Project Energy Connect Implementation – Final Report

February 2024

Project Energy Connect Market Integration - Settlements Residue Consultation

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Executive summary

Project Energy Connect (PEC) presents new challenges for the NEM with the construction of a high-capacity synchronous link in parallel with existing links between adjacent regions. At completion the project will provide approximately 800 MW of transmission capacity between New South Wales (NSW) and South Australia (SA) power networks, delivered over two stages. The issues discussed in this paper relate primarily to the full development of PEC, known as PEC stage 2.

This paper follows the Directions Paper[1] in a series of AEMO-led papers[2]

In its Directions Paper, AEMO requested stakeholders provide comment on the following proposals for the implementation of PEC:

- A new interconnector connecting SA and NSW in dispatch and the Settlement Residue Auction (SRA).
- The revision of procedures that manage negative interregional settlement residues, such that they apply only during periods of net negative interregional settlement residues (when settlement is in deficit) across the three interconnectors connecting NSW, Victoria (VIC) and SA.
- When aggregate interregional settlement residues across the three interconnectors connecting NSW, VIC and SA are net positive (when settlement is in surplus), any negative interregional settlement residues that accrue on any one or more of the directional interconnectors are to be reallocated to the importing TNSP of the directional interconnectors[3] that have positive residues, in proportion to the positive residues that accrue on them.
- When aggregate interregional settlement residues are in deficit across the three directional interconnectors connecting NSW, VIC and SA, they will be recovered from the importing TNSP of the interconnector upon which they reside, irrespective of any positive residues that may accrue on other interconnectors.

AEMO received stakeholder feedback on its Directions Paper

Several stakeholders responded to the consultation, including market participants, traders, network companies, consumer representative organisations, industry associations and the Australian Financial markets Association (AFMA). The responses from stakeholders were varied, but the following themes emerged in their views:

- An alternative dispatch integration method to the proposed ‘interconnector’, called the ‘micro-slice’, should be further considered.
  - It appeared to AEMO that it should clarify the relationship between physical transmission flows, negative residues, and interregional trading (via the SRA) associated with the interconnector and micro-slice models.

[1] AEMO, Project Energy Connect Implementation – Directions paper, published November 2023: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/directions-paper-for-consultation/pec-market-integration---directions-paper-for-consultation.pdf?la=en.

[2] https://aemo.com.au/en/consultations/current-and-closed-consultations/project-energy-connect-market-integration-paper

[3] NER 3.18(c) defines directional interconnectors.

- The current separation of positive and negative interregional settlement residues should be preserved, with positive residues distributed via SRA and negative residues charged to the importing TNSP.
- In intervals where aggregate inter-regional settlement residues around the loop are in surplus, any negative residues should be reallocated from the importing TNSP of the interconnector accruing negative residues to the importing TNSPs of the interconnector that is accruing positive residues. Where multiple interconnectors are accruing positive residues, negative residues are reallocated in proportion to the positive residues.

AEMO has conducted further analysis in response to stakeholder feedback

In response to this feedback, AEMO has completed further evaluation of the micro-slice and interconnector dispatch integration models.

Under the interconnector model, PEC is considered in dispatch and settlement as a new and separate transmission element between the New South Wales and South Australia regional reference nodes. Notably, it is assumed that if the interconnector model were implemented, it would be accompanied by an approach to reallocate negative residues.

Under the micro-slice model, the Victoria region is inserted between the NSW and SA regions and the capacity of PEC is added to the existing interconnectors that are modelled in dispatch. This means only the VIC to NSW interconnector and the VIC to SA interconnectors would be modelled in dispatch.

Irrespective of the choice of dispatch integration model, a physical transmission loop will exist. In accordance with the spring washer pricing effect[4], if a transmission constraint occurs between two nodes in the loop, the highest and lowest nodal prices will occur on either side of the constraint. As a result, in principle, even under the micro-slice model's radial representation of NEM regions, prices will not always increase in the direction of flow between regions and negative residues may be common.

To test this dynamic, AEMO has completed analysis of settlement under the interconnector and micro-slice models. The analysis assumes the models satisfactorily represent the physical system, facilitating comparison based only on settlement outcomes. Since the interconnector model would typically represent the physical system at the very least as accurately as the micro-slice model (through an equality constraint[5]), then, if the analysis showed the micro-slice was inferior on settlement grounds, there would be no need to compare the models to assess whether one may better reflect the physical transmission system than the other.

AEMO's analysis indicates that the micro-slice option distributes residues that would have otherwise accrued on PEC to the other two interconnectors. This did reduce the extent of negative interregional residues in some cases, however they remained pervasive in other cases. This finding was consistent with AEMO's expectations, validating the ideas that the micro-slice does not physically remove loop flows, and spring washer pricing effects can therefore result in negative residues if prices do not follow the direction of inter-regional flows modelled under the micro-slice. Given this finding, and although Stage 1 will be implemented as a micro-slice, AEMO will not implement PEC Stage 2 as a micro-slice. Additional reasons it has come to this conclusion include:

- Challenges for implementing negative residue management constraints with this model

[4] Described in AEMO's Market Integration Paper

[5] In the form $\alpha \times \text{V-NSW} + \beta \times \text{V-SA} + \gamma \times \text{SA-NSW}$ = Phase Shift Factor + Constant, where Phase Shift Factor is a constant that reflects the phase shift transformer tap position. A description of an equality constraint is provided in AEMO's Directions Paper.

- Greater difficulty reallocating negative residues between importing TNSPs
- Loss of the direct pricing of trade between NSW and SA that an interconnector implementation provides

AEMO recognises that the Directions Paper largely cited regulatory precedent as reason to preserve the hedging value of units and considers that this Final Report is an opportunity to further investigate hedging value and provide further reasoning in support of or opposition to its position[6]. Preserving the hedging value of units means retaining the current separation of positive and negative interregional settlement residues, with positive residues distributed via SRA and negative residues charged to the importing TNSP.

Negative interregional settlement residues can reduce the usefulness of the SRA for hedging interregional derivative trading. This is because, when they occur, there is a positive price difference, no flow from low-priced to high-priced regions and therefore no positive residue. At these times, the hedging value of an SRA unit is zero. Conversely, in theory, negative residues can support increased positive residues in aggregate around a transmission loop. AEMO considers that these opposing dynamics make this subject worthy of further investigation and modelling.

AEMO's analysis found that, despite increased frequency of counter-priced flows with the connection of PEC, SRA trading could provide a similar level of firmness in 'hedging value' as is available in the auctions today. This should not be construed as suggesting SRA units will provide a perfect hedge when trading an interregional position, because this is not so today. Historically, the usefulness of the SRA for inter-regional hedging has varied greatly by directional interconnector and quarter, and so by making a comparison with today's performance of the SRA is to accept that SRA trading with the interconnector loop is likely to retain a high degree of uncertainty.

It seems evident that, irrespective of the dispatch model, traders at the SRA will need to understand the spring washer pricing effect, and the likelihood of counter priced flows on the relevant interconnector they are trading. Rather than being more complex, this may be simpler for traders to do if the dispatch implementation model better reflects the underlying power system with the interconnector implementation.

AEMO aims to proceed with the approach set out in its Directions Paper

AEMO intends to implement PEC Stage 2 using the interconnector dispatch integration model.

- Creation of an interconnector in dispatch and the SRA should maximise flows and the value of trading. This should allow participants to trade across NSW and SA markets consistent with the power flows between these NEM regions. This approach allows negative settlement residues and provides a clear basis to separate negative from positive residues.
- Despite the micro-slice option distributing residues that would have otherwise accrued on PEC to the other two interconnectors, negative residues would be expected to remain. This is because the micro-slice does not remove the loop flow, and spring washer pricing effects could result in negative residues if prices did not follow the radial order of regions (and flows) in the micro-slice. By effectively reallocating interregional flows from PEC to the existing loop arms, it becomes more complex to separate negative residues from positive and fewer options exist for the imposition of negative residue management

[6] Refer to section 3.4 for detailed discussion.

constraints. Further, AEMO considers direct pricing between NSW and SA, supported by the SRA will better support interregional trade and competition than the micro-slice model.

AEMO intends to revise automated negative residue management constraints with the aim, subject to security constraints, of eliminating negative interregional settlement residues when the aggregate interregional settlement residue of all three interconnectors is in deficit.

- Under these conditions, if automated negative residue management constraints fail to eliminate negative residues, or the residues are within allowable tolerances, negative residues will remain payable by the importing TNSP.

AEMO intends, for each trading interval, to reallocate negative interregional settlement residues if settlement, in aggregate, is in surplus across the three interconnectors.

- The method of using the proportion of positive residues (as opposed to some other measure, like flow, or capacity) was implicitly endorsed by stakeholders, with stakeholders also rejecting the option to reallocate all interregional settlement residues (rather than simply the negative residues). This means an interconnector that has counter price flows and is accruing negative residues, would not be allocated a share of positive residues from other interconnectors, irrespective of there being a positive price difference between the two regions to which a participant may be exposed. AEMO considers this is sensible, because the larger price differences are more likely to be found on the interconnectors with the greatest positive residues.

AEMO intends for intervals where aggregate interregional settlement residues around the loop are in surplus, any negative residues that are reallocated under the method above, should be directly payable by the importing TNSPs.

- After reviewing stakeholder feedback, and consistent with the Directions Paper, AEMO remains of the opinion that the hedging value of the units should be prioritised over any cashflow issues, and this means any negative interregional settlement residues reallocated are then payable by the importing TNSP. This is consistent with regulatory precedent, the desire to encourage interregional trade, and was supported by stakeholder feedback.

1 Introduction

Project EnergyConnect (PEC) is an electricity transmission project to deliver a physical interconnection between South Australia and New South Wales electricity networks, to be constructed jointly by Electranet and Transgrid. At completion the project will provide approximately 800 MW of transmission capacity between New South Wales (NSW) and South Australia (SA) power networks, delivered over two stages:

- PEC stage 1 (150 MW bi-directional capacity). The first stage will comprise the connection between Robertstown and Buronga. Progressive capacity release is estimated from mid-2024.
- PEC stage 2 (combined transfer limit across Heywood and PEC interconnectors: 1,300 MW import into South Australia and 1350 MW export). The second stage comprises the connection between Buronga and Wagga Wagga. Full capacity release is currently targeted to be released by 1 July 2026.

The development of PEC will establish an AC transmission 'loop' across regulated interconnectors in the NEM. This has motivated the consideration of various issues through a series of AEMO-led papers which includes the Market Integration Paper[7], Directions Paper[8] and modelling conducted by ACIL Allen[9]. This Final Report is the last publication in this series. The Final Report treats previous papers as assumed knowledge and refers extensively to them.

In its Directions Paper, AEMO describes the changes to the National Electricity Rules (NER) that are necessary to give effect to the PEC implementation approach described in this paper. Shortly after the publication of this paper, AEMO will submit a rule change request to the AEMC detailing the proposed NER changes. The Directions Paper also describes the necessary procedure and system changes, and the consultation processes AEMO intends to follow in implementing these changes. Indicative timings for the rule change and procedure change processes, as well as the physical implementation of PEC are described in section 2.

Please note that the 'interconnector model' for dispatch integration, using terminology from this paper, would take the NEM from having only 'radial transmission configurations' to also having 'parallel transmission configurations', using terminology from AEMO's rule change request.

[7] AEMO, Project Energy Connect Market Integration Paper, published November 2022: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/pec-market-integration-paper.pdf?la=en.

[8] AEMO, Project Energy Connect Implementation – Directions paper, published November 2023: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/directions-paper-for-consultation/pec-market-integration---directions-paper-for-consultation.pdf?la=en.

[9] ACIL Allen, Modelling the settlement effects of project Energy Connect, final report, published July 2023: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/directions-paper-for-consultation/modelling-the-settlement-effects-of-pec---final-report.pdf?la=en.

2 Stakeholder consultation

2.1 Timeline

This table below describes the work undertaken to date to consider the implications on dispatch and negative settlement residue outcomes arising from PEC, and provides indicative timing for next steps.

Table 1 PEC integration timeline

Deliverable	Indicative Timeline
AEMO Market Integration Consultation	
Market Integration Paper published	15 November 2022
Stakeholder submissions received	19 January 2023
Update on Market Integration Paper published	18 May 2023
Technical Report – Phase 1 PEC Integration	9 June 2023
AEMO Directions Paper Consultation	
Engagement through Settlement Residue Committee (SRC) meeting	1 September 2023
Directions Paper published	1 November 2023
Engagement through Settlement Residue Committee (SRC) meeting	3 November 2023
Industry briefing	14 November 2023
Project Energy Connection (PEC) Industry Quarterly meeting	23 November 2023
Submissions due on Directions Paper	1 December 2023
Final Decision from Directions Paper published	9 February 2024
Australian Energy Market Commission (AEMC) Rule Change Proposal	
AEMC rule change proposal	Q1 2024 – Q4 2024
AEMO Procedure and system change processes	
AEMO procedure consultations – related to negative residue management and allocation of settlements residues	Q3 2024 – Q2 2025
AEMO system updates – settlements and negative residue management	Q1 2025 – Q4 2025
PEC Implementation / capacity release	
PEC stage 2 Testing	Q1 2025 – Q2 2026
PEC stage 2 sufficient capacity to impact negative IRSR	Q1 2026

2.2 PEC Market Integration Papers

In November 2022, AEMO published the initial Project Energy Connect Market Integration Paper, that introduced to stakeholders the market integration issues that arise from the transmission loop between VIC, SA, and NSW. The Paper also considered the market and settlement impacts of PEC that give rise to transmission loop flows and negative interregional settlement residues (IRSR). This consultation received 11 written submissions from stakeholders; the submissions requested more information on the occurrence of negative IRSR and the development of options for reallocation.

In May 2023, AEMO published the PEC Implementation Update on Market Integration (Update Paper)[10] detailing AEMO's proposed approaches to integrating PEC into dispatch and market settlement residue activities. The Update Paper discussed the need for AEMO to consider the appropriateness of the way loop flow negative settlement residue is managed and allocated. AEMO also published GHD's Technical Report[11] on power system studies to assess the impact of the integration PEC in stage 1 under various dispatch scenarios.

Most recently, in November 2023, AEMO released a Directions Paper which proposed approaches for addressing negative settlement residues in relation to dispatch and settlement residue auctions. Proposals were supported by the incorporation of ACIL Allen's modelling of the settlement effects of PEC, which quantified some of the issues described in the paper.

2.3 Stakeholder feedback

Table 2 Stakeholder feedback

	Category	Questions for consultation
Management of negative residues		
1	Current process	AEMO considers the current process is unsuitable and will restrict efficient dispatch. Are there any additional advantages or disadvantages with the current process identified by stakeholders that could apply in the context of transmission loop flows?
		AGL agreed that some modifications will be required, as did **Hydro Tas**. The **AEC** also agreed that some modifications are required (but did not necessarily agree on them). **Snowy Hydro** agreed current design of NRM via constraint automation or "clamping" is not operationally efficient if negative IRSR occurs normally and frequently affects interconnectors. Many other stakeholders concentrated on other matters, like the reallocation approach and whether to deduct negative residues from positive residues before distributing interregional settlement residues (IRSR) to settlement residue auction (SRA) unit holders. Only **Shell Energy** considered no amendments are required, but on the proviso that the dispatch model implemented be a micro-slice in a similar manner to stage 1 of PEC, and stage 1 be treated as a "natural experiment" to assess whether changes are required. This was endorsed by the **EUAA**. In response: Given the potential for negative settlement residues to accrue, irrespective of the dispatch model implemented, AEMO will at a minimum need to reassess its treatment of negative settlement residues in dispatch.
2	Approach	AEMO considers regulatory precedent requires negative residue management be retained for periods where IRSR is in deficit around the loop, that this be automated as far as possible, limited to $100,000 where possible, and any accruing negative residues be allocated to the importing TNSP. For these instances, there would not be any reallocation required. Are there any other approaches to negative residue management AEMO should consider?
		Electranet stated that TNSPs were considered a reasonable sink for negative inter-regional settlements residue because these were relatively minor versus TNSP revenues. **Electranet** agreed that interconnector clamping to reduce negative residues remains an important tool to limit the exposure of the ultimate recipients of those residues (customers). **AGL** agreed with

[10] AEMO Project Energy Connect Implementation Update, published 18 May 2023: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/pec-implementation--update-on-market-integration-may.pdf?la=en.

[11] GHD, Project Energy Connect, Steady State Market Integration Studies, published 29 May 2023: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/technical-report---phase-1-project-energy-connect-integration.pdf?la=en.

