Economic Regulation Authority

Limit Advice and Constraint Equations Review 2025

Draft report

31 July 2025

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Invitation to make submissions

Submissions are due by 4:00pm WST, Friday, 22 August 2025

The ERA invites comment on this paper and encourages all interested parties to provide comment on the matters discussed in this paper and any other issues or concerns not already raised in this paper.

We would prefer to receive your comments via our online submission form https://www.erawa.com.au/consultation.

You can also send comments through:

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Post: Level 4, Albert Facey House, 469 Wellington Street, Perth WA 6000

Please note that submissions provided electronically do not need to be provided separately in hard copy.

All submissions will be made available on our website unless arrangements are made in advance between the author and the ERA. This is because it is preferable that all submissions be publicly available to facilitate an informed and transparent consultative process. Parties wishing to submit confidential information are requested to contact us at info@erawa.com.au.

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Executive summary

Since the commencement of the new Wholesale Electricity Market (WEM) on 1 October 2023 and the introduction of Security Constrained Economic Dispatch (SCED), the WEM has been operating under a constrained network access model. Constrained network access supports the environmental limb of the State Electricity Objective, enabling more lower-emissions capacity to connect to the network, as well as improving network utilisation and efficiency of network expansions.

Limit advice is provided to the Australian Energy Market Operator (AEMO) by Western Power on the technical limitations of the network. AEMO then uses this data to develop constraint equations for managing congestion on the network, both in real-time dispatch and for the allocation of Network Access Quantities (NAQ's).

Fundamentally, there are two types of network limitations reflected through limit advice from Western Power and incorporated into market mechanisms as constraint equations. These are thermal and non-thermal network limits. Thermal limits define the maximum amount of electricity that can flow through network equipment without overloading it. Non-thermal limits relate to the impact of electrical flows on power system security and stability, for example voltage stability.

Limit advice and constraint equations are important elements of the dispatch process. While supporting power system security and reliability, they also facilitate efficient economic outcomes in the market, in terms of real-time operation and the allocation of capacity credits.

The energy transition is rapidly altering the ratio of carbon intensive scheduled generators to less carbon intensive or zero emission non-scheduled generators. As more non-scheduled generation enters the market, and more conventional scheduled fossil fuel intensive generators exit the market, maintaining power system security and reliability will become more challenging for both Western Power and AEMO.

Hence, limit advice and the consequent constraint equations are an essential enabling mechanism for the WEM. It is important that they are developed and formulated in a way that balances the guiding principles of the WEM: security and reliability of supply of electricity, the price of electricity, and decarbonisation of the power system.[1]

What was the review's scope and approach?

The Economic Regulation Authority (ERA) was given a new function, to review the effectiveness of limit advice developed by the network operator and constraint equations formulated by the power system operator in meeting the State Electricity Objective and good electricity industry practice.[2,3]

The ERA must conduct its first review of limit advice and constraint equations (LACE review) within two years of the commencement of the new market, setting the final report publication date at no later than 30 September 2025. The ESM Rules also require that the ERA publishes a draft report for consultation.

The ERA has undertaken an inter-jurisdictional review looking at Australia (NEM), Ireland (I-SEM), North America (CAISO and ERCOT) and New Zealand to identify whether external

[1] Electricity System and Market Rules, 4 June 2025, clause 1.2.1, (online)

[2] Electricity System and Market Rules, 4 June 2025, clause 2.27A.2, (online)

[3] Western Power is the sole network operator in the WEM, and the Australian Energy Market Operator (AEMO) is responsible for the operation of the power system.

oversight related to network constraint formulation is typical in other jurisdictions, to identify best industry practice and to develop a framework to guide its review.

The framework applied by the ERA for this project consists of a process and risk mitigation assessment review, and an effectiveness review. The framework also looks at how Western Power's and AEMO's processes compare against best industry practices identified across other jurisdictions.

Using this framework, the ERA has assessed Western Power's and AEMO's internal processes and governance in relation to the development of limit advice and constraint equations. Such assessment is intended to provide assurance to the market that both organisations have robust internal processes, which are well documented and there is evidence through a governance framework that these are followed.

The ERA has also reviewed relevant WEM Procedures and assessed whether they appropriately capture these internal processes and provide sufficient information to external stakeholders.

The ERA's LACE review has assessed whether Western Power's and AEMO's processes and governance frameworks ensure that limit advice and constraint equations are developed and formulated using best industry practice, standard calculation methods, and apply justifiable methods and assumptions. The ERA's aim has been to provide clarity around the development process for limit advice and constraint equations and to offer suggestions for improvement of deficiencies.

While undertaking the LACE review, the ERA engaged extensively with subject matter experts at both Western Power and AEMO and reviewed numerous internal and public documents.

What are the LACE review's findings?

The ERA has undertaken this first LACE review less than two years into the new market, which commenced on 1 October 2023. Both Western Power and AEMO have demonstrated their efforts to prepare their systems and processes before new market start.

The review has concluded that while the processes within both organisations are robust and internally transparent, the level of internal documentation available to staff varies in quality and quantity between both organisations. This is flagged as an area for improvement.

Both organisations have introduced automation where it supports streamlining the development of limits and constraints. Those processes appear to include sufficient checks and approvals at appropriate stages through development and formulation.

Western Power and AEMO apply standardised calculation methods and philosophies for the development and formulation of limits and constraints, and have adopted industry best practices from other jurisdictions, as appropriate.

The communication processes between Western Power and AEMO have matured over the last two years. Both organisations have taken the time to build communication lines and to better understand each other's requirements related to the SWIS network and their respective functions. There is a shared commitment to continuously improving and maturing their communication and respective processes.

A good example of the ongoing improvement effort is the work undertaken by Western Power, with support from AEMO, on the introduction of dynamic thermal line ratings. Western Power currently applies static thermal ratings for its network. Static thermal ratings, while varying between summer and winter, are based on worst case scenarios. They do not consider real-time weather conditions and external factors, like solar radiation or wind speed. At times this limits the amount of electricity that is allowed to flow through the network, resulting in sub-optimal network asset utilisation. Dynamic line ratings will be more flexible. Global experience identifies higher network utilisation rates through dynamic line ratings.

The LACE review's assessment of the public procedures has concluded that they contain an appropriate level of information to provide clarity to subject matter experts, fulfilling their basic functionality. However, these procedures could be improved to provide more information for less technical stakeholders. Public procedures are one of the early points of contact with the market's requirements and both Western Power and AEMO could extend their procedures to provide more educational information for potential new market entrants. This is another area that the ERA has identified for potential improvement.

Thermal limits and constraints effect not only the real-time dispatch but also influence the allocation of network access quantities and capacity credits through the WEM's Reserve Capacity Mechanism (RCM). The review has identified areas of limited transparency of the link between Western Power's investment decisions in augmenting the network and the RCM limits and constraints development processes.

In some cases, RCM limits and constraints may act to restrict allocated capacity, which can be resolved through the introduction of special protection schemes,[4] while in other cases Western Power may commit to network investments, the criteria for which lacks codification. These processes could benefit from improved clarity and transparency.

The efficiency of network investment is beyond the scope of this review and crosses into another regulatory function of the ERA – the network access arrangement. Network investments are regulated through Western Power's access arrangement and new investments must meet the New Facilities Investment Test or be approved Priority Projects. Such expenditure will be reviewed by the ERA as part of Western Power's next access arrangement.

LACE review public consultation

This first LACE review draft report identifies areas for potential improvement, which are outlined in detail in Section 7.2. These include:

- Updating and expanding the public procedures to include more information to support less technical stakeholders.
- Developing internal documentation to cover the internal processes.
- Increasing the transparency around RCM processes and how limits and constraints fit within the RCM framework.
- Continuing the roll out of dynamic thermal line ratings across the network.

The ERA is seeking views from market participants and interested stakeholders on whether these recommended improvements would benefit the market and whether there are other areas that should be considered. The ERA is would also welcome views on any other aspects of the LACE review or the overall LACE framework in the WEM.

The ERA's draft report is supplemented by a technical consultant's draft report which provides more detail on technical aspects of the effectiveness review and the broader LACE review.

[4] Special protection schemes are condition-triggered automated control systems that are designed to maintain wide-area system stability.

The consultant's report is also provided for public feedback and market participants and interested stakeholders are invited to comment on this report. The consultant's report is available at the ERA webpage together with the ERA's draft report. [5]

For information, the ERA has also published the inter-jurisdictional review report summarising findings of its review of oversight functions and best industry practices in other markets.[6]

5 Ampere Labs, *Limit advice and constraint equation effectiveness review – draft report*, July 2025, (online).

6 Ampere Labs, *Inter-jurisdictional review of limit advice and constraint equations development and assessment*, July 2025, (online).

1. Introduction

The Wholesale Electricity Market (WEM) has undergone major change and reforms introduced Security Constraint Economic Dispatch (SCED) and constraint network access to the WEM from 1 October 2023.

The SCED ensures power system security and reliability by incorporating the physical limits of the system, including network limits, essential system service requirements and balancing demand and supply, into the scheduling and dispatch decisions. These limits flow into the dispatch through 'constraint equations', which are mathematical equations the Australian Energy Market Operator (AEMO) develops and applies in the dispatch process.

Network constraint equations reflect the physical limits of the network. These are developed by Western Power, the sole network operator in the WEM and are provided to AEMO in the form of limit advice.

1.1 ERA's obligations under ESM Rule 2.27C

With the introduction of the SCED, the ERA was given a new function under clause 2.27C.1 of the Electricity System and Market (ESM) Rules to review the effectiveness of limit advice provided by Western Power and the constraint equations formulated by AEMO in meeting the State Electricity Objective (SEO) and good electricity industry practice.[7] As of 6 February 2025, the SEO replaced the Wholesale Market Objectives and states:

> The State electricity objective is to promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity in relation to:
>
> a. the quality, safety, security and reliability of supply of electricity; and
>
> b. the price of electricity; and
>
> c. the environment, including reducing greenhouse gas emissions.[8]

As part of the review into the effectiveness of limit advice and constraint equations (LACE review), the ERA must examine the appropriateness of the:

- limit margins applied by Western Power;
- operating margins applied by AEMO;
- WEM Procedures described in clauses 2.27A.10(b)(i) and 2.27A.11; and
- any other matters which the ERA considers relevant.[9]

In its review, the ERA must include the assessment of limit advice that relates to operational network limits and Reserve Capacity Mechanism (RCM) limit advice and the constraint equations AEMO develops for both purposes. Limit equations related to Frequency Co-optimised Essential System Services (FCESS) are excluded from this review.[10]

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7 Electricity System and Market Rules, 4 June 2025, clause 2.27C.1, (online)

8 Electricity Industry Act 2004 (WA), 6 February 2025, clause 3A(1), (online).

9 Electricity System and Market Rules, 4 June 2025, clause 2.27C.2, (online)

10 Electricity System and Market Rules, 4 June 2025, clause 2.27A.2, (online)

1.2 Timelines and deliverables

The ESM Rules define that the ERA must complete the first LACE review within two years of the start of the new market (1 October 2023) and then at least every three years. For this first review , the ERA must publish a final report by no later than 30 September 2025.

The ERA, with the support of external consultants, has undertaken a review across other jurisdictions to explore oversight functions, whether by regulator or another external body, in other comparable power systems.[11]

Following the inter-jurisdictional review, the ERA developed a framework to support its own review into the effectiveness of limit advice and constraint equations in the WEM. This framework is outlined in section 2.2 of this report.

The ERA engaged with Western Power and AEMO and has worked closely with them to undertake the review. The ERA is now publishing this draft report for consultation, closing at 4 PM on Friday, 22 August 2025.

Following public consultation, the ERA will publish a final report by 30 September 2025.

11 Section 2.3 of this report provides a high-level summary of the findings of this review and the ERA has also published this report, (online).

2. ERA's limit advice and constraint equations review (LACE review)

2.1 Scope and limitations of the review

The ESM Rules guide the limit advice and constraint equations development and application in the WEM. There are specific requirements around what information AEMO must publish on its Congestion Information Resource (CIR) website.[12]

The ESM Rules clause that governs the ERA's LACE review includes some compulsory components that the ERA must include in its review, like the appropriateness of the margins both Western Power and AEMO apply, as well as the appropriateness of some of their public procedures. Other components of the review are left at ERA's discretion to include in the scope of the review.[13]

The ESM Rules do not mandate a technical review that checks the accuracy of limit advice and constraint equations. The Governance Framework for Constraint Equations, published by the Energy Transformation Taskforce in August 2019, refers to the ERA undertaking monitoring and regulating compliance.[14] The paper states that the ERA can take a risk-based approach to this role and may "review all constraint equations or audit a sample". However, this is in the context of responding to concerns raised by market participants.[15]

A technical review confirming the reasonableness of limit advice and constraint equations would mean scrutinising and potentially duplicating the engineering work undertaken by both Western Power and AEMO. There is a distinction between reviewing whether technical documentation reflects good electricity industry practice and reviewing the accuracy of the calculations themselves.

The ERA review has not assessed the calculations of limit advice and constraint equations but instead reviewed documentation that describes the methods and approaches. The ERA also did not audit or review Western Power's or AEMO's automated systems, relying on the technical expertise of each organisation to ensure its systems are fit for purpose in line with their respective functions.

The ERA's review has assessed the completeness and appropriateness, including level of documentation and resourcing, of Western Power's and AEMO's processes and governance.

The ERA has explored the internal frameworks and governance structures and confirmed whether there is evidence that these are being followed. The review has established what these processes are, how are they documented and followed, whether there are gaps and what could be improved. An organisation with well-established processes and governance structures, can be expected to deliver its output in a consistent and reasoned manner.

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12 Australian Energy Market Operator, WEM Congestion Information Resource website, (online).

13 Electricity System and Market Rules, 4 June 2025, clause 2.27C.3, (online)

14 Energy Transformation Taskforce, *Governance Framework of Constraint Equations – Information paper*, August 2019, section 5, pp. 10-11, (online).

15 Energy Transformation Taskforce, *Governance Framework of Constraint Equations – Information paper*, August 2019, section 5, p. 11, (online).

This review can provide assurance to the market that the limit advice and constraint equations are developed and applied in an effective way, meeting the SEO and good electricity industry practice.

2.2 ERA framework

The ERA with support from its consultant undertook an inter-jurisdictional review to identify and explore oversight functions across other jurisdictions and to identify best industry practices. Subsequently, it developed a framework to support its review of Western Power's and AEMO's processes and governance in this area of their operations. The LACE framework subdivides the review in two main components that are outlined in the sections below.

2.2.1 Process and risk framework review

This assessment comprises two elements. One is looking at Western Power's and AEMO's internal processes and how these are captured in their external procedures (process review) as published by Western Power and AEMO. The second element looks at the internal structures (risk mitigation review) around risk identification and mitigation. This section will consider whether both Western Power and AEMO have:

- Comprehensive end-to-end processes that describe all necessary functions are in place and documented.
- Sufficient checks and balances in place inside and between the organisations.
- Controls in place to mitigate risks (including key person risks, single points of failure etc).
- Adequate resources (documentary and physical) to perform the necessary functions (allowing for staff absences and turnover).

Process review, including assessment of public procedures

This review section examined the internal processes Western Power and AEMO follow in developing limit advice and formulating constraint equations, respectively. The ERA has assessed whether these processes are aligned with the State Electricity Objective and good electricity industry practice.[16] This part of the review also assessed the appropriateness of three WEM Procedures, two developed and published by AEMO and one by Western Power.[17]

- AEMO's WEM Procedures must be assessed on whether they include a clear description of AEMO's processes and matters it considers when formulating and updating constraint equations (including operational and RCM constraint equations), specifically in relation to:
  - how AEMO applies Operating Margins; and
  - whether AEMO is following good electricity industry practices and is ensuring that the State Electricity Objective is met.

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16 Electricity System and Market Rules, 4 June 2025, clause 2.27C.2, (online)

17 These procedures are: AEMO WEM Procedure: Constraint Formulation (online), AEMO WEM Procedure: RCM Constraint Formulation (online), Western Power WEM Procedure - Limit Advice Development (online).

The ESM Rules requirement for what Western Power's WEM Procedure should include is twofold. The review must assess the appropriateness of this procedure and whether it includes a clear description of existing process. As part of the review, the ERA assessed:

- Whether Western Power's WEM Procedure includes all matters it considers when formulating and updating operational Limit Advice specifically in relation to:
  - how Western Power applies Limit Margins; and
  - whether Western Power is following good electricity industry practices and is ensuring that the State Electricity Objective is met.
- Whether Western Power's WEM Procedure includes all matters it considers when formulating RCM Limit Advice for the third year of each capacity cycle, specifically in relation to how Western Power:
  - estimates the configuration of the network at peak demand and the associated thermal limits;
  - estimates the peak demand at each electrical location on the network; and
  - allocates preliminary estimates of network thermal limits to Network Augmentation Funding Facilities.

In addition, the LACE review assessed the appropriateness of two further AEMO WEM Procedures that, while not required under the ESM Rules, are closely linked to the above procedures and it made sense to be assessed as part of this project. These procedures are:

- WEM Procedure: Limit Advice Requirements[18]
- WEM Procedure: RCM Limit Advice Requirements.[19]

The review examined these documents, assessing their completeness and appropriateness to allow Western Power and AEMO to effectively perform the necessary functions relevant to development and update of limits and constraints and whether they provide adequate guidance to external stakeholders.

Risk mitigation review

This part of the review examined Western Power's and AEMO's internal resources and structures to provide a view of how the following risks are identified and mitigated within each organisation:

- There is no single point of failure, e.g., one person that creates, reviews, and approves a limit and/or constraint without peer or external review. Analysing resources available and processes set up to ensure peer review, due diligence, error correction and feedback throughout the life cycle of limits and constraints.
- Key person risks are mitigated, e.g., processes are sufficiently detailed and documented to train new staff and adequate resources are in place such that a single person going on leave (or leaving the business) does not derail the development, application, and

[18] Australian Energy Market Operator, *WEM Procedure: Limit Advice Requirements*, 1 October 2023, (online).

[19] Australian Energy Market Operator, *WEM Procedure: RCM Limit Advice Requirements*, 20 June 2025, (online).

maintenance of limits and/or constraints. Ensuring there is sufficient documentation to allow for a qualified new starter to commence development of limits and/or constraints.

2.2.2 Effectiveness review

The effectiveness review examines the processes adopted by Western Power and AEMO to ensure that limits and constraints are developed consistent with the SEO and good electricity industry practice. Specifically, the ERA considered whether when developing limits and constraints Western Power and AEMO:

- ensure system security is achieved through the limits and constraints, while accounting for economic efficiency and environmental factors;
- are transparent and non-discriminatory, and
- adopt good electricity industry practices (where applicable).

