Project Energy Connect Implementation Update

May 2023

Update on Project Energy Connect Market Integration - Settlements Residue

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1 Introduction

1.1 Purpose and background to this paper

This paper provides an update on the market integration of the Project Energy Connect (PEC) transmission interconnector specifically relating to dispatch and the settlement residue activities.

This paper follows the Project Energy Connect Market Integration Paper, published in December 2022 and the receipt of stakeholder feedback in January 2023. The PEC Market Integration paper provided an overview of the PEC transmission interconnector, including discussion of the identified challenges associated with integrating PEC into the NEM, and options for the management of negative residues.

PEC will establish a new major transmission connection between South Australia and New South Wales, with an additional interconnection between Buronga (New South Wales) and Red Cliffs (Victoria). The interconnection of these three regions will establish the first 'loop flow' across regulated interconnectors in the National Electricity Market (NEM).

1.1.1 Project Energy Connect Overview

PEC is an electricity transmission project to deliver a physical interconnection between the power networks of South Australia and New South Wales, to be constructed jointly by Electranet and Transgrid. In total the project will provide approximately 800 MW of transmission capacity between New South Wales and South Australia power networks, delivered over two phases:

- PEC Phase 1 (150 MW bi-directional capacity). The first phase will comprise the connection between Robertstown and Buronga. Capacity release mid-2024.
- PEC Phase 2 (combined transfer limit across Heywood and PEC interconnectors: 1,300 MW import into South Australia; and 1,450 MW export). The second phase 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 the first AC transmission 'loop' across regulated interconnectors in the NEM. This transmission loop will give rise to 'loop flows' as power travels across interconnectors, and between regions.

Loop flows have the potential to give rise to the 'spring washer' pricing effect which can be observed between nodes connected in a loop. Typically, this would occur when the price spikes downstream of a constraint to reflect the congestion cost for the delivery of additional power to a region where marginal prices are higher. Prices then spiral downwards, from downstream to upstream of the constraint creating a spring washer effect that is likely to result in negative settlement residues in the loop.

1.2 PEC Market Integration Paper

The PEC Market Integration Paper was published as an overview and consultation paper that discussed several challenges for the integration into the NEM, including:

- Loop flows formed by PEC operating in parallel with Victoria – New South Wales Interconnector, Murraylink and the Heywood interconnector in the central dispatch process.
- Regional boundaries and interconnectors with PEC.
- Modelling interconnector marginal loss equations in the central dispatch process.
- Managing inter-regional settlements residues and designs for the Settlements Residue Auction (SRA).

The PEC Market Integration Paper discussed the occurrence of loop flows as well as the resulting pricing effects that give rise to 'negative settlement residues' (NSR) as an increasing part of normal dispatch operations.

Four options were presented for the management of NSR resulting from PEC loop flows.

1. **Removal of NSR clamping procedure** – Allow NSR to accrue unconstrainted in dispatch, with three sub-options for the allocation and recovery of NSR.
    a. *Allocate to the TNSP* – as per current procedures, all NSR would be recovered from the TNSP
    b. *Allocate to Traders* – Holders of SRA units would be responsible for the payment of NSRs based on their relative allocation of SRA units
    c. *Shared allocation between the TNSP and Traders*.
2. **Bundling SRA units along pathways** – Bunding SRA units into products that incorporate multiple directional interconnectors. For example, a VIC-NSW unit could be bundled into VIC-NSW, VIC-SA and SA-NSW product.
3. **Residue allocation for SRA** – Reallocate accrued NSR around the loop based on an agreed metric such as:
    a. *Co-efficient approach* – based on the co-efficient of the constraint equation applying to that transmission line under system normal conditions.
    b. *Relative flow approach* – based on the relative flow across each transmission line in the loop.
4. **Financial transmission right arrangement** – Development of products, trading, and management of Interregional Settlement Residues (IRSR) like those associated with Financial Transmission Rights (FTRs).

1.3 Stakeholder feedback

AEMO received 11 written submissions in response to the PEC Market Integration Paper. Stakeholders were invited to provide response to 11 consultation questions across areas the following categories:

- Market Integration
- NSR Options
- Principles
- SRA
- Reform.

Although stakeholders acknowledged the likely occurrence of loop flow and resulting NSR issues from the implementation of PEC, they requested further information regarding the integration of PEC in dispatch, the scale of NSR settlement outcomes and the options for reallocating NSR.

The following section summarises the stakeholder feedback received to the PEC Market Integration Paper across five general areas.

