# RELIABILITY STANDARD IMPLEMENTATION GUIDELINES

| | |
|---|---|
| PREPARED BY: | AEMO Forecasting |
| DOCUMENT REF: | RSIG_v2.3 |
| VERSION: | 2.3 |
| STATUS: | FINAL |

Approved for distribution and use by:

| | |
|---|---|
| APPROVED BY: | Nicola Falcon |
| TITLE: | Acting Chief System Design and Engineering Officer |

DATE: 17/12/2020

## VERSION RELEASE HISTORY

| Version | Effective Date | Summary of Changes |
|---|---|---|
| 1.0 | 18 December 2015 | Initial version following consultation. |
| 1.3 | 10 October 2016 | Update RSIG in accordance with Schedule 2 of the National Electricity Amendment (Energy Adequacy Assessment Projection timeframes) Rule 2016 No. 3. |
| 1.4 | 10 May 2018 | Changes related to MT PASA – Reliability Assessment Methodology following the recommended solution proposed by Ernst & Young (EY) and suggested by consulted persons during the RSIG consultation.<br>Updated *intermittent generation* and *network constraint* approach used in ESOO. |
| 2.0 | 25 June 2018 | Update RSIG to be consistent with Rules clause 4.8.4A and new format |
| 2.1 | 31 August 2020 | Updated to reflect the introduction of the Interim Reliability Measure |
| 2.2 | 7 September 2020 | Final version following consultation.<br>Updated RSIG to reflect changes to the Rules and to the Procedure for the Exercise of Reliability and Emergency Reserve Trader.<br>The updates also provide clarification around factors to be considered by AEMO in determining whether an ESOO update or change in MT PASA inputs is warranted. |
| 2.3 | 17 December 2020 | Updated RSIG to reflect Transparency of Unserved Energy Calculation rules change. |

## CONTENTS



## TABLES

# 1. INTRODUCTION

## 1.1. Purpose and scope

These are the *reliability standard implementation guidelines* (RSIG or Guidelines) made under clause 3.9.3D of the National Electricity Rules (NER). They outline current processes that evaluate the market against the *reliability standard*.

These Guidelines have effect for the purposes set out in clause 3.9.3D of the NER. The NER and the *National Electricity Law* prevail over these Guidelines to the extent of any inconsistency.

The Guidelines set out how the *Australian Energy Market Operator* (AEMO) implements the *reliability standard*, and the approach and assumptions AEMO uses in relation to:

- Demand for electricity.
- *Reliability* of existing and future *generation.*
- *Intermittent generation*.
- *Energy constraints*.
- The treatment of extreme weather events.
- *Network constraints*.
- Factors considered in determining whether additional *Energy Adequacy Assessment Projection (EAAP)* reporting is required.
- The method for calculating *unserved energy* ex post, including how the amount of *energy* demanded in the relevant *region* is determined.

These Guidelines also outline processes that evaluate the market against the *interim reliability measure*.

## 1.2. Definitions and interpretation

### 1.2.1. Glossary

The words, phrases and abbreviations in the table below have the meanings set out opposite them when used in these Procedures.

Terms defined in the National Electricity Law and the NER have the same meanings in these Procedures unless otherwise specified in this clause.

Defined terms/Terms defined in the NER are intended to be identified in these Procedures by italicising them, but failure to italicise a defined term does not affect its meaning.

**Table 1 Glossary**

| Term | Definition |
|---|---|
| AEMO | Australian Energy Market Operator |
| ASEFS | Australian Solar Energy Forecasting System |
| AWEFS | Australian Wind Energy Forecasting System |
| DER | Distributed Energy Resources |
| DFS | Demand Forecasting System |
| DSP | Demand Side Participation |
| EAAP | *Energy adequacy assessment projection* |

| Term | Definition |
|---|---|
| ESOO | Electricity *statement of opportunities* |
| EV | Electric Vehicles |
| GELF | *Generator Energy Limitation Framework* |
| GWh | Gigawatt hours (energy) |
| LOR | *Lack of reserve* |
| LRC | *Low reserve* condition |
| MT PASA | *Medium term PASA* |
| MW | Megawatt |
| NEM | National Electricity Market |
| NER | National Electricity Rules |
| NSCAS | *Network* Support and Control Ancillary Services |
| NSP | *Network Service Provider* |
| PASA | *Projected assessment of system adequacy* process |
| POE | Probability of Exceedance |
| RERT | *Reliability and emergency reserve trader* |
| RSIG | *Reliability standard implementation guidelines* |
| ST PASA | *Short term PASA* |
| TNSP | *Transmission Network Service Provider* |
| USE | *Unserved energy* |

### 1.2.2. Interpretation

The following principles of interpretation apply to these Procedures unless otherwise expressly indicated:

(a) These Procedures are subject to the principles of interpretation set out in Schedule 2 of the National Electricity Law.

(b) References to time are references to Australian Eastern Standard Time.

