physical market but merely to change the definition of the financial flows.

13. One such approach is the current proposal by the group of generators – to simply use the positive settlement residues on one interconnector to offset the negative settlement residues on the other interconnector. This approach is simple and practical and it requires minimal adjustment to the current market rules. The proposal eliminates negative residues, thereby eliminating the need for NEMMCO to intervene, with the undesirable consequences noted above. Specifically, the proposal would improve the efficiency of dispatch and would significantly improve the usefulness of inter-regional settlement residues as a hedging device.

14. In the context of a market with no intra-regional constraints and adequate generator competition in each region/node, it seems clear that this proposal effectively solve the problem of negative settlement residues in the vicinity of the Snowy region. Therefore, it seems to me that the key questions for the AEMC relate to the extent to which the NEM, in the Snowy region, departs from that theoretical ideal. Specifically, the key questions seem to be:

(a) In the context of the Snowy region where there is a significant intra-regional transmission constraint and a CSP/CSC mechanism to address some of the effects of that constraint, whether or not there will in fact be adequate settlement residues overall to offset negative settlement residues when they arise, and:

(b) The impact of the proposal on the incentives of Snowy and the efficiency of the resulting market outcomes.

15. In regard to the first question, in the second appendix to this note, I seek to demonstrate that, in a general model of the network in the Snowy region, there will always be sufficient revenues on the "other" interconnector to offset the negative settlement residues – provided the existing CSC/CSP mechanism in the Snowy region remains in place.

16. We can derive some further comfort in this result by actual examining the market outcomes on days when the Murray Tumut constraint was binding. In the second appendix to this note I show that on a recent day with significant negative settlement residues and a prolonged NEMMCO intervention, there were sufficient positive residues to offset negative settlement residues on the VIC-Snowy interconnector in the period when NEMMCO had not intervened in the market. Furthermore I show how NEMMCO's intervention significantly reduced the usefulness of inter-regional settlement residues as a hedging device.[4]

17. In regard to the second question, the primary issue relates to the impact of the proposal on the incentives on Snowy Hydro. Since Snowy Hydro owns generation facilities at each end of the Murray-Tumut constraint, it has a great deal of control over when that constraint is binding. For example, when the Murray-Tumut constraint is threatening to bind in the northerly direction, Snowy can (in principle) reduce the flows on the Murray-Tumut lines by simply reducing output at Murray and increasing output at Tumut. It can do this whether or not it has market power at either Murray or Tumut.

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[4] In principle it would be straightforward to carry out a straightforward "what-if" analysis by re-running the dispatch engine for all the dispatch intervals on 2 February with the NEMMCO intervention constraints removed. This would allow us to verify the impact of the intervention on the magnitude and "firmness" of the settlement residues .

18. We saw above that, under the present arrangements for handling negative settlement residues, Snowy Hydro has (in the case of northerly flows) an incentive to induce a constraint on the Murray-Tumut line so as to induce NEMMCO to intervene to limit VIC exports. It can do this by operating Murray at capacity, while reducing Tumut output to a minimum. If this proposal is implemented it seems likely that this incentive will be reversed – specifically, Snowy Hydro will have an incentive to limit the occasions when the Murray-Tumut constraint binds in the northerly direction. It can do this by reducing output at Murray (and possibly increasing output at Tumut). As long as the marginal value of water at Murray and Tumut is the same, shifting output between these plants has no impact on overall welfare. If doing so limits the occasions when the Murray-Tumut constraint binds, there is an overall improvement in dispatch efficiency. In other words, this preliminary analysis suggests that the proposal will improve the incentives on Snowy Hydro.

19. Snowy Hydro have, in their response to this proposal, raised several issues. These issues merit some further comment here:

(a) Snowy Hydro has argued for a change to the region boundaries in the Snowy region. This change would, amongst other things, place the Tumut generators in the NSW region. Snowy Hydro argues that if this proposal were adopted, the Murray-Tumut constraint would not bind and therefore this problem of negative settlement residues would not arise.

I have not yet given full consideration to the Snowy Hydro proposal. Snowy Hydro's assessment may be correct. Indeed, some of the other rule changes under consideration may also affect the frequency or magnitude of negative settlement residues.[5]

It seems to me that the key question for the AEMC is whether or not consideration of these two proposals can be or should be separated. Should a possible future decision on the Snowy proposal affect the decision of the AEMC on this issue of negative settlement residues? I suggest the answer is not necessarily. If the Snowy proposal is adopted and Snowy is correct in its assessment, then the Murray-Tumut constraint will not bind, so any action taken by the AEMC at this stage will have no impact. Conversely, if the Snowy proposal is not adopted, then action taken by the AEMC to improve the handling of negative settlement residues will be valuable for the market. Since, the AEMC action will either be harmless or valuable, it seems to me that it is worthwhile to continue to consider the issue of negative settlement residues. It seems to me that these two proposals can be (and probably should be) considered separately.

(b) Snowy Hydro also argue that the proposal will not increase the total flows into NSW. The impact of the proposal on flows into NSW is rather complex. The total flow into NSW depends on the total output of all Snowy, VIC and SA generation. If there are constraints on the interconnector from Snowy to NSW then, clearly no additional power can flow from the southern regions, so the claim is true in this case.

Let's focus on the case where there are no constraints (or no constraints which threaten to bind) north of Tumut. In this case, since the Tumut price is (under the CSC/CSP scheme) based primarily on the NSW price, Tumut output depends primarily on the NSW price. Let's assume that the proposal has a strictly limited impact on the NSW price, so that we can ignore the impact of the proposal on Tumut generation.

[5] This raises the much bigger issue of the appropriate process for the AEMC to handle a number of closely inter-related rule changes.

In this case the impact of the proposal on total flows into NSW depends on the impact on VIC/SA and Murray generation. Generation at both VIC and Murray has an impact on the Murray-Tumut constraint, but Murray generation affects the constraint more. If we reduce output in VIC by 1 MW we can increase output at Murray by around 0.75 MW without changing the Murray-Tumut flow. But this reduces the total flow into NSW by 0.25 MW. In other words, when the Murray-Tumut constraint is at or near its limit, an increase in Murray generation (accompanied by an offsetting drop in VIC generation so as to keep the Murray-Tumut flow constant) reduces the total flow into NSW. The impact of this proposal on the total flow into NSW therefore depends on the impact of the proposal on Murray generation.

Under the current arrangements (in the case of northerly flows) Snowy has a strong incentive to ensure that Murray is dispatched to a high level, in order to bind the Murray-Tumut constraint and to induce NEMMCO to respond by backing off VIC generation. Under the proposal, Snowy would likely have an incentive to reduce its output at Murray in order to ensure the Murray-Tumut constraint does not bind. On this basis, it seems clear that the proposal would likely increase the total flow into NSW.

(c) Snowy Hydro also argue in their draft submission that the proposal "will introduce blatant and transparent market inefficiencies". The argument seems to be that "Snowy Hydro will be actively … incentivised to withhold generation on Murray … and generate on its gas/oil fired plant located in Victoria". I do not see how this argument could be correct. It is true that Snowy Hydro will have an incentive to ensure that the Murray-Tumut constraint will not bind. However, generation at both Murray and Victoria contributes to the Murray-Tumut constraint. Snowy Hydro can reduce the Murray-Tumut flow by reducing output at either or both its Murray and Victoria generators. If it is currently producing from a high-marginal-cost generator in Victoria it makes sense for Snowy to reduce the output of that generator before reducing the output at Murray. I do not see that it would ever make sense for Snowy Hydro to reduce output at Murray and simultaneously increase output at its high-marginal-cost generators in Victoria. Therefore I do not see how the proposal will introduce blatant market inefficiencies.

20. In summary, the analysis in this note suggests that the proposed approach is an effective solution to the current problem in the context of the Snowy region in which there is a single intra-regional constraint and two interconnectors. The proposal will likely disadvantage Snowy Hydro on average. However, the proposal will likely improve the overall efficiency of the market.

21. My primary concern with this proposal is that it cannot easily be generalised to a more complex situation with more constraints or interconnectors. This point is recognised in the proposal itself. The proposal states that "this proposal is made … as a specific response to an acute problem … We expect that over time a more general measure may replace this specific one". [6]

[6] The proposal goes on: "[T]he proposal presented here relates to an interconnector itself and the physical network configuration it comprises. If the number of regions were increased, then the number of interconnectors would increase, and consequently the risk that an interconnector will include a loop will also increase. The incidence of interconnectors with looped network may also increase as the network is augmented. Thus the proposal presented here in relation to a specific instance may need to be generalised and extended as either the number of regions increases, or as the network is augmented". Page 6 of the proposal of the group of generators.

22. In my view, it is best to consider the proposal as an “interim” solution to a longstanding problem in the NEM. As new regions are established and new interconnectors are constructed, it is inevitable that loop-flow issues will become more severe in the NEM. I suggest it is timely to consider an approach which is resolves the issue of negative settlement residues for the long-term.

23. In the paper attached to this note I propose an alternative approach to dividing up the settlement residues, based not on interconnectors but on constraints. The resulting “constraint-based residues” are both useful for hedging and are always positive (negative residues are not possible). Importantly, this approach is also backwards-compatible with the existing settlement residues. This approach can be considered as a natural evolution or extension of the existing arrangements. I encourage the AEMC to consider this approach as a longer-term solution to the problem of negative settlement residues.

Darryl Biggar

Appendix 1: What would have been the outcome of the proposed approach in practice?

24. We can obtain some idea of the adequacy of the total settlement residues to offset negative settlement residues by exploring market outcomes on days with significant negative residues and a significant NEMMCO intervention.