1.3.1 Additional information

Stakeholders requested more information to support an assessment of the NSR approach, course of action, and more generally about the integration of PEC into dispatch and the impact of the PEC phase-shifting transformers (PST). Stakeholders noted that information, scenario analysis and modelling would be required before they can consider in detail the NSR reallocation options. Information requested included:

- Structure of the network topology and network constraints included in dispatch at the various stages of PEC implementation;
- How phase-shifting transformers are expected to operate and be reflected in the dispatch process;
- To what extent negative residues are expected to accrue, including modelled estimates, and worked examples of allocation options; and
- Further detail on each allocation option including an expected impact on settlement outcomes and pricing.

1.3.2 Dispatch and the operation of phase shifting transformers

Some stakeholders expressed concern that they did not have adequate information to consider how PEC will be integrated into dispatch across various stages of implementation.

A group of stakeholders noted that while the micro-slice model had been put forward as an option for reflecting the network topology of PEC into dispatch, it was unclear if this option was still being considered or, if this could be a more preferred option given it may limit the occurrence of loop flows. Stakeholders also requested further detail on the operation of the phase-shifting transformers, including the extent to which negative residues may be prevented or limited by its operation.

1.3.3 Accrual of NSR

Stakeholders acknowledged the issue and considered that NSR and spring washer pricing as likely outcomes from the created transmission loop flow. Whilst acknowledging the complexity of this issue, stakeholders emphasised the scale of the problem was not clear or demonstrated in AEMOs consultation paper. Most stakeholders requested that modelling is undertaken to establish the extent to which NSRs are likely to accrue as well as the dispatch constraints, market conditions and prices that are likely to result.

1.3.4 Options for management of NSR

There were broadly mixed views from stakeholders across all proposed options for the management of NSR.

A group of stakeholders expressed their preference for Option 1 a) to allow negative residues to accrue and retain current process of funding by the TNSPs. Whilst acknowledging the cash flow impact this may have on TNSPs, stakeholders considered that TNSPs were best placed to manage these risks and suggested this option would allow for the simplest and most efficient cost recovery from consumers.

TNSPs expressed preferences for Option 1b) citing the potentially limited and rigid ability for TNSPs to recover costs through regulated mechanisms and noted that Traders may be better placed to recover these costs under Option 1b) as they are able to participate in the market and optimise portfolios of SRA units to manage risks.

Varied views were received on Option 2 and Option 3, with stakeholders noting that before they can properly consider Option 3 more information and example scenarios that demonstrated the allocation process would be required. While some stakeholders considered Option 2 would undermine the efficient functioning of SRAs, as bundling removes the ability for Traders to use single units an interregional hedge, others considered that Option 2 may be preferrable to Option 3 in the balance of complexity, costs and benefits delivered.

Option 3 was broadly considered the most favourable potential option however with more work and detailed design required. Option 3 was viewed as positive to stakeholders as it spreads the cost of accrued NSR around the loop to ensure net positive or a minimum zero NSR is applied to all directional inter-connectors. It was noted that while this would be beneficial by ensuring the negative liability isn’t wholly allocated to individual interconnectors, some stakeholders raised concerns that Option 3 would also reduce the interregional hedging effect and reduce firmness of SRAs.

Option 4 was largely considered by all stakeholders to be too complex, not fit-for-purpose and not worthwhile considering in any further detail given ongoing ESB Transmission Access Reform.

1.3.5 Timing and consultation

Stakeholders noted that the consultation timings and processes were unclear and further consultation, including opportunity for stakeholders to provide further feedback on allocation options is required. Stakeholders also noted that while the guiding principles presented are broadly reasonable, further clarity and engagement on an assessment criteria or regulatory change process would be beneficial.

2 Dispatch

This section provides further description of integration arrangements for Project Energy Connect into dispatch.

The integration of PEC is expected to significantly change power system flows by increasing transmission capacity to NSW and SA. In parallel to increasing transmission capacity and associated network benefits, the complexity of inter-regional power flows will likewise increase and will continue to evolve driven by changing network conditions, new generator projects and market dynamics. The integration and impact of PEC in dispatch will evolve and continue to be influenced by these factors.

2.1 Dispatch regional boundaries

As described in the PEC Market Integration Paper, AEMO has considered and selected the 'Interconnector' model for the incorporation of PEC into NEMDE. The Interconnector model will implement and represent PEC as a separate line linking NSW and SA for the purposes of dispatch.

