RELIABILITY PANEL AEMC

GUIDELINES

Reliability Panel AEMC

RELIABILITY, SECURITY AND SAFETY FRAMEWORKS IN THE NEM - AN EXPLANATORY STATEMENT

30 MARCH 2023

INQUIRIES

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Reference: REL0087

CITATION

Reliability Panel, Reliability, Security and Safety Frameworks in the NEM - An explanatory statement, 30 March 2023

ABOUT THE RELIABILITY PANEL

The Panel is a specialist body established by the Australian Energy Market Commission (AEMC) in accordance with section 38 of the National Electricity Law and the National Electricity Rules. The Panel comprises industry and consumer representatives. It is responsible for monitoring, reviewing and reporting on reliability, security and safety on the national electricity system, and advising the AEMC in respect of such matters.

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1 INTRODUCTION

This summary of the reliability, security and safety frameworks in the NEM has been prepared as part of the Reliability Panel's (the Panel) *Annual Market Performance Review* (AMPR) of the National Electricity Market (NEM). It is intended as a companion document to the AMPR report itself. The objectives of this explanatory statement are to:

- Introduce the Reliability Panel and AMPR process
- Describe the frameworks which are used to deliver power system reliability, security and safety in the NEM
- Identify the set of metrics used by the Panel to monitor and report on reliability, security and safety outcomes in the NEM for the purposes of AMPR reporting.

This explanatory statement should be read in conjunction with the AMPR final report in its relevant year.

1.1 The Reliability Panel and Annual Market Performance Review

The Panel is a specialist body established by the Australian Energy Market Commission (AEMC) in accordance with section 38 of the National Electricity Law (NEL). Its purpose, constitution and review process are set out in Chapter 8 Part E of the National Electricity Rules (NER). The Panel comprises industry and consumer representatives who represent a range of participants in the NEM, including small and large consumers, generators, network businesses, retailers and the Australian Energy Market Operator (AEMO). Among other things, the Panel is required to:

- Monitor, review, and report on, in accordance with the Rules, the safety, security and reliability of the national electricity system.
- At the request of the AEMC, to provide advice in relation to the safety, security, and reliability of the national electricity system.
- Undertake any other functions and powers conferred on it under this Law and the Rules.

The AMPR is one of the Panel's core review functions and is undertaken by the Panel as required by the NER and in accordance with the terms of reference provided by the AEMC.[1] Each AMPR covers reliability, security and safety outcomes over the preceding financial year and includes observations and commentary of the NEM primarily relating to that period. It also provides commentary on current and emerging trends and issues, including the market and regulatory changes currently underway.[2]

The Panel must conclude each AMPR by the end of the financial year to which the review relates. The Panel must conduct the AMPR in terms of:[3]

- Reliability of the power system

1 For the complete standing terms of reference see https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

2 Clause 8.8.3(b) of the NER requires the Panel to conduct a review of the performance of certain aspects of the market, at least once every financial year and at other such times as the AEMC may request.

3 Clause 8.8.3(b) of the NER.

- The power system security and reliability standards
- The system restart standard
- The guidelines referred to in clause 8.8.1(a)(3) of the NER[4]
- The policies and guidelines referred to in clause 8.8.1(a)(4) of the NER[5]
- The guidelines referred to in clause 8.8.1(a)(9) of the NER.[6]

1.2 Role of this explanatory statement

This document provides the reader with background necessary to understand the security, reliability, and safety frameworks in the NEM necessary to understand the Panel's AMPR reporting. It provides:

- An introduction to the concepts, frameworks and role of security, reliability and safety in the NEM.
- Provides a description of the Panel's approach to the AMPR.
- Identifies and describes the metrics used in the Panel's AMPR for ongoing monitoring of reliability, security and safety.

In addition to supporting the AMPR, this document is also designed to provide a standalone overview of reliability, security and safety frameworks in the NEM, based on the frameworks that applied at March 2023.

This report does *not* include the following, which is set out in the 2021 – 2022 AMPR final report:

- Data in relation to the reliability, security, and safety performance of the NEM
- Commentary and observations of the above data
- Key regulatory changes from the previous AMPR period.

This explanatory statement should therefore be read in conjunction with the AMPR final report in the relevant year.[7]

4 The guidelines govern how AEMO exercises its power to issue directions in connection with maintaining or re-establishing the power system in a reliable operating state.

5 The policies and guidelines govern how AEMO exercises its power to enter into contracts for the provision of reserves.

6 The guidelines identify, or provide for the identification of, operating incidents and other incidents that are of significance for the purposes of the definition of 'reviewable operating incident' in clause 4.8.15 of the NER.

7 The FY2021-22 AMPR final report can be found at https://www.aemc.gov.au/market-reviews-advice/annual-market-performance-review-2022.

2 INTRODUCING SECURITY AND RELIABILITY IN THE NATIONAL ELECTRICITY MARKET

Power system reliability in the NEM is distinct from power system security but both involve 'keeping the lights on'. To achieve this, the power system overall needs to be:

- **Reliable** — have enough capacity (generation, demand response and networks) to supply customers, and
- **Secure** — able to operate within defined technical limits, even if there is an incident such as the loss of a major transmission line or large generator.

This chapter introduces the concepts of reliability and security in the NEM and describes their relationship and relevance to the Panel's AMPR process. The specific frameworks for delivering reliability and security in the NEM, along with the metrics used to report on security and reliability outcomes are presented in Section 3.1 and Section 4.4.

2.1 What is power system reliability

A reliable power system has enough generation, demand response and network capacity to supply consumers with the energy that they demand with a very high degree of confidence. Reliability events on the power system arise when there is a shortage of available generation and network capacity to meet end-user demand and so customers.

A reliable power system requires adequate investment and retirement as well as effective operational decisions, so that supply and demand are in balance at any particular point in time. In a reliable power system the expected level of supply will always include a buffer, known as reserves, that can be used if there are variances in supply and/or demand. The presence of reserves allows the actual demand and supply of the system to be kept in balance, even in the face of credible disturbances to the system's supply and demand balance.

If there is insufficient generation, demand response and network capacity to supply customers with the energy that they demand, then reliability issues can occur and customers can receive interruptions to their supply — known as 'lost load'.

The core objective of the existing reliability framework in the NEM is to deliver efficient reliability outcomes through market mechanisms to the largest extent possible. Market mechanisms involve sending price signals that provide commercial incentives to businesses, rewarding generation or demand response at times of high demand. These incentives encourage market participants to provide investment, retirement and operational decisions that support reliability.

In addition, AEMO provides information to participants on projections and forecasts relevant to reliability outcomes and also has tools that it can use to intervene, when needed, to maintain power system reliability consistent with relevant standards.[8] Further information on the frameworks used to deliver reliability in the NEM is provided in Section 3.

Reliability issues have traditionally occurred at times of peak demand for electricity, generally on very hot days, where unexpected generator or interconnector outages have resulted in insufficient capacity to satisfy demand. Under such circumstances, AEMO instructs network service providers to conduct controlled customer load shedding, which is generally performed on a rotational basis.

Lost load can also occur due to security issues, which are discussed in Section 4.

Stakeholders should note the NEM uses different terminology from overseas jurisdictions when it refers to reliability. Reliability in the NEM corresponds to the internationally used term 'resource adequacy'.

2.2 What is power system security

In addition to reliability, the Panel also reports on the security of the power system. Power system security involves maintaining components within their allowable equipment ratings, maintaining the system in a stable condition within defined technical limits, and returning the power system to operate within normal conditions following a disturbance. Power system disturbances for power system security are referred to as contingency events.[9]

AEMO manages the power system by dispatching the market such that it remains within a 'technical envelope' required to maintain the power system in a 'secure' state. When the power system is in a secure state, technical parameters such as power flows, voltage and frequency remain within the bands defined by relevant power system security standards and the power system remains stable without load shedding after a credible contingency event, such as the loss of a single transmission line or single generator.

The power system can also experience severe disturbances that require emergency load shedding to manage. These emergency response systems are provided to prevent a black system event or major supply disruption following a serious non-credible disturbance, such as the co-incident loss of multiple transmission lines or generators. Load is shed through automatic systems in response to a security event rather than through controlled rotational load shedding as is typically the case in a reliability event.

Reliability and security are distinct concepts managed by different NEM frameworks. The two are however closely related operationally and it is not always simple to separate them on operational timescales. A reliable power system will also be a secure power system however, the converse is not necessarily true; a power system can be secure even when it is not reliable. The NER requires AEMO to undertake involuntary load shedding, in order to maintain the power system in, and return the power system to a secure operating state within 30 minutes following a disturbance thereby compromising reliability in the short-term to maintain security.

8 The NEM reliability standard and interim reliability measure (IRM) are the standards relevant to reliability in the NEM. These are further described in Section 3.1.

9 Credible and non-credible contingency events are further described in Section 4.1.1.

3 HOW IS RELIABILITY DELIVERED IN THE NATIONAL ELECTRICITY MARKET

This chapter introduces the key frameworks for reliability in the NEM that are relevant to the Panel's AMPR reporting. As noted in Chapter 2, reliability in the NEM is provided through market prices that incentivise market participant investment, retirement, and operating decisions that provide sufficient generation and network capacity to satisfy customer demand. AEMO also supports market participant decision-making through the provision of information and is authorised to intervene should the market not deliver appropriate levels of reliability.

This chapter introduces the following:

- The reliability standard
- The market price settings
- Contract markets and their role in the NEM
- AEMO information and forecasting processes
- AEMO intervention mechanisms
- The performance of network service providers.

The Panel's approach to monitoring reliability performance is discussed in each of these areas with the monitoring metrics presented in Table 3.1.

3.1 The reliability standard describes the efficient level of unserved energy in the NEM

The National Electricity Objective (NEO)[10] is designed to promote the long-term interests of electricity consumers. A key component of the NEO is reliability, as shown in the box below.

> **BOX 1: THE NATIONAL ELECTRICITY OBJECTIVE**
>
> "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:
>
> - price, quality, safety and reliability and security of supply of electricity
> - the reliability, safety and security of the national electricity system."

The reliability standard (the standard) in the NEM is a measure that expresses the efficient level of unserved energy (USE) given the trade-off between the cost of investing in power system resources and the value that customers attach to a more reliable power system.

A fundamental tension in the reliability standard is between price, and by extension the costs borne by consumers, and the investment and operating costs associated with achieving a

10 Section 7 of the NEL.

reliable electricity supply. The higher the level of reliability, the more investment in capacity (e.g. more generation, demand-side resources or network assets) is required, all of which impose additional costs on consumers. Conversely, USE (an amount of customer demand that cannot be supplied) also has a cost. For example, if a customer has their electricity supply interrupted, they face losses associated with what they would have used the energy consumption for, if they could have consumed. These could be lost production if it is a business; or a colder/hotter home for residential customers with air conditioning.