The four elements comprising this review are outlined in the following sections.

Development of thermal limits

The review assessed the extent to which Western Power follows industry standards and practices and applies standard methods in the calculation of thermal limits.[20] The review sought to address whether:

- There are adequate checks and balances in place in all stages of the limits' life cycle.
- Western Power uses standard methods to calculate thermal limits for different asset types.
- There are ongoing processes in place that ensure continuous improvement of the utilisation of network assets based on real-time observations and are there well-established feedback loops.

Over-conservative outcomes

This element of the review examined whether Western Power and AEMO follow good electricity industry practices to mitigate over-conservativeness in limits and constraints in respect of both thermal and non-thermal limits and constraints, as well as operating and RCM limits and constraints. The ERA sought to identify and explore:

- What process are followed and what is the frequency for investigating binding constraints and how such investigations might improve network asset utilisation.
- What internal triggers lead to investigations of binding constraints, and whether these align with good electricity industry practices.
- The decision points for invoking discretionary constraints by the Real-Time Operations team and how these are subsequently reviewed and validated, including an assessment of the impact on the system outcomes and system costs.

[20] This section relates to Western Power, as thermal limits are developed solely by it.

- What criteria are used to determine when to apply discretionary constraints and the processes followed to add discretionary constraints to the constraints' library for ongoing use.

- Whether investigations into binding limits and constraints result in a review process of the appropriateness of limit margins and operating margins and whether there are robust and well documented processes that ensure margins are not overly conservative.

- The feedback loops between Western Power and AEMO, how feedback is considered and incorporated between both organisations, and how errors in the limits and constraints formulation are detected and corrected to ensure they correctly represent the power system's capabilities.

Insecure outcomes

This section looks into both organisations' internal processes that ensure situations are avoided where limits and constraints (both thermal and non-thermal; and operating and RCM) are missing or not performing as expected. This section identifies, explores and addresses:

- Whether existing processes are sufficiently robust to ensure that limits and constraints are accurately formulated to mitigate system security risks, and limits and constraint sets are complete and whether an insecure outcome is due to a non-performing limit and/or constraint, or a missing limit and/or constraint.

- That processes are followed when limits and constraints result in insecure outcomes to prevent reoccurrence, the steps taken to identify the root causes of insecure outcomes and to ensure updated limits and constraints are correct and fit for purpose.

- Whether statistics on real-time system security violations, operator interventions and power system incidents are documented and reviewed, and the ad-hoc review processes would verify discretionary constraints manually invoked by system operators in response to insecure system states.

Limit Margins and Operating Margins

This section assesses the appropriateness of limit margins and operating margins, as required by 2.27C.2 (a) and (b) of the ESM Rules. The ERA considers that margins are appropriate in the absence of either binding constraints, or non-performing constraints, as only the presence of those should trigger a review of the margin of a specific limit or constraint. This section addresses:

- Western Power's and AEMO's processes to determine and review the margins and the circumstances under which reviews occur.

- What parameters are reviewed and how existing margins are assessed for appropriateness and whether the assumptions used by both organisations appropriate and aligned with good electricity industry practice.

- Whether the processes and margins applied consider and reflect each organisation's risk framework.

2.3 Inter-jurisdictional review

The ERA commissioned an inter-jurisdictional review of regulatory oversight and best industry practices regarding the development of limit advice and constraint equations by network and market operators.

The five jurisdictions that were covered in the review were Australia's National Electricity Market (NEM), Ireland's Integrated Single Energy Market (I-SEM), the California Independent System Operator (CAISO), Electric Reliability Council of Texas (ERCOT), and New Zealand. All of these jurisdictions use linear equations to represent thermal and non-thermal constraints.

None of the jurisdictions reviewed have explicit obligations for a third-party oversight or review of network limits and/or constraint equation development. Good governance is achieved with a range of practices:

- Real time monitoring, to ensure that the power system is secure and the constraints are functioning.
- Robust and transparent processes, provides a template to periodically monitor and review limit and constraint outcomes. They also provide governance, accountability and transparency to the relevant stakeholders.
- Regular assessments of binding constraints (since these affect the market). Intended to ensure constraints legitimacy, appropriateness and effectiveness.
- Third party reliability, compliance, monitoring and enforcement. These have a focus on power system security and reliability and involve investigations and penalties for instances where reliability standards were breached.
- Stakeholder feedback, which is often the main pressure towards economic efficiency.
- Periodic business process audits, either self-imposed or required. This is a way to identify risks and improvements in developing, managing or implementing limits and constraint equations.
- Process focused assessments of constraint events, not the constraints technical details, derivation or economic efficiency.

The ERA has published the consultant's effectiveness review draft report, for consultation, and the inter-jurisdictional review report to provide further information.[21] Both these reports supplement the ERA's LACE review draft report.

[21] Ampere Labs, *Limit advice and constraint equation effectiveness review – draft report*, July 2025, (online) and Ampere Labs, *Inter-jurisdictional review of limit advice and constraint equations development and assessment*, July 2025, (online).

3. Security Constrained Economic Dispatch

This section outlines what security constrained economic dispatch (SCED) is, what is 'limit advice' and what are 'constraints equations' and their importance for economic dispatch.

3.1 What is SCED

Security Constrained Economic Dispatch (SCED) is an energy market optimisation algorithm, where software (termed a dispatch engine) calculates the least cost generation dispatch to supply demand and to meet system security needs (termed essential system services or ESS requirements), while respecting the physical limitations of the network and power system configuration.

SCED was introduced in the WEM on 1 October 2023 with the commencement of the new market, as part of a broader reform. The dispatch engine uses constraint equations to optimise the scheduling and dispatch of generation while maintaining power system security and reliability.

The reforms that introduced the SCED also fundamentally changed the access to Western Power's network. Before 1 October 2023, the WEM applied an unconstrained network access model, where generators either:

- connected to areas of the network where there was sufficient capacity to accommodate their full generation,
- funded deep network augmentation if connecting in a more constrained area, or
- operated under run-back schemes limiting their output at times of network congestion.

The balancing market applied a 'Constrained-Off' compensation mechanism that would compensate generators for being curtailed in real-time dispatch due to system security constraints.

From 1 October 2023, the WEM operates in a constrained access network model, where the physical capabilities of the network are considered through the SCED via constraint equations. Under the new constrained access model, generators are no longer compensated for being curtailed in real-time due to system security constraints.

3.2 Types of limits and constraints and their functions

Network limits reflect the physical capabilities of the network elements to transfer electricity. They are fixed values (mostly thermal) or can be also represented as limit equations (mostly non-thermal). Constraint equations are mathematical representations of network limits and ESS requirements, with network constraint equations that flow into dispatch being based on limit advice prepared and provided by Western Power. There are two main types of network limits that are used to develop network limit advice and from it network constraint equations.

3.2.1 Thermal

At a high level, thermal network ratings or limits define the maximum capacity for electrical throughput capability of network equipment, which can be a transmission line, cable or a transformer, but also other network equipment.

Network ratings represent the upper limit of the amount of power (measured in MW or MVA) that can flow through a specific network element continuously without overloading it. When transmission line conductors carry electricity, they heat and expand. When overloaded, they can sag too much, breaching allowed ground clearance limits. Further, overheated conductors may also be damaged. To prevent this, networks have automatic protection systems that take network elements that are overloading out of service.

There are different types of thermal ratings. At a high level, there are:

- dynamic ratings, calculated continuously and change subject to solar radiation, ambient temperature, wind speed and other external factors.
- static ratings, which are fixed for a period of time (year-round, day/night, seasonal such as winter/summer etc.) and the value varies between these periods only. The ratings, while static over a period of time are still calculated using some level external influence factors, like ambient temperature, sunlight, and wind speed.

There are also other classifications of ratings, like normal ratings, short-time ratings, fault ratings, emergency ratings and others that are used in varying circumstances.

Western Power currently uses static thermal ratings for summer and winter. These are calculated using individual equipment's type and nameplate ratings, geographical location, installation and other relevant parameters. Parameters considered vary from the types of equipment the ratings are calculated for (overhead lines, underground cables, transformers etc.) and the calculations are following industry standards.

Western Power and AEMO are currently working together on developing a dynamic rating system to implement in the South-West Interconnected System (SWIS).

Western Power provides the thermal ratings to AEMO in the form of thermal limit advice. AEMO formulates thermal constraint equations that are compatible for use in the dispatch engine in the dispatch algorithm to ensure the physical characteristics of the network are respected.

3.2.2 Non-thermal

Non-thermal network limits define the maximum capacity for electrical throughput related to the impact on power system security and stability, for example on voltage stability standards. These limits can apply to more than one piece of equipment and are often developed for network 'cut-sets', which can consist of a single network element or of several network elements. Western Power pre-defined cut-sets across the whole network before new market start. However, when new non-thermal limits are determined or existing ones reviewed, the cut-sets may be redefined.

In most cases, Western Power creates non-thermal limit advice for voltage and transient stability to ensure the system operates within its technical envelope and will be able to recover from disturbances. Stability limits vary with network location, generation quantity and types connected in that area and demand. Where more intermittent generation is connected to an area of the network (for example the North Country), Western Power monitors this area closely and has developed non-thermal limit advice to support power system security.

Voltage stability determines the power transfer limits through a defined cut-set to ensure that the system operates within the design tolerance limits and complies with the requirements of the Technical Rules. When voltage is stable on a power system, the system is able to recover from short-term voltage disturbances.

Transient stability is the ability of the power system to maintain synchronisation in the case of severe disturbances, for example a short circuit on a transmission line. Transient stability and the criteria for it are defined in Western Power's Technical Rules.[22]

There are other stability limits and requirements that Western Power must maintain, but it develops limit advice mostly for voltage and transient stability. These are also provided to AEMO for inclusion in the dispatch algorithm in the form of limit advice, however, the development process is more complex.

Non-thermal limit advice ensures that the power system is dispatched securely and is maintained within the parameters of the Technical Rules.

3.2.3 Reserve Capacity Mechanism limits and constraints

As part of the Reserve Capacity Mechanism (RCM) in the WEM, generation facilities are allocated capacity credits.[23] The RCM seeks to ensure there is sufficient generation capacity in the SWIS. With the introduction of the constrained access network model, the allocation of capacity credits includes an additional step that considers the physical capacity of the network in the area where a generator is connected or is planning to connect.

As part of the capacity credits allocation process, AEMO calculates the network access quantity (NAQ) for each facility, which among other parameters, is based on network capacity available for each facility at its location during peak demand periods.

All calculations that relate to the RCM process assume an ambient temperature of 41°C.[24] Network limits are considered in NAQ modelling runs to estimate the output from each facility the network can accommodate under system stressed conditions.

Western Power must develop RCM limit advice to provide to AEMO to formulate RCM constraint equations that are used in the NAQ model. RCM thermal ratings calculated by Western Power are done in the same way it calculates operational thermal ratings but are calculated at an ambient temperature of 41°C. AEMO then uses the RCM limit advice to develop RCM constraint equations for the NAQ model. The calculations apply to the third year in the capacity cycle and provide an expectation of the system configuration based on currently available information.

22 Western Power, *Technical Rules*, 1 Dec 2016, (online).

23 Australian Energy Market Operator, Reserve Capacity Mechanism webpage, (online).

24 Electricity System and Market Rules, 4 June 2025, clause 4.4B.3(a)(i), (online)

4. Development and maintenance of limit advice and constraint equations – process review

As outlined in section 2.2, the ERA framework for the Limit Advice and Constraint Equations review (LACE review) under clause 2.27C of the ESM Rules, is broken down in two main parts: a process and risk mitigation review section and an effectiveness review section.

The first section assessed the internal processes Western Power applies when developing limit advice and AEMO's follows when formulating constraint equations, and the interactions between both entities, as covered in the process and risk mitigation part of the ERA framework.

The ERA worked closely with Western Power and AEMO while undertaking the review, meeting with subject matter experts from the teams responsible for the development, maintenance and application of limit advice and constraint equations.

The ERA requested and reviewed multiple documents from both organisations, including internal guidelines, procedures, flowcharts etc. to satisfy itself that Western Power and AEMO follow well formulated internal processes and there is a good level of governance with clear delineation of responsibilities. These documents are listed in Appendix 3. The findings of the review are summarised below.

4.1 Intra and inter-organisational process review, information flow and documentation

This section steps out the processes the ERA explored in the review. It highlights observations on process completeness, governance, documentation completeness.

As part of the review, ERA held interviews with Western Power's and AEMO's subject matter experts to step out through their respective processes applied in the development and formulation of thermal, non-thermal and RCM limit advice and constraint equations. These processes are described in this section.

Both Western Power and AEMO have reviewed the description sections of their respective processes for completeness and correctness and have provided feedback, which was incorporated in the final process descriptions.

4.1.1 Thermal limit advice and constraint equations

4.1.1.1 Thermal limit advice (Western Power)

Process

Western Power, as the network operator in the SWIS, is responsible for developing thermal ratings. These are required for system security and have been developed and utilised by Western Power prior to new market start. AEMO requires the information on thermal limits for all network elements to be able to operate and dispatch the system securely.[25]

The development of thermal ratings is based on the physical capabilities of the individual network elements and is well understood amongst network operators across all jurisdictions.

[25] The review relates to transmission network elements, although Western Power also has ratings for distribution network elements.

Western Power applies standard methods when calculating thermal limits for transmission elements, including mostly but not limited to transmission lines, cables and transformers. These standard methods ensure that defined thermal limits comply with national and international standards, as applicable, and that the requirements of the Technical Rules are met.

As thermal limits have been used prior to the start of the new market, there was an ‘initial’ set of thermal limits at market start which has since been amended and updated on an as needed basis. This can be the case when for example new transmission elements are added to the network, changes in asset performance, decommissioning of network elements and others.

There are multiple triggers that can cause Western Power to review and (re)calculate updated or new thermal limits. These include in-service notifications and commissioning notes, when new transmission elements are to be added to the network, or ad-hoc changes, like asset replacements The process of developing thermal limits itself is the same, regardless of the type of trigger.

The annual Reserve Capacity Mechanism (RCM) cycle and the determination of network thermal limits at 41 degrees Celsius is another trigger for the review of thermal limits (peak demand limits). This process is discussed separately in section 4.1.3.1.

Western Power calculates summer and winter thermal ratings for operational purposes, based on the nameplate attributes of the transmission elements, their physical location, static solar radiance and wind values and other relevant information.[26] The thermal ratings currently used by Western Power are static, meaning they do not change with weather conditions, except that there are summer and winter limits. The maximum rating of each piece of equipment is the hard limit for that equipment, with the most limiting rating being the “lowest limiting factor” in a circuit.

Western Power uses a broad range of systems that contain different information. There are no manual interventions in the calculation process of transmission lines thermal limits itself. However, depending on the trigger, there are manual entries of data in specific systems, from setting up a new transmission element to only updating an existing data entry. Where values are manually changed, entries are noted in a report to be checked.

All these systems are interconnected to varying degrees and thermal limits related information is collected in the System Access Limit Manager, which is the system where ratings are managed. This system automatically generates the final thermal limit advice, which is an Excel workbook that is provided to AEMO and to Western Power’s internal systems.

When Western Power calculates transformer thermal ratings, the process is not automated due to the higher complexity of that equipment. Developing thermal limits for a transformer is a manual process that requires the active involvement of an engineer in terms of undertaking research and studies before defining the limits. The engineer undertakes calculations to determine short- and long-term emergency limits and normal cyclic loading levels, which are required before the transformer rating studies are completed.

Overall, a minimum of five different studies are undertaken before the transformer thermal limits are determined. Competed studies are recorded in a master file and a study report is prepared for review and approvals. Western Power has a standardised approval protocol for

[26] These external factors influence the physical throughput capabilities of the conductors.

transformer limit calculations. Competed studies reports are reviewed by more senior level engineer before approved by the group leader.

Dynamic line ratings

Dynamic line ratings, differ from the static line ratings currently used by Western Power, as they account for external factors like for example solar irradiance and wind speed and direction constantly, and the thermal rating values change based on these. This results in thermal ratings being at times less restrictive depending on the weather conditions, improving network utilisation.

At around the start of the new market, Western Power commenced a project to introduce dynamic line ratings on its network. This project is being undertaken in collaboration with AEMO, as once introduced, AEMO's systems will use them in dispatch processes.

The project will be delivered in six stages, with the starting point being the status quo – using static thermal ratings for summer and winter. The application of dynamic ratings is dependent on availability of data on solar irradiance, ambient temperature, wind speed and direction, as well as direct observation of the lines.

Through the different stages Western Power has increased the amount of real-time data that is added to the static rating equations. Stage two of the project resulted in proof of concept of the platform that Western Power is intending to use and is not used operationally at this stage.

Western Power is currently completing stage three of the project and has selected a formulation method for dynamic line ratings. This has now been applied in Western Power's internal systems, and at the end of this phase these will start flowing into some of AEMO's systems. At the end of the third stage, currently planned for October 2025, Western Power aims to apply dynamic ratings on a selected set of transmission lines, and these will also be used in AEMO's systems and in the dispatch process.

Once the project is completed, Western Power will have a fully implemented platform that will provide dynamic line ratings across the whole transmission network to AEMO for utilisation in dispatch.

Western Power is sourcing data from the Bureau of Meteorology (BOM), who has a large set of weather information around wind speed and provide access to sophisticated wind speed analysis. BOM has received funding from the federal government under the 'Rewiring the Nation' initiative to support network providers in the introduction of dynamic line ratings. One of the goals of this initiative is to ensure that existing networks are utilised to a maximum, before new transmission lines are built.

Findings

Overall, the ERA is satisfied that Western Power has robust processes for the development of thermal limit advice. The majority of the work is automated. Where manual calculations are undertaken, because of their complexity, there are review and approval processes to ensure it is completed to the required standard.

The ERA has not audited the code for automated processes, such as the calculation of thermal line ratings, and instead focussed on Western Power's internal governance structures and requirements.

The development of thermal ratings involves many individual processes and teams within Western Power, depending on the trigger for the thermal rating development and therefore, multiple systems are also involved. There are areas of the process that require manual data entry, including Excel workbooks.

Once information has been entered into a system, the flow from one system to another is mostly automated. Human error at the entry point could cause an erroneous data entry. However, there are multiple checks and system alerts that get activated if errors or missing information are detected by the system. Western Power staff also manually reviews much of the information to ensure any errors are captured early.

4.1.1.2 Thermal constraint equations (AEMO)

Process

AEMO, as the market operator is responsible for the secure and reliable dispatch of generation in the SWIS to meet operational demand. To prevent the dispatch engine from dispatching generation outside the network's defined thermal limits, AEMO has to convert the network thermal limits provided by Western Power into linear constraint equations that the dispatch engine can interpret.