The PEC Market Integration Paper noted that the 'Micro-slice' model had also been considered for the integration of PEC. The Micro-slide model inserts a small Victorian region interfacing between NSW and SA and in doing so, maintains the current topology of the NEM as there is no direct link created between NSW and SA in the dispatch model. This option was considered not suitable for the integration of PEC into dispatch because it would not be a proper representation of the physical network. Further, AEMO does not consider it would remove the occurrence of loop flows but instead removes the ability for accrued NSR through VIC to be reallocated around the loop and offset by positive flows from the NSW and SA link.

For stage 1 of the PEC, AEMO will implement PEC as an incremental increase in the capacity of the Victoria-SA interconnector because that is consistent with the representation of the physical system.

2.2 NEMDE constraint

AEMO develops constraints of various system topology scenarios for integration of network elements into NEMDE. As discussed in the PEC Integration Report, AEMO will reflect the PEC loop flows in NEMDE through the creation of a new interconnector between New South Wales and South Australia (the 'Interconnector' model). This creates a network loop between the regional nodes of South Australia, New South Wales, and Victoria. In addition to the thermal and stability constraints of the line, this requires the inclusion of a mesh constraint that governs power flow between regions and sharing between the interconnectors.

The mesh constraint will be included in NEMDE and operate as an 'equality constraint', meaning it approximates the physical power system to represent the relative flows across interconnectors. Importantly, unlike a limit constraint, it will always bind in dispatch. The equality constraint dictates the balance of flows around the loop. If itself the equality constraint is not expected to cause spring washer pricing, because it affects flows, but if the balance of flows is constrained by another security constraint or limit, then prices will diverge around the loop.

The equality constraint was developed and tested using statistical techniques and power system modelling to obtain approximate linear constraints. The application of an inter-regional loop in the NEM is a new concept and therefore engineering assessment of the effectiveness of the constraint in representing power flows, and the effect of the PST, will continue. Please note AEMO may implement PEC differently to that represented below.

Proposed PEC loop model equality constraint:

$$PEC = x_{VNI} * VNI + x_{Heywood} * Heywood + \theta_{PST}$$

where PEC, VNI and Heywood are southward flows i.e:

- x### represents the coefficient
- PEC represents NSW to SA
- VNI represents NSW to VIC
- Heywood represents VIC to SA
- The ϴ PST represents positive flow from SA to NSW

Coefficients and θPST are set out below:

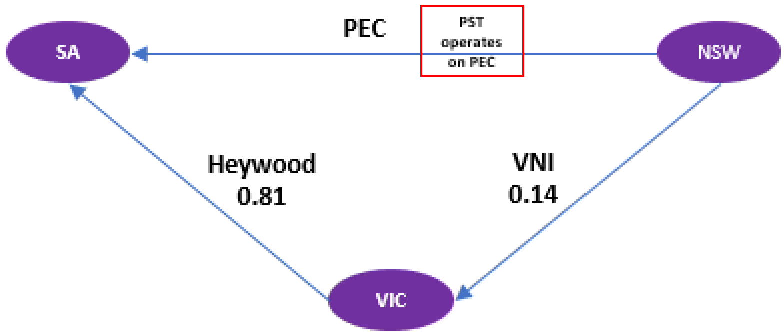
Scenario	Coefficients - Analytical Estimation		
	xVNI	xHeywood	θPST
1) No outage, PST -6.73°	0.1413	0.8084	-20.9260
2) No outage, PST 0 °	0.1410	0.8073	73.7164
3) No outage, PST 8 °	0.1408	0.8090	186.6568

The following applies (noting **positive flow is to SA)**

- PEC is close to binding to SA, the ϴ PST should be **negative**, because this **reduces** the flow on PEC to SA.
- PEC is close to binding to NSW, the ϴ PST should be **positive**, because this **increases** the flow on PEC to SA.

In summary, the PST seems to act to increase or decrease flow on PEC, allowing NEMDE to then change the dispatch more optimally around the loop. In general, if the angle is negative it will result in a negative θPST, thus meaning less flow on PEC towards SA.

Figure 1 Representation of PEC equality constraint



The above constraint equation represents the inclusion of PEC in NEMDE under different system topology scenarios and with different phase shifting transformer settings. The equality constraint operates as a binding constraint in dispatch, setting the targets for interconnector limits for the sharing of flow relative to each other.

PEC PSTs acts when either PEC or Heywood is constrained by changing the impedance on PEC to promote the sharing of flows between the two interconnectors.