## 1.3. Related documents

**Table 2 Related documents**

| Reference | Title | Location |
|---|---|---|
| Demand Forecasting | Load Forecasting SO_OP3710 | https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/operational-forecasting/load-forecasting-in-pre-dispatch-and-stpasa |
| Directions | Intervention, Direction and Clause 4.8.9 Instructions SO_OP3707 | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures |
| EAAP | Energy Adequacy Assessment Projection | http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Energy-Adequacy-Assessment-Projection |

| Reference | Title | Location |
|---|---|---|
| ESOO | NEM Electricity Statement of Opportunities (ESOO) web page | http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities |
| LOR Declarations | Reserve Level Declaration Guidelines | https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation |
| MT PASA | MT PASA Process Description | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/data-nem/market-management-system-mms-data/projected-assessment-of-system-adequacy-pasa#mtpasaprocess |
| Network constraints | Constraint Implementation Guidelines | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource |
| Network constraints | Constraint Formulation Guidelines | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information-resource |
| Reserve contracts – procuring reserve contracts | Procedure for the Exercise of Reliability and Emergency Reserve Trader (RERT) SO_OP_3717 at the AEMO web page | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures |
| Short term weather events | Power system security guidelines SO_OP3715 | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures |
| ST PASA | Short Term Reserve Assessment SO_OP3703 | https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures |
| ST PASA | ST PASA Process Description | http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Dispatch-information/Policy-and-process-documentation |
| RRO | Retailer Reliability Guidelines | https://www.aer.gov.au/retail-markets/retailer-reliability-obligation |
| FBPG | Forecasting Best Practice Guidelines | https://www.aer.gov.au/retail-markets/retailer-reliability-obligation |

## 1.4. The reliability standard

The *reliability standard* is a measure of the effectiveness, or sufficiency, of installed capacity to meet demand. It is defined in clause 3.9.3C(a) of the NER as the maximum expected *unserved energy* (USE), as a percentage of total energy, in a *region* over a financial year, and is currently set at 0.002%. USE is measured in gigawatt hours (GWh).

The USE that contributes to the *reliability standard* is defined in clause 3.9.3C(b) and 3.9.3C(c) of the NER.

The NER does not give specific direction to AEMO on how to implement the *reliability standard*, except in relation to the RRO where, under clause 4A.C.1(a) AEMO must request the AER to consider making a reliability instrument if AEMO identifies a *forecast reliability gap* for a *region*. Section 14G(1) of the National Electricity Law states – A *forecast reliability gap* occurs when the amount of electricity forecast for a *region*, in accordance with the Rules, does not meet the *reliability standard* to an extent that, in accordance with the NER, is material.

The NER does require AEMO to perform the following functions in accordance with the RSIG:

(a) Clause 3.7.2 MT PASA – (f)(6) Identify and quantify any projected failure to meet the *reliability standard* as assessed in accordance with the RSIG.

(b) Clause 3.7.3 ST PASA – (h)(5) Identify and quantify any projected failure to meet the *reliability standard* as assessed in accordance with the RSIG.

(c) Clause 4.2.7 Reliable Operating state – (c) Assess whether the *power system* meets, and is projected to meet, the *reliability standard*, having regard to the RSIG.

(d) Clause 4.3.1 Responsibility of AEMO for *power system security* –

(l) Monitor demand and *generation* capacity in accordance with the RSIG and, if necessary, initiate action in relation to a relevant *AEMO intervention event*.

(m) Publish as appropriate, information about the potential for, or the occurrence of, a situation which could significantly impact, or is significantly impacting, on *power system security*, and advise of any *low reserve* condition for the relevant periods determined in accordance with the RSIG.

(e) Clause 4.8.4 Declaration of conditions –

(a) AEMO may declare a *low reserve* condition when it considers that the balance of *generation* capacity and demand for the period being assessed does not meet the *reliability standard* as assessed in accordance with the RSIG.

(b) AEMO may declare a *lack of reserve* level 1, 2 or 3 when AEMO determines in accordance with the *reserve level declaration guidelines* that the probability of *involuntary load shedding* is, or is forecast to be, more than remote.

## 1.5. The interim reliability measure

The *interim reliability measure* is defined in clause 3.9.3C(a1) of the NER as a maximum expected USE in a *region* of 0.0006% of the total *energy* demanded in that *region* for a given financial year. The USE that contributes to the *interim reliability measure* is consistent with the USE defined in clause 3.9.3C(b) of the NER.

An *interim reliability exceedance occurs i*f the level of USE in a financial year, for a *region*, exceeds the level set by the *interim reliability measure* in the Electricity Statement of Opportunities (ESOO) or an update to the ESOO.

## 1.6. AEMO's process for managing low reserve, lack of reserve conditions or an interim reliability exceedance

If AEMO declares a *lack of reserve* (LOR) or *low reserve* condition (LRC), *AEMO* will follow the processes set out in clauses 4.8.5A and 4.8.5B of the NER. This includes publishing any foreseeable circumstances that may require *AEMO* to implement an *AEMO intervention event*.

The aim of implementing an AEMO *intervention event* is to maintain the reliability of *supply* and *power system security* where practicable, when a *low reserve* or lack *of reserve* condition exists. *AEMO intervention events* include:

(a) Issuing an instruction or direction in accordance with clause 4.8.9; or

(b) Exercising the *reliability and emergency reserve trader* in accordance with rule 3.20.

Details on these can be found in the Intervention, Direction and Clause 4.8.9 Instructions document and the Procedure for the Exercise of Reliability and Emergency Reserve Trader (RERT) SO_OP_3717 document listed in Section 1.3.

**Interim Reliability Reserves**

If AEMO determines in an ESOO or an ESOO update that an *interim reliability exceedance* will occur, AEMO may exercise the *reliability and emergency reserve trader* in accordance with clause 11.128.

## 2. RELIABILITY STANDARD IMPLEMENTATION PROCESSES

AEMO implements the *reliability standard* using forecasts and projections over different timeframes. AEMO uses the following processes:

(a) Electricity Statement of Opportunities (ESOO) to provide market information over a 10-year projection to assist planning by existing and potential *Generators* and *Market Participants*. The ESOO is also used to implement the *interim reliability measure*.

(b) Energy Adequacy Assessment Projection (EAAP) to forecast USE for energy constrained scenarios over a two-year projection.

(c) Medium Term Projected Assessment of System Adequacy (MT PASA) to forecast USE over a two-year projection.