Northerly flows: 2 February 2006

25. Consider the market outcomes on 2 February 2006. On this day, from around 7 am in the morning, the flow on the Murray-Tumut lines, increased rapidly, due largely to a large increase in output at Murray (rising to its maximum of 1350 MW by 8:45 am). The Murray-Tumut constraint first started binding around 11 am. At this point the NSW price stayed at $100, but the VIC price dropped to around $35, and the Snowy price dropped even further (for reasons related to loop-flow around the Snowy region, as explained in the attached paper), to around $23. Flows on the VIC-Snowy interconnector were weakly in the northerly direction, so inevitably negative settlement residues started accumulating on the VIC-Snowy interconnector.

26. Initially NEMMCO did not respond to these negative settlement residues as they were not large (and, apparently, NEMMCO were concerned about the reliability implications of limiting VIC exports). However, around 1 pm the NSW price jumped to $7450, while the Snowy price fell to zero. At the same time VIC exports were increasing and negative settlement residues started accumulating rapidly. NEMMCO issued a market notice at 2:15 pm stating that they would intervene to manage negative settlement residues by limiting VIC exports. This intervention continued to have an impact until 5:30 pm.

27. The events on this day are useful for our purposes because around 40 dispatch intervals (i.e., around 200 minutes) elapsed between the time when negative residues emerged on the VIC-Snowy interconnector and the time when NEMMCO intervened. Exploring the outcomes in these intervals should give us some insight into the likely outcomes under the proposed approach (which would involve merely a change in the settlement residues, with no requirement for NEMMCO to intervene).

28. It is straightforward to calculate the settlement residues for each dispatch interval. I find that the total settlement residues (the sum of the settlement residues on the VIC-Snowy and Snowy-NSW interconnectors) remained positive during this interval, even after subtracting the payment to Snowy Hydro required under the CSC/CSP scheme. The total settlement residues (after CSC/CSP payments) do not start dropping until after NEMMCO starts intervening around 2:15 pm. Therefore, there were always enough positive residues on the Snowy-NSW interconnector to offset negative residues on the VIC-Snowy interconnector.

29. In addition, we can obtain a measure of the "firmness" of the total settlement residues (that is, a measure of the usefulness of the settlement residues as a hedging device) by dividing the total settlement residues by the NSW-VIC price difference. If the settlement residues were fully firm the settlement residues divided by the price difference would be constant. As can be seen in the next graph, the settlement residues divided by the price difference remain roughly constant until around 2:15 pm when NEMMCO intervenes, and remains highly variable until around 5:30 pm when NEMMCO's intervention ceases to bind.

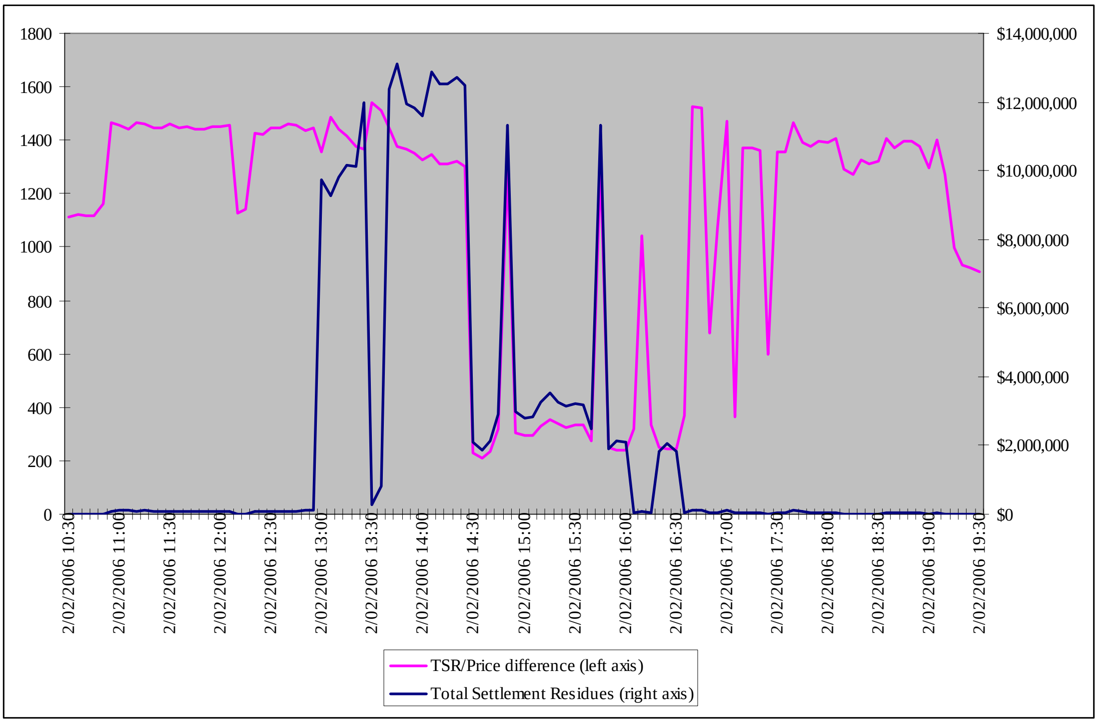
30. In summary, on this day in the period when NEMMCO was not intervening, the settlement residues on Snowy-NSW were more than sufficient to offset negative residues on

VIC-Snowy, and the settlement residues were significantly firmer than during the period when NEMMCO intervened.

In principle, it would be straightforward to carry out a "what-if" analysis to explore what the market outcomes would have been on this day (under the assumption that bidding behaviour of generators did not change[7]) in the event that NEMMCO had not intervened in the market. This could be achieved by re-running the dispatch engine with the NEMMCO intervention constraints removed. I have not yet carried out this analysis.

[7] This assumption is obviously important. In practice we would expect the implementation of the proposal to change Snowy Hydro's incentives.

Figure 1: Settlement Residues (post CSC/CSP payments) and Settlement Residues by Price Difference 2 Feb 2006



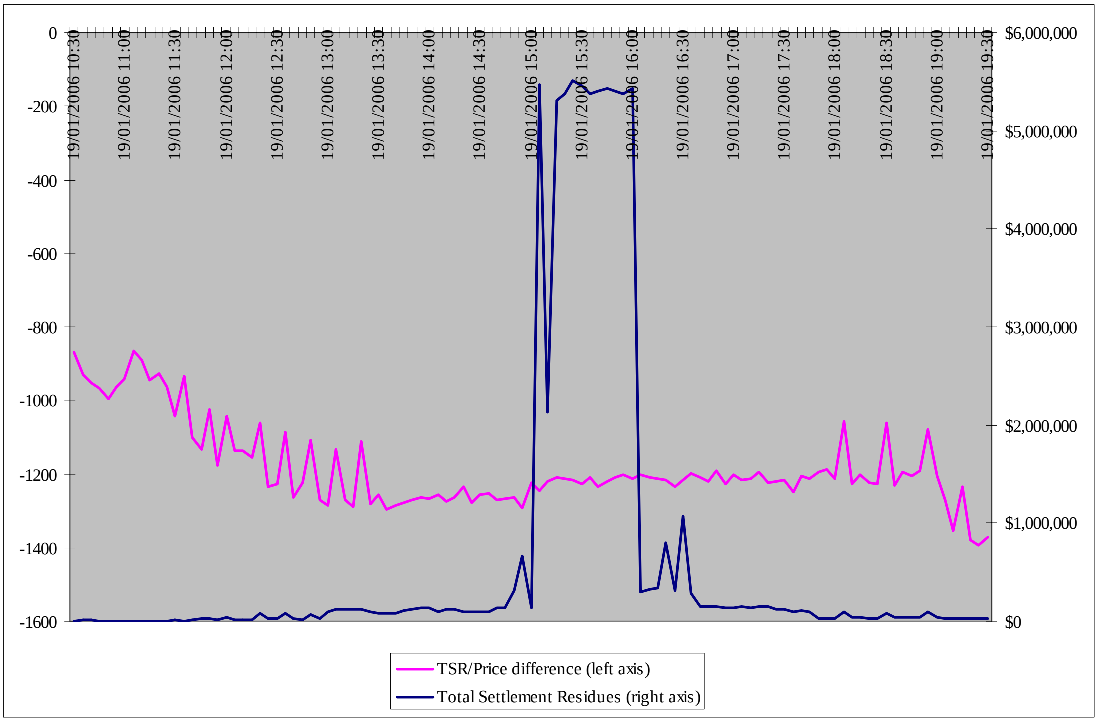
Southerly flows: 19 January 2006

31. It is also valuable to explore the adequacy of settlement residues on a day of southerly flows on the Murray-Tumut lines. On 19 January 2006 high demand in VIC-SA caused strong southerly flows. From 1:15 pm the Murray-Tumut constraint was binding, inducing NEMMCO to invoke its negative settlements management procedures from around 1:40 pm, remaining in place until 6 pm.

32. Despite the negative settlement residues on VIC-Snowy (and, in fact, strongly negative residues on Snowy-NSW at the same time), the total payments into the settlement residue funds after taking account of CSC/CSP payments is positive and remains positive throughout this period.

33. In addition, as can be seen in the following graph, the “firmness” of the total settlement residues (after CSC/CSP payments) also remains high, as seen by the fact that the total settlement residues divided by the NSW-VIC price difference remains high during this period.

Figure 2: Settlement Residues (post CSC/CSP payments) and Settlement Residues by Price Difference 19 January 2006



Appendix 2: Are there always sufficient residues available to offset negative residues elsewhere?