It is not in the long-term interests of consumers to have no USE. Such an approach would be inefficient as the investment and operating costs of supplying energy at certain times would exceed the value placed on it by consumers. The reliability standard is therefore the level of USE that seeks to minimise total system costs considering power system capacity investment and operating costs, as well as the cost of any USE that would be borne by consumers. The standard currently targets a maximum expected USE in a region of 0.002% of the total energy demand in that region for a given year.[11]

The standard is not a regulatory or performance standard that is "enforced". The standard is instead intended to indicate an efficient level of generation, demand response and inter-regional transmission capacity sought for the NEM for the purpose of informing the market and AEMO processes. The Panel's AMPR sets out the forecast USE versus the reliability standard, as well as monitors historical actual reliability outcomes against the standard.

The Panel considers the appropriateness of the level of the reliability standard in the NEM every four years in its reliability standard and settings review (RSS review).[12]

Form of the reliability standard

The reliability standard is expressed as an 'expected' amount of USE, where the definition of USE for the purposes of reliability and security in the NEM is as described in Section 3.1.[13] An 'expected value' statistically represents a weighted average of all possible outcomes in a probability distribution. The reliability standard of 0.002% expected USE in a region in a financial year, therefore, represents the average of the probability distribution of all possible USE outcomes where each outcome is weighted by its probability of occurrence.

Stakeholders should note a reliability standard of 0.002% expected USE does not imply that there is no possibility of an actual outcome that is worse than 0.002% USE. Outcomes with levels of USE far higher (or indeed, far lower) than 0.002% are possible, although low probability and correspondingly discounted when assessing their impact against the reliability standard. This is referred to as tail risk.

The value of customer reliability

An understanding of the value consumers place on reliability is required to trade-off power system resource operating and investment costs and consumer willingness to pay for reliability. The value of customer reliability (VCR) currently describes this for each region in

11 Clause 3.9.3C(a) of the NER.

12 For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

13 Clause 3.9.3C of the NER.

the NEM thereby allowing consumer preferences to be established for the purposes of identifying the efficient level of the reliability standard.

The VCR in the NEM is calculated by the Australian Energy Regulator (AER) for standard outages (i.e. outages up to twelve hours in duration) using a combination of contingent valuation and choice modelling survey techniques.[14]

The contingent valuation and choice modelling results are then combined to calculate the dollar value which a customer cohort places on specific outage scenarios. The dollar values for the outage scenarios are then used to derive the standard outage VCR for the customer segment.[15]

The interim reliability measure and retailer reliability obligation

In addition to the reliability standard in the NEM, a secondary reliability measure, the interim reliability measure (IRM) is also in place. The IRM for generation and inter-regional transmission elements in the NEM is a maximum expected USE in a region of 0.0006% of total energy demanded in that region for a given financial year.[16]

The IRM was introduced more recently into the regulatory framework and was developed as part of the Energy Security Board (ESB) work to improve the reliability of the electricity system through interim measures while more enduring reforms are developed.[17] The IRM is not used to determine market price settings (further described below) and instead:

- Informs AEMO's procurement of any reliability and emergency reserve trader (RERT) — a mechanism for AEMO intervention and further discussed in Section 3.5.1.
- Triggers the retailer reliability obligation (RRO).

The RRO is an obligation for retailer forward contracting. The RRO commenced on 1 July 2019, providing stronger incentives for market participants to invest in the right technologies in regions where it is needed, to support reliability in the NEM. AEMO will identify any potential reliability gaps in each NEM region against the IRM in the coming five years. If AEMO identifies a material gap three years and three months out, it will trigger obligations for retailers to enter into sufficient qualifying contracts to cover their share of a one-in-two year peak demand.[18]

While the Panel does not have a role in considering the appropriateness of the IRM, as it does for the reliability standard, its AMPR reporting considers actual and forecast reliability outcomes in the NEM against the IRM in addition to the reliability standard.

14 Contingent valuation was used to determine the willingness to pay (WTP) to avoid a baseline outage scenario (defined as two localised one hour outages in a year, occurring in winter in off-peak times). Choice modelling was used to determine the increment (or decrement) in value respondents' placed on specific outage attributes in addition to the baseline outage scenario. Attributes tested in the choice model were peak (7-10 am and 5-8 pm) and off-peak time of day, season (winter / summer), day of week (weekday / weekend), severity (localised / widespread) and duration (1 hour, 3 hours, 6 hours, 12 hours).

15 Further information on the AER's 2019 VCR methodology and VCR values can be found at: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/values-of-customer-reliability/final-decision.

16 Clause 3.9.3C(a1) of the NER.

17 For more information see https://www.energy.gov.au/government-priorities/energy-ministers/priorities/national-electricity-market-reforms/post-2025-market-design/interim-reliability-measures.

18 For more information see https://www.aer.gov.au/retail-markets/retailer-reliability-obligation.

3.2 Market price settings define the revenue potential supporting new investment in the NEM

The existing reliability framework in the NEM aims to deliver efficient reliability outcomes through market mechanisms to the largest extent possible. These mechanisms provide strong financial incentives for participants (generators, retailers, aggregators and customers) to make investment, retirement and operational decisions that support reliability.

The NEM operates as a 'gross pool' wholesale electricity market. All electricity supplied and consumed is settled in the market with the price for all being set by the marginal power system resource dispatched to satisfy demand in each 5-minute interval.

Gross pool electricity markets, such as the NEM, provide for periods of very high market prices that reflect the scarcity of supply. This is known as scarcity pricing and is the primary mechanism via which investment supporting reliability outcomes is supported in the NEM. Scarcity pricing is complemented by financial contract markets which allow market participants to manage financial risk supporting their investment and operating decisions. The market price settings (market price cap, cumulative price threshold, market floor price, and administered price cap) define the limits to scarcity pricing in the NEM and are introduced below.

In its AMPR reporting, the Panel monitors wholesale market price trends including, market price cap and market price floor events, diurnal wholesale electricity price profile evolution and wholesale price distribution. Monitoring wholesale market price outcomes allow the Panel to consider the investment environment and trends relevant to commercial incentives for investment and retirement affecting future reliability outcomes.

The market price settings

The limits of scarcity pricing in the NEM are defined by the market price settings. The market price settings are set at levels that are sufficient to provide enough revenue potential to support new entrant investment required to achieve outcomes consistent with the standard, but not too high to create systemic financial risks that may compromise the stability of the market. The level of the market price settings are therefore critical parameters in the delivery of reliability under current NER frameworks.[19]

- The market price cap (MPC) places an upper limit on wholesale market prices that can be reached in any trading interval. It serves as a limit on customer bids, preventing them from paying more than a set amount for energy in any dispatch interval. The value of the MPC is specified in the NER and is currently set at $15,500/MWh. The MPC is updated on 1 July each financial year, indexed relative to inflation.[20]
- The cumulative price threshold (CPT) has two purposes that are closely related to the MPC. The CPT aims to cap the total price risk to which market participants are exposed over a given time period, and maintain the effectiveness of the MPC, by not hindering the market price signals for efficient operational decisions and efficient investment in

19 For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

20 For more information see https://www.aemc.gov.au/news-centre/media-releases/2022-23-market-price-cap-now-available.

generation capacity and/or demand-side response. An administered price period (APP) is triggered should the rolling sum of market prices exceed the CPT in a region. The CPT is updated on 1 July each financial year, indexed relative to inflation.[21] For the period from 1 October 2021 to 30 June 2022 the CPT was $1,359,100.[22]

- The administered price cap (APC) is the maximum market price paid to participants, measured as a $/MWh value, that can be reached in any dispatch interval and any trading interval, during an APP and the prevailing dispatch price that applies during a period when prices exceed the CPT. The APC, combined with the CPT, is a mechanism to minimise financial instability risks to the market arising from an extended period of supply scarcity and corresponding high prices. It is, however, intended to be at a level sufficiently high to incentivise generation to make itself available during an APP. The APC is currently set at $600/MWh.[23]
- The market floor price (MFP) sets a lower limit on wholesale market prices that can be reached in any trading interval measured in $/MWh. The level of the MFP is specified in the NER and is currently set at -$1,000/MWh.[24] The purpose of the MFP is to allow the market to clear during low demand periods, while preventing market instability by imposing a negative limit on the total potential volatility of market prices.

The Panel assesses the level of each market price setting every four years in its RSS review, making recommendations to the AEMC to be progressed through a rule change if it considers these should be changed.[25]

3.3 Contract markets in the NEM support investment by allowing market participants to manage risk

Scarcity pricing in the NEM allows for volatile spot price outcomes which may vary between the market floor price (-$1000/MWh) and market price cap (currently $15,500/MWh) on a 5-minute basis. This potential volatility creates a significant level of financial risk. Wholesale market participants typically enter into various wholesale hedging contracts to manage these financial risks and increase certainty over their wholesale energy costs.

Both buyers and sellers in the wholesale market are exposed to variations in the spot price in the wholesale market but in the opposite direction. Buyers and sellers in the market are therefore known as natural counter-parties who have the incentive to agree to contracts that convert volatile spot revenues and costs to a more certain cash flow. The stable cash flows provided by financial contracts also help to finance new investments in both generation and retail assets by reducing financing risk thereby.

21 For more informationsee https://www.aemc.gov.au/sites/default/files/2022-02/Schedule%20of%20reliability%20settings%20-%20Calculation%202022-23%20financial%20year.pdf.

22 The base CPT was multiplied by six on 1 October 2021 with the commencement of the five-minute settlement.

23 On 1 September 2022, the Panel published its 2022 RSSR final report. The purpose of the 2022 RSSR was to consider whether the existing form and level of the reliability standard and settings remain appropriate for the expected market conditions from 1 July 2025 to 30 June 2028. One of the recommendations proposed by the Panel was to increase the APC from $300/MWh to $600/MWh. For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

24 For more information see https://www.aemc.gov.au/news-centre/media-releases/2022-23-market-price-cap-now-available.

25 For more information see https://www.aemc.gov.au/market-reviews-advice/2022-reliability-standard-and-settings-review.

While the primary role of entering into these contracts is to manage risk and cash flows, contracts can also be considered as another means of expressing the price of the same underlying product, meaning that the spot and contract prices are intrinsically linked. The price of hedging contracts reflects the balance of expectations as to the level and volatility of future wholesale spot price outcomes and therefore supports reliability by informing forward-looking investment and operational decisions.

Contracts in the NEM are traded either on the ASX, FEX or bilaterally. Swaps and caps are two examples of commonly traded contracts.

Under a swap contract:

- A given volume of energy is traded during a fixed period for a fixed price (normally 1 MW for a quarter at the strike price).
- The variable wholesale market spot price is, in effect, swapped for the fixed strike price.
- The contract is settled through payment between the contract parties based on the difference between the spot price and the strike price.

Under a cap contract:

- A fixed volume of energy is traded during a fixed period for a fixed price but only when the spot price exceeds a specified price.
- It provides electricity purchasers with insurance against high prices.
- The standard cap contract traded in the market is a "$300 cap". This means the seller of a cap is required to pay to the buyer the difference between the spot price and $300/MWh every time the spot price exceeds $300/MWh during the specified contract period.

