Review of Technical Requirements for Connection

4 April 2023

Addendum to Draft Report

Draft recommendations for amendments to Schedule 5.3 of the National Electricity Rules

Important notice

Purpose

This is an addendum to, and forms part of, a draft report published by AEMO in accordance with clause 5.2.6A(d) of the National Electricity Rules, as part of AEMO's periodic review of the technical requirements for connection in the National Electricity Market.

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Executive summary

This addendum to the draft report presents AEMO's consideration and initial recommendations on changes to the National Electricity Rules (NER) technical requirements for connection in the National Electricity Market (NEM) relating to Schedule 5.3 (conditions for connection of customers). This addendum forms part of the separate draft report document published on 3 March 2023, which focuses on Schedules 5.2 and 5.3a of the NER. Section 4 of this document should be taken as being Section 4 of the draft report published on 3 March 2023 and is to be read in this context. Both documents are part of the review (Review) that AEMO must conduct, pursuant to clause 5.2.6A(a) of the NER, at least once every five years.

The NER require the Review to consider some or all of the technical requirements set out in Schedule 5.2, Schedule 5.3 and Schedule 5.3a and assess whether those requirements should be amended, having regard to the following criteria (review criteria):

- The national electricity objective (NEO);
- The need to achieve and maintain power system security;
- Changes in power system conditions; and
- Changes in technology and capabilities of facilities and plant.

Objectives and recommendations

AEMO recommends six new or amended technical requirements to address nine issues considered in relation to Schedule 5.3. The high-level objective of all these recommendations, developed with regard to the review criteria, is to appropriately incorporate the impact and capability of large loads in the NEM.

The table below summarises AEMO's overarching policy positions to guide Schedule 5.3 recommendations, and the recommended amendments themselves.

Table 1 Schedule 5.3 Recommendations summary

Issue	Schedule 5.3 Recommendations
Policy positions	
Recognition of different load technologies	Consider inverter-based load (IBL) ride through requirements and general requirements for load separately.
Size and technology-based thresholds for ride through capability requirements	Apply different thresholds for traditional loads and IBL: • Require ride-through performance standards for traditional loads above a high threshold. • Require ride-through performance standards for IBL above a lower threshold. • Require a minimum access standard (MAS) for all single facility loads of 5 megawatts (MW) or more to have protection systems that do not disconnect the plant for voltage, frequency and rate of change of frequency (RoCoF) disturbances within the inherent technical capability of the plant, allowing for modest safety margins.
Treatment of different load technologies within a load facility	Apply thresholds based on the size of load which is IBL and the size of load which is traditional load, with the agreement of the network service provider (NSP) and AEMO.

Issue	Schedule 5.3 Recommendations
Continuous uninterrupted operation (CUO) requirements	Apply a light-handed CUO which requires a large load not to: • Disconnect for the specified conditions. • Operate unstably, or change its active power by more than [20%] following the disturbance, or as agreed with the NSP and AEMO, except where it is required to participate in load-shedding or frequency response. • Materially exacerbate or prolong the disturbance or cause a subsequent disturbance for other connected plant, except as required or permitted by its performance standards.
Treatment of loads with uninterruptible power supplies (UPS)	Treat a large load with a UPS consistent with any other load, either as a traditional load or an IBL depending on the technology used for the UPS. The same thresholds as other loads would apply for determining what ride through requirements would be required.
AEMO advisory matters	Prescribe load access standards that relate to AEMO's system security functions under the National Electricity Law (NEL) to be AEMO advisory matters.
New definitions – for use with ride through requirements	
Single facility load	A load that forms part of a single installation (as distinct from, say, the connection between a transmission and distribution network). It may have one or more physical connection points, which are in electrical proximity to each other, and the plant within the facility can be described as one geographical location, so that most power system disturbances affect the facility as a whole. A single facility load may have different types of load technologies. For the purposes of the technical requirements of Schedule 5.3, a single facility load is 5 MW or greater.
Large single facility load	A "single facility load" equal to or greater than a size threshold that is the minimum of the regional maximum load contingency size and [200 MW]. Under the Australian Energy Market Commission (AEMC) Reliability Panel's Draft Frequency Operation Standards[1] (Draft FOS), a maximum load contingency size of 144 MW has been proposed for Tasmania.
Large single facility IBL	A "single facility load", or portion of a "single facility load", that contains [30 MW] or more IBL with discretion for the NSP to use a threshold down to 5 MW, depending on circumstances in the network. In applying this discretion, the NSP must consult with AEMO and have regard to its views. Amend NER 5.3.3 (Response to connection enquiry) to require the NSP to advise whether a proposed connecting IBL would be treated as a large single facility IBL, should the proposed connection proceed. Where the load comprises IBL and other types of load, Schedule 5.3 large single facility IBL access standard requirements apply to the IBL component of the load. Unless inconsistent, large single facility load requirements will also apply to the balance of the load, where relevant, if the balance of load size exceeds the threshold for that definition.
New/amended clauses for ride through requirements	
Operation of large loads during frequency disturbances	Automatic access standard (AAS) • For a large single facility load and for a large single facility IBL, apply an AAS consistent with the S5.2.5.3 AAS requirements. This would also include a RoCoF requirement, consistent with NER S5.2.5.3. MAS • For large single facility IBL, apply a MAS consistent with NER S5.2.5.3 MAS, including RoCoF. • For large single facility loads (other than large single facility IBL), apply a MAS consistent with a single credible contingency event, and RoCoF in accordance with the NER S5.2.5.3 MAS. Both AAS and MAS • Apply light-handed CUO requirements. Specify access standard as an AEMO advisory matter.
Operation of large loads during contingency events	AAS

[1] At https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

Issue	Schedule 5.3 Recommendations
	• For large single facility loads and large single facility IBL, apply an AAS consistent with the AAS levels of S5.2.5.5 for faults, credible contingency events, and multiple disturbance ride through requirements. MAS • For large single facility IBL, apply a MAS consistent with the MAS of S5.2.5.5 for faults, credible contingency events, and multiple disturbance ride through. • For large single facility loads (other than large single facility IBL), apply the same MAS, but for credible contingency events only. Both AAS and MAS • Apply light-handed CUO requirements. Specify access standard as an AEMO advisory matter.
Operation of large loads during voltage disturbances	AAS • For large single facility loads and large single facility IBL, apply an AAS consistent with the AAS levels of S5.2.5.4. MAS • For large single facility IBL, apply a MAS consistent with the MAS level of S5.2.5.4. • For large single facility loads (other than large single facility IBL), the MAS is that no capability is required. Both AAS and MAS • Apply light-handed CUO requirements. Specify access standard as an AEMO advisory matter.
NER S5.3.3 – protection systems and settings	
Link to 'ride through' requirements and maximising protection	• Set a MAS requirement that protection be set to maximise capability to ride through voltage and frequency disturbances including RoCoF subject to the technical capabilities of the plant and safe operation, and modest safety margins. This access standard is not an AEMO advisory matter.
NER S5.3.10 – Load shedding facilities	
Emergency under-frequency ramp down of large loads	Provide the option for a load to remain connected where alternative options to ramp down are agreed instead of making its load available to be shed as part of an UFLS scheme. Specify access standard as an AEMO advisory matter.
New clause for instability monitoring and prevention	
Stability of IBL – monitoring, protection and performance	• Require monitoring for single facility loads with IBL components ≥[5] MW • Require protection for instability for single facility loads with IBL components ≥[20] MW • In the AAS, require detection devices that can determine the contribution to an instability. • In the AAS, permit alternative actions to tripping (to reduce instability). • Require single facility loads to not to cause an oscillation that isn't adequately damped and does not amplify any oscillation. (Amend NER S5.3.11 MAS) Specify access standard as an AEMO advisory matter.

Next steps

AEMO invites submissions on this addendum to the draft report from interested parties. **Please provide submissions by 5:00 pm AEST on 23 May 2023 to contact.connections@aemo.com.au.** Any inquiries and/or meeting requests should also be directed to the same email address. Please note that there is an earlier date to respond to Part 1 of this draft report, as set out in Table 2 below.

Table 2 Indicative timeframes for Review

Activity	Timing
Approach Paper released	12 October 2022 (complete)
Draft Report (Part 1) published	3 March 2023 (complete)
Draft Report (Part 2) addendum published	4 April 2023 (complete)
Information forum	12 April 2023
Draft Report (Part 1) consultation closes	20 April 2023
Draft Report (Part 2) addendum consultation closes	23 May 2023
Draft Rules consultation commences	May-June 2023 (indicative timing)
Final Report released	October 2023
AEMC formally notified of outcomes	November 2023 (indicative timing)

AEMO intends to publish all submissions on its website. Please identify any part of your submission that is confidential, which you do not wish to be published. Respondents should note that if material identified as confidential cannot be shared and validated with other interested persons then it may be accorded less weight in AEMO's decision-making process than published material. AEMO prefers that submissions are provided in electronic format, to be published on the AEMO website.

