Amendments to the Inertia Requirements Methodology

Draft Report – Standard consultation for the National Electricity Market

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Executive summary and consultation notice

The publication of this draft report commences the second stage of the standard consultation procedure conducted by AEMO to consider proposed amendments to the Inertia Requirements Methodology (the **Methodology**) under the National Electricity Rules (**NER**) (the **proposal**).

This consultation is undertaken as required by NER 5.20.4, following the procedure in NER 8.9.2.

The Australian Energy Market Commission (**AEMC**) published the *National Electricity Amendment (Improving security frameworks for the energy transition) Rule 2024* (**Amending Rule**) in March 2024[1]. With effect from 1 December 2024, the Amending Rule introduces new inertia planning requirements, removes restrictions on the procurement of synthetic inertia, and increases alignment between the inertia and system strength procurement frameworks.

AEMO commenced consultation on 5 July 2024 and identified the following broad categories for proposed Methodology amendments:

- Meeting NER requirements:
  - **calculation of the system-wide inertia level** to support secure interconnected operation on the mainland and allocation of this level to inertia sub-networks,
  - **description of how the likelihood of a sub-network islanding is determined**, and
  - **the inclusion of a new inertia network service specification** for synchronous and synthetic inertia service providers.
- Methodology improvements:
  - **amendment of assumptions relating to unit minimum operating levels** via the central dispatch process under certain conditions,
  - **consideration of credible contingency events that may cause the formation of an island**,
  - **additional modelling considerations**, and
  - **other minor amendments** and updates.

AEMO received five submissions and feedback from meetings with stakeholders in response to its Consultation Paper, which put forward a range of views on the proposal. AEMO thanks all stakeholders for their submissions, and appreciates the thoughtful contributions on these complex matters.

AEMO has issued a Draft Inertia Requirements Methodology for further consultation. The Draft Inertia Requirements Methodology reflects AEMO's draft determination of the following matters after considering all submissions and feedback from meetings with stakeholders:

- **NER requirement: system-wide inertia level and inertia sub-network allocation** – AEMO will base the sub-network allocation on the individual inertia subnetwork requirements and will vary the total amount of inertia in its power system simulation studies to determine the system wide level of inertia.
- **NER requirement: process for determining sub-network islanding risk** – AEMO will consider the list of factors in new NER 5.20B.2(d) when forecasting and determining the likelihood of sub-network islanding.

[1] At https://www.aemc.gov.au/sites/default/files/2024-03/ERC0290%20-%20ISF%20final%20determination.pdf.

These factors include any other matters AEMO considers relevant in making its assessment. AEMO will also consider factors relating to evidence from historical islanding events, and the frequency or likelihood of specific non-credible events being reclassified as credible in operational timeframes. In addition to its usual consideration of the likelihood of inertia sub-networks islanding individually, AEMO will conduct additional inertia assessments of cases where two or more inertia sub-networks are at risk of forming a combined island.

- **NER requirement: inertia network services specification** – AEMO will include the inertia network service specification as part of the Methodology. AEMO will draw from its voluntary grid-forming inverters specification and test specification[2] published under the Engineering Framework program to inform the specification for synthetic inertia providers. As part of the approvals process described in NER 5.20.4 (g)(2), AEMO will estimate the equivalent inertia supplied by a non-synchronous provider through power system simulation. The assessment method used will be quantifying synthetic inertia using the swing equation – 'indirect approach'[3].
- **Methodology improvement: redispatch assumptions** – AEMO will not amend the assumption that a generating unit's output will reduce to its minimum operating level via the central dispatch process under certain conditions to reduce the size of the generation contingency to the lowest practical level.
- **Methodology improvement: credible events leading to island formation** – AEMO will amend the methodology to allow satisfactory inertia level requirements to consider credible events that may cause the formation of an island.
- **Methodology improvement: additional modelling considerations** – AEMO will update the Methodology to explicitly provide for:
  - Modelling expected changes in supply, demand, and network assumptions over the 10-year horizon. This includes, but is not limited to, generator retirement, committed projects, network augmentations, distributed photovoltaics (DPV), and load modelling assumptions.
  - Improvements to the modelling approach to account for network parameters that impact contingency sizes, and possible use of more sophisticated modelling approaches (such as multi mass models (MMMs)) where necessary to add confidence to system-wide inertia results.
- **Methodology improvement: other amendments and updates** – AEMO will undertake several minor amendments and updates to reflect the Amending Rule and to improve the clarity or accuracy of the existing Methodology. This includes amendments and updates to reflect revised NSCAS arrangements and terminology updates.

AEMO's draft proposal is to amend the Methodology in the form published with this draft report, with a proposed effective date of 1 December 2024.

[2] AEMO, Voluntary Specification for Grid-forming Inverters: Core Requirements Test Framework, January 2024. At https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en.

[3] Option 1 (a) and (b) were introduced and investigated in CIGRE Symposium Paper 1296, "Determining inertia contribution from grid-forming battery energy storage systems". See https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en.

Consultation notice

AEMO invites written submissions from interested persons on the draft proposal and issues identified in this draft report to 2024_security_consultations@aemo.com.au by 5:00 pm (Melbourne time) on 23 October 2024.

Submissions may make alternative or additional proposals you consider may better meet the objectives of this consultation and the national electricity objective in section 7 of the National Electricity Law. Please include supporting reasons.

Before making a submission, please read and take note of AEMO's consultation submission guidelines, which can be found at https://aemo.com.au/consultations. Subject to those guidelines, submissions will be published on AEMO's website.

Please identify any parts of your submission that you wish to remain confidential, and explain why. AEMO may still publish that information if it does not consider it to be confidential, but will consult with you before doing so. Material identified as confidential may be given less weight in the decision-making process than material that is published.

Submissions received after the closing date and time will not be valid, and AEMO is not obliged to consider them. Any late submissions should explain the reason for lateness and the detriment to you if AEMO does not consider your submission.

Interested persons can request a meeting with AEMO to discuss any particularly complex, sensitive or confidential matters relating to the proposal. Please refer to NER 8.9.1(k). Meeting requests must be received by the end of the submission period and include reasons for the request. AEMO will try to accommodate reasonable meeting requests but, where appropriate, we may hold joint meetings with other stakeholders or convene a meeting with a broader industry group. Subject to confidentiality restrictions, AEMO will publish a summary of matters discussed at stakeholder meetings.

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1. Stakeholder consultation process

As required by National Electricity Rules (**NER**) 5.20.4, AEMO is consulting on the Inertia Requirements Methodology (the **Methodology**) in accordance with the standard rules consultation procedure in NER 8.9.2 (the **proposal**).

Note that this document uses terms defined in the NER, which are intended to have the same meanings. There is a glossary of additional terms and abbreviations in Appendix A.

AEMO's process and expected timeline for this consultation are outlined below. Future dates may be adjusted, and additional steps may be included as needed, as the consultation progresses.

Table 1 Consultation process and timeline

Consultation steps	Dates
Consultation Paper published	**5 July 2024**
Submissions closed on Consultation Paper	**2 August 2024**
Draft report published	**25 September 2024**
Submissions due on draft report	**23 October 2024**
Final report published	Expected **13 November 2024**

AEMO's consultation webpage for the proposal contains all previous published papers and reports, written submissions, and other consultation documents or reference material[4] (other than material identified as confidential). AEMO publishes the Draft Inertia Requirements Methodology alongside this determination without changes tracked noting that the changes are widespread and substantial.

In response to its Consultation Paper on the proposal, AEMO received five written submissions, one of which was partly confidential.

AEMO also held a meeting with SMA Australia on 9 August 2024, and the Clean Energy Council (CEC) and its members on 28 August 2024.

AEMO thanks all stakeholders for their feedback on the proposal to date, which has been considered in preparing this draft report, and looks forward to further constructive engagement.

[4] AEMO. *Amendments to the Inertia Requirements Methodology,* at https://aemo.com.au/consultations/current-and-closed-consultations/amendments-to-the-inertia-requirements-methodology.

2. Background

2.1. Context for this consultation

The Australian Energy Market Commission (**AEMC**) published the *National Electricity Amendment (Improving security frameworks for the energy transition) Rule 2024* (**Amending Rule**) in March 2024. The Amending Rule will expand the system security procurement frameworks for the National Electricity Market (**NEM**), providing AEMO with new tools to manage power system security in the NEM through the energy transition.