(d) Short Term Projected Assessment of System Adequacy (ST PASA) to forecast capacity reserve over a six-day projection.

As noted above, AEMO runs two processes to implement the *reliability standard* over a two year period: EAAP and MT PASA. The main difference between EAAP and MT PASA is that the EAAP is assessed under a range of predefined energy scenarios and is published at least once every 12 months, whereas the MT PASA is based on participants' best expectation of *generation* availability and is published on a weekly basis.

Detailed information about each process and methodologies applied can be found on AEMO's website (links as listed in Section 1.3).

This section of the Guidelines describes how each process evaluates key components that contribute to AEMO's forecast of reliability. Different assumptions used under the various processes reflect the study timeframe and hence level of uncertainty in the inputs.

Table 3 explains the processes AEMO undertakes to forecast *reliability*, inform *Market Participants* and *Network Service Providers* if the *reliability standard* is likely to be exceeded, and intervene where necessary.

**Table 3 Summary of processes that AEMO uses to implement the reliability standard and the interim reliability measure**

| Process | Study Time Frame/Publication Frequency* | Assessment Method | Primary Action | Second Action | Assumption for Potential Exceedance of Reliability Standard (or Interim Reliability Measure) |
|---|---|---|---|---|---|
| ESOO | 10 year/Annually | USE | Inform, and request reliability instrument if required | 4.8.9 instruction, RERT or direction* | Forecast USE>0.002% in any forecast year for the reliability standard.<br>Forecast USE>0.0006% in any forecast year for the interim reliability measure. |
| EAAP | 2 year/Annually | USE | Inform | | Forecast USE>0.002% in any forecast year |
| MT PASA | 2 year/Weekly | USE | Inform | | Forecast USE>0.002% in any forecast year |
| ST PASA | 6 day/2 hours | Capacity | Inform | | LOR2 or LOR3 |

* The frequencies shown in this table correspond with the NER and will be updated if changes are made to the underlying rules.
** AEMO will consider the most up to date relevant information when considering whether to take a second action.

## 2.1. Electricity Statement of Opportunities

AEMO is required to publish an ESOO annually under clause 3.13.3A of the NER. The ESOO provides information that can help stakeholders plan their operations over a 10-year outlook period, including information about the future supply demand balance.

The ESOO also indicates when *generation* or demand management capacity or augmentation of the power system is required to meet the *reliability standard*, using probabilistic modelling to determine the *regiona*l USE at an hourly resolution. This involves using time-sequential, security-constrained optimal dispatch simulations, incorporating Monte-Carlo simulations. AEMO compares the probability-weighted USE assessment against the *reliability standard*, and identifies potential future exceedances. Detail on this approach and assumption can be found in the ESOO methodology document.[1]

AEMO then publishes details of any forecast LRC where the *reliability standard* may be exceeded. The ESOO is also used as an input in the procurement of reserves.

The ESOO also indicates when *generation*, demand capacity or augmentation of the power system is required to meet the *interim reliability measure*. In doing so, AEMO uses the same methodology used in relation to the *reliability standard*. AEMO then publishes details of any forecast *interim reliability exceedance*. The ESOO is also used as an input in the procurement of *interim reliability reserves*.

[1] See AEMO ESOO web page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.

The following sub-sections outline some key inputs to the ESOO model. A detailed description of the ESOO modelling methodology is available on the ESOO webpage as listed in Section 1.3.

### 2.1.1. ESOO generation capacity

For the *generation* component of the ESOO assessment, AEMO uses the total of current *generation* capacity plus any committed future *generation*[2] and withdrawals, obtained from operators of generating plant in the National Electricity Market (NEM).[3] AEMO does not assume or forecast any further new *generation* capacity.

Planned outages are not modelled as it is assumed they can be scheduled at times of surplus supply.

Forced outages are stochastically modelled using probabilities derived from historical performance or expert advice where historical information is not available or suitable. The historical information may not be considered suitable in instances where a deteriorating or improving trend in reliability is evident in the historical data and there are reasonable grounds to indicate that this trend may continue. In these instances, AEMO may make targeted requests to *Registered Participants* under clause 3.13.3A(d) of the NER for best estimates of future generator forced outage rates. In providing this information, *Registered Participants* are expected to give due consideration for the age and condition of the asset, future maintenance plans, any assumptions used internally for activities such as budgeting, and any other relevant information. AEMO may further validate these assumptions through consultant peer review. In specific circumstances where consultant advice is inconsistent with information explicitly provided by a *Registered Participant*, AEMO provides the participant with an opportunity to provide further evidence in support of their view.

### 2.1.2. ESOO intermittent generation

For *intermittent generation*, AEMO prepares *intermittent generation* profiles from a model that includes historical performance and/or meteorological variables proven to be effective for this purpose. At least eight different *intermittent generation* profiles are developed for each generator, based on historical weather traces, and sampled as part of the Monte-Carlo simulations. These *generation* profiles are linked to the corresponding demand trace based on that same historical weather pattern to ensure any correlation between *intermittent generation* and demand is preserved. Detail on this approach and assumptions can be found in the ESOO methodology document.

### 2.1.3. ESOO energy constraints

The ESOO process accounts for projected *energy constraints* via inputs to the ESOO model. Any *energy constraint*, such as low water levels of dams used by hydroelectric *Generators*, is an input to the model as total *energy* available for the particular *Generator*. These assumptions are based on historical observations, and long-term average hydroelectric yields assessed by AEMO in consultation with relevant stakeholders. The same principle applies for any other *energy* limitation affecting a *Generator* in the model.