AEMO will hold a public forum on both parts of the draft report from 3:00-5:00 pm (AEST) on Wednesday 12 April 2023.

Prior to publishing the final report, currently expected in October 2023, AEMO intends to undertake a further round of consultation to seek feedback on a draft of amended rules arising from the recommendations. The draft amendments will incorporate feedback from consultation on the draft report. While not a requirement under NER 5.2.6A, AEMO considers that obtaining this feedback is an important step to optimise drafting of any rule change request arising from the Review, and to inform a decision on whether to request 'fast track' consideration of any changes[2].

[2] The ability for the AEMC to fast track a rule change request is described in Section 96A of the National Electricity Law.

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Introduction

This document is an addendum to AEMO's draft report on its review of the technical requirements for connection in the National Electricity Market (NEM) under clause 5.2.6A of the National Electricity Rules (NER) published on 3 March 2023 (Review), and uses the same defined terms unless otherwise specified.

Section 4 of this document (immediately below) replaces section 4 of the draft report.

Appendix A1 of this document is to be read as an addendum to Appendix A3 of the draft report.

4 Recommendations – Schedule 5.3

Recommended amendments primarily seek to extend existing customer connection requirements to accommodate connections for large loads in light of anticipated growth in large inverter-based loads, and more generally, anticipated electrification of industrial processes as a part of the energy transition to use of renewable energy sources.

AEMO recommends amendments to incorporate the impact and capability of large loads by aligning technical requirements with generating systems to the extent appropriate, in relation to:

- Operation during frequency disturbances, voltage disturbances and contingency events.
- Stability performance, monitoring and protection.
- Emergency frequency response.

4.1 Introduction

The changing nature of loads in the NEM

After a long period with relatively low load growth, there are now proposals for some very large new loads in the NEM. Some of these loads will be of a similar size to the largest generating units in the power system, or possibly even larger. For example, three green hydrogen projects of size ranges 200-800 megawatts (MW), 1.2 - 2.5 gigawatts (GW) and 0.6-2.6 GW have been proposed in South Australia, a Hydrogen Hub of 3 GW has been proposed for Gladstone in Queensland, and a 500 MW project has been proposed for Bell Bay in Tasmania[3].

In addition, there may be a large volume of new load connections as the transition to renewable energy encourages a move away from use of fossil fuels in industrial processes, which is expected to result in electrification of more loads.

AEMO understands that many proposed new loads, including hydrogen electrolysers, are likely to use similar inverter technologies to those used in inverter-based production units.

Inverter-based loads (IBL) present opportunities and risks to the power system: they may therefore have similar technical capabilities to production units, but also similar vulnerabilities to instability resulting from control interactions. Increased IBL presents an opportunity to make use of these inherent capabilities, but also introduces a need to protect against the vulnerabilities.

The present technical standards for loads are inadequate for proposed loads

The present access standards for loads in NER Schedule 5.3 focus on steady state behaviour and power quality, but does not extend to performance during power system disturbances. Ride through requirements for power

[3] AEMC, "Hydrogen: the new Australian manufacturing export industry and the implications for the National Electricity Market (NEM)", at https://www.aemc.gov.au/hydrogen-new-australian-manufacturing-export-industry-and-implications-national-electricity-market#introduction.

system disturbances such as frequency and voltage excursions and contingency events like generation, load or line trips and faults are absent from the current load technical requirements.

The size of some proposed new loads will make them challenging to manage on the power system without unduly constraining power system operation, or necessitating augmentation of the network. Performance of these large loads for power system disturbances, and especially their capability to ride through disturbances, is going to be important, as it affects the voltage, frequency and stability of the power system. The stability performance of new IBL is also of concern, as there is potential for adverse control interactions between IBL and inverter-based generating systems or integrated-resource systems (IRS). This was identified in the AEMO Engineering Roadmap to 100% Renewables[4].

Future-proofing the load technical standards

In this Review, AEMO proposes to add new requirements for large load performance for frequency and voltage disturbances, and for contingency events. These will draw on the more fully developed performance requirements for generating systems and IRS, but consider the implications of the wider range of load technologies.

These requirements represent a major change to previous practice and may necessitate a significant resource cost to industry. Therefore, some stakeholders considered these requirements should apply to only those large-scale loads that will have a larger impact on the power system voltage and frequency and may impact the stability limits of the power system. Once the industry has gained experience in the operation of the additional technical requirements, there will be further opportunity to apply them to a wider range of loads, where consistent with the NEO.

AEMO is therefore reviewing the technical requirements of NER Schedule 5.3 to identify what additional technical requirements are necessary to support system security with the emergence of future large loads which comprise diverse technology types. At this stage of the Review, AEMO has developed recommendations for specific requirements for responses to frequency and voltage disturbances and contingency events, subject to overarching policy positions set out in Section 4.2 relating to:

- Recognition of different load technologies.
- Size and technology-based thresholds for ride through capability requirements.
- Treatment of different load technologies within a load facility.
- Continuous uninterrupted operation (CUO) requirements.
- Treatment of loads with uninterruptable power supplies (UPS).

AEMO is only proposing changes to the requirements in NER Schedule 5.3 in relation to a large load in a single facility. The proposed changes are not intended to apply where multiple separate load facilities are behind a connection point, such as at a distribution substation.

Context

A significant difference between the current requirements in Schedule 5.3 and the generating system and IRS requirements in Schedule 5.2 is that loads are not required to ride through a range of disturbances (typically

[4] AEMO "Engineering Roadmap to 100% Renewables", December 2022, available on the AEMO website.

referred to as remaining in CUO). The only exception applies at the load substation level for voltages specified in the system standards, which only consider credible contingency events:

- S5.3.9 (Customer – load standard)

  A *substation* must be capable of continuous uninterrupted operation with the levels of *voltage*, harmonics, unbalance and *voltage* fluctuation specified in the *system standards* as modified in accordance with the relevant provisions of Schedule 5.1.

- Schedule 5.1

  …the voltage may vary, as a consequence of a *credible contingency event* or *protected event* in accordance with clause S5.1a.4.

- S5.1a.4 (system standard)

  As a consequence of a *credible contingency event*, the *voltage* of *supply* at a *connection point* should not rise above its *normal voltage* by more than a given percentage of *normal voltage* for longer than the corresponding period shown in Figure S5.1a.1 for that percentage.

Definitions

The following NER Chapter 10 definitions, incorporating changes made by the "Integrating energy storage systems into the NEM" rule (IESS Rule) may be particularly useful in reading this section:

- "*Disconnect*" means the operation of switching equipment or other action so as to prevent flow at a *connection point*.
- "*Inverter based resource*", comprising *asynchronous generating units*, *asynchronous bidirectional units* and *inverter based loads*.
- "*Inverter based load"* A load that is supplied by power electronics, including inverters, and potentially susceptible to inverter control instability, and that is classified as an *inverter based load* applying criteria specified in the *system strength impact assessment guidelines*.

4.2 Policy positions

This section:

- Sets out key issues relating to the connection of large loads;
- Identifies overarching policy options to address identified issues; and
- Recommends preferred policy positions to guide the development of technical requirements for connection.

The consideration of policy positions has been informed by discussion with Technical Focus Groups[5] at prioritisation workshops and options assessment workshops facilitated by AEMO to support this Review.

Broadly, key points raised by stakeholders included:

[5] Technical Focus Groups comprised stakeholders representing network service providers (NSPs), connection proponents and market participants, original equipment manufacturers (OEMs), and industry associations. See the draft report (3 March 2023) for further information.

- There are a large variety of load technologies – some load types can ride through faults, while others are expected to have less inherent capability. Therefore, the access standards for large loads need to be flexible to accommodate a range of capabilities.
- Future IBL should have additional requirements compared to other loads because they have inherent ride-through capability available at little additional cost.
- The connection of loads could be discouraged or delayed if extensive modelling requirements are imposed through the connection process, including through the access standards.
- Loads with UPS should provide ride-through capability when they are larger than a threshold, with some stakeholder support for a 30 MW threshold.

These policy positions have been applied to the development of recommended technical requirements in Sections 4.4 to 4.7 of this draft report.

4.2.1 Recognition of different load technologies

Description

The ability of future large loads to ride through system frequency and voltage disturbances and multiple network faults will impact the security of the power system. These connecting loads will use a range of different technologies, meaning that their ride through capabilities will vary significantly. For example:

- Some traditional large loads have limited or no capability to ride through disturbances; examples include general industrial loads and large induction motor loads. Loads that do not inherently have a ride-through capability would require expensive additional equipment, such as a battery energy storage system (BESS), to provide this capability. On the other hand, some of the largest loads in the NEM, such as various smelters, perform well for power system disturbances by their design, and have a good tolerance for deviations in voltage and frequency.
- IBL use similar technologies to those used by generating systems and have some inherent capability to ride through disturbances; examples include some electrolysers and other power electronic connected loads such as variable speed drives. Similarly, some more traditional loads like large rectifiers can also have good ride-through performance, depending on their design. These types of loads can be designed to ride through multiple faults and system disturbances to support the secure operation of the power system for minimal additional cost.
- Sensitive loads may automatically disconnect when a disturbance or fault is detected. Examples include datacentres that use UPS to maintain continuous supply to the load. These loads could potentially have an adverse impact on power system security if their connection is not managed.