	Category	Questions for consultation
		the principle that if negative residues create a settlement deficit, they should be managed, but they expressed a desire to review this requirement after operation of PEC. In response: AEMO agrees with **Electranet** and **AGL** that where settlement is in deficit, negative residues should continue to be minimised in dispatch. AEMO does not agree with a "wait and see" approach put forward by **AGL**. While it may be useful to have some experience of the interconnector loop before implementing new negative residue management constraints, AEMO is required to have a procedure to manage negative interregional settlement residues and is expected to manage them to approximately $100,000. This implies AEMO should have a procedure at the outset upon stage 2, yet to AGL's point, this procedure could be enhanced with operating experience of the PEC interconnector.
Reallocation of IRSR		
3	Approach	In considering the reallocation approach, AEMO considers a sensible method is to allocate negative residues is in proportion the with positive residues on the other interconnectors in the loop. AEMO considers it is preferrable that an interconnection that is negative not receive a proportion of the positive residues. Do stakeholders agree?
		Electranet considered it prudent to reallocate negative residues. **EA** considered reallocating in proportion to positive residues in importing regions reflects the benefit accruing to those regions that is enabled by the loop flow configuration. **AGL** agreed with only reallocating negative residues because consumers in the importing region are already realising the benefits of counter price flow. **Origin** agreed with the approach for reallocation and considered reallocating all residues would likely erode the value of SRA units. **Engie** made a similar point but cited regulatory precedent to support the view. **Hydro Tas**, **Delta** and **Snowy** did not comment on the reallocation methodology, instead focusing on the separation of negative from positive residues but implicitly accepted the reallocation approach. **AEC** was unconvinced with the need for reallocating negative residues, instead being concerned more with the separation of negative from positive residues to preserve the value of the SRA for hedging. **Shell Energy** similarly supported the separation of residues, but flatly rejected the reallocation approach, preferring negative residues to remain paid by consumers in the importing region. In response: AEMO considers although there was some consensus amongst the stakeholders as to the chosen reallocation approach, the priority of stakeholders was more with the separation of negative from positive residues to preserve the value of the SRA for hedging. AEMO believes this was largely because, if the negative residues are not deducted from positive residues distributed to unit holders, most participants that responded would not be affected by the reallocation approach. Further, engagement on the reallocation approach was somewhat limited due to many respondents discussing the applicability of the micro-slice dispatch implementation.
4	Approach	Do stakeholders consider these approaches to be reasonably robust, irrespective of whether negative IRSR is deducted from the payouts to SRA unit holders? In response: stakeholders did not comment further than above.
5	Approach	Do stakeholders have a different method for the reallocation of negative IRSR that should be considered? In response: No stakeholders recommended an alternative approach, bar several stakeholders discussing the micro-slice option (which is a form of reallocation itself). AEMO considers stakeholders implicitly endorsed the reallocation approach by commenting on and agreeing to further recommendations that relied on such an approach.
Payment for negative IRSR – whether to deduct from SRA unit holders		
6	Approach	Which option best meets the guiding principles identified in Appendix A3? Are there other options that also meet the guiding principles that should be considered?

	Category	Questions for consultation
7	Approach	Should AEMO propose a method that deducts negative IRSR from the payout to SRA unit holders; or reallocates negative IRSR, in proportion to positive IRSR, directly to consumers in the importing regions?
		EA consider [AEMO's position in Directions Paper] would be less detrimental to the market overall and have less unintended consequences than altering SRA arrangements. Similarly, **Engie**, **Delta**, **Snowy**, **Hydro Tas**, **Shell**, and **AFMA** all recommended negative residues be payable by the importing TNSP, rather than deducted from the distribution of positive residues to SRA unit holders.
8	Approach	What, if any, other factors need to be included when considering the payment for negative IRSR?
9	Implementation	The reallocation approach would require updates to AEMO's settlement systems and procedures. What does AEMO need to consider in terms of: • Participant or TNSP market and settlement systems? • Timing of implementation?
Other matters raised		
	Interregional trading and hedging	**Pacific Energy Trading** (PET) consider "the micro-slice option is more conducive of inter-regional hedging", **AFMA** consider there to be a tension between AEMO wanting to better reflect the electricity system and yet financial market participants wanting a less precise approach, inferring the latter to be preferable. In response: the creation of a new interconnector in dispatch and the SRA, the ability to maximise flows by allowing negative settlement residues, and the separation of negative from positive residues should allow participants to trade NSW and SA consistent with the power flows between these states. By contrast the micro slice does not provide for direct trading between NSW and SA and makes it more difficult to separate negative residues from positive and impose negative residue management constraints. AEMO considers direct pricing between NSW and SA, supported by the SRA will better support interregional trade and competition. AEMO does not agree with AFMA's premise of a less precise approach, such as the micro-slice being better for financial trading. Under the micro-slice traders will still need to try to assess loop flows, spring washer pricing to assess where negative interregional settlement residues may occur.
	Interregional trading and hedging	**Snowy Hydro** considered that AEMO should extend the discussion on how a trader would hedge inter-regional price risk across the three limbs. This was noted in the Australian Energy Council's (AEC) initial submission. In response: AEMO recognises that the Directions Paper largely cited regulatory precedent as reason to try to preserve the hedging value of units. In this paper AEMO broadly describes the concept of interregional hedging, discusses how traders may participate in the SRA and investigates, a basic level, the value of units in hedging interregional trading. AEMO recognises the spring washer pricing effect can cause a counter-price flow as part of efficient dispatch, this can lead to increased negative residues. This paper indicates negative residues can support increased positive residues across the three interconnectors - so despite increased occasion of counter-priced flows with the connection of PEC, analysis indicates that trading in the SRA could be like today in terms of the interconnectors' "hedging value", because across the three interconnectors the positive residues are greater than the negative. This should not be construed as suggesting SRA units will a perfect hedge when trading an interregional position, because this is not so today and should not be with PEC.
	Micro slice modelling	**PET**, **AEC**, **Origin**, **Shell Energy**, **EA, EUAA** and **Engie** all requested more modelling of a micro-slice for PEC stage 2. In response: AEMO has completed analysis of settlement as if implemented radially under a micro-slice. AEMO does not have a full set of dispatch constraints to model a micro-slice and has therefore assumed a similar dispatch could be achieved without the equality constraint, instead using generic constraints . AEMO's thinking is, if the analysis shows a micro-slice is

	Category	Questions for consultation
		no better in settlement than PEC as an interconnector, then there is no need to complete full dispatch modelling. Despite the micro-slice option distributing residues that would have otherwise accrued on PEC to the other two interconnectors, the analysis indicates a prevalence of negative residues with the micro-slice option. This is because the micro-slice does not remove the loop flow, and spring washer pricing effects can therefore result in negative residues if prices do not follow the radial order of regions (and flows) in the micro-slice. Given this, difficulties reallocating negative residues, the challenges for implementing negative residue management constraints with this model, and the loss of the direct pricing of trade between NSW and SA that an interconnector implementation provides, the micro-slice option is unfavoured.
	Micro slice implementation	**Shell Energy** contend a micro-slice could be better than PEC as an interconnector and discussed the relevance of the Snowy region abolition, despite the Snowy region being a micro slice between VIC and NSW. **AEC** and **Shell Energy** put forward the proposition that a micro-slice would be better suited to the NEM's regional settlement and dispatch model. The implication seemed to be that in trying to represent PEC as an interconnector as a first best solution, trying to achieve improvements in dispatch, pricing and competition, a worse outcome may occur than implementing something simpler like the micro-slice. In response: Presenting the micro-slice as a "do-nothing" option where existing negative residue management arrangements are untouched, and counter-priced flows are simply constrained, is false. Given the likely prevalence of negative residues even with the micro-slice option, AEMO will have to develop alternative procedures irrespective. There seems to be a misunderstanding where representing PEC as an interconnector, integrated into the SRA, is seen as inconsistent with the current arrangements. Rather than consider this a novel, new approach, this should really be considered the default approach for the treatment of interconnectors and the changing of NEM regional boundaries. The novelty is the power flow and pricing effects created by the new interconnection, and this occurs irrespective of the settlement model used.
	Micro slice implementation	**Origin Energy** considered AEMO should consult on both implementing as an interconnector or as a micro-slice. Both **Shell Energy** and **EUAA** consider the micro-slice implementation for stage 1 should be retained for stage 2 and then further options should be developed in time. By contrast **AGL** does not support the micro slice because they consider it would not reflect the physical market and be inconsistent with rest of NEM. In response: AEMO considers it has consulted on the market integration of PEC and notes further consultation on the treatment of negative residues will commence when the AEMC considers a rule change proposal that AEMO intends to submit after publishing this report.
	Residues from unsold units	**Electranet** stated that a problem with the current process is the treatment of positive inter-regional settlement residues arising from unsold or surrendered units or new interconnector capacity that has not been converted into SRA units. These are paid to the importing TNSP. Fixed proceeds from sold units allows TNSPs to set stable prices for their customers - Electranet was concerned any unsold units could affect them in publishing transmission prices for customers. **Snowy** and **Delta** recommended the SRA continue irrespective of these amendments and that those sold should not be re-auctioned, citing a possible precedent undermining confidence in the SRA. In response: AEMO considers the SRA provides two functions to consumers. It provides market participants an opportunity to hedge, at least to some extent, interregional trade, and also converts a highly variable revenue stream into a relatively fixed and predictable payment for TNSPs. In the Directions Paper AEMO set out two options for the treatment of impacted units if the reallocated IRSR is deducted from unit holders. AEMO has since consulted with the Settlements Residue Committee (SRC) who confirmed a desire to continue the auctions and rely on the relevant provisions in the auction agreements to resolve any consequences from changing the calculation methodology.

Given substantial feedback on the micro-slice dispatch integration model, AEMO has responded in detail to stakeholder concerns on this topic in a dedicated section (section 3).

3 Dispatch integration models

AEMO described in the PEC Market Integration Paper[12] its intention to implement PEC as a separate interconnector linking NSW and SA for the purposes of dispatch (the 'Interconnector' model) in AEMO's dispatch model. The Paper also considered integrating PEC using a 'Micro-slice' model to maintain the current topology of the NEM, and without a direct link between NSW and SA.

As is evident in Table 2, several stakeholders requested a better explanation of why AEMO had rejected the micro-slice model in the Directions Paper. The implication of feedback was that a micro-slice could remove the loop flow, remove negative residues and be better for interregional trading and hedging. Section 3.2 discusses and responds directly to these points. Stakeholders also requested that more analysis be prepared on the micro-slice model. This is included in sections 3.3 and 3.4. To support these sections, section 3.1 firstly describes the two models in detail.

3.1 Description of models

3.1.1 Model definitions

This paper, and the previous market integration and directions papers, consider two main options for implementing PEC stage 2 into NEM market processes:

- The 'interconnector', where PEC is considered as a separate line linking New South Wales and South Australia (left-hand side of Figure 1).
- The 'micro-slice', which inserts a small Victoria region interfaced between the New South Wales and South Australia regions model (right-hand side of Figure 1). This would require consideration of the definitions and boundaries of each adjacent region. AEMO notes the micro-slice option retains the radial (i.e., no loops) network topology of the current network.

Figure 1 Diagram showing the interconnector and micro-slice dispatch integration models

[12] AEMO, PEC Market Integration Paper 2022, Section 3.2: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/pec-market-integration-paper.pdf?la=en.

The definitions above indicate that the core difference between options is in the modelled flow paths between regions[13] and, as a result, differences in settlement. Given the prevalence of negative residues under the interconnector model established in the directions paper, there is often (i.e., when the loop is in aggregate surplus) a need to reallocate this residue to other loop arms. Though this reallocation is not strictly a pre-requisite for an interconnector model, this paper's comparison of interconnector and micro-slice models assumes that the former approach includes reallocation unless stated otherwise.

Further, and as described below, the two options *may* also be associated with different ways of representing the physical system through dispatch constraints.

3.1.2 Why and when would the interconnector model be used?

The interconnector model, combined with reallocation of negative residues when the inter-regional loop is in aggregate deficit, reflects two objectives:

- Allowing inter-regional trade to reflect all of the physical flow pathways
- Minimising the extent of negative residues

Given that the interconnector model recognises all the physical flow pathways, it is logical that this model reflects the physical realities of loop flows as accurately as possible i.e. that the model utilises an 'equality constraint' in dispatch. However, similar to negative residue reallocation, an equality constraint is not strictly a pre-requisite for the interconnector model. Depending on the specific network topography and the strength of policy preferences to deliver the objectives of the interconnector model, it could instead be sufficient to use alternative and more approximate methods of reflecting loop flows (see discussion of the micro-slice model in the next sub-section). In general, however, an interconnector model is appropriate in circumstances where either:

A) More approximate methods of reflecting loop flows than an equality constraint create sub-optimal dispatch or security risks, or;

B) Where the trading or settlement effects of representations that do not recognise certain physical flow paths (NSW-SA in the case of PEC) are undesirable.

Section 3.2 assesses PEC stage 2 against criterion B in detail.

3.1.3 Why and when would the micro-slice model be used?

When loop flows have been physically introduced amongst regions, the micro-slice model reflects an objective of retaining radial flow pathways for trading and settlement purposes, without materially compromising efficient dispatch or power system security. It effectively allocates the flow, and therefore the residues from the new link (NSW-SA in the case of PEC) of an inter-regional loop to the existing links. However, unlike the interconnector model with reallocation of negative residues, the micro-slice model does not specifically target negative residues, meaning there are several plausible outcomes in terms of the sign (+/-) of residues accruing on interconnectors over particular periods. For example, even if the sum of residues on the non-PEC loop arms tends more positive, this does not necessarily imply that any individual arm tends more positive. The mechanics of some of these outcomes are described in the examples in section 3.3.

[13] As market constructs

In general, the micro-slice model is appropriate where both criteria (A) and (B) as described in the previous sub-section (3.1.2) are inverted. In the case of PEC stage 1, the GHD Project Energy Connect Integration Report[14] determined that existing dispatch constraints were largely sufficient, and therefore that dispatch did not need to be altered (for example through an equality constraint) to reflect loop flows, from a security perspective. Further, the SA-NSW interconnection created through PEC stage 1 is of significantly smaller magnitude than other arms of the inter-regional loop and the interconnection is only temporarily implemented before PEC progresses to stage 2. These factors are expected to limit the impact of simplifying physical flows in NEMDE by using a micro-slice model to assume that inter-regional flows follow existing pathways for trading and settlement purposes. Related matters taken into account in adopting a micro-slice for PEC stage 1 include:

- A high-impedance, low-capacity link is being connected in parallel with a larger interconnector (that is, lower impedance, high capacity).
- Power system security can be managed without risking operating the power system outside the technical envelope while allowing the full capacity of the new link to be achieved during periods of high transfer.
- Sharing between parallel links can be described in the central dispatch process.
- As a result of the above, AEMO expects that the central dispatch process can produce efficient price signals that reflect the physical characteristics of the power system.

As an aside, strictly, just as the interconnector model is not defined by the presence of an equality constraint, the micro-slice model is also not defined by the lack of one. In fact, to facilitate comparison between models, the analysis methodology described in section 3.3 assumes equality constraints in both models and therefore that the models have equivalent representation of physical power flows.

3.2 Response to key stakeholder feedback points

3.2.1 Would a radial implementation remove the loop flow and negative residues?

If a region is implemented as a micro slice as per the right-hand side of Figure 1, the representation of the regions in dispatch is effectively radial. This will be the case for PEC stage 1 and would be the case for stage 2 if it were implemented as a micro-slice. The micro-slice only removes the transmission loop in settlement and does not remove the physical loop flows.

The spring washer pricing effect means that prices do not necessarily follow the same order as the radial representation (i.e. prices do not necessarily increase in the direction of flow), even if settlement is modelled radially. Fundamentally, the micro-slice model does not change prices compared to the interconnector model. This means that the region with the transmission loop running *through* it (VIC, in the context of PEC) may be lowest or highest if there is a constraint on one of the interconnectors, or within either of the adjacent regions (NSW or SA).

Assuming the main transmission constraints are at the interconnectors, or constraints prevail in NSW or SA, the effect of implementing a region as a slice *between* two regions that are themselves directly interconnected is to

[14] GHD, Project Energy Connect Integration Report, published May 2023: https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2022/pec-market-integration-paper/technical-report---phase-1-project-energy-connect-integration.pdf?la=en

subsume the settlement of the new circuits into the settlement of the other two interconnectors. As explained in section 3.1.3 and examined through modelling in section 3.3, this would generally transfer the settlement residues on PEC (if it were instead an interconnector in dispatch) to the existing interconnectors as either a credit or debit on the settlement residues. This *may* make residues on existing (radial) interconnectors more positive under a micro-slice model, but it also may not. The two radial interconnectors are commonly expected to accumulate negative residues on one arm, and positive residues on the other, as per the two examples in section 3.3.1. This expectation will be validated in section 3.3.

If there is a constraint within the region that is the middle region in the radial representation (VIC in the case of PEC) the highest and lowest local prices in the spring washer will be within that region and whether the regional price is the highest or lowest in the radial representation will depend on the choice of node for calculation of the RRP. This would, in turn, influence whether negative residues accrue on either interconnector.

