2023 GPSRR Approach Paper

December 2022

National Electricity Rules

Important notice

Purpose

AEMO has prepared the 2023 General Power System Risk Review (2023 GPSRR) approach paper under clause 5.20A.2(c)(3) of the National Electricity Rules.

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Version control

Version	Release date	Changes
1.0	7/9/2022	Initial release for consultation
2.0	20/12/2022	Final approach paper following consultation

AEMO acknowledges the Traditional Owners of country throughout Australia and recognises their continuing connection to land, waters and culture. We pay respect to Elders past and present.

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1 Introduction

1.1 Purpose

In accordance with rule 5.20A of the National Electricity Rules (NER), AEMO is required to undertake a General Power System Risk Review (GPSRR) and prepare a GPSRR report for the National Electricity Market (NEM) at least annually. From 2023, the GPSRR replaces and expands on the scope of the previous biennial Power System Frequency Risk Review (PSFRR).

AEMO has commenced the 2023 GPSRR and plans to publish the 2023 GPSRR report by 31 July 2023.

The purpose of the GPSRR is to review:

- A prioritised set of risks comprising contingency events and other events and conditions that could lead to cascading outages or major supply disruptions.
- The current arrangements for managing the identified priority risks and options for their future management.
- The arrangements for management of existing protected events and consideration of any changes or revocation.
- The performance of existing emergency frequency control schemes and the need for any modifications.

This document is the contains the final approach paper published by AEMO following consultation on:

- The prioritised set of risks comprising contingency events and other events and conditions that could lead to cascading outages or major supply disruptions that AEMO plans to review in the 2023 GPSRR (see Section 3).
- The approach, methodologies, information, and assumptions AEMO will use in assessing the priority risks (see Sections 2, 3.5, and 4).
- How AEMO proposes to consult with relevant parties throughout the review (see Section 5).

For completeness, the approach paper also includes a high-level description of the work planned to address the other core elements of the GPSRR.

1.2 Stakeholder consultation and update

AEMO prepared this approach paper with the benefit of input from network service providers (NSPs) on potential priority risks, and their initial feedback on the assessment approach.

In September 2022, AEMO issued in initial version of the approach paper for consultation, in accordance with NER 5.20A.2(c)(3). Based on stakeholder feedback received, and additional AEMO review, AEMO has modified some aspects of this final version of the approach paper. AEMO has published a separate report[1] on stakeholder feedback received, AEMO's responses, and the reasons for changes made to this final approach paper.

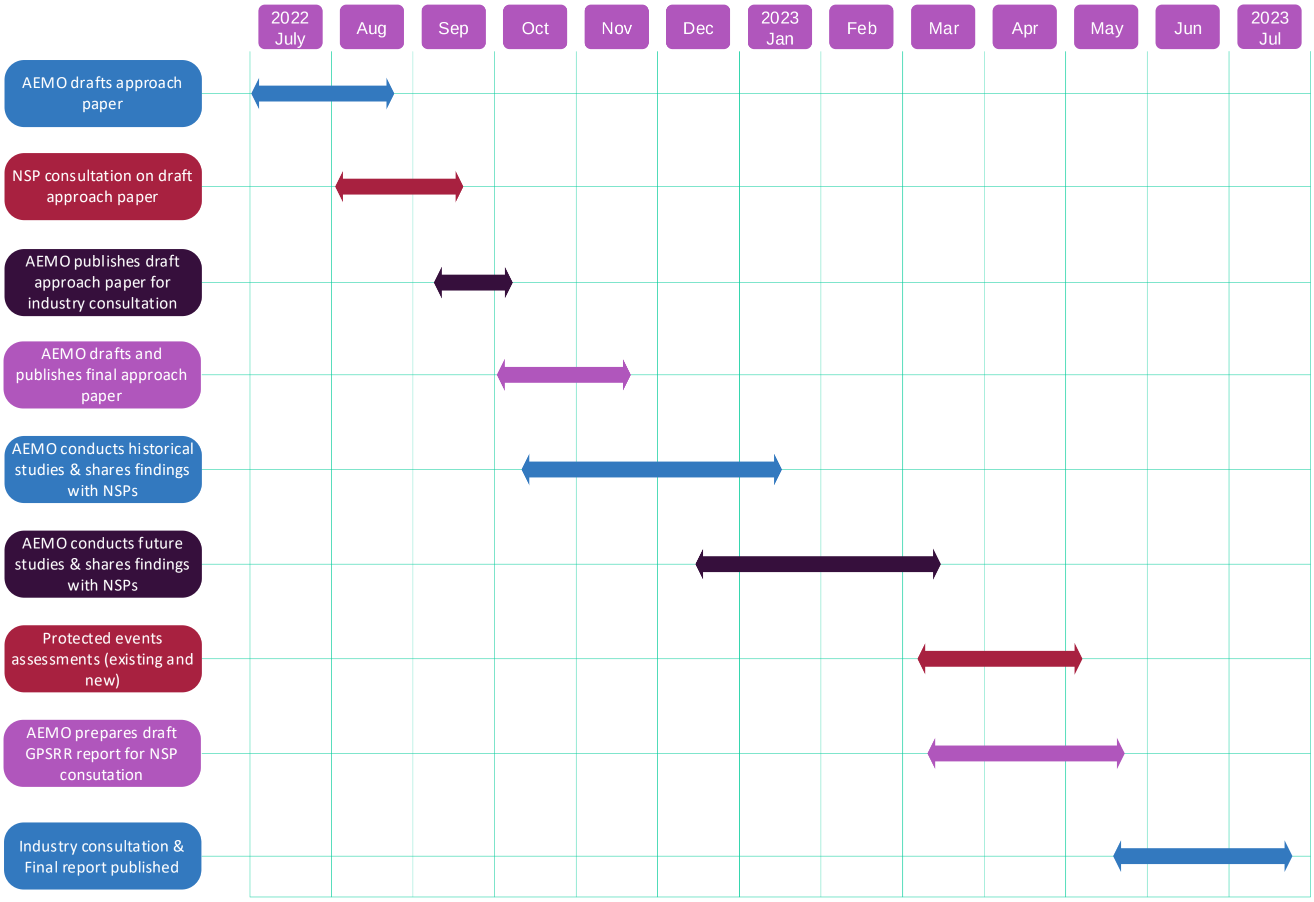
[1] GPSRR Approach Consultation Report, at https://aemo.com.au/consultations/current-and-closed-consultations/general-power-system-risk-review-approach-consultation.