Policy options

The policy options considered to accommodate different load technologies were:

1. Consider IBL requirements and general requirements for load uniformly.
2. Consider IBL requirements and general requirements for load separately.

Option 1 is technology-neutral in that the ride through requirements imposed on loads would not depend on their technology. However, being technology-neutral is not an advantage when the different types of loads have quite different ride-through capabilities. In particular, IBL has inherent ride through capability that can be relatively easily specified and captured, while many traditional loads do not have this inherent capability.

Option 2 would differentiate between IBL and other loads. This means that the access standards for IBL can better reflect their inherent capability, with the flexibility to avoid any unnecessary cost burden on traditional and sensitive loads that may not inherently have this capability.

Recommended policy position

AEMO recommends policy Option 2, that is to consider IBL ride through requirements and general requirements for load separately.

4.2.2 Size and technology-based thresholds for ride through capability requirements

Description

The potential impacts on power system security that can occur when a large load does not ride through a fault or frequency disturbance and instead disconnects or significantly reduces its active power consumption include:

- An increase in the system frequency.
- Local network over-voltages and voltage phase angle change.
- Potential increases to intraconnector (within a region) or interconnector flows, that can overload the network or cause voltage instability.
- Reduction in network limits due to reduction in power system transient stability.

Some impacts of large load disconnections are dependent on location of the load and others are not. For example, the impact on system frequency does not depend on the location of the load and would currently be managed by frequency control ancillary services (FCAS) procured by AEMO. However, the size of an over-voltage resulting from load disconnection will depend on the fault level at the load's connection point and the extent of local voltage control. Similarly, the impact on major intra- or inter-regional transmission line flows would also depend on the location of the load in the network.

A limit on the size of the largest allowable credible generator event in Tasmania has been set at 144 MW since the Reliability Panel review of the Tasmanian Frequency Operating Standards (FOS) in 2008. In addition, on 8 December 2022 the Reliability Panel published a draft determination on its 2022 review of the FOS and proposed to extend the 144 MW contingency size limit for generation events to load and network contingencies.

The tripping of an individual load would be a credible contingency event and therefore AEMO would have to procure sufficient FCAS lower services to manage the associated frequency increase. The connection arrangements negotiated with the NSP will also need to address the individual load tripping as a credible contingency event. Thus, the inability of a single load in isolation to ride through a disturbance would not be an additional concern, because tripping of the individual load would already be a credible contingency event and this impact accounted for in the procurement of FCAS and potential network constraints.

However, the inability of individual loads to ride through a disturbance would be a potential threat to power system security if there are multiple other large loads in close electrical proximity. This is because a single disturbance could lead to the uncontrolled tripping of these loads if they do not have sufficient ride through capability, which could lead to emergency frequency control schemes (EFCS) operating or a major supply disruption. Therefore, the security and resilience of the power system could be significantly improved if at least a portion of large loads have ride-through capability.

Introducing ride-through capability into the technical requirements of Schedule 5.3 is only likely to meet the NEO to the extent this can be achieved without imposing disproportionate additional costs on the connection of new loads, which also involves consideration of technical capabilities and likely technology solutions. The potential for additional costs exists in relation to:

- Additional equipment costs of providing the capability.
- Additional modelling costs to demonstrate and negotiate the level of ride-through capability, including the cost of developing and validating a detailed model of the relevant load.
- Additional costs for testing[6], monitoring and analysis to demonstrate ongoing compliance.
- Additional time, and commercial and technical resourcing, (including for NSPs and AEMO) associated with the negotiation and verification of additional standards.

Therefore, at least for the medium term, it would only be appropriate to require ride-through capability from a load when it is sufficiently large to cause a significant impact on the power system and the additional modelling and negotiation costs would be justified in the interests of maintaining security and reliability. This means it is necessary to determine size thresholds applicable to the automatic access standard (AAS) and minimum access standard (MAS) for ride-through capability.

Most single facility loads, however, will have some inherent capability to remain in operation for a disturbance of some limited magnitude and duration. AEMO considers it would be appropriate for the access standards to capture this inherent capability and require it to be provided to the extent reasonably possible. This would not be expected to add significant costs because the protection systems for these loads already need to be approved by the NSP. In addition, this additional requirement should not unnecessarily restrict the operation of UPS loads.

Policy options

The policy options considered to set thresholds for loads to have ride-through requirements were:

1. Prescribe a MW threshold to apply to load connections for AAS and MAS regardless of location or other system conditions.
2. Apply different thresholds for traditional loads and IBL:
   - Require ride-through performance standards for traditional loads above a high threshold (with the threshold set through a new definition of large single facility load in Section 4.3.2).
   - Require ride-through performance standards for IBL above a lower threshold (with the threshold set through a new definition of large single facility IBL in Section 4.3.3).

[6] Voltage and frequency response can to some extent be tested by means of signal injection into a control system or protection system.

3. Require a MAS for all single facility loads [of 5 MW or more] to have protection systems that do not disconnect the plant for voltage, frequency and rate of change of frequency (RoCoF) disturbances within the inherent technical capability of the plant, allowing for modest safety margins.

Option 1 would have a single threshold and would not distinguish between traditional loads and IBL. If the threshold was too low, it could impose additional costs and requirements on too many traditional loads, or it could fail to capture the inherent low-cost ride-through capability of many IBL if the threshold was too high.

Option 2, in distinguishing between traditional loads and IBL, allows for a higher threshold for traditional loads to reduce potentially disproportionate costs on smaller traditional loads, some of which may not have material inherent ride-through capability, while a lower threshold for IBL would capture their inherent capability when it is efficient to do so.

Option 3, in addition to either Option 1 or 2, captures the inherent capability of all single facility loads of 5 MW or more, reducing the likelihood of disconnection for a voltage, frequency or RoCoF disturbance unless it was necessary to protect the safe and normal operation of the plant.

Recommended policy position

AEMO recommends Option 2 to apply different thresholds for traditional loads and IBL, and Option 3 for all single facility loads [of 5 MW or more]. The proposed threshold levels for Option 2 are discussed in Section 4.3 (new definitions).

This policy position is applied later in this section in considering the capability of large loads to ride through voltage, frequency disturbance and multiple faults.

4.2.3 Treatment of different load technologies within a load facility

Description

It is common for a single load facility to include multiple loads of varying technologies. The portion of the total load that comprises traditional loads or sensitive loads may not inherently be able to provide material ride-through capability, and it would be expensive to do so. However, the portion of the load that comprises IBL would have inherent ride-through capability that should be registered in the load facilities' performance standards.

Separating loads within a facility may not always be straightforward. For example, the load associated with a particular process may be able to ride through a disturbance but may also depend on another process within the facility that cannot. Similarly, a common set of auxiliary supplies may not ride through a disturbance and affect the whole facility, even though part of the facility would otherwise have ridden through the disturbance.

Policy options

The policy options considered to accommodate different load technologies within a load facility were:

1. Apply a threshold based on total load at the facility.
2. Apply thresholds based on the size of load which is IBL and the size of load which is traditional load, with the agreement of the NSP and AEMO.

Option 1 would capture large loads, and require a performance standard to be agreed, even when the size of the load without ride-through capability does not exceed the MW threshold. This could impose unnecessary administrative burden and costs on AEMO, the NSP and the large customer.

For Option 2, AEMO proposes that, where the IBL component of a load meets the applicable threshold for ride through capability requirements, the traditional load component is only required to meet ride through requirements if the size of the traditional load alone exceeds the higher threshold applicable to non-IBL facilities. The practical application of this is set out in Section 4.3.3.

Recommended policy position

AEMO recommends Option 2 to accommodate different load technologies within a load facility.

This applies to the treatment of each of the technical requirements set out in the following subsections.

4.2.4 Continuous uninterrupted operation requirements

Description

The AAS and MAS for the ride through requirements of generating systems and IRS in NER S5.2.5.3, S5.2.5.4 and S5.2.5.5 all rely on the defined term *continuous uninterrupted operation*. That is, the generating system is required to remain in CUO under the conditions defined in the AAS and MAS.