The Amending Rule requires changes to several AEMO documents, including the Methodology which is the focus of this consultation. In addition to required changes, AEMO is also proposing several amendments that improve the clarity, accuracy, or utility of the Methodology itself.

The Amending Rule has made four key updates to the inertia framework:

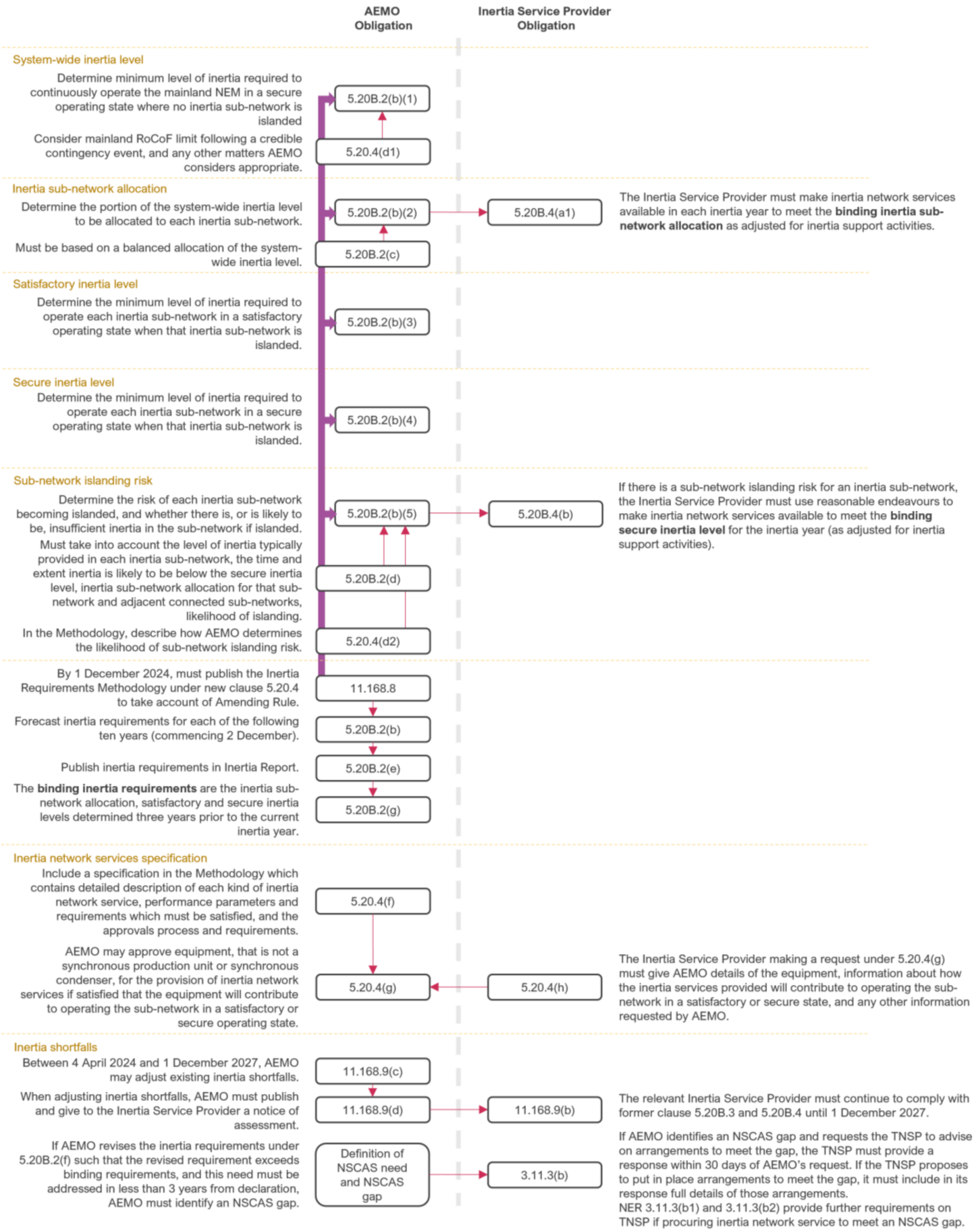
1. AEMO must now set a system-wide inertia level for the mainland NEM regions, based on satisfying relevant frequency excursion bands and rate of change of frequency (**RoCoF**) limits following any credible contingency event. Previously no inertia requirements were specified during the typical interconnected operation of NEM mainland regions.
2. AEMO must allocate portions of this new system-wide inertia level among mainland inertia sub-networks in a way that promotes balanced procurement. The relevant transmission network service provider (**TNSP**) must then procure sufficient services or assets to ensure the full regional allocation is continuously available.
   - If AEMO determines that a sub-network carries a likely risk of islanding, the relevant TNSP must also procure to meet higher local requirements that can be enabled during periods where such a credible contingency event is in effect.
3. The Amending Rule aligns the procurement timeframes of the system strength and inertia frameworks, providing TNSPs with an opportunity for greater investment coordination. In particular:
   - AEMO must annually forecast the inertia requirements for all inertia sub-networks over a 10-year period commencing 1 December 2024.
   - TNSPs will be required to procure inertia to meet the inertia requirements as published three years prior, starting from 1 December 2027.
   - In the interim three years, the Amending Rule allows AEMO to address any identified inertia shortfall through the network support and control ancillary service (**NSCAS**) framework.
4. The Amending Rule broadens the scope of services capable of meeting requirements to qualify as an inertia network service to include synthetic and other non-synchronous service providers. Procurement from these providers is subject to AEMO approval.
   - To facilitate this process, AEMO is required to consult on an inertia network service specification to be included in the Methodology which details the minimum requirements and performance parameters that such services must meet.

AEMO is also conducting a separate consultation process on proposed changes to the NSCAS procedures that implement other aspects of the Amending Rule.

2.2. NER requirements

Figure 1 lists some clauses in the Amending Rule which impose obligations on either AEMO or the TNSPs and are discussed in this draft report.

Figure 1 Key Amending Rule clauses discussed in this draft report



2.3. The national electricity objective

Within the specific requirements of the NER applicable to this proposal, AEMO will seek to make a determination that is consistent with the national electricity objective (NEO) and, where considering options, to select the one best aligned with the NEO.

The NEO is expressed in section 7 of the National Electricity Law as:

> *to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:*
>
> *(a) price, quality, safety, reliability and security of supply of electricity; and*
>
> *(b) the reliability, safety and security of the national electricity system; and*
>
> *(c) the achievement of targets set by a participating jurisdiction—*
>
> *(i) for reducing Australia's greenhouse gas emissions; or*
>
> *(ii) that are likely to contribute to reducing Australia's greenhouse gas emissions.*

3. List of material issues

The key material issues arising from the proposal or raised in submissions or consultation meetings are listed in the following table.

Table 2 List of material issues

No.	Issue	Raised by
1.	NER requirement: system-wide inertia level and inertia sub-network allocation	AEMO
2.	NER requirement: process for determining sub-network islanding risk	AEMO
3.	NER requirement: inertia network services specification	AEMO
4.	Methodology improvement: redispatch assumptions	AEMO
5.	Methodology improvement: credible events leading to island formation	AEMO
6.	Methodology improvement: additional modelling considerations	AEMO
7.	Stakeholder feedback: inertia, FFR and VFFCAS relationship	Transgrid, SMA Australia, Tesla, Shell Energy

A detailed table of issues raised by stakeholders in written submissions to the Consultation Paper, together with AEMO's responses, is in Appendix B.

Each of the material issues in Table 2 is discussed in Section 4.

4. Discussion of material issues

4.1. NER requirement: system-wide inertia level and inertia sub-network allocation

4.1.1. Issue summary and submissions

The Amending Rule introduces a new annual obligation on AEMO to calculate a system-wide inertia level[5] to support secure interconnected operation on the mainland. AEMO must allocate portions of this inertia level among mainland inertia sub-networks based on a balanced procurement approach.

In the Consultation Paper, AEMO proposed that the total amount of inertia, and the inertia distribution across the NEM in its power system simulation studies, will be varied to understand the impacts of the distribution on the level of inertia required overall. This will be used to calculate the sub-network allocation for all regions.

Stakeholders (**SMA, Tesla,** and **Transgrid**) were generally supportive of AEMO's proposed overarching approach on calculation of the system-wide inertia level and inertia sub-network allocation, with suggested amendments.