1.3 2023 GPSRR delivery plan

1.3.1 Project schedule

Figure 1 shows the high-level 2023 GPSRR project schedule for key activities, including the approach paper development and consultation.

Figure 1 High-level project schedule



1.3.2 Project critical activities

To deliver a high standard review report as planned by July 2023, successful completion of the following key activities within the planned period is considered critical.

Completed

- Collation of all preliminary models and data for the study[2] (September 2022).
- Submissions on approach paper close (6 October 2022).

Planned

- Publication of final GPSRR report (by 31 July 2023).

[2] Or application of appropriate and agreed modelling assumptions.

1.4 Recommended actions from the 2022 PSFRR

The 2023 GPSRR will review the status of recommendations made in the 2022 PSFRR. The 2022 PSFRR key recommendations are summarised below.

Based on PSFRR historical studies

1. New over frequency generation shedding (OFGS) scheme to manage Queensland over frequency during Queensland separation: AEMO and Powerlink to implement OFGS in Queensland.
2. To manage the loss of both Dederang Terminal Station (DDTS) – South Morang Terminal Station (SMTS) 330 kilovolt (kV) lines: AEMO Victorian Planning (AVP) to review existing Interconnector Emergency Control Scheme (IECS) when Victoria is importing and develop a new Special Protection Scheme (SPS) for when Victoria is exporting, jointly with Transgrid.
3. To manage loss of both Columboola – Western Downs 275 kV lines: Powerlink to implement a new SPS under NER S5.1.8.

Based on PSFRR 2027 future studies

4. Management of Queensland UFLS and QNI instability:
   a) Management of Queensland under frequency load shedding (UFLS): Powerlink and Energy Queensland to identify and implement measures to restore UFLS load, and to collaborate with AEMO on the design and implementation of remediation measures.
   b) Queensland – New South Wales Interconnector (QNI) instability: To manage QNI instability and separation after Heywood interconnector contingencies, AEMO plans to conduct further investigation to consider appropriate mitigation measures such as a protected event or work with Powerlink for a SPS under NER S5.1.8.
5. Review of Wide Area Monitoring Protection and Control (WAMPAC) scheme to mitigate risks associated with non-credible loss of Calvale – Halys 275 kV lines: Powerlink to review the adequacy of WAMPAC to manage increased risks due to QNI transfers increases following QNI upgrade.
6. Further work is required to mitigate risks associated with reduced effectiveness of UFLS schemes as reported in the 2020 PSFRR:
   a) To address the impact of distributed photovoltaics (DPV) growth on UFLS, NSPs should regularly audit the availability of effective UFLS considering the impact of DPV in their respective networks.
   b) NSPs to immediately seek to identify and implement measures to restore emergency under frequency response to as close as possible to the level of 60% of underlying load at all times.
   c) NSPs to investigate measures to remediate the impacts of ‘reverse’ UFLS operation due to negative power flow on UFLS circuits.
7. Further work is required to assess the impacts of higher rates of change of frequency (RoCoF) as system inertia reduces: AEMO will continue to monitor this in future GPSRRs and review OFGS/UFLS settings, if required.

Revision of existing protected event

8. Revise constraints on Heywood associated with the existing protected event for destructive wind conditions in South Australia: AEMO plans to retain the existing protected event until Project EnergyConnect (PEC) stage 1 is commissioned. Post PEC stage 1 commissioning, during destructive wind conditions, AEMO plans to increase the Heywood Interconnector limit from 250 megawatts (MW) to 430 MWs with PEC stage 1 flow to 70 MW.

Other key 2022 PSFRR recommendations

9. Manage risks associated with large generation ramping events in South Australia: AEMO is analysing historical ramping events to understand ramping risks and how changes in synchronous generator dispatch requirements could impact AEMO's ability to manage future ramping events. After its review is complete, AEMO plans to explore options to forecast and manage future NEM ramping events.
10. Manage risks associated with non-credible loss of future North Ballarat – Sydenham 500 kV lines: The non-credible loss of the proposed 500 kV lines between North Ballarat and Sydenham during periods when the new 500 kV lines flow exceeds the limits of the parallel 220 kV lines could result in multiple line losses. AVP will consider this risk in the planning process.

AEMO will provide a status update for the 2022 PSFRR recommendations in the 2023 GPSRR report.

2 Study background

2.1 Evolving power system risks

As a part of the GPSRR, AEMO will assess the risks of the future power system. These studies will investigate system changes including:

- Operational loads.
- Distributed photovoltaics (DPV) and inverter-based resources (IBR) penetration.
- Retirement of existing synchronous generators.
- Addition, upgradation, or decommissioning of SPS.
- Major network augmentations.

2.2 Network development path

The 2022 Integrated System Plan (ISP) and its optimal development path support Australia's complex and rapid energy transformation towards net zero emissions. The 2022 ISP *Step Change* scenario is considered by energy industry stakeholders to be the most likely scenario to play out[3], so forecasting data from the 2022 ISP *Step Change* scenario will be used in the 2023 GPSRR for future projections.