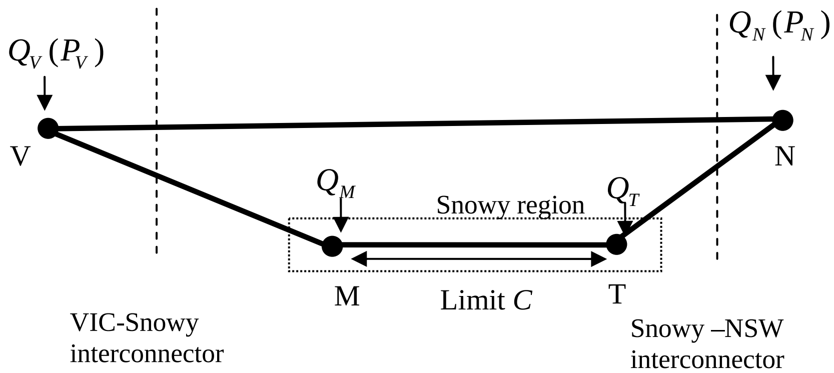
34. As described above, the proposal of the group of generators is a change in the definition of settlement residues on either side of the Snowy region in order to prevent negative settlement residues arising which, under present arrangements, forces NEMMCO to take inefficient and undesirable intervention to limit the negative residues.

35. A primary question we must address, therefore, is whether or not adequate revenues are earned on the other interconnector to offset the negative residues on the Vic-Snowy or Snowy-NSW interconnector. Put another way, we need only establish that the total settlement residues on both the Vic-Snowy and Snowy-NSW interconnectors are positive (as long as the total is positive then, obviously, it is possible to compensate any negative residues on any individual interconnector with the positive residues on the other interconnector).

36. As mentioned above, the total settlement residues are always positive in the case of fully-efficient nodal dispatch. However, as I demonstrate in the attached paper, this doesn't always hold in the context of the NEM when there are intra-regional constraints. In the context of the Snowy region this is important because the negative settlement residues arise precisely at the time of binding intra-regional constraints.

37. However, a CSC/CSP mechanism has been implemented to correct the mis-pricing at the Tumut node that arises at the time of binding Murray-Tumut constraints. This CSC/CSP mechanism also involves payments to and from the settlement residues. Specifically, under the CSC/CSP mechanism, payments are made out of the Snowy-NSW settlement residue in the case of binding northerly flows and payments are made into the Snowy-NSW settlement residue in the case of binding southerly flows. The question for us, therefore, is whether or not, *in the presence of this CSC/CSP scheme*, there are positive residues overall (for both directions of flow).

38. I will demonstrate this result in the context of a general network with four nodes as illustrated below. The four nodes are VIC, Murray, Tumut, and NSW. There are three regions: VIC, Snowy, and NSW. Murray is assumed to be the regional reference node for the Snowy region. There is a link, giving rise to a loop-flow, between VIC and NSW:



39. I will assume that there is only one possible constraint in this network – the constraint between the Murray and Tumut nodes. The net injection of power (i.e., generation less consumption) at each node is Q_V, Q_M, Q_T and Q_N at the VIC, Murray, Tumut and NSW nodes respectively. Since the total amount of power injected must equal zero (also known as the energy balance equation) we have that:

$$Q_V + Q_M + Q_T + Q_N = 0$$

40. There are two notional interconnectors in this network. The flow on the VIC-Snowy interconnector is defined to be the sum of the flow on the two lines involved – the flow on the line between VIC and NSW and between VIC and Murray. The settlement residue on the VIC-Snowy interconnector is equal to the price difference between Snowy and VIC times the flow on the interconnector. This is just equal to the price difference times the net export of the VIC region. In other words:

$$SR_{VM} = (P_M - P_V)Q_V \text{ and}$$
$$SR_{MN} = (P_M - P_N)Q_N$$

41. If we had full nodal pricing in this network the total "trading surplus" (which is called the merchandising surplus) would be defined as:[8]

$$MS = -P_V Q_V - P_M Q_M - P_T Q_T - P_N Q_N$$

42. The total settlement residue in this network (ignoring the effect of the CSP/CSC mechanism) can now be written as:

$$\begin{aligned} TSR = SR_{VM} + SR_{MN} &= -P_V Q_V + P_M Q_V + P_M Q_N - P_N Q_N \\ &= -P_V Q_V - P_M Q_M - P_M Q_T - P_N Q_N \\ &= (-P_V Q_V - P_M Q_M - P_T Q_T - P_N Q_N) + Q_T (P_T - P_M) \\ &= MS + Q_T (P_T - P_M) \end{aligned}$$

Adequacy of settlement residues in the case of northerly flows

43. The next step is to work out the implications of the mechanism set out in part 8 of chapter 8A of the National Electricity Rules. From clause (n), in the case of northerly flows, an amount EVA is defined to be equal to the difference between the CSP and the regional reference price times the output of Tumut generation. In other words, $EVA = Q_T (P_T - P_M)$.

44. In the case of northerly flows, the amount paid to Snowy Hydro is equal to: $\min(EVA, SR_{MN})$. From the equation above, $SR_{MN} = MS + EVA - SR_{VM}$. Since the merchandising surplus is always positive, in the case of negative settlement residues on the VIC-Snowy interconnector, $MS - SR_{VM}$ is always positive. Hence the residues on the Snowy-NSW interconnector must always be larger than EVA, so the amount paid to Snowy Hydro is just equal to EVA.

45. In other words, in the case of northerly flows, the impact of the CSC/CSP mechanism is to subtract an amount equal to $EVA = Q_T (P_T - P_M)$ from the settlement residues. Since we know from the above analysis that $TSR = MS + Q_T (P_T - P_M)$, the remaining settlement residues are then just equal to the merchandising surplus which we have seen is always

[8] The concept of the merchandising surplus and some key results related to this concept can be found in Wu, Varaiya, Spiller and Oren, "Folk Theorems on Transmission Access: Proofs and Counterexamples", *Journal of Regulatory Economics*, 10:5-23 (1996).

positive. The settlement residues on Snowy-NSW are therefore sufficient to offset negative settlement residues on VIC-Snowy.

Adequacy of settlement residues in the case of southerly flows

46. The case of southerly flows is more difficult. Demonstrating the adequacy of settlement residues in this case requires specific facts about the market.

47. In the case of southerly flows (and southerly flows on Snowy-NSW), the mechanism in part 8 of chapter 8A of the Rules defines two payments to Snowy Hydro. The first payment to Snowy Hydro is, as before, $EVA = Q_T(P_T - P_M)$. The second payment to Snowy Hydro is equal to $(SR_{MN} - EVA) \times \beta$. Here β is called the "CSC allocation factor" and is equal to 550/1350. These two payments correspond roughly to the CSP and the CSC part of the CSP/CSC mechanism.

48. Taking the second payment first, we know from the analysis above that $SR_{MN} - EVA = MS - SR_{VM}$. Therefore, the total remaining settlement residues after the payments to Snowy Hydro are:

$$\begin{aligned} TSR &= MS + Q_T(P_T - P_M) - EVA - (SR_{MN} - EVA_S) \times \beta \\ &= MS - \beta(MS - SR_{VM}) \\ &= (1-\beta)MS + \beta SR_{VM} \end{aligned}$$

49. Now, one of the results of transmission pricing theory[9] is that when there is a single constraint the merchandising surplus is equal to $MS = \lambda K$ where λ is a positive constant, and *K* is the flow limit on the constrained link.

50. Another result of transmission pricing theory is that if additional generation at node *M* increases the flow on the constrained link by 0.9 and if additional generation at node *V* increases the flow on the constrained link by 0.7 then the price difference between *M* and *V* is $P_M - P_V = (0.9 - 0.7)\lambda = 0.2\lambda$ [10]. Hence $SR_{VM} = Q_M(P_M - P_V) = 0.2\lambda Q_M$. So the total settlement residues after payments to Snowy are: $TSR = (1-\beta)\lambda K + \beta 0.2\lambda Q_M$.

51. This is positive as long as VIC imports are less than $\frac{(1-\beta)K}{0.2\beta}$. Taking $K = 1350$ and $\beta = \frac{550}{1350}$ we find that there are sufficient residues in total provided that VIC imports are less than 9818 MW. Since this number is larger than the capacity of the VIC-Snowy interconnector we can conclude that even in the case of southerly flows, there are sufficient residues on one interconnector to offset the negative residues on the other.

Does this proposal imply that any positive residues can be used to offset negative residues?

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[9] See, for example, chapter 2, section 2-2.5 of my draft book, *Economic Analysis of Power Systems*.

[10] Obviously we could choose different parameters here and find a different coefficient – however as is clear below even for a coefficient as large as 0.5 the result still holds.

52. What about the concern that this proposal will set a precedent that positive settlement residues on one interconnector could be used to offset negative settlement residues on another, potentially unrelated interconnector – such as the use of positive settlement residues on QNI to offset negative settlement residues on Vic-SA?

53. In a market with efficient locational pricing (i.e., no intra-regional transmission constraints), the total settlement residue must always be positive. This means that if there are negative settlement residues on one interconnector, there must arise positive residues on at least one other interconnector. In the proposal considered above, the settlement residues on the Snowy-NSW interconnector are used to offset negative residues on the VIC-Snowy interconnector – but not because the other interconnector happens to be close by or because it is convenient, but because it is possible to demonstrate that, at times of binding Murray-Tumut constraint, the "deficit" on the VIC-Snowy interconnector is precisely matched by an "excess" on the Snowy-NSW interconnector.

54. In other words, the decision to use the positive residues on one interconnector to offset the negative residues on the other is not an arbitrary choice but the result of analysis which shows that the Snowy-NSW interconnector is "benefiting" precisely at the expense of the VIC-Snowy interconnector.

55. Should a problem of negative settlement residues arise on some other interconnector (such as Vic-SA), it follows that there must be corresponding "excess" residues on at least one other interconnector.[11] The choice of interconnector to offset the negative residues in this case would not be arbitrary but would be the result of analysis which showed where those excess residues were accumulating. It is theoretically possible that (in a sufficiently meshed network) negative residues on VIC-SA could lead to excess residues on QNI but this seems unlikely (if not impossible) under the current network arrangement.