Trangrid have recommended:

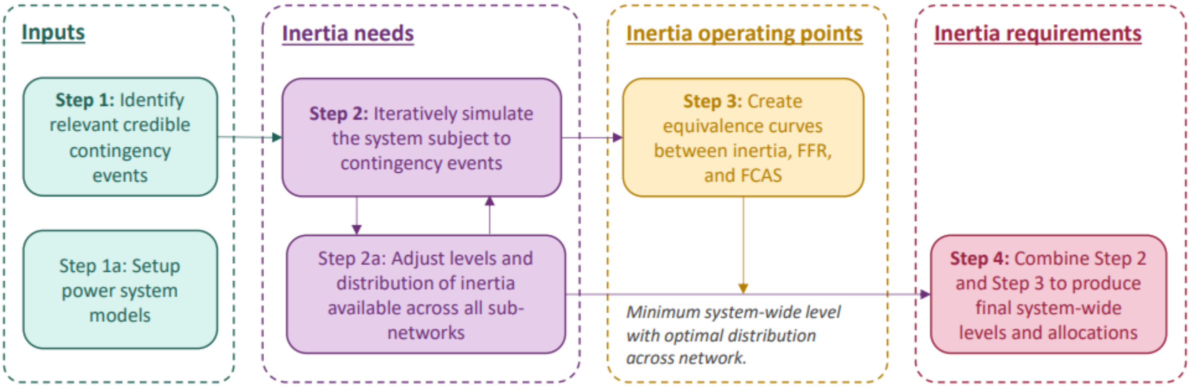
- Assessing line contingencies that have associated transfer tripping scheme that would result in the trip of several generators. Transgrid have noted Wagga – Darlington Point 330 kV line as an example.
- AEMO to test the ability of the network to withstand non-credible contingency events by assessing multiple generator trips or interconnector trip events. AEMO in this analysis should confirm the ability of the under-frequency loadshedding or over frequency generator tripping schemes to manage these events. If the schemes are not sufficient to manage these risks, **Transgrid** recommended focussing on the development of special projection/control schemes.
- In the assessment of sub-network inertia allocation to consider the transfer limits of interconnectors.

SMA Australia remarked that AEMO's proposed approach predominately focuses on inertial response to RoCoF and questioned whether "inertial response to voltage angle deviation had been considered".

Shell Energy, whilst supportive of Step 1 and 2 in Figure 2 below, expressed concerns that it is "unclear what Step 2a would mean in practice". **Shell Energy** also voiced concerns over AEMO's proposed modelling approach, noting the "high risk that the development of the system does not align with modelled requirements over the 10 year horizon which could lead to substantial levels of inefficient investment". **Shell Energy** further recommended that AEMO consider how "the location of inertia services could result in different frequency oscillation modes at a system-wide level".

[5] New clause 5.20B.2(b)(1) to be substituted by the Amending Rule.

Figure 2 AEMO's proposed high level overview of assessment methodology for system-wide inertia levels



Note: As proposed in the Amendments to the Inertia Requirements Methodology – Consultation Paper, see https://aemo.com.au/consultations/current-and-closed-consultations/amendments-to-the-inertia-requirements-methodology.

4.1.2. AEMO's assessment

Specific contingency events

While AEMO agrees with Transgrid's recommendation to consider a range of contingency events when undertaking studies pertaining to the system-wide inertia level, AEMO will only consider credible contingency events when determining the inertia requirements. Regarding the specific non-credible contingency events mentioned, the frequency or likelihood of specific non-credible events being reclassified as credible in operational timeframes is considered when AEMO determines the sub-network islanding risk. This approach ensures that inertia is procured to the secure level in sub-networks at risk of islanding. For the adequacy of under-frequency load shedding and similar backstop mechanisms, these matters and other non-credible events are not covered in the Inertia Requirements Methodology and may be assessed in the General Power System Risk Review[6].

Inertial response based on voltage angle deviation

AEMO agrees with SMA Australia that voltage angle deviation is an important consideration related to power system security. However, the stability of voltage waveforms is specifically accounted for under the System Strength framework[7]. AEMO will use the RoCoF requirements following a credible contingency specified in the FOS, not the voltage angle deviation. However, AEMO notes that a device's response to voltage angle deviation is important and proposes to introduce a test in the inertia services specification to ensure the robustness of a device providing an inertial response (see section 4.3 for details).

Step 2a and modelling of system deviating from actual system

AEMO has modified its approach in this draft determination from the approach proposed step 2a of the consultation paper to vary the distribution of inertia in each inertia sub-network when calculating the system-wide inertia requirements. Step 3) in section 4.6 of the Draft Inertia Requirements Methodology published with this report specifies that the inertia distribution across inertia sub-networks will be determined by the islanded

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[6] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/general-power-system-risk-review.

[7] Stable Voltage Waveform Criteria 2, see https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/system-strength-requirements-methodology.pdf?la=en.

sub-network requirements, and held in this proportion when varying the system-wide inertia level. The purpose of this step is to vary the system wide inertia levels within plausible ranges to understand when the success criteria are not met, so that the technical operating envelope is understood.

AEMO agrees with Shell Energy that accurate modelling of the power system is fundamental to ensuring appropriate investment is undertaken. All forward-looking scenarios will draw on the Integrated System Plan (**ISP**) and the Electricity Statement of Opportunities (**ESOO**) results as appropriate, to improve the accuracy of the calculated inertia requirements.

System-wide frequency oscillation modes and location of inertia services

AEMO agrees with Shell Energy that it is important to consider the impact of geographic distribution of inertia across the NEM. The impacts on factors including the exceedance of interconnector transfer limits, the occurrence of frequency oscillation modes, and the overall stability of the system are accounted for through AEMO's proposed methodology, specifically with the use of appropriate power system modelling. Islanding considerations are accounted for through the procurement of inertia services up to the secure level for regions with a plausible risk of islanding.

4.1.3. AEMO's conclusion

Following assessment of stakeholder feedback, AEMO has made a minor amendment to the proposed methodology for inertia distribution to calculate the system-wide inertia level and the sub-network allocation outlined in the Consultation Paper. AEMO considers this amended approach is fit-for-purpose and aligned with the intent of the Amending Rule.

The Draft Inertia Requirements Methodology published alongside this Draft Report implements the proposed approach from the Consultation Paper, with additional information and clarifications to reflect the assessment of stakeholder feedback provided above.

4.2. NER requirement: process for determining sub-network islanding risk

4.2.1. Issue summary and submissions

The Amending Rule requires that the Methodology describe how the likelihood of a sub-network islanding is determined[8] and sets out the matters that AEMO must take into account in its determination[9].

In the Consultation Paper, AEMO proposed to provide a set of principles in the Methodology that will guide AEMO's determination of sub-network islanding risk in each annual Inertia Report. These principles include the level and duration of inertia typically available, the inertia sub-network allocation in adjacent sub-networks, and the likelihood of islanding under contingency events.

Stakeholders (**SMA Australia** and **Transgrid**) were generally supportive of AEMO's proposed overarching approach on determining the sub-network islanding risk, with **Shell Energy** raising several concerns.

Shell Energy noted that AEMO's proposed approach for determining potential network islanding is "open-ended" which may result in excessive resources being required to determining sub-networks. **Shell Energy**

[8] New clause 5.20.4(d2) to be inserted by the Amending Rule.

[9] New clause 5.20B.2(d) to be inserted by the Amending Rule.

considered further consultation (which AEMO assumes to mean consultation by AEMO) is required to ensure that any sub-network identification progress has applied an appropriate methodology to determine suitable sub-networks.

Shell Energy also suggested that AEMO "use a pragmatic approach based on identifying the weak cut-sets of network edges, and the potential for high power flows across the branches to cause trips, separating the system into islands". **Shell Energy** further noted that radially-fed networks connecting load or generation should not be included as sub-networks.

4.2.2. AEMO's assessment

Granularity of sub-networks and pragmatic approach

AEMO agrees with Shell Energy's assessment that a pragmatic approach should be utilised when determining the sub-network islanding risk, such that the use of overly complex and difficult engineering assessments is avoided. AEMO will classify the islanding risk as either 'plausible' or 'not plausible' for the purposes of applying any calculated regional inertia requirements. This will be based on the list of factors from NER 5.20B.2(d), including matters that AEMO reasonably considers to be relevant to its assessment: evidence from historical islanding events (and any updates since the event occurred); and the frequency or likelihood of specific non-credible events being reclassified as credible in operational timeframes. Additionally, AEMO agrees that small radial islands are not appropriate when identifying the inertia sub-regions, and AEMO has confirmed that the inertia sub-networks remain as the NEM regions at this time.