AEMO typically receives new or updated thermal limit advice when there has either been an error, there is network augmentation, or any other reason Western Power had to review and update the existing thermal ratings, as described in the previous section.

The Grid Modelling team receives Western Power's thermal limit advice in the form of an Excel workbook and provides those limits to the WA Operations Planning team.[27] The WA Operations Planning team's role is to assess what thermal limit advice has changed, how it has changed, why it has changed. During WA Operations Planning team's initial check of the thermal limit advice, they may send an email to Western Power if clarification is required, or if they deem something is unusual about the limit advice provided.

Thermal limit advice, however, is rarely challenged by AEMO unless there has been a drastic change, or if the limit advice is related to a constraint equation that has previously bound in dispatch and is expected that the updated limit advice may result in power system security and reliability issues. The primary reason is that AEMO does not have access to all the information needed to develop and check thermal limit advice.

Once the WA Operations Planning team have reviewed and accepted the thermal limit advice, it is entered into AEMO's internal system (the energy management system). If there is any degree of urgency to implement the new limit advice that was provided, WA Operations Planning team can directly communicate that information to the Real-Time Operations team.

Once a thermal rating is entered into the energy management system, it flows on to other systems where it may be used and is converted into a format that can be processed by the dispatch engine. Where there is only a small change in a thermal rating and no review of constraint equations required, the existing constraint equations that use this specific thermal rating will be automatically updated.

AEMO's WA System Engineering team is responsible for the thermal constraint equation formulation. The way in which the WA System Engineering team formulates thermal constraint equations is standardised and documented in AEMO's public WEM Procedure: Constraint Formulation.[28] The procedure details a standard method that AEMO must follow

[27] This team supports the Real-Time Operations team and gives them advice how to operate the system during planned outages. They ensure that AEMO's systems contain the correct information for dispatch.

[28] Australian Energy Market Operator, *WEM Procedure: Constraint Formulation*, 1 October 2023, (online).

when formulating thermal constraint equations. This consistency in thermal constraint equation formulation has allowed process automation.

Whenever a thermal constraint needs to be updated or built, the WA System Engineering team commence the process. The team uses multiple tools for this analysis.

AEMO receives a PowerFactory model of the transmission network in the SWIS from Western Power that reflects the current network configuration. AEMO includes any additional information that is needed for the purpose of constraints formulation before it can be validated.

Should AEMO encounter problems with running or validating the model (the model does not solve), AEMO seeks information and clarification from Western Power until the team is satisfied that the model is valid and can be used for their purposes. This typically occurs through emails between Western Power and AEMO. Depending on how long it takes to clarify issues between the two entities, for example when a new generator is added to the system, a model validation may take multiple weeks.

Once the thermal limits and the associated PowerFactory model are reviewed and validated, an engineer will execute scripts that run PowerFactory.

An engineer will supervise the scripts running and the outputs, since troubleshooting and debugging may be required. Among other factors, new and unique system configurations, contingencies and addition or removal of facilities may need new constraint equations to be formulated, whilst already existing combinations may only require updates to previously created constraint equations.

While the process of formulating the constraint equations is highly automated, all inputs and outputs are reviewed by an engineer, assessed for reasonableness and completeness and where unexpected results occur, multiple review steps are undertaken until it is resolved. At any stage of the formulation process, other engineers may be involved to provide support and advice as required.

The process will produce constraint equations, a file that highlights differences between new and existing constraints and output information. These outputs are reviewed by another, typically more senior, member of the WA System Engineering team as part of the peer review process before being approved.

The review process for new or updated constraint equations depends on both time limitations and familiarity with the SWIS. The most extensive review uses historical real-time data to make sure that the theoretical output matches empirical results. Familiarity with the SWIS and engineering judgement are also part of the review process, and where applied, and its justification is recorded.

Following review, a constraint equation is then added to an internal system and is then published on AEMO's public Congestion Information Resource (CIR) and to the dispatch engine.

AEMO has an internal repository where all information used in constraint equation or constraint set development is stored for future reference, audit purposes, justification and version control. AEMO's WA Operations Planning team is notified that the requested constraints are available.

Initially, constraint equation sets were built for system normal conditions (the N-0, or NIL sets) that represent a grid configuration with no network outages. These NIL sets are typically always invoked, as they are the least conservative group of thermal constraint equations. Since, the majority of the constraint equations that have been built are for network outages.

Any other constraint equation designed for a more specific system configuration, for example for an outage (N-1), is inherently more conservative and therefore can be layered added on top of the NIL sets to account for different real-time changes in network configuration. The NIL sets ideally would be reviewed be WA System Engineering team every month but are currently being reviewed approximately once every two to three months.

AEMO's WA System Engineering team also formulate constraint equations for scenarios that may occur under specific circumstances. The team's ongoing work includes development of sets of constraint equations for many system configurations where any one or more transmission elements can drop out of service (N-1, N-2 etc. contingencies). Some of these sets may never be invoked. At this stage the majority of the N-1 constraint sets are available to the Real-Time Operations team and the WA System Engineering team is also in the process of developing some N-2, N-3 etc. sets.

While two or more engineers can work independently on a constraint set, before any changes are approved, more experienced engineers review and accept all, or some changes made by less experienced engineers. They would then combine all approved changes into a final set. Business as usual processes include the review of the NIL sets every two to three months. In addition, the WA System Engineering team also assesses regularly the general power system performance and reviews constraint equations, to either add or remove them from particular constraint equation sets.

Real-Time Operations

Power flows in the SWIS are highly dynamic with changing combinations of network outages, generation outputs resulting in different system configurations that have or are likely to happen. The large amount of system configurations requires a library of thousands of different constraint equations.

Currently, the Real-Time Operations team only have the ability to invoke and revoke whole sets and lack the ability to revoke individual constraint equations within a set. There is a project in the testing phase to give the Real-Time Operations team more granular control by revoking individual constraint equations within an invoked set.

If any constraint set has been updated or changed, an email is sent to the Real-Time Operations team and other teams that require this information.

The Real-Time Operations team is responsible for ensuring it has access to the constraints that are needed are ready to be implemented and appropriate at shift start, and if not inform the constraints team. Before invoking any outage related constraints, the Real-Time Operations team runs their own validation tests to make sure the constraint equations sets are fit for the real time situation.

To maintain power system security and reliability, the Real-Time Operations team has the ability to intervene in the dispatch process. When a constraint violation (power exceeds network limits) is picked up by the contingency analysis tool that runs every two minutes, the Real-Time Operations team may invoke a constraint.

The Real-Time Operations team tries to minimise the impact of any intervention they make, so, if possible, the constraint chosen for the intervention will be taken from the operational constraints' library. However, if a relevant constraint cannot be found, the Real-Time Operations team may need to invoke a discretionary constraint.

Because discretionary constraints are a tool created during real-time monitoring for power system security and reliability, they are usually very simple.[29] The Real-Time Operations team may need to invoke a discretionary constraint not because a constraint equation does not exist, but because in its current form it may not be appropriate for the real-time issue at hand. In such cases, the Real-Time Operations team may communicate this to the WA System Engineering team, and they may rebuild an existing constraint equation or build a new constraint.

Following all discretionary interventions, an intervention report is produced to assess what happened and why it happened. Not all market interventions require new constraint equations to be formulated. However, the Real-Time Operations team may request a new constraint equation to replace a discretionary constraint.

The real-time monitoring process in the energy management system is focused on preventing insecure outcomes, it has no current function to assess whether a constraint equation is binding too often or is efficient. Retrospectively, the WA System Engineering team review (on a weekly basis) the intervention reports and assesses whether a constraint equation could have resulted in a more efficient outcome, and if so, the team may formulate a constraint equation for future use.

For issues that cannot be resolved through constraint equations, the Real-Time Operations team develops guides and procedures (control room instructions). These processes, such as the intervention process to manage RoCoF shortages, ensure that there is consistency in responses from different Real-Time Operations team operators to the same issue and minimises the interference and therefore market impact. The control room instructions are only developed and reviewed by the more experienced team members and there is currently no extended formal review process.

Findings

AEMO has well developed processes and systems when it comes to the development of thermal constraint equations. As mentioned, N-0 and N-1 constraint sets have largely been formulated and are available to the Real-Time Operations team before the start of the new market. While the review of the N-0 sets is undertaken less often than ideal, the WA System Engineering team still ensures that these sets are up to date, as they are always invoked.

The team that is responsible for the formulation, update and maintenance the constraint equations sets is rather small and at times there are limited resources. For this reason, ongoing development of new, or update of existing constraint equations is undertaken on an ‘as needed' basis.

While having resource limitations, the WA System Engineering team has strict peer review and approval protocols that are followed. For example, where no one is available to undertake peer review, no new or updated constraint equations or sets are approved for use and publication until the peer review can be conducted. In such cases, the system is operated with the existing sets that are available to the Real-Time Operations team.

This is supported by AEMO’s work to develop N-0, N-1 and N-2 constraint sets on an ongoing basis that aim to cover as many critical cases on the network as possible, providing the Real-Time Operations team with sufficient tools to manage the system.

AEMO have made efforts to automate processes where logical and have ensured that there is an appropriate amount of engineering supervision and checking.

[29] For example, setting a generation output to be greater than or equal, or less than or equal a certain output.

AEMO has well developed systems, a constraints repository where all information is stored that relates to the formulation process of a constraint equation or constraint sets. All internal communication is captured there, any discussions between the team members and if other teams are consulted in the process. This ensures that in the case of an audit or otherwise need to review how and why constraints were formulated, there will be sufficient information available to demonstrate the decision process.

The systems were established before new market start. However, because of the lack of testing prior to the start of the new market they have needed to evolve and have matured over time. Where errors were gradually found through the real-time operation, they were rectified. The actual constraint formulation scripts, however, are based on the principles as published in various WEM Procedures and have not been amended over time, as this would result in a change in the core systems functionality. This degree of rigidity means that AEMO adheres to the standard formulation methodology.

There has been a shift in how the Real-Time Operations team functions. The control room instruction documents are now more common than they were prior to new market start. However, they lack a formal review process. There has also been a reduction in the amount of invoked discretionary constraint equations, reflecting the increased level of completeness of the N-0 and N-1 constraint sets, the naming of discretionary constraints has even changed since market start to provide extra clarity as to what the constraint is doing.

4.1.1.3 Interactions between Western Power and AEMO – end-to-end process map – thermal

Thermal limit advice is provided from Western Power to AEMO via an Excel workbook, which is uploaded to a SharePoint. Every two weeks AEMO sends the Excel workbook to Western Power to review and update, where applicable. Western Power has an internal protocol that lists what documents must be submitted to AEMO.

If there have been changes to the thermal ratings, as flagged in the spreadsheet, AEMO undertakes a review to assess whether updated ratings and limits appear reasonable and whether they would affect an area of the network, which is subject to, but not limited to, regularly binding operational constraints.

In the areas of higher congestion, AEMO undertakes a more thorough review of the changes, specifically if they would cause further congestion, or other power system security and reliability issues. In such cases, there may be more communication between AEMO and Western Power until both entities have resolved any possible concerns with the revisions. This communication usually occurs via phone or online calls and emails, with verbal communication being confirmed via emails.

In the case of unplanned outages, when for example there is a forced outage on the network, Western Power's control room can directly engage with AEMO's Real-Time Operations team. These real time events are retrospectively reviewed and eventually included in the limit advice, once system normal has been restored.

Western Power also provides its PowerFactory model to AEMO, again via SharePoint. The latest model is critical for AEMO to be able to formulate accurate constraints. The model is not provided at regular (defined) intervals and cannot be readily used by the WA System Engineering team. Before using an updated version of it to develop constraint equations, AEMO must undertake its own validation steps to ensure that the model reflects the current system configuration, and it is fit for AEMO's purposes.

The process of communication and validation of the PowerFactory model has matured since the start of the new market, and both entities have worked to improve their communication and better understand each other's requirements. AEMO's use of the PowerFactory model may require Western Power to make some adjustments to its the model.

While these requirements have been and are being communicated on an ongoing basis between both entities, this is currently not codified in guidelines or procedures. This may result in adjustments being lost, or new starters not being aware of them, and need to be followed up as part of the validation process.

As part of its risk mitigation work, AEMO's Python scripts include model validation rules that raise exceptions (warnings and errors), when discrepancies are found during the model validation or constraint building processes.

The cooperation between Western Power and AEMO, which includes regular meetings in addition to the case related email exchanges, involves regular discussion between both entities to work on specific improvements. Where for example AEMO has identified an operational problem and has implemented a temporary, operational solution through constraint sets, there may be the need for Western Power to develop a longer-term solution through an appropriate limit advice development.

There is also an external procedure, published by AEMO that provides information around what data and in what form Western Power must provide in relation to thermal limit advice.[30]

A flow chart that demonstrates the end-to-end process of the development of thermal limit advice and constraint equations is shown in Appendix 4.

4.1.2 Non-thermal limit advice and constraint equations

4.1.2.1 Non-thermal limit advice (Western Power)

Western Power is responsible for the secure and reliable operation of the network in the SWIS. In addition to thermal limits that define the physical capabilities of the network assets, Western Power define non-thermal limits when and where required.

Non-thermal limit advice is created for voltage and transient stability, generally for specific locations of the network, 'cut-sets'. These are defined areas of the network and consist of one or more transmission elements. The purpose of the non-thermal limit advice is to ensure the power flow across the cut-set from a neighbouring zone would not cause violations of the requirements of the Technical Rules. Cut-sets do not overlap with each other.

For system normal conditions (N-0), when all network elements are in operation and for some N-1 contingencies Western Power prepared non-thermal limit advice and AEMO has developed non-thermal constraint equation sets before the start of the new market. Subsequently, non-thermal limit advice is typically updated only when there are specific triggers, like addition of new network equipment (network augmentation), new generation or loads connecting to the system, network outages, changes in generators' operating modes, issues identified through ongoing monitoring, modified protection schemes or asset decommissioning (network and/or generation).

[30] Australian Energy Market Operator, *WEM Procedure: Limit Advice Requirements*, 1 October 2023, (online).

4.1.2.2 System normal

Process

Once a review of existing system normal non-thermal limit advice is triggered, Western Power commences initial studies to assess whether the Technical Rules would be violated through the trigger events. If no violations are identified, no further action is needed. Where violations are identified, the development process of non-thermal limits commences, and Western Power undertakes further studies to determine whether and what type of non-thermal limit advice is needed.

Western Power undertakes system studies to test for violations by creating case studies that push the cut-set limits under the worst possible operating scenarios.[31] Voltage related studies look whether the test case will breach the Technical Rules for steady state performance, being the minimum and maximum post-contingent steady state voltage criterion, or long term voltage stability.

For transient stability Western Power tests Technical Rules compliance with the transient rotor angle criterion, short term voltage criterion, temporary over-voltage criterion and oscillatory rotor angle stability.

Thes assessments result in Western Power determining whether:

- no non-thermal limit advice is required if no violation of the Technical Rules is identified – no action is required.
- non-thermal limit advice is required, if there is a violation of the Technical Rules.

In preparation for the new market, Western Power have developed non-thermal limit advice for all cut-sets of the network under system normal (N-0) and some N-1 system conditions. When it is determined that a new or updated non-thermal limit advice must be assessed due to change in system configuration, the Planning Engineering team's leader will allocate the work to a planning engineer, who will commence the non-thermal limit assessment process.

Depending on the complexity of the violations, the planning engineer will develop up to 8,000 study cases of credible system conditions with marginal transfer across the cut-sets for each non-thermal limit equation by randomly varying combinations of independent variables and changes in system load. PowerFactory is used to set up study cases for non-thermal limit equation development.

These study cases are then used in a regression analysis to determine the contribution factors (coefficients) for all variables included in the limit equation that formulates the transfer limit.

The Technical Rules stipulate that transfer limits must not exceed 95% of the calculated transfer limits in non-thermal limit equations associated with stability limits.[32] Western Power achieves this by either:

- reducing all marginal limits to 95% before doing linear regression; or
- doing the linear regression with all marginal limits and then scaling down the coefficients until the transfer limits threshold of 95% is met.

[31] For example, by maximising energy import or export from a specific cut-set.

[32] Western Power, *Technical Rules*, 1 December 2016, clause 2.3.8 (b), (online).

Consistent with network operators across the NEM, Western Power determines the limit margin for all types of non-thermal limit equations by using a 95% confidence level of a normal distribution. This limits the probability of operating the power system at transfer limits exceeding the calculated limits is not more than 5%.[33]

Once the limit equation is developed and validated, the planning engineer will write an internal assessment report and will log it into the approval system. From there, the report will be reviewed by a principal engineer and will be approved by the planning team's manager. The finalised non-thermal limit equation is entered into a central non-thermal limit advice register, and in Western Power's document management system. The internal report is used for documenting the non-thermal limit advice as such and is also used for version control and record keeping.

Once the internal report has been finalised, Western Power develops and submits non-thermal limit advice to AEMO for publication. AEMO assesses the non-thermal limit advice and publishes it alongside with the non-thermal constraint equations derived from it.

Findings

Overall, Western Power appear to have a well-established process when it comes to the development of system normal non-thermal limit advice. Developing this type of limit advice is complex and requires engineering expertise and knowledge, as well as good understanding of the specifics of the SWIS. Most of the work is undertaken manually by the planning team.

The work for developing system normal non-thermal limit advice involves different tools and information is entered into these tools partially manually. Excel workbooks are partially used for studies with manual entries, which that could result erroneous or missing manual entries. Multiple levels of review aim to ensure that all information used for any study is correct and complete. Final and approved PowerFactory studies, inputs and reports are stored in Western Power's document management system.

These processes do not guarantee that system normal non-thermal limit advice is always error free, but they provide confidence that Western Power have set up a robust framework to ensure high standards are met and that in a case of a potential problem, or an audit, there is sufficient documentation to go back and to review. The internal reports are also used for compliance and version control.

There is high level of dependence on the knowledge and experience of the allocated planning engineer of what the study set up would be, which then directly impacts the final limit advice. Setting up test cases and selecting input assumptions can partially be dependent on the specific engineer's preferences and expertise.

Nevertheless, by strictly applying the peer review and approval processes, it is expected that any differing approaches would tend to converge on outcomes aligned with Western Power's overall approach to developing system normal non-thermal limit advice. This approach is expected to reflect engineering outcomes, and engineering judgment decisions are recorded in the approval document.

A planning engineer who develops non-thermal limit advice must be suitably qualified and undergoes many months of on-the-job training. Their work is subsequently reviewed by a

[33] Australian Energy Market Operator, *ESOPP Guide: Confidence levels, offsets and operating margins – policy*, 6 July 2010, page 8, (online).

principal engineer and approved by the team leader or area manager. This shows that Western Power has a robust governance framework for reviewing non-thermal limit advice.