56. Of course, the negative residues on one interconnector could be linked with excess residues on many other interconnectors. As I have argued elsewhere, it makes more sense to move to a long-term solution of the form of the "constraint-based residues" discussed in the attached paper.

[11] Recall that I am discussing here a market with no intra-regional congestion. The result still remains true in the case of a market with intra-regional congestion but in this case the "excess" residues accrues to one or more generators – it is therefore likely to be difficult to recover this revenue in order to compensate the negative settlement residues.

MANAGING NEGATIVE SETTLEMENT RESIDUES ON THE VIC-SNOWY INTERCONNECTOR

Darryl Biggar[1]

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1. At present, due to the presence of a "loop-flow" in the network in and around the Snowy region, binding constraints on the transmission line from Murray to Tumut give rise to negative settlement residues on the Vic-Snowy interconnector. For reasons which are discussed below, when negative settlement residues arise, NEMMCO is forced to intervene in the market[2]. In the event of northerly flows, NEMMCO intervenes by reducing Vic-Snowy interconnector flows. In the event of southerly flows, NEMMCO intervenes by merging the VIC and Snowy regions.

2. But why are negative settlement residues a problem? Do they signal an inefficiency in dispatch which necessitates intervention by NEMMCO? If not, how should they be handled? The key messages of this paper are as follows:

- The negative settlement residues that arise on the VIC-Snowy interconnector as a result of a constraint on the Murray-Tumut line will arise even in fully efficient dispatch. They are not the result of a mis-match between pricing and dispatch at any node.

- In this circumstance, any intervention by NEMMCO to control these negative settlement residues which affects dispatch in the market will reduce the efficiency of dispatch. In particular, the current and proposed interventions – limiting VIC-Snowy flow and merging the VIC and Snowy regions, will reduce the efficiency of dispatch.

- The current arrangements in the NEM for handling settlement residues are not sustainable going forward. As the NEM evolves, with increasing numbers of regions and increasing interconnection between regions, the presence of loop-flow will become increasingly likely. The current arrangements for handling settlement residues do not efficiently handle loop-flow (as occurs in the Snowy region) and lead to arbitrary and ad hoc intervention by NEMMCO, of the kind discussed in this consultation.

- This paper proposes an evolution of the current arrangements for handling settlement residues. This evolution is away from the current "inter-regional" settlement residues, towards "constraint-based" settlement residues. This approach is an extension of the current arrangements, allows loop-flows to be handled correctly, and retains the value of settlement residues as a tool for hedging trading across different pricing nodes. This approach could be easily implemented in the Snowy region and would allow the current inefficient practices for managing negative settlement residues to be eliminated.

[1] Dr Darryl Biggar is an independent economic consultant associated with the ACCC. The views expressed in this paper are not necessarily those of the ACCC, the Commissioners, or ACCC staff.
[2] The procedures NEMMCO follows in the event that such intervention is necessary are set out in section 6 of NEMMCO Dispatch Procedure SO_OP3705.

Introduction

3. The issue of negative settlement residues is inherently complex, touching on many aspects of the design of the NEM. Before proceeding to look in detail at issues arising on the VIC-Snowy interconnector, it is valuable to return to first principles, to review why negative settlement residues arise, why they are a problem, and the link between negative settlement residues and the design of the market.

4. As is well known, in the current NEM, a separate price is determined for each of six regions, joined by notional interconnectors. NEMMCO, as the system operator, in effect purchases electricity from generators located in different regions and sells that electricity back to users or consumers in the same or different regions. This process of buying and selling electricity generates a net surplus (or deficit) for NEMMCO which is sometimes called the "merchandising surplus"[3].

5. NEMMCO does not keep this surplus (or deficit). Instead, under the current arrangements, the merchandising surplus is divided up into streams of payments known as "inter-regional settlement residues". Inter-regional settlement residues are defined between each of the neighbouring regions of the NEM (where there is notional interconnector between the two regions). Ignoring losses, the settlement residues are a stream of payments equal to the price difference between the two regions multiplied by the flow on the notional interconnector between those regions in each dispatch interval.[4]

6. Access to the stream of payments equal to the inter-regional settlement residues is valuable to market participants as a hedging device – primarily to hedge inter-regional trading. In order to make this stream of payments available to market participants for hedging purposes, the right to receive a share of these inter-regional settlement residues is auctioned. The proceeds from these auctions are returned to TNSPs to reduce TUOS charges.

7. The current approach to dividing up the merchandising surplus into different payment streams is, of course, not the only possible approach. In fact, as we will see, the current approach is unsatisfactory and unsustainable in the presence of loop flows. There are many other ways of dividing up the merchandising surplus into separate payment streams.

8. One of the results of the theory of transmission pricing is that when two conditions are satisfied (namely: (a) when there are no binding intra-regional constraints and (b) the regions are arranged in a "linear" manner – i.e., no "loop flow" between separately-priced nodes), the flow on an interconnector between two neighbouring regions is always in the direction of the price difference (in the direction from the low price region to the high price region). In other words, under these conditions, we can divide the merchandising surplus into separate streams of payments known as inter-regional settlement residues and we can be sure that each one of these streams of payments will always be positive.

9. Now suppose that we retain the assumption of no binding intra-regional constraints, but relax the assumption of no loop-flows between regions. In this case, there can be negative inter-regional settlement residues but, still, the sum of all the settlement residues – that is, the total merchandising surplus – must be positive. It is this case, the appearance of negative

[3] This term comes from the economics literature on transmission pricing. We might also call it the "total settlement residues". The merchandising surplus is equal to the sum, for each pricing region or node of the price in that region or node times the net withdrawal (load less generation) in that region or node.

[4] Actually, in practice, a separate residue fund is established for flows in each direction on an interconnector. Therefore, although there are five notional interconnectors, there are ten inter-regional settlement residue funds.

settlement residues is not a sign of any need to intervene in the market – rather, *the appearance of negative settlement residues in such a market is merely a sign that the approach to dividing the merchandising surplus into separate payment streams is inappropriate*. In this case the appropriate policy response to the appearance of negative settlement residues merely amounts to "shifting funds around" from one stream of payments to another – no change to dispatch is necessary nor desirable.

10. Finally, in a network with binding intra-regional constraints, negative settlement residues can arise purely as a result of the mis-match between pricing and dispatch at an individual node. In this case, correcting that mis-pricing will eliminate the negative settlement residues. This argument highlights the close connection (technically: "complementarity") between policy action to improve the locational marginal pricing signals on generators, on the one hand, and action to improve the definition of settlement residues on the other. Once action has been taken to improve the pricing signals to generators, action on settlement residues amounts to simply improving the division of a flow of funds – there is no need to take any action to change dispatch in the market.[5]

Managing Settlement Residues on the VIC-Snowy interconnector

11. Let's turn now to focus on the question of negative settlement residues (as those residues are currently defined) on the VIC-Snowy interconnector, which arise when there is a constraint on the Murray-Tumut line.

12. The first observation to make is that the negative settlement residues on the VIC-Snowy interconnector do not arise as a result of any mis-pricing of an intra-regional constraint (or any strategic behaviour on the part of any party). They arise entirely as a consequence of the loop-flows that occur in this part of the network.

13. Under current market arrangements, there is a theoretical[6] mis-pricing at the Tumut node (since Murray and Tumut are both located within the same region). However, that mis-pricing does not cause, nor does it have much impact on the negative settlement residues on the VIC-Snowy interconnector. Action to improve the price signals at Tumut will have little or no effect on the existence of negative settlement residues on the VIC-Snowy interconnector. In particular the recent implementation of a CSP/CSC scheme at the Tumut node has no effect on the existence of negative settlement residues on the VIC-Snowy interconnector. The negative settlement residues on the VIC-Snowy interconnector arise solely as a consequence of the "loop-flow' structure of the network in and around the Snowy region.

14. In order to illustrate the arguments throughout this paper, I will use a simplified form of the network in the Snowy region. In particular, I will here assume that the Tumut node is in the NSW region. In other words, the Murray-Tumut constraint becomes an inter-regional constraint in this network. In effect, I am assuming that the mis-pricing at the Tumut node has been corrected (perhaps by a CSP/CSC). This assumption is not essential for the conclusions that follow – these conclusions still apply whether or not the CSP/CSC mechanism (or some other mechanism such as a regional boundary change) is adopted to improving pricing at the Tumut node.

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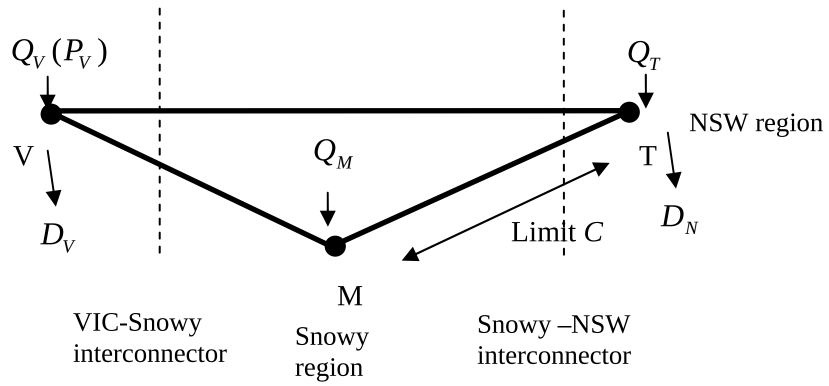
[5] This is, in part, why NEMMCO is undertaking this consultation on managing negative settlement residues in the Snowy region at the current time, when active consideration is being given to a proposal to improve the price signals faced by Snowy generation through a CSP/CSC mechanism.

[6] In practice this mis-pricing may not have a significant impact on dispatch as long as Snowy Hydro acquires sufficient Snowy-NSW inter-regional settlement residues. This issue is discussed later.