Sub-network identification process

AEMO agrees with Shell Energy that open stakeholder consultation is important to ensure that an appropriate methodology is applied when determining the sub-network islanding risk. As required by NER 5.20.4, AEMO will apply the standard rules consultation procedure in NER 8.9.2. This will include consultation on the Draft Methodology published alongside this Draft Report, which outlines AEMO's proposed process for determining the sub-network islanding risk.

4.2.3. AEMO's conclusion

Following assessment of stakeholder feedback, AEMO concludes that the proposed methodology to determine the sub-network islanding risk, as outlined in the Consultation Paper, is fit-for-purpose and aligned with the intent of the Amending Rule.

The Draft Inertia Requirements Methodology published alongside this Draft Report implements the proposed approach from the Consultation Paper.

4.3. NER requirement: inertia network services specification

4.3.1. Issue summary and submissions

The Amending Rule requires that the Methodology include a new inertia network service specification that sets out the required capabilities of each kind of inertia network service, and the process and requirements for AEMO to approve the equipment by which inertia network services will be made available[10].

[10] New clause 5.20.4(f) to be inserted by the Amending Rule.

In the Consultation Paper, AEMO proposed to draw from the voluntary grid-forming specification and test specification[11] to provide criteria in the Methodology for non-synchronous inertia providers to qualify as inertia network services. As part of the approvals process, AEMO proposed to estimate the equivalent inertia supplied by a non-synchronous provider through power system simulation. The three assessment methods proposed were:

- Option 1 (a) – Quantifying synthetic inertia using the swing equation – 'direct approach'.
- Option 1 (b) – Quantifying synthetic inertia using the swing equation – 'indirect approach'[12].
- Option 2 – Probing frequency injection method[13].

There was a diverse range of views from stakeholders (**SMA Australia, Tesla** and **Shell Energy**) regarding the necessary contents of the inertia network service specification.

Process and requirements for AEMO to approve equipment – quantifying synthetic inertia assessment method

SMA Australia considered method 1(a) Quantifying synthetic inertia using the swing equation – 'direct approach' as the most appropriate methodology for estimating inertia level provided by inverter-based resources (**IBR**), noting that "it demonstrates grid-forming capability of the equipment". **SMA Australia** noted that method 1(b) Quantifying synthetic inertia using the swing equation – 'indirect approach' and method 2 Probing frequency injection method "may also be passed successfully by using grid-following controls and may not be appropriate to determine the actual capability of the equipment for the provision of grid support during critical network events". **SMA Australia** further remarked "While any of the proposed tests may be able to evaluate the inertial behaviour of the equipment, to ensure that a voltage source control is used, we recommend including a test that validates the contribution of "active phase jump power" in case of a sudden voltage angle change at the [point of interconnection]".

Telsa, noting its extensive experience in this area, expressed its support for method (1)(b) quantifying synthetic inertia using the swing equation – 'indirect approach'. Tesla noted that this method has already been successfully utilised on actual IBR assets, namely AEMO using this method to verify the inertia contribution from Hornsdale Power Reserve. **Telsa** noted that this method is most reliable for correctly assessing inertia contributions.

While **Telsa** noted support for method (1)(b), they still consider method (1)(a) quantifying synthetic inertia using the swing equation – 'direct approach' as being widely adopted by industry and AEMO, and so are still 'relatively supportive' of this method. **Tesla** noted that Method (2) probing frequency injection is less widely adopted by industry and presents more complexity as it would be more challenging to implement.

Shell Energy considered that while not enough information has been provided to determine which approach is most appropriate, all three methods including alternative methods not listed could be appropriate for different contexts. **Shell Energy** further noted that "Explicitly modelling the response of the power system to a loss of

[11] See https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en.

[12] Option 1 (a) and (b) were introduced and investigated in CIGRE Symposium Paper 1296, "Determining inertia contribution from grid-forming battery energy storage systems". See https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en.

[13] Option 2 was introduced and investigated in CIGRE Science & Engineering CSE032, "An online probing frequency injection method for Grid-Forming IBRs inertia measurement". See https://cse.cigre.org/cse-n032/an-online-probing-frequency-injection-method-for-grid-forming-ibrs-inertia-measurement.html.

load, generation or interconnector and considering the frequency control contribution of each type of service is an approach that we support".

Process and requirements for AEMO to approve equipment – damping factor and inertia constant

Transgrid noted the importance of testing the inertial response under a range of different RoCoFs given the complexity of implementing the inertial response in GFM resources, stating:

> *In the reference[14] that explains the method of calculation for IBR, it has correctly referenced to the impact of D being damping factor which is a tuneable parameter in IBRs. However, it has the assumption behind it that the D factor is programmed to be the multiplier of Δf which is not the case for all the GFM technologies. There are technologies that the D factor becomes a multiplier of the second order component of the swing equation due to the effect of filtering (it gets multiplied by S operator in the frequency domain). So, it would be good if AEMO could comment what should be done for those conditions. Transgrid, in the GFM specification, has recommended that for simplicity of planning that if swing equation is implemented, it must be implemented exactly as the synchronous machine to avoid this non-linearity. What this additional filtering can also add is non-linearity between RoCoF and inertia constant because of the ratio I_total on page 19, will have S in its formula which means unlike Synchronous generators, GFM technologies may have different synthetic inertia at different RoCoF.*

SMA Australia recommended the consideration of the "impact of damping and inertia constant as these parameters influence the dynamic of power provision during a given RoCoF profile".

SMA Australia also requested clarification of AEMO's statement on page 18, regarding 'the requirement for a tuned inertia constant based on both local and broader network conditions and requirements if configurable', raising the following questions:

1. *Is the ability to configure inertial behaviour considered necessary?*
2. *Will configurability of inertia be mandatory?*
3. *What would be the desired range of tuneable inertia constant?*
4. *What conditions would trigger different inertia constant values?*
5. *Would a proposed system have to perform modelling for a range of different inertia constant values?*

Process and requirements for AEMO to approve equipment – other

Transgrid encouraged AEMO to consider the following points:

> *We recommend that the GFM [original equipment manufacturer] be provided with the control block diagram, as this will allow us to back calculate the swing equation from the block diagram into the swing equation format to understand the exact inertia numbers.*
>
> *We believe it would be appropriate for AEMO to explore what the status of Frequency control including PFR and FFR should be when all of these tests are undertaken for calculating the synthetic inertia.*

[14] Transgrid is referring to CIGRE Symposium Paper 1296, "Determining inertia contribution from grid-forming battery energy storage systems" https://www.e-cigre.org/publications/detail/cse020-cse-020.html.

There could be limitations in the GFM BESS [grid-forming battery energy storage system] technologies such as how many times full charge or discharge can occur in the event of frequency disturbances within a limited window of time.

There could also be limitations of providing fault current during a system fault (voltage disturbances) which is concurrent with a frequency disturbance such as a synchronous machine fault which leads to a trip of the synchronous generator. The tests must ensure that the same inertia is provided if the voltage and frequency disturbances are happening simultaneously.

In some country grid codes, the use of virtual impedance in the GFM technology is not allowed. It would be great if AEMO could clarify its position about that and more specifically mentions it in the specification.

Another specification that may need to be considered is the post fault behaviour. In some batteries which are programmed to provide synthetic inertia, it has been observed that post a fault that is associated with a frequency drop, there has been significant Active Power disturbance which adversely impact the nadir. It might be worth emphasising that such observation will not be acceptable.

Considering that inverters typically function under active or reactive current priority, under some conditions system strength service (reactive power) and inertia service might have aligned interest.

It is worth investigating the effect of System Strength over the Inertia service to understand if there is a direct or indirect influence.

Can AEMO also discuss if the approval is fully dependent on the modelling prior the connection or this approval is conditional to the proving of results during the Commissioning and operation. Considering the lack of maturity of the industry in this area, Transgrid recommend specific commissioning, R2 model validation and more onerous ongoing compliance monitoring is applied for the projects which provide these services.

SMA Australia noted support for the certification of equipment and further remarked that "plant level performance should be validated via laboratory and HIL [hardware in the loop] testing of equipment and plant level simulations with EMT [electromagnetic transient] capable software for provision of inertia and other stability services by AEMO". **SMA Australia** also remarked that plant and equipment level assessments of performance is required as the "point of interconnection" is where stability is measured and must be maintained.

SMA Australia requested that AEMO provide a comprehensive explanation for excluding "alternator-based technologies" from the approval procedure.

SMA Australia also proposed "implementation of a RoCoF test to determine compliance".