Clearly, in a variety of circumstances, negative residues remain likely with a micro-slice. AEMO therefore concludes that a radial implementation of PEC through a micro-slice does not remove transmission loop flows physically, and it does not remove the resultant negative interregional settlement residues. This conclusion will be supported by section 3.3 which presents modelling that quantifies the frequency and magnitude of negative residues.

A less obvious problem with a micro-slice model is a potential for challenges to managing negative settlement residues in dispatch with two interconnectors and yet three physical AC interconnections. While AEMO may be able to identify occasions when it should impose negative residue constraints (for example, when VIC-SA and VIC-NSW in aggregate are not generating a settlement surplus), it would likely be increasingly complex to effectively clamp the physical interconnection.

3.2.1.1 Snowy region discussion and applicability to PEC

In submission to the Directions Paper Shell Energy[15] states:

- “NEM has already operated under a loop flow model during the time in which the Snowy region existed”;
- “the accumulation of negative settlement residues and the distortionary impact on pricing and dispatch as a result of the loop flow between the three regions, was one of the issues that led to the rule that eventually abolished the Snowy region”; and
- “abolition of the Snowy region resulted in the inclusion in the NEM dispatch engine of what was a significantly sized loop flow path, exceeding PEC, as effectively a slice of the Vic to NSW bi-directional flow paths without compromising secure dispatch outcomes”.

For these reasons Shell Energy:

- “queries the need to reintroduce the known deficiencies of a network loop flow model into the NEM when there is a potential alternative in the form of implementing a micro-slice model.”

It is worth investigating these three points.

Regarding the first point, the NEM did not operate under a loop flow model (equivalent to what is being proposed with PEC being modelled as a new interconnector in dispatch). Instead, when the Snowy region existed, the NEM

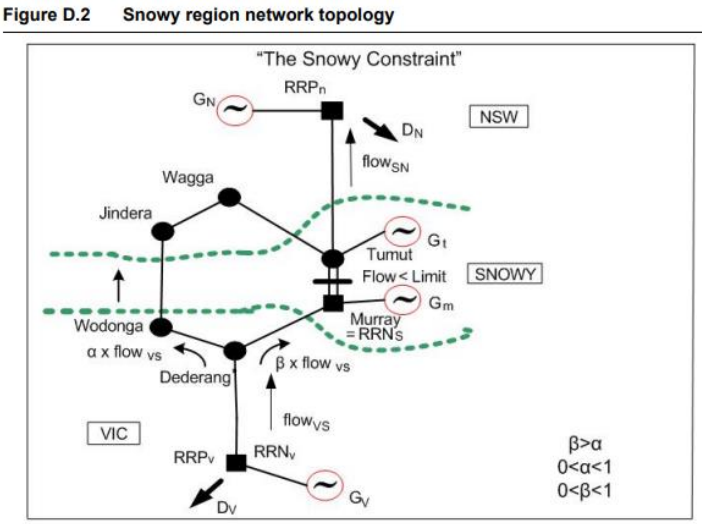
[15] Shell Energy submission to AEMO Directions Paper, p2

operated as a radial representation of the network running northwards VIC – Snowy – NSW, with Snowy in *between* the other two regions, and a transmission loop *straddling* the three regions (Figure 2)

The Snowy region was implemented as a layer or slice between the NSW and VIC regions. The Snowy RRP was calculated with reference to the Murray node and the layer extended from between Buronga – Red Cliffs in the west, Wodonga – Jindera and then widening to include both nodes Murray and Tumut, with Murray connecting into VIC and Tumut into NSW.

Regarding Shell's second point, understanding that Snowy region had a loop running *through* it because it was *between* VIC-NSW rather than part of a three-region interconnection in dispatch, allows us to investigate some of the reasons why the Snowy region was abolished. Figure 2 is sourced from the AEMC final determination to abolish the Snowy region [16]. In Appendix D of this determination, the AEMC discuss the Snowy constraint between Murray and Tumut.

Figure 2 Snowy region constraint as presented in the abolish Snowy region Final Determination



Appendix D highlights that, with power flowing northwards, the lowest local price[17] of electricity in the loop running from Murray to Dederang to Tumut is at Murray, increasing through Dederang and to Tumut. With the Dederang local price close to the VIC RRP, and yet power flow northward, counter price flows tended to occur and negative settlement residues would accrue across the VIC-SNOWY interconnector in the direction of NSW. This demonstrates the general point that the order of the RRPs was often not following the order of the radial representation.

When power is flowing southwards in the figure, the lowest local price of electricity in the loop running from Tumut to Dederang to Murray is at Tumut, increasing through Dederang and to Murray. With the Dederang shadow price

[16] Abolition of Snowy Region, Rule Determination, AEMC, 30 August 2007. Appendix D, p206.

[17] In the NEM dispatch model, this is calculated as the RRP adjusted by the sum product of the marginal value and coefficient of any constraint a dispatch variable is included. The local price is presented energy the Electricity Market Management System EMMS. A dispatchable unit will need to offer a price below the local price to be dispatched.

equivalent to the VIC RRP, and yet power flow southward, counter price flows tended to occur and negative settlement residues would accrue across the VIC-SNOWY interconnector in the direction to VIC.

The AEMC was not comfortable with the either the bidding and dispatch incentives caused by this dynamic, nor the negative settlement residues to which it noted affected the usefulness of interregional settlement residue units as a mechanism to hedge trading interregional financial contracts.

The abolition of the Snowy region set the region boundary between the VIC-NSW regions at the Murray-Tumut constraint. The region boundary was now placed at the location of an enduring transmission constraint, whereas beforehand the enduring transmission constraint was otherwise within the Snowy region. The AEMC considered this was a more appropriate location for the region boundary. As a result of the change, the loop affected only two regions and not three.

Regarding Shell's third point, it is true that a transmission loop became part of the VIC to NSW interconnector without compromising secure dispatch outcomes. Though AEMO would of course need to thoroughly assess the security implications if it were to implement PEC through a micro-slice (possibly without an equality constraint), AEMO considers that Shell is fair to suggest that the size of PEC stage 2 alone should not preclude the micro-slice model from consideration. Nonetheless, the observation that micro-slices have historically been applied to "significantly sized loop flow paths" is true, but it was abolished in favour of a region boundary established at an enduring transmission constraint bisecting a loop, where the loop only affects two regions. Therefore, AEMO considers that the comment does not support the micro-slice model above the interconnector model. concerned.

In the context of considering options for PEC, recreating a Snowy region would be akin to implementing stage 2 as a VIC micro-slice. Abolishing Snowy, would be akin to abolishing VIC by either merging it into SA (or NSW), or splitting VIC into two and merging each section into SA and NSW respectively.

Implementing PEC as an interconnector in dispatch is therefore not reintroducing "the known deficiencies of a network loop flow model into the NEM". In contrast the "potential alternative in the form of implementing a micro-slice model" is more likely to reintroduce deficiencies, as seen with the Snowy region.

3.2.2 Would a micro slice be better for interregional trading, and the SRA?

In submission to the Directions Paper, both AFMA and Pacific Energy Trading posited the idea that a micro-slice representation of the three regions (NSW, SA and VIC) would better support interregional hedging than implementing a new interconnector. This section responds directly to this feedback. This response is supported by the analysis in section 3.4.

Implementing a radial representation would mean that the NSW-SA interconnector would no longer be able to generate a settlement residue and for this to be auctioned at the SRA. For market participants this means the settlement residue is unavailable to the SRA to support any interregional derivative trading between NSW and SA. From a first principles assessment, by including PEC in the SRA as two directional interconnectors (NSW-SA and SA-NSW), this makes available a product that can support participants trading interregionally between these two regions. The micro-slice, in contrast, cannot do this.

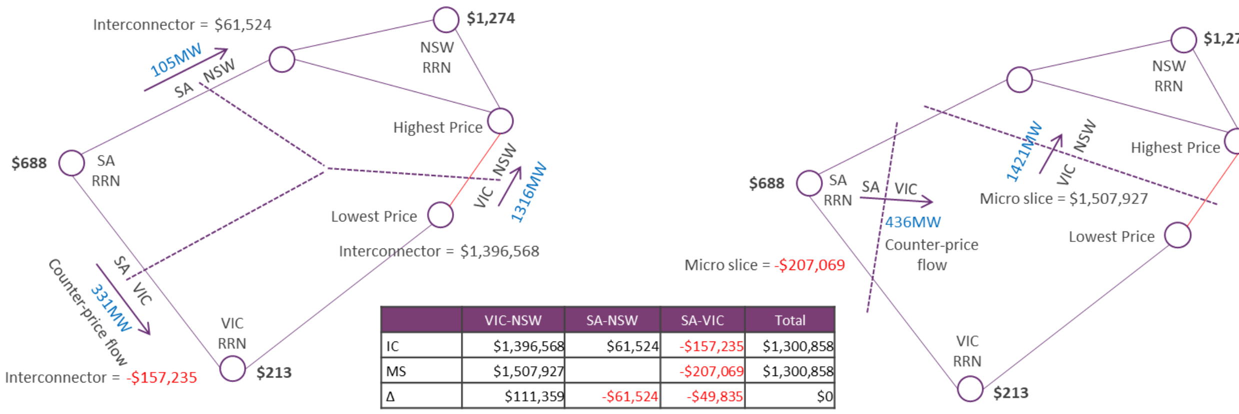
AEMO accepts that implementing PEC as an interconnector and allowing counter price flows when aggregate settlement is in surplus will result in periods where there is no settlement residue to support a price difference between two regions, thus exposing participants to the price difference[18].

For example, consider a physical participant in the lower priced region that has sold a derivative in the other region and purchased units at the SRA. Clearly during these periods, the SRA units will not pay the difference between the two regional prices, (because there is counter-price flow), and therefore will have no hedging value. However, by being part of efficient dispatch and with a settlement surplus in aggregate around the loop, and if this settlement surplus is preserved for the SRA unit holders by not being used to fund negative residues, AEMO considers that the loss of effectiveness of the counter price flow as a hedge is more than offset by the hedging value provided to the other interconnector where the price difference and, or flow is larger and where there are greater interregional settlement residues.

Figure 3 presents this dynamic for a transmission constraint, V>>N-NIL_HA, which aims to avoid Murray to Upper Tumut (65) overload on the trip of Murray to Lower Tumut (66) circuit. It shows interconnector (left) and micro-slice (right) representations and the differences in settlement outcomes between the two. The values in the figure are sampled from a specific interval in the ACIL Allen modelling. The spring washer effect is evident in the example, with the lowest nodal price at Murray in VIC and highest at Tumut in NSW, either side of the constrained line. The VIC RRP is lowest, increasing through SA (applicable to the interconnector model only), and then highest in NSW.

The gross settlement between the two approaches is the same (as is explained in section 3.3.1) but flows on PEC now result in a credit and debit on the other two interconnectors. VIC-NSW increases settlement residues available for the SRA by $111,359 and VIC-SA increases negative residues by $49,835. Absent any reallocation of negative residues, if it is assumed that the proceeds from the SRA equal the residues, then overall NSW consumers “gain” and VIC consumers “lose” $49,835 through adjustments to TUOS between the models.

Figure 3 Comparison of settlements between interconnector and micro-slice models



	VIC-NSW	SA-NSW	SA-VIC	Total
IC	$1,396,568	$61,524	-$157,235	$1,300,858
MS	$1,507,927		-$207,069	$1,300,858
Δ	$111,359	-$61,524	-$49,835	$0

Under both models, negative settlement residues accrue, but they are larger in the radial representation using the micro-slice implementation because of the credit to VIC-NSW and corresponding debit on the other interconnector. In this example, the flow on SA-NSW (at $61,524 in the interconnector model) is repriced,

[18] Having said this, AEMO considers that a historically comparable level of ‘firmness’ of SRAs will still be available if PEC is introduced using the interconnector model in dispatch. This is discussed further in section 3.4.

crediting $111,359 to VIC-NSW, and debiting SA-VIC $49,835. This inflates the value of the SRA as compared to the interconnector option, through increased negative interregional settlement residues. Although settlement is in surplus across the two interconnectors, and the underlying power flows and prices should represent efficient dispatch, this example raises the question as to whether the increased negative interregional settlement residues on SA-VIC should be allowed in dispatch.

Under the interconnector model, negative settlement residues are reallocated to the NSW TNSP, in being the importing TNSP of VIC-NSW and SA-NSW. In principle, this could also be done under the micro-slice model and, arguably, this is needed even more so than under the interconnector model due to the increased negative interregional settlement residues that would otherwise be payable by VIC consumers. It should be recognised that even if a reallocation is performed, with $207,069 payable by the NSW TNSP and net settlement remaining at $1.3M, gross settlement (through the different transactions under the SRA and payable by importing TNSPs) remains higher than the interconnector model. With a reallocation of negative residues, if you assume the proceeds from the SRA equal the residues, then one can assume overall NSW consumers would be indifferent, but it is questionable whether increasing the SRA distributions by paying negative residues is sensible, nor consistent with the idea behind the SRA which is to auction the economic surplus of the interconnection between regions. This section does not intend to infer that these results are general, as they are drawn from an arbitrarily sampled interval, but rather to demonstrate that they are possible.

Returning to the discussion on interregional hedging, and looking at the example of a physical participant in the lower priced region (i.e. VIC) that has sold a derivative in the other region (i.e. SA) and purchased units at the SRA (i.e. VIC-SA), it is clear the radial representation offers no benefit over the interconnector option. In either model there is no distribution of cash to unit holders. Irrespective of the dispatch model, traders at the SRA will need to assess the spring washer effect, and the likelihood of counter priced flows on the relevant interconnector they are trading. This may be easier for traders to do if the dispatch implementation model better reflects the underlying power system.

In summary, AEMO is not persuaded that the micro-slice implementation option would better support interregional trading and hedging at the SRA, nor is the micro-slice a do-nothing option that simplifies trading.

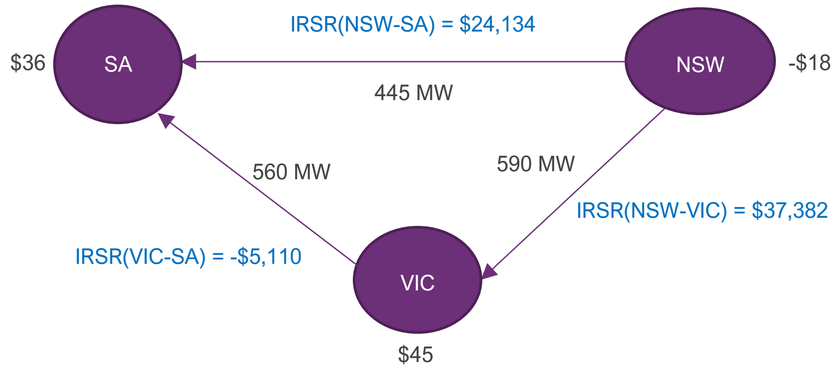
3.3 Micro-slice settlement analysis

3.3.1 Analysis methodology

AEMO used ACIL Allen's results described in the Directions Paper to model a micro-slice approach to settlement. This involved adjusting flows on NSW-VIC and VIC-SA to reflect the flows on PEC, such that it could be assumed that no power flows between NSW and SA without flowing through VIC. Three examples of the mechanics of this adjustment are described in detail in appendix 2 of AEMO's Directions Paper. The first two of these examples are condensed and repeated below.

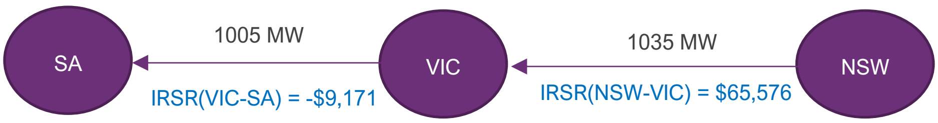
Example 1: VIC operating as transitory import-export region

<u>Interconnector</u>



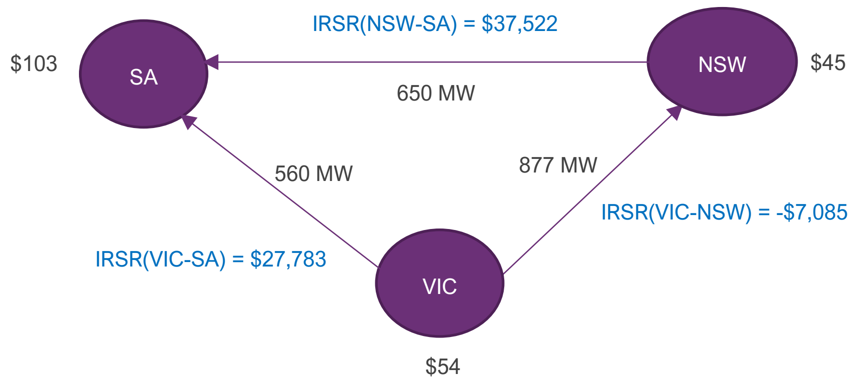
In this example, VIC-SA and NSW-SA are both flowing towards SA. This would be represented in a micro-slice by a single increased flow on VIC-SA as sum of the VIC-SA and the NSW-SA flowing to SA, and a single increased flow on NSW-VIC as the sum of NSW-VIC and NSW-SA.