The coefficients of the constraint equation under system normal conditions are shown in Figure 1 and reflect that there may be natural areas of operation around the loop. Typical flow conditions are likely to be oriented towards SA or away from SA, rather than one of PEC or Heywood flowing away from SA and the other not. This is because the loop flow on VNI cannot adjust to accommodate flows on one of PEC or Heywood flowing into SA and the other away from.

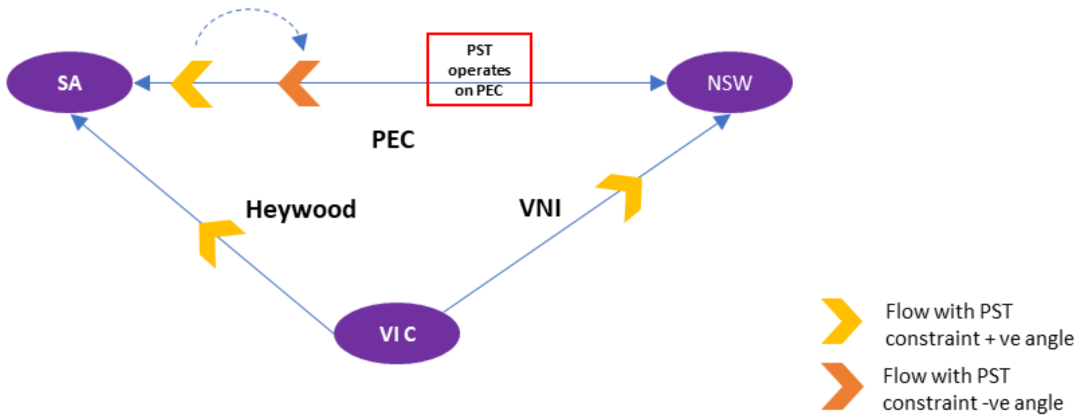
Phase shifting transformers

PEC PSTs will be operated by a TNSP with the intention of shifting the PST position to promote sharing power between the PEC and HIC interconnectors. The shifting of the PSTs is enabled by changing the PST angle of the voltage waveform between the primary and secondary terminals of the transformers using a Phase Angle Regulator (PAR).

The impact of the PST angle is represented in the NEMDE loop flow equality constraint as ϴ PST. While the coefficients dictate the sharing of power between the circuits, the ϴ PST acts as an offset on the starting position of flow on PEC. If the PST angle is changed a new loop flow equality constraint will apply in NEMDE, and the ϴ PST will change markedly, but the coefficients for PEC, VNI and Heywood (x_{VNI}, $x_{Heywood}$) will largely stay the same in absolute terms.

The two examples below are used to demonstrate the intended effect of the PST in an example scenario where network conditions have caused PEC to be operating close to constraint, and power is flowing to South Australia from the eastern states. In general, if power is flowing towards South Australia, the ϴ PST will be changed lower to promote the sharing of flows between Heywood and PEC.

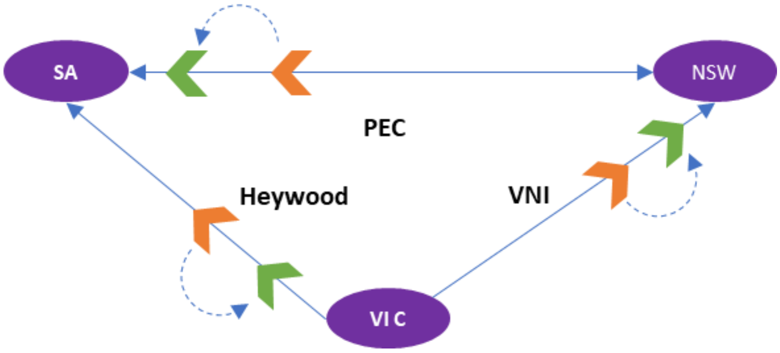
Figure 2 PEC approaches its limit and PST is changed



In this example, the PEC interconnector is approaching its limit, but Heywood is not, therefore the PST angle will be decreased, and the constraint that produces the lower value of PEC (i.e., constraint that has the lowest ϴ PST) should be used.

Now the ϴ PST and NEMDE have the most optimum combination for balancing flows into SA, NEMDE can increase flows around the loop (Figure 3) to use the available capacity on PEC resulting from the change of PST angle.

Figure 3 Impact of NEMDE dispatch following change of PST



In this scenario, this would allow NEMDE to spread the flows around the loop, whilst respecting the flow constraint coefficients, and decrease the extent to which PEC is operating at its limit. This is done in NEMDE by changing the relevant ϴ PST constant in the loop flow equality constraint to reflect a change of PST phase angle.