[2] Committed future generators represent generation that is considered to be proceeding based on AEMO's commitment criteria. For more detail see the AEMO Generation Information page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

[3] See ESOO Methodology, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.

### 2.1.4. ESOO forecast demand

For the forecast demand component of the ESOO, AEMO uses the most recent forecast of annual consumption and maximum demand. AEMO converts the *energy* and maximum demand forecasts into hourly, or half-hourly, demand profiles based on reference year weather patterns. The demand profile also incorporates assumptions on future distributed energy resources (DER), such as rooftop photovoltaic (PV), battery storage penetration and electric vehicles (EVs).

The demand traces used in the ESOO are on an operational[4] sent-out basis, meaning they exclude generator auxiliary load. Auxiliary load is modelled for each generating unit based on information provided by *Market Participants* or the best information available from consultants. The aggregate auxiliary load in each *region* adds to the demand that is met by available capacity.

Extreme weather events are considered by using demand profiles derived from the 10% probability of exceedance[5] (10% POE) maximum demand forecasts. At a minimum, a combination of 50% POE and 10% POE demand profiles from at least eight historical reference years are sampled probabilistically in the Monte-Carlo simulations to develop the expected USE. At AEMO's discretion, more POE demand profiles (such as 90% POE) may be included, if USE outcomes are expected to be materially different from 50% POE outcomes[6]. If not explicitly modelled, the USE values included in the probability weighted calculation of expected USE arising from 90% POE demand profiles are assumed to be zero.

### 2.1.5. ESOO demand side participation

The ESOO model uses AEMO's most recent estimates of existing and committed Demand Side Participation (DSP). These estimates are updated annually according to the DSP Forecasting Methodology, which utilises information provided by participants[7].

### 2.1.6. ESOO network constraints

AEMO continues to update and refine *network constraints* through its modelling projects during the year. These models are used to develop thermal constraint equations which are augmented by stability constraint equations which use the ST PASA formulation. The ESOO constraints also take into consideration future committed *network* and *generation* upgrades.

Given the 10-year outlook period, ESOO constraint equations need to make assumptions on the future status of the *network*. Such assumptions are made using long-term averages or estimates based on demand levels.

Planned network outages are not included in the ESOO modelling based on the assumption that these outages will be scheduled at times of surplus supply. Unplanned network outages in the transmission network that significantly impact the ability to transfer power between *regions* are stochastically modelled using probabilities derived from historical performance.

Detailed information on *network constraints* can be found in the *network constraints* documents listed in Section 1.3.

[4] For more information on operational demand, refer to the document "Demand terms in the EMMS data model", available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/dispatch-information

[5] Probability of exceedance is the chance that the observed value is greater than the reported value. A 10% probability of exceedance means there is a 10% chance that the outcome is greater than the reported value.

[6] Appendix A3 of the 2018 ESOO documented the rationale of the selection of the 10%, 50% and 90% POE weightings

[7] These are available at https://aemo.com.au/en/consultations/current-and-closed-consultations/demand-side-participation-forecast-methodology-consultation

### 2.1.7. Updates to the ESOO

As per clause 3.13.3A(b), AEMO is required to update the *statement of opportunities* when information becomes available that in AEMO's opinion materially changes the *statement of opportunities* (whether it is a material improvement or deterioration in the reliability forecast). One of the components of the rule under clause 3.13.3A(a)(1) are the projections of aggregate MW demand and energy requirements for each *region*. The AER's Forecasting Best Practice Guidelines, which relate to the *reliability forecast* and the *Integrated System Plan*, outline a number of potential circumstances that may trigger an update to the ESOO.

When considering whether a change in inputs is material enough to trigger an update to the ESOO and the associated demand and energy projections, AEMO gives consideration to a number of factors including:

- The time at which the information becomes available relative to the previous and next ESOO release.
- The period over which the change is expected to impact demand.
- The *region* in which the change applies and the circumstances in that *region*.
- Whether the change is likely to materially impact the level of expected USE.
- Any obligation on AEMO to protect the confidentiality of the input required.

In considering updates to the demand and energy forecasts, and the subsequent publishing of information relating to these forecasts in MT PASA, AEMO will also consider whether updated information would be valuable to participants by providing information which may be useful for scheduling and coordination of generator maintenance.

## 2.2. Energy Adequacy Assessment Projection

The EAAP implements the *reliability standard* over a two-year timeframe. As well as the demand outlook, *generation* capacity availability and *network constraints*, the EAAP particularly focuses on the impact of potential energy constraints, such as water shortages during drought conditions, and identifies and reports forecast USE that exceeds the *reliability standard*.

AEMO is required to publish an EAAP in accordance with NER clause 3.7C. The EAAP makes available to the market an analysis that quantifies the impact of potential energy constraints on energy availability for a range of scenarios, specified in the EAAP guidelines. AEMO identifies potential periods of USE and quantifies projected annual USE that may exceed the *reliability standard*.

The energy constraints that AEMO considers for the EAAP are defined in the EAAP guidelines. AEMO uses a market model to forecast two years at hourly resolution for these energy constraint scenarios. This involves using time-sequential Monte-Carlo market dispatch simulations. It uses a probability-weighted USE assessment to identify any potential *reliability standard* exceedances.

The following sub-sections outline key inputs to the EAAP model and factors for additional EAAP reporting. A detailed description of EAAP modelling is available on AEMO's website as listed in Section 1.3.

### 2.2.1. EAAP generation capacity

*Generation* capacity is an input to the EAAP model. AEMO uses the most recent MT PASA offers to derive total capacity and planned outage information.

### 2.2.2. EAAP intermittent generation

*Intermittent generation* forecasts are the same *generation* profiles used in ESOO, which are based on historical performance where appropriate and/or meteorological data.