Micro-slice



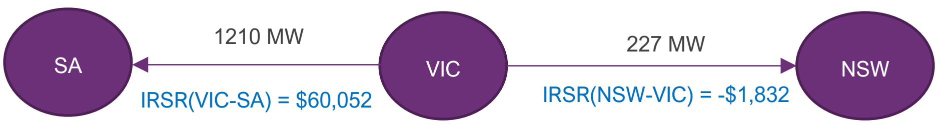
Example 2: NSW is operating as a transitory import-export region

Interconnector



This example demonstrates the function of the micro-slice when flow on PEC (NSW-SA) is flowing in the opposite direction to one of the other interconnectors (VIC-NSW). In this case the negative IRSR accrued on VIC-NSW is decreased as the counter-priced flow on VIC-NSW is offset by the flow on NSW-SA.

Micro-slice



NEM regions are market constructs. Compared to the interconnector approach, the micro-slice modelling approach redefined the path of PEC in terms of its flow between these regions. However, the modelling assumed there were no differences in prices, constraints or *physical* flows compared to the interconnector approach. The objective of the analysis was to compare settlement outcomes under the interconnector and micro-slice models, with a particular focus on the extent of negative residues in the micro-slice model. As is evident in the examples above, there is no difference in the net settlement residue aggregated around the whole loop between the two models.

Section 3.3.2 describes AEMO's rationale for its approach to analysis.

3.3.2 Rationale for methodology

As described in section 3.1, the two dispatch integration models considered by this paper differ in terms of settlement and potentially differ in terms of the accuracy of their representation of the physical power system. Differences across either of these dimensions could change outcomes for participants or influence the overall economic efficiency of the chosen integration model.

As is also described in section 3.1, an interconnector model typically involves defining an equality constraint in dispatch. An equality constraint captures a physical phenomenon which a micro-slice model either does not capture, or it approximates the phenomenon through other methods. In principle, it would be possible to carry out an exercise of approximating loop flows through other methods and modelling the extent to which including an equality constraint (typically associated with the interconnector model) is superior to approximations (typical of the micro-slice model) in terms of representing the physical power system.

Despite this, AEMO's quantitative analysis approach assumes that the micro-slice model results in the same representation of the physical power system as the interconnector model. AEMO considers that its approach is reasonable for modelling purposes because:

- The presence or absence of an equality constraint is not strictly a defining characteristic of either model.
- It enables all conditions to remain the same, and to compare only different approaches to settlement in terms of market outcomes and efficiency.
- It is equivalent to assuming an upper bound on how well the micro-slice reflects the physical system. This may be helpful if the interconnector model is preferred on settlement grounds[19]. This is because there would then be no need for modelling to determine the extent to which the interconnector model is superior to the micro-slice on the grounds of physical representation – there is nothing such modelling could show to result in a preference for a micro-slice approach.

3.3.3 Settlement analysis results

How to interpret results

As described in section 3.1, the interconnector model manages the real-time impacts of negative residues in cases where the inter-regional loop is in aggregate surplus by allocating these residues to other arms of the loop

[19] This possibility will be tested in section 3.3.3.

and charging consumers for these residues over a longer timeframe[20]. In principle, when applied to the NSW-SA-VIC loop, a micro-slice model will, on average over time, increase the surplus on the non-PEC arms of the loop. This is because, as was established in ACIL Allen's modelling, PEC is expected to accrue generally positive residues, so allocating its flow to other arms effectively allocates its residues as well. In a different way to the interconnector model, this also reduces the negative residues created by loop flows, but it does not remove them. This section quantifies the impact of the micro-slice on residues, using the modelling methodology described in section 3.3.

Micro-slice results have 'approach' labelled 'MS' in the figures below. They are compared to a baseline where inter-regional flow *can* occur directly between NSW and SA. This baseline corresponds to results with 'approach' labelled 'IC' in the figures below. Please note that results labelled 'IC' do not factor in the reallocation of negative residues to other arms of the loop as would occur under this dispatch integration model in practice. The purpose of presenting results in this fashion is to show the extent to which the micro-slice model impacts negative residues[21]. Readers can largely assume that negative residues in 'IC' cases shown below would not be problematic in practice because, to the extent they arise when the inter-regional loop is in aggregate surplus, they would be removed by reallocation to other arms.

Analysis assumptions

The quantitative analysis described in this section utilises the results of ACIL Allen's modelling of the settlement effects of PEC, and therefore inherits the same assumptions as this modelling. Further, AEMO highlights the following about how it has processed these results:

- For simplicity, results are shown only for a single phase-shifting transformer (PST) angle scenario (-6.73°). This scenario is 'PST1' in ACIL Allen's report. The findings hold across all PST scenarios.
- ACIL Allen's modelling saw negative residues on aggregate around the inter-regional loop 2-6% of the time (depending on PST setting and the modelled year[22]), under a modelling assumption that there was no process for negative residue management (NRM) or 'clamping'. As is discussed in the Directions Paper, these cases are conceptually similar to negative residue occurrences in the current NEM, and some form of NRM may be needed to manage these cases. The figures presented in this section do include this small proportion of cases with aggregate loop deficit. Arguably, these cases reflect different issues to the core challenges described in this paper and could be filtered out of the results set. Such results are included in appendix 0 for completeness, where each of figures are repeated with filtering applied to remove cases of aggregate loop deficit.

The micro-slice model generally increased residues on the two existing interconnectors compared to the baseline

As described earlier in this section and in section 3.3, presuming equivalent representation of the physical system,

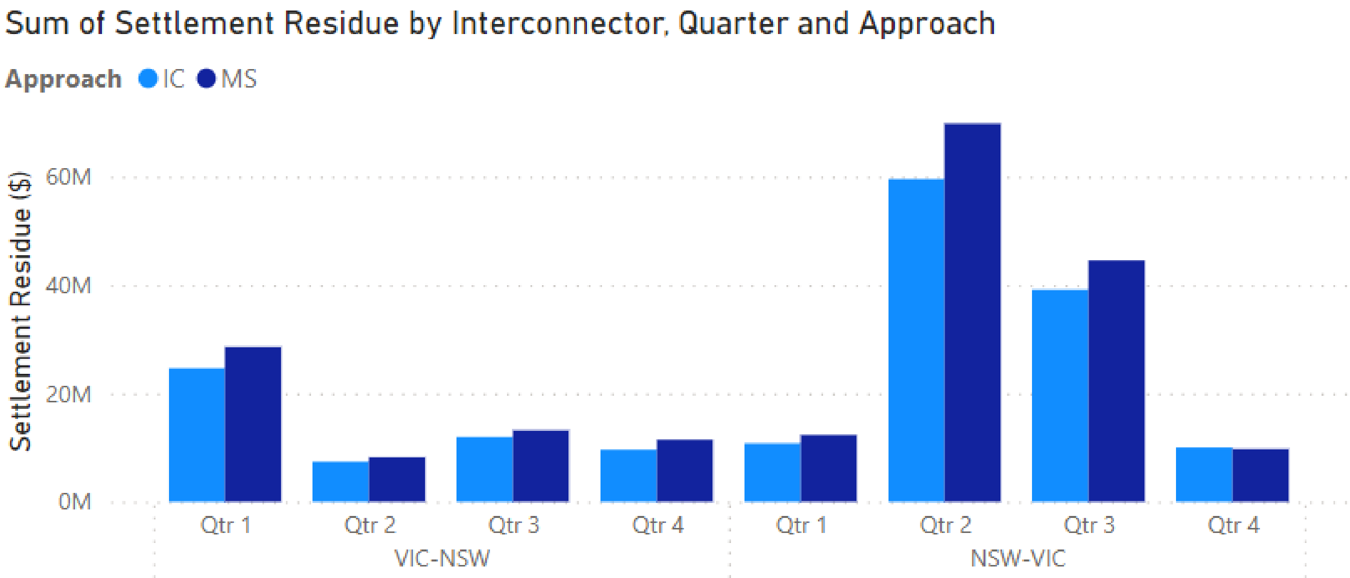
[20] Through either deduction from proceeds to SRA unit holders or TuoS charges; options described in detail in the Directions Paper

[21] An alternative results presentation would compare micro-slice results to loop results *after* reallocation in the loop model. This would not be particularly insightful, as reallocation sets negative residues to zero in most cases in the loop approach – something that does not need modelling to demonstrate. Presenting results *before* reallocation gives an indication of how much reallocation would occur in the interconnector dispatch model. The difference between loop results before reallocation and micro-slice results is therefore a measure of how much the micro-slice model has impacted residues relative to the loop model.

[22] ACIL Allen modelled sample years 2027 - 2030

the micro-slice model does not change the aggregate surplus around the loop compared to the interconnector model. Therefore, by effectively distributing the (net positive) residue on PEC to other arms of the loop, it was expected that results would show a net positive change in residue on other interconnectors. This was indeed the observation in many instances. For example, Figure 4 shows how, in 2027, the micro-slice approach increased NSW-VIC surplus compared to the interconnector approach in both flow directions.

Figure 4 Settlement residue for both VIC-NSW directional interconnectors, 2027



Like Figure 4, Figure 5 shows residues tending more positive under the micro-slice than under the baseline of the interconnector model. Figure 5 highlights that, strictly, this trend is observed due to the aggregation over time of increases in negative residues and even larger increases in positive residues.

In Figure 5, cumulative negative residues[23] (thin, solid bars) are of greater magnitude under the micro-slice than under the interconnector model. However, net residues (wide, translucent bars) are more positive, indicating that cumulative positive residues increased in magnitude to an even greater extent than negative residues.

[23] i.e. the sum of only negative residues, prior to any netting from positive residues

Figure 5 Quarterly aggregate settlement residue for both VIC-SA directional interconnectors, 2027-2030

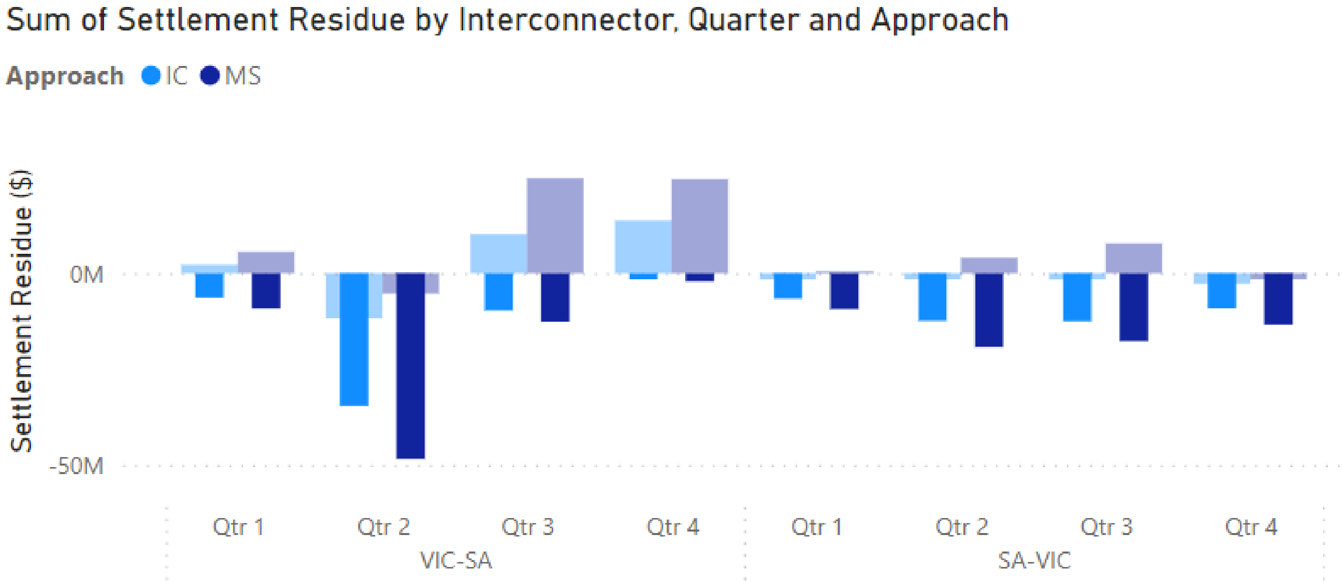
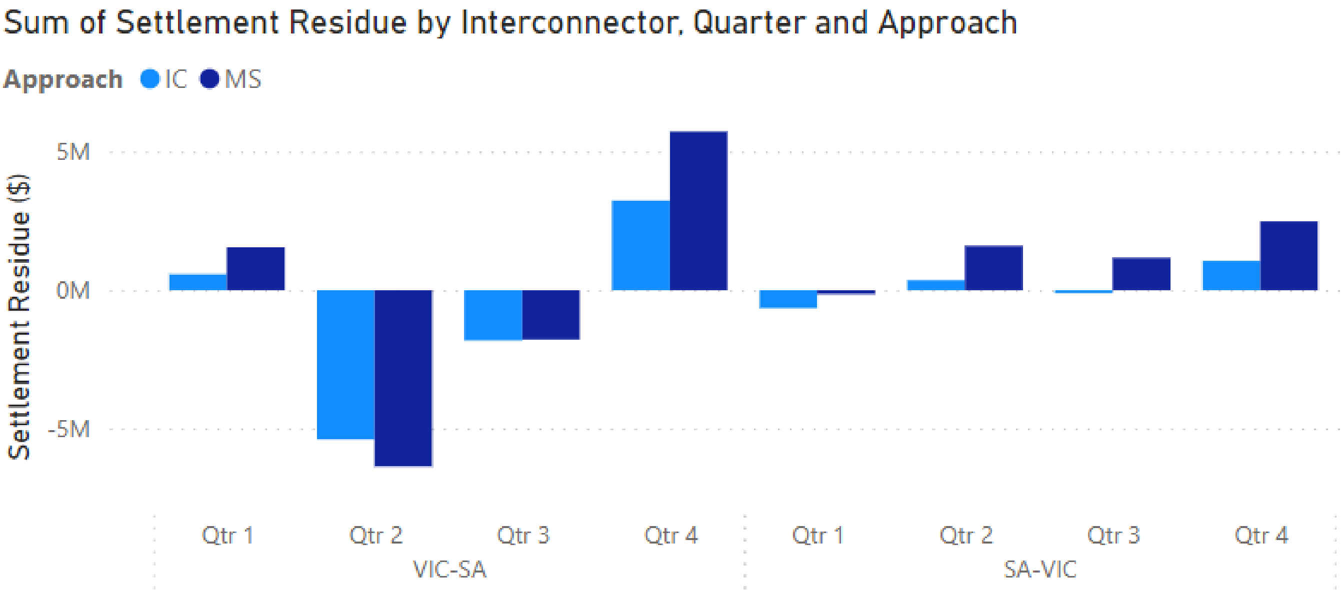


Figure 5 shows the dynamic that was described qualitatively in section 3.1.2 ('Why and when would the micro-slice model be used?') and through the worked examples in section 3.3. It shows the aggregation over time of cases like 3.3 example 1, where negative residues increased on VIC-SA, with cases like 3.3 example 2 where there were larger magnitude increases in positive residues on VIC-SA.

There were instances of interconnector deficit over whole quarters under the modelled micro-slice approach

In some results, the modelled micro-slice affected the residue accruing on an interconnector so as to change its net quarterly value from negative (deficit) to positive (surplus) (for example, SA-VIC Q3 in Figure 6). However, in other cases, even though it made net residues less negative, it did not make them positive (for example, SA-VIC Q1 in Figure 6). There were also cases where net residues under the micro-slice were more negative than in the baseline (for example, VIC-SA Q2 in Figure 6). Though the modelled micro-slice was more likely than not to make residues tend more positive (or less negative), it is clear from these results that it is inconsistent in this effect, and deficit on particular interconnectors should be expected over some quarters under a micro-slice approach. This makes sense conceptually because the objective of a micro-slice (described in section 3.1.1) approach is to change assumed inter-regional flow paths for settlement purposes. As shown in earlier results, this may help to reduce negative residues, but it does not target this outcome and therefore should not be expected to avoid negative residues to nearly the same extent as an interconnector dispatch integration model (with reallocation).

Figure 6 Settlement residue for both VIC-SA directional interconnectors, 2027



Deficit over whole quarters is a potentially problematic outcome because it indicates insufficient positive residues accruing on interconnectors to fund payments for negative residues. This outcome is not observed in practice in the current NEM. This challenge associated with the micro-slice model could perhaps be resolved through a novel approach to reallocating residues. However, such an approach would cause settlement to depart from physical flows. If reallocation were substantial, the intent of the micro-slice model would arguably no longer be achieved.