The Panel monitors contract market outcomes in the AMPR through benchmark cap and contract prices and liquidity volumes across the different contract duration traded in Australian electricity contract markets. Contract prices and liquidity provide an insight into the health of the NEM's investment environment given the importance of such instruments for efficient investment decision-making.

3.4 AEMO implements the reliability standard and provides information to the market on reliability outcomes

Maintaining reliability through a market requires the provision of information (forecasts and notices) to inform market participants of the need for future investment. AEMO operationalises the reliability standard to provide information to the market about reliability outcomes over investment and operating time scales to achieve this.

The Panel uses AEMO information provision in its AMPR as a key indicator of current and emerging reliability challenges.

3.4.1 Electricity Statement of Opportunities

AEMO publishes the electricity statement of opportunities (ESOO) to inform market participants, new investors, and jurisdictional bodies of possible reliability gaps on investment timescales.[26] The ESOO includes projections of future USE (both in terms of the reliability standard and IRM) over a ten-year period. This ten-year period is divided into a reliability forecast identifying any forecast reliability gaps in the coming five years,[27] and an indicative projection of any forecast reliability gaps in the second five years of the forecast.[28]

The Panel considers ESOO projections in the AMPR when reporting on possible USE outcomes and supply-side challenges given expected generator retirements and the new investment pipeline.

3.4.2 Projected Assessment of System Adequacy and Energy Adequacy Assessment Projection

A market reserve level indicates the amount of potential available resources in the market to meet demand e.g. supply that can meet demand, but which has not yet been dispatched. Reserves help cater for unplanned power system events, such as unplanned transmission outages, sudden loss of generation (for example by a fault, or a reduction in renewable energy resources) or a sudden increase in system load.

AEMO performs projected assessment of system adequacy (PASA) assessments on the short-term and medium-term basis to inform the market of the potential for insufficient reserve levels as real-time is approached. In addition, AEMO also projects energy adequacy through the energy adequacy assessment projection (EAAP) to inform the market of the reliability risks associated with energy limited plant, such as hydro during drought conditions.

In its AMPR, the Panel considers market reserve level outcomes indicated by AEMO's PASA and energy limitations identified in the EAAP when considering near term reliability risk.

Short-Term PASA

AEMO conducts its short-term PASA (ST-PASA) process that includes forecasts of the level of reserves between real-time and seven days in the future.

ST-PASA provides information to market participants on the expected level of short-term capacity reserve and hence the likelihood of interruptions due to a shortage of power. It can also provide a benchmark for AEMO to intervene in the market.

Information from ST-PASA can encourage market participants and transmission network service providers (TNSPs) to respond by providing more capacity into the market or shift of planned outages respectively. For example, generators may offer more supply, or consumers may reduce their demand in response to reserve levels indicated in ST PASA. Both responses have the effect of improving market reserve margins, helping maintain power system reliability.

Medium-Term PASA

26 For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/nem-electricity-statement-of-opportunities-esoo.

27 The reliability forecast is to inform the RRO.

28 As required under clause 3.13.3A of the NER, the ESOO also includes projections of aggregate demand and energy requirements for each region, generating capabilities of existing and committed units, planned plant retirements, and committed network development.

AEMO uses its medium-term PASA (MT-PASA) reports to provide regular assessments of any projected shortage of market reserves that may result in a failure to meet the reliability standard over a 2-3 year time-frame. This enables market participants to make decisions about supply, demand, and the timing of planned outages of transmission network and generation assets for periods up to three years in advance.

Through the MT-PASA process, AEMO collects information on the capacity that each dispatchable unit can make available given 24 hours of notice. Participants submit their expected plant availability for the next 36 months and are required to update their PASA submission on an ongoing basis to ensure it matches their current intentions and best estimates.

Energy Adequacy Assessment Projection

The EAAP report provides information on the impact of potential energy constraints, such as water storage during drought conditions or constraints on fuel supply for thermal generation, on supply adequacy in the NEM over a two-year period.

Under the EAAP's data collation process, all scheduled generators in the NEM are required to submit information to AEMO regarding the effect of energy supply limitations on their production outputs. This data provides a broad assessment of impacts of energy limited plan on supply and reliability in the NEM.[29]

3.4.3 AEMO demand and intermittent generation forecasting

AEMO's information and market processes are informed by forecasts of demand and intermittent generation outcomes.

Due to the variable nature of intermittent generation and demand, there is potential for material variations in the availability of these generators which may have implications for operational power system reliability outcomes. At times of peak demand, even small variations within a tight time-frame can create reliability issues, especially if firming capacity is not available to replace this generation.

The accuracy of forecasting is therefore a key factor in NEM reliability outcomes. Forecasting systems and forecasting improvements, along with the appropriate market structures and operational tools, will be increasingly important tools for promoting efficiencies in NEM dispatch, pricing, system reliability and security, as renewable generation continues to make up a larger share of the generation mix.

The Panel considers the accuracy of AEMO's forecasting in its AMPR. The Panel considers how accurate forecasts have been as an assessment of how well the market is managing growing uncertainty associated with demand and intermittent generation.

Demand forecasting

Accurate demand forecasting is crucial to a reliable power system to ensure there is sufficient capacity to meet customer demand for energy. AEMO is responsible for producing electricity

29 For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/energy-adequacy-assessment-projection-eaap.

demand forecasts for the NEM. AEMO's Forecasting Data Portal has been in operation since 2015 and includes operational consumption, maximum demand and, minimum demand forecasts.[30]

Demand is defined in three key ways:[31]

- **Demand** — describes electricity consumed by end users at a particular time (MW).
- **Consumption** — refers to electricity consumed over a period of time (MWh).
- **Operational Demand —** operational demand (MW) refers to the electricity used by residential, commercial and large industrial consumers, as supplied by scheduled, semi-scheduled and significant non-scheduled generating units. The demand satisfied by behind-the-meter generation such as residential solar PV is subtracted from operational demand.

AEMO's demand forecasting accounts for uncertainty though 90%, 50%and 10% probability of exceedance (POE) demand forecasts which are published for the next 24 months. AEMO also forecasts minimum demand given its increasing significance for system security.

Intermittent generation forecasting

AEMO prepares forecasts of the available capacity of semi-scheduled generators to schedule sufficient generation in the dispatch process.[32] AEMO also prepares an unconstrained intermittent generation forecast (UIGF) to be used in PASA processes for reserve assessment purposes.

Three forecasting systems are used for this purpose:

- Australian solar energy forecasting system (ASEFS) produces forecasts for any solar farm greater than or equal to 30 MW registered capacity and any solar farms that AEMO is required to model in network constraints for power system security reasons.[33]
- ASEF2 produces forecasts for aggregated regional solar generation forecasts for small-scale PV systems (less than 100 kW system capacity).[34]
- The Australian wind energy forecasting system (AWEFS) produces wind generation forecasts for all semi-scheduled and non-scheduled wind generators in the NEM.[35]

30 For more information see http://forecasting.aemo.com.au/.

31 For more information see https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/demand-forecasts/operational-consumption-definition.pdf.

32 Semi-scheduled generators are intermittent renewable generations such as grid scale wind and solar farms.

33 AEMO uses the following inputs to produce solar generation forecasts for large-scale solar power stations: Real-time supervisory control and data acquisition (SCADA) measurements from the solar power station; Numerical weather prediction data from multiple weather data providers; Standing data from the solar power station as defined in the ASEFS energy conversion model; Additional information provided by the solar power station, including inverters under maintenance and the upper limit MW on the solar farm; Solar radiation imagery from the Himawari-9 satellite.

34 ASEFS2, uses the following inputs to produce aggregated regional solar generation forecasts for small-scale PV systems: Numerical weather prediction data from multiple weather data providers; Output measurements and static data from selected household rooftop PV systems from PvOutput.org and Solar Analytics; Aggregate kilowatt capacity by installed postcode for small-scale solar systems as recorded by the Clean Energy Regulator (CER); Imagery from the Himawari-8 satellite.

35 AWEFS produces forecasts from the following inputs: Real-time SCADA measurements from the wind farms; Numerical weather predictions from weather forecasters from around the world; Standing data from the wind farms; Availability information provided by the wind farms, including turbines under maintenance and the upper MW limit of the wind farm.

In addition to the centralised forecasts provided by ASEFS, ASEFS2, and AWEFS, market participants can optionally provide dispatch self-forecasts of the unconstrained intermittent generation from their semi-scheduled generating units for use in dispatch. These forecasts are only subject to technical factors and do not reflect market intentions. Market participants must register with AEMO to submit dispatch self-forecasts. AEMO anticipates that the use of self-forecasting will deliver system-wide benefits by reducing generation forecast error and providing greater autonomy to existing semi-scheduled generators.[36]

3.4.4 Lack of reserve notices

AEMO provides advanced warning to the market of reliability issues on operational timescales by forecasting and then declaring actual lack of reserve (LOR) conditions. LOR notices are published to elicit a market response to address a possible reliability issue prior to AEMO intervening in the market to maintain reliability.

The Panel monitors the number and type of LOR events declared by AEMO in each region in its AMPR. This assessment allows the Panel to identify actual and emerging reliability threats.

AEMO declares LOR conditions when it determines there is a non-remote probability of load shedding due to a shortfall of available capacity reserves over a seven-day period (corresponding to the ST-PASA time horizon).[37] There are three levels of LOR notices that AEMO can issue depending on market conditions. These are:

- **Lack of reserves 1 (LOR 1)** — actual and forecast LOR 1 conditions will be declared for a region(s):
  - (actual LOR1) when the consecutive occurrence of both the largest and the second largest relevant credible contingency events would result in load shedding occurring as a result of a shortfall of available capacity reserves, or
  - (forecast LOR1) for a period when available capacity reserves in the ST-PASA or pre-dispatch schedule are forecast to be less than the largest and the second largest credible risk; or less than the forecast uncertainty measure (FUM)[38] for the relevant period and region.
- **Lack of reserves 2 (LOR 2)** — actual and forecast LOR 2 will be declared for a region(s):
  - (actual LOR2) when the occurrence of the largest relevant credible contingency event would result in load shedding as a result of a shortfall of available capacity reserves; or

36 For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/solar-and-wind-energy-forecasting.

37 For more information see https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Power_System_Ops/Reserve-Level-Declaration-Guidelines.pdf.

38 The FUM introduces a probabilistic element into the determination of LOR levels alongside the traditional deterministic approach which allows for the impact of estimated reserve forecasting uncertainty in the prevailing conditions when calculating the LOR levels. These estimates are made on the basis of modelling past reserve forecasting performance for demand, output of intermittent generation and availability of scheduled generation.

- (forecast LOR2) for a period when the forecast of available capacity reserves in the ST-PASA or pre-dispatch schedule is less than the largest relevant credible risk; or less than the FUM for the relevant period and region.
- **Lack of reserves 3 (LOR 3)** — actual and forecast LOR 3 will be declared for a region(s):
  - (actual LOR3) when load shedding is occurring as a result of a shortfall of available capacity reserves; or
  - (forecast LOR3) for a period when the forecast of available capacity reserves in the short-term PASA or pre-dispatch schedule is at or below zero.