### 2.2.3. EAAP energy constraints

AEMO's approach is to model *EAAP* scenarios that reflect credible *energy constraints*, as identified in the *EAAP guidelines*. The *energy constraint* information is provided to AEMO by participants through the *Generator Energy Limitation Framework* (GELF)[9].

### 2.2.4. EAAP demand

For the forecast demand component of the EAAP, AEMO uses the most recent forecast of annual consumption and maximum demand. AEMO converts the energy and maximum demand forecasts into hourly, or half-hourly, demand profiles based on reference year weather patterns. The demand profile also incorporates assumptions on future DER, such as rooftop PV, battery storage penetration and EVs.

The demand traces used in the EAAP are on an operational[10] sent-out basis, meaning they exclude generator auxiliary load. Auxiliary load is modelled for each generating unit based on information provided by *Market Participants* or the best information available from consultants. The aggregate auxiliary load in each *region* adds to the demand that is met by available capacity.

Extreme weather events are considered by using demand profiles derived from the 10% POE[11] maximum demand forecasts. At a minimum, a combination of 50% POE and 10% POE demand profiles from at least eight historical reference years are sampled probabilistically in the Monte-Carlo simulations to develop the expected USE. At AEMO's discretion, more POE demand profiles (such as 90% POE) may be included, if USE outcomes are expected to be materially different from 50% POE outcomes[12]. If not explicitly modelled, the USE values included in the probability weighted calculation of expected USE arising from 90% POE demand profiles are assumed to be zero.

### 2.2.5. EAAP demand side participation

For the EAAP, AEMO uses the estimated amounts of existing and committed DSP consistent with those used in the most recent ESOO (or any more recent updates if available).

### 2.2.6. EAAP network constraints

The *EAAP* simulations model *network power transfer capability* using system normal constraint equations only. Detailed information on the preparation of *EAAP network constraints* can be found in the *EAAP guidelines*. The *EAAP* currently uses the same *constraint* equation formulations as ST PASA and MT PASA, see Section 1.3. However whereas MT PASA includes both system normal and *network outage constraint* equations, the EAAP uses only system normal *constraints*.

[9] See Rules 3.7C (b) (g) to (j).

[10] For more information on operational demand, refer to the document "Demand terms in the EMMS data model", available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/dispatch-information

[11] Probability of exceedance is the chance that the observed value is greater than the reported value. A 10% probability of exceedance means there is a 10% chance that the outcome is greater than the reported value.

[12] Appendix A3 of the 2018 ESOO documented the rationale of the selection of the 10%, 50% and 90% POE weightings

### 2.2.7. Factors for additional EAAP reporting

Without limitation, AEMO will consider the following factors in determining whether it has an obligation to publish an additional *EAAP*:

- Hydro storage levels.
- A major *transmission* limitation.
- A prolonged interconnection outage that results in a major restriction in energy transfers between *NEM regions*.
- A prolonged *power station* outage or fuel *supply* interruption that results in a material *energy constraint*.
- The requirement for AEMO to exercise the *RERT* under rule 3.20.
- A major increase or decrease in operational consumption.
- Any other events or emerging events that may materially impact the energy adequacy projection by way of *energy* limitations.

AEMO will also consider publishing additional *EAAP*s if a *Market Participant* informs AEMO of an event or circumstances it considers may result in a material *energy constraint*.

## 2.3. Projected Assessment of System Adequacy

AEMO's *projected assessment of system adequacy* (PASA) processes collect, analyse, and publish information that will inform the market about forecasts of *supply* and demand.

PASA is administered in two timeframes:

1. *Medium-term PASA* (MT PASA) – a 24-month projection reported at daily resolution (although modelled at a 30 minute resolution).
2. *Short-term PASA* (ST PASA) – a six-day projection at 30 minute resolution.

Separate reserve assessments are applied for MT PASA and ST PASA processes. MT PASA identifies LRC while ST PASA identifies LOR[13] conditions based on determined *capacity reserve* levels.

AEMO's response to an LRC or LOR depends on the extent of the projected *supply* shortfall, and the timeframe in which it is projected to arise. AEMO's potential responses include:

(a) Notifications to the market via reports, data, or market notices.

(b) Intervening in the market via *directions*[14] under NER clause 4.8.9.

(c) Contracting for *reserve*

(d) Intervening in the market by *activating* or *dispatching*[15] contracted *reserve*.[16]

AEMO assumes that if a period of LRC or LOR is identified, there is a risk that the *reliability standard* may be exceeded.

[13] See AEMO procedure (section 6) Short Term Management SO_OP3703, on web page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation

[14] See Intervention, Direction and Clause 4.8.9 Instructions SO_OP3707, on web page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation

[15] Procedure for the Dispatch and Activation of Reserve Contracts SO_OP3717, on web page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Power-system-operation

[16] See AEMO web page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Emergency-Management

### 2.3.1. Medium Term PASA (MT PASA)

AEMO implements the *reliability standard* over a two-year timeframe by providing an estimate of expected annual USE as part of the MT PASA process, which is run at least weekly.

MT PASA uses probabilistic modelling to estimate the likelihood and magnitude of USE in each half hour based on the availability that *Registered Participants* have offered, the expected demand estimated by AEMO, *intermittent generation* forecasts and estimated *transmission constraints*. This involves using time-sequential, security-constrained optimal dispatch simulations, incorporating Monte-Carlo simulations.

If the expected annual USE, averaged across the simulations, exceeds the maximum level specified by the *reliability standard*, an LRC is identified. The *reliability standard* is implemented by identifying, disclosing and responding to periods of forecast LRC.