Required capabilities of synchronous and synthetic inertia service providers

Tesla noted alignment with the synthetic inertia description and parameters AEMO noted in section 3.3.3 of the Amendments to the Inertia Requirements Methodology Consultation Paper but also noted that there is an increasing body of evidence showing that GFM battery energy storage systems can provide synthetic inertia.

Transgrid noted the following advice that it has used to assist project proponents to better understand sufficient levels of headroom for system strength services from GFM battery energy storage systems, in case useful for AEMO also:

> *The headroom for Active Power must be selected in such a way that generator would not reach its maximum active power (whether continuous rating limit or optional overload limit), for a 1.0 Hz/s event as the highest ROCOF for a credible contingency in Frequency Operating Standard [6]. As the response from the battery is considered to be dependent on the swing equation modelling, the required headroom can be back-calculated from the swing equation which is a function of constant inertia for the highest ROCOF identified in [6], being 1.0 Hz/s for Mainland. The AEMC may revise this value of ROCOF in the Frequency Operating Standard, and if so, then the amount of headroom will need to be amended by the Proponent accordingly.*

SMA Australia considered it critical that assets dedicated to providing system strength and inertia remain in voltage control mode at all times.

SMA Australia suggested that the following wording be amended from "[…] in the form of an inherent change in active […] which results in a voltage angle or frequency change" to "Active Phase Jump Power" or "RoCoF Power" in order to align with industry standards.

SMA Australia agreed that "inverters equipped with advanced functionality for the provision of grid services do not need to detect a frequency disturbance, they must react inherently to frequency events or voltage angle changes. This reaction is immediate and therefore there is no time delay". **SMA Australia** further suggested "defining inherent response as a current/power response that occurs within <5 [milliseconds] ms of the disturbance".

SMA Australia agreed with AEMO that the service's resistance to change in frequency is bi-directional resisting frequency changes for both rising and falling frequency events". **SMA Australia** agrees that this is required, as asymmetrical inertia services may cause frequency drift and oscillatory issues negatively impacting stability.

SMA Australia further noted that due to the limited boost capacity of inverters, a higher number of assets may be required to provide the same service unless capacity is reserved. Reserving capacity has a cost to the project due to lost revenue, this would need to be compensated in order to make it attractive. **SMA Australia** are therefore proposing that "an availability threshold should be defined, e.g. 95% fixed contractually". **Shell Energy** suggested that AEMO reconsider the requirement that the initiation of synthetic inertia response must be inherent, that is, it should not require the calculation of the frequency or RoCoF through measurements of the grid voltage waveform. **Shell Energy** considers that this requirement would rule out IBR as contributors to synthetic inertia provisions as all electric systems require measurements of the voltage waveform.

Shell Energy recommended including other services which have the ability to contribute to frequency control and system security such as fast load modulation, load shedding and generation curtailment.

Increasing penetration of GFM

Transgrid noted that "In a recent observation, that one of the OEM batteries equipped with Synthetic inertia, for a given 2-second window from the beginning of a disturbance, the battery energy storage system provides 27% of the total energy injected in the first second (first half) and the rest in the second half. For a synchronous generator, the same ratio is about 58% in the first half and the rest in the second half". **Transgrid** further remarked "This may not be problematic but only an observation to Transgrid; however, this raises a question whether the rate of response throughout 1-2 seconds would matter or not for the system if many large-scale Synchronous Generators are replaced by large-scale batteries with the noted behaviour".

4.3.2. AEMO's assessment

Process and requirements for AEMO to approve equipment - quantifying synthetic inertia assessment method

AEMO will use Option 1 (b) – Quantifying synthetic inertia using the swing equation – 'indirect approach' to quantify synthetic inertia as part of the approvals process. However, AEMO has proposed the following additions following stakeholder feedback:

- AEMO agrees that "active phase jump power" in case of a sudden voltage angle change is an important characteristic to ensure that the inertial response is provided robustly. AEMO proposes to draw on Test 7 of the Voluntary Simulation Test Framework for Grid Forming Inverters[15] if the plant being tested is an IBR.
- Explicitly modelling frequency response after a contingency event.

Process and requirements for AEMO to approve equipment – damping factor and inertia constant

AEMO agrees with Transgrid and SMA Australia that the non-linearity between damping factor and RoCoF, and RoCoF and the inertia constant are important. Therefore AEMO has now proposed that:

- AEMO's inertia service specification intends to test a range of RoCoF conditions, to ensure the inertial response is robust against a range of possible operating conditions. AEMO proposes to limit the RoCoF used in testing to 3 hertz per second (**Hz/s**). This value is based on the difference between what must be maintained under the Frequency Operating Standard (**FOS**) and what constitutes reasonable endeavours. Note these tests are different for Tasmania, given its different treatment under the FOS.
- AEMO will test for a range of charge and discharge levels to ensure the provision of inertia is understood across a range of operating conditions. AEMO also notes that operational headroom requirements may be specified in contracts for inertia services if required to meet the required inertial response.

Regarding SMA Australia's specific question on whether the inertia constant required to be tuneable or configurable, AEMO's statement on page 18 of the Consultation Paper refers to tuning the inertia constant at the design stage to allow provision of the inertia without resulting in other negative impacts on the grid.

Process and requirements for AEMO to approve equipment – other

AEMO agrees with Transgrid that:

- Status of frequency control modes (primary frequency response (**PFR**) and fast frequency response (**FFR**)) should be disabled when all of these tests are undertaken. This has been included in the testing methodology for non-synchronous equipment in the Inertia Network Services Specification published alongside this determination. This is aligned with AEMO's voluntary grid-forming inverters specification and test specification, as referenced in the Consultation Paper[16].

[15] See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en&hash=7778A2249D8C29A95A2FADCD9AAA509D.

[16] AEMO, Voluntary Specification for Grid-forming Inverters: Core Requirements Test Framework, January 2024. At https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf?la=en.

- Inertia should be provided and quantified if a voltage and frequency disturbance happen simultaneously. After receiving this stakeholder feedback, AEMO has included a test reflecting this in the Inertia Network Services Specification[17].
- Response to fault events is critical. Following the receival of this feedback, AEMO has included fault events and the subsequent response as part of the Inertia Network Services Specification.
- There are significant opportunities to align the provision of system strength services and inertia services. This is an ongoing area of investigation for AEMO, which will continue to work with TNSPs to ensure any opportunities are realised.
- It is important how many times a battery energy storage system can fully charge/discharge during a frequency disturbance within a limited window of time. However, AEMO anticipates that this is outside of the inertia test specification and considers it as part of the commercial arrangements the TNSP may determine when contracting with potential inertia providers.

Transgrid noted that in some country grid codes, the use of virtual impedance in the GFM technology is not allowed. AEMO is not aware of any reason why it would be appropriate to restrict this particular technology, as NER 5.20B.4(g) will enable AEMO to approve devices under the inertia network service specification that can provide inertia network services that meet the specified criteria, and which are not synchronous production units or synchronous condensers. This means the test specification could apply to other non-GFM plant.

While it can be beneficial to have block diagrams to back calculate the swing equations as noted by Transgrid, AEMO does not consider this to be required to be included in the Methodology.

SMA Australia requested an explanation of the rationale behind the exclusion of alternator-based technologies from such an approval procedure. AEMO notes that NER 5.20.4(g) will only enable non-synchronous devices to be tested under the inertia services specification for the purposes of approval.

AEMO notes that approval under the Inertia Network Services Specification is fully dependent on demonstrating compliance with the relevant specification through modelling, and this approval is conditional to the validation of modelling results during commissioning and operation where relevant.

Required capabilities of synchronous and synthetic inertia service providers

SMA Australia suggested that the equipment should remain in voltage control mode at all times. AEMO acknowledges this has merit, however, considers that the inertia service specification needs to cover any technology type and specifying a mode may restrict future novel solutions.

SMA Australia suggested defining inherent response as a current/power response that occurs within <5 ms of the disturbance. AEMO agrees that the speed of response is important but will be assessing the active power output or inertial response over 2 seconds from the time of the disturbance. AEMO has defined an inherent inertial response in section 2.1.1 of the Draft Inertia Requirements Methodology as initiated by the device resisting a change to the voltage angle at its point of connection that occurs during a change in system frequency.