15. The diagram of the network is set out below. There are only three nodes – the VIC node (in the VIC region), the Murray node (in the Snowy region), and the Tumut node (in the NSW region). As in the previous paper, I will ignore losses and inter-regional constraints. As before, in this model the only binding constraint is the Murray-Tumut constraint. In addition, I will assume that the electrical characteristics of all the transmission links are identical (this assumption is not important for the conclusions but allows for easier arithmetic).



16. The key equations for this network are as follows: The energy balance equation:

$$Q_V(P_V) - D_V + Q_M + Q_T(P_N) - D_N = 0$$

17. The flow on the Murray-Tumut constraint is:

$$F_{MT} = \tfrac{1}{3}(Q_V - D_V) + \tfrac{2}{3}Q_M$$

18. The theory of optimal dispatch shows that when there is a constraint on the Murray-Tumut line, the prices in this network must bear the following relationship to each other:

$$P_V = \tfrac{1}{2}P_M + \tfrac{1}{2}P_N$$

19. In this simple network the flow on the (notional) VIC-Snowy interconnector is defined to be the sum of the flow on the VIC-Murray line and the VIC-Tumut line, which is unsurprisingly equal to the net export of the VIC region:

$$F_{VM} + F_{VT} = Q_V - D_V$$

20. Similarly, the flow on the (notional) Snowy-NSW interconnector is defined to be the sum of the flow on the Murray-Tumut line and the VIC-Tumut line:

$$F_{MT} + F_{VT} = Q_V - D_V + Q_M$$

21. The inter-regional settlement residues on the VIC-Snowy interconnector are defined as the flow on the VIC-Snowy interconnector times the price difference between Murray and VIC. In other words:

$$SR_{VS} = (F_{VM} + F_{VT})(P_M - P_V) = (Q_V - D_V)(P_M - P_V)$$

22. Similarly, the inter-regional settlement residues on the Snowy-NSW interconnector are equal to:

$$SR_{SN} = (F_{MT} + F_{VT})(P_N - P_M) = (Q_V - D_V + Q_M)(P_N - P_M)$$

23. Using these equations we can re-write the settlement residues on the VIC-Snowy interconnector as follows: $SR_{VS} = -(Q_V - D_V)(P_N - P_V)$. In other words, negative settlement residues will arise when:

(a) VIC-Snowy interconnector flow is northerly and the NSW price is higher than the VIC price; or

(b) VIC-Snowy interconnector flow is southerly and the NSW price is lower than the VIC price.

24. In other words, negative inter-regional settlement residues are an inevitable consequence in this market whenever the Murray-Tumut constraint binds.

25. It is worth emphasising, at the risk of repetition, that the negative settlement residues on the VIC-Snowy interconnector in this model (as is the case on the VIC-Snowy interconnector in reality) are not a consequence of any mis-pricing of intra-regional constraints. Rather, these settlement residues are the inevitable consequence of the presence of loop-flow between the VIC, Snowy and NSW regions.[7]

26. This observation has implications for how we should deal with these negative settlement residues. In particular, if the dispatch is efficient without any settlement residue-management procedures, then we should take care to ensure that the settlement residue-management procedures do not distort dispatch in any way.

27. This is, of course, not the approach taken in practice. In practice, the current NEMMCO procedures for handling the negative settlement residues will induce a distortion in dispatch – as will the proposal put up for consultation by NEMMCO.

Approaches to handling negative settlement residues which distort dispatch

28. Let's look first at those approaches for handling negative settlement residues which induce a distortion in dispatch. In the next section we will look at those approaches for handling negative settlement residues which do not affect dispatch – but which involve different approaches to "dividing up" the merchandising surplus into separate payment streams.

29. In this section, let's suppose that the system operator does not have the option of reallocating the merchandising surplus. Instead, let's suppose that the division of the merchandising surplus into the settlement residues is fixed. Specifically the total merchandising surplus is divided into two streams equal to $SR_{VS} = (Q_V - D_V)(P_M - P_V)$ and $SR_{SN} = (Q_V - D_V + Q_M)(P_N - P_M)$.[8]

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[7] Mis-pricing of the Tumut node could, under some circumstances, cause negative settlement residues on the Snowy-NSW interconnector but I will not discuss that case here.

[8] It is worthwhile going through the mathematical exercise to prove that these two payment streams do, in fact, sum to the merchandising surplus. The merchandising surplus is defined as being equal to $MS = -P_V(Q_V - D_V) - P_M Q_M - P_N(Q_T - D_N)$. The sum of the two inter-regional settlement

30. Under the market design principles set out earlier, all of these payment streams must be positive. If we do not change the definition of the settlement residues, what are the options for reducing the negative inter-regional settlement residues on the VIC-Snowy interconnector? The equation for the settlement residues is equal to the price-difference between the regions times the interconnector flows. Therefore controlling the negative settlement residues comes down to either eliminating the price differences or controlling the flows.

31. Both of these approaches are used at present. Under current market arrangements, in the case of northerly flows, NEMMCO limits VIC exports to the point where either the constraint no longer binds, or VIC exports are close to zero (so that the settlement residues are also close to zero). In the case of southerly flows, NEMMCO eliminates the price differences through a policy known as "re-orientation of the constraint equations". In effect NEMMCO effectively merges the VIC and Snowy regions, eliminating any price difference and therefore eliminating the negative settlement residues.

The problems with limiting VIC exports

32. Let's focus first on the case where NEMMCO controls the flow by limiting the VIC exports. We know that, since the dispatch is efficient without NEMMCO intervention, any action by NEMMCO to reduce VIC exports must reduce the efficiency of dispatch – specifically, higher cost generation is turned on to meet a constraint when lower cost generation is available which could meet the constraint more cheaply. This is shown through a worked example in the following box.

Reducing VIC exports to control settlement residues reduces dispatch efficiency

Let's suppose that before any NEMMCO intervention we have the following market outcome. The price at the NSW node is \$200. The flow is in the northerly direction and the Murray-Tumut constraint is binding. The price at the Murray node is \$20. Given the equations set out above, the price at the VIC node must be \$110. Let's assume that we have a competitive market so that, at each node, the marginal cost of the last MW generated is equal to the price at each node.

Now let's suppose that NEMMCO intervenes to limit the exports out of VIC. Specifically, let's consider a change in dispatch which reduces the output of VIC by one MW and simultaneously increases the output at Murray and Tumut by one half MW. This change in dispatch satisfies $\Delta F_{MT} = \frac{1}{3}\Delta Q_V + \frac{2}{3}\Delta Q_M = 0$, so the flow on the Murray-Tumut line is unchanged and $\Delta Q_V + \Delta Q_M + \Delta Q_T = 0$ so the energy balance equation is satisfied.

Let's suppose that the output at VIC is backed off to the point where the marginal cost of the last MW generated is now \$100 (at the same time, let's assume that the marginal cost of generation at Murray and Tumut is unchanged). The change in the total cost of dispatch for an additional reduction in VIC output is then: $-MC_V + \frac{1}{2}MC_M + \frac{1}{2}MC_T = -100 + \frac{1}{2}\times 20 + \frac{1}{2}\times 200 = \$10$ - in other words, this reduction in output has raised total dispatch cost – so the reduction in output is inefficient.

33. Given that NEMMCO chooses to limit VIC exports, there are several possible market outcomes. The first possible outcome is that NEMMCO reduces the flow to close to zero, and

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residues are: $SR_{VS} + SR_{SN} = (Q_V - D_V)(P_M - P_V) + (Q_V - D_V + Q_M)(P_N - P_M)$ which is equal to $-P_V(Q_V - D_V) - P_M Q_M + (Q_V - D_V + Q_M)P_N = MS$ as required.

the Murray-Tumut constraint still binds. In this case, settlement residues are zero and NEMMCO need take no further action to reduce negative settlement residues. The Murray price remains below the VIC price.

34. The second possible market outcome is for NEMMCO to reduce the flow sufficiently so that the Murray-Tumut constraint no longer binds. In this case the Murray price increases to equal the Tumut price. Note that this yields an inefficient price signal at the Murray node. Since Murray output contributes to worsening the constraint, the efficient price at Murray is lower than the price at Tumut in the case of northerly flows (and lower even than the price at VIC). Murray generation will respond to this price signal by increasing its output – requiring NEMMCO to further reduce output at the VIC node.

35. This process can continue (with Murray increasing its output and VIC generation forced to back-off) until the VIC exports are reduced to zero, at which point we return to the first case above – where NEMMCO can allow the constraint to continue to bind without fear of negative settlement residues. In effect (in the absence of other complicating factors such as hedging/SRA positions), Murray generation is incentivised to increase its output to a point where VIC-SN interconnector flows are reduced to a small (but not zero) level, so as ensure that NEMMCO must relieve the constraint if it is to eliminate the negative settlement residues.

36. At the point where the constraint is very close to binding the Murray price will be very sensitive to small changes in the interconnector limits. As long as the Murray-Tumut constraint is binding, the price at Murray must be below the VIC price and may be very low. A small reduction in VIC-Snowy flows would then unbind the interconnector and allow the Murray and Tumut prices to increase to the NSW price which must be above the VIC price and could be significantly higher.

37. NEMMCO recognise this extreme sensitivity of prices to the interconnector flows in their consultation paper:

> "If Tumut and Murray offer prices differ considerably, for example from \$800 to \$0.04 the NEMDE co-optimisation can cause the Snowy price to swing from somewhere around \$800 to \$0.04 from dispatch interval to interval, producing a movement between large negative residues to extensive positive residues if the constrained flow is marginally outside of where it should be from dispatch interval to interval".[9]

38. An example of this effect in the simple network above is set out in the box below:

Murray price is very sensitive to NEMMCO action near the point where the constraint binds

Taking the figures in the box above, let's suppose that before any NEMMCO intervention the price at the NSW node is \$200. The flow is in the northerly direction and the Murray-Tumut constraint is binding. The price at the Murray node is \$20. Given the equations set out above, the price at the VIC node must be \$110.