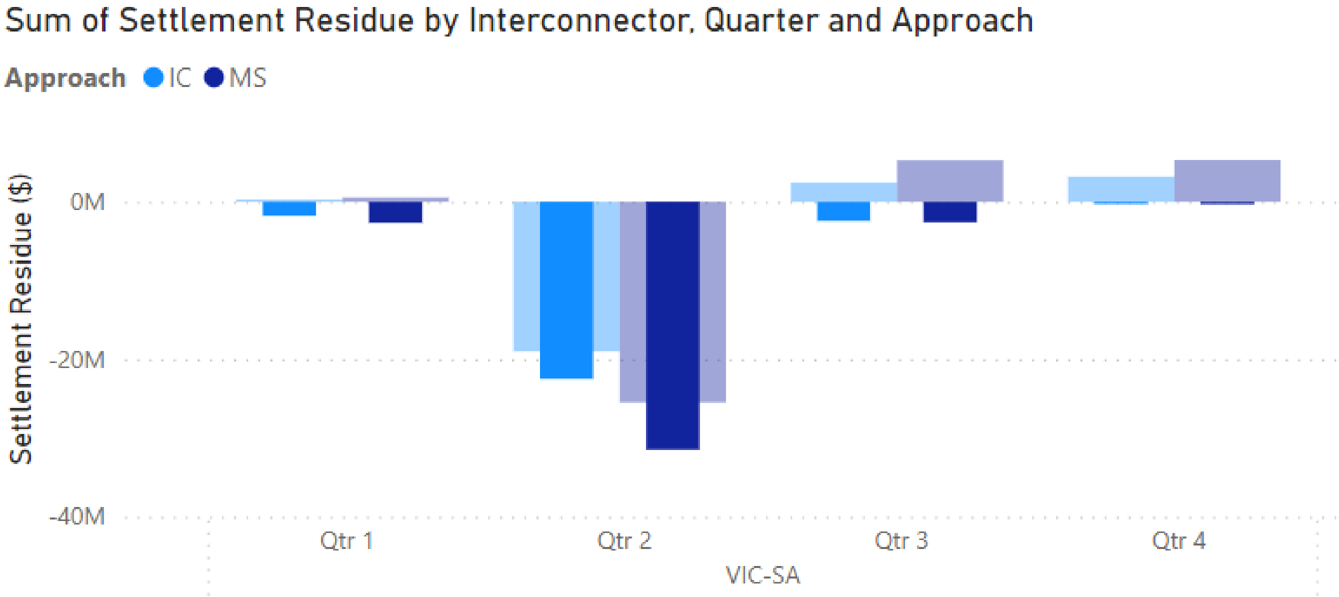
Specific modelling results may suggest further risks associated with the micro-slice approach

The points below describe additional modelling results aimed to provide further insight into cashflow dynamics revealed by the modelling. AEMO is not treating these specific outcomes as definitive given modelling was a proof-of-concept exercise rather than a forecasting one. Further, AEMO largely leaves assessment of the financial implications of these findings for different participants up to others. Despite these caveats, AEMO considers that the results below do infer some plausible risks associated with the micro-slice model. They show additional ways that a micro-slice may be problematic in terms of the magnitude, frequency and location of negative residues.

- **Quarterly deficits and cumulative negative residues are large at times for particular interconnectors under the modelled micro-slice.** For example, Figure 7 shows the largest single quarter of deficit in the modelled sample for a single interconnector, which occurred in Q2 2028 in VIC-SA. The net residues (wide, translucent bars) are -$25.5 million while the cumulative negative residues (thin, solid bars) are -$31.5 million. For reference, aggregate cumulative negative residues across all NEM interconnectors has been approximately $10 million in recent quarters[24]. Quarters with large deficits are an outcome broadly consistent with the finding described in the directions paper that the introduction of loop flows in dispatch is expected to significantly increase negative residues in dollar terms.

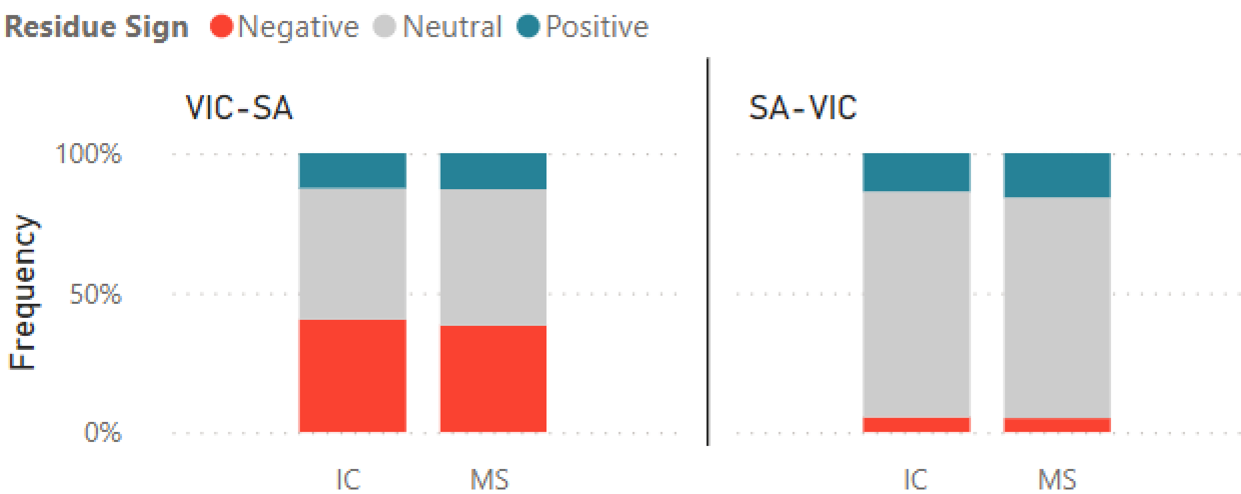
[24] As caveated, this comparison is indicative only, since net residues in practice are outcomes of a more sophisticated dispatch process than was modelled by ACIL Allen.

Figure 7 Settlement residue on VIC-SA, 2028



- **In some cases, the frequency of negative residues is very high under the modelled micro-slice.** The high frequency of negative residues under an interconnector model (prior to reallocation) was established in the Directions Paper. However, this modelling shows that, in some cases, the micro-slice may not materially reduce the incidence of negative residues compared to the baseline. For example, Figure 8 shows that VIC-SA accrued negative residues 40% of the time under the interconnector baseline and 38% of the time under the micro-slice in Q2 2028. This was the highest frequency quarter for any interconnector in the sample (in addition to being the largest single quarter of deficit as per Figure 7). For reference, negative residues typically occur <10% of the time on VIC-SA in practice.

Figure 8 Frequency of residues with various signs[25] for both VIC-SA directional interconnectors, Q2 2028



- In the current NEM, TNSPs may be accountable for the negative residues associated with one (QLD, SA, TAS TNSPs) or two (NSW, VIC TNSP) directional interconnectors. This section has already established that it is

[25] Note the presence of 'neutral' residues is an artefact of modelling that ignores inter-regional losses.

likely that certain directional interconnectors will be in deficit over certain quarters under the micro-slice. An additional nuance to this finding is that ***VIC-SA specifically* sees quarters of substantial settlement deficit (Figure 7) caused by frequent negative residues (Figure 8).** This may be significant because, unlike in other regions, the SA TNSP is accountable for negative residues on only one directional interconnector. Therefore, it cannot draw from other interconnectors or jointly consider cashflow risks across multiple interconnectors in determining how to manage negative residues. AEMO highlights this result for the awareness of readers, with the understanding that its significance will depend on the specific financial arrangements of the TNSP in SA.

3.4 Discussion on interregional trade, hedging value, and competition

3.4.1 Rationale for discussion

While section 3.3 focussed on the settlement differences between dispatch integration models with particular emphasis on negative residues, stakeholder submissions also highlighted the value of considering the introduction of PEC, and the dispatch integration models, from a trading perspective. This was described in section 3.2.2. In particular, some stakeholders[26] posited the idea that a micro-slice representation of the three regions would better support interregional hedging, while others[27] have requested AEMO consider the effect of a new interconnector on interregional trading and interregional hedging using SRA units.

AEMO recognises that, especially in quarters soon after the introduction of PEC, it may be challenging for traders to estimate the value of units in settlement residue auctions. However, of itself, this does not mean that the firmness or hedging value (defined formally in section 3.4.5) of SRA units will reduce (unless the negative residues are deducted from positive residues available through SRA unit payouts).

Given this context, and in response to stakeholder requests, AEMO has developed metrics for analysis of the “typical” hedging value of units from the SRA and compared historical values to the modelled outcomes from the ACIL Allen results. This analysis is presented in section 3.4.5, supported by discussion of foundational hedging concepts in earlier sub-sections. Section 3.4.6 ultimately links the analysis to the choice of dispatch integration model for PEC.

3.4.2 What is hedging?

In the NEM wholesale electricity market, rather than retailers (Market Customers) directly buying electricity from generators (Market Generators), AEMO pays all generators, and retailers all pay AEMO, the spot price. Spot prices in the NEM are changeable and retailers cannot offer a residential customer a fixed price retail tariff and be exposed to spot prices that are higher than they estimate in setting the tariff. Generators cannot pay fixed debt instalments, fund operating costs, nor raise funds to invest if they cannot smooth their cashflows. Both retailers and generators need to “hedge” cashflows, manage working capital and avoid going insolvent. It is these diametrically opposing risks that encourage retailers and generators to buy and sell (respectively) electricity derivative “hedge” contracts.

The following table outlines a basic electricity “swap” where a retailer buys a swap on the NSW spot price. If a retailer buys a swap it agrees to pay the “fixed” price it paid for it, in return for receiving the “floating” spot price.

[26] AFMA and Pacific Energy Trading in response to the Directions Paper

[27] Snowy in response to the Directions Paper, AEC in response to the consultation paper

These payments, when coupled with AEMO settlements at the "floating" spot price, leave the generator and the retailer with the "fixed" price.

Table 3 Retailer and generator swap, single region (NSW)

	Retailer	Generator	Notes
AEMO	Pays ${}_{\text{floating}}$NSW	Rec ${}_{\text{floating}}$NSW	
Swap	Rec ${}_{\text{floating}}$NSW	Pays ${}_{\text{floating}}$NSW	
	Pays ${}_{\text{fixed}}$NSW	Rec ${}_{\text{fixed}}$NSW	Floating nets out, gen and retailer left with ${}_{\text{fixed}}$NSW
Costs		Pays fuel	
Profit	Tariff - ${}_{\text{fixed}}$NSW	${}_{\text{fixed}}$NSW - Fuel	

3.4.3 What is interregional price risk?

The NEM is five regions with regional demand requirements, local transmission limits represented as constraints oriented to each region's reference node, and interconnectors between regional reference nodes independently modelled in dispatch. This results in a regional reference price (RRP) for each region, dispatched flows for interconnectors and the calculation of interregional settlement residues.

The interconnector flow from one region to another is a surplus of generation in one region being settled at the exporting region's price, supplying customers who are paying the importing region price. With the customers in the importing region paying the higher price and the generators in the exporting region receiving a lower price, in settlements there is surplus cash remaining with AEMO.

Recognising the need for participants to "cashflow hedge" generation and retail load (as discussed in the previous section), Table 4 assumes the generator in the exporting region (NSW) sells a derivative to a retailer in the importing region (SA). In the table, it is evident that unlike Table 3 above, for the generator the floating does not net out and if the floating SA spot price is higher than NSW it can make a loss.

Table 4 Retailer and generator swap, different regions (NSW and SA), no SRA

	Retailer	Generator
AEMO	Pays ${}_{\text{floating}}$SA	Rec ${}_{\text{floating}}$NSW
Swap	Rec ${}_{\text{floating}}$SA	Pays ${}_{\text{floating}}$SA
	Pays ${}_{\text{fixed}}$SA	Rec ${}_{\text{fixed}}$SA
Costs		Pays fuel
Profit	Tariff - ${}_{\text{fixed}}$SA	${}_{\text{fixed}}$SA – Fuel + (${}_{\text{floating}}$NSW – ${}_{\text{floating}}$SA)

Legend for tables in this section: 'Rec' = 'receives', ${}_{\text{floating}}$SA = 'the floating RRP in SA'

As can be seen in the table a retailer has bought a swap on the SA spot price. If a retailer buys a swap it agrees to pay the "fixed" price it paid for it, in return for receiving the "floating" spot price. The retailer is hedged because its exposure to the floating SA spot price is no more, and it simply pays the fixed price of the swap. The generator is not hedged because it must pay the floating SA spot price and yet it only receives the floating NSW spot price, leaving it to fund any difference in settlements if the NSW spot price is lower than the SA spot price.

3.4.4 What is interregional hedging using SRA units?

With interconnectors between regional reference nodes independently modelled in dispatch, giving target flows for interconnectors and regional reference prices for each region at each notional end of the interconnectors, AEMO can calculate interregional settlement residues adjusted for transmission losses. These interregional settlement residues are distributed to trader participants that have acquired units in the SRA. Units are auctioned in twelve tranches on a quarterly basis ahead of the quarter. Table 5 extends the example in Table 4 to include the hedging strategy of purchasing a NSW to SA SRA unit, and obtaining the matching entitlement to NSW to SA interregional settlement residues, which is the floating SA price less the floating NSW price[28].

In this example the generator is no longer exposed to the floating SA spot price if the interregional settlement residue distribution paid out is the full floating SA price less the floating NSW price. Hedging this way carries the cost of buying an SRA unit and therefore a generator may consider this if the cost of the NSW to SA exceeds the difference between the price of selling an NSW swap as opposed to selling an SA swap. Of course, if the NSW swap price exceeds the SA swap, then there is no need for the generator to sell an SA swap or buy the SRA unit.

Table 5 Retailer and generator swap, different regions (NSW and SA), with SRA

	Retailer	Generator
AEMO	Pays $_{\text{floating}}$SA	Rec $_{\text{floating}}$NSW
Swap	Rec $_{\text{floating}}$SA	Pays $_{\text{floating}}$SA
	Pays $_{\text{fixed}}$SA	Rec $_{\text{fixed}}$SA
Costs		Pays fuel
SRA		Pays $_{\text{unit}}$NSWtoSA
		Rec $_{\text{IRSR}}$NSWtoSA [this may be up to ($_{\text{floating}}$SA - $_{\text{floating}}$NSW)]
Profit	Tariff - $_{\text{fixed}}$SA	$_{\text{fixed}}$SA - Fuel + ($_{\text{floating}}$NSW - $_{\text{floating}}$SA) - $_{\text{unit}}$NSWtoSA + $_{\text{IRSR}}$NSWtoSA
If $_{\text{IRSR}}$NSWtoSA = ($_{\text{floating}}$NSW - $_{\text{floating}}$SA)		$_{\text{fixed}}$SA - Fuel - $_{\text{unit}}$NSWtoSA

Table 6 applies the calculations in earlier tables to facilitate comparison across the different hedging scenarios. It, deliberately shows the SRA unit cost as being the same as the different swap prices between the regions and the

[28] Only if the flow = the auctioned number of SRA units – an unreliable assumption explored later in this document

IRSR payout being the full floating price difference, thus ensuring the profit outcome is the same for the generator selling a swap contract in SA instead of NSW.

Table 6 Worked example, multiple hedging scenarios

Element	Retailer	Generator	Notes
Single-region swap			
Region	NSW	NSW	
AEMO	-$100	$100	Retailer pays floating, generator rec floating
Swap floating	$100	-$100	Retailer rec floating, generator pays floating
Swap fixed	-$50	$50	Retailer pays fixed, generator rec fixed
Tariff/fuel	$75	-$25	Retailer rec Tariff, generator incurs fuel costs
Profit	$25	$25	
Two-region swap			
Region	SA	NSW	
AEMO	-$15,000	$100	Retailer pays SA floating, generator rec NSW floating
Swap floating	$15,000	-$15,000	Retailer rec SA floating, generator pays SA floating
Swap fixed	-$100	$100	Retailer pays SA fixed, generator rec SA fixed
Tariff/fuel	$125	-$25	Retailer rec SA Tariff, generator incurs fuel costs
Profit	$25	-$14,825	Generator exposed to (NSW floating – SA floating)
Two-region swap with SRA unit			
Region	SA	NSW	
AEMO	-$15,000	$100	Retailer pays SA floating, generator rec NSW floating
Swap floating	$15,000	-$15,000	Retailer rec SA floating, generator pays SA floating
Swap fixed	-$100	$100	Retailer pays SA fixed, generator rec SA fixed
Tariff/fuel	$125	-$25	Retailer rec SA Tariff, generator incurs fuel costs
SRA - units		-$50	Generator pays SRA units
SRA - IRSR		$14,900	Generator rec IRSR NSWtoSA [up to SA floating less NSW floating]
Profit	$25	$25	
Input assumptions			
Fixed NSW	$50		
Floating NSW	$100		
Fixed SA	$100		
Floating SA	$15,000		
Tariff NSW	$75		
Tariff SA	$125		
Fuel	$25		
SRA unit(s) cost	$50		
Hedge ratio[29] SRA	1		Maximum value is 1, so this is a generous assumption

The table deliberately represents interregional settlement residue surplus paid to unit holders "$_{\text{IRSR}}$NSWtoSA" as being different to the difference in the two spot prices, ($_{\text{floating}}$SA - $_{\text{floating}}$NSW), because interconnectors are regularly constrained below the notional capacity due to intraregional constraints (as shown in the ACIL Allen modelling).