The team that is responsible for developing system normal non-thermal limit advice is staffed sufficiently to allow for staff absences and contingencies. Given that this team is responsible for other engineering work, there is no single workflow tool that is used within the team. Therefore, work is allocated by the team leader depending on staff expertise, capacity and availability.

4.1.2.3 Planned Outages

Process

Where Western Power intends to undertake a planned outage on the network, there must be an assessment whether existing non-thermal limit advice will be sufficient to maintain power system security for the duration of the outage,[34] or whether new non-thermal limit advice is needed. The network operations team is responsible for undertaking the assessment. These assessments relate to network outages.

Many planned outages do not require non-thermal limit advice, for example where the outage will be in an area where no generation is located. In other areas of the network, Western Power knows that an outage may require non-thermal limit advice assessment. Here, the initial submission in AEMO's outage planning system will have a flag 'pending limit advice', until Western Power makes the assessment of whether non-thermal limit advice will be required or not.

Western Power identifies whether there are concurrent outages and if so, these concurrent outages are registered in the system with allocated request numbers. Concurrent outages would result in varying levels of constraints, depending on their overlap. Western Power then determines and concentrates on which of the concurrent outages will cause the highest level of constraints, which will be the most limiting constraint, but still all concurrent outages are taken into consideration as part of the assessment process.

If this assessment identifies that no non-thermal limit advice is needed, the outage request in AEMO outage management system will be updated with the flag 'no limit advice needed', otherwise the flag will remain as 'pending limit advice'. From there on, there are multiple options that Western Power will explore, if:

- Existing non-thermal limit advice can be used as is, or with some minor adjustment is sufficient for the current outage.
- Existing non-thermal limit advice can be adapted through a so called 'offset adjustment' to a new version of an existing non-thermal limit equation. This is used for example for small network augmentations, where an additional constraint is needed on top of the existing limit.[35]
- New non-thermal limit advice is needed and must be created. This process can take up to eight weeks, or longer in very complex cases.

34 This includes system normal, or previous limit advice which was developed for outages in the same lines or network area.

35 Western Power has provided information on this method and has discussed with the ERA what considerations are taken when using this method. An offset is used where an outage does not change the limit on a cut-set materially, usually less than ten percent of the intercept of the existing equation.

If Western Power determines that an existing non-thermal equation can be used, for example because there was a comparable previous outage in the same cut-set, Western Power will still run a sub-set of PowerFactory studies (100-200) to ensure the solution remains appropriate.

If the outage combination is similar to a previous set of outages, Western Power makes an engineering decision that the existing non-thermal limit advice may cover the current requirements. However, it still undertakes all required system studies to confirm this. Subsequently, the study results from the initial limit advice are compared against the new study results to assess suitability of the limit advice for the current outage combination.

Western Power lodge any non-thermal limit advice assessment case in the limit advice management application (LAMA). This is a shared platform with AEMO, however, Western Power’s view includes limit advice still under consideration, while AEMO can see only limit advice that has been completed and provided to them to assess together with the planned outage submitted in the outage management system.

When an outage related non-thermal limit advice is assessed, Western Power will assess whether an existing system normal non-thermal limit equation can be used for the current outage. These equations constraint market participants the least, as they are expected to apply permanently. However, as the outage would typically take out at least one piece of transmission equipment out of operation, system normal non-thermal limits are usually not sufficient to ensure system security.

In the next step, the allocated engineer starts assessing existing limit equations related to a single outage contingency N-1 (same line for example) and then gradually add further outage contingencies (N-x) until it is identified whether existing non-thermal limit advice can be used.[36] Throughout this process, the engineer applies engineering judgement and experience and concentrates their effort to the concurrent outage that is expected to cause the highest restriction on the network.

Once the analysis is complete, the allocated engineer will either provide information to AEMO that an existing non-thermal limit advice can be used as is or will provide a new one. The processes and the governance framework followed there are the same as described in section 4.1.2.2 above.

The finalised limit equation is entered into the non-thermal limit advice register, which includes information on the outages this particular limit advice relates to, and this list may be updated as additional studies are undertaken to assess the applicability of that limit advice for new outage combinations.

When the non-thermal limit advice is finalised, peer reviewed and approved, Western Power lodges the external report in LAMA (which is in SharePoint) and AEMO is able to see and extract the documents. Western Power provides a document that lists the outage numbers (as registered in the outage management system) that limit advice relates to, as well as all outage combinations that have been tested and for which the updated limit advice can also be used. AEMO reviews these documents before it creates constraint equations and approves the outages.

[36] This is for example non-thermal limit advice developed for previous outages of that asset or in that cut-set.

Findings

Western Power have well defined processes for the development and update of outage related non-thermal limit advice. As these processes were mostly introduced at the start of the new market, they are still maturing and are being updated.

Western Power discussed that once a process is applied and observed for a period of time, and areas of improvement are identified, these are recorded and shared with staff through internal trainings and shared information. An implemented process improvement is for example the inclusion of evidence in the internal assessment reports and workbooks to support future validation.

When developing non-thermal limit advice for an outage or a set of concurrent outages, Western Power's approach seeks to apply the least constraining option. Re-calculation of existing non-thermal limit equations developed for a previous outage on top of the system normal non-thermal limit equations will result in more constraining dispatch outcomes.

Western Power stated that applying the offset approach to reuse an existing limit equation result in the most conservative outcome and this approach is used rarely. Approach selection is based on several considerations, including time requirements, staff availability and case complexity.

At times of high demand, staff may be under pressure to produce many non-thermal limit equations and select a less time-consuming approach, which could result in a more conservative outcome for the duration of the outage than necessary. In any case, the non-thermal limit advice is always reviewed and approved to ensure system security. Every time there is a change in network configuration, the use of non-thermal limit advice must be reassessed, and Western Power applies lessons learned to gradually improve through time.

There is also a pro-active approach taken by the team to reassess and review and prepare assumption sets for future use when demand is low. For example, Western Power is reviewing information and assumptions in preparation for future decarbonisation driven network expansion.

4.1.2.4 Non-thermal constraint equations (AEMO)

Process

Where Western Power submits non-thermal limit advice in the limit advice management application, AEMO receives an automatically generated email. As with the thermal limit advice, before the start of the new market, a set of system normal non-thermal limit advice was produced and shared with AEMO from which AEMO derived the system normal non-thermal constraint equation sets that are always invoked.

Western Power submits new or updated non-thermal limit advice when required. This is mostly the case where new sections of the transmission network are added (new system normal non-thermal limit advice is required) or augmented (updated system normal non-thermal limit advice is required), or otherwise mostly in connection with planned network outages.

When AEMO receives an email that non-thermal limit advice was submitted, the WA System Engineering team downloads the information and commences the review process. Unlike thermal limit advice, AEMO reviews non-thermal limit advice before formulating non-thermal constraint equations. AEMO has an internal guideline that steps out the process of what it needs to review in non-thermal limit advice before it can proceed with the formulation of non-thermal constraint equations.

When Western Power submits a network outage plan and flags that there is no need for non-thermal limit advice, the WA Operation Planning team that reviews the outage plan would request that the WA System Engineering team conduct an assessment to determine whether this is the case or not. Generally, where a piece of equipment is taken out of the transmission network, a non-thermal limit advice would only be required in cases where the outage affects a more problematic area of the network.[37]

Where this assessment concludes that AEMO considers that non-thermal limit advice may be needed, the WA System Engineering team will respond to Western Power to request Western Power to conduct specific or otherwise studies to confirm that there is no such limit on the network and provide the reasons for this decision.

In cases when this assessment concludes that non-thermal limit advice may be needed, the WA System Engineering team will go back to Western Power to request Western Power to conduct specific or more general studies to confirm if there is such limit on the network and where necessary, provide the justification for these conclusions. This is then recorded by AEMO as a confirmation whether non-thermal limit advice is required or not for that specific outage and if the outage can be approved by the WA Operations Planning team without non-thermal limit advice.

In parallel, while this is resolved, the WA Operations Planning team will communicate to the Western Power's planning team that AEMO's WA System Engineering team is seeking further information.

The communication internally within AEMO between the WA Operations Planning and the WA System Engineering teams occurs through in-person discussions, emails and other written means (often a combination of multiple communication methods). The WA Operations Planning team can access the central non-thermal constraint equations register that is maintained to check whether non-thermal constraint equations for a specific outage already exist.

When Western Power submits a network outage plan and flags 'pending limit advice', the WA Operations Planning team commences an internal review within AEMO.[38] An engineer will be allocated to a specific outage request, and they will review AEMO's internal non-thermal constraints register to identify if non-thermal constraint equations already exist for this specific outage (for example when a transmission line or a transformer will be taken out of operation for the duration of the outage). If there is already an existing constraint equation, or a set, as part of their assessment of whether this can be used for the current outage, the WA Operations Planning team may contact the WA System Engineers to request further studies to confirm this.

Where the WA Operations Planning team identifies that there is no existing non-thermal constraint equation, they will send a request to the WA System Engineering team for an estimate of the time that will be required to formulate a new non-thermal constraint equation for that outage. It may be the case that the WA System Engineering team may need longer to review new non-thermal limit advice and formulate new non-thermal constraint equations than the outage commencement date is stated in the outage request. In such cases, there

37 There is a separate communication process between AEMO's WA Operations Planning team and Western Power's planning team in relation to the actual outage approval. This is not covered here.

38 As discussed in section 4.1.2.3, Western Power may provide that existing non-thermal limit advice can be used or develop new one. While the outage request is set with the flag 'pending limit advice', the AEMO WA Operations Planning team commences the process of exploring whether existing non-thermal constraint equations can be used or new non-thermal constraint equations would be required in parallel.

may be a requirement to go back to Western Power and seek to push back the outage to accommodate the time required to formulate the new non-thermal constraint equations.

Where the formulation of new non-thermal limit advice can be finalised before the commencement of the planned outage, the outage can be preliminary approved, pending the formulation of non-thermal constraint equations. The WA Operations Planning team can only give a final approval for an outage once the non-thermal limit advice and constraint equations are formulated and approved.

AEMO has requirements what information Western Power must provide as part of the non-thermal limit advice. This is checked as part of the review process, and AEMO may go back to request further information, if needed. An engineer from the WA System Engineering team will assess the non-thermal limit advice.

As part of the validation of non-thermal limit advice, AEMO try to confirm whether the constraint outcome of the limit advice is as intended by Western Power. If AEMO is unable to confirm said intention, they respond to Western Power and seek clarification, with no new non-thermal constraint equations being created until all queries are resolved.

Once AEMO has accepted the submitted non-thermal limit advice, AEMO may write a non-thermal limit advice assessment report. AEMO typically create a non-thermal limit advice assessment report for system normal non-thermal limit advice. This is the case, because system normal non-thermal limit advice is used in system normal non-thermal constraint equations that are always invoked. This means that this type of limit advice will have a substantially longer impact on the network and the dispatch process.

For system normal non-thermal limit advice, AEMO follows its internal guideline to ensure that this limit advice is assessed fully and correctly. This includes the creation of an internal assessment report will be documented and approved for record keeping and future reference. This report is comprehensive and includes the complete assessment process, like inputs, assumptions, simulations and outcomes and AEMO’s conclusions. Therefore, it is a time-consuming process to create such report.

AEMO may not always create assessment reports for planned outages. AEMO may receive a large amount of outage requests that involve non-thermal limit advice at the same time and in such situation the team must prioritise its workflow. Therefore, determining whether an assessment report will be written is based on an outage’s impact and duration. This is left to AEMO’s discretion and is guided by staff availability and other work priorities.

This does not mean that AEMO has not undertaken an assessment of the planned outages and non-thermal limit advice t and has not undergone through the proper peer review and approval processes, but only that while no assessment report is written based on priority allocation, all relevant information is captured in emails and other forms of written documentation.

Once a non-thermal limit advice has been accepted by the WA System Engineering team, the team will then formulate the non-thermal constraint equation sets.

From here on the process of the formulation of the non-thermal constraint equations to be used by the dispatch engine and how these are documented, approved and published is the same as described in section 4.1.1.2 above.

The only difference in the publishing process between non-thermal and thermal constraint equations is that when non-thermal constraint equations are published, the non-thermal limit advice provided by Western Power is also published and linked to the constraint equations set. This is a manual process where the publishing engineer has to select the specific document to be attached.

Findings

AEMO has well established processes for the review and assessment of non-thermal limit advice and the subsequent formulation of non-thermal constraint equations. There is a high-level guideline that steps out how the non-thermal limit advice is to be reviewed. The work is allocated in the WA System Engineering team, which seem to be at times resource constrained.

While the team directly responsible for assessing and accepting the non-thermal limit advice is small, they have access to other engineers in the team where peer review, second opinions and support with studies and simulations is required.

The resource constraint is mostly be reflected in the need for AEMO to prioritise whether or not a non-thermal limit advice assessment report will be created, which is a comprehensive document. AEMO appears to have an internal, but not documented, threshold around that appears to be dependent on workload of the team.

The flow chart provided by AEMO shows the interactions between the WA Operations Planning team and the WA System Engineering team and there might be some room of improvement as some of the processes between the two AEMO teams seem to not have been included, which does not mean they do not exist.

The lack of internal documentation while not problematic for the existing team members who are familiar with the work, may be a barrier to a new starter or a junior engineer joining the team, as it might be difficult for them to understand what processes and steps are to be followed.

There are sufficient stages throughout the process where communication with Western Power is undertaken, which is mostly undertaken via emails to ensure documentation is available. Overall, the process appears reasonably mature and has undergone improvements since the commencement of the new market.

4.1.2.5 Interactions between Western Power and AEMO – end-to-end process map – non-thermal

Since before the start of the new market, both Western Power and AEMO have been communicating with each other constantly. There are regular meetings and both entities work together to identify issues, streamline and improve processes and communication ways.

As part of the non-thermal limit advice process, depending on whether it is for system normal or planned outages, there may be follow up communication between multiple teams within both organisations. These are in most cases reasonably timely, but as discussed earlier, due to these processes still being in the maturing phase, there have been improvements around the understanding between the requirements on both sides.

It can be expected that over the next few years, as both organisations have developed their processes further, there will be further improvements in the communications between them.

There is also an external procedure, published by AEMO that provides information around what data and in what form Western Power must provide in relation to thermal limit advice.[39]

Process maps that demonstrate the processes in both organisations and the points of interaction between them on both system normal and planned outages non-thermal limit advice are included in Appendix 4.

4.1.3 RCM limit advice and constraint equations

4.1.3.1 RCM limit advice (Western Power)

Process

In addition to operational thermal and non-thermal limit advice, Western Power must also provide limit advice for RCM, where the thermal ratings of the network equipment are calculated at an ambient temperature of 41°C.[40] Where for operational thermal ratings Western Power uses a range of temperature measures, depending on the location of the transmission assets on the network, the ESM Rules stipulate a fixed temperature for RCM purposes.[41]

RCM limit advice is prepared for a future state of the network. The RCM cycle is a three-year cycle and RCM limit advice relates to the expectations of what the network configuration will be in the third year of that cycle, as required by the ESM Rules. Any information that is used to calculate RCM limit advice, including information provided by AEMO, relates to that third capacity year.

The RCM limit advice is prepared initially by Western Power, however, before being able to commence its process Western Power requires multiple inputs from AEMO. These are listed in the ESM Rules and include details of each facility that:

- submitted an expression of interest (EOI);
- notified AEMO it will cease operation permanently by at the start of the third year in the current capacity cycle;
- applied to AEMO for Early Certified Reserve Capacity and whether the facility was nominated as Network Augmentation Funding Facility;
- has entered into a Non-Co-optimised Essential System Service (NCESS) contract with AEMO; as well as
- AEMO's preliminary forecast of peak demand for the third capacity year in that capacity cycle.[42]

Western Power needs this information to be able to estimate the system configuration at peak demand and the associated thermal limits, assuming ambient temperature of 41°C. In calculating the RCM thermal limits, Western Power also considers any expected network

39 Australian Energy Market Operator, *WEM Procedure: Limit Advice Requirements*, 1 October 2023, (online).

40 Western Power could provide non-thermal limit advice for RCM if deemed necessary, however, Western Power advised that at this stage only thermal limit advice is prepared for RCM. Its practical ability to develop non-thermal limit advice for RCM purposes is hindered by timing requirements for the development of non-thermal limit advice, as well as at times by the lack of information on the new facilities, which does not allow Western Power to undertake non-thermal limit advice modelling for RCM.

41 Electricity System and Market Rules, 4 June 2025, clause 4.4B.3 (a)(i), (online).

42 Electricity System and Market Rules, 4 June 2025, clause 4.4B.2, (online).

augmentation, transmission asset retirements and its own NCESS contracts that are expected to be in-service.

RCM limit advice process sits with Western Power's Planning Engineering team. When estimating the system configuration, the planning engineer takes the existing system configuration and considers any current and committed generation and load projects, contracts, network augmentation and asset retirements to develop a SWIS base case model for the summer peak.

The planning engineer reviews the EOI and other information provided and updates the PowerFactory model to show for example how and where new facilities will be connected to the network. Western Power includes only facilities that have committed to connect before or by the third year in the update of the PowerFactory model. In some cases, facilities in the EOI list have not yet engaged with Western Power, have not yet accepted Western Power's access offer, or have not yet signed an access arrangement. Here, Western Power must estimate a connection time and location based on the best information available in the system.

Western Power uses its own load forecast to calculate the estimated peak load at each substation. Western Power uses historical data and forecast trends of each substation, information on current and future distributed photovoltaic generation etc. to estimate the forecast load at each substation. From there, Western Power calculates the percentage of the peak demand for each substation.

When all required information is collected, Western Power calculates the thermal ratings of all existing and new (committed) transmission elements that are expected to be in operation in the relevant year of the capacity cycle. This also considers any permanent retirements of transmission elements.

The process of calculating the thermal ratings is the same as described in section 4.1.1.1 and sits with the Asset Performance team. The main difference here is that Western Power uses fixed values for solar irradiance and ambient temperature (41°C) across the whole network.

Where there is no change in the equipment itself or in the substations where each line is connected, there is generally no change in the RCM thermal ratings year-on-year. Before RCM thermal limit advice is provided to AEMO, Western Power as part of its internal process, checks any changes in the existing transmission asset ratings and provides commentary as appropriate. This is part of Western Power's standardised approval process. Version history and approval is embedded in the internal file where the RCM limit advice is calculated.

Once Western Power has provided all required information to AEMO, AEMO will commence the process on its side. It will set up the PowerFactory model for its purposes based on Western Power's system configuration and RCM limit advice. Where the final NAQ results in forecast capacity deficits or substantial changes to capacity allocations the settings may be reviewed.

In such cases Western Power may commit to network augmentation or the application of special protection schemes. Where such discussions are needed and actions agreed to ensure there is sufficient capacity to meet peak demand, Western Power must provide an updated version of the RCM limit advice to AEMO. This could result in Western Power initiating a capital project to reinforce the network.