The definition of CUO in the NER glossary, after the IESS Rule, is:

> In respect of a *generating system*, *generating unit, integrated resource system or bidirectional unit* operating immediately prior to a *power system* disturbance:
>
> (a) not *disconnecting* from the *power system* except under its *performance standards* established under clauses S5.2.5.8 and S5.2.5.9;
>
> (b) during the disturbance contributing active and reactive current as required by its performance standards established under clause S5.2.5.5;
>
> (c) after clearance of any electrical fault that caused the disturbance, only substantially varying its *active power* and *reactive power* as required or permitted by its *performance standards* established under clauses S5.2.5.5, S5.2.5.11, S5.2.5.13 and S5.2.5.14; and
>
> (d) not exacerbating or prolonging the disturbance or causing a subsequent disturbance for other *connected plant*, except as required or permitted by its *performance standards*,
>
> with all essential auxiliary and *reactive plant* remaining in service.

This definition of CUO for generating systems and IRS is being considered as part of the Review.

Policy options

The policy options considered for the application of a CUO requirement for load connections were:

1. Apply the NER definition of CUO.
2. Apply a light-handed approach to CUO that includes part (d) of the CUO definition.
3. Apply a light-handed approach to CUO that excludes part (d) of the CUO definition.

For Option 1, the current NER definition of CUO is not necessarily appropriate for the ride through requirements for loads. It is very prescriptive, and it may be difficult for loads to demonstrate and achieve strict compliance. In addition, the NER definition includes specific references to other Schedule 5.2 access standards, such as S5.2.5.8, S5.2.5.9, S5.2.5.11, S5.2.5.13 and S5.2.5.14, which are not relevant to the load standards AEMO is considering for amendment in this Review. Similarly, references to reactive power and voltage control are not currently in the access standards for loads.

For Option 2, a light-handed approach could be applied to CUO for relevant large load access standards. This approach would require a large load not to:

- disconnect for the specified conditions.
- operate unstably, or change its active power by more than [20%] following the disturbance, or as agreed with the NSP and AEMO, except where it is required to participate in load-shedding or frequency response.
- materially exacerbate or prolong the disturbance or cause a subsequent disturbance for other connected plant, except as required or permitted by its performance standards.

Option 2 would not cover other aspects of the CUO definition:

- Reactive power and reactive current, because voltage or reactive power control standards are not proposed for large loads.
- Active current during a fault or disturbance.

The tolerance on the active power of [20%] is proposed to keep the requirements for loads light-handed and is not likely to result in large risks to power system security. AEMO requests stakeholder views on the implications of an active power tolerance of this size, or whether a total change in active power of, say, 100 MW from loads in close electrical proximity should be imposed to limit the impact on the power system for a ride through event.

In addition, the Australian Energy Market Commission (AEMC) is reviewing part (d) of the definition of CUO in relation to not exacerbating or prolonging the disturbance or causing a subsequent disturbance, as part of the "Efficient relative current access standards for inverter-based resources" rule change[7]. A final determination on this change is expected to be published on 20 April 2023.

For Option 3, the requirements would be the same as Option 2 except that the requirement would be further relaxed to remove the requirement not to exacerbate or prolong the disturbance or cause a subsequent disturbance for other connected plant. Option 3 is less arduous for connecting loads but could reduce the actions available to AEMO and the NSP to reduce a power system security risk caused by the ride through response of a large load exacerbating or prolonging a disturbance.

Recommended policy position

AEMO recommends Option 2 as a light-handed approach which could be applied to CUO for relevant large load access standards.

[7] The AEMC is considering changes to part (d) of the definition of continuous uninterrupted operation in the rule change "Efficient reactive current access standards for inverter-based resources". See https://www.aemc.gov.au/rule-changes/efficient-reactive-current-access-standards-inverter-based-resources.

4.2.5 Treatment of loads with uninterruptible power supplies

Description

Sensitive electronic loads such as data centres are generally protected from loss of supply by the use of a UPS. UPS installations typically connect between the load and the supply from the network to provide continuous supply to the load during interruptions to the network supply. UPS installations include sufficient storage to enable supply to the load during an interruption and can include additional backup such as diesel generation.

Some UPS installations do not attempt to ride through system disturbances, but rather deliberately disconnect for fault conditions to ensure continuity of supply to the sensitive load. Some other UPS installations provide continuous supply to the sensitive load while riding through most disturbances in the power system, but these are generally more expensive to build and operate.

If the generating units of a UPS system connect to the network as part of a NER Chapter 5 connection process, they will be subject to the connection requirements of NER S5.2. The generating units only connect to the network for a very short time – 2-30 seconds for resynchronisation of the load to the network. Therefore, in many cases where the combined generator nameplate is 5 MW or more, the generating units may be exempted from the registration and technical requirements of NER S5.2.

A new technology-neutral category of registered participant, the Integrated Resource Provider (IRP) will be introduced from June 2024 for connecting facilities that will be an IRS, and NER Schedule 5.2 applies to facilities meeting the new IRS definition from 15 March 2023. IRS include a range of plant combinations with two-way energy flows such as grid-scale storage, hybrid projects, and aggregators of small generation and storage units. Currently under the IRS arrangements:

- Loads and UPS loads that do not have the capability to export will not be recognised as IRS;
- UPS loads that export will be recognised as IRS; and
- UPS loads that wish to provide FCAS will also need to meet the market ancillary services specification (MASS).

Therefore, under the current AEMO guidelines[8], a UPS load of 5 MW or more is likely to be treated like a generating system, and under the IESS Rule, the combined UPS and load centre may be treated as an IRS if the UPS is considered to be a bi-directional unit. However, it would be difficult for a UPS to meet the Schedule 5.2 access standards, for example CUO under S5.2.5.4 and S5.2.5.5, reactive current injection, active power recovery time, as well as other clauses.

Policy options

The policy options considered for the treatment of loads with UPS were:

1. Treat large loads with UPS in the same way as other large loads.
2. Develop a new definition for loads with UPS and bespoke arrangements for loads.

[8] AEMO "Guide to generator exemptions and classification of generating units", at https://aemo.com.au/-/media/files/electricity/nem/participant_information/new-participants/generator-exemption-and-classification-guide.pdf?la=en.

For Option 1, a large load with a UPS would be treated as any other load, either as a traditional load or an IBL depending on the technology used for the UPS. The same thresholds as other loads would apply for determining what ride through requirements would be required.

For Option 2, UPS loads would need to be identified with a separate new definition and new arrangement developed. AEMO considers that this would introduce uncertainty for some loads without any benefit in terms of managing power system security.

AEMO recommends treating UPS loads consistently with other large loads, that is, either as a traditional or inverter-based load depending on the technology used. The technical and commercial constraints of UPSs have been considered in relation to other policy positions and reflected in proposed amendments to Schedule 5.3.

Recommended policy position

AEMO recommends Option 1 to manage power system security whilst minimising uncertainty for some loads.

4.2.6 AEMO advisory matters

Description

Some of the access standards in the NER are specified as AEMO advisory matters. These matters generally relate to AEMO's system security functions under the NEL and any matters in which AEMO has a role in schedules 5.1a, 5.1, 5.2, 5.3 and 5.3a of the NER. For each relevant AEMO advisory matter, AEMO advises the NSP on the negotiation of the associated access standard and the NSP must reject a proposed negotiated access standard if AEMO advises it would adversely affect power system security.

At present the majority of generator access standards in NER S5.2.5 are AEMO advisory matters, but the only current AEMO advisory matter relating to loads is for system strength in NER S5.3.11 - Short circuit ratio (customers).

Policy options

1. Do not prescribe any additional AEMO advisory matters.
2. Prescribe load access standards that relate to AEMO's system security functions under the NEL to be AEMO advisory matters.

Under Option 1 the new access standards for large loads would not be prescribed as AEMO advisory matters. That is, AEMO would not be consulted on whether a proposed access standard that may impact AEMO's ability to maintain power system security is acceptable, with only the NSP being able to accept or reject a proposed access standard.

Option 2 would require the NSP to consult with AEMO when negotiating an access standard that relates to AEMO's system security functions under the NEL. This would give AEMO the ability to assess the impact of a proposed load performance standard in accordance with its system security functions under the NEL. Option 2 would also be consistent with negotiation process for the equivalent generator access standard in NER S5.2.5.

Recommended policy position

AEMO recommends Option 2 to provide AEMO the ability to assess the impact of a proposed load performance standard in accordance with its system security functions under the NEL and consistent with the negotiation process for the equivalent generator access standard in NER S5.2.5.

4.3 New definitions – for use with ride through requirements

NER Schedule 5.3 nominally includes all types of loads including down to the distribution level, if they connect under the NER Chapter 5 process. For the purpose of this Review, AEMO therefore needs to differentiate between the loads for which additional technical requirements will be defined and those which are excluded.

Aggregate loads, such as a distribution network service provider's (DNSP's) connection to the transmission network at a substation, are not relevant to the considerations of this Review, and need to be excluded. As with the other Chapter 5 schedules considered in the review, the application of Schedule 5.3 by reference to registration categories is not very useful, as it is the performance of the connected load that is of concern.