AEMO's response to projected LRC identified in MT PASA may be to take direct action in the form of *directions* – for example, directing a *Generator* to reschedule an outage – or contracting for RERT under rule 3.20. AEMO is able to *activate* or *dispatch* these contracted *reserves* to manage *power system* reliability and, where practicable, security, noting that AEMO may not specifically contract *reserves* for the purpose of maintaining *power system security*.

A detailed description of the MT PASA process is available on AEMO's website as listed in Section 1.3.

#### 2.3.1.1. MT PASA generation capacity

AEMO uses the most recent MT PASA offers to derive total *generation* capacity and planned outage information on a half-hourly basis. The information is derived from several sources:

- *Scheduled Generators* are required to submit to AEMO a daily PASA availability[17,18]. The availabilities submitted represent the *generation* capacity that could be made available within 24 hours, taking into account the ambient weather conditions at the time of 10% POE demand.
- *Semi-Scheduled Generators* submit capacity information, which is then used in AEMO's process of forecasting available *intermittent generation* capacity .
- Committed *generation* development and retirement projects are included in the capacity forecast by using expected commissioning and decommissioning timeframes and associated availabilities.

Forced outages are assessed probabilistically as part of MT PASA modelling. The probability of forced outages is based on historical performance or expert advice where historical performance is not available.

#### 2.3.1.2. MT PASA intermittent generation

Modelling of *intermittent generation* is consistent with the ESOO. *Intermittent generation* profiles are derived for each generator from at least eight historical weather years. Meteorological data, historical correlations and geographic locations are used to estimate output from new or committed *intermittent generation*. The probabilistic model samples from these *generation* profiles, maintaining linkages between the sampled *intermittent generation*

[17] For MT PASA see NER Clause 3.7.2(d) and for ST PASA see NER Clause 3.7.3(e)(2).

[18] PASA availability is a defined term in the NER: The physical plant capability (taking ambient weather conditions into account in the manner described in the procedure prepared under clause 3.7.2(g)) of a scheduled generating unit, scheduled load or scheduled *network* service available in a particular period, including any physical plant capability that can be made available during that period, on 24 hours' notice.

profile and the corresponding demand profile. This allows the model to capture the varying contributions of wind and solar output to total *supply*, which is particularly relevant at times of high demand.

Significant non-scheduled *intermittent generation* (>30 MW) is modelled explicitly as this *generation* can impact *network constraints*. Non-significant non-scheduled *intermittent generation* is accounted for through adjustments to demand traces.

#### 2.3.1.3. MT PASA energy constraints

As part of the MT PASA process, *energy constrained Generators* submit weekly *energy* limits. While these may represent the maximum energy available in any given week, units may not be capable of operating up to these weekly limits indefinitely. There may also be annual energy limits that are more constraining. Since the *reliability standard* is assessed annually, AEMO may also use information provided under the *GELF* or through generator surveys to set relevant annual *energy constraints* for MT PASA modelling. MT PASA modelling then allocates *energy constrained generation* to periods where forecast demand is high with respect to available capacity to minimise USE over the year.

#### 2.3.1.4. MT PASA demand

The demand traces used in MT PASA are equivalent to those used in the ESOO (see Section 2.1.4) with regards to being modelled on a sent-out basis, with auxiliary load added as a function of *generation* dispatch.

AEMO converts the *energy* and *maximum demand* forecasts from the latest demand forecasts into at least eight half-hourly demand profiles for each *region*, based on historical weather patterns. The demand profiles also incorporate assumptions on future DER such as rooftop PV, battery storage penetration and EV.

Extreme weather events are considered by using demand profiles derived from the 10% POE *maximum demand* forecasts. A combination of 50% POE and 10% POE demand profiles are sampled probabilistically in the Monte-Carlo simulations to develop the expected USE. At AEMO's discretion, more POE demand profiles (such as 90% POE) may be included, if USE outcomes are expected to be materially different from 50% POE outcomes.

#### 2.3.1.5. MT PASA demand side participation

MT PASA uses the estimates of existing and committed DSP consistent with those used in the most recent ESOO (or any more recent updates if available).

#### 2.3.1.6. Network constraints

MT PASA uses the latest version of ST PASA formulation constraints (see Section 1.3) as a base set, with additional customised constraints, and *network* constraints to model future (committed) *network* and *generation* upgrades. AEMO constructs system normal and outage constraint equations for the MT *PASA* time frame.

Information to formulate *network constraint equations* is provided to *AEMO* by *Transmission network* Service Providers (TNSPs) via the *Network* Outage Scheduler (NOS)[19] and limit advice. Within *AEMO*'s market systems, *constraint equations* are marked as system normal if they apply for all plant in service. To model *network* or plant outages in the *power system*, separate

[19] Available at http://nos.prod.nemnet.net.au/nos

outage *constraint equations* are formulated and applied alongside the system normal *constraint equations*.

Detailed information on *network constraints* can be found in the *network constraints* documents listed in Section 1.3.

### 2.3.2. Updates to the MT PASA

When considering whether to update the demand and energy projections used in MT PASA in response to new information that AEMO is made aware of, AEMO gives consideration to a number of factors including:

- The period over which the change is expected to impact demand.
- The *region* in which the change applies and the circumstances in that *region*.
- Whether the change is likely to materially impact (increase or decrease) the level of expected USE.
- Whether the updated information would be valuable to participants in the scheduling and coordination of maintenance, including but not limited to a material change (increase or decrease) in forecast operational consumption.
- Any obligation on AEMO to protect the confidentiality of the input required.