AEMO proposes the energy buffer required to provide the inertial response is best managed through contractual arrangements. The inertia services specification will test the device for a range of different operating points

[17] This is an additional requirement to the testing approach established by AEMO in *Quantifying Synthetic Inertia of a Grid-forming Battery Energy Storage System – Preliminary Report*. See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2024/quantifying-synthetic-inertia-from-gfm-bess.pdf?la=en.

(charge/discharge etc) to understand how it performs, and any application of an energy buffer will be addressed through contractual arrangements, where relevant.

Shell Energy queried AEMO's use of the term 'inherent', and indicated all electronic systems require measurements of the voltage waveform. AEMO notes that in this context 'inherent' does not mean that the output is independent of the grid, rather that the voltage reference used to determine the output is independent of the grid over the sub-transient timeframe. AEMO has clarified the meaning of 'inherent' in the definition of an 'inertial response' in the Draft Inertia Requirements Methodology.

Shell Energy noted that services such as fast load modulation, load shedding, and generation curtailment in response to frequency excursions should be considered as possible non-synchronous inertia network services. AEMO agrees that these can assist with frequency control, however they may not strictly provide an *inertial response,* which is what is required for an inertia network service. Separately, fast load modulation and generation curtailment controls schemes may fall within the frequency control ancillary services (**FCAS**) which is part of the overarching approach to frequency control in the NEM.

Increasing penetration of GFM resources

AEMO thanks Transgrid for sharing its learnings in this space. AEMO agrees and the Inertia Network Services Specification will be focused on <2 second (s) timeframes, and the way that the inertial response varies over this timeframe.

AEMO notes that the number of GFM resources in the NEM is increasing quickly so it is important to evolve this relatively new framework to keep pace with industry's growing understanding of the characteristics of GFM resources and their benefits to the power system.

4.3.3. AEMO's conclusion

Following assessment of stakeholder feedback, AEMO concludes that the core concepts proposed in the Consultation Paper are valid and aligned with the intent of the Amending Rule. AEMO has sought to integrate significant feedback and add appropriate detail and clarification in the inertia service specification as part of the Draft Inertia Requirements Methodology. AEMO notes that much of the feedback focused on GFM inverters, however the inertia service specification must cater for all devices which are not synchronous.

The Draft Inertia Requirements Methodology published alongside this Draft Report implements the proposed approach from the Consultation Paper, with the changes noted in section 4.3.2 to reflect the incorporation of stakeholder feedback.

4.4. Methodology improvement: redispatch assumptions

4.4.1. Issue summary and submissions

The current Methodology assumes that a generating unit's output will reduce to its minimum operating level via the central NEM dispatch process under certain conditions to reduce the size of the generation contingency to the lowest practical level[18].

[18] See p 18, https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-security-market-frameworks-review/2018/inertia_requirements_methodology_published.pdf?la=en&_sm_au_=iVVNjrDPDvrGWTv7j03pfK3k7WNW4.

In the Consultation Paper, AEMO proposed to amend this assumption in the Methodology to account for circumstances where it is not practicable to reduce the size of a contingency event by reducing a generating unit's output in advance of the contingency occurring.

Regarding the amendment of this assumption, some stakeholder submissions were supportive (**Transgrid** and **SMA Australia**), whilst others offered suggestions (**Powerlink** and **Shell Energy**).

Powerlink was supportive but urged AEMO to consider "only plausible system conditions and dispatch patterns".

In response to the merit of increasing the threshold for inertia (to 99.7th percentile), **Powerlink** raised concerns that this change presents a risk of over-procuring inertia services, with associated potential for increased costs. **Powerlink** noted the challenges with changing the existing measure (1% tolerance band), considering their obligations to respond to declared inertia shortfalls. **Powerlink** also highlighted that AEMO still have the capability to use directions in lieu of using more conservative assumptions. **Powerlink** made the same recommendation for when AEMO considers the maximum contingency size.

Shell Energy noted that "The current level of detail around sub-network selection, location and resource mix is insufficient to make an informed determination regarding the appropriateness of the proposed amendments". **Shell Energy** also considered that "further consultation on identifying sub-networks is necessary to inform the methodology for calculating inertia requirements in each area". **Shell Energy** further remarked that "The transition of the grid to low or near zero (physical) inertia should be considered" and that "The secure and reliable operation of the grid under the widest range of conditions is the goal rather than inertia levels alone".

4.4.2. AEMO's assessment

While AEMO acknowledges Powerlink and Shell Energy's feedback, AEMO does not propose to change its approach from that proposed in the Consultation Paper. AEMO does have existing operational procedures and practices in place for managing the contingency size, such as reducing interconnector flow or generator output, and several stakeholders (Transgrid and SMA Australia) did highlight that modelling generator dispatch to a plausible level above minimum stable level may be appropriate.

4.4.3. AEMO's conclusion

Following assessment of stakeholder feedback, AEMO concludes that the proposed methodology to consider dispatch of generators above their minimum stable level is appropriate, as long as the dispatch level is plausible given the system conditions and justified in the Inertia Report. AEMO considers this aligns with the intent of the Amending Rule.

4.5. Methodology improvement: credible events leading to island formation

4.5.1. Issue summary and submissions

The current Methodology does not explicitly account for the contingency event(s) that may cause an island to form, and instead assumes that during credible islanding risks the relevant interconnector flows could be constrained to manage this risk. However, historical events[19] have shown that this is not always a valid assumption.

In the Consultation Paper, AEMO proposed to amend the Methodology to allow consideration of credible events that may cause the formation of an island, when assessing satisfactory inertia level requirements.

Transgrid and **SMA Australia** were generally supportive of AEMO's proposed methodology amendment to allow consideration of credible events that may cause the formation of an island, when assessing satisfactory inertia level requirements. **Powerlink** were supportive but urged AEMO to consider "only plausible system conditions and dispatch patterns".

Shell Energy requested further information on sub-network determination and interconnector flows reiterating that is it uncertain how inertia sub-networks will be determined and that it is unclear how interconnectors flows are expected to behave or be considered.

4.5.2. AEMO's assessment

Stakeholders generally agreed that considering credible events that led to the island formation should be considered when setting the inertia requirements. Stakeholders also noted that the interconnector flows in general are important when setting the inertia requirements. AEMO considers that modelling interconnectors at a range of operating conditions is important to setting the inertia requirements for an interconnected NEM.

4.5.3. AEMO's conclusion

AEMO will consider contingencies that could cause the formation of an island as part of the Methodology. AEMO agrees that further detail is required, and this has been added the Draft Inertia Requirements Methodology for stakeholder consideration.

4.6. Methodology improvement: additional modelling considerations

4.6.1. Issue summary and submissions

The Amending Rule requires that AEMO annually publish a forecast of inertia requirements for the next 10 years[20]. In the Consultation Paper, to improve the accuracy of these inertia requirement forecasts, AEMO proposed to update the Methodology to explicitly provide for:

- Modelling expected changes in supply, demand, and network assumptions over the 10-year horizon. This includes, but is not limited to, generator retirement, committed projects, network augmentations, distributed photovoltaics (**DPV**), and load modelling assumptions.
- Improvements to the modelling approach to account for network parameters that impact contingency sizes, and possible use of more sophisticated modelling approaches (such as multi mass models (**MMM**s)) where necessary to add confidence to system-wide inertia results.

[19] AEMO, Final Report – South Australia Separation Event, 1 December 20216. At https://aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Final-report---SA-separation-event-1-December-2016.pdf.

[20] New clause 5.20B.2(b) to be substituted by the Amending Rule.

Submissions were generally supportive (**Transgrid** and **Tesla**) of AEMO's proposed methodology improvement to explicitly provide for the above considerations, whilst also offering suggestions (**Transgrid**, **SMA Australia** and **Shell Energy**).

Transgrid expressed support in response to the proposal to model expected changes in supply, demand and network assumptions. However, **Transgrid** highlighted the need for consistency of data with a focus on the consistency of forecast demand that is delivered from distribution network service providers and the location of future IBRs. **Transgrid** suggested the development of a template for the exchange of forecast data to allow all participants to take advantage of accessing consistent data, and that the template should be prepared in consultation with network service providers.

Transgrid would like to understand if AEMO intends to use the MMM for modelling synchronous generators or if AEMO will include other types of generators such as wind turbines, and whether this is applicable to existing or only future generators. **Transgrid** highlights that careful consideration is required, raising concerns that new forms of oscillations may be introduced that would be difficult to investigate.

Transgrid have requested for AEMO to share with TNSPs the PSS®E model used to prepare the requirements.