3.5 AEMO can intervene should the market not deliver sufficient levels of reliability

AEMO can intervene in the market to help maintain power system reliability should the market not sufficiently respond to LOR notices and other information provided by AEMO.[39] AEMO intervention is an acknowledged and important feature of the NEM's market design, however, the use of such mechanisms requires careful consideration as to the flow-on effects for investment and operational signals, as well as costs to consumers. As such, interventions are used as a last resort. There are three primary AEMO intervention mechanisms for reliability being:

- RERT
- Reliability directions
- Instructions for load shedding.

The Panel considers the number, frequency, and type of AEMO interventions in the market to maintain reliable supply. The causes and costs of AEMO interventions are important signposts for current and emerging reliability challenges.

3.5.1 Reliability and emergency reserve trader

RERT is an intervention mechanism that allows AEMO to contract for additional emergency reserves for use when supply shortfall is forecast. These emergency reserves include generation or demand response that are not otherwise available in the market. RERT reserves are contracted in addition to the reserve buffer that is already made available by the market (and assessed via PASA processes) as part of the market's usual operation.

These emergency reserves are used as a safety net to avoid or reduce the need for involuntary load shedding when the market hasn't provided sufficient reserves.[40] RERT is activated when there is insufficient market reserve to keep the power system in a reliable operating state, or, where practicable, to maintain power system security.[41]

39 Clause 4.8.9 of the NER.

40 For more information see https://aemo.com.au/energy-systems/electricity/emergencymanagement/reliability-and-emergency-reserve-trader-rert.

41 Clause 3.20.2(a) of the NER.

The RERT guidelines specify three types of RERT based on how much time AEMO has in which to procure the RERT prior to the projected reserve shortfall occurring:[42]

- **Long-notice RERT** — At least ten weeks' notice of a projected reserve shortfall
- **Medium-notice RERT** — Between one and ten weeks' notice of a projected reserve shortfall
- **Short-notice RERT** — Between three hours and seven days' notice of a projected reserve shortfall.

Under the NER, AEMO may enter reserve contracts to ensure the reliability of supply.[43] Historically, AEMO has set up a RERT panel of providers for both the medium-notice and short-notice RERT and only triggers the procurement contract when it has identified a potential shortfall and after seeking offers from RERT panel members. However, from 2020-21 onward AEMO will only set up a panel of providers for short-notice RERT. There is no panel for the long-notice RERT; rather, contracts are signed following the close of a public tender process. Under the long-notice RERT framework, AEMO may enter into a multi-year reserve contract for a region for up to 3 years[44]. There are a number of safeguards in place when entering into multi-year reserve contracts, including the precondition that any multi-year contracts must be at a lower-cost than the aggregate payments AEMO would have made under reserve contracts for the same period. [45]

Following the introduction of the IRM, the RERT guidelines were updated by the Reliability Panel in August 2021 to allow AEMO to procure long-notice RERT (known as interim reliability reserve) if a breach of the IRM is forecast to occur.[46] Interim reliability reserve contracts can be signed for a period of 3 years when AEMO identifies a reliability gap against the IRM in the ESOO.[47]

3.5.2 Reliability directions

AEMO may issue directions to registered participants, such as scheduled generators, where it is necessary to do so to maintain or return the power system to a reliable operating state.[48] AEMO can issue directions to generators to vary their output or a scheduled load to vary its consumption for reliability purposes. Reliability directions can be used alongside and in addition to the dispatch of any RERT reserves which may be available in an affected region.

Reliability directions are only used under supply shortage conditions when generation may be technically available to generate but is otherwise not participating in the market. These circumstances have traditionally been uncommon in the NEM as LOR 2 and 3 conditions

42 For more information see https://www.aemc.gov.au/sites/default/files/2020-08/Updated%20Amended%20Panel%20RERT%20Guidelines%20-%2018%20August%202020%20-%20Final%20for%20publication_0.pdf.

43 Clause 3.20.2(a) of the NER.

44 Clause 11.128.4(f)

45 Clause 11.128.4(g).

46 For more information see https://aemo.com.au/en/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert.

47 Clause 11.128.4of the NER.

48 Clause 4.8.9(a)(1) of the NER.

generally occur at times when market prices are very high and provide a strong signal for generation to make itself available for dispatch. There are however occasions on which AEMO has directed for reliability, most notably during the administered price period and market suspension that occurred in June 2022.[49]

3.5.3 Load shedding instructions

An instruction differs from a direction in the types of market participants that AEMO can require to take action and the nature of the action taken. Instructions often involve AEMO requiring a network service provider or large energy user to shed load.[50]

Controlled load shedding or involuntary disconnection of customer supply for reliability purposes is implemented when there is a shortage of electricity supply to meet customer demand while also keeping the power system in a secure state (an actual LOR3).

Load shedding for reliability purposes is manually initiated as a last-resort response to bring supply and demand securely into balance. Under manual load shedding a limited number of customers experience load shedding for a short period (generally on a rotational basis). Load shedding is the deliberate shutdown of power to parts of the electricity network to reduce a predetermined volume of electricity usage to maintain system stability and the supply-demand balance. Each state and territory has a plan for how load shedding will be carried out.

3.6 Performance of networks

The Panel considers the performance of networks by monitoring outage minutes, upgrades, and other performance outcomes in the AMPR. In assessing reliability performance in the NEM, the Panel may consider the performance of:

- Interconnectors
- Transmission networks
- Distribution networks.

The Panel analyses the performances of the interconnectors between the different regions of the NEM. These interconnectors allow sharing of generation and reserves between regions. As the geographical and technological diversity of the variable renewable energy generators and batteries in the NEM continues to develop, the role and value of interconnectors in providing reliability in each region will continue to increase. This trend is also being accompanied by a number of new interconnectors being built, or being considered.[51]

The scope of reliability-related USE in the NEM is limited to inter-regional transmission outages. Unplanned intra-regional transmission and distribution network outages result in lost load that is not counted towards USE for the purposes of the reliability standard.

49 For more information see https://www.aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/market_event_reports/2022/nem-market-suspension-and-operational-challenges-in-june-2022.pdf.

50 Clause 4.8.9 of the NER.

51 For more information see https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

The performance of distribution networks, and the reliability standards that must be met, fall within the responsibility of each jurisdiction with reliability that is governed by jurisdictional level frameworks. All jurisdictions have their own monitoring and reporting frameworks for the reliability of distribution network service providers (DNSPs).

While the performance of intra-regional transmission and distribution networks are outside the scope of the Panel's responsibilities in respect of reliability, the Panel may elect to consider indicators of distribution network reliability. Two important indicators of distribution network reliability are:

- System average interruption duration index (SAIDI)
- System average interruption frequency index (SAIFI).

SAIDI indicates the average number of minutes of outages that each customer served by the DNSP experiences. More specifically, it is the sum of the duration of each sustained customer interruption, divided by the number of customers excluding certain events that are not within the control of the distribution network.

Network reliability standards are often measured in terms of SAIDI. It is calculated for different parts of each DNSP's network, for example, the reliability on long rural lines is calculated differently to the reliability on CBD networks. The reliability targets for these different parts of the network are also different.

SAIFI indicates the average number of outages for each customer served by the DNSP.

3.7 Panel metrics for AMPR reliability outcomes monitoring in the NEM

This section presents the metrics the Panel considered in its reliability monitoring as published in the AMPR. The Panel considered metrics that cover:

- Trends in generation, demand, investment, and market price outcomes that provide insight into the factors and incentives influencing generation investment and retirement decisions.
- Operational reliability metrics which indicate the sufficiency of power system resources over the review periods.

The metrics in each of these areas are summarises in the following tables.

Table 3.1: Metrics for monitoring market trends influencing reliability outcomes in the NEM

Supply side trends	These trends indicate how the power system is evolving, particularly in relation to the growth of variable renewable electricity and the withdrawal of thermal generation. Movements on the supply side of the power system have important implications for reliability and security and how this may be impacted in future years.	Generator entry and exits and installed capacity (NEM installed capacity by technology over the previous 10 years)
		The change in generation output (NEM capacity by technology)
		Investment environment (installed capacity in MWs in the investment time-frame)
Demand-side trends	Demand-side trends have implications on power system security and reliability, including how much DER is influencing system load trends in the NEM. These trends highlight intra-day system load variability (the difference between daily minimum and maximum system load) and whether this is increasing or decreasing, as well as the impact on both maximum and minimum system load.	Maximum and minimum system load (in MWs by state)
		Diurnal system load profile evolution (in MWs by state and by season)
Market price outcomes	Sport and contract market price outcomes provide an indication of the investment environment and financial incentives available to new generation to enter to support reliability.	Market price cap and market price floor events
		Diurnal wholesale electricity price profile evolution
		Wholesale price distributions
		Contract market price trends

Table 3.2: Operational reliability metrics

Actual levels of USE	Whether the standard was met and the amount of customer demand that was not supplied within a region due to a shortage of generation or interconnector capacity, and the forecasts for unserved energy in the future.	Actual levels of USE (MWh) and performance against reliability standard
Actual reliability events	Details of the occasions, if any, where customers experienced supply interruptions specifically because demand was higher than the available supply. This includes the frequency, depth, duration, and location of actual reliability events.	Characteristics of USE events (MW, duration, frequency, location)
Energy market reserve levels	The amount of spare capacity that was available, considering the amounts of generation, forecast demand, demand response and interconnector capability.	MT-PASA projection distributions
		ST-PASA projection distributions
		Dispatch reserve level distributions
AEMO market interventions	Whether AEMO intervened in the market to maintain reliable supply using the three key intervention mechanisms related to reliability: the RERT, directions and instructions, and controllable load shedding.	RERT dispatch events and procurement costs
		Directions for reliability
		Instructions for load shedding
Forecast accuracy	How accurate forecasts have been. Forecasts help inform operational and investment decisions to deliver reliability.	Demand forecast accuracy
		Intermittent generation accuracy
Network performance	Outage minutes, upgrades, and other performance outcomes from interconnectors, transmission networks and distribution	SAIDI
		SAIFI
		Transmission interruption minutes

	networks. As in previous reports of the AMPR, these indicators have been examined to assess the overall reliability of the NEM.	

4 HOW IS SYSTEM SECURITY DELIVERED IN THE NATIONAL ELECTRICITY MARKET

Power system security involves keeping the power system stable across a range of system conditions including during and following common and uncommon disturbance events.[52]

AEMO has primary responsibility for system security in the NEM and operates the power system within a technical envelope by defining constraints for this purpose[53] AEMO also procures system security services, and may issue directions to participants to maintain or re-establish the power system to a secure operating state following a disturbance.[54]

The Panel plays an important role in determining standards that are required to deliver a secure, reliable, and safe power system in the most efficient way in order to minimise costs for consumers. This chapter introduces the key frameworks for delivering system security in the NEM along with the metrics the Panel uses to monitor system security outcomes in its AMPR. In particular:

- System security events and maintaining power system security
- Technical performance requirements
- System security services
- AEMO security intervention and minimum load framework.