The process for reviews and the decision making arising from them would benefit from clear, transparent and economically driven criteria. Network augmentation projects, although beyond the scope of this review, are subject to separate regulation by the ERA through Western Power's access arrangement or specific exemptions as Priority Projects.

Findings

Western Power's process to develop RCM thermal limit advice is defined and documented in an internal procedure document. There is also a separate documentation on how Western Power determines peak demand. The process appears to be well understood by the engineers responsible for undertaking it. This workflow is shared between Western Power's Planning Engineering team and its Network Operations team. The standard organisational approval framework applies to this process too, which demonstrates well defined governance. The team is well staffed, similar to the other teams across Western Power, allowing for redundancies.

Initial information is dependent on AEMO commencing the RCM process, which is sometimes delayed. However, Western Power appears to be flexible accommodating this, as part of its planning process. Regardless of when the RCM process commences, there is a fixed timeline that guides this process in relation to which organisation has to provide what information to the other and by when.

Where there is communication between Western Power and AEMO on the resolution of identified issues, everything is recorded through email correspondence. There is a degree of iteration in setting the NAQ. Some of these resolutions could potentially result in Western Power setting up special protection schemes or capital projects initiating network reinforcement.[43] While special protection schemes are published, decision making where such interventions occur through the NAQ process is not codified or public to the market.

Overall, Western Power's processes are internally well documented and the overall governance framework that applies across the other areas of the limit advice development system, is applied here as well.

4.1.3.2 RCM constraint equations (AEMO)

Process

As part of the RCM constraint equations process, AEMO provides Western Power with the information required under the ESM Rules. Once Western Power has sent back to AEMO information, including but not limited to an updated PowerFactory model and the RCM thermal ratings, AEMO commences the process of formulating RCM constraint equations and running test models. The initial formulation of RCM constraint equations sits with the WA System Engineering team, however, there are close interactions between this team and the WA Capacity Investment and Assessment (CIA) team.

AEMO must adjust the PowerFactory model, which contains the network configuration to contain all current and new generation facilities and loads that are expected to be in operation in the third year of the capacity cycle, their connection points on the network, facility retirements, as well as any other relevant information.

The actual process of formulating RCM constraint equations is very similar to that for operational thermal constraints. In particular, the same automated tools are used to produce RCM constraint equations, subject to some configuration changes.

43 Special protection schemes are condition-triggered automated control systems that are designed to maintain wide-area system stability.

One difference is that before RCM constraint equations are formulated, the WA System Engineering team runs various scenarios in the forecast year that aim to stress test the system and to push generation flows in different directions of the network. This is used to identify which constraint equations are possibly required.

The WA CIA team are responsible for the test NAQ model, and associated tools, which mimics the formal application and is used to assess the impact of RCM constraint equations in the context of many different dispatch simulations. The WA System Engineering team will internally review and test RCM constraint equations in trial runs of this NAQ model, in addition to test runs performed by the WA CIA team. An output of this model includes summary documents to assist the engineer to identify congestion and network risks and possible issues with RCM constraint equation formulation.

This testing undertaken as part of the RCM constraint equations validation process using the NAQ test model includes runs of hundreds or thousands of simulations, covering various scenarios and assumptions. One hundred simulations in a single run are a small number of simulations and these runs are used simply to help identify issues, as results may vary a lot across different 100-simulation runs.

This aims to identify whether any congestion may occur under specific circumstances and dispatch scenarios during a summer peak. If these simulations reveal any issues with RCM constraint equations, they may be adjusted and the models run again. AEMO tests every changed assumption or input, before it is approved and incorporated into the RCM constraint equations. Every assumption is based on engineering expertise and documented for future reference.

Where these tests identify network risks (thermal or non-thermal), the team communicates back and forth with Western Power's Asset Management and Planning Engineering teams to develop possible solutions. If technical solutions are found to resolve specific issues, for example Western Power confirms an alternative network configuration in an updated limit advice, and are agreed between Western Power and AEMO, AEMO continues testing based on the updated assumptions and inputs.

Both AEMO and Western Power retain any information exchange for record keeping purposes, predominantly through emails, and in Western Power's case, agreements could lead to the initiation of capital projects or development of special protection schemes. Should Western Power commit for example to introducing a special protection scheme, it will submit an updated RCM limit advice. AEMO will take these updated ratings and rebuilds the constraint equations.

The CIA team is responsible for calculating the final capacity allocations. Once the PowerFactory model is finalised, and the RCM thermal constraint equations are formulated, the WA System Engineering team provides finalised RCM constraint equations to the CIA team. The CIA team undertakes their own modelling, leading ultimately to the allocation of capacity credits.

The CIA team runs many scenarios, to identify any limitations on the network, potentially going back to the WA System Engineering team for further information and constraint equations. These simulations, which are performed for the purpose of validating the constraint sets or for estimating the capacity in different scenarios, are run in a test environment allowing more flexibility.

As discussed in section 4.1.3.1, where AEMO's testing identifies constraints on the network, they may contact Western Power and request information, for example, whether there could be an intention to reinforce a specific area of the network.

For the final NAQ determination, the CIA team will run over 100,000 test cases to confirm the appropriateness of the allocation. The final runs are done in the RCM system, while any previous testing is undertaken in a test system that mimics it. The final NAQ determination as part of the formal RCM process is performed using a system embedded into the WEMS portal. This automated system pulls data directly from the databases and reduces the risk of operator mistake. Other NAQ simulations performed for the purpose of validating the constraint sets or for estimating the capacity in different scenarios are run in a test environment allowing more flexibility.

Once the NAQ allocation has been finalised and approved through AEMO's internal processes, its outputs flow into capacity credits allocation, which is then published on AEMO's website.

Findings

AEMO's process for the formulation of RCM constraint equations appears to be robust, based on consistent testing and communication between the WA System Engineering and the CIA teams, as well as with Western Power's engineers. There are working instructions available for new starters, however, the intensity of the process requires a good understanding of the SWIS, as well as of the information provided by Western Power and ability to operate the systems and account for changes in assumptions.

The team that is responsible for developing the RCM constraint equations is the same that is responsible for developing the operational constraint equations. While the actual 'build process' of the constraint equations is automated and in principle the same as for operational constraints, the development of RCM constraint equations requires a large amount of testing and coordination with the CIA team and Western Power.

While the processes are not documented in internal procedures, they are well understood, and team members follow AEMO's overall governance framework on constraints formulation. Any modelling and constraint equations are tested by at least two engineers (with different seniority levels) before being approved and provided for testing to the CIA team. There further testing and many thousands of test cases are run, assumptions followed up and reconfirmed etc., which provides further checks of the process.[44]

Overall, AEMO appears to rigorously test and check the RCM constraints development, as the results from this process impact the market and market participants heavily.

4.1.3.3 Interactions between Western Power and AEMO – end-to-end process map – RCM

The information exchange between Western Power and AEMO is undertaken via emails and SharePoint. Data is contained mostly in Excel workbooks as well as in Western Power's PowerFactory model. Where information is uploaded via SharePoint, emails are sent to ensure that the other organisation is informed that new information has been provided. The Excel workbooks provided to AEMO sometimes contain different acronyms and/or labels for specific assets from the legacy systems. This has required AEMO to build in a work-around in its work processes to ensure its systems can ingests the correct data.

While all communication between Western Power and AEMO is captured in written form (mainly emails), this does not appear to be a formal requirement in the process. Instead, the

[44] No interviews were conducted with CIA staff, so their processes and governance are not discussed here.

staff in both organisations have adopted this practice of communicating via emails for record keeping and documentation purposes.

Throughout the RCM process there is a lot of communication going between Western Power and AEMO's teams. Specifically, where potential congestions are resolved, these discussions may involve multiple teams at the same time, or subsequently. This sometimes can result in bottlenecks, and instances within Western Power where one team is updated on information about NAQ schemes but not the other, demonstrating that there is room for improvement within this process.

While AEMO and Western Power document communication between the organisations, such as, updating assumptions or limit advice and hypothetical network augmentation to relieve congestion that is to be implemented in the model, this information is not available to the market.

Though the process for decision making is unclear and responsibility remains with Western Power. Network augmentation decisions must be made in a manner consistent with the network access regulation for the investment to be recovered through the regulated asset base. The ERA will review these decisions at the appropriate time.

At the completion of the process, AEMO publishes the NAQ allocation, the capacity credits allocation, as well as the RCM constraint equations and Western Power's RCM limit advice. There is an external procedure by AEMO that guides Western Power what information it must provide to AEMO for the RCM limit advice, in what form and by when (depending on the commencement of the capacity cycle).[45]

While the ESM Rules define the timing of the development process for RCM limit advice and constraint equations, ultimately, the timing is determined by AEMO. Where AEMO delays the commencement of the capacity cycle for example, Western Power cannot commence work on its side until AEMO has provided the first set of information.

A flow chat that covers the end-to-end process for the development of RCM limit advice and constraint equations is available in Appendix 4.

4.2 Risk framework assessment

This section will provide view on the adequacy of the internal structures within both organisations in relation to resources both physical and technical, succession planning and ensuring that both organisations can demonstrate functional continuation.

4.2.1 Western Power

The work that relates to thermal, non-thermal and RCM limit advice development and maintenance within Western Power is split between various teams, or sub teams in Western Power's engineering functions.

The ERA undertook interviews with subject matter experts from all relevant teams, and these were also attended by staff from related teams, in case there were cross-process queries. Depending on the type of limit advice and the trigger, other teams for example the Grid

45 Australian Energy Market Operator, *WEM Procedure: RCM Limit Advice Requirements*, 20 June 2025, (online).

Transformation and the Engineering and Design teams, may be involved and provide ‘pre-work’ before the limit advice development commences.

The engineering teams that are responsible for developing the different types of limit advice appear to be well resourced with a sufficient number of adequately qualified and experienced engineers. All teams are subject to an organisational governance structure where any limit advice is peer reviewed by a more senior engineer and then approved by a group leader or an area manager.

Depending on the complexity of the case and the workload, work is allocated to the various engineers, and they have access to peers for support and discussions throughout the process, on a case-by-case basis. Therefore, the review did not detect concerns around single point of failure, key person risk or lack of governance that would hinder robust processes.

Western Power also has a graduate program, where junior engineers are moved through the different teams as part of their learning process and are given adequate learning targets. The teams put effort in mentoring and supporting junior engineers. This demonstrates Western Power’s drive for succession planning and future development of engineers, ensuring continuation of the business requirements.

Where a more senior engineer is to move to a new responsibility area, or is hired externally, depending on their qualifications and experience they may need between three and up to nine-ten months to become sufficiently trained to undertake specific functions without supervision. This depends on the area, with non-thermal limit advice development requiring longer training periods due to the higher complexity and manual nature of the assessment process.

Some of the processes are more mature than others. As discussed, the thermal limit advice development and provision has existed prior the start of the new market, given that Western Power has always been required to ensure the physical capabilities of the network are well understood and respected.

Other processes are less mature, for example the non-thermal limit advice and its provision to AEMO has undergone some development since the start of the new market, as this is a new function. Both organisations have spent time understanding each other’s needs and requirements in relation to shared resources, for example the PowerFactory model of the SWIS, which has gradually resulted in improved communication and processes. Both organisations are still working through potential improvements as part of their regular meetings and discussions.

Western Power has mostly automated the production of thermal limit advice, where non-thermal limit advice is a more manual process. All functions and teams use a number of systems and tools, which at times can lead to human error. There appear to be quite an extensive use of Excel as a tool, which while helpful and useful, has its shortcomings, where for example links may be broken or data input missed. However, these limitations are well known and understood within the team.

There are many points in any one of the processes where manual interventions can result in human error and this in overall erroneous limit advice. While such risk cannot be eliminated, Western Power mitigates this through multiple stages of peer reviewing and approval processes and consistent documentation. In addition, where information is provided to AEMO, there is a second point of checks that further reduces potential errors and improves the process.

Western Power has several internal documents that provide guidance on its processes, philosophies, calculation and development methods. Some process descriptions are still being written and under regular review so Western Power can identify potential gaps and areas of improvement.

The communication with AEMO occurs at various stages of the processes and various teams are involved. There are regular fortnightly meetings between both organisations to discuss topics. These meetings may also be used to discuss a more challenging limit advice currently under consideration. Otherwise, the communication on current cases is usually via emails, which then serve also as decision and confirmation evidence and are stored in the organisations' respective record keeping systems.

4.2.2 AEMO

AEMO has a single engineering team, WA System Engineering, working on the development of constraint equations. Staff are allocated and specialise in formulating constraint equations, including for RCM, or assessing non-thermal limit advice before it can be approved for constraint equations.

The whole WA System Engineering team is larger than the resources allocated specifically to the constraint modelling area, so team members of the Congestion Modelling sub-team have access to more engineering resources, where required. There is also the Operations Planning team, who approve outages and support the Real-Time Operations team. Due to the nature of their work, they have sufficient familiarity with the constraint equations work and requirements and if required are able to provide support to other teams.

Also, AEMO's engineers appear to move between teams as part of on-the-job learning and progression, so while there are engineering personnel who have the expertise to formulate constraint equations, they may have moved to other areas of the business.

There appears to be a reasonably large pool of adequately qualified and experienced personnel throughout the business, if not necessarily currently allocated to that function. Members of the Congestion Modelling sub-team are able to take over each other's work and the pool of experienced resources throughout the organisation can adequately mitigate key person risk and support function continuity in AEMO. This method of covering for personnel has arisen due to the niche and technical expertise required for the work.

New starters and graduate engineers are supported through on-the-job learnings and receive guidance from experienced engineers. Depending on the function, adequate qualification and knowledge of the system is critical. Depending on their experience level, new engineers are able to start undertaking their functions over time, which could be up to (or more than) one year.

Due to low amount of documentation within the team, new starters may not be able to pick up work and instructions as easily as they might if more internal procedures, guidelines and other documentation were available.

AEMO has nevertheless well developed and strictly followed processes. For example, approving a new constraint equation is only possible where at least one other engineer peer reviews it. Where this is not possible, due to absences, workloads or other reasons, the WA System Engineering team will not approve new constraint equations.

Processes are dictated by AEMO's risk assessment framework, which requires efforts to find workarounds in such cases, for example using the control room instructions or adapting existing constraint equations to meet the needs of a particular situation. While this is not ideal as a particular solution may well be less efficient than a tailored solution, it mitigates the risk to power system security and reliability of allowing an unreviewed constraint equation to be published and used in the dispatch process.

This framework is followed by the team, which provides confidence that there should be overall no single point of failure. There are multiple checks that aim to minimise the number of errors that may occur along a process.

The congestion modelling function is new, commencing with the start of the new market. While there was time prior to the start of the new market to prepare AEMO's systems and process, this function appears to be still maturing.[46] For instance, there are flow charts that outline various processes that relate to constraint equations, however, internal documentation beyond work instructions is minimal. These work instructions, while being a supportive tool for the engineers directly on the job, do not provide an overarching documentation of process, methodologies and philosophies that guide AEMO's processes.

As a critical part of power system security, the Real-Time Operations team has four people on standby (outside the roster) to mitigate leave related staff shortages and key personnel risks.

[46] For example, AEMO developed a large number of thermal and non-thermal system normal (NIL) sets prior to new market start.

5. Appropriateness of WEM Procedures

Clause 2.27C.2.(c) of the ESM Rules requires ERA to assess the appropriateness of the following procedures as part of the LACE review:[47]

- AEMO WEM Procedure: Constraint Formulation - clause 2.27A.10(b)(i);
- AEMO WEM Procedure: RCM Constraint Formulation - clause 2.27A.10(b)(i); and
- Western Power WEM Procedure: Limit Advice Development - clause 2.27A.11.[48]

In addition, the ERA has reviewed two other procedures due to their direct relevance to the LACE processes:[49]

- AEMO WEM Procedure: Limit Advice Requirements - clauses 2.27A.10(a)(i)/(ii), 2.27A.10(bA)/(d)
- AEMO WEM Procedure: RCM Limit Advice Requirements - clauses 2.27A.10(a)(i)/(ii), 2.27A.10(bA)/(d).

In assessing the appropriateness of these documents, the ERA review made its assessments based on whether the documents are:

- complete: there are no missing processes, and
- consistent: there is no incompatibility between public procedure and internal processes.

The ERA recognises that public procedures require a different level of detail compared to internal processes. Therefore, the goal of the review is not to identify missing individual process steps, but rather to ensure that all processes can 'fit' within the public procedure and that there are no contradictions between either.

The ESM Rules clauses 2.27A.10(b)(i) and 2.27A.11 require that these procedures outline how the processes covered by each document apply the State Electricity Objective (SEO) and good electric industry practice.

The ERA's LACE review has sought to establish whether Western Power's and AEMO's processes satisfactorily meet these requirements. Specifically, whether Western Power's and AEMO's processes related to limit advice and constraint equations, as well as the public procedures are developed on the basis that they meet the SEO and good electricity industry practice

47 Electricity System and Market Rules, 4 June 2025, clause 2.27C.2 (c), (online).

48 These procedures are: AEMO WEM Procedure: Constraint Formulation (online), AEMO WEM Procedure: RCM Constraint Formulation (online) and Western Power WEM Procedure: Limit Advice Development, (online).

49 These procedures are: AEMO WEM Procedure: Limit Advice Requirements (online) and AEMO WEM Procedure: RCM Limit Advice Requirements (online).

5.1 Procedures assessed as required by the ESM Rules

5.1.1 AEMO WEM Procedure: Constraint Formulation

The procedure revolves around a high-level process titled the Standard Methodology, which comprises a set of principles and general mathematical methods that AEMO commits to following in the development of constraint equations. Subsections provide additional detail on specific procedural commitments.

Overall, the procedure is deemed to be appropriate. Internal processes have matured and evolved within the limits established by the document. There is a good balance between granting AEMO the flexibility necessary to adapt to a changing electricity landscape and maintaining best practice as the expected standard. The procedure's technical tone is suitable for its audience and does not require further simplification.

Nonetheless, there are a few opportunities for improvement. As internal processes surrounding constraint equation formulation have matured within AEMO, some operational practices have become more defined and codified. The public procedure may benefit from examples of these operational applications being incorporated into its subsections.

There are no major processes or internal practices omitted from the procedure's standard methodology. However, some internal processes, while covered at a high level, could be expanded upon more explicitly. For example, the review confirmed that AEMO engages in extensive quality assurance processes when formulating and maintaining operational constraint equations. While these are covered by the high-level principles in the procedure, explicit references to these practices are absent, and can benefit the overall goal of the procedure.