For the purpose of recommending amendments related to ride through requirements for frequency and voltage disturbances, and contingency events, presented in Section 4.4 of this report, AEMO proposes some new definitions which will be used across the recommended changes. AEMO invites feedback on the proposed definitions below, including the threshold levels suggested in square brackets.

4.3.1 Single facility load

Recommendation

AEMO recommends defining a "single facility load" as a load that forms part of a single installation (as distinct from, say, the connection between a transmission and distribution network). It may have one or more physical connection points, which are in electrical proximity to each other, and the plant within the facility can be described as one geographical location, so that most power system disturbances affect the facility as a whole. A single facility load may have different types of load technologies. For the purposes of the technical requirements of Schedule 5.3, a single facility load is 5 MW or greater.

4.3.2 Large single facility load

Recommendation

AEMO recommends defining a "large single facility load" as a "single facility load" equal to or greater than a size threshold that is the minimum of the regional maximum load contingency size and [200 MW].

Under the AEMC Reliability Panel's Draft Frequency Operation Standards[9] (Draft FOS), a maximum load contingency size of 144 MW has been proposed for Tasmania.

[9] At https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

4.3.3 Large single facility IBL

Description

AEMO recommends that if a "single facility load" contains a large quantity of IBL then that IBL should be classified as a "large single facility IBL" and have a MAS ride through requirements that are specific to IBL. This approach was supported by the majority of stakeholders at the AEMO options assessment workshops.

The level of IBL that should be used to classify a load as "large single facility IBL" should reflect the potential impacts of the load on the power system, should the load not ride through a contingency event.

Options

Define a "large single facility IBL" as either:

1. A "single facility load", or portion of a "single facility load", that contains [30 MW] or more IBL with discretion for the NSP to use a threshold down to 5 MW, depending on the circumstances in the network. In applying this discretion, the NSP must consult with AEMO and have regard to its views.
2. A "single facility load", or portion of a "single facility load", that contains [5 MW] or more IBL with discretion for the NSP to exempt up to a threshold of [30 MW] depending on the circumstances in the network. In applying this discretion, the NSP must consult with AEMO and have regard to its views.
3. A "single facility load", or portion of a "single facility load", that contains [30 MW] or more IBL.

Option 1 would require access standards to be negotiated for all large single facility IBL [30 MW] or greater but would also permit the NSP to define an IBL down to a threshold of [5 MW] where the network conditions are more sensitive. This could be at a lower voltage connection or a weaker part of the network, or it could be where there are expected to a large quantity of similar loads.

Option 2 is essentially the same as option 1 and should achieve similar outcomes in practice, but reversal of the default threshold for IBL level to the higher quantity might affect the assessment and negotiation. AEMO has included this option to seek stakeholder feedback on issues it may not have considered.

Both options 1 and 2 have the potential to introduce uncertainty to the proponents of single facility IBL in the range of 5 MW to [30 MW]. Therefore, AEMO recommends that NSPs should advise the proponent of a single facility IBL whether it would be treated as a large single facility IBL as part of its "Response to connection enquiry" under NER 5.3.3. This would provide the proponent with more certainty regarding the process and requirements, and the potential costs.

Both options 1 and 2 would also require the NSP to consult with AEMO on what threshold should be applied to a specific IBL connection. This requirement is to ensure that the NSP is aware of any concerns AEMO has, which would be informed by its experience with other previous IBL connections, before the NSP makes its decision.

Option 3 would provide certainty for stakeholders and generally balances the costs of imposing access standards for a large single facility IBL with the benefits to the operation of the power system. However, it has the disadvantage that it cannot accommodate conditions specific to the connection point and surrounding network, in which a lower threshold may be needed to minimise adverse impacts.

Where the load comprises IBL and other types of load, large single facility IBL access standard requirements apply to the IBL component of the load. Unless inconsistent, large single facility load requirements will also apply to the balance of the load, where relevant, if the balance of load size exceeds the threshold for that definition.

Recommendation

AEMO recommends Option 1, with an associated amendment to NER 5.3.3 to require the NSP to advise whether a proposed connecting IBL would be treated as a large single facility IBL, should the proposed project proceed.

4.4 New/amended clauses for ride through requirements

Application of policy for recognition of different load technologies

The application of the recommended policy position set out in Section 4.2.1 requires consideration in the following sections for technical requirements relating to frequency disturbances, contingency events, and voltage disturbances (set out in Sections 4.4.1 to 4.4.3). This section therefore sets out options and recommendations for how the policy to treat IBL and general requirements for load separately will be applied to technical requirements in practise.

Description

As discussed in Section 4.2.1, AEMO's recommended policy for addressing the different inherent ride through capabilities of different load types is to consider the requirements for IBL differently to the general requirement for other loads. This is because IBL are expected to have similar inherent ride through capabilities to those of inverter-based generation, and this should be reflected in specific access standards for IBL. In addition, these IBL specific access standards would also apply to those sensitive loads that use inverter-based technology as discussed in Section 4.2.5.

Options

Policy application – large single facility loads

The policy application options considered to accommodate large single facility loads with technologies that may not have inherent ride through capability were:

1. Align the AAS with equivalent requirements for generators and IRS in NER S5.2.5 and define the MAS to require no ride through capability for loads.
2. As Option 1, but with the MAS for loads above a size threshold having a requirement not to disconnect for a credible contingency event.
3. As Option 2, except with discretion for AEMO and the NSP to relax the MAS.

For Option 1, the alignment of the AAS with equivalent requirements for generators would allow the inherent capability of some load technologies to be captured at minimal cost. This will promote power system security, and is considered consistent with the NEO. Specifying the MAS as no ride through capability would allow maximum flexibility for the connection of loads that do not inherently provide the equivalent performance.

For Option 2, the MAS would set an expectation for very large loads to, as a minimum, remain connected for a credible contingency event in the power system. This would improve power system security by minimising the risk that large load disconnections will increase the severity of a contingency event.

For Option 3, flexibility would be retained to relax the requirement to not disconnect for credible contingency events with the agreement of AEMO and the NSP. This would remove a potential barrier to connection for some loads when the risks to power system security can otherwise be efficiently managed.

All the options have the disadvantage that there is a large difference between performance required under the AAS and MAS. While this means that flexibility is retained, it introduces the potential for extended negotiation for loads in some circumstances.

Policy application – IBL (above a size threshold)

The policy options considered to accommodate loads with technology that have inherent ride through capability, such as IBL, were:

1. Align the AAS with equivalent requirements for generators and IRS in NER S5.2.5 and define the MAS to require no ride through capability.
2. As Option 1, but with a MAS as not to disconnect for a credible contingency event.
3. As Option 2, except with discretion for AEMO and the NSP to relax the MAS.
4. As Option 1, but with the MAS aligned with equivalent MAS requirements for generators and IRS in NER S5.2.5.
5. As Option 4, but allowing for the NSP and AEMO to agree to no ride through capability for the MAS.

For Option 1, the alignment of the AAS with equivalent requirements for generators would allow the inherent capability of some load technologies to be captured at minimal cost. This will promote power system security and is considered consistent with the NEO. Specifying the MAS as no ride through capability would allow maximum flexibility for the connection of loads that don't inherently provide the equivalent performance.

For Option 2, the MAS would require a large load to at least remain connected to the power system for credible contingencies and, therefore, not introduce additional constraints on the operation of the power system to manage the increased contingency size.

For Option 3, AEMO and the NSP may agree exemptions, which may be appropriate where the impact of the load disconnecting would not introduce a material risk to the operation of the power system. AEMO has included this option to seek stakeholder views on whether discretional flexibility to make the MAS less arduous may be required. This would remove a potential barrier to connection for some IBL when the risks to power system security can otherwise be efficiently managed.

For Option 4, the MAS would require the inherent ride through capability of IBL to be captured by aligning the MAS with equivalent MAS requirements for generating systems and IRS in NER S5.2.5, for loads above a size threshold. This option could potentially be a barrier to connection in some circumstances (expected to be very limited) if the inherent capability of some IBL is less than the equivalent MAS in NER S5.2.5.

Option 5 has the advantage in Option 4 of capturing the inherent ride through capability expected from most IBL but introducing the flexibility of reducing the MAS requirements should some IBL not have this capability. This would remove a potential barrier to connection for some loads when the risks to power system security can otherwise be efficiently managed. However, giving the NSP and AEMO the discretion to accept a less arduous performance than the MAS would introduce uncertainty for connection loads and is not consistent with the general approach to the framework for access standards.

Recommendations

AEMO recommends the following options to accommodate different load technologies in applying the new technical requirements considered in this draft report:

- For large single facility loads, Option 2.
- For large single facility IBL, Option 4.

In summary this means:

- Define AAS and MAS for the ride through capability of large single facility loads above a size threshold (see New Definition of large single facility load).
  - AAS to be similar to the AAS requirements for generators and IRS in NER S5.2.5.3, S5.2.5.4 and S5.2.5.5;
  - MAS as not to disconnect for a credible contingency event.
- Define AAS and MAS for the ride through capability of large single facility IBL above a size threshold (see New Definition of large single facility IBL).
  - AAS to be similar to the AAS requirements for generators and IRS in NER S5.2.5;
  - MAS requirements for generators and IRS in NER S5.2.5.