SMA Australia highlighted that "other markets around the world are implementing standardised network models for relevant sub-networks to aid proponents with assessing project viability by facilitating initial feasibility studies without the need to commit to full connection studies at an early stage. Implementation of cloud-based network models may be an interesting initiative for the Australian market to support project proponents in the initial stages of project assessment".

Shell Energy noted that sufficient detail is required for future system conditions to enable the assessment of each type of service explicitly. It noted to build confidence that the procurements of services will deliver the expected system security outcomes, a "range of future service mix outcomes" should be considered. **Shell Energy** also highlighted the importance of model calibration, in particular the model should align with real world outcomes.

4.6.2. AEMO's assessment

Future network models

Generally, stakeholders considered that inclusion of future network developments was appropriate where sufficient information is available. AEMO expects flexibility is warranted when determining the inertia requirements towards the end of the 10-year horizon, however the binding requirement (t+3) will be based on committed[21] projects only. Transgrid also suggested greater information sharing with TNSPs and distribution network service providers, which AEMO suggests can be discussed further through existing joint planning processes.

Multi-mass model

The MMM would be an extension of the simplified NEM-like model in PSS®E developed by Vysus for the report '*The role and need for inertia in a NEM-like system*'. This work was part of the Engineering Roadmap[22]. AEMO

[21] For the definition of committed, please see AEMO's latest Transmission augmentation information page, at https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/transmission-augmentation-information .

[22] AEMO, Engineering Roadmap Execution Reports, at https://aemo.com.au/initiatives/major-programs/engineering-roadmap/engineering-roadmap-execution-reports.

may use the MMM to help assess secure interconnected operation, however using a full NEM model is a more appropriate approach. AEMO agrees that caution needs to be exercised when using an MMM. The Vysus work used generic models 'lumped' together to reflect the generators in the NEM, including synchronous, grid-following, and grid-forming models.

Single mass model

A single mass model is an equivalent representation of generating units with various inertia to a generating unit with an equivalent inertia. This model represents the swing equation of the power system. AEMO will continue using a tuned single mass model to assess secure operation for an inertia sub-network when islanded. This is appropriate as the interconnector and other regions are not relevant for this case.

Explicit modelling and monitoring models

AEMO agrees that model performance should be benchmarked against actual real world events wherever possible. Likewise, the range of available services (in particular the available FCAS) will be included in the model as appropriate. This is further discussed in section 4.7.

4.6.3. AEMO's conclusion

Following assessment of stakeholder feedback, AEMO concludes that the additional modelling considerations, as outlined in the Consultation Paper, are appropriate and aligned with the intent of the Amending Rule. AEMO has provided additional information in the Draft Inertia Requirements Methodology in response to stakeholder feedback.

4.7. Stakeholder feedback: inertia, FFR and Very Fast FCAS (VFFCAS) relationship

4.7.1. Issue summary and submissions

There is an important relationship between the inertia requirements, FFR and VFFCAS. Essentially, the more FFR (or VFFCAS) is available, the less inertia is required, up to a point. Several submissions (**Transgrid, SMA Australia, Tesla** and **Shell Energy**) specifically suggested further exploration and definition of the relationship between inertia, FFR and VFFCAS when defining the inertia requirements.

Transgrid supported the Methodology proposed by AEMO. In step 3 of the process where AEMO proposes that higher FFR would be needed for lower inertia conditions, Transgrid requested that AEMO clarify whether the FRR technology sources is mostly IBR. **Transgrid** further stated that "it would be prudent to assess the dynamics of Active Power injection from different sources of energy (e.g. battery energy storage systems versus Synchronous Generators), which may change the contracted FFR service". **Transgrid** stated that if this is not considered "it would be beneficial to test a diverse range of dynamic responses to check the sensitivity of the required FFR for operation with lower inertia".

SMA Australia affirmed its understanding that network service providers will issue competitive tenders triggered by the identification of a shortfall as per AEMO's annual Inertia Report. **SMA Australia** propose "an inertia market based on $/MWs paid according to plant desired availability, for example, >95% under a fixed time-based contract (e.g. 10 years)". Both **Shell Energy and SMA Australia** expressed concerns regarding any overlap of services. **SMA Australia** noted that "these markets are different and complementary to one another, frequency response does not substitute the provision of inertia". **SMA Australia** requested "a clearer differentiation between frequency markets and the inertia market as a mechanism to prevent "cannibalization" between these".

Similarly, **Shell Energy** noted that various services, such as FFR and FCAS should be modelled explicitly, warning against the use of equivalence curves as they could result in an incorrect understanding of the physical relationships between the services "risking serious engineering errors due to inadequate or flawed understanding of the system". **SMA Australia** further highlighted that "inertia is an inherent, delay-free response, whereas VFFCAS is a response to a measurement, and it operates in a longer timescale".

Telsa supports AEMO's work in identifying and expanding the relationship between inertia and FFR. **Tesla** also encouraged "further exploration on this issue to better understand how inertia requirements could be substituted by procuring 1-second (1s) FCAS". **Tesla** noted that on the 12 November 2022 the procured FRR capacity from both Hornsdale Power Reserve and Telsa South Australia Virtual Power Plant demonstrated the effectiveness of non-network solutions such as GFM resources providing inertia support activities.

4.7.2. AEMO's assessment

Explicit separation of FCAS services, FFR, Inertia and other services

A number of stakeholders highlighted the importance of being clear about how FFR, FCAS, and inertia are delineated, as well as how they interact. Furthermore, many of the submissions highlighted the importance of ensuring the actual behaviour is explicitly modelled. AEMO agrees this is important and dynamic power system analysis in appropriate software such as PSS®E will be undertaken.

AEMO notes that it is still important to understand how the inertia requirements will change given the increasing amount of 1s FCAS being registered in the market. While it is complex and non-linear, more 1s FCAS or FFR can reduce the inertia requirements, to a certain point. AEMO will use both PSS®E and lumped (either single mass or multi-mass) models to understand these interactions, given the resources required to run hundreds of PSS®E dynamic studies can be onerous. These lumped models will be tuned and benchmarked to ensure they are reasonable.

Commercial arrangements

Several submissions provided feedback on potential market and commercial arrangements. While AEMO welcomes this feedback, the Methodology will focus on the technical nature of the requirements. TNSPs are better placed to engage with commercial considerations if any inertia shortfall is declared.

4.7.3. AEMO's conclusion

AEMO has concluded that the inclusion of FFR and the FCAS services are appropriate in determining the inertia requirements and will model these services and their interdependencies using appropriate techniques. AEMO has provided further information on this in the Draft Inertia Requirements Methodology. AEMO considers this is aligned with the intent of the Amending Rule.

5. Other matters

5.1. Minor amendments and updates

In the Consultation Paper, AEMO proposed several minor amendments and updates to reflect the Amending Rule and to improve the clarity or accuracy of the existing Methodology. These are summarised as follows.

- **Revised NSCAS arrangements** – the Amending Rule changes the definitions of "NSCAS need" and "NSCAS gap" [23]. This change allows shortfalls in inertia network services and system strength services to be identified under the NSCAS framework within a rolling three-year period[24]. AEMO proposed to update the Methodology to remove references to the previous approach.
- **Terminology updates** – the Amending Rule changes the NER-defined term "minimum threshold level of inertia" to "satisfactory inertia level" and "secure operating level of inertia" to "secure inertia level". However, there is no change to the content of the definitions of these two inertia requirements[25]. AEMO proposed to update these terms accordingly in the Methodology.

One stakeholder, **Shell Energy**, highlighted the importance of assessing inertia holistically within the broader context of frequency control at the system-wide and inertia sub-network levels, highlighting the potential for overly concentrated inertia to produce unwanted effects.

5.1.1. AEMO's assessment

AEMO agrees with stakeholders that inertia is only one part of the required services for appropriate frequency control. Likewise, high levels of inertia or concentrations of inertia in a particular area can have unwanted effects, as noted by Shell Energy. The inertia requirements are set with the goal of achieving frequency control, which is defined in the FOS[26]. Inertia requirements sit alongside a range of other system services to meet the FOS, including FCAS, FFR, and PFR.

5.1.2. AEMO's conclusion

The minor amendments and updates are appropriate and aligned with the Amending Rule.

[23] New NER Chapter 10 definitions of 'NSCAS gap' and 'NSCAS need' to be substituted by the Amending Rule.

[24] New clause 5.20.3(c1) to be inserted by the Amending Rule.

[25] New clause 5.20B.2(b)(3) and (4) to be inserted by the Amending Rule.