Table 1 displays each of the ISP committed, anticipated and actionable projects in the next five years[4]. These projects will be considered in the assessment of future network conditions. Announced potential closures of power stations such as Liddell Power Station (2022 and 2023) and Eraring Power Station (2025) will also be considered in future studies.

[3] As per section 2.3 of the 2022 Integrated System Plan, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

[4] As per section 5.3 and 5.4 of the 2022 Integrated System Plan, at https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en. All dates are based on current schedules as advised to AEMO and may change.

Table 1 Committed, anticipated and actionable major transmission projects to June 2028

Project	Deliverable date	Status
Victoria – New South Wales Interconnector (VNI) Minor	November 2022	Committed
Eyre Peninsula Link	Early 2023	Committed
QNI Minor	Mid-2023*	Committed
Northern Queensland Renewable Energy Zone (QREZ) Stage 1	September 2023	Anticipated
Central West Orana REZ Transmission Link	Mid-2025	Anticipated
Project EnergyConnect	July 2026**	Anticipated
Western Renewables Link	July 2026	Anticipated
HumeLink	July 2026	ISP Actionable Project
Sydney Ring	July 2027	NSW Actionable Project***
New England REZ Transmission Link	July 2027	NSW Actionable Project***

* This timing is when full capacity is expected to be available following commissioning and interconnector testing.
** This projected delivery date for Project EnergyConnect refers to full capacity available following completion of inter-regional testing.
*** Sydney Ring and New England REZ Transmission Link are actionable under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework.

3 Contingencies and events to be assessed

3.1 Priority risk criteria

When identifying priority risks for assessment in the 2023 GPSRR, AEMO had regard to the following criteria[5]:

- The severity of the likely power system security outcomes if the events or conditions occur.
- The likelihood of occurrence.
- Whether technically and (on preliminary assessment) economically feasible management options are likely to be available.
- Information provided by NSPs and Jurisdictional System Security Coordinators (JSSCs).
- Other relevant factors including those listed in Section 3.4.
- Stakeholder submissions and feedback on AEMO's initial proposed approach paper[6].
- Publication timeframe of final GPSRR report (by 31 July 2023).

3.2 NSP consultation

To identify candidate events and conditions for priority assessment, AEMO requested each transmission network service provider (TNSP) and distribution network service provider (DNSP) share with AEMO any:

- Priority contingency events that may result in uncontrolled changes in frequency leading to cascading outages, or major supply disruptions.
- Other events or conditions that would likely lead to cascading outages or supply disruptions.

To aid the collection and assessment of this information, AEMO requested NSPs to complete a risk assessment document as part of this process. The risk assessment document requested the following information in relation to each system contingency risk:

1. A high-level description of the non-credible contingency event or risk.
2. The primary risk category (the primary risk categories defined for this risk assessment are in Table 2).
3. A description of which network elements would trip if the contingency event occurred.
4. A description of which protection elements are likely to operate if the contingency event occurred
5. Details of any historical occurrence (or near misses) of the event.
6. Details of any existing control or risk management strategies.

[5] As required by NER 5.20A.1(a1)

[6] As detailed in AEMO's consultation report at https://aemo.com.au/consultations/current-and-closed-consultations/general-power-system-risk-review-approach-consultation.

7. An outline of the likely consequences of the event.
8. Whether the contingency has the potential to cause cascading failures.
9. Details of any previous studies/assessments into events.
10. The likelihood of the contingency/event occurring (Table 3 below outlines how likelihood is categorised for this risk assessment).
11. Consequence (Table 4 below outlines how consequence is categorised for this risk assessment).

An inherent risk rating was then calculated based on the likelihood and consequence of the event/contingency (the outcomes of this calculation are as per the matrix in Table 5).

Table 2 Risk categories

Risk category	Description
Frequency risk	Any incident caused by unacceptable frequency conditions on the power system.
Voltage risk	Any incident caused by unacceptable voltage conditions on the power system.
Inertia risk	Any incident caused by a lack of system inertia; this lack of inertia could lead to a ROCOF event.
System strength services risk	Any incident caused by a lack of system strength services. This lack of availability could lead to system instability and/or protection maloperations.
Distributed energy risks	Any incident which is caused by distributed energy resources. This could be DER disconnecting during a fault and leading to an excessive frequency change, or it could be an incident directly caused by the DER in an area.
SPS risks	Any incident which is caused by unexpected interactions or mal operations of SPS systems.
Cyber security risks	Any incident which is caused by a malicious cyber attack.
IT risks	Any incident which is caused by an IT failure (not a cyber attack).
Weather related risks	Any incident caused by weather impacts such as flooding, lightning and storms.
Other	Any incident not categorised above.

Table 3 Likelihood descriptions

Likelihood	Annual probability	Qualitative description
Almost certain	>90%	Will occur in most circumstances; statistical record of several occurrences.
Likely	51% - 90%	Can be expected to occur in most circumstances; statistical record of some occurrence.
Possible	11% - 50%	May occur, but not expected in most circumstances; statistical record of at least one occurrence.
Unlikely	1% - 10%	Conceivable but unlikely to occur in any given year; no history of occurrence.
Rare	<1%	Will only occur in exceptional circumstances; no history of occurrence.

Table 4 Consequence descriptions

Consequence	Market and system impact
Extreme	Loss of supply to multiple states for any duration. Market suspension of multiple markets for a prolonged period.
Major	Loss of supply to a large portion of a state, for any duration. Market suspension in one jurisdiction or market for a short period.
Moderate	Localised/minimal loss of supply in a state. Market(s) in administered state or material scheduling error.
Minor	Intervention required to maintain supply. Immaterial scheduling error (below dispute threshold).
Immaterial	No restriction of supply. No disruption to markets.