4.1 System security events and maintaining power system security

System security relates to maintaining a stable power system, with key technical parameters within appropriate limits following a disturbance. Power system disturbances for the purposes of AEMO's maintenance of system security are referred to as contingency events. System security frameworks manage the impact of contingency events depending on AEMO's assessment of their probability of occurrence.

4.1.1 Credible and non-credible contingency events

Contingency events are disturbances that pose a risk to, and uncertainty in, the stable and secure operation of the power system. Contingency events have historically been defined as events affecting the power system which AEMO expects would likely involve the failure or removal from operational service of one or more generating units and/or transmission elements.[55]

In addition to the failure or removal from service of generation or transmission elements, the types of power system disturbances which qualify as contingency events was expanded in the AEMC's 'enhancing operational resilience to indistinct events rule' to include:

52 The NER defines power system security as the safe scheduling, operation and control of the power system on a continuous basis in accordance with the power system security principles. See clause 4.2.6 of the NER.

53 Clauses 4.2.6(a), 4.2.4(a), 4.2.4(b)(2), 4.2.5(c)(2) of the NER.

54 Clause 4.2.6(b) of the NER.

55 Clause 4.2.3(a) of the NER.

- The failure or removal from operational service of plant
- A sudden and unplanned change to the level of output consumption or power flow of plant.

The revised definition of contingency event will apply from 9 March 2023 and will expand the contingency framework to capture events that can impact multiple generators or transmission lines in an unpredictable and uncertain manner, such as major storms, widespread fires, and cyberattacks.[56]

The NER divides the set of all possible contingencies, involving the failure or removal from service or sudden unplanned change to output or power flow of plant into two categories depending on their probability of occurrence:[57]

- **Credible contingency events** — those that AEMO considers are reasonably possible, such as the loss of a single element or generator. Contingencies that AEMO considers reasonably possible are termed 'credible' contingencies.
- **Non-credible contingency events** — those that AEMO considers are not reasonably possible, given prevailing conditions. These are termed non-credible contingencies and are generally considered to be events that are rare in occurrence, such as the combination of a number of credible contingency events occurring at the same time.

Non-credible contingencies occur, but the probability of their occurrence is sufficiently low to make them not reasonably possible. Power system security frameworks typically require the implementation of emergency frequency control schemes, as a last line of defence preventing a black system or major supply disruption due to the occurrence of a non-credible contingency.

Protected events are a special class of non-credible contingencies. The Panel can declare a non-credible contingency event to be a protected event where AEMO identifies it can be managed cost-effectively. If the Panel declares a protected event, AEMO can take additional steps to proactively manage the risk.[58]

The Panel considers the number and type of non-credible contingency events in the AMPR to provide insight into any changes in the NEM's system security risk profile.

4.1.2 The technical envelope and a secure power system

The current system security arrangements in the NER impose an obligation on AEMO to operate the power system, to the extent practicable, to prevent the loss of any load following the occurrence of a credible contingency event. This obligation is referred to as being in a secure operating state.[59]

A secure power system has the following characteristics:

56 For more information see https://www.aemc.gov.au/rule-changes/enhancing-operational-resilience-relation-indistinct-events.

57 Clauses 4.2.3(b) and (e) of the NER.

58 Clause 8.8.4 of the NER.

59 Clause 4.2.4(b) of the NER, with clause 4.2.2(a) requiring a satisfactory operating state to exclude under-frequency load shedding.

- It is able to maintain a satisfactory operating state following the occurrence of a credible contingency event.[60]
- A satisfactory operating state is achieved when power system frequency, voltage, current, and plant operation all remain within appropriate limits as specified by the power system security standards.[61]

To maintain the power system in a secure state, AEMO defines a "technical envelope" within which generation is dispatched and the market and power system operated.[62] The technical envelope represents the operating limits applied to each element of the power system. The technical envelope is implemented through constraints applied to the operation of the power system. These constraints include limits to generator dispatch and reflect thermal, voltage, and transient stability limits in the power system such that it remains stable and without load shedding following a credible contingency.[63]

Constraints prevent the NEM Dispatch Engine (NEMDE) from producing a dispatch outcome that leads to load shedding following a credible contingency. This way, NEMDE minimises total dispatch cost but always subject to the requirement that the power system is in a secure state.

AEMO derives network constraints from NSP's providing advice about the technical limits of the system. Constraint equations are changed or added to for a number of reasons including:

- New advice from the NSP
- An item of plant (such as a generator) was commissioned or decommissioned
- Adjustments were made to improve the performance of the constraint equation
- Power system studies identified a new condition that needs to be managed by a constraint equation
- A new FCAS requirement was identified.

The Panel considers the number of occasions, and length of time, in which the power system is not in a secure state in its AMPR reporting, as well as changes to constraint equations.

4.1.3 Reclassification

As noted above, a credible contingency is "reasonably possible" given the prevailing circumstances and AEMO is required to maintain the power system in a secure state for all credible contingencies.[64]

Events which are not reasonably possible, and therefore non-credible, under normal conditions may under abnormal conditions become reasonably possible, and therefore

60 Clause 4.3.1(k) of the NER.

61 Clause 4.2.2 of the NER.

62 Clause 4.2.5 of the NER.

63 For more information see https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource.

64 Clause 4.2.3(b) of the NER.

credible.[65] The NER defines abnormal conditions as conditions posing added risks to the power system including, without limitation, severe weather conditions, lightning, storms, and bushfires.[66] AEMO is required to develop and publish criteria for deciding whether any non-credible contingency has become 'reasonably possible' and therefore given such conditions.[67]

AEMO is required to re-classify the normally non-credible contingency as credible under such conditions and notify the market.[68] The decision to reclassify allows AEMO to take ex-ante action to maintain the system in a secure state for the event, including by:

- Adjusting the technical envelope (such as by limiting inter-connector flows), and/or
- Procuring appropriate levels of ancillary services to maintain voltage and frequency within appropriate bands following the occurrence of the event.

The Panel considers the number and causes of reclassification events in its AMPR reporting to understand the extent to which abnormal conditions are leading to an increase in power system security risk.

4.1.4 Reviewable operating incident reporting

AEMO has the responsibility to investigate and review all major power system operational incidents and publish detailed incident reports. This allows them to assess the adequacy of the provision and response of facilities or services, and the appropriateness of actions taken to restore or maintain power system security.[69] A reviewable operating incident is an incident identified, in accordance with guidelines determined by the Reliability Panel under the NER, to be of significance in the operation of the power system or a significant deviation from normal operating conditions.[70]

AEMO is currently required to report on the following categories of incidents as reviewable operating incidents:

- A non-credible contingency event or multiple contingency events on the transmission system
- A black system condition
- An event where the frequency of the power system is outside limits specified in the power system security standards
- An event where the power system is not in a secure operating state for more than 30 minutes
- An event where AEMO issues a clause 4.8.9 instruction for load shedding
- An event where AEMO's oscillatory and transient stability monitoring systems detect potential generator instability for more than 30 minutes

65 Clause 4.2.3A(e) of the NER. Assessment of what is and is not reasonably possible given the presence of an abnormal decision for AEMO to make having regard to all relevant facts and circumstances.

66 Clause 4.2.3A(a) of the NER.

67 Clause 4.2.3B of the NER.

68 Clause 4.2.3A of the NER.

69 Clause 4.8.15(b) of the NER.

70 Clause 4.8.15(a) of the NER.

- Incidents that result in the operation of under-frequency or over-frequency protection and control schemes
- Incidents where the power system is not in a satisfactory state for more than five minutes. AEMO may also report on other significant events or systemic issues at its discretion or be requested to review particular events by the Panel.

AEMO's reviewable operating incident reports are a source of information on key power system events which are made publicly available to all market participants and provide a structured process via which learning from major power system events can be captured for the purpose of informing the evolution of NER risk management frameworks.

The AMPR reports the number and type of reviewable operating incidents and gives detailed consideration on incidents of a particularly material nature.

4.2 Technical performance requirements

A set of standards define technical performance requirements for the NEM. Currently, the Reliability Panel is responsible for determining two of these standards: the frequency operating standard (FOS) and the system restart standard (SRS).

The NER also defines a set of system standards for system stability, voltage, protection system operations, and fault levels. These standards are contained in Schedule 5.1a of the NER. NSPs maintain and operate their networks in accordance with system standards and the requirements of the NER more generally.[71]

This section introduces performance requirements that are key to the Panel's AMPR monitoring of technical performance outcomes in the NEM.

4.2.1 Frequency performance and the frequency operating standard

Controlling or maintaining frequency is a key element of power system security. All generation, transmission, distribution, and load components connected to the power system are standardised to operate at a normal system frequency of 50 Hz. The power system must therefore stay at or close to this level for equipment to stay connected to the system and continue to operate within technical bounds. Uncontrolled changes in frequency can cause cascading failures leading to major supply disruptions or black system events. To protect against this, it is important there are sufficient measures in place to provide frequency control.

To maintain a stable system frequency at or close to 50 Hz, AEMO must balance the supply of electricity with demand at all times. When there is more generation than load, the frequency will increase. When there is more load than generation, the frequency will fall. AEMO relies on a number of processes and factors to ensure that frequency remains within the acceptable window, including:

- **The dispatch process** — balances forecast supply and demand on a five-minute basis

71 Clause S5.1.8 of the NER requires NSPs to plan for non-credible contingencies that pose a risk to the stability of the power system, and develop emergency control schemes to manage these risks.

- **FCAS regulation services** — balances supply and demand on a four-second basis, accounting for changes that occur within a dispatch interval
- **FCAS contingency services** — response that is on standby to arrest the fall in frequency following a contingency event and return frequency to the normal operating band
- **Local generator frequency responses** — generators vary their output within a defined envelope, to correct deviations in frequency in real-time, as measured by the generators.

Under the NER, AEMO must keep the power system stable and securely operating at a frequency in line with the NER's power system security requirements set out in the frequency operating standard (FOS).[72] Where frequency deviates from 50 Hz, the FOS defines the range of allowable frequencies for the power system under different conditions, including normal operation and following contingencies, and is reviewed and updated periodically by the Panel.[73]

Figure 4.1: NEM frequency bands

	NORMAL (HZ)		ISLAND (HZ)		SUPPLY SCARCITY (HZ)
	MAINLAND	TASMANIA	MAINLAND	TASMANIA	MAINLAND[1]
normal operating frequency band	49.85 – 50.15		49.5 – 50.5	49.0 – 51.0	49.5 – 50.5
normal operating frequency excursion band	49.75 – 50.25		49.5 – 50.5	49.0 – 51.0	49.5 – 50.5
operational frequency tolerance band	49.0 – 51.0	48.0 – 52.0	49.0 – 51.0	48.0 – 52.0	48.0 – 52.0
extreme frequency excursion tolerance limit	47.0 – 52.0	47.0 – 55.0	47.0 – 52.0	47.0 – 55.0	47.0 – 52.0

Source: Reliability Panel.

Note: Figure 4.1 shows the NEM frequency bands as of March 2023. The Panel is in the process of reviewing the FOS with a final determination to be published April 2023.