This demonstrates the way PST intend to operate and the possible role on limiting the extent to which PEC and Heywood are constrained and may reduce the presence of spring washer pricing, and counter-priced flows within the loop. Whilst the use of PSTs will likely affect the prevalence of spring washer pricing and negative settlement residues; it is unlikely to avoid them. The implementation of PEC and creation of the inter-regional transmission loop is a significant shift in inter-regional power flows and PST impact is likely to be secondary to the relative impact of PEC and isn't considered as having the ability to eliminate or account of NSR.

3 Approach and next steps

As part of the broader implementation of PEC, this section describes the key next steps and approach for the management of transmission loop negative residues resulting from Phase 2 implementation of PEC.

3.1 Approach

The implementation of PEC has created a need for AEMO to consider the appropriateness of the way loop flow NSR is managed and allocated. This includes recognising that NSR is a feature and likely occurrence of loop flow network topology, and it may not be technically feasible or economically efficient for dispatch to maintain the current process of clamping NSR via constraint application.

The initial round of stakeholder feedback demonstrated that further analysis is needed of both the problem and possible options before a choice on NSR management can be made. The following demonstrates the approach AEMO intends to take to develop thorough and holistic consideration of the issue.

Given the stakeholder feedback and broader transmission reform program, AEMO will not consider Option 4 (Financial Transmission Right) in any further detail.

The approach going forward intends to progress stepwise to develop the following:

1. **Grounds to change operational practice and allow NSR** – Demonstrate the need to allow NSR to accrue from the transmission loop, accounting for the extent to which NSR is mitigated by the Phase

Shifting Transformer. The occurrence of NSR from the transmission loop as part of normal dispatch has been largely agreed by stakeholders.

2. **Robust and reasonably efficient process to allocate NSR around the loop** – Develop clear set of rules for sharing NSR between the interconnectors in the loop. For example, none (Option 1 or Option 2), co-efficient approach (used in Option 3a), relative flow approach (used in Option 3b) or other based on NSR accrual.
3. **Options for NSR reallocation of costs** – identify who the allocated NSR costs should be reallocated to i.e., TNSPs or SRA unit holders, including how costs may ultimately be borne by consumers. Recommendations will also include identification and delivery of any required operational and Settlement Residue Auction (SRA) process or NER changes.
4. **What are the impacts of allocation** – Consider the impacts of NSR management and allocation process including:
    - Resulting value of Interregional Settlement Residues (IRSR) – Allowing NSR to accrue as a normal feature of dispatch will intrinsically change the overall value of IRSRs as negative costs will increase and lead to a change in price and accumulated value of SRA units. For example, in Option 3 the residue reallocation of NSR around the loop would dilute the value of accrued cashflows for each directional interconnector.
    - Impact on hedging and SRA participation – SRA units were developed as a product for traders to manage their inter-regional financial risk. The inclusion of NSR without an efficient way to allocate negative residues presents a material change to the value of SRA units. Consideration should be given to the increased risk and complexity this adds for SRA participants and if the overall purpose of SRA processes is retained.
    - Prudential and cashflow issues – The extent to which NSRs accrue on the loop has the potential to impact the cash flow of TNSPs and Traders if allocated to them.
        - TNSPs - NSRs are currently recovered as per the IRSR settlement schedule that does not align with, TNSPs regulatory reset and price setting process. If NSRs continued to be allocated to the TNSPs there may be a significant increase in negative cash flow requirements impacting TNSP management of regulated opex.
        - Traders – If Traders are liable for NSRs the relatively unpredictable nature of this cash flow may increase prudential requirements and impact Trader liquidity.

3.2 Next steps

This section describes the short-term next steps in preparation for both phases of PEC commissioning.