Table 5 Risk matrix

	Almost certain	Likely	Possible	Unlikely	Rare
Extreme	25	20	15	10	5
Major	20	16	12	8	4
Moderate	15	12	9	6	3
Minor	10	8	6	4	2
Immaterial	5	4	3	2	1

The risk assessment document also included the contingencies and risks that AEMO itself had identified as potential candidates based on operational experience. Section 3.4 outlines how AEMO has categorised the information received on key contingencies and risks for the 2023 GPSRR.

3.3 Review of relevant system events since the 2022 PSFRR

AEMO has identified the following relevant system events that have occurred since the 2022 PSFRR report:

- 10 June 2022 to 25 June 2022: Operational challenges and market suspension.
- 23 June 2022: South Australian power system oscillations
- 25 July 2022: Buronga isolator fault.
- 14 October 2022: Trip of both Liapootah – Palmerston 220 kV transmission lines.
- 12 November 2022: Trip of both Tailem Bend – South East 275 kV transmission lines.

AEMO will consider the findings and recommendations from these incidents when completing the 2023 GPSRR.

3.4 Initial risk categorisation

AEMO considered all the risks gathered as part of the consultation exercise and organised them into three broad categories:

- **Category 1 – contingencies and risks where AEMO believes there are adequate controls in place. AEMO will not discuss or study these as part of the 2023 GPSRR**. For example, these contingencies or risks may have:
  - Re-classification procedures to identify and control risk.
  - Tools in place to monitor and alert control room operators.
  - Automatic protection which operates to limit the impact of the contingency.
  - Been analysed/managed as part of normal NSP processes.
- **Category 2 – contingencies or risks where the impact is difficult to define and study, or that are outside the GPSRR scope, or that could be studied but are deemed to have a lower impact and consequence than other contingencies**. AEMO will discuss these in the report but does not plan to carry out additional studies. AEMO may also include additional commentary regarding whether systems and tools are fit for purpose to manage these risks[7]. Examples include:
  - Weather-related issues including space weather related risks.
  - Fuel supply interruptions.
  - Market/supply scarcity issues.
  - IT/SCADA failure.
  - Cyber attack related risks.
  - Communication related risks.
  - Control/protection system interaction risks.
  - Contingencies with a lower inherent risk rating (see Table 5).
  - Insufficient generation available for dispatch due to various reasons.
  - Future contingencies with great uncertainties in detailed design/parameters.

  As part of the 2023 GPSRR, AEMO plans to assess the measures in place to manage the other events such as:
  - The solar eclipse expected 22 July 2028.
  - Potential for persistent oscillations from inverter-based resources to cause tripping of distributed energy resources (DER).
- **Category 3 – contingencies or risks without adequate protection or an adequate process to manage the event.** Risks in this category are candidates for review as part of the 2023 GPSRR. AEMO will assess these risks to identify whether they should be prioritised for study in this year's review. Where risks are not selected for study, AEMO will consider them in future reviews or refer to relevant work underway by NSPs and/or AEMO to assess/control the risk.

[7] See details relating to AEMO's Operations Technology Roadmap at https://aemo.com.au/initiatives/major-programs/operations-technology-roadmap.

3.5 Contingencies to be assessed (Category 3)

AEMO has reviewed the Category 3 risks to select key contingencies and other events or conditions as priority risks for assessment. These were selected for the 2023 GPSRR based on:

- The likely power system impact of the contingency and its estimated probability of occurrence.
- Details of any review/work previously completed to understand or manage the contingency/risk.
- Any changes to power system conditions or other factors which may have materially changed the risk profile of a contingency/risk.
- How recently a contingency or risk has been reviewed as part of AEMO's risk review process (that is, reviewed under a recent PSFRR).

Priority risks were selected for study against historical and future (2027-28) operating conditions.

Risks to be assessed against historical operating conditions

To assess contingencies based on historical conditions, AEMO will use the operations and planning data management system (OPDMS) snapshots representing operating boundaries relevant to the contingency considered. The contingencies in Table 6, Table 7 and Table 8 will be studied for historical conditions.

Table 6 Historical contingency 1

Contingency	Loss of line 62: 330 kV Wagga – Jindera and line 63: 330 kV Wagga – Darlington Point
Likelihood	Unlikely (1% to 10% annual probability)
Impact	Major (loss of supply to a large portion of a state, for any duration) • The double circuit contingency is likely to impact IBR fault ride-through (FRT) and post-event system voltage management. • Could cause generation lack of reserve (LOR) conditions.
Risk conditions	• High flows in lines 62, 63, and 51 (Wagga -Lower Tumut). • High generation (wind and solar) around Wagga and Darlington Point regions. • High and low NSW and VIC demand. • High IBR generation in NSW/VIC regions. • High QNI QLD export and high HIC SA export. • High DPV in NSW and VIC regions. • Low UFLS in the NEM regions.
Existing management strategies	UFLS
Potential solutions	Protected event. SPS may not be a practical solution due to PEC commissioning.
Study software	Power System Simulation for Engineering (PSS®E) and Power System Computer Aided Design (PSCAD)
Risk raised by	2022 PSFRR, Transgrid

Table 7 Historical contingency 2

Contingency	Tamworth double 330 kV bus trip (Sections 1 and 3) due to circuit breaker (CB) failure of bus coupler CB 5102
Likelihood	Unlikely (1% to 10% annual probability)
Impact	Major (loss of supply to a large portion of a state, for any duration) • Thermal overloads, generation loss, frequency excursions, UFLS operation.
Risk conditions	• High flows in lines (northerly and southerly) that will be tripped for bus fault. • High net generation from the plants that are likely to be tripped due to the bus fault. • High and low NSW and VIC demand. • High IBR generation in NSW/VIC regions. • High QNI export /import and high HIC export /import. • High DPV in NSW and VIC regions. • Low UFLS in the NEM regions.
Existing management strategies	UFLS
Potential solutions	Control scheme, UFLS
Study software	PSS®E
Risk raised by	Transgrid