These are applied in determining the technical requirements under the following 3 subsections.

4.4.1 Operation of large loads during frequency disturbances

Ref.	Group	Standard type	Objective(s)
#5	General	AAS / MAS / NAS	• Incorporate the impact and capability of large loads

Description

Currently there are no frequency disturbance ride through requirements specified for loads in Schedule 5.3, although NER S5.3.10 does require loads greater than 10 MW to have automatically interruptible load for under-frequency events in accordance with NER 4.3.5. This capability is utilised to implement under-frequency load shedding (UFLS) schemes.

There are some large loads proposed for the NEM that will, if tripped from higher loading levels, affect both the frequency in the NEM and the local voltage in the nearby transmission network. If these large loads trip during over-frequency events or high rate of increase of frequency, in conjunction with an over-frequency, they could materially exacerbate a frequency disturbance. Similarly, with an under-frequency event or a high rate of decrease of frequency, the tripping of a large quantity of load in an uncontrolled or unexpected manner could exacerbate a frequency disturbance by causing an under-frequency event to become an over-frequency event.

Discussion and feedback

In prioritisation workshops held by AEMO, participants indicated a medium level of support in principle for addressing this issue.

Stakeholders agreed that loads should have frequency ride through requirements but these need to be flexible to allow for future loads that do not have this capability or have multiple parts with different capabilities.

There was some support for the AAS to be applied to industrial and commercial loads, storage, data centres, hydrogen production and IBL. However, there were other views that the capability to ride through frequency disturbances should not be mandatory for loads.

There was general consensus that the assessment and negotiation of any frequency ride through requirements for loads is likely to present a significant administrative burden for participants, NSPs and AEMO.

There was less consensus on the size of loads that the AAS should apply to, but there was some support divided between 30 MW and 100 MW thresholds. Some stakeholders considered that the connection agreement with the NSP should also address the contingency size and the need for frequency disturbance ride through.

Options

The options below reflect the policy positions proposed by AEMO in Section 4.2 and discussed above in the introduction to Section 4.4. The definitions used in the option descriptions are from Section 4.3 which reflect AEMO's proposed thresholds.

1. Do nothing – this is not preferred, as it does not manage the impact of future large loads on the power system, which is expected to become significant.
2. In line with the principles proposed in the previous subsection:
   - AAS:
     - For a large single facility load and for a large single facility IBL, apply an AAS consistent with the S5.2.5.3 AAS requirements. This would also include a RoCoF requirement, consistent with NER S5.2.5.3.
   - MAS:
     - For large single facility IBL, apply a MAS consistent with NER S5.2.5.3 MAS, including RoCoF.
     - For large single facility loads (other than large single facility IBL), apply a MAS consistent with a single credible contingency event, and RoCoF in accordance with the NER S5.2.5.3 MAS.
   - Both AAS and MAS
     - Apply light-handed CUO requirements, as discussed in Section 4.2.4.

The widest band of operation for a credible contingency event[10] under the Draft FOS[11] is shown in Table 3.

[10] For an island condition.

[11] At https://www.aemc.gov.au/market-reviews-advice/review-frequency-operating-standard-2022.

Table 3 Widest frequency bands for a credible contingency event

Location of connection	Containment band	Stabilisation band	Recovery band
Mainland	49.0 to 51.0 hertz (Hz) for up to 2 minutes	49.5 to 50.5 Hz for up to 10 minutes	49.5 to 50.5 Hz continuously
Tasmania	47.0 to 55 Hz for up to 2 minutes	48.0 to 52 Hz for up to 10 minutes	49.0 to 51.0 Hz continuously

In the context of "light-handed CUO" for the frequency disturbance ride through, AEMO proposes that this means not disconnecting or changing load by more than [20%] except for the purposes of frequency response or load shedding.

Load shedding should not occur for a single credible contingency event, but a credible contingency event could occur in an islanded situation, in which load shedding has occurred. The load might participate in providing frequency services to the NEM – for example, an IBL providing synthetic inertia, phase angle jump or fast frequency response (FFR) as a service, or primary frequency response (PFR).

Option 2 is consistent with the overall strategy proposed for treatment of loads.

AEMO is seeking stakeholder views on whether additional flexibility may be required to permit AEMO and the NSP to accept a performance standard that is less arduous than the MAS under some circumstances.

Recommendation

AEMO recommends Option 2.

AEMO also recommends that this is an AEMO advisory matter because it relates to AEMO's system security functions.

4.4.2 Operation of large loads during contingency events

Ref.	Group	Standard type	Objective(s)
#2 / #4	General	AAS / MAS / NAS	• Incorporate the impact and capability of large loads

Description

As discussed in Section 4.2 above, the tripping of large loads can lead to an over-frequency disturbance, or cause a local voltage disturbance or large change to the flows in the transmission and/or distribution network. This is of particular concern when multiple loads trip as a consequence of a credible contingency. Therefore, the ability of loads to ride through credible contingency events also impacts power system security and resilience for severe power system events.

While some large loads such as IBL have the inherent capability to ride through contingency events, other loads either do not have this capability or have commercial reasons to trip to protect their plant. Considering that some of the largest loads proposed for connection on the power system will be IBL, it is prudent to seek a more arduous level of performance from them, to support efficient investment in and operation of the power system.

Discussion and feedback

In prioritisation workshops held by AEMO, participants indicated a high level of support in principle for addressing this issue. However, there was a wide range of views on what should be implemented, and concerns about the modelling requirements implied.

Options

The options below reflect the policy positions proposed by AEMO in Section 4.2. The definitions used in the option descriptions are from Section 4.3 and reflect AEMO's proposed thresholds.

1. Do nothing – this is not preferred, as it does not address the issues of load tripping impact on power system operation, nor does it capture the performance capabilities of IBL.
2. In line with the principles proposed in Section 4.1:
   - AAS:
     - For large single facility loads and large single facility IBL, apply an AAS consistent with the AAS levels of S5.2.5.5 for faults, credible contingency events, and multiple disturbance ride through requirements.
   - MAS:
     - For large single facility IBL, apply a MAS consistent with the MAS of S5.2.5.5 for faults, credible contingency events, and multiple disturbance ride through.
     - For large single facility loads (other than large single facility IBL), apply the same MAS, but for credible contingency events only.
   - Both AAS and MAS:
     - Apply light-handed CUO requirements, discussed in Section 4.2.4.

The limits on active power reduction in the proposed light-handed CUO requirements should encourage tuning of controls to minimise the effect of the disturbance on the power system while not imposing excessive requirements on loads. AEMO welcomes stakeholder feedback on the appropriateness of this definition in the context of loads, including alternative proposals or different thresholds.

AEMO is seeking stakeholder views on whether additional flexibility may be required for AEMO and the NSP to accept a performance standard that is less arduous than the MAS under some circumstances.

Option 2 is consistent with the overall strategy proposed for treatment of loads.

Recommendations

AEMO recommends Option 2.

AEMO also recommends that this is an AEMO advisory matter because it relates to AEMO's system security functions.

4.4.3 Operation of large loads during voltage disturbances

Ref.	Group	Standard type	Objective(s)
#69	General	AAS / MAS / NAS	• Incorporate the impact and capability of large loads

Description

Currently the only reference to CUO within the load standards is in NER S5.3.9 for substations, which are required to remain in "continuous uninterrupted operation" (not italicised)[12] for levels of voltage, harmonics, unbalance and voltage fluctuations specified in the system standards, as modified in accordance with the relevant provisions of NER S5.1. This means there are no voltage disturbance ride through requirements for loads other than for the substations that connect them.

Discussion and feedback

This issue was not separately discussed in the workshops, but tripping for voltage disturbances is similar to tripping for contingency events. Different load technologies can have very different capabilities for voltage disturbance ride through. In the NEM some large loads currently connected have demonstrated very robust performance for voltage disturbances. In future, AEMO anticipates that new IBL will have capability similar to inverter-based generation, which would be capable, in most cases, of meeting the S5.2.5.4 AAS requirements.

If IBL were to have capability at that level, commensurate access standards would help improve the resilience of the power system to abnormal conditions.

Options

1. Do nothing – not preferred.
2. In line with the principles proposed in Section 4.2:
   - AAS:
     - For large single facility loads and large single facility IBL, apply an AAS consistent with the AAS levels of S5.2.5.4.
   - MAS:
     - For large single facility IBL, apply a MAS consistent with the MAS level of S5.2.5.4.
     - For large single facility loads (other than large single facility IBL) the MAS is that no capability is required[13].
   - Both AAS and MAS:
     - Apply a light-handed CUO approach, as discussed in Section 4.2.4.