The FOS also provides that in the absence of a contingency event, AEMO should maintain system frequency within the applicable normal operating excursion band and should not exceed the applicable normal operating band for more than five minutes on any occasion, and not for more than 1% of the time over any 30-day period. AEMO calculates the percentage of time spent inside the normal operating frequency band on a daily rolling average.

4.2.2 System restart standard

While the NEM and its regulatory frameworks are designed to avoid the occurrence of a black system, major supply disruptions or black system events are still possible. Should a major supply disruption or black system occur, specially procured resources are called on to supply energy to restart power stations, and assist the process of re-energising the power system

72 Clause 4.4.1 of the NER.

73 For more information see https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022 for more information.

and restoring customer supply. These resources are referred to as system restart ancillary services (SRAS).

The Panel is responsible for determining the system restart standard (SRS). The SRS specifies the parameters for restoring generation and transmission system operations after a major supply disruption, including a black system event, and acts as the targets AEMO must satisfy in its procurement of SRAS. SRS targets are defined for a set of sub-networks declared by AEMO. There is at present a single SRAS sub-network for each region of the NEM.[74]

The parameters included in this standard are:

- The maximum time in which a specified level of generation capability (MW) must be restored in each sub-network
- The aggregate level of reliability of restart services in each sub-network, that is, the overall reliability of the SRAS procured for the sub-network rather than for any individual source of SRAS.

The SRS applicable to the reporting period was determined by the Panel in January 2021 following consultation with energy users, industry, jurisdictional system security coordinators and state and territory governments, and came into effect on 28 January 2021. Under the standard:

- The level and time components are tailored for each electrical sub-network to reflect the speed at which the generation can be restored, the characteristics of the transmission network and the economic circumstances that apply to the sub-network
- Costs of SRAS are minimised by specifying the minimum level of generation and transmission capacity to be restored by SRAS in each sub-network in accordance with a detailed economic assessment of procuring different levels of SRAS
- The aggregate reliability of the SRAS procured for each electrical sub-network is included. This requirement better specifies the performance of the procured SRAS, and includes a requirement for AEMO to consider the reliability and damage to the transmission network following a major supply disruption when it calculates aggregate reliability.

The following table presents the time, level and aggregate reliability required for each NEM electrical sub-network.[75]

74 The SRS also defines sub-regional level requirements including the requirement for AEMO to procure SRAS north of Sydney capable of independently restarting 500MW within 4 hours with an aggregate reliability of at least 75%; and SRAS north of Bundaberg capable of independently restarting at least 825MW of generation capacity north of Bundaberg within 4 hours with an aggregate reliability of at least 80%.

75 For more information see https://www.aemc.gov.au/markets-reviews-advice/system-restart-standard.

Figure 4.2: SRS requirements

1. Electrical Sub-Network[4]	2. Level of Restoration (MW)	3. Restoration time[5] (hours)	4. Required Aggregate Reliability
Queensland	1650	4	90%
New South Wales	1500	2.0	90%
Victoria	1100	3.0	90%
South Australia	330	2.5	90%
Tasmania	300	2.5	95%

Source: NEM System Restart Standard January 2021.

4.3 System security services

In addition to the constraints making up the technical envelope, AEMO also makes sure that there is sufficient system security services procured in line with standards to maintain voltage, frequency, and other system parameters in line with power system standard following a credible, or non-credible disturbance.

System security services in the NEM include:

- Frequency control ancillary services (FCAS)
- Network support and control ancillary services (NSCAS)
- System restart ancillary services (SRAS)

AEMO operates eight separate markets for the delivery of FCAS, and purchases NSCAS, and SRAS under agreements with service providers.

The Panel monitors AEMO's procurement of these services in its AMPR to provide an insight into system security issues and risk in the NEM.

4.3.1 FCAS markets and primary frequency control

FCAS services are used to raise system frequency if it has fallen (by increasing generation or reducing load) and to lower system frequency if it has risen (by decreasing generation or increasing load) above acceptable bounds. The different FCAS types are intended to work together to maintain a steady frequency during normal operation, and to stabilise and restore the frequency by reacting quickly and smoothly to contingency events that cause frequency deviations.

FCAS markets are divided into two types:

- Regulation

- Contingency.

Regulation frequency control can be described as the ongoing correction of the generation/demand balance in response to minor deviations in load or generation. Regulation FCAS provided by generators on Automatic Generation Control (AGC). The AGC system allows AEMO to continually monitor the system frequency and to send control signals every four seconds to generators providing regulation services to increase or decrease generation in such a manner that the frequency is maintained within the normal operating band of 49.85Hz to 50.15Hz on an ongoing basis.

Contingency frequency control refers to the correction of a sudden generation/demand imbalance following a major contingency event such as the loss of a generating unit/major industrial load, or a large transmission element. Contingency FCAS corrects frequency following a contingency event such that the frequency deviation remains within the contingency band defined by the FOS and is returned to the normal operating band within five minutes. Contingency frequency control uses technologies that locally detects the frequency deviation and respond in a manner that corrects the frequency. [76]

During each and every trading interval of the market, NEMDE must enable a sufficient amount of each of the eight FCAS products, from the FCAS bids submitted, to meet the FCAS MW requirement required to achieve the FOS. Eight FCAS markets are co-optimised with the energy market and dispatched every five minutes for this purpose. These eight FCAS markets are:

- **Regulation Raise:** Regulation service used to correct a minor drop in frequency.
- **Regulation Lower:** Regulation service used to correct a minor rise in frequency.
- **Contingency Fast Raise (6 Second Raise):** 6 second response to arrest a major drop in frequency following a contingency event.
- **Contingency Fast Lower (6 Second Lower):** 6 second response to arrest a major rise in frequency following a contingency event.
- **Contingency Slow Raise (60 Second Raise):** 60 second response to stabilise frequency following a major drop in frequency.
- **Contingency Slow Lower (60 Second Lower):** 60 second response to stabilise frequency following a major rise in frequency.
- **Contingency Delayed Raise (5 Minute Raise):** 5 minute response to recover frequency to the normal operating band following a major drop in frequency.
- **Delayed Lower (5 Minute Lower):** 5 minute response to recover frequency to the normal operating band following a major rise in frequency.

The amount of FCAS AEMO enables in each market, and the cost of that FCAS, are key parameters the Panel monitors in the AMPR.

76 Some examples of these technologies include: Generator Governor Response: where the generator governor reacts to the frequency deviation by opening or closing the turbine steam valve and altering the MW output of the set accordingly. Contracted load shedding: where a load can be quickly disconnected from the electrical system (can act to correct a low frequency only). Rapid Generation: where a frequency relay will detect a low frequency and correspondingly start afast generator (can act to correct a low frequency only). Rapid Unit Unloading: where a frequency relay will detect a high frequency and correspondingly reduce a generator output (can act to correct a high frequency only).

4.3.2 Network support and control ancillary service

NSCAS are non-market ancillary services that may be procured by AEMO to maintain power system security and reliability and to maintain or increase the power transfer capability of the transmission network. AEMO is required to assess NSCAS needs in the NEM on a five-year assessment cycle. When AEMO identifies an NSCAS gap, the NER gives TNSPs the primary responsibility for putting arrangements in place to address the gap. [77]AEMO will be required to acquire NSCAS only to ensure power system security and reliability if the NSCAS gaps remain unmet after TNSP's attempt to procure services.[78]

Network control ancillary services can be subdivided into the following types:

- **Voltage Control Ancillary Service (VCAS)** — AEMO must control the voltage on the electrical network to within specified tolerances defined in the system standards.[79] One method of controlling voltages on the system is through the procurement and dispatch of VCAS. Under these ancillary services, contracted generators absorb or generate reactive power from or onto the electricity grid and control the local voltage accordingly.
- **Network Loading Control Ancillary Service (NLCAS)** — NLCAS involves services are used, by AEMO, to control the flow on inter-connectors to within short term limits.
- **Transient and Oscillatory Stability Ancillary Service (TOSAS)** — Transient and Oscillatory Stability Ancillary Services (TOSAS) provide for services to maintain power system stability within the requirements defined in the system standards.[80] These services can include the control and fast-regulate the network voltage, increase the inertia of rotating mass connected to the power system or rapidly increase/reduce load connected to the power system.

The Panel considers AEMO's procurement of NSCAS as well as any identified NSCAS gaps in its AMPR.

4.3.3 System restart ancillary services

SRAS enable the recovery of the power system following a major disturbance, where large parts of the power system have collapsed to a "black system" condition.[81] SRAS is currently provided by generators with the capability to start or remain in service without electricity being provided from the grid.

Generators consume electricity to power auxiliary plant required for the generator's operation. Auxiliary plant includes the internal power station equipment such as coal conveyors, crushers, and pumps. Auxiliary plant requires energisation prior to the main generating system commencing generation. No electricity is available from the power system

77 Clause 3.11.3(a) of the NER.

78 Clause 3.11.3(c)(3) of the NER.

79 Clauses S5.1a.4 of the NER- Power frequency voltage, Clause S5.1a.5 of the NER Voltage fluctuations, Clause S5.1a.6 of the NER — Voltage waveform distortion, and Clause S5.1a.7 of the NER - Voltage unbalance of the NER set out requirements for voltage performance.

80 Clause S5.1a.3 of the NER.

81 A black system condition is defined in Chapter 10 of the NER as the absence of voltage on all or a significant part of the transmission system or within a region during a major suplpy disruption affecting a significant number of customers.

in a black system condition for this purpose. SRAS capable generators are able to start their auxiliary systems locally to commence generation without supply from the wider network.[82]

Once an SRAS provider has restarted its own plant, it provides energy to re-energise the connected transmission network elements to restart other generators and commence the processes required for system restoration. There is an additional cost involved to equip generating plant with this capability and not all generators have it. Payments under SRAS contracts provide for these additional costs.

AEMO must use reasonable endeavours to acquire sufficient SRAS for each defined electrical sub-network to meet the requirements of the SRS as described in section 4.2.2.

The Panel considers AEMO's procurement of SRAS, and any occasions in which it is used, in its AMPR reporting.

4.3.4 System strength and inertia services

Historically, most generation in the NEM has been synchronous and, as such, the inertia and system strength provided by these generators has not been separately valued from the wholesale market price of energy. As the generation mix shifts to smaller and more inverter-connected sources, such as wind and solar generation and batteries, however, inertia and system strength is not provided as a matter of course giving rise to increasing challenges for the AEMO in maintaining the power system in a secure operating state.

NEM frameworks for providing sufficient inertia and system strength are in a period of development with initial frameworks, implemented in 2017, in the process of being replaced. The Panel will consider outcomes under the existing and newly implemented inertia and system strength frameworks in its AMPR reporting as relevant.