Table 8 Historical contingency 3

Contingency	Non-credible loss of Bayswater – Mount Piper (5A3) and Mount Piper – Wollar (5A5) 500 kV lines
Likelihood	Likely (51% to 90% annual probability) • Tripped twice in past three years.
Impact	Major (loss of supply to a large portion of a state, for any duration) • Thermal overloads, generation loss, frequency excursions, UFLS operation.
Risk conditions	• High flows in on the lines 5A3 and 5A5 along with high flows in the parallel corridors to lines 5A3 and 5A5. • High generation in Bayswater and Liddell regions that will impact the contingency. • High and low NSW and VIC demand. • High IBR generation in NSW/VIC regions. • High QNI export /import and high HIC export /import. • High DPV in NSW and VIC regions. • Low UFLS in the NEM regions.
Existing management strategies	Identified as vulnerable line – contingency is reclassified as credible during a lightning storm if a cloud to ground lightning strike is detected within a specified distance of these lines. End date for probable state is 17/02/2023.
Potential solutions	Reclassification, UFLS, control scheme
Study software	PSS®E
Risk raised by	AEMO for the 2023 GPSRR

The above contingencies have been identified as potential existing risks to the system and are therefore being assessed under historical operating conditions.

Risks to be assessed against 2027-28 projected operating conditions

The 2027-28 future studies will consider the ISP projected levels of demand, generation, and DER/DPV. In addition, updated UFLS/OFGS settings, planned network augmentations/upgrades, and corresponding protection schemes will be considered in the study. The Category 3 risk selected for future studies is likely to be impacted by forecast changes to operating conditions in the NEM. The contingencies in Table 9 will be considered for 2027-28 future studies.

Table 9 Future contingencies

Contingency	**Assessment of non-credible events that could lead to QNI instability, including, but not limited to:** • **Victoria – New South Wales Interconnector (VNI),** • **South Australia separation at Moorabool Terminal Station (MLTS) with Emergency Alcoa-Portland Potline Tripping (EAPT) operation included,** • **Large amount of generation and DPV loss in the south of Queensland**
Likelihood	Unlikely: 1% to 10% annual probability
Impact	Major (loss of supply to a large portion of a state, for any duration) • Tripping of QNI – separation of Queensland from the rest of the NEM, frequency excursions, UFLS/OFGS operation.
Risk conditions	• High IBR generation with low synchronous units online and inertia. • High and low regional demands. • High IBR generation in NEM regions. • High flows on QNI, VNI, PEC and HIC in both directions. • Projected seasonal maximum and minimum conditions. • Moderate to high DPV in NSW and VIC regions.
Existing management strategies	None
Potential solutions	Various special protection schemes
Study software	PSS®E
Risk raised by	2022 PSFRR recommendation

Contingencies to be studied under future operating conditions were selected on the basis that they do not currently pose as a significant threat to the power system, but the consequences of them are predicted to become more severe due to changes in the power system over time.

Additional assessments by NSPs

AEMO is also liaising with NSPs on studies planned by each NSP to assess the non-credible risks (including system stability assessment and identification of any required SPSs) planned as the part of each new transmission line development, as required by NER S5.1.8.

3.6 Other review tasks

The following activities will also be included in the 2023 GPSRR scope:

- Review of existing protected events.
  - South Australian protected event for destructive wind conditions.
  - Update regarding planned protected event for management of high South Australian imports during periods where UFLS is ineffective.
- Consider the outcome of the NEM UFLS/OFGS review, including updated settings depending on the availability of the revised settings at the time of commencement of the studies.

Requirement and benefit of new protected events.

4 Models and study case scenarios development

Model and data requirements for 2023 are discussed in this chapter. For the successful assessment of non-credible risks, it is important that all the updated models of relevant systems are included in the studies, or appropriate assumptions be made where information is unavailable. The GPSRR model requirements are summarised in subsequent sections.

4.1 Monitored parameters

The 2023 GPSRR studies will consider the following system parameters to assess the risks:

- Violation of voltage and frequency operating standards.
- Performance generators, fault ride-through (FRT) of the IBR units (specifically in PSCAD studies) and DPV disconnections.
- Adequacy of emergency frequency control schemes (EFCS) relevant to the contingency.
- Voltage, frequency, and transmission line flow instabilities.
- Indications in the results towards insufficiencies in system strength or inertia.
- High RoCoF conditions.

4.2 Study software

AEMO plans to use both PSS®E and PSCAD software to assess the contingency events where FRT behaviours of IBR might impact the assessment results will be studied in PSCAD. Other events will be studied using PSS®E.

4.3 Network model

Historical studies

OPDMS system snapshots[8] between 1 July 2021 and 30 June 2022 will be used to assess the level of existing risk in the power system. Historical cases will be selected based on the network conditions detailed in Table 10, to represent the system operating boundaries relevant for each contingency. Each historical contingency identified in Section 3.5 will be assessed using all historical cases. To conduct an accurate assessment of existing system risk, AEMO will not alter the generation and load dispatch in these historical snapshots.

[8] A system snapshot represents the network configuration at the time the snapshot was taken. Outages (planned or unplanned) remain as they were at the snapshot time.