[12] The term continuous uninterrupted operation in NER S5.3.9 is not italicised. Therefore, a general meaning of the term applies rather than the NER definition in the NER glossary.

[13] A MAS of no capability the existing requirements in S5.3 apply, which does not include frequency and voltage disturbance or fault ride through requirements. This provides the maximum flexibility for loads that have no inherent ride-through capability, noting that a performance of no ride-through capability would not be accepted as a NAS unless the performance of the load does not impact power system security.

Option 1 is not preferred. If large loads are not required to have frequency ride-through capability in future there would be adverse impacts on power system operation, considering the anticipated growth in large loads.

Option 2 seeks a more arduous requirement for those technologies that ought to be able to provide it, while still allowing flexibility, considering a range of technologies that might be applied in the future. This is consistent with the overall strategy proposed for treatment of loads.

AEMO is seeking stakeholder views on whether additional flexibility may be required to permit AEMO and the NSP to accept a performance standard that is less arduous than the MAS under some circumstances.

Recommendation

AEMO recommends Option 2.

AEMO also recommends that this is an AEMO advisory matter because it relates to AEMO's system security functions under the NEL.

4.5 NER S5.3.3 – protection systems and settings

4.5.1 Link to 'ride through' requirements and maximising protection

Ref.	Group	Standard type	Objective(s)
#4, #5, #69	General	AAS & MAS	• Incorporate the impact and capability of large loads

Description

AEMO proposes to add new ride through requirements for certain loads as described in Section 4.4. To support these requirements, AEMO proposes an additional requirement that the protection systems must not trip the plant for conditions under which it is required to remain in operation under those clauses. This is similar to NER S5.2.5.8 for generating systems and IRS.

The Schedule 5.3 proposed requirements differ from the generating system and IRS requirements in that a minimum threshold for application of ride through requirements has been proposed. This means that there is no requirement for loads under the lowest threshold, which is currently proposed as between 5 MW and 30 MW (for large single facility IBL).

However, linking protection settings to ride through requirements sometimes does not capture the inherent capability of the plant to remain in operation for wider ranges of frequency or voltage disturbance than required by the clauses. Capability of plant to remain in operation for wider ranges of power system disturbances than required by the FOS or system standards improves the resilience of the power system to abnormal conditions. For example, if a load is capable of operation for frequency above 52 hertz (Hz) it is beneficial for the power system that it does not unnecessarily limit its ability to do so.

Discussion and feedback

This issue was not separately considered in workshops with stakeholders, but is an out-working of the discussions on thresholds in workshops held to discuss frequency and contingency ride through capabilities of loads.

AEMO considers that these requirements impose very little extra cost on connection applicants, but could provide significant benefit for resilience of the power system. As described in the policy position in Section 4.2.2, AEMO therefore considers that a low threshold is appropriate for these requirements.

Options

1. Do nothing.
2. Set a MAS requirement that protection be set to maximise capability to ride through voltage and frequency disturbances including RoCoF subject to the technical capabilities of the plant and safe operation, and modest safety margins.

Option 1 is not preferred because it does not close the link between protection and ride through requirements. Likewise, it does not capture benefits to the power system that are otherwise available at little cost.

Option 2 aims to capture the inherent ride through capability of all smaller loads not otherwise captured by a negotiated performance standard. AEMO notes that it may not always be practical for the NSP to assess whether a load is complying with this requirement, without a detailed understanding of the operation of the load facility. However, AEMO notes that it would generally be in the interests of the load facility to ride through disturbances (subject to safety concerns) to avoid disruptions to its operation.

AEMO considers that Option 2 is consistent with the NEO.

Recommendation

AEMO recommends Option 2.

AEMO does not recommend that this is an AEMO advisory matter. This is because this requirement will effectively only apply to single facility loads (that is load of at least 5 MW) that are not classified as large single facility loads or large single facility IBL, as those loads will be required to negotiate ride through performance standards[14].

All loads that have ride through NAS will have their performance modelled and assessed by both AEMO and the NSP.

4.6 NER S5.3.10 – Load shedding facilities

Emergency under-frequency ramp down of large loads

Ref.	Group	Standard type	Objective(s)
#6	General	AAS / MAS / NAS	• Incorporate the impact and capability of large loads

Description

Currently NER S5.3.10 requires load shedding facilities on all Market Customer loads greater than 10 MW:

[14] The assessment of ride through requirement for large single facility loads and large single facility IBL will include consideration of the load's protection settings, superseding this MAS for these types of loads.

> *Network Users* who are *Market Customers* and who have expected peak demands in excess of 10 MW must provide automatic *interruptible load* in accordance with clause 4.3.5 of the Rules.
>
> *Load shedding procedures* may be applied by *AEMO*, or *EFCS settings schedules* may be determined, in accordance with the provisions of clause 4.3.2 of the *Rules* for the shedding of all *loads* including *sensitive loads*.

The purpose of NER S5.3.10 is to require loads to participate in EFCS to facilitate coordinated UFLS, to assist power system security in the event of a severe under-frequency event. UFLS schemes only operate in the event of large under-frequency excursions, but their operation is likely to cause a significant voltage disturbance.

For some loads, an alternative to shedding the whole load is to quickly and proportionally ramp down the load in response to frequency below an agreed level. This approach is likely to result in a smaller commercial and productivity impact on the affected load, could reduce the impact on the voltage at individual loads, and may even result in less load being tripped overall. This would also allow smooth and automatic restoration of the load where this is appropriate.

Discussion and feedback

In prioritisation workshops held by AEMO, most participants indicated a medium level of support in principle for addressing this issue.

It was agreed that the 10 MW threshold determining requirements for load shedding facilities should continue to allow for the automatic interruption of load in a controlled manner for emergency under-frequency events. Some stakeholders considered that load ramping should apply to loads greater than 100 MW.

There was some stakeholder support for ramping down active power for emergency under-frequency events, but this should only be an option when the load technology can accommodate it. Fast ramping down of active power would not be possible from all loads including many industrial loads. Also, while some loads could ramp down their active power consumption, this would need to be sufficiently fast to be an effective part of an UFLS scheme.

Various options that could increase flexibility for large loads were considered at the options assessment workshop including:

- Response proportional to frequency.
- Rapid ramp down when frequency drops below a frequency.
- Load shedding in steps.

There was some degree of support for all the options proposed, including for allowing combinations of responses.

Options

Together all the above options would increase the flexibility available to AEMO and NSPs when designing UFLS schemes. This is likely to:

- Spread the impact of emergency load reductions around the network, potentially reducing the severity of some localised over-voltages; and
- Reduce the impact on some loads that can remain connected, potentially speeding up the subsequent load restoration.

For some loads, ramping their output may also be less onerous than tripping, and make it easier to restore full operation following frequency recovery from the disturbance.

This increased flexibility would advance the NEO by providing more options for load response while not compromising, the capability of the UFLS to maintain system security.

The options can be summarised as:

1. Do nothing – which retains the status quo. Practically the present standard would not preclude stepped load shedding. However, it does not capture the benefits provided by additional flexibility.
2. Provide the option for a load to remain connected where alternative options to ramp down are agreed instead of making its load available to be shed as part of an UFLS scheme.

Option 1 is not preferred as it does not increase the flexibility for some loads to participate in emergency frequency control schemes.

Option 2 would provide acceptable alternative ways for a large load to meet its UFLS obligations while remaining connected. Acceptable alternatives that would require the agreement of AEMO and the NSP could include:

- Rapid ramp down of active power in proportion to the frequency
- Rapid ramp down of active power when frequency drops below a threshold
- Rapid ramp down of active power in multiple blocks at different frequency thresholds or
- Combinations of these.

Any alternative capabilities would be recorded in the performance standard and the settings would be part of the relevant EFCS settings schedule.

Recommendation

AEMO recommends Option 2.

AEMO also recommends that this is an AEMO advisory matter because it relates to AEMO's system security functions.

4.7 New clause for instability monitoring and prevention

4.7.1 Stability of IBL – monitoring, protection and performance

Ref.	Group	Standard type	Objective(s)
#3	General	AAS / MAS / NAS	• Incorporate the impact and capability of large loads

Description

Given the prospect of many IBL connecting to the NEM in the next few years, there is a growing potential for such loads to participate in inverter controller instability. Instability might result from interactions between IBL and inverter-based generation, or between different IBL plant. Concerns about load stability under low system strength conditions are reflected in the new NER S5.3.11 introduced in the Efficient Management of System Strength on the Power System rule[15], which requires that:

> "…electrical *plant* must have *plant* capability sufficient to operate stably and remain *connected* at a *short circuit ratio* of 3.0, assessed in accordance with the methodology prescribed in the *system strength impact assessment guidelines*."

However, at present there is no requirement for monitoring or disconnection of loads for unstable operation.