System Strength

System strength can be understood as the ability of the power system to maintain and control the voltage wave form at any given location in the power system, both during steady state operation and following a disturbance. A smooth, consistent and predictable voltage waveform is critical to the power system's voltage remaining within the parameters required for a safe and secure transfer of energy from generators to consumers.[83]

The exit of large thermal synchronous generation, together with an increasing proportion of inverter connected resources like batteries, wind and solar, has contributed to decreases in system strength in some areas of the power system. A reduction in system strength in certain areas of the network may mean that generators are no longer able to meet their technical performance standards and may be unable to remain connected to the system at certain times. It may also lead to voltage instability and a reduction in the effectiveness of

82 Generators who are able to remain in service sufficient to maintain auxiliary supply following a black system event are known as having 'trip to house load' SRAS capability.

83 The system strength at a given location is proportional to the fault level at that location, inversely proportional to effective grid-following inverter based resource (IBR) penetration seen at that location. System strength is also a function of the severity of system events on the stability of IBR (for example, loss of a major transmission line connecting the aforementioned location to the broader power system, resulting in sudden changes in fault level and voltage angle at that location). For more information see https://aemo.com.au/-/media/files/electricity/nem/system-strength/explained.pdf.

the protection systems used by network businesses, generators and large customers. If not addressed, these effects could lead to system instability and potential major supply interruptions.

The existing system strength framework where AEMO forecasts minimum system strength levels, and if forecasts were below such levels, identified a gap to be addressed by the relevant TNSP, in the NEM is being evolved. On 21 October 2021, the AEMC made a final rule on *Efficient management of system strength on the power system*[84] This rule evolves the existing system strength provision framework to a more proactive framework that planned for system strength needs in advance any shortfall occurring. Under the new framework, AEMO must provide an annual assessment of system strength requirements in the NEM for the coming decade, against a new power system standard comprising:

- A minimum fault level requirement for power system security at each system strength node
- A requirement for stable voltage waveforms at connection points to host AEMO's forecast levels of IBR (also known as the efficient level of system strength) at each system strength node.

Each NEM region's system security service provider (SSSP), being the relevant TNSP, must plan to meet the standard (both minimum and efficient levels) from December2025 onwards. 2022 will be the first year in which AEMO publishes its annual assessment of system strength requirements.[85]

The Panel may consider outcomes under the efficient management of system strength on the power system rule to the extent that they are available for consideration prior to publication of the FY2021-22 AMPR.

Inertia

System black events can occur when a sudden, unexpected loss of a major source of supply causes very rapid changes in system frequency which undermines the security of the electrical system. Power system inertia, primarily associated with the spinning masses of synchronous generator turbines, acts to slow the rate of change of frequency occurring in response to a power system disturbance.

Generators and networks automatically disconnect or 'trip' when there is an excessively rapid change in frequency in order to protect equipment and personnel from harm. The disconnection of multiple generators can lead to cascading failures and ultimately a system black if not addressed in time by emergency measures such as load shedding.

On 19 September 2017, the AEMC published a final rule, the National Electricity Amendment (Managing the rate of change of power system frequency) Rule 2017 to place an obligation on TNSPs to procure minimum required levels of inertia or alternative frequency control services to meet these minimum levels should an insufficient amount be identified.[86]

84 For more information see https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

85 For further information see https://www.aemc.gov.au/sites/default/files/2021-10/ERC0300%20-%20Final%20determination_for%20publication.pdf.

86 For more information see https://www.aemc.gov.au/rule-changes/managing-the-rate-of-change-of-power-system-frequency.

The Panel will consider outcomes relating to inertia in the AMPR.

4.3.5 AEMO security intervention

Consistent with its overall obligation to maintain power system security, AEMO has powers to intervene in the market to maintain the power system in a secure state.[87]

AEMO intervenes for security purposes using the approaches described in Section 3.4 of this report being:

- RERT
- Clause 4.8.9 Directions
- Instructions

While AEMO can dispatch RERT resources for security reasons it is unable to explicitly procure RERT to manage security.

AEMO's primary intervention mechanism to maintain system security is through the use of Clause 4.8.9 Directions. AEMO has extensively utilised security directions and the Panel will consider AEMO's security directions in its FY2021-22 AMPR.

AEMO intervention to manage low operational demand

Minimum operational demand refers to the lowest level of demand from the grid in any given day, week or year. While minimum operational demand has traditionally occurred during the early morning, increasing behind-the-meter residential solar PV penetrations have seen minimum operational demand shift to occur during the daytime.

One of the challenges of minimum or low operational demand is maintaining sufficient levels of essential system services, including frequency control, system strength, voltage management and inertia. Minimum load constraints must be taken into account when AEMO determines and revises the technical envelope.[88] In periods of very low operational demand, these services need to be sourced from elsewhere or, if that isn't possible, AEMO must intervene to keep the grid in a secure operating state.[89]

AEMO's interventions under low operational demand conditions include directing network service providers to return lines or elements to service, directing available loads to increase consumption and behind the meter generation, such as residential solar PV to curtail generation.

AEMO has introduced new market notifications to let the market know about these actions and when they think there may be a problem ahead that could result in rooftop solar being affected. These notices signal for a market response such as additional load prior to operational measures being taken. This process for managing a 'lack of supply' mirrors the LOR notice process and involves three steps:[90]

87 Clause 4.8.5A(c) of the NER.

88 Clause 4.2.5(c) of the NER.

89 Clause 4.8.9(A) of the NER.

90 For more information see https://www.aemo.com.au/-/media/files/electricity/nem/security_and_reliability/power_system_ops/consumer-fact-sheet.pdf.

- **Notice 1:** Advance notice of possible event to manage the risk of rooftop solar PV disconnecting at the same time as a large power station and/or minimum system load. This notice will generally be issued 1 day in advance where challenging operating conditions are forecast to provide the market time to prepare.
- **Notice 2:** Confirm operational actions taken. This means the market hasn't been able to take sufficient action to clear the risk and that AEMO is taking available steps to maintain system security, such as cancelling maintenance on the network or turning down large power plants.
- **Notice 3:** Notify that curtailment of rooftop solar PV is occurring. Signals that some rooftop solar PV is being prevented from generating as a last resort to protect system security and reduce risks, such as a statewide black-out.

4.4 Panel metrics for AMPR monitoring of system security outcomes

Table 4.1: Panel metrics for AMPR monitoring of system security outcomes

System strength and inertia	System strength reflects the sensitivity of power system variables to disturbances.	Number of directions issued by AEMO for system strength and inertia
		System strength gaps declared or forecast
		Inertia gaps declared or forecast
Constraint changes and performance	Constraints aim to prevent the power system from operating in a state that is vulnerable to supply disruptions in response to a credible contingency event. Constraint changes measure the changing congestion patterns over the previous financial year.	Cost of binding thermal constraints
		Changes in security constraints
		Total number of constraint changes
Frequency performance	AEMO is required to keep the power system at, or close to, 50 Hz.	NEM frequency distribution
		Breakdown of events outside FOS ranges
Security services	System ancillary services are used by AEMO to manage the power system safely, securely, and reliably. This includes: • Frequency Control and Ancillary Markets (FCAS) • System Restart and Ancillary Services (SRAS) • Network Support and Control Ancillary Services (NSCAS)	Cost, volume and variation of FCAS per quarter
		Cost and volume of SRAS contracts across each state
		Cost and volume of NSCAS contracts across each state
Market notices	AEMO issues market notices to communicate to participants events that impact the market, including interventions, reserves notices and	Breakdown of security related market notices

	power system events.	
Operating incident reporting	AEMO's operating incident reports provide details on security events and the sufficiency of responses and systems for managing non-credible and other significant deviations from normal operating conditions.	Reviewable operating incidents by number and type
		Number of periods the power system is insecure > 30 mins
		Special reporting on particularly material events

5 SAFETY

The Panel also reports on the safety of the power system including associated equipment, power system personnel and the public which are covered in general terms under the NEL. There is however no national safety regulator specifically for electricity. Instead, state and territory legislation governs safety generally which includes the safe supply of electricity and the broader safety requirements associated with electricity use in households and businesses.

5.1 Role of the Panel in NEM safety outcomes

The Panel notes that its safety role for the purposes of this report is narrow and relates primarily to the operation of assets and equipment within their technical limits and not to the broader safety requirements governed by jurisdictional legislation.

5.2 Panel approach to considering safety outcomes in the NEM

The NEL and NER set out the functions and power of the Reliability Panel, which include a function to monitor, review, and report on safety in accordance with the Rules.[91] However, the NER do not specify additional requirements in relation to safety performance reporting.[92] The Panel also has the function of advising in relation to the safety of the national electricity system at the request of the AEMC. The terms of reference provided by the AEMC request that the Panel provide advice in relation to the safety, security, and reliability of the power system. In accordance with the terms of reference issued by the AEMC, for the purposes of the safety assessment, the Panel has considered the maintenance of power system security within the relevant standards and technical limits.

The safety of the power system, and associated equipment, power system personnel and the public is covered in general terms under the NEL.[93] There is no national safety regulator specifically for electricity. Instead, state and territory legislation governs safety generally, including the safe supply of electricity and broader safety requirements associated with electricity use in households and businesses. Each jurisdiction has its own approach to setting out obligations relating to safety in the power system and enforcing these obligations. [94] These arrangements provide the specific health and safety obligations and responsibilities relating to the safety of personnel and the public that network service providers and other market participants must comply with. The power system is also designed with extensive safety systems to provide the protection of the system itself, workers, and the public. Network constraints, developed from TNSP limit advice, are used by AEMO in the NEM

91 Section 38(2)(b) of the NEL.

92 Instead, the functions of the Reliability Panel under clause 8.8.1 of the NER provide that the functions of the Panel is to, among other things, monitor, review and report on the performance of the market in terms of reliability of the power system, report to the AEMC and jurisdictions on overall power system reliability matters and undertake a number of functions relating to the security of the power system. The reliability and security focus of the Panel under the NER is reflected in the scope of the annual market performance review that the Panel is required to undertake under clause 8.8.3(b) of the NER.

93 Section 109-118 of the NEL.

94 For example New South Wales *Electricity Safety Act 1945 No 13 of 1946,* Victoria's *Electricity Safety Act 1998,* Queensland's *Electricity Safety Act 2002,* South Australia's *Electricity Safety Act 1996,* Tasmania's *Electricity Safety Act 2022,* Australian Capital Territory's *Electricity Safety Act 1971* and Northern Territory's *Electricity Safety Act 2022.*

dispatch process to make sure that plant remains within rating and power transfers remain within stability limits so that the power system is in a secure operating state. Should AEMO not be able to manage secure and satisfactory limits through the use of network constraints, the following options can be used, potentially in combination. These options are listed in AEMO's suggested priority order and may not all be available under all circumstances:

- Revision to generator thermal ratings
- Revision to power system limits
- Implement plan agreed between AEMO and relevant registered participants (e.g. Contingency plan, Network Support Agreement (NSA))
- Reconfigure network
- Dispatch or activation of reserve contracts to address a power system security event
- System security direction or instruction issued under clause 4.8.9 of the NER
- If sufficient raise FCAS are unavailable, use system security constraints to reduce the size of the largest generation at risk. If sufficient lower FCAS are unavailable, issue a direction under section 116 of the NEL for a reduction in the size of the largest load at risk
- Instruct involuntary load shedding.