Table 10 Proposed study scenarios – historical studies

Scenarios	Line flows	Generation	Demand	IBR	Interconnectors	DPV	UFLS
H1	High flows in lines 62, 63, and Line 51 (Wagga - Lower Tumut)	High generation (wind and solar) around Wagga and Darlington Point regions	High and low NSW and VIC demand	High IBR generation in NSW/VIC regions	High QNI QLD export and high HIC SA export	High DPV in NSW and VIC regions	Low UFLS in the NEM regions
H2	High flows in lines (northerly and southerly) that will be tripped for bus fault	High net generation from the plants that are likely to be tripped due to the bus fault	High and low NSW and VIC demand	High IBR generation in NSW/VIC regions	High QNI export /import and high HIC export /import	High DPV in NSW and VIC regions	Low UFLS in the NEM regions
H3	High flows in on the lines 5A3 and 5A5 along with high flows in the parallel corridors to lines 5A3 and 5A5	High generation in Bayswater and Liddell regions that will impact the contingency	High and low NSW and VIC demand	High IBR generation in NSW/VIC regions	High QNI export /import and high HIC export /import	High DPV in NSW and VIC regions	Low UFLS in the NEM regions
H4…	Additional cases for a range of NEM demand, interconnector flows, synchronous generation dispatch and VRE operation.						

Future studies

Five-year ahead (2027-28) studies will be carried out using a combination of a full NEM model based on OPDMS snapshots which includes the new interconnectors that are planned for completion by June 2028 (see Table 1), and a simplified NEM network model which includes QNI upgrades and PEC Stage 2. Importantly, the use of a simplified NEM model will enable the assessment of a wider range of future dispatch scenarios and contingencies, with the full NEM model used to benchmark the simplified model. This approach is consistent with that used for the 2022 PSFRR future studies.

Projected developments including generation, battery energy storage systems (BESS) and synchronous condensers will also be modelled, depending on the availability of models and data at the time of study. The key system forecast parameters that will be considered in setting up the study cases are included in Table 11. Future studies will assume a system normal network configuration[9].

Assumptions and limitations of simplified NEM model

For the simplified NEM model, the following network configuration and modelling approaches will be used:

- Each mainland region will be represented by a common high voltage bus (New South Wales, Victoria and Queensland 330 kV and South Australia 275 kV buses). All the regional generators will be assumed to be connected to these regional common buses through appropriate generator transformers.

[9] System normal snapshots restore the nominal configuration of the network. Network outages (planned or unplanned) are restored to the nominal configuration whilst generation and load are retained as they were in the snapshot timestamp. In the future studies the load a generation will be redispatched, and network projects will be added to match the forecasted network conditions.

- Regional generators will be lumped as steam, gas, hydro, wind and solar with appropriate generic models such as alternator, voltage controller, governors and IBR controllers included to the lumped generators according to each generator type.
- UFLS and underlying DPV will be grouped according to their frequency trip bands and connected at medium voltage (MV) buses
- The grouped UFLS and DPV feeders will be also connected to common high voltage buses through appropriate transformers.
- Interconnectors will be modelled as per OPDMS network with compensating devices, such as reactors, capacitors and static VAR compensators (SVCs).
- PEC Stage 2 will be included based on the latest planning information available (at the time of study).
- The high voltage (HV) network between South East Switching Station (SESS) and Moorabool Terminal Station (MLTS), and between Red Cliffs Terminal Station (RCTS) and Buronga will be modelled as per OPDMS network.
- South Australia generators and generators connected between Heywood Terminal Station (HYTS) and MLTS will be modelled as per OPDMS including their dynamic models.
- APD network loads will be modelled as per the OPDMS.
- The South Australian OFGS generators will be modelled as per OPDMS generator models for the respective plants along with their OFGS trip settings.

Even though the simplified network can capture frequency variations with reasonable accuracy, it is impacted by the following limitations:

- The model excludes actual network impedances, therefore, it will not accurately predict power system voltages.
- The model is an approximation of fault ride-through characteristics of IBR plant.
- The model is an approximation of the voltage-based tripping behaviour of DPV.
- The power swings on interconnectors and their angular stability predictions may be less conservative when compared with the full NEM OPDMS model. To address this, as part of the 2023 GPSRR studies, the simplified model will be benchmarked against the full NEM model with PEC Stage 2. Specifically, the fault levels at key system nodes in the simplified model will be matched with the full NEM model and the accuracy with which the simplified model can predict QNI instability will be assessed.

Table 11 Proposed study scenarios – future studies

Scenarios	Line flows	Generation	Demand	IBR	Interconnectors	DPV	UFLS
F1	No specific requirement	High IBR generation with low synchronous units online and inertia	High and low regional demands	High IBR generation in NEM regions	High flows on QNI, VNI, PEC and HIC in both directions	Projected seasonal maximum and minimum conditions	Moderate to high DPV in NSW and VIC regions
F2…	Additional cases for a range of NEM demand, interconnector flows, synchronous generation dispatch and VRE operation.						

4.4 Primary frequency response (PFR) governor models

PFR applied settings

PFR settings data applied to the generators are required to model generator frequency performance accurately. These settings are available to AEMO and have been included in the model.

Governor models for units with no governor model available in OPDMS

Where generating units have implemented new PFR settings, updated governor models are not available to AEMO (in the majority of cases). To address this, AEMO has developed three generic governor models corresponding to steam, hydro and gas turbines which represent governor response in line with new PFR settings during frequency events. These generic governor models will be used for 2023 GPSRR studies.

Governor models for units with governors in OPDMS

Generators have an ongoing obligation to provide NSPs and AEMO with up-to-date modelling information which encompasses all control systems that respond to voltage or frequency disturbances on the power system. AEMO has sent reminders to all mainland NEM generators of their obligations to provide updated frequency control models, and the need for this information to support the GPSRR. Where updated site-specific information is not available, generic governor models with appropriate PFR settings will be used.

BESS models

For future committed projects where specific models of BESS are not available suitable generic models will be used.