Now let's suppose that NEMMCO intervenes to limit the exports out of VIC. Specifically, let's suppose that when VIC exports are limited to 101MW the constraint remains binding, but when VIC exports are limited to 100 MW the constraint is no longer binding. If VIC exports are limited to 101 MW, the prices at VIC might be say, \$80, the price at Murray might be \$50 (and the price at Tumut remains unchanged at \$200, say). Under these assumptions the settlement residues on the VIC-Snowy interconnector are 101 MW times (\$50-\$80)= -\$3030 per hour.

[9] NEMMCO, "Management of Negative Residues on Vic-Snowy and Snowy to NSW Directional Interconnectors", 6 April 2005, page 10.

Now suppose the VIC exports are reduced a little more to 100 MW. In this case the VIC price might drop to, say, $79, and, since the constraint is relieved, the Murray price will rise to the Tumut price ($200). The settlement residues are now 100 MW times ($200-$79)=$12100 per hour.

If NEMMCO deem that the these are "significant positive inter-regional settlement accumulations", they will be led to relax the constraint back to 101 MW, leading to negative settlement residues, and repeating the cycle.

39. Since the Murray price is extremely sensitive to small changes in the interconnector flows in the vicinity of the region where the constraint is almost binding, the objective of NEMMCO becomes particularly important. If NEMMCO's objective is to simply eliminate the negative settlement residues, it could simply lower the interconnector flows to the point where the Murray-Tumut constraint is no longer binding or likely to bind. At this point the VIC-Snowy settlement residues would be positive (and potentially very large).

40. However, the current settlement residue management procedures state that "periodic adjustment of the level of the constraint might be necessary … [when] significant positive inter-regional settlements accumulations indicate the current level of the constraint is excessive"[10]. Therefore, if there is a significant price difference between Tumut and VIC relaxing the constraint in this way may lead to very substantial positive settlement residues which (by the above clause) would trigger further "adjustment" by NEMMCO. Even a small relaxation of the constraint at this point could lead to large negative settlement residues again.

41. NEMMCO might seek to ensure that, on average, the settlement residues remain close to zero over the course of some period – such as a trading interval, hour or day. To achieve this NEMMCO would have to allow the constraint to bind over some part of the period (thereby accumulating negative settlement residue) and to relax the constraint over some part of the remainder of the period (thereby accumulating positive settlement residue). In effect the actions of NEMMCO in this case are to ensure that the average Murray price over the period is the same as the average VIC price. This could introduce significant Murray price volatility.

42. The following table summarises the possible market outcomes under this approach:

Market Outcome	Constraint and Prices	Efficiency Consequences
(1) Interconnector flows reduced to zero	Murray-Tumut constraint still binds; Murray price lower than VIC price;	Inefficiently low prices at the VIC node; and (slightly) inefficiently high prices at the Murray node;
(2) Interconnector flows reduced to the point where the Murray-Tumut constraint no longer binds	Murray-Tumut constraint relieved; Murray price equal to Tumut price; Potentially large positive settlement residues.	Inefficiently low prices at the VIC node; and (significantly) inefficiently high prices at the Murray node;
(3) Interconnector flows reduced to a point where there are on the edge of binding and adjusted so that the settlement residues are zero on average	Murray-Tumut constraint could be binding or relieved in any given interval; settlement residues could be large positive or negative in any given interval; potential for large Murray price volatility;	Both the above effects could arise

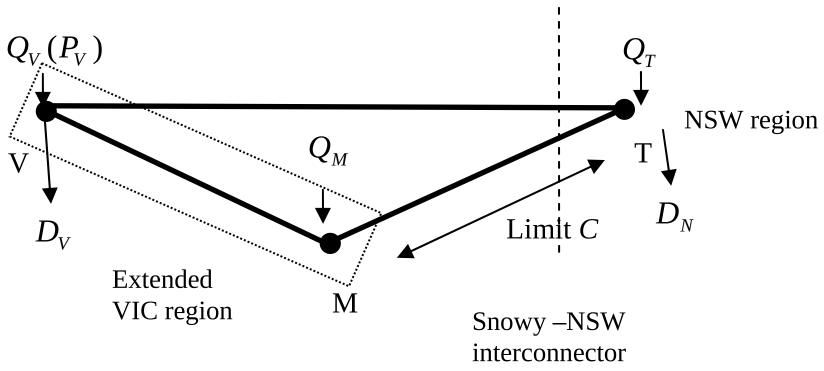
[10] Page 27 of SO_OP3705.

43. As can be seen, this approach always yields a dispatch inefficiency. The price at the VIC node is always inefficiently low. This is offset by inefficiently higher prices at the Murray node, sometimes only slightly higher and sometimes significantly higher. Since the flows on the Vic-Snowy interconnector are reduced, the "firmness" of the VIC-Snowy settlement residues is also reduced. In the third scenario above there is the potential for significant Murray price volatility.

The problems with merging two regions

44. An alternative approach to controlling the negative settlement residues is simply to merge the two regions. The impact on the network can be reflected in a diagram as below. This approach automatically eliminates the negative settlement residues and thereby eliminates the need for NEMMCO to otherwise intervene directly in controlling the dispatch.

45. The new network arrangements are summarised in the following diagram:



46. This approach is currently used by NEMMCO for controlling negative settlement residues in the case of southerly flows. In the current consultation NEMMCO is proposing to use this approach to control negative settlement residues in the case of northerly flows.

47. Even though NEMMCO does not intervene directly in the market under this approach there still arises an inefficiency in dispatch. This inefficiency in dispatch arises due to the mis-match between pricing and dispatch at the Murray node. Under this approach Murray is paid the VIC price even though the efficient price for Murray output is significantly lower than the VIC price (in the case of northerly flows). Murray has an incentive to respond by reducing its bids to the point where it is dispatched to the level it would like to be dispatched at the VIC price.

48. As an aside, NEMMCO claim in their issues paper that this approach (merging the VIC and Snowy regions) "effectively minimises the accumulation of negative residues without disruption to dispatch outcomes or loss in productive efficiency"[11]. This statement is incorrect. It is true to say that, unlike the alternative above, if all generators bid their true costs, this approach would ensure an efficient outcome. However, because this approach introduces a new mis-match between pricing and dispatch at the nodes in the Snowy region, generators in the Snowy region will not have an incentive to truthfully bid their true costs. This has the potential to introduce just as significant a distortion in dispatch as if NEMMCO intervened directly to control flows as in the first alternative above.

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[11] NEMMCO, "Management of Negative Residues on Vic-Snowy and Snowy to NSW Directional Interconnectors", 6 April 2005, page 7.

49. In fact, it is theoretically possible for the distortion in dispatch to be more significant than in the alternative above. In the alternative above, as Murray increased its output, NEMMCO is forced to intervene by reducing the output of VIC generators – but this process need only continue to the point where VIC exports are zero. At this point, settlement residues are zero (and, indeed, any further reduction in VIC exports would lead to negative settlement residues). If the two regions are merged, on the other hand, Murray output can by bidding low, ensure it is dispatched up to its full theoretically maximum (Murray has as registered capacity of 1500 MW) even if that forces the VIC region to import electricity.[12]

50. In summary, the net effect of this approach is to increase output at Murray and reduce output at VIC – in a manner similar to the alternative approach discussed above. This analysis has provided no theoretical guarantee that the market outcome under this approach will yield higher efficiency that the market outcome under the status-quo approach above.

51. However, as a lead-in to the discussion in the next section of this paper, it is worthwhile observing that *if* the correct price could be restored at the Murray node, this approach of merging the VIC and Snowy regions would yield the efficient outcome – that is, we would have an efficient dispatch without the problem of negative settlement residues.

52. Note, however, that this amounts to a sophisticated "fudge". We started out with efficient dispatch, then we merged the VIC and Snowy regions leading to a pricing distortion at the Murray node, which we then corrected with some other mechanism, restoring us to efficient dispatch. No "real" behaviour in the market has been changed – only the financial flows have been altered. Why not simply alter the financial flows directly rather than risk distorting dispatch? This is discussed in the next section.

53. But how might the correct price signals be restored at the Murray node? There are a variety of mechanisms which are all, in some sense, a variant of the CSP/CSC concept. But there is one approach which is attractive simply because it is a plausible market outcome even without any intervention in the market. Let's suppose that Murray generation acquires the settlement residue units on the Snowy-NSW interconnector. The following box demonstrates that this action restores the efficient price signals at the Murray node. In the appendix I demonstrate that the same approach restores efficient price signals at *both* the Murray and Tumut nodes in the context of a more realistic network model in which Tumut is in the Snowy region.

Access to Snowy-NSW settlement residues restores pricing signals at the Murray node

Let's suppose that the VIC and Snowy regions are merged and that the generator at Murray is given (or acquires) the Snowy-NSW settlement residues. The profit function of Murray generation is now:

$$\begin{aligned}\pi &= (P_V - c_M)Q_M + (P_N - P_V)(Q_V - D_V + Q_M) \\ &= (P_V - c_M)Q_M + (P_N - P_V)(3F_{MT} - Q_M) \\ &= (2P_V - P_N - c_M)Q_M + (P_N - P_V)3F_{MT}\end{aligned}$$

From this expression it is clear that the Murray output faces a marginal price equal to $2P_V - P_N$ which is precisely the efficient nodal price at the Murray node.

[12] In the simple network above, flow on the Murray-Tumut line is $F_{MT} = \frac{1}{3}(Q_V - D_V) + \frac{2}{3}Q_M$. Therefore, when the Murray-Tumut constraint is binding, for every 1 MW increase in output at Murray, VIC exports must be reduced by 2 MW.