### 2.3.3. Short Term PASA (ST PASA)

AEMO implements the *reliability standard* over a six-day timeframe by providing a *capacity reserve* assessment as part of the ST PASA process. Available *capacity reserves* are assessed taking into account *credible contingency events* and estimated forecasting errors for the *available capacity of scheduled generating units*, the *unconstrained intermittent generation forecast* and Operational Demand, to indicate if *supply* is sufficient to meet demand and thereby avoid USE. If necessary, AEMO declares a LOR in accordance with clause 4.8.4 of the NER. The three levels of LOR are defined in the *reserve level declaration guidelines* which are developed according to the process established under clause 4.8.4A of the NER. In the ST PASA timeframe, it is not realistic to consider USE over a financial year in a six-day ST PASA timeframe. As ST PASA has access to short-term weather and participant offer information, it therefore has less input uncertainty than is the case for longer term forecasts such as MT PASA and ESOO. Given the proximity to operational timeframes, intervention decisions aim to minimise expected USE, with intervention being considered to address a forecast LOR2 or LOR3.

A detailed description of the ST PASA process is available on AEMO's website.

#### 2.3.3.1. ST PASA generation capacity reserve assessment

For the ST PASA six-day timeframe, AEMO assesses *capacity reserve*[20] using a deterministic reserve assessment. If the *reserve* level for any *region* is less than the LOR1 level for that *region*, AEMO advises the existence of LOR1 condition for that *region* to the market. If the *reserve* level indicates a LOR2 or LOR3, AEMO may take action to restore the required *reserve* capacity by implementing an *AEMO intervention event*.

[20] See section 2.1.2 of AEMO Short Term PASA Process Description on the AEMO web page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Dispatch-information/Policy-and-process-documentation

#### 2.3.3.2. ST PASA intermittent generation

AEMO uses the Australian Wind Energy Forecasting System (AWEFS) and Australian Solar Energy Forecasting System (ASEFS) models to forecast ST PASA *intermittent generation*. The model outputs for ST PASA are a half–hourly *generation* contribution, based on 50% POE per facility.

The semi-scheduled *intermittent generation* forecasts are aggregated per *region* and then added to the scheduled *generation* capacity (participant PASA offers) of the associated *region*. Non-scheduled *intermittent generation* is subtracted from the associated *region*al demand forecast.

#### 2.3.3.3. ST PASA scheduled generation capacity

The ST PASA draws information on scheduled *generation* from the *availability* data submitted with generators' market offers. When a *slow-start generating unit* plans to be off-line at a specific time but could operate had it received a direction 24 hours previously, the *PASA availability* of that unit will indicate what capacity AEMO can assume at that specific time.

#### 2.3.3.4. ST PASA demand

For the demand component, AEMO uses a 50% POE, 30 minute resolution, demand forecast[21] for each NEM *region*. This forecast is produced by AEMO's automated Demand Forecasting System[22] (DFS).

The main inputs to the DFS are:

(a) Half-hourly historical demand for NEM *regions*.

(b) Historical and forecast weather data.

(c) Non-scheduled wind *generation* forecasts from AWEFS.

(d) Non-scheduled solar forecasts from ASEFS.

(e) Calendar information such as weekday/weekend, school holidays, public holidays, and daylight savings information.

#### 2.3.3.5. Energy constraints

As part of the ST PASA process, *energy constrained* generators submit daily *energy* availability forecasts. The ST PASA process then allocates this *energy* limited *generation* over the forecast period, maximising *capacity reserves* throughout the PASA period.

AEMO's approach in the ST PASA timeframe is thereby to allocate *constrained generation* efficiently, usually to periods of high demand. AEMO assumes that this best reflects a likely market outcome that appropriately minimises forecast *capacity* shortfalls.

*Capacity reserve* is then assessed in accordance with the ST PASA process.

[21] For further information about the ST PASA demand forecast see AEMO Load Forecasting procedure (SO_OP3710) on web page: https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures

[22] See Load Forecasting SO_OP3710 on web page: https://www.aemo.com.au/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation/power-system-operating-procedures

#### 2.3.3.6. Network constraints

*Capacity reserve* is assessed in accordance with the ST PASA process. Even in the ST PASA timeframe, assumptions similar to those made in the ESOO process need to be made in formulating ST PASA *network constraint* equations, to address uncertainty around future *power system* conditions. The difference between ST PASA and ESOO constraints is that ST PASA assesses half-hourly snapshots of *capacity reserves* without taking into account the previous period's dispatch. This means ST PASA cannot use certain types of data that are available to the dispatch and pre-dispatch systems, such as supervisory control and data acquisition (SCADA) terms. These terms provide previous period feedback in *network constraints* to reflect the real-time data collections. More detail on the preparation of PASA *network constraints* can be found in the ST PASA process description in Section 1.3.

#### 2.3.3.7. Extreme temperature events

Extreme ambient temperatures affect *generation* availability and forecast demand in the ST PASA timeframe.

For *generation* availability, the capacity offered by *Generators* is based on a predetermined temperature. In the event of an anticipated extreme weather event, *Generators* are required to revise their availability offers, with respect to a revised forecast temperature covering the extreme weather event. The revised *generation* availability offers are then assessed in accordance with the ST PASA process.

When forecast temperatures exceed *regional* reference temperatures, *AEMO* publishes a market notice reminding *Generators* to review the *available capacities* in their *dispatch offers* consistent with the forecast extreme temperature conditions. Further details are available in the Short Term Reserve Assessment operating procedure in Section 1.3.

For demand, the AEMO DFS is periodically updated with forecast weather over the six-day forecast, therefore extreme temperature events are automatically incorporated into the DFS as the event moves into the six-day forecast timeframe.