The processes described in the procedure are consistent with those followed in internal documentation and as confirmed in interviews with AEMO subject matter experts. For instance, the mathematical calculations outlined in the procedure have remained stable and form the basis of the WA System Engineering team's Python tools. As mentioned earlier, the inputs and outputs of these semi-automated processes are subject to quality assurance throughout, in alignment with the priorities outlined in the procedure. Additionally, the procedure already lays the groundwork for the future use of dynamic line rating.

Overall, the procedure is complete and correctly covers AEMO's internal processes for formulating operational constraint equations. The procedure references have not been updated to reflect the naming change of the ESM Rules; however, this is true for most procedures.

5.1.2 AEMO WEM Procedure: RCM Constraint Formulation

The RCM Constraint Formulation procedure mirrors the operational procedure, while accounting for some differences in the process of formulating RCM constraint equations. The mathematical principles are the same as in the previously mentioned (operational) Constraint Formulation procedure and so will not be discussed further here. The procedure sets out the processes and high-level methodology used by AEMO to produce, update and maintain RCM constraint equations. It does not include specific operational information of what teams and steps ensure that the procedure's methodology and principles are followed.

The procedure is appropriate in general, setting up high level practices and useful examples of the mathematical principles used by AEMO. There are no major processes or internal practices inconsistent with the description in the procedure. All internal processes fall within the limits outlined by the procedure.

Nonetheless, it lacks explicit details of some important internal processes, examined by the ERA in prior sections and detailed in other related procedures.[50] For example, the effect of special protection schemes, which also has a significant role in the relationship between RCM constraint equations and the NAQ, is not included in the procedure, but could provide useful additional information.

Overall, the RCM Constraint Formulation procedure is generally sound and aligns with operational practices but could benefit from more contextual explanations and where RCM constraint equations sit within the NAQ and RCM framework. These would help stakeholders, especially new market entrants, better understand its implications. Enhancing the procedure with more background and principle-based insights would improve clarity and accessibility to less technical stakeholders and potential new market entrants.

5.1.3 Western Power WEM Procedure: Limit Advice Development

Western Power has developed a single procedure that covers both its operational and RCM limit advice development processes. The procedure describes distinct principles and best practices in developing, maintaining, and providing limit advice. The procedure is divided in self-contained subsections explaining the distinct workflows, e.g. thermal, non-thermal and RCM limit advice development. Each subsection contains a “Overview” introduction, which outlines the operational context of the processes described.

The procedure is appropriate, and steps are outlined at a sufficiently detailed level. The contextual/operational overviews and figures starting off each section are particularly useful for intelligibility. No internal processes are missing from the procedure. Nonetheless, some sections would benefit from more supporting evidence of best industry practices.

The procedure is partially outdated and there are several inconsistencies with current legislation. Sections 5 and 6 outline obsolete timeframes for the provision of RCM limit advice to AEMO. The procedure was also not updated with ESM Rules requirements included in clauses 4.4B.8 and 4.4B.9, which were added to the ESM Rules post publication of the procedure. This is partially due to the existing references in the ESM Rules clause that guide the content of the procedure.[51] Reference to the ESM Rules as WEM Rules is also inconsistent with current legislation; but this is an issue throughout most WEM procedures.

In conclusion, Western Power's procedure for Limit Advice Development (including RCM) is generally sound and aligns with operational practices. However, it could benefit from some transparency and contextual explanations. Updating this procedure to include more detailed principles, operational overviews, and alignments with current legislation would enhance clarity and accessibility, particularly for new market entrants. This improvement would foster greater transparency and confidence among market participants.

50 Though these schemes are covered in different documents their effect is nonetheless relevant to RCM constraint equations. Relevant other WEM Procedures include: Network Access Quantity (NAQ) Model Procedure (link), Power System Security Guidelines (link), and RCM Limit Advice Requirements – V2.0 (link).

51 Clauses 2.27A.11 (b) (i) and (ii) refer to 4.4B.3 and 4.4B (a) and (b) respectively, and do not expand on the requirements in the later added clauses 4.4B.8 and 4.4B.9 of the ESM Rules, (online).

5.2 Additional procedures assessed

As mentioned, the ERA has also assessed the following procedures, despite their assessment not being explicitly required by the ESM Rules obligation. These procedures are closely related to the LACE processes.

5.2.1 AEMO WEM Procedure: Limit Advice Requirements

This procedure details the communication, timelines, and data requirements surrounding the provision of operational limit advice from Western Power to AEMO. The review finds the procedure is consistent with internal documentation and confirmed by interviews with both Western Power and AEMO staff.

Nonetheless, some internal processes, though covered by the range of actions outlined in the procedure, would benefit from more specificity in public procedures. Explicit mention or examples of this communication may help increase perceptions of transparency among market participants.

Overall, the review finds the procedure appropriate, albeit similarly to prior procedures, lacking in operational details which could aid clarity. Additionally, the procedure would also benefit from updated legislative references.

5.2.2 AEMO WEM Procedure: RCM Limit Advice Requirements

The recently updated procedure outlines the timelines, legislative references, and data requirements around the provision of RCM limit advice by Western Power to AEMO. The current update amends the procedure to include information requirements in clause 4.4B.9 of the ESM Rules, provide clarification on specific data format requirements, and remove irrelevant clauses of the ESM Rules.

There are no major discrepancies between internal processes and practices and the public procedure.

The recent amendments provide a useful example of how future LACE-related procedures can be improved to showcase some of the mature operational practices used by both AEMO and Western Power. For example, sections 3.5.3, 3.5.4, and 3.5.5 provide useful details on the tools used by Western Power for transmitting the results of their work on limit equations.

It is the review’s understanding that the practices outlined in the procedure updates were followed prior to the publishing of the amendment. Nonetheless, publishing them provides value to market participants’ understanding of how best practices and efficiency are ensured in the handover of RCM limit advice from Western Power to AEMO.

6. Effectiveness review

As part of the framework for ERA's LACE review, the ERA assessed how effectively limit advice and constraint equations are:[52]

- in striking the appropriate balance between economic efficiency and system security while accounting for environmental factors;
- being applied in a transparent and fairly non-discriminatory manner; and
- adopting industry best practices (where applicable).

In meeting the first objective, limits and constraints should be developed to balance the risk of the following two types of errors:

- Type I error (false positive): A constraint is binding despite the system being in a secure operating state, i.e., overly conservative constraint. With this type of error, system security is achieved, but in an economically inefficient manner, e.g., network and generation assets are not optimally utilised.
- Type II error (false negative): A constraint does not bind despite the system being in an insecure operating state, i.e., insecure constraint. With this type of error, there is an elevated risk of insecure operational outcomes leading to customer supply outages and, in the worst case, asset damage and/or safety incidents

The inter-jurisdictional review identified a set of well-established industry practices, as listed in section 2.3. Subsequently, these industry practices were adopted as part of the ERA's LACE review framework and applied across the different sections of the review to assess how Western Power develops limit advice and AEMO formulates constraint equations. The inter-jurisdictional review report is published together with this report for stakeholder's information and is available on ERA's website.[53]

The ERA engaged an external consultant to undertake a deep dive into the technical aspects of the effectiveness review. The consultant's report contains more information and deeper technical analysis on the effectiveness review components and a more technical perspective on the overall LACE review. The consultant's draft report is published for consultation together with this report and is available on ERA's website.[54]

High-level findings on the components of the effectiveness review are summarised in the sections below.

6.1 Development of thermal limits

The ERA's LACE review framework, as part of the effectiveness review section, specifically looks at how Western Power develops thermal limits. As discussed in section 4.1.1. Western Power is solely responsible for calculating thermal limits (both operational and RCM). AEMO does high-level sense checks on changes to thermal limits, as they receive them from

52 The ERA LACE review framework was developed by the ERA and its consultant as part of stage 1 of the project, together with the inter-jurisdictional review. The ERA framework report is not published as part of this consultation package but is outlined in section 2.2 of this report.

53 Ampere Labs, *Inter-jurisdictional review of limit advice and constraint equation development and assessment*, July 2025, (online).

54 Ampere Labs, *Limit Advice and Constraint Equation Effectiveness Review – draft report*, July 2025, (online).

Western Power, but they do not have the information required to be able to self-assess whether the thermal limits are correct.

The ERA's framework specifically considers how Western Power develops thermal limit advice as part of the effectiveness review. This is assessed against the following best industry practices:

Robust and transparent processes

Western Power develops thermal limits using standard methods similar to network operators globally. The inputs used in the calculations are well known, including transmission network equipment parameters, line design, geographical location, and other information that is commonly used by network operators.

Western Power has well developed internal documents that demonstrate and guide its methods on the calculation of thermal limits. While these are not publicly available, the ERA and its technical consultant have reviewed these and are satisfied that Western Power calculates thermal limits in accordance with industry standards and practices.

Regular assessments of thermal limits for binding constraints

While Western Power's thermal limit advice development process is well described and organised, it also conducts reviews on thermal limits for binding constraints as part of the feedback loop process with AEMO. This is particularly prominent as part of the RCM limit advice process, where there is a lot of communication between Western Power and AEMO, during the development of RCM constraint equations and NAQ modelling. This communication is not public, which reduces the transparency on how final decisions are made and this has been identified as an area of improvement through this review.

The introduction of dynamic line ratings is expected to improve the efficiency of the network performance and reduce the amount of binding constraints.

Real-time system security monitoring

In addition, as described in section 4.1.1.3, in the case of unplanned outages, there is the option for direct communication between Western Power's control room and AEMO's Real-Time Operations team that ensure that at the time of a forced outage, both entities work together to ensure power system security is maintained. AEMO's Real-Time Operations team continuously monitors the system and any issues with the thermal limits that result in constraints binding often are retrospectively reviewed and are communicated back to Western Power, as needed.

6.2 Over-conservative outcomes

Over-conservative outcomes can be identified where Type I errors (false positive) occur. This is where a constraint binds when the system is in a secure state. This results in inefficient outcomes and could disadvantage affected market participants.

AEMO has only recently introduced a consideration around economic impacts in the decisions making process of formulating constraint equations. Before that, the only consideration was on system security. Such consideration does not appear to be part of Western Power's processes, which is limited to power system security.

The ERA framework includes the following best industry practices into the assessment of over-conservative outcomes and adopting these could help provide for secure and efficient access to the network for market participants.

Robust and transparent processes

Both organisations have undergone an evolution process since the start of the new market. Many processes were introduced then, and while there was technical preparation, there was no market trial, which meant, market participants, including Western Power and AEMO, were learning (and still are) in a live market.

As mentioned, while some functions are well established (the development of thermal limit advice), others are still maturing. The novelty is not in the technical sense (Western Power always had to maintain the network in a stable operating state and within the requirements of the Technical Rules), but the interactions and communication responsibilities between Western Power and AEMO are partially new.

For AEMO, the engineering concepts have also remained mostly unchanged while the responsibilities expanded, however, the method of operating the system has changed fundamentally. The development of thermal, non-thermal and RCM constraint equations is a new process.

The technical preparation of the systems mostly occurred before the start of the new market. However, launching a new system without a testing period has resulted in inefficient impacts of the constraint equations application that have only been discovered and gradually understood over time. Both entities are continuing to implement changes to LACE fundamentals and processes such as dynamic line ratings and control room instructions.

The ESM Rules have obligations on AEMO to publish information on its Congestion Information Resource (CIR) website, including constraint equations, limit advice, as well as a set of annual and more regular (weekly) reports. Most of the published information surrounding real-time market constraints is very technical, which limits its accessibility and as detailed in section 4.1.3.3, there is limited transparency around RCM constraint development despite substantial revenue streams dependent on them.

There are no direct additional obligations on Western Power to publish information in relation to limit advice. For example, detail on development methods, philosophies and reasons behind network augmentation resulting from the NAQ process is an important accountability.

There is limited transparency around the use discretionary constraints. AEMO publish market advisories where such constraint equations will be invoked at the time. It also publishes shadow prices for each binding constraint in the market dispatch solution files, so an interested and committed observer could calculate the implied market impacts of discretionary constraints. However, public market data is difficult to access and interpret and is also poorly documented and supported.

Regular assessments of binding limits and constraints

AEMO has internal processes to review and assess binding and discretionary constraints on a weekly basis. This gradually improves the understanding around those and their impacts, leading to ongoing improvements. Over time, the Real-Time Operations team has reduced the quantity of invoked discretionary constraints, as process and understanding have been maturing and the constraint sets have become more complete.

As part of the review processes of thermal, non-thermal and RCM limit advice, the feedback loops that were incorporated in the communication between Western Power and AEMO allow for limit advice to be questioned and potentially ‘improved’. Where binding constraints have been assessed to demonstrate Type I errors (false positive), this is fed back to Western Power for further investigation and discussion, as part of the ongoing engagement between both organisations.

In addition, Western Power, in cooperation with AEMO, is working on a project to introduce dynamic line ratings, as discussed in section 4.1.1.1. Dynamic line ratings application is broadly recognised as a method that improves the utilisation of transmission networks, reducing or delaying the requirement for network expansion.

Western Power is working to deliver initial implementation of dynamic line ratings for a selected set of transmission lines later this year. Once dynamic line ratings are implemented across the whole network, it should allow for better utilisation of transmission capacity.

Stakeholder feedback mechanisms

Where market participants request information on binding constraints or NAQ allocations, they may contact either Western Power or AEMO and seek further clarification. Both organisations provide avenues for communication for external stakeholders, mainly through emails, in-person discussions and written correspondence, as needed.

External stakeholders have sought information from Western Power after system events if they have suspected that they have been constrained by limit advice. Western Power does not have a standardised process, and this is resolved on a case-by-case basis. This ERA review has not sought further information on whether and how such issues were resolved, as this is beyond this current review's scope.

AEMO has more defined processes in how external stakeholders' feedback is managed, given that AEMO is the end point of the process and it publishes information on constraints, so it is more externally visible.

Where queries relate to operational constraints, the WA Energy Market Management (EMM) team is the first point of contact for external stakeholders, whereas queries related to RCM constraints are dealt with by the CIA team. Both these teams may seek more technical information from the WA System Engineering team, as required.

This team is also sometimes approached by external stakeholders directly around technical queries on constraint equations. The WA System Engineering team responds to public queries that are directly related to constraint equations and the team's responsibilities. Any queries that are outside of this, the team forwards to the WA EMM team or to the CIA team.

AEMO is the more public facing organisation and has access to sensitive and confidential information. For this reason, AEMO staff are trained in confidentiality to ensure that any information provided to external stakeholders does neither compromise its confidentiality obligations, nor provide unfair market advantage.

While AEMO has the obligation to publish an annual congestion report, there is no obligation to publish the RCM congestion report. AEMO has nevertheless started publishing this report, which has provided the market with better visibility.

6.3 Insecure outcomes

Insecure outcomes are deemed to occur when due to missing (a risk not being identified) or not-performing (constraint exists but does not prevent the risk) constraints the power system is not in a secure state. When limits and constraints are initially developed, Western Power and AEMO use power system simulations to identify risks and potential violations of Technical Rules requirements.

These are however snapshots of the power system at a point in time and are based on a specific set of assumptions and inputs. In reality, the power system is dynamic, and things can change instantly, for example through forced outages of network or generation equipment. It is not possible to have constraint equations built and ready for every theoretically possible system state.

The ERA review framework has identified several common industry best practices. While these do not guarantee complete coverage, the real-time operators have a sufficiently developed set of tools that aim to minimise the adverse impact of unexpected occurrences.

Robust and transparent processes

No level of preparation can foresee every possible outcome. The robust framework that sits around the limits and constraints process, covered by legislative requirements, and applied by Western Power and AEMO, aims to ensure the system can be operated in a secure manner.

There are also sufficient redundancies and contingency measures integrated within and between both organisations for instances that cannot be predicted – such as physical damage to network equipment, forced generator/load outages, or technical system contingencies.

Real-time system security monitoring

The end-to-end processes provide a sufficiently robust framework for Western Power and AEMO to manage the system securely and to support each other as required. Manual interventions by both Western Power's control room and AEMO's Real-Time Operations team allow for the system operators to react in the moment to maintain power system security and reliability.

Both of these real-time functions are manned continuously, and staffing contingencies are built around them to account for leave and unexpected absences. The system operators monitor the power system constantly and may identify insecure outcomes through the dispatch process.

Where issues are identified, the Real-Time Operation team will record them through incident reports that are subsequently reviewed and assessed, to ensure ongoing improvements to the constraint sets and real-time operation processes. Real-time system security violations, operator interventions and power system incidents are therefore constantly compiled and reviewed.

Reliability compliance monitoring and enforcement

Limit advice is developed by Western Power with the goal of ensuring ongoing compliance of the network's operation with the requirements of the Technical Rules, which guide power system security and reliability.

AEMO, as part of its constraint formulation processes undertake power system studies that compare theoretical outcomes (from the simulation) with empirical data. Any modifications to limits and constraints are sufficiently tested to demonstrate their suitability to prevent future insecure outcomes.

6.4 Appropriateness of limit margins and operating margins

Clauses 2.27C.2(a) and 2.27C.2(b) of the ESM Rules require that as part of its review the ERA assess the appropriateness of the margins applied by both organisations.[55]

The ERA's review framework assesses this from a perspective that margins are considered appropriate in the absence of either:

- binding constraints; or
- non-performing constraints (leading to insecure outcomes).

Only the presence of these occurrences should trigger a review of the appropriateness of the margins. In practical terms, the review assessed whether both Western Power and AEMO use standard methodologies and assumptions to calculate margins and under what circumstances they may review them.

Western Power sets a limit margin only for non-thermal limit advice, while AEMO applies operating margins on all constraint equations. Both organisations appear to apply standard approaches in the calculation of margins.

Western Power's limit margin is a 95% confidence level (which is a statistical offset based on the empirical standard deviation that could be taken on any number).

AEMO's operating margin of 0.95 for thermal constraint equations, including RCM constraint equations, is used to multiply thermal ratings. For non-thermal constraint equations, AEMO applies another offset to account for inaccuracies in calculating flows from generator terms. The inaccuracies include measurement errors, dispatch errors and model approximation margins, and can inherently occur through the dispatch process.

Where AEMO reviews a range of constraints following real-time events, it reviews binding and non-performing constraints. The review can also include a reassessment of the margins' values of such binding or non-performing constraints as part of the cause discovery process. This may result in AEMO re-formulating the constraint equations or updating the margins. Where AEMO reassesses a margin, it would undertake additional testing by incrementally changing the margins, depending on the case and the cause of the reassessment.

Any new operating margin needs to be manually implemented by a member of the WA System Engineering team, where an operating margin of a constraint equation is to be updated. Any constraint that has had its operating margin updated is monitored with empirical data that is used to assess its performance. Changes to the operating margin of constraint equations are a rare process.