54. The significance of this observation – that, following a merger of the VIC and Snowy regions, acquisition by Snowy Hydro of the Snowy-NSW settlement residues restores the correct nodal pricing incentives at Murray – depends on whether or not Snowy Hydro acquires Snowy-NSW settlement residues in practice (and would continue to do so after the VIC and Snowy regions were merged). Obtaining information on the hedge positions of different generators is difficult but it is my understanding that Snowy Hydro currently voluntarily purchases SRA units on the Snowy-NSW interconnector. If this is the case (and would continue to be the case following a merger of the VIC and Snowy regions), the observation above (that the merger of the VIC and Snowy regions induces mis-pricing at the Murray node) must be tempered by the observation that this mis-pricing could be mitigated or eliminated by the purchase of Snowy-NSW settlement residues. At best therefore, we can say that the merit of merging the VIC and Snowy regions is unclear. Further research on the hedging incentives on Snowy would be valuable.

55. In summary, merging the VIC and Snowy regions eliminates the VIC-Snowy settlement residues but introduces a new pricing distortion at Murray. The overall welfare implications of this approach relative to the alternative approach above (limiting VIC exports) are not clear. In particular, it is not possible to say with certainty that this approach is preferred over the alternative.

56. The pricing distortion could be removed through some form of a CSP/CSC-like mechanism which restores the correct marginal price at the Murray node. Note that this is *not* achieved by the current CSP/CSC proposal under consideration by the ACCC, which focuses only on the Tumut node. In any case, if the pricing distortion were removed, the dispatch outcome would be exactly the same as if the two regions were never merged in the first place. In this case the only impact of the "double intervention" (merging regions plus CSP/CSC at Murray) is merely to reallocate the merchandising surplus in some other way. Let's turn now to other approaches which are more explicit that this reallocation is precisely what they seek to achieve.

Approaches to handling negative settlement residues which do not distort dispatch

57. As noted above, the primary problem with negative settlement residues on the VIC-Snowy interconnector has nothing to do with an inefficiency in dispatch. In fact, the dispatch would be fully efficient if NEMMCO took no action to control the negative settlement residues at all. As we have seen in the previous section, NEMMCO can intervene to eliminate the negative settlement residues but, in this event, in the best possible outcome, the dispatch remains the same as before – the only outcome is that the total settlement residues (the merchandising surplus) have been divided in some different way.

58. So let's explore in more detail some of the options which involve dividing the merchandising surplus in some other way. Perhaps the easiest approach is simply to use the positive settlement residues on one interconnector to offset the negative settlement residues on another interconnector.

59. The theory mentioned above shows that (provide we have adequate locational marginal pricing) the merchandising surplus must always be positive – therefore there must always be sufficient residues on some interconnectors to offset negative settlement residues elsewhere.

60. In the simple network above with two interconnectors and a single binding constraint, this approach amounts to just taking residues from one interconnector and using them to offset negative residues on another interconnector. More specifically – using positive residues

on the Snowy-NSW interconnector to offset negative residues on the VIC-Snowy interconnector. Since the total residues must be positive (in the simple network above where there are no pricing distortions) there are always sufficient residues on the Snowy-NSW interconnector to offset negative residues on the other interconnector.

61. In effect, under this approach the Snowy-NSW residues (after the offset) would always be zero and the Snowy-NSW residues (after the offset) would always be positive or zero. In fact, the Snowy-NSW residues in this case would be simple equal to the total merchandising surplus. In effect, this outcome is simply the confirmation of something which we knew all along – that, as long as there is a single binding constraint there is only a single source of residues – dividing up this single source of revenues into two payment streams (corresponding in this case to two inter-regional settlement residues) is arbitrary and unnecessary.

62. In this simple network with a single binding constraint, rather than dividing up the payment stream corresponding to the merchandising surplus into two separate settlement residues it makes more sense to simply auction the merchandising surplus as a single entity. By the theory of transmission pricing, the merchandising surplus is always positive, so we have achieved the desired outcome – dispatch is efficient and the stream of settlement residues (as we have defined them) are always positive.

63. The approach of using the settlement residues on one interconnector to offset the settlement residues on another interconnector works in this simple example where there are two interconnectors and a single binding constraint.[13] But this approach does not generalise to more sophisticated networks with more interconnectors or constraints. Intuitively, it is clear that the approach cannot work when the number of constraints exceeds the number of interconnectors. In my view it makes sense to develop an approach which can apply without modification to the range of different network configurations which may arise in the future.

A new approach to dividing the merchandising surplus

64. There is a serious question about the sustainability of the concept of inter-regional settlement residues. The notion of inter-regional settlement residues has worked well in the NEM to date – but largely because the NEM has retained a linear (i.e., non-loop-flow) structure and intra-regional constraints have been contained. We cannot be certain that these characteristics will continue in the future. The addition of a South-Australia-NSW interconnector, for example, will introduce a significant new loop into the NEM. Over time, as region boundaries change, new regions are defined, and transmission networks are extended, it is inevitable that further loops in the network will emerge. The existing settlement residue structure is unable to handle these developments.

65. Rather than continue to make adjustments on an ad hoc basis to address shortcomings in the current definition of settlement residues, it makes sense to move now towards a long-term sustainable and robust framework for dividing the merchandising surplus into separate payment streams.

66. How should we divide the merchandising surplus into payment streams in such a way that (a) all of the payment streams are always positive; and (b) the payment streams are useful for hedging purposes.?

[13] Note that this result relies on the assumption that there are no other pricing distortions in the market. In the paper I demonstrated that this result doesn't hold when there is mis-pricing at the Tumut node.

67. I propose the development of a new approach to handling the merchandising surplus, as follows. This approach has the advantage that it is compatible with the existing settlement residue mechanisms whenever transmission constraints occur on the existing interconnectors, and can be extended to any new intra-regional or inter-regional constraints as they emerge.

68. The theory of transmission pricing tells us that the merchandising surplus on a network with nodal pricing is equal to the sum, for each constraint in the network, of the "marginal value" (also called "lambda") of that constraint times the flow on the constrained link. For each constraint, the marginal value times the flow is always positive. Therefore we can divide the merchandising surplus into a number of different payment streams. Each payment stream would be equal to the marginal-value-times-the-flow for each binding constraint. Since each of these payment streams is positive, we can simply auction the right to each of these streams of payments independently.

69. In a linear network, the marginal value of a constrained interconnector is equal to the price difference across the interconnector. Therefore the "marginal value times the flow" is just equal to the price-difference times the flow – that is, just equal to the inter-regional settlement residues as they are currently defined. In other words, for genuine inter-regional constraints the payment streams defined under this proposal are precisely equal to the inter-regional settlement residues as they are currently defined.

70. In more complicated networks, such as networks with loop flow, the marginal value of a constrained link is no longer equal to the price-difference across the link (although it is still related to the price-difference across the link). In the simple network used to illustrate the arguments in this paper, the "marginal-value times the flow" is equal to one-and-a-half times the price-difference between Murray and Tumut times the (constrained) flow between Murray and Tumut. If the Murray-Tumut flow limit is 1000, these residues are equal to $1500 \times (P_N - P_M)$.

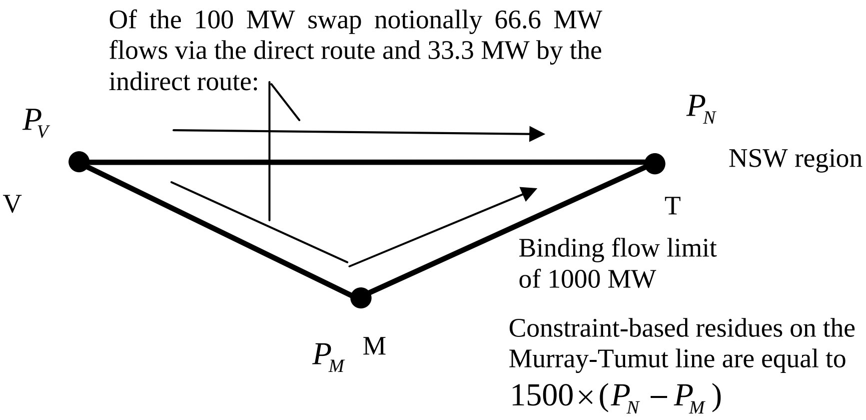
71. Since these residues are no longer linked to inter-regional interconnectors, it no longer makes sense to call them inter-regional settlement residues. A possible alternative is to call them "constraint-based residues".

72. Having access to these constraint-based residues allows market participants to fully hedge their risks, in a manner analogous to the way they use settlement residues at present. For example, suppose that a generator located at the VIC node in the network above wanted to sell a swap contract for 100 MW to a retailer located at the Tumut node. This generator would know that, of the 100 MW notional flow from VIC to Tumut, two-thirds travels from VIC-Tumut directly and one-third travels from VIC-Tumut via the Murray node. This generator must therefore purchase 33 MW of the Murray-Tumut constraint-based residues. If the limit on the Murray-Tumut line is 1000 MW, this generator must purchase a 3.3% share of the constraint-based residues. 3.3% of the constraint-based revenues yields a payment stream which is exactly equal to a the payoff on a financial transmission right between VIC and NSW:

$$0.033 \times 1500 \times (P_N - P_M) = 50 \times 2 \times (P_N - P_V) = 100(P_N - P_V)$$

73. This is illustrated in the following diagram:

A generator located at the VIC node who wished to sell a swap contract of 100 MW to a retailer in NSW would, in order to hedge the risk of locational price differences, simply purchase $\frac{1}{3}\times 100$ MW of the constraint-based residues on the Murray-Tumut constraint:



Purchasing $\frac{1}{3}\times 100$ MW of the 1000 MW flow, which pays $\frac{3}{2}(P_N - P_M)$ per MW, yields a payoff of $50(P_N - P_M) = 100(P_N - P_V)$ which precisely hedges the risk of locational price differences between NSW and VIC.