In Schedule 5.2 for generating systems and IRS, there is a requirement in NER S5.2.5.10 for protection systems for instability. In this review, AEMO has recommended amendments to this clause, to improve its effectiveness. These include:

- Protection capable of disconnecting the plant when instability is detected (settings agreed with the NSP and AEMO) for systems of 20 MW or greater (MAS).
- Monitoring for instability (MAS).
- An instability detection system (which may be a local device, or implemented by means of a phasor measurement unit (PMU) linked with a central system) that identifies the contribution of the plant to an instability (AAS).
- Permitted responses as alternatives to tripping, which could address the instability (AAS).

See Section 3.9 of the draft report for more detail on the proposed changes.

Discussion and feedback

In prioritisation workshops held by AEMO, participants indicated a medium level of support in principle for addressing this issue.

There was agreement that large single facility IBL should be monitored for instability, but there was a concern that protective actions like disconnection or ramping down should not occur if the plant is not the cause of the instability.

AEMO considers that monitoring is an important element of managing instabilities, and that protective functions should be implemented for larger plant.

Similar arrangements to those proposed for generating systems and IRS could apply to loads, where the actions on detection of instability could be modified by information about contribution level, if a device were installed that could identify the plant's contribution to an instability.

In the event inverter instability protection operates, the plant owner or operator would need to deal with it by investigating the cause, and, if necessary, retuning controls to make them more stable. NER Schedule 5.3 is not prescriptive about load controls, other than requiring the approval of the NSP (and AEMO if it is a matter that would involve AEMO under NER 5.3.4A(c)) before changing or applying a setting.

There are costs associated with protection, monitoring and detection systems, which must be balanced against the benefit of managing undesirable oscillations effectively.

[15] At https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system.

AEMO considers that monitoring should be applicable broadly but that a higher threshold could apply for a protection system. Actions other than tripping to address an instability could be an optional part of an AAS for large loads above the threshold. This would be consistent with the approach proposed for generating systems and IRS in NER S5.2.5.10.

In addition, it should be noted that NER S5.3.11 is a capability requirement that does not require the plant to operate stably, except for the short circuit ratio (SCR) level agreed under the clause (a minimum of 3.0), with settings that might not be consistent with the usual settings on the plant. It does not impose a requirement for stable operation with the usual settings. AEMO considers that, along with the obligation to monitor for stability and have a protection system to disconnect for instability, it would be reasonable to include a complementary requirement to not cause or amplify a poorly or undamped oscillation (in the present conditions and with current settings).

Options

The options considered for monitoring and actions are:

1. Do nothing – no monitoring or protection.
2. Require monitoring for single facility loads ≥[5] MW.
3. Require monitoring for single facility loads with IBL components ≥[5] MW.
4. Require protection for instability for single facility loads ≥[20] MW.
5. Require protection for instability for single facility loads with IBL components ≥[20] MW.
6. In the AAS, require detection devices that can determine the contribution to an instability.
7. In the AAS, permit alternative actions to tripping (to reduce instability).
8. Require single facility loads to not to cause an oscillation that is not adequately damped and does not amplify any oscillation. (Amend NER S5.3.11 MAS).

The 5 MW and 20 MW thresholds for monitoring and protection systems are consistent with the NER S5.2.5.10 proposals. Some of these options are not mutually exclusive, noting that:

- The difference between Options 2 and 3 is whether the 5 MW threshold for monitoring applies to IBL loads or all single facility loads. NER S5.3.11 applies to all load where the plant includes any inverter-based resource, but AEMO considers the risk of instability is greater for IBL loads.
- Likewise, the difference between Options 4 and 5 is whether the 20 MW threshold for protection applies to IBL or all single facility loads. For the same reason, AEMO prefers the narrower requirement for IBL.

Option 8 as proposed applies generally to single facility loads. It does not necessarily imply a requirement for modelling for very small plant, but if a load causes an instability, modelling might need to be undertaken to retune the controller, to improve the plant's performance. Note, however, that for large single facility IBL, modelling would be required for other ride through requirements, and likewise for other large single facility loads above the applicable threshold.

Recommendation

AEMO recommends Options 3, 5, 6, 7 and 8.

AEMO welcomes feedback on the proposed thresholds, noting that the proposed thresholds are currently consistent with those proposed in S5.2.5.10, and a change in one might be reflected in the other.

AEMO also recommends that this is an AEMO advisory matter because it relates to AEMO's system security functions.

4.8 Omitted issues

Of the eight issues identified in and following the approach paper that relate to the access standards for loads in NER S5.3, two have not been further considered in the draft report, and for one a 'do nothing' option was preferred after consideration. Issues were omitted primarily on the basis that stakeholder consultation and AEMO analysis indicated that the issues were already addressed elsewhere in the Review or being considered in other processes.

Table 4 sets out these issues related to loads in NER S5.3 and the rationale for omission.

Table 4 Summary of omitted issues

Ref.	Rule	Issue	Omission rationale
7	S5.3 (possible new rule)	Limiting active power ramp rate	'Do nothing' option recommended. See discussion in Appendix A3.
8	S5.3 (possible new rule)	Treatment of loads with uninterruptible power supplies when supplying into the power system	The issue is incorporated into the Policy Position in section 4.2.5.

A1. Recommendations to 'do nothing'

A1.1 Limiting active power ramp rate

Description

Some large loads can rapidly control their consumption and this can impact the system frequency by causing a supply-demand imbalance. Many of these loads are not controlled in a way that makes ramping feasible, rather the loads are switched or controlled with on-line tap-changers. This effect can be accumulative if multiple loads in a region ramp their consumption in response to a change in the electricity price. The increased variability in the system frequency may cause additional FCAS costs, and could increase the wear and tear to generators from the additional frequency excursions and use of PFR. Therefore, the combined impact of an increase in the size and quantity of large loads could reduce the effectiveness of frequency control in the NEM.

There is no requirement for scheduled loads to ramp linearly over a five-minute interval in the same way as generators under S5.2.5.14. Similarly, non-scheduled loads, like non-scheduled generators, do not have limitations on the rate of change of active power. Unlike non-scheduled generators, however, there are no limits on the size of non-scheduled loads that connect to the power system. If a load is large relative to the demand of the region, or if there are multiple loads that are large in aggregate and which may operate without diversity, then rapid active power ramping may impact frequency control on the power system. Variations in plant active power are currently managed through dispatch to the extent they are forecast, the procurement of FCAS and the provision of PFR.

The extent to which such variations in active power would adversely affect the cost of maintaining power system security might depend on the relative size of other variations in supply or demand. Also, it must be considered that not all loads can be readily controlled to limit their rate of change of active power.

Discussion and feedback

In prioritisation workshops held by AEMO, participants indicated a medium level of support in principle for addressing this issue.

There was general consensus that large flexible loads capable of controlling ramp rate should be required to limit ramping to a level that will not adversely impact power system frequency control. The specifics of this requirement would need to account for the nature and capability of the load to ramp its consumption. For example, some loads increase or decrease their consumption in stages and the various parts of the plant switch on and off, or use tap-changers to change the load. It would not be viable to require all plant to be capable of achieving a ramp rate and it would need to be averaged for 'lumpy' loads.

Also, it was considered the AAS should only apply above a MW threshold. Some stakeholders supported a threshold of 30 MW, while others supported 100 or 200 MW. There was no strong consensus on a threshold. Some stakeholders also considered the cumulative effect of multiple loads in an area needs to be considered if loads are expected to respond to the same price signals.

Some stakeholders considered that only scheduled loads should have to be capable of ramping over a five-minute interval, while others considered the requirement should be linked to the size of the load. One noted that multiple loads responding to price would have an accumulated effect, regardless of the size of the individual loads.

Some loads, including some datacentres, have negotiated ramp rates with the NSP on a case-by-case basis. The NSP would need to consider the impact on load voltages and potential impacts on interconnector flows.

Some stakeholders considered that a mechanism should be developed to incentivise loads to ramp their consumption. This could be through the market or through the Transmission Use of System (TUoS) charge.

Options

The following options were considered for the ramp rate:

1. Do nothing.
2. Apply an AAS for scheduled loads to ramp active power linearly over a five-minute interval. In addition, apply a MAS for scheduled loads establishing an active power, average (positive and negative) rate of change limits, over five minutes and exclude transient loads (like motor starts) from the requirement.

Option 1 means that ramp rate requirements would continue not to be captured in performance standards. A large load that is a scheduled load would be required to meet the registration requirements in NER Chapters 2 and 3.

Option 2 was generally supported at the option assessment workshop. In addition, Option 2 would apply a MAS of no required ramp rate for scheduled loads, to accommodate some loads such as starting of large motors.

AEMO considers that imposing ramp rate obligations for scheduled loads through the access standards in NER S5.3 is not currently necessary for power system security and may be confusing. In addition, the accumulated impact of multiple loads responding to price would be complex to address through the access standards and is being addressed by other review processes.

Recommendation

AEMO recommends Option 1.