Phase 1

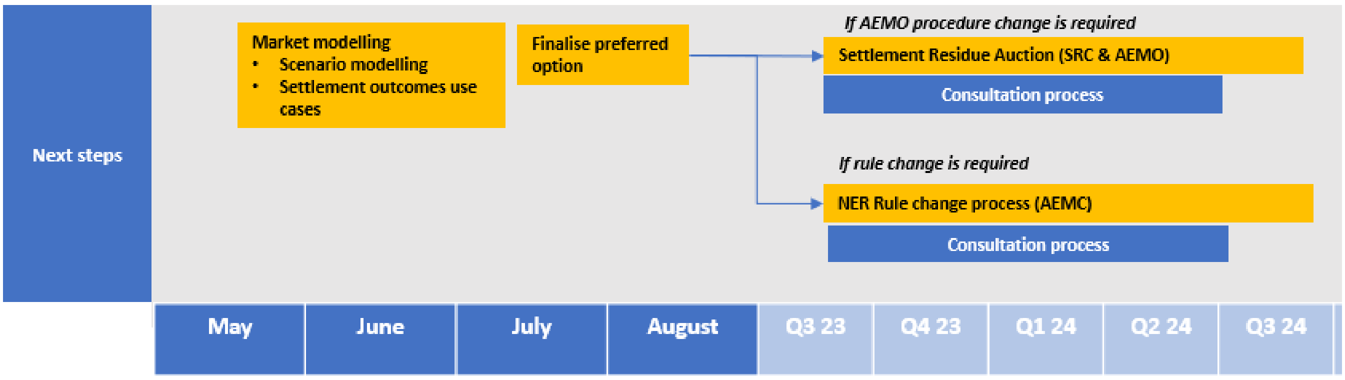
Phase 1 implementation is progressing on track for progressive capacity release from early 2024. The impact of negative residues and the required dispatch constraint equation are only applicable for Phase 2 when the transmission loop will be developed. To support implementation of phase 1, AEMO has commissioned independent power system modelling that will be published following completion.

Phase 2

Market integration activities for the implementation of Phase 2 are underway in parallel and are the focus of this report. This includes the development of the constraint and network model into NEMDE as discussed in Section 2. Key activities for the development of the negative settlement residues approach are:

1. **Market modelling work** – AEMO is undertaking dispatch modelling to demonstrate example dispatch and settlement outcomes across the directional interconnectors, resulting from the implementation of PEC. This scenario-based modelling seeks support understanding of the extent of NSR accrual, demonstrate power flows and compare options for NSR reallocation around the loop.
2. **Stakeholder webinar –** Stakeholder webinar will be held following to provide further information about PEC NSR integration including the AEMO's preferred option for the management and reallocation of NSR.
3. **Implementation approach –** AEMO will confirm its preferred position for the management of NSR and a recommended approach, including identification of any NER change requirements and engagement with the AEMC. This will include ongoing engagement with the Settlement Residue Committee (SRC) and alignment to the guiding principles that were provided in the PEC Market Integration Paper. Depending on the preferred approach there are likely to be two primary pathways for regulatory change: 1) Settlement Residue Auction Rule Change and 2) NER change. AEMO may undertake a second round of stakeholder consultation if this would fast track and not duplicate a round of consultation in any AEMC rule change process or SRC auction rule change process.

Figure 4 Estimated timings for next steps



3.3 PEC implementation

The integration of the PEC Phase 2 transmission loop into dispatch and market processes represents a significant change and AEMO acknowledges that unknowns remain regarding the operation and impact on dispatch outcomes. During the implementation and commissioning of PEC capacity, interim or transitional arrangements for settlement residues will likely be required as PEC capacity progressively becomes available in parallel to the implementation of any change in NSR management and residue allocation. This section includes estimated timings and PEC implementation requirements, noting that in progressing closer to commissioning, implementations actions and requirements are likely to change.

- **Auction process for existing capacity** – as per the Settlement Residue Auction guidelines, interconnector capacity is auctioned up to three years ahead of the accrual period. As the PEC loop and resulting reallocation of NSR will likely change the way units across all three interconnectors are calculated and valued, existing capacity that has already been auctioned will be affected. If this is the case, units that have already been auctioned for VNI, Heywood and any progressive PEC capacity that has been released post engineering completion may need to be adjusted once new settlement residue processes have been developed. Any required redistribution of allocated units will only be undertaken with the approval of the Settlement Residue Committee and discussed with stakeholders as part of the development of new NSR management options.

- **Transition period** – The Settlement Residue Committee has confirmed that interconnector capacity should be not auctioned or included in SRA process until after engineering completion and commissioning. Given the progressive release of PEC capacity, there is likely to be a period where settlement residues are accruing on PEC and around the transmission loop, but capacity has not been included in an SRA process as the capacity is pre-completion or in a testing phase. AEMO will consider the settlement residue implications and timing for this, including the likely need for a transitional process for the management of IRSR as PEC capacity progressively comes online for settlement residues that are accruing but capacity has not yet been included within an SRA process. Prior to engineering completion and commissioning, units will not be offered in the SRA process and will not exist.

Figure 5 Estimated timings for PEC implementation actions