Where insecure outcomes have been identified, constraint engineers can and have increased operating margins from the default 0.95. This is typically done because of either the operating power factor or large line losses and is always assessed on a case-by-case basis.

The operating margins for constraint equations are either a standard value of 0.95 or as changed after a review, testing and monitored post implementation. The operating margins

55 Electricity System and Market Rules, 4 June 2025, clauses 2.27C.2.(a) and (b), (online).

for constraints equations are deemed appropriate to ensure power system security, if not necessarily always economically optimal.

To date, AEMO has not undertaken a broad review of its approach around operating margins. Given that the new market has commenced less than two years ago, a broad review might be premature. Also, AEMO has adopted the current approach from the NEM, where the system has been operated under the SCED model for a long time and there is sufficient experience.

By reviewing the operating margins on a case-by-case basis, where constraints are binding or an in secure outcome was identified, AEMO undertakes additional due diligence to assess the appropriateness of the margins. As deemed necessary, feedback is provided to Western Power for its review.

For Western Power the development of non-thermal limit advice is a new function. Western Power has adopted the approach used by network operators in the NEM.[56] While this can be considered as a conservative approach, conservativeness is an inherent feature of power system security.

Western Power can also reassess limit margins, as part of the feedback loop with AEMO on binding constraints on a case-by-case basis. At this stage, Western Power consider that the current approach is reasonable and is still in the process of collecting a sufficiently large sample of data to be able to assess the appropriateness of the current margins.

Establishing robust processes, frameworks and understanding around the development of non-thermal limit margins, as well as the project on the introduction of dynamic line ratings are of higher priority for Western Power.

Overall, the ERA considers that both organisations have established sufficiently justifiable approaches around the application of margins, with these being reviewed at on as needed basis.

56 Australian Energy Market Operator, *Confidence levels, offsets and operating margins – policy*, 6 July 2010, (online).

7. Conclusions/ Areas of improvement

While not all aspects of the limit advice function are new, the overall process is new for Western Power. Western Power has taken the approach of adopting methods and practices from other transmission network providers, predominantly those operating in the NEM, where the SCED has been operational for many years. Western Power has sought to adopt standard methods and calculations for developing limit advice and limit margins.

AEMO has been operating in the NEM for a long time, and many of the concepts and principles adopted for the WEM were adopted from there. AEMO has been utilising standard and well-established methods and systems in its approaches in the WEM.

The novelty around the requirement for both organisations to communicate with each other and to understand each other's needs, as demonstrated for example around the PowerFactory model exchanges, is something that both organisations recognise. Both entities are committed to fulfilling their responsibilities and functions, and they have developed suitable processes. These processes have matured substantially since their inception and there is ongoing work to identify and implement improvements.

Overall, the review identified that given that both Western Power and AEMO have been operating in a new market environment for less than two years without a market trial, there is evidence that both organisations are putting effort in ensuring the systems work and power system security and reliability are maintained.

7.1 Effectiveness in meeting ESM Rules principles

The ESM Rules require that when undertaking its review under clause 2.27C.1, the ERA must assess how effectively Western Power and AEMO meet the State Electricity Objective (SEO) and good electricity industry practice when developing limit advice and formulating constraint equations, respectively.[57] These two principles have therefore guided the ERA's review at an overarching level.

7.1.1 State Electricity Objective

The SEO is defined in the Electricity Industry Act as:

> The State electricity objective is to promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity in relation to
>
> (a) the quality, safety, security and reliability of supply of electricity; and
>
> (b) the price of electricity; and
>
> (c) the environment, including reducing greenhouse gas emissions.[58]

The ERA's review concluded that some elements of the SEO are consistently considered by both Western Power and AEMO when developing limit advice and formulating constraint equations. Limb (a) of the SEO appears to be effectively met, given that both organisations' functions are embedded in ensuring the quality, safety, security and reliability of electricity supply.

[57] Electricity System and Market Rules, 4 June 2025, clause 2.27A.9, (online).

[58] Electricity Industry Act 2004 (WA), 6 February 2025, clause 3A(1), (online).

As part of the maturation process, AEMO indicated that it has recently started implementing a consideration of economic impacts of constraint equations and the price of electricity, in its constraint equations formulation philosophies and processes. More work will be required develop robust understanding of the implication of this consideration.

Western Power does not appear to explicitly consider the price of electricity in its limit advice development; however, it could be implied that through the commencement of the dynamic line ratings project, in cooperation with AEMO, there is an expectation of future consideration of limb (b) of the ESO as part of Western Power's processes. The introduction of dynamic line ratings across the network is expected to partially reduce and/or delay the need for network expansion, which could be expected to save large investments and will ultimately flow into the market's pricing outcomes.

The dynamic ratings project also supports limb (c) of the SEO, reducing the network's footprint and supporting the connection of new, (mostly expected to be) renewable energy resources. Further, the RCM limit advice and constraint equations end-to-end process could be improved for clarity. For example, documenting the series of steps Western Power will go through to examine whether or not to consider applying a special protection scheme or the process it will explore for network augmentation. Accountability for network investment decisions driven by NAQ rests with Western Power noting outcomes are likely to be of benefit to the market and support limb (c) of the ESO.

7.1.2 Good electricity industry practice

Good electricity industry practice is a defined term in the Electricity Networks Access Code:

> **"good electricity industry practice"** means the exercise of that degree of skill, diligence, prudence and foresight that a skilled and experienced person would reasonably and ordinarily exercise under comparable conditions and circumstances consistent with applicable written laws and statutory instruments and applicable recognised codes, standards and guidelines.[59]

Based on the review's findings, the ERA concludes that both Western Power and AEMO adhere to good electricity industry practice as part of their processes around development of limit advice and formulation of constraint equations. Both have adopted standard methods for the calculation of thermal limits and constraints widely used across other jurisdictions and therefore tested and accepted as meeting good electricity industry practices.

Western Power develops non-thermal limit advice in a way that ensures there are no breaches to the requirements of the Technical Rules in relation to non-thermal instabilities. While potentially conservative, the approaches taken by Western Power appear to align with good electricity industry practices.

The end-to-end processes between both organisations demonstrate that overall good electricity industry practices are followed. While there is always room for improvement, both organisations are reasonably well set to ensure power system security and reliability are consistently met.

7.2 Areas of improvement

While the ERA's first LACE review concluded that overall Western Power and AEMO have well established processes and governance frameworks, meet good electricity industry practices and their processes are largely aligned and follow best industry practices, as

59 Electricity Networks Access Code 2004, 30 November 2004, clause 1.3 Definitions, (online).

identified through the inter-jurisdictional review, there are areas where improvements can be made.

The following, areas would benefit from additional work and might be used as a guide for what matters might be assessed in a subsequent ERA review:

1. Procedures while complete and adequate are partially outdated and by adding more examples and background information will benefit market participants and potential new entrants. This will increase the transparency around the overall LACE framework and could provide more clarity around the interactions between the processes.

2. Additional transparency around the RCM processes would benefit market participants and especially new entrants; in particular, what guides the decisions around potential network investment and special protection schemes, as well as information on the NAQ allocation process and where limit advice and constraint equations sit within the overall RCM framework.

3. Western Power's internal documentation that guides its processes around development of limit advice appears comprehensive and of appropriate quality. The ERA notes that one internal document, related to the RCM process includes outdated timeframes, similar to the RCM section of its public WEM procedure, and should be updated. Western Power continues to develop not yet documented processes, which was demonstrated during the review, which shows consistency around Western Power's internal requirement to ensure a complete set of internal documentation is available.

4. AEMO has less internal documentation, mostly limited to process flow charts and internal wiki pages with work instructions. While these are helpful, they do not provide sufficient and comprehensive documentation coverage of internal processes, which would benefit new starters. While time-consuming, the benefit of documenting internal processes is that possible gaps and areas of improvement are identified, which could lead to improved processes and effectiveness.

5. Both organisations have been on a steep learning curve over the last few years, including the preparation time prior new market start. As discussed, some processes are more mature than others, but there appears to be an ongoing effort between Western Power and AEMO to continue improving communication between the organisations, increasing mutual understanding of each other's requirements and overarching work that would impact market outcomes. It is expected that these learning processes will continue into the future.

6. Dynamic line ratings are used across transmission network providers around the world and there is strong evidence of the benefits they provide. There is also a well-established base of knowledge and understanding, that would allow Westen Power to benefit from a wide range of existing information in its implementation process. This work will be of interest to the market and the ERA may seek to assess progress in future reviews.

7. The ESM Rules impose obligations on AEMO to publish information related to limit advice and constraint equations. AEMO has developed the CIR website where information is available to the public. This in combination with the procedures provide a good basis. However, more information and potentially in less technical form would provide educational benefits to specifically new market entrants. Both Western Power and AEMO could consider publishing more 'explanatory and educational' information around its processes to increase transparency without the need of an external review. Any information published above and beyond ESM Rules requirements will increase market transparency and will have high educational value to stakeholders.

Appendix 1 List of Tables

Appendix 2 Glossary and definitions

Table 1: Glossary and definitions

Term	Definition[60]
AEMO	Australian Energy Market Operator
Capacity year	A period of 12 months commencing at the start of the Trading Day which commences on 1 October and ending on the end of the Trading Day ending on 1 October of the following calendar year.
CIR	Congestion Information Resource – An information resource comprising the information described in clause 2.27B.3 of the ESM Rules.
Constraint equation	A mathematical representation of a Constraint on the SWIS
Constraint set	A group of Constraint Equations that respond to a particular condition or set of conditions
Constraints Library	The collection of Constraint Equations and Constraint Sets, Limit Advice, Reserve Capacity Cycle information and other supporting information.
Contingency Event	Has the meaning given in clause 3.8A.1 of the ESM Rules
Dispatch algorithm	Means the algorithm used in the Central Dispatch Process developed by AEMO in accordance with section 7.2 of the ESM Rules.
ESM Rules	The Electricity System and Market Rules
FCESS	Frequency Co-optimised Essential System Services
Intervention Event	An event where AEMO intervenes in the Real-Time Market by issuing a direction
LACE review	Limit Advice and Constraint Equations review
Limit advice	Information to be provided to AEMO by a Network Operator in respect to limitations of, or relating to, its Network that gives rise to a Network Constraint.
Limit Equation	Means a mathematical expression defining the power transfer capability across a particular Network element or group of Network elements.
Limit Margin	A margin applied by a Network Operator when formulating a Limit Equation, or a Network Limit where a Limit Equation is not appropriate, to account for uncertainty.
Loss Factor	Means a factor representing network losses between any given node and the Reference Node where the Loss Factor at the Reference Node is 1, expressed as the product of a Transmission Loss Factor and a Distribution Loss Factor and determined in accordance with clause 2.27.5 of the ESM Rules.
MW	Mega Watt

60 Capitalised terms are defined terms in the ESM Rules, Chapter 11, (online).

Term	Definition[60]
MVA	Mega Volt-Amperes is a unit to measure the apparent power in a circuit. It is a product of the voltage and current in a circuit
NAQ	Network Access Quantity
NCESS	Non-Co-optimised Essential System Service
Near Binding Constraint Equation	For a Constraint Equation used in the Dispatch Algorithm as part of the Central Dispatch Process, where the absolute value of difference between the value of the left-hand side and the value of the right-hand side of the Constraint Equation is less than 20 times the absolute value of the largest coefficient on the left-hand side of the Constraint Equation.
NEM	National Electricity Market
Network Constraint	A limitation or requirement in a part of a Network that may impact one or more Registered Facilities in the Central Dispatch Process, such that it would be unacceptable to transfer electricity across that part of the Network at a level or in a manner outside the limit or requirement.
Network Limit	A limitation or requirement affecting the capability to transfer power in a part of a Network, such that it would be unacceptable to transfer electricity across that part of the Network at a level or in a manner outside the limit or requirement.
Non-thermal limit	Is a Network Limit that is not a Thermal Network Limit
Operating Margin	A margin applied by AEMO when formulating a Constraint Equation to account for uncertainty.
Planned Outage	An Outage Plan that has been approved by AEMO
Power System Reliability	Means the safe scheduling, operation and control of the SWIS in accordance with the Power System Reliability Principles.
Power System Security	Means the safe scheduling, operation and control of the SWIS in accordance with the Power System Security Principles.
RCM	Reserve Capacity Mechanism
RCM Constraint Equation	Means a Constraint Equation developed by AEMO in accordance with section 4.4B of the ESM Rules.
RCM Limit Advice	Means Limit Advice for a Thermal Network Limit at an ambient temperature of 41°C.
RoCoF	Rate of change of frequency, a measure of system inertia
SCADA	Supervisory Control and Data Acquisition
SEO	State Energy Objective as defined in Electricity Industry Act 2004 (WA), 6 February 2025, clause 3A(1)
SWIS	South West Interconnected System
Technical Rules	Has the meaning given in section 1.3 of the Access Code

Term	Definition[60]
Thermal limit	Means a Network Limit that describes the maximum capacity for electrical throughput of a particular Network element due to temperature or related effects.
Transformer	A piece of equipment that reduces or increases the voltage of alternating current.
Transient stability	The ability of the power system to maintain synchronism when subjected to severe disturbances.
Transmission line	A power line that is part of a transmission system
Voltage stability	The ability of a power system to attain steady voltages at all busbars after being subjected to a disturbance from a given operating condition.
WEM	Wholesale Electricity Market
WEMDE	Wholesale Electricity Market Dispatch Engine

Appendix 3 Documentation review

This section lists the documents that were provided by both Western Power and AEMO and were reviewed by the ERA and their consultant to support the review.

Table 2: Western Power documents list

Document name	Other / Overall	Thermal	Non-thermal	RCM
WP Organisational structure	X			
WEM Procedure - Limit Advice Development (public)	X			
WEM Procedure Limit Advice Development - ERA questions - WP response Dec 2024	X			
Western Power ERA Limit Advice – initial presentation	X			
ERA Limit Advice Review – high-level summary		X		
SALM Operational Limits Rating Philosophy		X		
G332 Operating Limits and Ratings Guideline		X		
G408 AEMO Grid Modelling Guideline		X		
SALM Work Process Document		X		
SOLE Role - Thermal limits workflow		X		
Guide for Maintaining and Managing Transmission Asset Thermal Ratings and Limits in WP Asset Management Systems		X		
Procedure for Calculation of Transformer Ratings		X		
Transmission Thermal Ratings Methodology		X		
WP Thermal Limits Process – presentation to ERA - June 2025 – and Western Power responses to follow up queries		X		
Transmission Asset Ratings Process for Ad-Hoc Rating Requests – flow chart		X		
Transformer Rating Study - PyRate Instructions		X		
Transformer Rating (TORP) Study Guide & Instruction		X		
Thermal Ratings and Limits Work Triggers		X		
Temperature Zones for Line Ratings		X		
Western Power Thermal Limit Advice 2025-03-24 – sample Excel workbook		X		
AEMO Confidence Levels, Offsets and Operating Margins (public)	X		X	

Document name	Other / Overall	Thermal	Non-thermal	RCM
G356 Operation of Transformers and Transmission lines		X	X	
Limit Equation Development for SWIS		X	X	
Limit advice #1 development - EGF under N-0 or with a prior outage of MU-NT91 - Internal Report			X	
Non-thermal Limit Advice development - North Region under N-0 or with a prior outage of MU-NT 91 - Internal Report			X	
Non-thermal limit equation process in connection study			X	
Non-Thermal Limit Equation calculation - process			X	
Non-Thermal Limit Assessment - process			X	
Non-Thermal System Normal Limit Equation Advice Process – presentation to ERA - June2025 – and Western Power responses to follow up queries			X	
WP Non-Thermal Limit Equation Register – sample Excel workbook			X	
Guide to using Transformer Loading Calculations as per AS60076X			X	
Non-Thermal Planned Outages – Presentation to ERA -June 2025 – and Western Power responses to follow up queries			X	
G 488 Planned Outage Non-Thermal Limit Assessment Process			X	
Assessment of outage for Limit Advice LAMA (multiple numbers) – template example			X	
Assessment of outage for Limit Advice LAMA # 801 – template example			X	
Assessment of outage for Limit Advice LAMA # 1622 – template example			X	
LAMA design requirements			X	
Non-thermal Limit Advice for outages – model assessment sample			X	
Response to ERA queries planned outage non-thermal limits – July 2025				
Limit advice RCM presentation – July 2025				X
Asset Management Configuration Change Request for Addition of RCM Ratings Nameplate Attributes (@41DegC)				X

Document name	Other / Overall	Thermal	Non-thermal	RCM
Reserve Capacity Management Limit Advice Process				X
Work Instruction – RCM Limit Advice – GT – Estimate SWIS Configuration Peak Demand				X