IBR models for large-scale wind and solar generation

The following approach will be used for modelling of IBR in the GPSRR studies:

- For those IBR units that have completed PFR commissioning, where appropriate, the generator supplied model represented in OPDMS will be used.
- Generators have an ongoing obligation to ensure that the NSP and AEMO have accurate models that reflect the voltage and frequency performance of their plant. AEMO will shortly be seeking to confirm that IBR generators have provided models that are representative of their actual performance.
- Legacy IBR plants represented in OPDMS as negative loads will be represented using generic PSS®E IBR models.
- For future studies, committed plant will be modelled using generic models with minimum PFR settings.

4.5 Frequency control ancillary services (FCAS) response

Unless stated otherwise, FCAS response of synchronous generators will not be considered in the studies apart from the frequency responses provided by PFR governors. The FCAS lower capabilities of IBR will be considered according to PFR settings, if PFR commissioning is completed. The FCAS lower capability of IBR plants will not be considered if confirmation of frequency control enablement from the generator is not available at the time of the study.

4.6 Special protection scheme (SPS) models

Typically, for most simulation studies that involve assessment of credible contingency events, SPS models are not included. Given the criticality of such models in the assessment of power system security in response to non-credible contingency events, the SPS models to be considered in the study are outlined in Table 12.

Table 12 Special protection scheme models to be considered

Model	Region	Model owner	Implementation	Status
EAPT Scheme	VIC	AVP	Fortran	Model being updated following review of the scheme (update by AEMO in progress)
IECS	VIC	AVP	Python	Model being updated following review of the scheme (per 2020 PSFRR recommendation) (update by AEMO in progress)
System Integrity Protection Scheme (SIPS)/ Wide Area Protection Scheme (WAPS)	SA	ElectraNet	Fortran	It is expected that ElectraNet will develop and provide PSS®E and PSCAD models of the WAPS scheme (not available).
Central Queensland – South Queensland (CQ-SQ) WAMPAC scheme	QLD	Powerlink	Python	WAMPAC model has been developed. Any changes following studies associated with 2022 PSFRR recommendation 5 are expected to be excluded based on model availability timeframe.
PEC scheme	SA	ElectraNet	-	ElectraNet/TransGrid are presently developing the scheme, in consultation with AEMO (not available)

Apart from the above SPS models, protection schemes relevant to key study contingencies will be used. Schemes in this category may include, but are not limited to:

- All Murraylink runback schemes.
- Victoria – Emergency Moorabool Transformer/Reactor Trip (EMTT) scheme.
- Victoria – South West 500 kV Special Control Scheme (SW500SCS).
- To model QNI trip, AEMO plans to use a generic distance protection relay model based on relay data provided by the Transgrid and Powerlink.

For the 2023 GPSRR studies, if any updated SPS model/relay models are not available, the latest SPS models available at the time of study or appropriate study assumptions will be used.

4.7 Emergency frequency control scheme (EFCS) models

UFLS model

UFLS settings will be based on UFLS data presently available to AEMO.

At the time of study, if the UFLS OPDMS bus mapping information is available, the UFLS loads as identified by the mapping will be used to model the UFLS scheme. If bus mapping is not available, UFLS loads will be allocated within relevant region(s), so the net UFLS loads in the region match the net measured regional UFLS for the given snapshot instant. For future studies, assumptions will be made based on Electricity Statement of Opportunities (ESOO) forecasts to project future UFLS levels at each frequency band.

OFGS model

Existing OFGS model settings will be used unless the scheme is reviewed and revised settings are available prior to the studies being undertaken.

4.8 DER/DPV models

An approach similar to UFLS (see Section 4.7) will be used to model DPV. Depending on the availability of data, DPV bus mapping will be used to model the DER/DPVs in PSS®E at relevant buses. For future scenarios, assumptions will be based on ESOO forecasts to project future DPV MW generation at each frequency band.[10]

4.9 Load models

The composite load model (CMLD) is planned to be used to model load response in all GPSRR studies. The CMLD model captures load shake off in response to large disturbances.[10]

4.10 Data to assess future scenarios

To assess contingencies with future network operating conditions, the following five-year ISP 2022 *Step Change* projection data will be applied:

- Regional load (high and low).
- Regional inertia (high and low).
- DER generation (high and low).
- UFLS load availability (high and low).

4.11 Forecasting assumptions

Assumptions will be used which align with AEMO forecasting information including from the ISP.

AEMO anticipates using the following information sources:

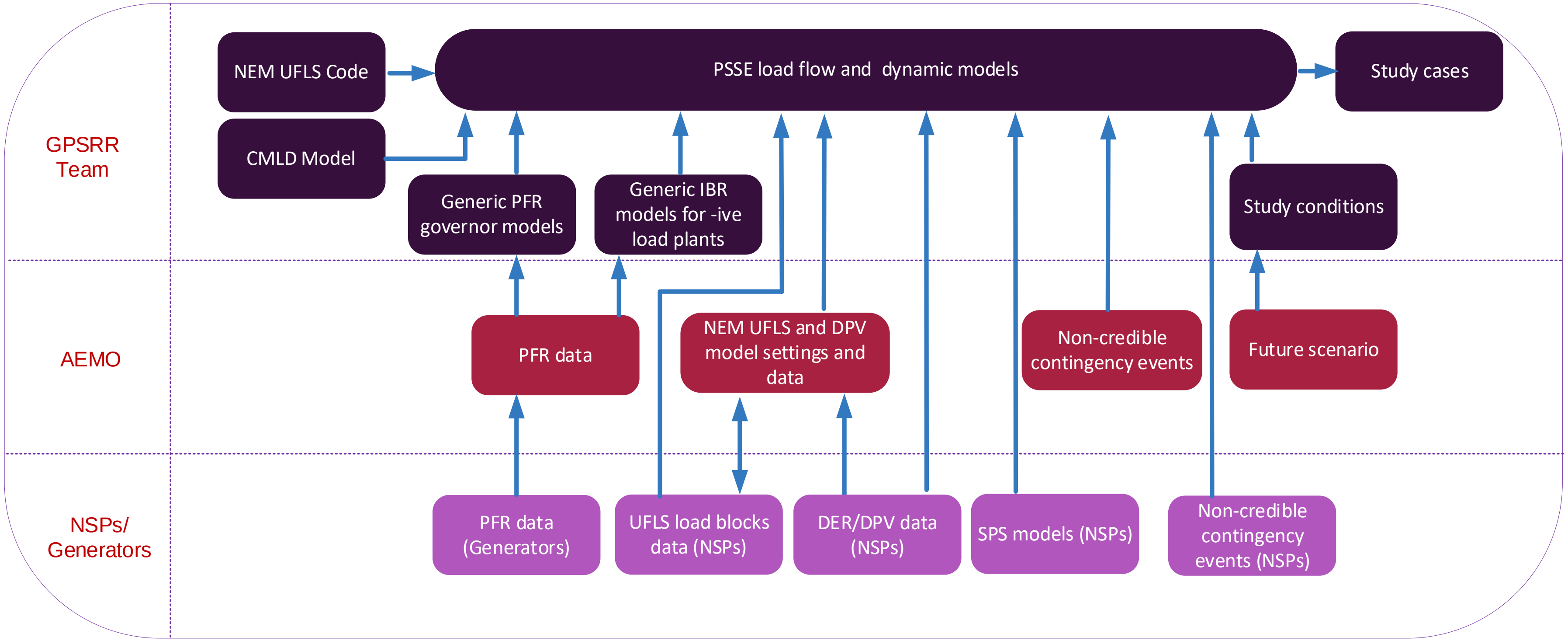
- Regional operational load (high and low) – ISP.
- Regional inertia (high and low) – ISP.
- DER generation for all regions – ISP.
- UFLS load availability for all regions – projected values provided by AEMO.

[10] Further details on AEMO PSS®E models for load and distributed PV in the NEM is available at https://aemo.com.au/-/media/files/initiatives/der/2022/psse-models-for-load-and-distributed-pv-in-the-nem.pdf?la=en

4.12 2023 GPSRR model sources

2023 GPSRR model sources are shown in Figure 2.

Figure 2 2023 GPSRR model sources



5 Consultation approach

Key consultation activities and tentative timelines for the 2023 GPSRR are below.

Complete

1. Engaging with AEMO internal teams and NSPs to finalise the scope of 2023 GPSRR. This includes discussions with NSPs in finalising the list of contingencies to be included in the study (July 2022 to mid-August 2022).
2. Seeking NSP and JSSC feedback on 2023 GPSRR draft approach paper (mid-August 2022 to end of August 2022).
3. Industry consultation on the 2023 GPSRR draft approach paper (first week of September 2022 to first week of October 2022).
4. GPSRR approach industry briefing session (12 October 2022)
5. Publication of the 2023 GPSRR final approach paper (December 2022).

Planned

6. On completion of the studies, AEMO to share the findings with NSPs (historical study results mid-January 2023 and future results mid-March 2023).
7. Seeking feedback from NSPs on the draft 2023 GPSRR report (mid-April 2023 to mid-May 2023).
8. Draft 2023 GPSRR report published for industry consultation (mid-May 2023 to mid-June 2023).
9. Publication of final 2023 GPSRR report (by 31 July 2023).

Abbreviations

Abbreviation	Term	Abbreviation	Term
AVP	AEMO Victorian Planning	**NEM**	National Electricity Market
BESS	battery energy storage system/s	**NER**	National Electricity Rules
CB	circuit breaker	**NSP**	network service provider
CQ-SQ	Central Queensland – South Queensland	**OFGS**	over frequency generation shedding
DDTS	Dederang Terminal Station	**OPDMS**	Operations and Planning Data Management System
DER	distributed energy resources	**PEC**	Project EnergyConnect
DNSP	distribution network service provider	**PFR**	primary frequency response
DPV	distributed photovoltaics	**PSCAD**	Power System Computer Aided Design
EAPT	Emergency Alcoa-Portland Potline Tripping	**PSFRR**	Power System Frequency Risk Review
EFCS	emergency frequency control scheme	**PSS®E**	Power System Simulation for Engineering
EMTT	Emergency Moorabool Transformer/Reactor Trip	**QNI**	Queensland – New South Wales Interconnector
ESOO	Electricity Statement of Opportunities	**RCTS**	Red Cliffs Terminal Station
FCAS	frequency control ancillary services	**RoCoF**	rate of change of frequency
FRT	fault ride-through	**SESS**	South East Switching Station
GPSRR	General Power System Risk Review	**SIPS**	system integrity protection scheme
HV	high voltage	**SMTS**	South Morang Terminal Station
HYTS	Heywood Terminal Station	**SPS**	special protection scheme/s
IBR	inverter-based resources	**SVC**	static VAR compensators
IECS	Interconnector Emergency Control Scheme	**SW500SCS**	South West 500 kV Special Control Scheme
ISP	Integrated System Plan	**TNSP**	transmission network service provider
JSSC	Jurisdictional System Security Coordinator	**UFLS**	under frequency load shedding
kV	kilovolt/s	**VAR**	Volt-Amperes Reactive
LOR	lack of reserve	**VNI**	Victoria – New South Wales Interconnector
MLTS	Moorabool Terminal Station	**WAMPAC**	wide area monitoring protection and control
MV	medium voltage	**WAPS**	wide area protection scheme
MW	megawatt/s		