[29] Defined in section 3.4.5

3.4.5 Hedging value of interregional settlement residue units

To this point, section 3.4 has assumed that if a trader purchased a unit at the SRA, then the surplus distributed to them would be the full price difference between the two regions. This section investigates the extent to which the price difference is distributed to unit holders in practice. Analysis results are presented for both historical distributions to unit holders and modelling outcomes from ACIL Allen. The aim of this sub-section is to explain how the SRA currently functions, and then to discuss how it may possibly support interregional trade if PEC is modelled as an interconnector in dispatch.

The approach taken is to compare quarterly surplus distributions (to unit holders) in historical settlement (or ACIL Allen modelled results) against quarterly surplus distributions that would be required for each unit to have a hedging value of one, as assumed in the sub-sections above. From herein the quarterly surplus required at full hedging value is referred to as “nominal” because this is calculated using the number of auctioned units (at the maximum interconnector capacity), yet those buying units reasonably expect interregional price differences to occur at constrained flows less than full rating.

The calculations are as follows:

- **Quarterly surplus** is the sum of the positive interregional settlement residues distributed to unit holders for the quarter (as calculated by AEMO).
- **Nominal value** is calculated as the positive price difference multiplied by the number of units sold at the SRA, then summed for the quarter.
- **Hedging value** is defined as quarterly surplus divided by the nominal value. This provides a “hedging ratio”, which is between zero and one.

Figure 9 presents SRA results from 2013 for each directional interconnector for each quarter. Please note the nominal value should be interpreted as an estimated benchmark to provide a ratio, and it is not the absolute value of the ratio that is important, more the range of ratios that occurs for any given unit.

As can be seen from the results, the total surplus is highly variable from quarter to quarter – a quarter could be dominated by unseasonable weather, a fuel price shock, an unexpected combination of outages, aggressive bidding strategies etc.

Rather than the scale of the total surplus, the figures present the relationship between the two, as in the hedging value. Quarters of concern are those in the bottom right, with a high nominal value yet very little surplus distributed to unit holders. During these quarters there is likely to have been high prices at highly constrained flows, or possibly with counter price flows (which provide zero payout).

Historical data demonstrates the highly variable hedging value of SRA units and implies that any physical participant (retailer, generator) or financial participant (trader) taking a position in two adjacent regions and then buying in the SRA would not be able to eliminate the exposure to the RRP of the region the SRA unit supports – the amount of units to buy to cover a position in any trading interval is inherently uncertain.

Further, the results are historical values for the quarter. This means the hedging value is likely to vary significantly on any given day in that quarter, and therefore a participant imposing stricter limits on say, value at risk, maximum daily loss, or hedge quantity requirements in dispatch, may be less likely to use SRA units, or consider them less firm than they are on a quarterly basis.

Figure 9 Estimated hedging value of SRA units based on 2013-2023 historical data

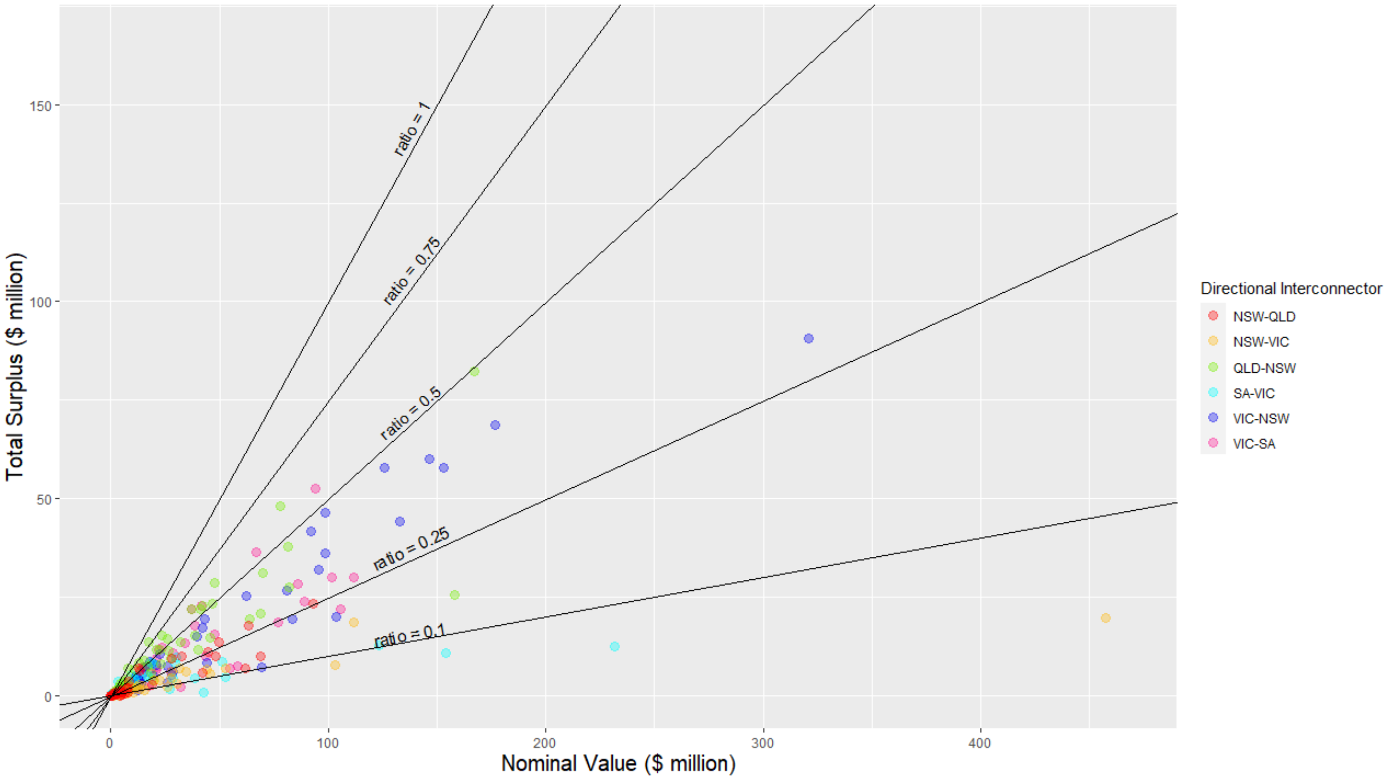
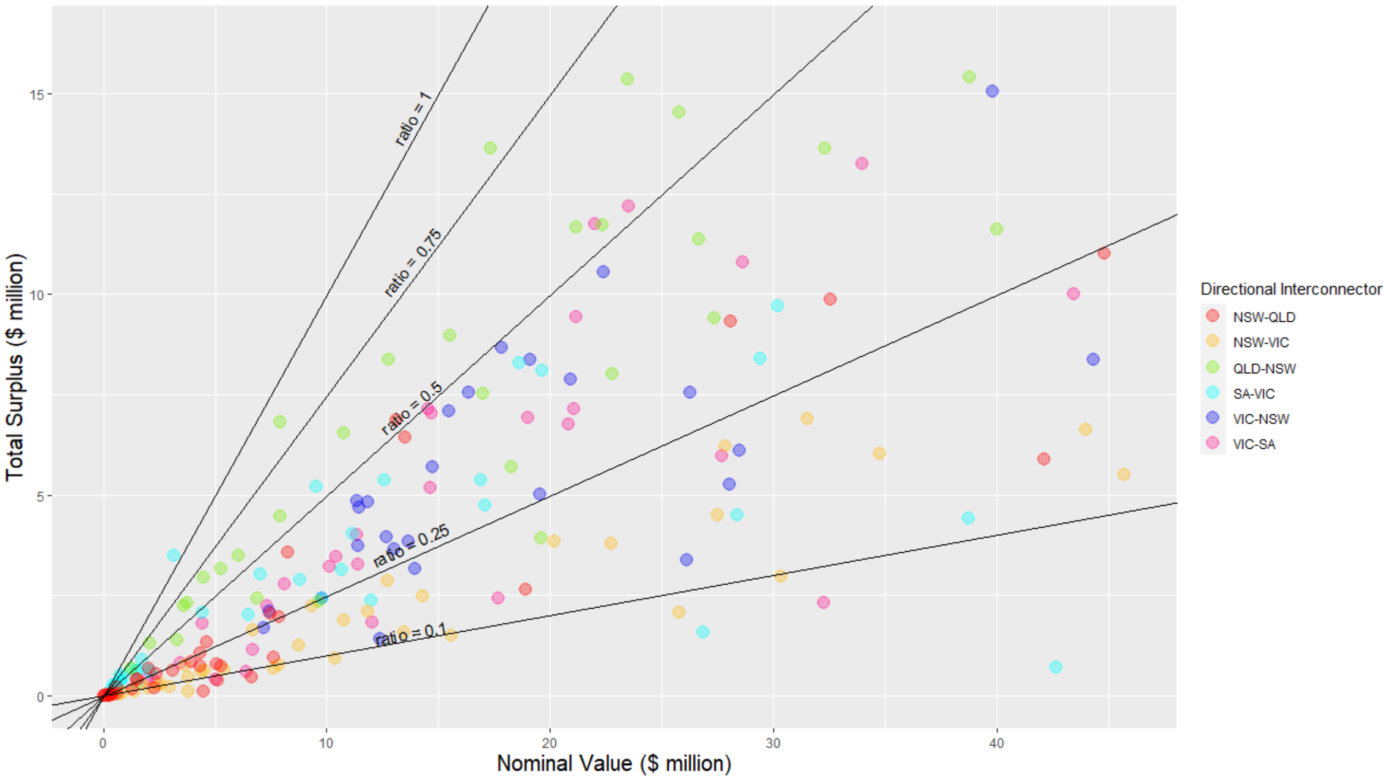


Figure 10 Estimated hedging value of SRA units based on 2013-2023 historical data (zoomed in)



It must also be noted that interregional settlements residue surplus distributed to unit holders consists of:

1. interconnector limit constraints in dispatch;
2. differences in price attributable to intra-regional constraints binding that include the interconnector term;
3. marginal transmission loss of the interconnector, creating price differences between the two regions; and
4. actual transmission loss of the interconnectors.

The first three factors above increase the surplus, the fourth reduces the surplus as this is real energy loss heating the circuit.

The first two factors are the primary drivers of interregional settlements residue, because prices can vary markedly between regions (from the Market Price Cap ($16,600/MWh) to the Market Floor Price (-$1,000/MWh)) when interconnectors are constrained. It is at these times market participants particularly value the surplus from the SRA units in managing interregional positions.

The third and fourth factors, when netted, represent the interconnector loss surplus created using the marginal interconnector loss in dispatch. This surplus accumulates whenever the interconnector is flowing in the direction of the SRA unit of flow. So, whilst the price differences may be smaller, it is less sporadic and can accumulate to be significant. However, at times when only loss differences apply, the interconnector is unconstrained, and one can assume participants are satisfied with the trading conditions and price differences, and do not need the interconnector to flow at full capacity. This implies there is no need for the surplus to support trading and ideally this should be excluded from the valuation of hedging value. Including the periods where residues accumulate solely because of losses would understate the hedging value of units, because losses accumulate throughout the loading of the interconnector, and the nominal value is calculated as if participants would have wanted the interconnector to flow at full capacity – and yet they did not because the interconnector was unconstrained. For simplicity, AEMO did not account for this nuance in the analysis presented in this section.

Figure 11 and Figure 12 extend this analysis to the ACIL Allen results. Recognising that these results are without the application of loss factors, (thus reducing the scale of the total surplus, but increasing the estimated hedging value), the results are like the historical calculations in their general variation, although generally closer to 1.

This gives an indication that, should PEC be implemented as an interconnector in dispatch, (and negative residues not be deducted from positive residues before distributing to SRA unit holders), it would be a similar exercise for traders to purchase units at the SRA on the three interconnectors as they do today yet with the benefit of being able to trade directly between NSW and SA.

It should be noted that the modelling exercise with ACIL Allen was targeted at developing an understanding of the nature of flows and the feasibility of reallocating negative residues rather than trying to predict future price outcomes. This analysis was not its express purpose, and this should be recognised when considering the results.

Figure 11 Estimated hedging value of SRA units based on 2027-2030 ACIL Allen Modelling

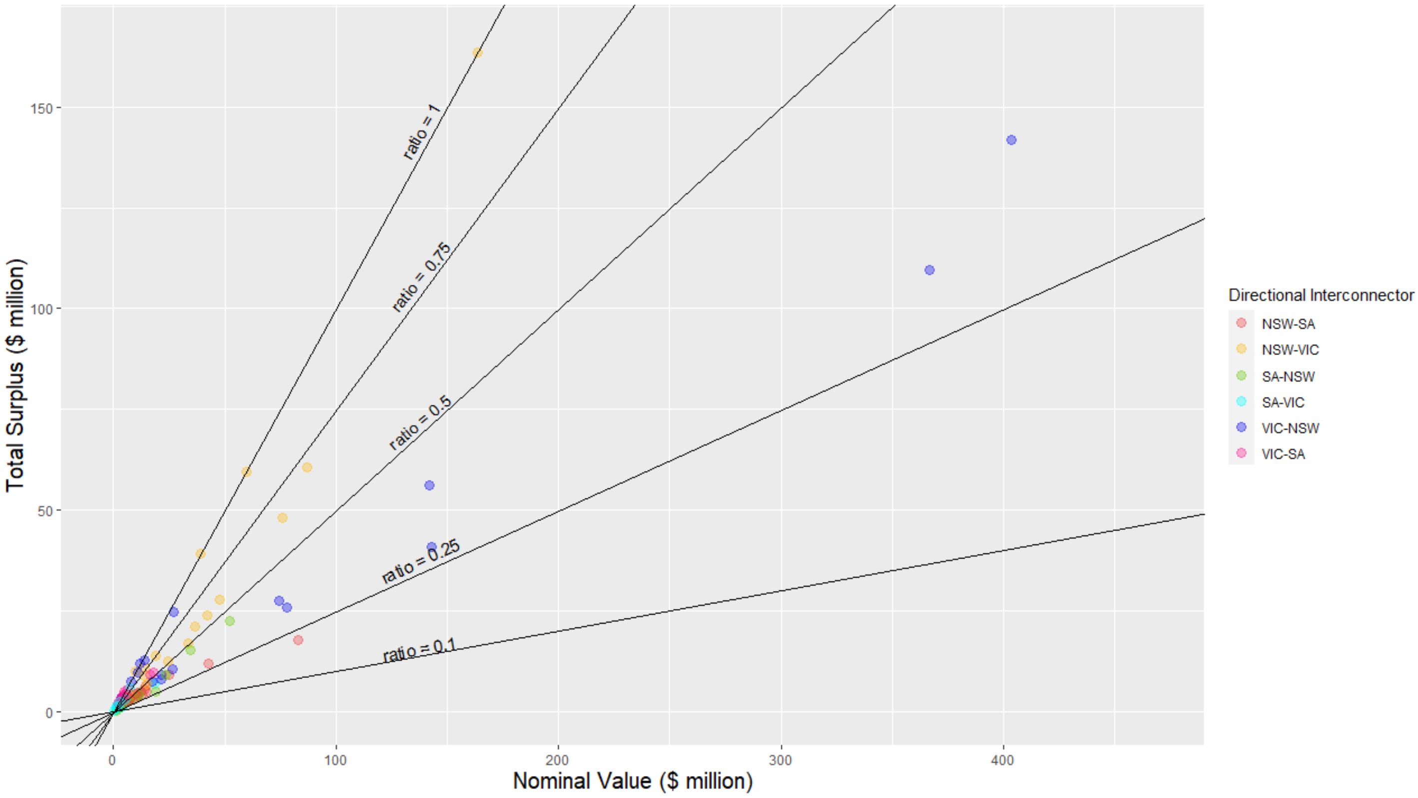
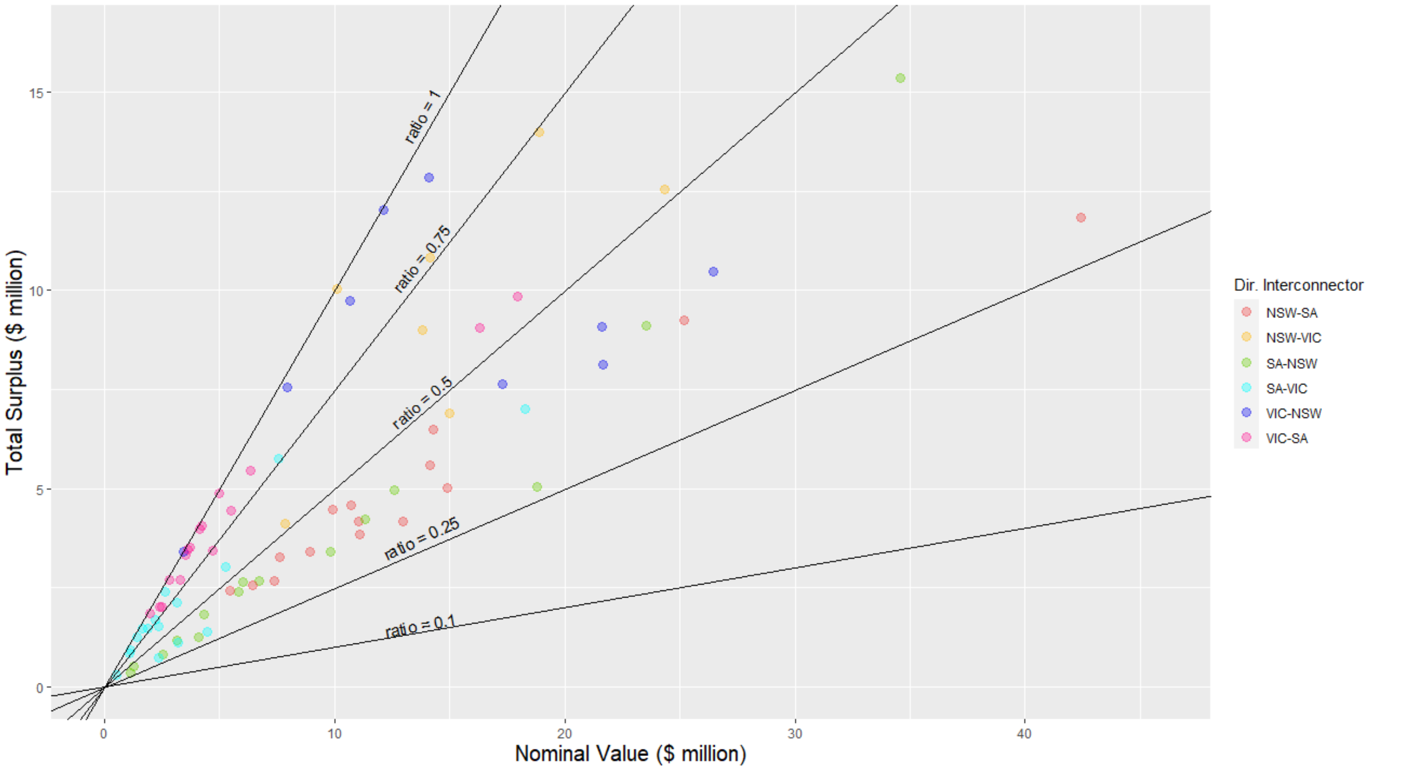