[26] See https://www.aemc.gov.au/sites/default/files/2024-01/Frequency%20Operating%20Standard.pdf.

6. Draft determination on proposal

Having considered the matters raised in submissions to the Consultation Paper, AEMO's draft determination is to amend the Methodology in the form published with this draft report, in accordance with NER 5.20.4 (as amended by the Amending Rule).

Effective date

The amended Methodology will take effect on 1 December 2024 and be used for the purposes of the Inertia Report to be published by AEMO on that date.

Appendix A. Glossary

This document uses terms defined in the NER, with the same meanings. NER acronyms and some additional terms used in this document are defined here for convenience.

Term or acronym	Meaning
Acceptable Frequency	The frequency at all energised busbars of the power system is within the normal operating frequency band, except for brief excursions outside the normal operating frequency band which remain within the normal operating frequency excursion band.
AEMC	Australian Energy Market Commission
Amending Rule	National Electricity Amendment (Improving security frameworks for the energy transition) Rule 2024 No. 9
Contingency FCAS	Each of the following: • Very fast (1s) raise service. • Very fast (1s) lower service. • Fast (6s) raise service. • Fast (6s) lower service. • Slow (60s) raise service. • Slow (60s) lower service. • Delayed (5m) raise service. • Delayed (5m) lower service.
DPV	distributed photovoltaics
ESOO	Electricity Statement of Opportunities
Fast FCAS	fast raise service and fast lower service
FCAS	frequency control ancillary service/s
FFR	fast frequency response
FOS	Frequency Operating Standard
FRT	fault ride-through
Generation event	Any of the following events: 1. A synchronisation of a generating unit of more than the generation event threshold of: a) for the Mainland: 50 megawatts (MW). b) for Tasmania: 20 MW. 2. An event that results in the sudden, unexpected and significant increase or decrease in the generation of one or more generating systems totalling more than the generation event threshold for the region in aggregate within no more than 30 seconds. The disconnection of generation as the result of a credible contingency event (not arising from a load event, a network event, a separation event or part of a multiple contingency event), in respect of either a single generating system or a single dedicated connection asset providing connection to one or more generating systems.
GFM	Grid-forming
IBR	inverter-based resource/s
Inertia Rule	National Electricity Amendment (Managing the rate of change of power system frequency) Rule 2017 No. 9.
Inertia year	Each period of 12 months commencing 2 December.
Island	A part of the power system that includes generation, networks and load, for which all of its alternating current network connections with other parts of the power system have been disconnected, provided that the part: 1. Does not include more than half of the combined generation of each of two regions (determined by available capacity before disconnection); and Contains at least one whole inertia sub-network.
ISP	Integrated System Plan

Term or acronym	Meaning
Load event	• For the Mainland: connection or disconnection of more than 50 MW of load not resulting from a network event, generation event, separation event or part of a multiple contingency event. • For Tasmania: either a change of more than 20 MW of load, or a rapid change of flow by a high voltage direct current interconnector to or from 0 MW to start, stop or reverse its power flow, not arising from a network event, generation event, separation event or part of a multiple contingency event.
Mainland	The Queensland, New South Wales, Victoria and South Australia regions.
Methodology	AEMO's Inertia Requirements Methodology
minimum operating level	As defined in clause S5.2.5.11 of the NER.
MMM	multi-mass model
ms	millisecond/s
MW	megawatt/s
MWs	megawatt-second/s
NEM	National Electricity Market
NEO	National Electricity Objective as expressed in section 7 of the National Electricity Law
NER	National Electricity Rules
Network event	A credible contingency event other than a generation event, load event, separation event or part of a multiple contingency event.
New clause/rule [number]	A clause or rule from the NER as amended by the Amending Rule.
Non-synchronous equipment	See 'IBR'
NSCAS	network support and control ancillary service/s
PCC	Point of common coupling
PFR	Primary Frequency Response, an automatic change in a generating system's active power output, to oppose or arrest frequency changes.
RoCoF	rate of change of frequency
s	second/s
Separation event	A credible contingency event affecting a transmission element that results in an island.
SMM	Single mass model, an equivalent representation of generating units with various inertia to a generating unit with an equivalent inertia. This model represents the swing equation of the power system.
Synthetic inertial response	The emulated inertial response from an inverter-based resource that is inherently initiated in response to a power system disturbance, and sufficiently fast and large enough to help manage RoCoF.
TNSP	transmission network service provider
UFLS	under-frequency load shedding
VFFCAS	Very Fast FCAS, the 1 second raise and lower FCAS markets

Appendix B. List of submissions and AEMO responses

No.	Stakeholder	Issue	AEMO response
1	Various	NER requirement: system-wide inertia level and inertia sub-network allocation	See section 4.1.
2	Various	NER requirement: process for determining sub-network islanding risk	See section 4.2.
3	Various	NER requirement: inertia network services specification	See section 4.3.
4	Various	Methodology improvement: redispatch assumptions	See section 4.4.
5	Various	Methodology improvement: credible events leading to island formation	See section 4.5.
6	Various	Methodology improvement: additional modelling considerations	See section 4.6.
7	Various	Stakeholder feedback: inertia, FFR and VFFCAS relationship	See section 4.7.
8	Powerlink	"It is not clear to Powerlink why the secure level of inertia is required prior to the separation event occurring. Given that the secure level of inertia is greater than the satisfactory level this would incur additional unnecessary costs, assuming that these additional levels of inertia could be made available within 30-minutes".	This is a requirement under NER 5.20B.4. Furthermore, making additional inertia available within 30 minutes does not assist with meeting the FOS requirements.
9	SMA Australia	"SMA considers inverters with true voltage source controls to behave in an equivalent manner to synchronous equipment, we therefore would recommend against the use of the term non-synchronous to refer to our equipment. True voltage source control is defined in this context as an inverter that remains in voltage source control even in the event of a fault, never reverting to current control during operation".	AEMO defines a synchronous inertial response as the electromechanical inertial response from stored kinetic energy in the rotating mass of a machine that is electro-magnetically coupled to the power system's voltage waveform at 50 Hz. As IBR are interfaced with the power system through power electronic devices, AEMO considers their inertial response to be non-synchronous[27]. AEMO acknowledges that GFM inverters can provide inertial responses similar to synchronous machines, and will capture this in the synthetic inertia specification.
10	SMA Australia	"Further detail and additional criteria would be required to fully understand the inertia market design (e.g. what is the unit of inertia that will be procured? MWs, MW, etc.)".	Further detail pertaining to the requirements for non-synchronous services to qualify as inertia network services is outlined in AEMO's draft inertia networks services specification, published in parallel of this report.
11	Shell Energy	"In Section 3.3.4: The first formula listed is incompletely defined and requires reference to the source CIGRE document. When we downloaded the referenced document to validate the formula it appeared not to contain the relevant formula. We would suggest the second formula be revised to conform with conventions to avoid confusion".	AEMO agrees with Shell Energy that the document referenced in Footnote 22 did not contain the relevant formula. AEMO's preliminary report on Quantifying Synthetic Inertia of a Grid-forming Battery Energy Storage System contains an overview of the approach and the relevant formulas[28].

[27] For further information, see https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/inertia-in-the-nem-explained.pdf?la=en.

[28] See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2024/quantifying-synthetic-inertia-from-gfm-bess.pdf?la=en.

No.	Stakeholder	Issue	AEMO response
12	Transgrid	"Page 8- point 1 refers to ROCoF limit following any credible contingency event. Considering the RoCoF after the contingency event is the function of remained inertia within the system, and also the fact that the most onerous contingency in this condition could be tripping of one of the synchronous machine, is this requirement always referring to RoCoF under N-1? We would appreciate further clarification on this point".	The requirement to consider the RoCoF limit for the mainland NEM following a credible contingency event is described under NER 5.20.4(d1). NER 5.20B.2(b)(1) also defines the system-wide inertia level as the minimum level of inertia required to continuously operate the power system (excluding the Tasmania region) in a secure operating state where no inertia sub-network is islanded. To operate the power system in a secure operating state, AEMO must be able to return power system operation to a satisfactory operating state following a credible contingency event (N-1).
13	Transgrid	"Page 8- point 4 refers to AEMO's approval of the service based on the specifications defined in inertia service specifications. Considering the timeframe Dec 2027 that TNSPs must meet this requirement, what is the timeframe of this specification publication".	Refer to section 4.3. AEMO's final inertia network services specification will be published in parallel with the final methodology. A draft inertia network services specification has been published in parallel with this report.