74. The following box shows how this approach would operate in more complex networks.

The theory of "constraint-based residues"

Let's suppose that we have an arbitrary network with *N* nodes and *L* links between the nodes. Let z_i be the net injection at node *i* (i.e., the production at node *i* less the consumption at node *i*). By the energy balance equation $\sum_i z_i = 0$. In a DC load flow model, the flow on link *l* can be related to the net injection at the nodes on the network as follows: $f_l = \sum_{i=1}^{N-1} H_{li} z_i$ where f_l is the flow on link *l*, H is the matrix of power-transfer distribution factors and node *N* is designated the reference node (or swing node).

The theory of optimal dispatch in this network shows that the locational marginal price must satisfy: $P_N - P_i = \sum_l \lambda_l H_{li}$ where λ_l is the "marginal value" or "constraint multiplier" on the constraint equation for the link *l*. The "marginal value" of a constraint is zero unless the constraint is binding.

The merchandising surplus in this network is equal to $MS = -\sum_{i=1}^{N} P_i z_i$. We can substitute the expression for the optimal nodal price above to determine that $MS = \sum_l \lambda_l f_l = \sum_l \lambda_l K_l$ where K_l is the flow limit (the "capacity") on link *l*. Since relaxing the flow limit always (weakly) increases welfare, it must be that for each binding link *l*, the product $\lambda_l K_l$ is positive.

Hence we can divide the merchandising surplus into a number of different streams – one for each binding constraint, and each of which can be auctioned separately.

All that remains to be shown is how these new payment streams would be used to hedge the risk of trading across different pricing nodes. Suppose a generator at node *i* wishes to sell a swap contract to a retailer at node *j* in the quantity *X*. This retailer need only purchase a share $\frac{X}{K_l}(H_{li} - H_{lj})$ of the constraint-based residues of link *l*, for each constraint which is likely to bind. Purchasing this share for constraint *l*, yields the payment stream $\frac{X}{K_l}(H_{li} - H_{lj}) \times \lambda_l K_l = X\lambda_l (H_{li} - H_{lj})$. Summing this over all the payment streams purchased yields the payment stream: $\sum_l X\lambda_l (H_{li} - H_{lj}) = X(P_j - P_i)$ which is precisely the payment stream for a firm financial transmission right between node *i* and node *j*.

So we have shown that this approach to dividing the merchandising surplus both yields a number of payment streams which are positive (and therefore can be voluntarily acquired at auction) and these payment streams can be used for hedging in a straight-forward manner, in an arbitrarily complex network.

87. In summary, I am proposing an evolution of the current arrangements for handling the merchandising surplus. Specifically I am proposing that a policy decision be taken to move away from "inter-regional" settlement residues towards "constraint-based" residues. More specifically, I propose that this policy be implemented in the Snowy region through the establishment of a new residue fund called the "Murray-Tumut" constraint-based residue fund. This new fund would be in addition to and would not replace the existing inter-regional settlement residue funds.

75. When the Murray-Tumut constraint binds, residues would be paid into Murray-Tumut constraint-based fund, equal to the "marginal value times the flow" as described earlier. The total quantity of funds available (the merchandising surplus) would, of course, not change, so the sum of the funds paid into the existing inter-regional settlement residue funds would, of course, drop by the amount paid into this new fund. At the same time, provided there are no other constraints which affect loop flow, the negative settlement residues on the VIC-Snowy interconnector will be eliminated.[14] As new constraints emerge which give rise to negative settlement residues, they could be handled in the same way – through the establishment of a new constraint-based residue fund.

76. The proceeds in the Murray-Tumut constraint-based residue fund would be auctioned in exactly the same manner as the existing inter-regional settlement residues are auctioned.

Conclusion

77. Negative settlement residues on the VIC-Snowy interconnector are not the result of any inefficiency in dispatch. It is therefore inefficient for NEMMCO to take actions which reduce the efficiency of dispatch in order to control negative settlement residues. Instead, a better approach to solving the problem of negative settlement residues is to redefine the settlement residues themselves.

[14] Of course, if there are other constraints which affect loop flow we cannot be sure that these other constraints will not cause negative settlement residues on the interconnectors. The solution is the same as advocated here – to establish a new constraint-based residue fund for that constraint.

78. The proposal to use the positive settlement residues on one interconnector to offset the negative settlement residues on another is a feasible and practical approach to solving the problem that has arisen around the Snowy region. It is straightforward to show that the positive residues on one interconnector are always more than sufficient to offset negative residues on the other interconnector. This approach could be implemented through relatively minor changes to the existing CSP/CSC derogation.

79. However, as the NEM develops, loop-flows between regions are increasingly likely. Rather than make heuristic adjustments to the market rules in response to shortcomings in the definition of settlement residues as they arise, it seems sensible to move now to a long-term sustainable and robust approach to dividing up the merchandising surplus into payment streams.

80. Specifically, I propose that the existing inter-regional settlement residues evolve into constraint-based settlement residues. Since the constraint-based residues are always positive, the right to receive this stream of payments could be auctioned, as at present. Market participants can then fully hedge their trading requirements by purchasing a share of this stream of payments in a manner analogous to the manner in which they hedge inter-regional trading risk at present.

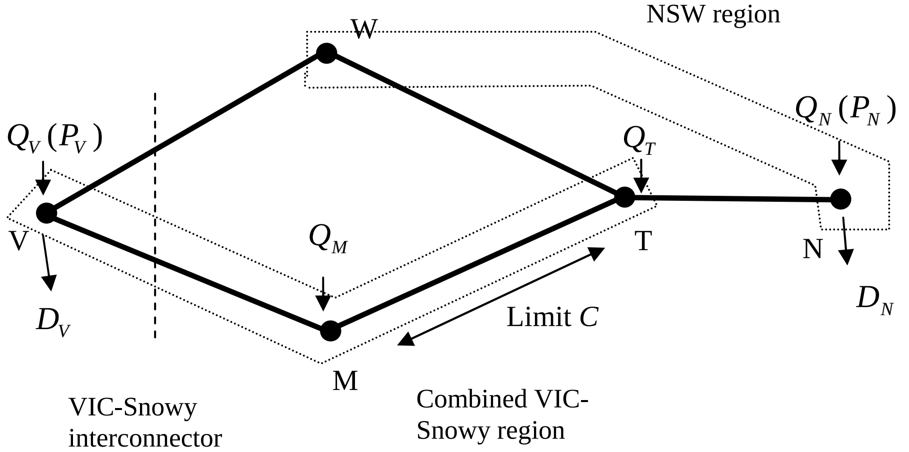
81. It would be relatively simple to implement this approach in the context of the Snowy region. All that would be required is the establishment of a new "settlement residue" account which accrues funds when (and only when) the Murray-Tumut constraint binds. These funds would then be auctioned alongside the existing settlement residue auctions.

Appendix:

82. The purpose of this appendix is to show that a result which is proved in the text extends to a more complicated network. Specifically, in the text it was shown that the merger of the VIC and Snowy regions leads to a mis-match of pricing and dispatch at the Murray node. This mis-pricing can be eliminated if Murray generation acquires sufficient SRA units on the Snowy-NSW interconnector.

83. This result also holds in the case where Tumut is in the Snowy region. In fact, if the VIC and Snowy regions are merged, if Snowy acquires sufficient SRA units on the Snowy-NSW interconnector, efficient nodal pricing incentives are restored at *both* the Tumut and Murray nodes.

84. Suppose that we have a network which is as in appendix B of my earlier paper, except now we will assume that the VIC and Snowy regions are merged. The network diagram is as below:



85. In this network the flow on the Murray-Tumut line is $F_{MT} = \frac{2}{3}(Q_V - D_V) + \frac{5}{6}Q_M$. When the Murray-Tumut line is constrained the price in the VIC, Snowy and NSW regions must satisfy: $P_V = \frac{4}{5}P_M + \frac{1}{5}P_N$.

86. Now, the settlement residues on the Snowy-NSW interconnector are equal to:

$$\begin{aligned} SR_{SN} &= (P_N - P_M)(Q_V - D_V + Q_M + Q_T) \\ &= (P_N - P_M)(\tfrac{3}{2}F_{MT} - \tfrac{1}{4}Q_M + Q_T) \end{aligned}$$

87. Now consider the profit function of Snowy Hydro after purchasing these settlement residues:

$$\begin{aligned} \pi(Q_M, Q_T) &= (P_M - c_M)Q_M + (P_M - c_T)Q_T + (P_N - P_M)(\tfrac{3}{2}F_{MT} - \tfrac{1}{4}Q_M + Q_T) - F \\ &= (\tfrac{5}{4}P_M - \tfrac{1}{4}P_N - c_M)Q_M + (P_N - c_T)Q_T + (P_N - P_M)\tfrac{3}{2}F_{MT} - F \end{aligned}$$

88. From this expression it is clear that Tumut output faces the correct nodal price (P_N). What about Murray output? From this expression we can see that Murray output faces a price

equal to $\frac{5}{4}P_M - \frac{1}{4}P_N$. Again, this is precisely the correct nodal price in this market (from the expression above $P_M = \frac{5}{4}P_V - \frac{1}{4}P_N$).

89. In summary, we have shown that (i) if the VIC and Snowy regions are merged and (ii) Snowy Hydro acquires the Snowy-NSW inter-regional settlement residues, both Murray and Tumut output face the correct nodal price.

90. However, I have not shown that purchasing the settlement residues is in the private interest of Snowy Hydro – in other words, does this action increase the profit of Snowy Hydro? This is a question for further research.