Figure 12 Estimated hedging value of SRA units based on 2027-2030 ACIL Allen Modelling (zoomed in)



3.4.6 Summary of interregional trading

The aim of this section was to explain how the SRA currently functions, how it could be used to cashflow hedge interregional trading positions and provide some analysis as to how the SRA could operate with three directional interconnectors in the loop.

AEMO's position in the Directions Paper was to try to preserve trading value for the SRA. This was considered consistent with previous regulatory determinations that aimed to encourage interregional trade between participants.

Investigating the historical hedging value of units and comparing these to modelled results with the new interconnector has allowed AEMO to address a key stakeholder query concerning the effect of a new interconnector on interregional trading and interregional hedging using SRA units. It appears that implementing PEC using the interconnector model (and with a reallocation method that does not deduct negative residues from the surplus distributed to units) will allow the SRA to function in a manner reasonably consistent with the current range of performance of the SRA in supporting interregional trade.

This observation was somewhat surprising given the spring washer pricing effect can cause a counter-price flow as part of efficient dispatch, and this can lead to increased negative residues in the NEM's regional settlement model. Negative interregional settlement residues reduce the usefulness of the SRA for hedging interregional derivative trading. This is because, when they occur, there is a positive price difference, no flow from low-priced to high-priced regions and therefore no positive residue. At these times the hedging value of an SRA unit is zero.

Conversely, with the transmission loop, negative residues can support increased positive residues. As is evident in the figures and analysis above, these two opposing dynamics led to the conclusion that SRA trading should provide a similar level of firmness in 'hedging value' as is available in the auctions today.

Though it is fair to conclude that having PEC integrated with NEM settlement using the interconnector model would not provide an improvement in the hedging value of units, it should also be noted that this model does allow for participants to trade between SA and NSW rather than via VIC. In terms of improving trading, competition, and price discovery, this appears to be a core benefit in implementing PEC as an interconnector in dispatch, as opposed to under the micro slice option.

3.5 Comparative analysis summary

This section provides a summarised comparison of the two dispatch integration models across a range of qualitative and quantitative factors. This includes incorporating the results of the settlement analysis described in section 3.2 and the analysis of the trading value described in section 3.4.

Basis for comparison	Comment
Facilitating inter-regional trade	• As established in section 2.3, some stakeholders expressed concerns with loop flows being reflected in dispatch, indicating that this could disrupt inter-regional trading. Such stakeholders pointed to the micro-slice model as a way of retaining existing trading pathways.

Basis for comparison	Comment
	• As established in section 3.4, the ACIL Allen modelling results suggested that, via SRAs, existing opportunities for inter-regional trade and hedging should continue to an historically comparable extent even when loop flows are introduced into dispatch (i.e. under the interconnector model). • AEMO did not quantitatively analyse the micro-slice model in terms of its impact on inter-regional trade and hedging. • The ACIL Allen results also suggested that loop flows would give reasonable opportunities by historical standards for trade between NSW and SA. These opportunities would not exist under the micro-slice model.
Managing negative settlement residues	• Section 3.2 details that, although the micro-slice model has some value in reducing the extent of negative residues, substantial amounts of negative residues have the potential to endure that would not be present in the interconnector model (with reallocation). • Substantial and frequent negative residues under the micro-slice model have the potential to cause adverse financial effects on TNSPs.
Managing power system security	• Equality constraints help capture the physical reality of loop flows and therefore facilitate the management of security in dispatch. • Equality constraints are typically associated with the interconnector model but not the micro-slice model. However, strictly, the models only differ by their assumed inter-regional flow pathways. As a micro-slice model *could* still be implemented with an equality constraint there is not necessarily a difference between the two models in terms of how they *could* manage power system security.

4 Approach to accommodate PEC

4.1 Dispatch integration model

The Directions Paper set out the proposition that PEC be implemented as a new interconnector in dispatch, rather than be subsumed into the two existing interconnectors in the micro-slice model. In response to stakeholders' feedback, AEMO has completed further analysis and investigation of the micro-slice model.

Analysis indicates a micro-slice model would not remove loop flows, negative settlement residues would remain, and where flows follow the radial order, but prices do not, increased positive residues on one interconnector may be artificially increased by negative residues on the other, thus changing the performance of the SRA and distribution of residues to customers in the different regions.

Despite the micro-slice option distributing residues that would have otherwise accrued on PEC to the other two interconnectors, negative residues would be expected to remain. This is because the micro-slice does not remove the loop flow, and spring washer pricing effects could result in negative residues if prices did not follow the radial order of regions (and flows) in the micro-slice. Given this, the challenges for implementing negative residue management constraints with this model, and the loss of the direct pricing of trade between NSW and SA that an interconnector implementation provides, the micro-slice option is unfavoured.

The creation of a new interconnector in dispatch and the SRA should maximise flows and the value of trading. This should allow participants to trade across NSW and SA markets consistent with the power flows between these NEM regions. This approach allows negative settlement residues and provides a clear basis to separate negative from positive residues. In contrast, the micro-slice model does not allow direct trading between NSW and SA, and, by effectively reallocating inter-regional flows from PEC to the existing loop arms, it becomes more complex to separate negative residues from positive and fewer options exist for the imposition of negative residue management constraints. Further, AEMO considers direct pricing between NSW and SA, supported by the SRA will better support interregional trade and competition than the micro-slice model.

For reasons described in section 3.1.3, AEMO intends to integrate PEC stage 1 into dispatch using a micro-slice model. Some stakeholders considered that stage 2 of PEC should be implemented as a micro-slice as a continuation of stage 1, and then an interconnector model be considered after assessing the performance of dispatch and settlement. Given the likely prevalence and scale of negative residues that may remain with the micro-slice model, AEMO does not consider that deferring from implementing PEC as an interconnector in dispatch is a sensible proposition. To follow such an approach, AEMO would need to either allow systemically higher negative residues or strengthen negative settlement residue management procedures. The former would expose the system to all the risks described throughout this paper. The latter would diminish the total benefits of trade across the NEM, and it is not clear how negative residue management should be modified.

Consistent with the Directions Paper, AEMO intends to implement PEC Stage 2 using the interconnector dispatch integration model.

4.2 Negative residue management

The Directions Paper set out the proposition that, following the implementation of PEC, negative residue management may still be required, but limited to cases when the aggregate interregional settlement residue of all three interconnectors is in deficit (“net negative” overall). This aligns with the original design of NRM clamping, that is, to manage the accumulation of inefficient counter-price flows, when there is not enough money to pay generators in settlement. This approach would then allow negative IRSRs to accrue in dispatch when aggregate interregional settlement residues around the loop are in surplus, when there is enough money to pay generators in settlement.

As discussed in the Directions Paper, this approach would require consideration of the feasibility of monitoring and automating NRM constraints. The aim is to retain NRM constraints for directional interconnectors but only invoking them when aggregate interregional settlement residue is in deficit and negative interregional settlement residue as accrued on a directional interconnector is projected to exceed the threshold of $100,000. This would largely retain existing processes for the application of NRM constraints for the incremental[30] and stepwise clamping of counter-priced flows specific to each directional interconnector. The threshold level of $100,000 could be likewise retained as the level that balances minimising the risk of intervention in the market and the risk of increased payments for negative interregional settlement residue.

The proposed approach seeks to limit the extent to which intervention via clamping constraints is required in a system where loop flows increase the prevalence of counter-priced flows. Limiting the application of interconnector clamping to when aggregate loop IRSR is negative, seeks to limit the extent to which interconnector clamping is a driver of dispatch outcomes.

Consistent with the Directions Paper, AEMO intends to revise automated negative residue management constraints with the aim of eliminating negative settlement residues when the aggregate interregional settlement residue of all three interconnectors is in deficit (“net negative” overall). Under these conditions, if automated negative residue management constraints fail to eliminate negative residues, or the residues are within allowable tolerances, negative residues will remain payable by the importing TNSP.

4.3 Reallocation of negative IRSR

The Directions Paper set out the proposition of distributing negative interregional settlement residue around the loop. It recommended, on the condition of aggregate interregional settlement of the three interconnectors being in surplus, that negative settlement residues be reallocated based on the share of positive interregional settlement residues. The option explained in the Directions Paper was either to reallocate all interregional settlement residues, or simply distribute the negative interregional settlement residues to the other interconnectors based on the proportion of positive residues, (noting that with the precondition of settlement being in surplus there was always enough cash to fund the negative residues). The Directions Paper recommended this reallocation method be applied regardless of who pays for them, which could either be payable by unit holders (reduced SRA distributions) or importing TNSPs.

[30] Clamp increments are not symmetrical when applied and released. The clamp is applied in greater increments to halt the accrual of negative IRSR than when released. Interconnector clamp is only applied where power system security is maintained.

The following example was provided, where there is a single negative directional interconnector e.g. SANSW. This would leave the original ratio of positive residues: $IRSR(SAVIC): IRSR(VICNSW)$

Aggregate around the loop $IRSR(loop) > 0$

Negative reallocation:

$$Negative\ IRSR(SAVIC) = \left[\frac{IRSR(SAVIC)}{IRSR(SAVIC) + IRSR(VICNSW)}\right] * negative\ IRSR(SANSW)$$

$$Negative\ IRSR(VICNSW) = \left[\frac{IRSR(VICNSW)}{IRSR(SAVIC) + IRSR(VICNSW)}\right] * negative\ IRSR(SANSW)$$

Consistent with the Directions Paper, AEMO intends, for each trading interval, to reallocate negative interregional settlement residues when settlement, in aggregate, is in surplus across the three interconnectors.

AEMO considers the method of using the proportion of positive residues (as opposed to some other measure, like flow, or capacity) was implicitly endorsed by stakeholders, with stakeholders also rejecting the option to reallocate all interregional settlement residues (rather than simply the negative residues). This means an interconnector that is negative, would not be allocated a share of positive residues, irrespective of a positive price difference between the two regions to which a participant may be exposed. AEMO considers this is sensible, because the larger price differences are more likely to be found on the interconnectors with the greatest positive residues.

4.4 Payment of reallocated negative IRSR

The Directions Paper set out that negative IRSR could either be payable by unit holders (by reducing cash distributions to SRA unit holders) or directly payable by importing TNSPs. AEMO recognises the SRA auction converts a highly variable cashflow into a relatively fixed payment for importing TNSPs, more suited to the calculation and publication of annual TUoS prices. Ignoring negative interregional settlement residue, the SRA therefore provides a useful working capital, or cashflow service to the TNSP.

Recovery of negative interregional settlement residue from TNSPs is performed through weekly billing. Payments for negative interregional settlement residue are due 14 business days after the end of the billing week. If negative interregional settlement residue are allowed in dispatch when settlement is in surplus, and these are substantial, this would impose more working capital on TNSPs, because the TNSP would not simultaneously be receipting matching positive settlement residues from dispatch, instead receipting fixed auction proceeds.

After reviewing stakeholder feedback, and consistent with the Directions paper, AEMO remains of the opinion that the hedging value of the units should be prioritised over any cashflow issues, and this means any negative interregional settlement residues reallocated are then payable by the importing TNSP. This is consistent with regulatory precedent, the desire to encourage interregional trade, and was supported by stakeholder feedback. Further, AEMO intends to include PEC in the SRA as soon as practicable.

Nevertheless, under this proposal if negative residue (when settlement is in surplus) is not immediately deducted from the available cash that is distributed to unit holders, the TNSP retains a fixed cashflow from SRA proceeds yet a larger, variable cashflow of negative interregional settlement residue than it would usually expect today.

Because of this, some of the stakeholders may be correct in suggesting the need for consequential amendments to the recovery of negative interregional settlement residue.

An option could be for residues being payable by Market Customers (retailers) in the importing region. AEMO notes that, unless smoothed by AEMO, there is a risk this option would simply shift the problem, rather than resolving it, because electricity retailers typically charge a fixed price tariff. Alternatively, options under Chapter 6A of the NER could be considered aiming to expedite reconciliation between forecast and actual costs for TNSP TUoS, or to shorten the recovery period.

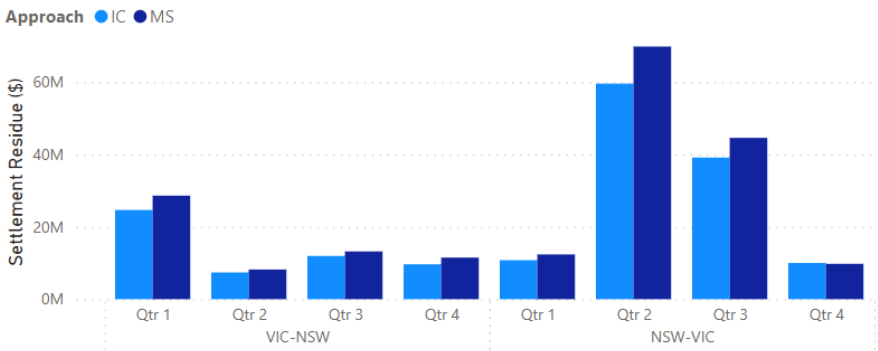
A1. Settlement analysis results filtered by aggregate loop residue sign

This section repeats the figures included in section 3.3, filtering out cases where the aggregate residues around the loop are negative (settlement is in deficit). The rationale for including these filtered figures is described in the 'Analysis Assumptions' sub-section of 3.3.3. Filtering did not materially change the findings associated with any of the figures and, as a result, most changes are not visually discernible. Results tables are included to assist readers with comparison.