The Panel reviews AEMO's power system incident reports and consults with AEMO to understand if there were any instances where actions to maintain the power system within relevant standards and technical limits resulted in technical safety issues.

The Panel notes that its safety role for the purposes of this report is narrow and relates primarily to the operation of assets and equipment within their technical limits and not to the broader safety requirements governed by jurisdictional legislation.

ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
APC	Administered Price Cap
APP	Administered Price Period
ASX	Australian Securities Exchange
Commission	See AEMC
CPT	Cumulative Price Threshold
DNSP	Distributed Network Service Provider
EAAP	Energy Adequacy Assessment Projection
ESB	Energy Security Board
ESOO	Electricity Statement of Opportunities
FCAS	Frequency Control Ancillary Services
FOS	Frequency Operating Standard
FUM	Forecast Uncertainty Measure
IBR	Inverter Based Resources
IRM	Interim Reliability Measure
IRP	Integrated System Plan
LOR	Lack of Reserve
MBAS	Market Benefit Ancillary Service
MFP	Market Floor Price
MPC	Market Price Cap
MT-PASA	Medium Term-Projected Assessment of System Adequacy
NEL	National Electricity Law
NEMDE	NEM Dispatch Engine
NEO	National electricity objective
NER	National Energy Rules
NERL	National Energy Retail Law
NSCAS	Network Support Control Ancillary Services
RERT	Reliability and Emergency Reserve Trade
RSS(R)	Reliability Standard and Settings (Review)
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SRAS	System Restart Ancillary Service
SRS	System Restart Standard
ST-PASA	Short-Term Projected Assessment of System Adequacy

GLOSSARY

Available capacity	The total MW capacity available for dispatch by a scheduled generating unit or scheduled load (i.e. maximum plant availability) or, in relation to a specified price band, the MW capacity within that price band available for dispatch (i.e. availability at each price band).
Busbar	A busbar is an electrical conductor in the transmission system that is maintained at a specific voltage. It is capable of carrying a high current and is normally used to make a common connection between several circuits within the transmission system. The rules define busbar as 'a common connection point in a power station switchyard or a transmission network substation'.
Cascading outage	The occurrence of a succession of outages, each of which is initiated by conditions (e.g. instability or overloading) arising or made worse as a result of the event preceding it.
Contingency events	These are events that affect the power system's operation, such as the failure or removal from operational service of a generating unit or transmission element. There are several categories of contingency event, as described below: • credible contingency event is a contingency event whose occurrence is considered "reasonably possible" in the circumstances. For example: the unexpected disconnection or unplanned reduction in capacity of one operating generating unit; or the unexpected disconnection of one major item of transmission plant • non-credible contingency event is a contingency event whose occurrence is not considered "reasonably possible" in the circumstances. Typically a non-credible contingency event involves simultaneous multiple disruptions, such

	as the failure of several generating units at the same time.
Customer average interruption duration index (CAIDI)	The sum of the duration of each sustained customer interruption (in minutes) divided by the total number of sustained customer interruptions (SAIDI divided by SAIFI). CAIDI excludes momentary interruptions (one minute or less duration).
Directions	Under s. 116 of the NEL, AEMO may issue directions. Section 116 directions may include directions as issued under clause 4.8.9 of the NER (e.g. directing a scheduled generator to increase output) or clause 4.8.9 instructions (e.g. instructing a network service provider to load shed). AEMO directs or instructs participants to take action to maintain or re-establish the power system to a secure operating state, a satisfactory operating state, or a reliable operating state.
Dispatch	The act of initiating or enabling all or part of the response specified in a dispatch bid, dispatch offer or market ancillary service offer in respect of a scheduled generating unit, a scheduled load, a scheduled network service, an ancillary service generating unit or an ancillary service load in accordance with NER rule 3.8, or a direction or operation of capacity the subject of a reserve contract as appropriate.
Distribution network	The apparatus, equipment, plant and buildings (including the connection assets) used to convey and control the conveyance of electricity to consumers from the network and which is not a transmission network.
Distribution network service provider (DNSP)	A person who engages in the activity of owning, controlling, or operating a distribution network.
Frequency control ancillary services (FCAS)	Those ancillary services concerned with balancing, over short intervals, the power supplied by generators with the power consumed by loads (throughout the power system). Imbalances cause the frequency to deviate from 50 Hz.

Interconnector	A transmission line or group of transmission lines that connect the transmission networks in adjacent regions.
Jurisdictional planning body	The transmission network service provider responsible for planning a NEM jurisdiction's transmission network.
Lack of reserve	This is when reserves are below specified reporting levels.
Load	A connection point (or defined set of connection points) at which electrical power is delivered, or the amount of electrical power delivered at a defined instant at a connection point (or aggregated over a defined set of connection points).
Load event	In the context of frequency control ancillary services, a load event: involves a disconnection or a sudden reduction in the amount of power consumed at a connection point and results in an overall excess of supply.
Load shedding	Reducing or disconnecting load from the power system either by automatic control systems or under instructions from AEMO. Load shedding will cause interruptions to some energy consumers' supplies.
Low reserve condition (LRC)	This is when reserves are below the minimum reserve level.
Momentary average interruption frequency index (MAIFI)	The total number of customer interruptions of one minute or less duration, divided by the total number of distribution customers.
Medium term projected assessment of system (MT PASA) (also see ST PASA)	A comprehensive programme of information collection, analysis and disclosure of medium-term power system reliability prospects. This assessment covers a period of 24 months and enables market participants to make decisions concerning supply, demand and outages. It must be issued weekly by AEMO.
Minimum reserve level (MRL)	The minimum reserve margin calculated by AEMO to meet the reliability standard.
Ministerial Council on Energy (MCE)	The MCE is the national policy and governance body for the Australian energy market, including for electricity and gas, as

	outlined in the COAG Australian Energy Market Agreement of 30 June 2004.
National Electricity Code	The National Electricity Code was replaced by the National Electricity Rules on 1 July 2005.
National electricity market (NEM)	The NEM is a wholesale exchange for the supply of electricity to retailers and consumers. It commenced on 13 December 1998, and now includes Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia, and Tasmania.
National Electricity Law (NEL)	The NEL is contained in a schedule to the National Electricity (South Australia) Act 1996. The NEL is applied as law in each participating jurisdiction of the NEM by the application statutes.
National Electricity Rules (NER)	The NER came into effect on 1 July 2005, replacing the National Electricity Code.
Network	The apparatus, equipment and buildings used to convey and control the conveyance of electricity. This applies to both transmission and distribution networks.
Network capability	The capability of a network or part of a network to transfer electricity from one location to another.
Network control ancillary services (NCAS)	Ancillary services concerned with maintaining and extending the operational efficiency and capability of the network within secure operating limits.
Network event	In the context of frequency control ancillary services, the tripping of a network resulting in a generation event or load event.
Network service providers	An entity that operates as either a transmission network service provider (TNSP) or a distribution network service provider (DNSP).
Network services	The services (provided by a TNSP or DNSP) associated with conveying electricity and which also include entry, exit, and use-of-system services.
Operating state	The operating state of the power system is defined as satisfactory, secure or reliable, as described below.

	The power system is in a **satisfactory** operating state when: • it is operating within its technical limits (i.e. frequency, voltage, current etc are within the relevant standards and ratings) • the severity of any potential fault is within the capability of circuit breakers to disconnect the faulted circuit or equipment. The power system is in a **secure** operating state when: • it is in a satisfactory operating state • it will return to a satisfactory operating state following a single credible contingency event. The power system is in a **reliable** operating state when: • AEMO has not disconnected, and does not expect to disconnect, any points of load connection under NER clause 4.8.9 • no load shedding is occurring or expected to occur anywhere on the power system under NER clause 4.8.9 • in AEMO's reasonable opinion the levels of short term and medium term capacity reserves available to the power system are at least equal to the required levels determined in accordance with the power system security and reliability standards.
Participant	An entity that participates in the national electricity market.
Plant capability	The maximum MW output which an item of electrical equipment is capable of achieving for a given period.
Power system reliability	The measure of the power system's ability to supply adequate power to satisfy demand, allowing for unplanned losses of generation capacity.
Power system security	The safe scheduling, operation and control of the power system on a continuous basis.

Probability of exceedance (POE)	POE relates to the weather/temperature dependence of the maximum demand in a region. A detailed description is given in the AEMO ESOO.
Reliable operating state	Refer to operating state.
Reliability of supply	The likelihood of having sufficient capacity (generation or demand-side response) to meet demand (the consumer load).
Reliability standard	The Reliability Panel's current standard for reliability is that there should be sufficient generation and bulk transmission capacity so that the maximum expected unserved energy is 0.002 per cent.
Reserve	The amount of supply (including available generation capability, demand side participation and interconnector capability) in excess of the demand forecast for a particular period.
Reserve margin	The difference between reserve and the projected demand for electricity, where: Reserve margin = (generation capability + interconnection reserve sharing) – peak demand + demand-side participation.
System average interruption duration index (SAIDI)	The sum of the duration of each sustained customer interruption (in minutes), divided by the total number of distribution customers. SAIDI excludes momentary interruptions (one minute or less duration).
System average interruption frequency index (SAIFI)	The total number of sustained customer interruptions, divided by the total number of distribution customers. SAIFI excludes momentary interruptions (one minute or less duration).
Satisfactory operating state	Refer to operating state.
Scheduled load	A market load which has been classified by AEMO as a scheduled load at the market customer's request. A market customer may submit dispatch bids in relation to scheduled loads.
Secure operating state	Refer to operating state.
Separation event	In the context of frequency control ancillary services, this describes the electrical

	separation of one or more NEM regions from the others, thereby preventing frequency control ancillary services being transferred from one region to another.
Short term projected assessment of system adequacy (ST PASA) (also see MT PASA)	The PASA in respect of the period from two days after the current trading day to the end of the seventh day after the current trading day inclusive in respect of each trading interval in that period.
Spot market	Wholesale trading in electricity is conducted as a spot market. The spot market allows instantaneous matching of supply against demand. The spot market trades from an electricity pool, and is effectively a set of rules and procedures (not a physical location) managed by AEMO (in conjunction with market participants and regulatory agencies) that are set out in the NER.
Supply-demand balance	A calculation of the reserve margin for a given set of demand conditions, which is used to minimise reserve deficits by making use of available interconnector capabilities.
Technical envelope	The power system's technical boundary limits for achieving and maintaining a secure operating state for a given demand and power system scenario.
Transmission network	The high-voltage transmission assets that transport electricity between generators and distribution networks. Transmission networks do not include connection assets, which form part of a transmission system.
Transmission network service provider (TNSP)	An entity that owns operates and/or controls a transmission network.
Unserved energy (USE)	The amount of energy that is required (or demanded) by consumers but which is not supplied due to a shortage of generation or interconnection capacity. Unserved energy does not include interruptions to consumer supply that are caused by outages of local transmission or distribution elements that do not significantly impact the ability to transfer power into a region.