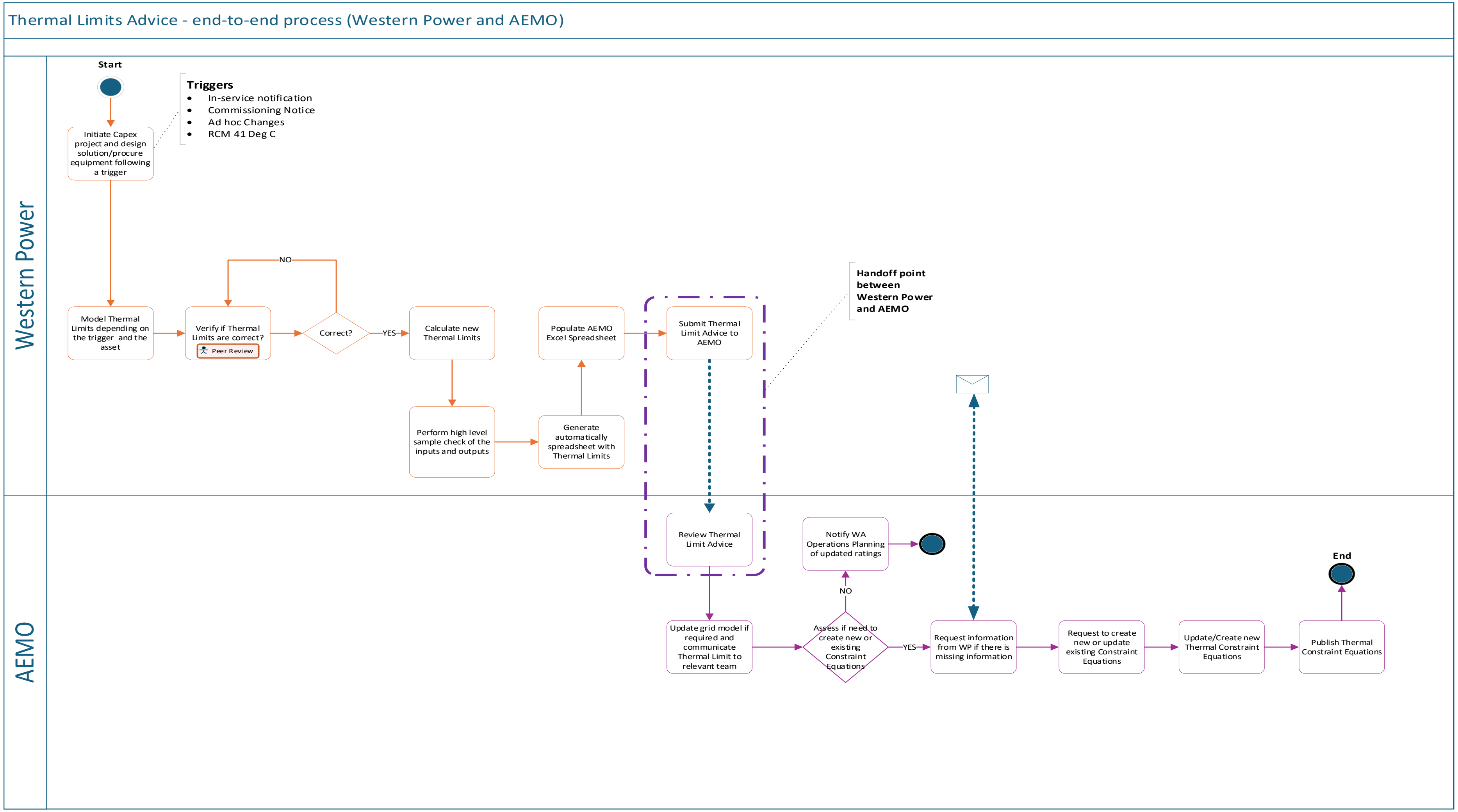
Table 3: AEMO documents list

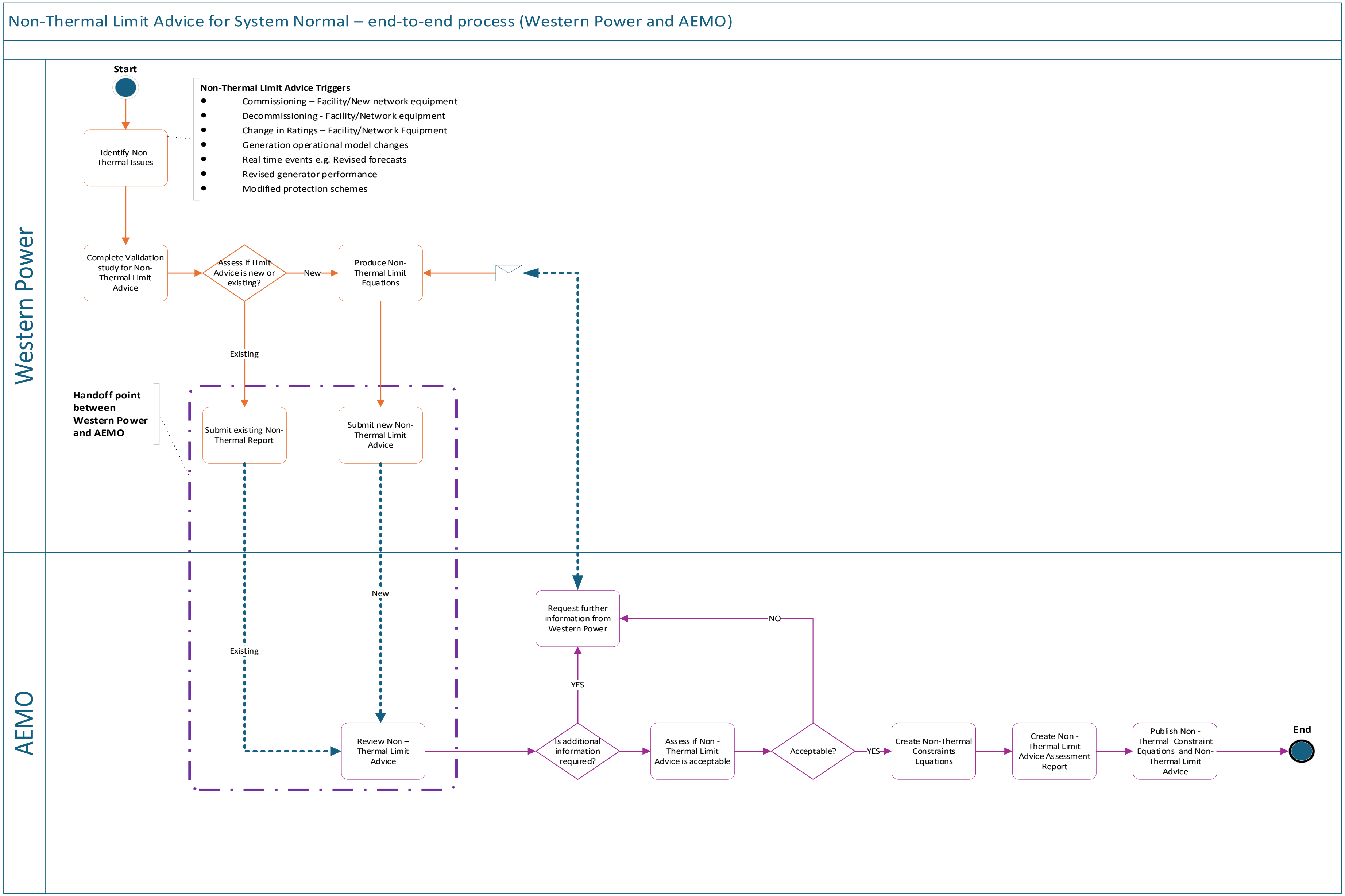
Document name	Other / Overall	Thermal	Non-thermal	RCM
WEM Procedure: Constraint Formulation (public)		X	X	
WEM Procedure: Limit Advice Requirements (public)		X	X	
WEM Procedure: RCM Constraint Formulation (public)				X
WEM Procedure: RCM Limit Advice Requirements – draft for consultation (public)				X
AEMO Confidence Levels, Offsets and Operating Margins (public)	X	X	X	
AEMO Congestion Information Resource (public website)	X			
AEMO Limit Advice review guideline			X	
AEMO response to ERA on document review queries and constraints sample– July 2025	X	X	X	X
AEMO response to ERA follow up queries on non-thermal limit advice – July 2025			X	
AEMO Limit Advice 3 Assessment Report v1.1			X	
Congestion modelling – flow chart	X			
Congestion modelling – Limit Advice non-thermal – flow chart			X	
Congestion modelling – Limit Advice thermal – flow chart		X		
Congestion modelling – Constraint formulation – flow chart	X			
Congestion modelling – CIR Management – flow chart	X			
Congestion modelling – Developing and updating constraints lists – flow chart	X			
Outage Management – Network – flow chart	X			
OMS screenshot sample	X			

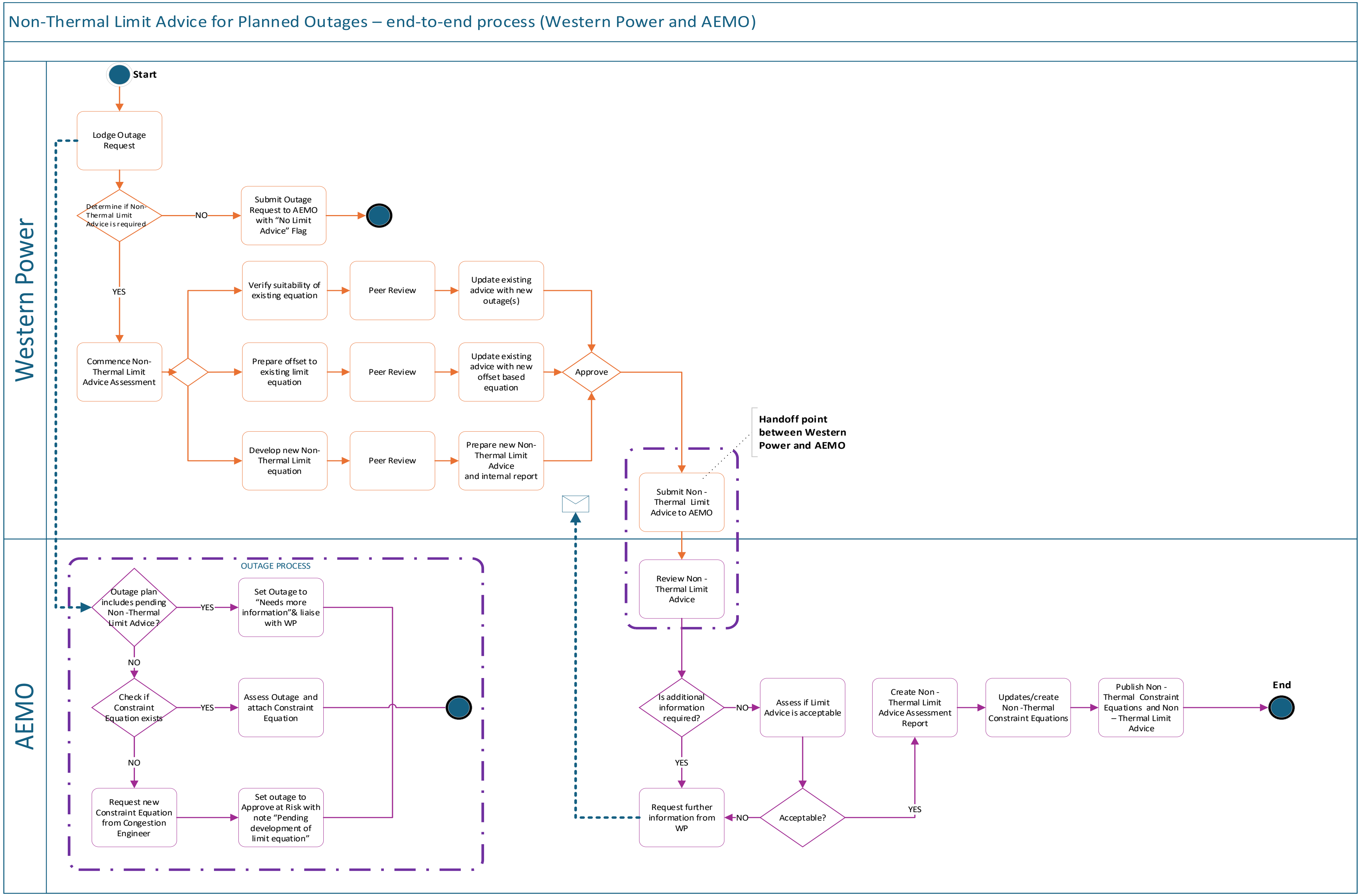
Document name	Other / Overall	Thermal	Non-thermal	RCM
Real-Time Operations Confluence – sample on ROCOF shortfall intervention and Control Room Instructions	X			
Real-Time Operations Confluence – sample on a thermal limit issue management and Control Room Instructions		X		
Constraint builder governance samples (multiple samples)	X			
Constraint management system sample	X			
Outage Management – Generator – flow chart	X			
Network Augmentation – flow chart	X			
WEM Annual congestion report 2023-24 (public)	X			
Internal Wiki – Archived Material		X	X	
Internal Wiki – Current Material		X	X	
Internal Wiki – RCM Material				X
WEM RCM Congestion report 2024 (public)				X
Formulating RCM Constraint Equations (RCMCE)(NAQ)				X

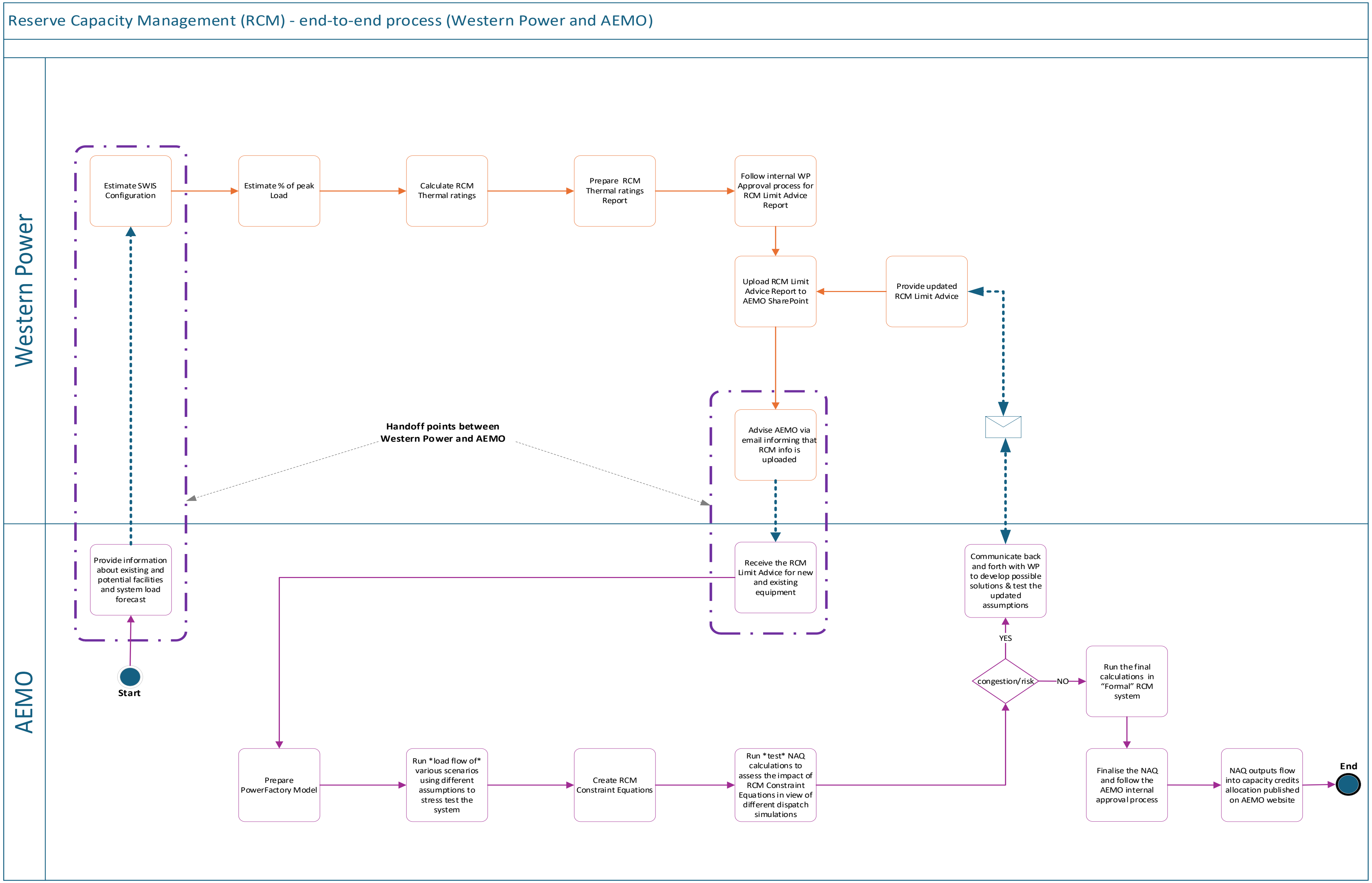
Appendix 4 End-to-end process flow charts

The below flow charts were developed by the ERA to demonstrate the complete end-to-end processes.




Non-Thermal Limit Advice for System Normal – end-to-end process (Western Power and AEMO)
Western Power
AEMO
Start
Non-Thermal Limit Advice Triggers
Commissioning – Facility/New network equipment
Decommissioning - Facility/Network equipment
Change in Ratings – Facility/Network Equipment
Generation operational model changes
Real time events e.g. Revised forecasts
Revised generator performance
Modified protection schemes
Identify Non-Thermal Issues
Complete Validation study for Non-Thermal Limit Advice
Assess if Limit Advice is new or existing?
New
Produce Non-Thermal Limit Equations
Existing
Handoff point between Western Power and AEMO
Submit existing Non-Thermal Report
Submit new Non-Thermal Limit Advice
New
Existing
Request further information from Western Power
NO
YES
Review Non – Thermal Limit Advice
Is additional information required?
Assess if Non - Thermal Limit Advice is acceptable
Acceptable?
YES
Create Non-Thermal Constraints Equations
Create Non - Thermal Limit Advice Assessment Report
Publish Non - Thermal Constraint Equations and Non-Thermal Limit Advice
End


Non-Thermal Limit Advice for Planned Outages – end-to-end process (Western Power and AEMO)
Western Power
AEMO
Start
Lodge Outage Request
Determine if Non-Thermal Limit Advice is required
NO
YES
Submit Outage Request to AEMO with "No Limit Advice" Flag
Commence Non-Thermal Limit Advice Assessment
Verify suitability of existing equation
Peer Review
Update existing advice with new outage(s)
Prepare offset to existing limit equation
Peer Review
Update existing advice with new offset based equation
Approve
Develop new Non-Thermal Limit equation
Peer Review
Prepare new Non-Thermal Limit Advice and internal report
Handoff point between Western Power and AEMO
Submit Non-Thermal Limit Advice to AEMO
Review Non-Thermal Limit Advice
OUTAGE PROCESS
Outage plan includes pending Non-Thermal Limit Advice?
YES
Set Outage to "Needs more information"& liaise with WP
NO
Check if Constraint Equation exists
YES
Assess Outage and attach Constraint Equation
NO
Request new Constraint Equation from Congestion Engineer
Set outage to Approve at Risk with note "Pending development of limit equation"
Is additional information required?
NO
YES
Assess if Limit Advice is acceptable
Acceptable?
NO
YES
Request further information from WP
Create Non-Thermal Limit Advice Assessment Report
Updates/create Non-Thermal Constraint Equations
Publish Non-Thermal Constraint Equations and Non-Thermal Limit Advice
End


Reserve Capacity Management (RCM) - end-to-end process (Western Power and AEMO)
Western Power
AEMO
Estimate SWIS Configuration
Estimate % of peak Load
Calculate RCM Thermal ratings
Prepare RCM Thermal ratings Report
Follow internal WP Approval process for RCM Limit Advice Report
Upload RCM Limit Advice Report to AEMO SharePoint
Provide updated RCM Limit Advice
Handoff points between Western Power and AEMO
Advise AEMO via email informing that RCM info is uploaded
Provide information about existing and potential facilities and system load forecast
Start
Receive the RCM Limit Advice for new and existing equipment
Communicate back and forth with WP to develop possible solutions & test the updated assumptions
YES
congestion/risk
NO
Run the final calculations in "Formal" RCM system
Prepare PowerFactory Model
Run *load flow of* various scenarios using different assumptions to stress test the system
Create RCM Constraint Equations
Run *test* NAQ calculations to assess the impact of RCM Constraint Equations in view of different dispatch simulations
Finalise the NAQ and follow the AEMO internal approval process
NAQ outputs flow into capacity credits allocation published on AEMO website
End