Figure 1A - Settlement residue for both VIC-NSW directional interconnectors, 2027

All cases

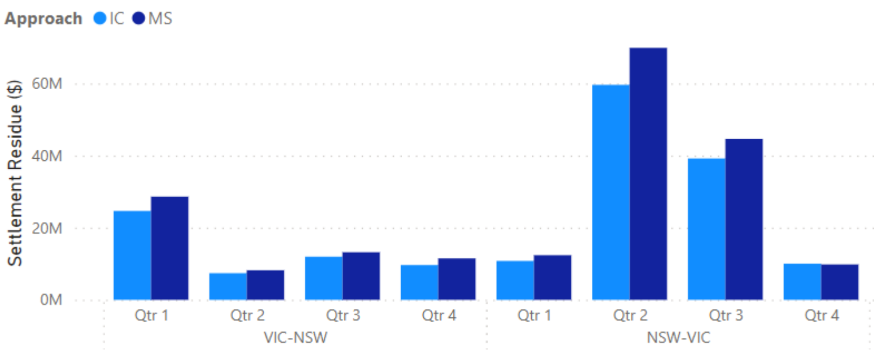
Sum of Settlement Residue by Interconnector, Quarter and Approach



IC, Quarter	IC	MS
VIC-NSW, Qtr 1	24,651,725.04	28,614,754.51
VIC-NSW, Qtr 2	7,385,077.12	8,204,158.42
VIC-NSW, Qtr 3	11,951,338.82	13,194,165.18
VIC-NSW, Qtr 4	9,643,295.69	11,491,391.11
NSW-VIC, Qtr 1	10,783,006.19	12,366,047.16
NSW-VIC, Qtr 2	59,577,917.27	69,818,611.53
NSW-VIC, Qtr 3	39,144,729.88	44,584,254.25
NSW-VIC, Qtr 4	9,999,492.19	9,770,689.67

No 'aggregate loop deficit' cases

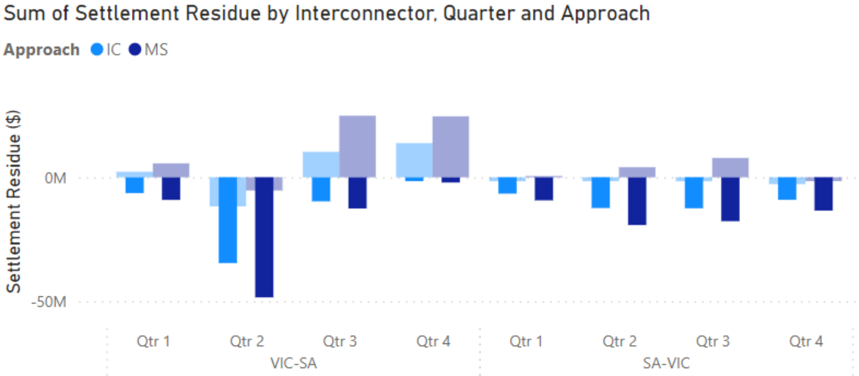
Sum of Settlement Residue by Interconnector, Quarter and Approach



IC, Quarter	IC	MS
VIC-NSW, Qtr 1	24,651,725.04	28,614,754.51
VIC-NSW, Qtr 2	7,385,077.12	8,200,602.52
VIC-NSW, Qtr 3	11,951,338.82	13,194,088.98
VIC-NSW, Qtr 4	9,643,295.69	11,491,391.11
NSW-VIC, Qtr 1	10,785,346.45	12,369,696.37
NSW-VIC, Qtr 2	59,620,993.26	69,879,878.75
NSW-VIC, Qtr 3	39,194,854.17	44,633,736.21
NSW-VIC, Qtr 4	10,024,095.89	9,809,866.36

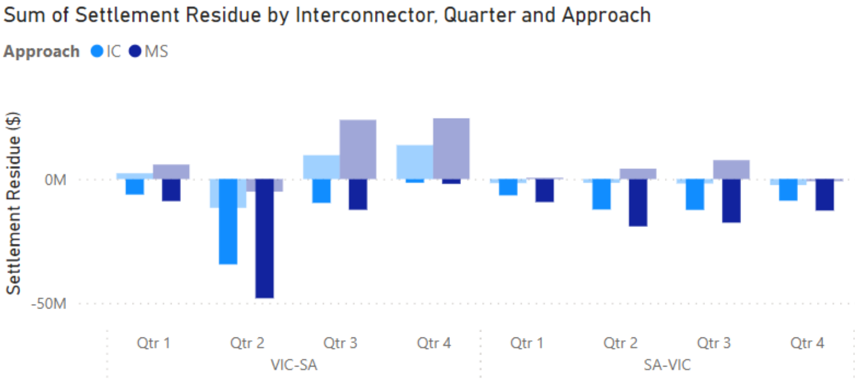
Figure 2A – Quarterly aggregate settlement residue for both VIC-SA directional interconnectors, 2027-2030

All cases



IC, Quarter	IC	MS
VIC-SA, Qtr 1	-6,365,357.97	-9,116,419.53
VIC-SA, Qtr 2	-34,578,274.51	-48,418,303.46
VIC-SA, Qtr 3	-9,698,038.37	-12,579,808.04
VIC-SA, Qtr 4	-1,550,761.66	-2,100,342.70
SA-VIC, Qtr 1	-6,580,442.46	-9,287,924.73
SA-VIC, Qtr 2	-12,390,863.36	-19,257,609.89
SA-VIC, Qtr 3	-12,497,235.87	-17,695,089.07
SA-VIC, Qtr 4	-9,078,600.37	-13,421,296.73

No 'aggregate loop deficit' cases

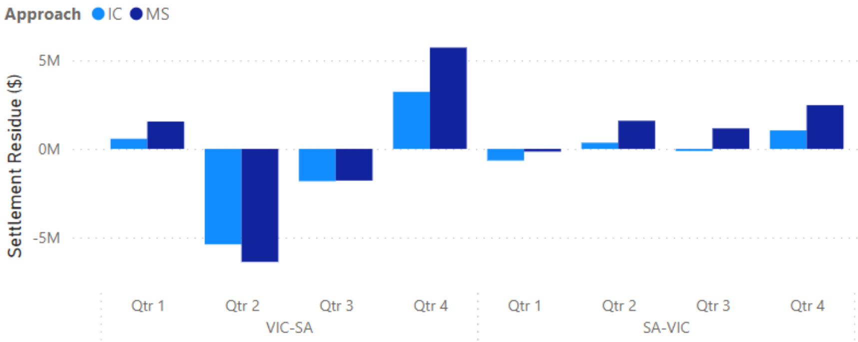


IC, Quarter	IC	MS
VIC-SA, Qtr 1	-6,261,218.98	-8,893,554.68
VIC-SA, Qtr 2	-34,411,925.76	-48,061,840.10
VIC-SA, Qtr 3	-9,632,762.71	-12,396,581.36
VIC-SA, Qtr 4	-1,476,331.35	-1,926,322.85
SA-VIC, Qtr 1	-6,578,362.73	-9,283,990.73
SA-VIC, Qtr 2	-12,297,243.60	-19,081,371.28
SA-VIC, Qtr 3	-12,450,097.56	-17,593,766.38
SA-VIC, Qtr 4	-8,732,688.81	-12,714,025.73

Figure 3A – Settlement residue for both VIC-SA directional interconnectors, 2027

All cases

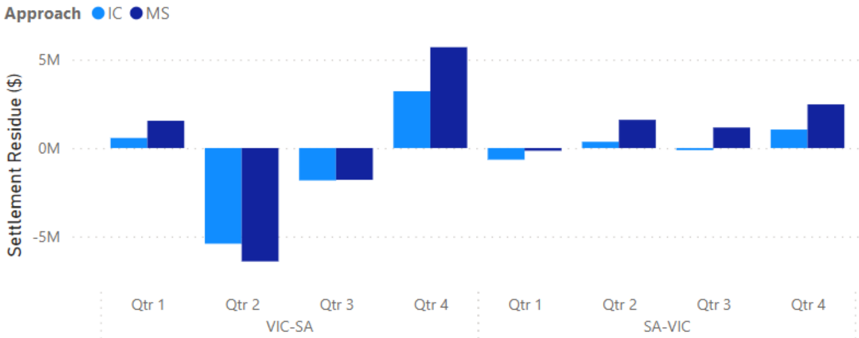
Sum of Settlement Residue by Interconnector, Quarter and Approach



IC, Quarter	IC	MS
VIC-SA, Qtr 1	570,505.54	1,543,769.87
VIC-SA, Qtr 2	-5,390,226.65	-6,381,054.70
VIC-SA, Qtr 3	-1,823,256.43	-1,787,965.20
VIC-SA, Qtr 4	3,222,223.41	5,718,126.62
SA-VIC, Qtr 1	-656,570.81	-152,050.90
SA-VIC, Qtr 2	350,299.97	1,586,860.20
SA-VIC, Qtr 3	-116,843.22	1,156,135.31
SA-VIC, Qtr 4	1,044,336.83	2,466,572.97

No 'aggregate loop deficit' cases

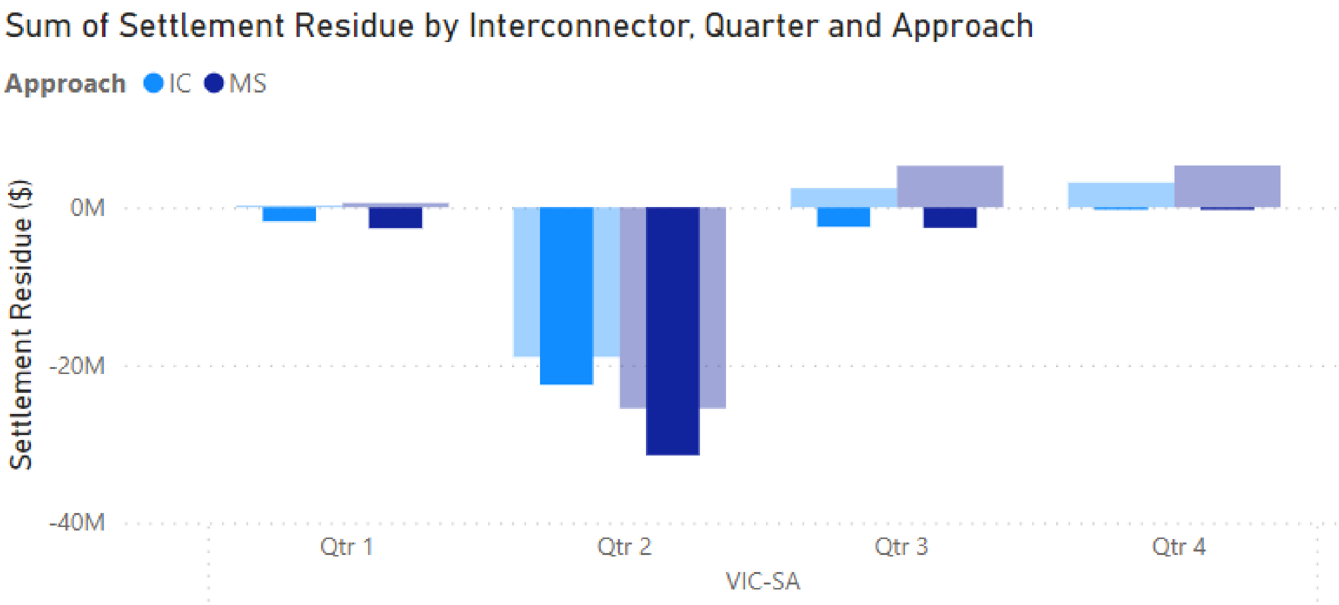
Sum of Settlement Residue by Interconnector, Quarter and Approach



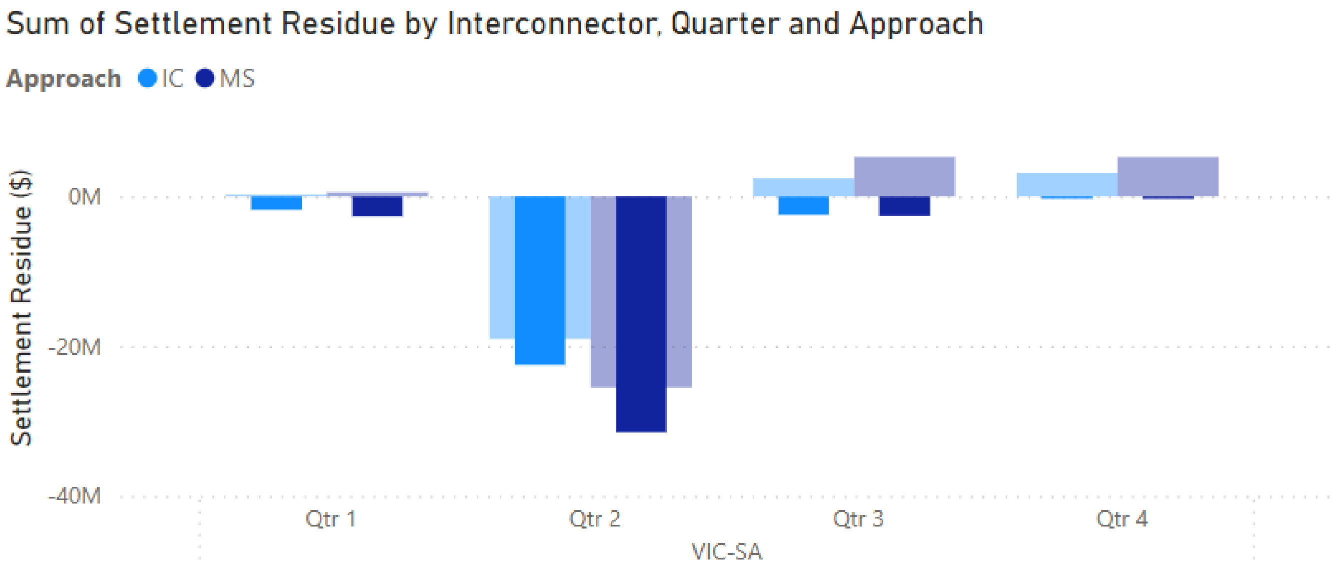
IC, Quarter	IC	MS
VIC-SA, Qtr 1	569,478.48	1,542,157.02
VIC-SA, Qtr 2	-5,406,882.07	-6,408,029.07
VIC-SA, Qtr 3	-1,829,197.10	-1,795,884.20
VIC-SA, Qtr 4	3,210,704.46	5,699,218.42
SA-VIC, Qtr 1	-656,570.81	-152,050.90
SA-VIC, Qtr 2	353,928.45	1,594,461.24
SA-VIC, Qtr 3	-115,726.83	1,159,497.73
SA-VIC, Qtr 4	1,044,623.23	2,467,431.64

Figure 4A - Settlement residue on VIC-SA, 2028

All cases



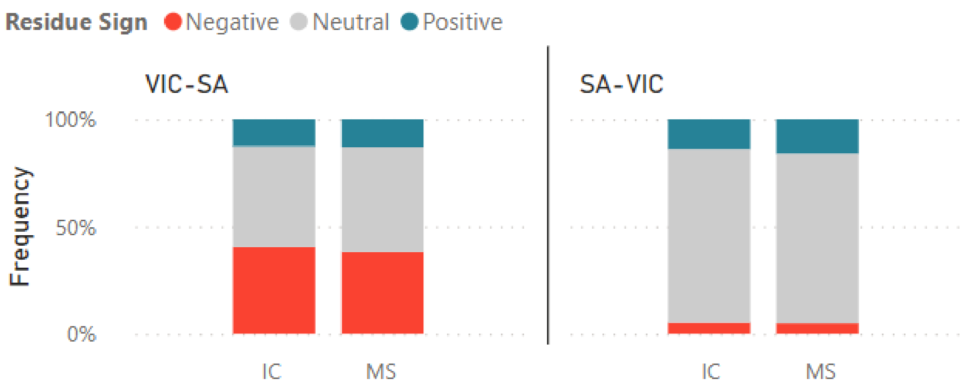
No 'aggregate loop deficit' cases



Note that the results in the two cases in Figure 4A are identical.

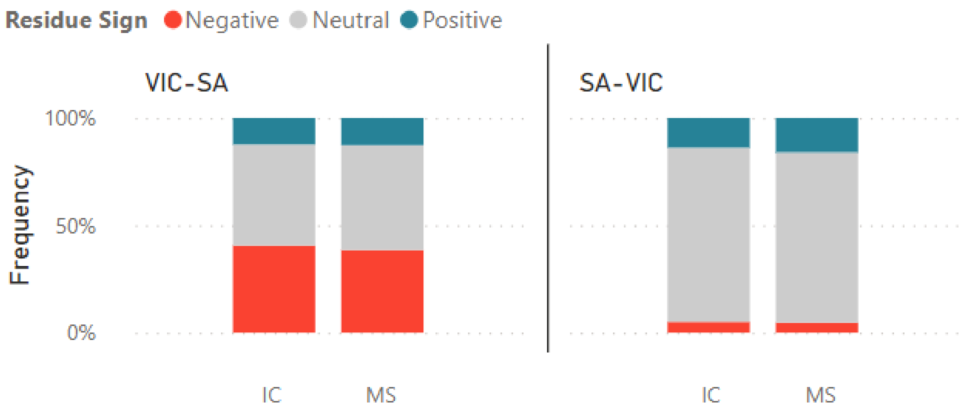
Figure 5A – Frequency of residues with various signs for both VIC-SA directional interconnectors, Q2 2028

All cases



IC	Negative	Neutral	Positive
VIC-SA			
IC	882	1026	276
MS	835	1066	283
SA-VIC			
IC	117	1766	301
MS	110	1726	348

No 'aggregate loop deficit' cases



IC	Negative	Neutral	Positive
VIC-SA			
IC	874	1014	268
MS	827	1053	276
SA-VIC			
IC	106	1749	301
MS	98	1710	348

Note that table results in Figure 5A show the number of (hourly) intervals.