## 2.4. Ex post calculation of unserved energy

### 2.4.1. Methodology

If an event is determined to have resulted in USE as defined in clause 3.9.3C of the NER, AEMO applies the following methodology to calculate the amount of USE in a *region*.

(a) Determine the *energy* demanded that was unmet as follows:

(i) If USE resulted from a direction issued by AEMO to a *Network Service Provider* (NSP) for *load shedding*[23], including *load shedding* in a *region* to implement the equitable 'pain-sharing' requirements referred to in clause 4.8.9(i) of the NER, the USE is equal to the *load* directed to be shed for the period the direction is in effect (including any subsequent updates). For these purposes:

(A) Where AEMO issues a direction for a volume of *load shedding*, but a different amount is shed, only the amount of directed *load shedding* is considered USE[24].

[23] A direction for *load shedding* is defined in the NER as a *clause 4.8.9 instruction*.

[24] The requirements for *load shedding* plans is outlined in Section 3.1 of the Manual Load Shedding Standard, refer: http://sharedocs/sites/nd/BusinessAsUsual/RSIG/Reliability Standard Implementation Guidelines.docx

(B) The period of USE in relation to an amount of *load* shed is considered to end at the time AEMO issues a direction to the NSP to restore that amount of *load*.

(ii) If USE occurs, but is not related to a *load shedding* direction issued by AEMO:

(A) Where SCADA telemetry is available for large, *transmission-connected* customers whose *load* has become *disconnected* from the *network* during a USE event, the recorded amount of *load* lost at the time of *disconnection*, at the SCADA measurement point regardless of any behind-the-meter generation, will be the assumed USE, for the period until the earlier of when AEMO provides permission to restore the load, or the load is restored.

(B) For *disconnected loads* where SCADA telemetry is unavailable, AEMO will request the NSP to advise the amount of lost *load* at the time of the event. This *load* will be the assumed USE for the period until the earlier of when AEMO provides permission to restore the load or the load is restored.

(b) To determine the annual USE in a *region* as compared to the *reliability standard*, the calculated USE is divided by the actual annual consumption for each *region* as provided in the ESOO[25] to obtain the USE as a percentage of annual consumption. Actual annual consumption was defined as operational consumption for assessments in 2019-20 and before, while underlying consumption is used for assessments in 2020-21 and beyond to ensure greater consistency with forecast USE.

### 2.4.2. Example

An example of a USE calculation for a single event is provided below:

- AEMO directs relevant TNSP to shed 250MW *load* in Victoria from 1635hrs.
- This direction is updated from 1655hrs for a further 50MW of *load* shed.
- The direction to restore all *load* is issued at 1745hrs.

| Time | Load Shed (MW) | Duration | Unserved Energy (MWh) |
|---|---|---|---|
| 1635 – 1745hrs | 250 | 1.1667 hrs (70 mins) | 250 * 1.1667 = 291.7 |
| 1655 – 1745hrs | 50 | 0.8333hrs (50 mins) | 50 * 0.8333 = 41.7 |

[25] For ESOO data, refer to the AEMO Forecasting Portal: http://forecasting.aemo.com.au/

## 2.5. Implementation summary

**Table 4 Implementation summary**

| | ESOO | EAAP | MT PASA | ST PASA |
|---|---|---|---|---|
| **How is the reliability standard implemented?** | Directly assess USE expectations based on probabilistic modelling. | Directly assess USE expectations based on probabilistic modelling. | Directly assess USE expectations based on probabilistic modelling. | Is any *region* in LOR 2 or LOR3? |
| **Demand** | Sampling 10% POE and 50% POE hourly profiles based on latest energy forecasts and historical weather patterns. The 90% POE demand profiles are not normally modelled, as USE values are assumed to be immaterial. | Sampling 10% POE and 50% POE hourly profiles based on latest energy forecasts and historical weather patterns. The 90% POE demand profiles are not normally modelled, as USE values are assumed to be immaterial. | Sampling 10% POE and 50% POE hourly profiles based on latest energy forecasts and historical weather patterns. The 90% POE demand profiles are not normally modelled, as USE values are assumed to be immaterial. | 50% POE half hour demand based on expected weather trends. |
| **Intermittent generation** | Sampling hourly profiles based on historical weather patterns. | Sampling hourly profiles based on historical weather patterns | Sampling half-hourly profiles based on historical weather patterns. | Half-hourly, 50% POE based on AWEFS and ASEFS. |
| **Scheduled generation capacity and outages** | Survey at least annually. | MT PASA offers. | MT PASA offers. | Available capacity – PASA availability. |
| **Energy constraints** | Monthly inflow of water assumed for hydro plants based on historical observations. Hydro storages optimised over an annual period. | Provided through GELF. | Weekly *energy constraints* submitted by participants. Monthly inflow of water assumed for hydro plants based on historical observations. GELF information or additional voluntary information provided by participants may also be used where appropriate to assist in modelling annual *energy constraints*. | Daily *energy constraints* are considered. |

| | ESOO | EAAP | MT PASA | ST PASA |
|---|---|---|---|---|
| **Extreme weather events** | Use of both 10% POE and 50% POE and at least 8 historical weather years capturing low renewable generation periods or heat waves. | Scenarios defined in the *EAAP guidelines*. | Use of both 10% POE and 50% POE and at least 8 historical weather years capturing low renewable generation periods or heat waves. | 50% POE. |
| **Network constraints** | System normal constraints, supplemented with customised constraints where appropriate. | System normal ST PASA type constraints, supplemented with customised constraints where appropriate. | System normal ST PASA type constraints, supplemented with customised constraints where appropriate.<br>Planned outage constraints derived from the *Network* Outage Schedule information. | ST PASA type constraints and outage information from the Network Outage Schedule. |