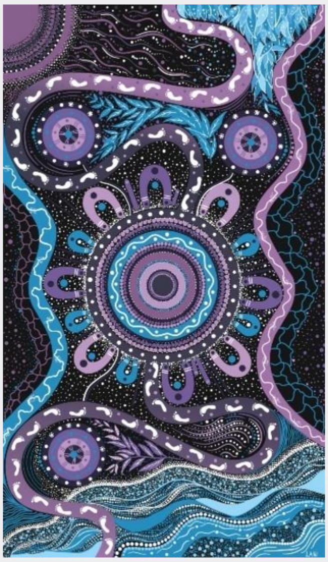
Technical Requirements for 200 kW to 5 MW DER connections

September 2024

Public consultation report

A report for the National Electricity Market



We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.

We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO Group is proud to have launched its first Reconciliation Action Plan in May 2024. 'Journey of unity: AEMO's Reconciliation Path' was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation - a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

Important notice

Purpose

The purpose of this publication is to recommend technical specifications for distributed energy resources that may inform the decision-making processes of regulatory bodies, market participants, new investors, and jurisdictional bodies. The report outlines the potential options assessed for making performance-related specifications, and the proposed implementation approach for the recommended settings.

This publication has been prepared by AEMO using data available and observations made at different times as indicated in the document, and other information available to AEMO as at July 2024.

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Version control

Version	Release date	Changes
#1	02/09/2024	Initial publication released for consultation

Executive summary

Australia's power system is becoming increasingly decentralised as more generator and storage connections are occurring on the distribution network. The aggregate performance of these distributed energy resources (DER) is already influential in the National Electricity Market (NEM) bulk power system and will continue to be so as their penetrations increase. AEMO has already worked extensively to adapt the technical performance standards of residential and small-scale commercial DER and is now seeking to extend this work to focus on the size range 200 kilowatts (kW) up to 5 megawatts (MW) ("sub-5 MW").

The technical performance standards for sub-5 MW DER systems are currently defined through distribution network service providers' (DNSPs') connection requirements, however there are no clear requirements to incorporate matters that would capture bulk power system needs. In many cases, it is understood that the Australian Standard AS/NZS4777.2 is being utilised for these larger connections, however this does not necessarily translate well for larger systems and the same requirements will not necessarily apply directly.

This review seeks to understand the current technical performance requirements and regulatory scope for sub-5 MW DER and identify where gaps might exist. Once the gaps have been identified, the review will consider consistent and appropriate specifications that would assist with the effective management of any risks to the operation of the NEM bulk power system and propose the most appropriate pathway to implement any performance requirement recommendations. This review is intended for DER generation and storage connected to a DNSP's network but excludes DER loads.

The review was informed by the following principles and considerations:

- Facilitate the integration of these plants into the NEM – the technical requirements should support the operation of the power system for secure and reliable operation and not hinder greater participation of these plant in the market.
- **Provide certainty and consistency for original equipment manufacturers (OEMs) and developers** – this can enable the competitive facilitation of greater volumes of such systems across the NEM. For example:
  - Aligning requirements with international standards as far as practicably possible is likely to facilitate more OEMs being able to service the Australian market (without additional development cost), fostering competition in provision of system solutions.
  - Enabling overall functionality to be consistent across the NEM distribution network landscape can support efficient development outcomes while balancing the need for settings and enablement of functions to vary in different parts of the network where necessary.
- **Minimise cost of technical requirements and implementation costs** – this would support the potential for a greater volume of such systems being installed across the NEM, through:
  - Minimising the need for negotiation (preference for mandatory standards), which is likely to provide for quicker connections and reduce the cost and effort required to process them.

   – Minimising the complexity of connections, avoiding requirements for modelling, which reduces cost and time for connection[1].

   – Avoiding technology-specific requirements that could stifle innovation or limit competition, and that would otherwise increase the cost of connection or even result in sub-optimum performance outcomes.

- **Consider implementation mechanisms to achieve a high level of compliance with the proposed technical requirements.**
- **Recognise that DNSPs may have additional requirements that are not relevant to bulk power system needs** – there may be value in harmonising these requirements across DNSPs, however, it is not an essential requirement of this review to do so. DNSPs may wish to consider further steps towards harmonising their requirements, while it is acknowledged that differences may always remain due to the distinctive technical characteristics of each distribution network.

Key findings

Reviewing the historical deployments and forecast installations of sub-5 MW DER, AEMO considers the potential influence on the bulk power system of these resources warrants the establishment of performance requirements which support the safe and reliable operation of the bulk power system, including:

- Frequency ride-through.
- Rate of change of frequency (RoCoF) ride-through.
- Voltage excursion ride-through.
- Phase angle shift ride-through.
- Active power curtailment (via remote signal).
- Ramp rate limits.
- Frequency response (with a deadband).
- Remote monitoring.
- Measurement and control.

Most recently, changes made to AS/NZS 4777.1[2] remove the 200 kilovolt amperes (kVA) threshold from the scope of the Standard and reinforce that the series applies to 230 volts (V)/400 V inverters only. The AS/NZS 4777.1 changes allow for its application to inverter energy system (IES) connections at voltages above 1,000 V alternating current (ac) (high voltage (HV) connections), where low voltage (LV) load is part of the connection.

Given the changes to the AS/NZS 4777.1 Standard, AEMO has sought to ensure its review's scope covers all sub-5 MW DER that otherwise are not covered by the revised Standard (AS/NZS 4777.1:2024).

[1] AEMO notes that DNSPs may impose their own requirements for modelling. DNSP modelling requirements have not been addressed as part of this review.

[2] AS/NZS 4777.1:2024 Grid connection of energy systems via inverters, Part 1: Installation requirements, at https://www.standards.org.au/standards-catalogue/standard-details?designation=AS-NZS-4777-1-2024, and AS/NZS 4777.2:2020 Amd 2:2024 Grid connection of energy systems via inverters, Part 2: Inverter requirements, at https://www.standards.org.au/standards-catalogue/standard-details?designation=AS-NZS-4777-2-2020-Amd-2-2024.

Next steps

Feedback is sought from interested parties on the following recommendations:

- Application of specific settings for the focus technical requirements, within the framework of the IEC TS 62786-1 technical specification for HV-connected DER <5 MW, except for:
  - 230/400 V ac IES, with less than 1.5 MW aggregate rated capacity connected to the HV distribution network with LV load.
- The proposed IEC TS 62786-1 would also apply to synchronous generation 200 kilowatts (kW) to <5 MW[3].
- With the very recent amendments to AS/NZS 4777.1 making the standard apply to all 230/400 V ac inverters connected to the LV distribution system, AEMO proposes these requirements be additionally set for 200 kW up to 5 MW IES:
  - Remote active power monitoring, including curtailment status and remote active power curtailment.
  - Active power ramp rate of 20%/minute, with specific exceptions permitted for conditions that do not lead to cumulative impacts on the bulk supply power system.
  - Primary frequency droop of 5% with a ±0.5 hertz (Hz) deadband, (±1 Hz in Tasmania). A lower (more aggressive) droop may be agreed with the DNSP when the IES is offering frequency control ancillary services (FCAS).

AEMO also seeks feedback from interested stakeholders on its proposed implementation approach, which includes undertaking the following steps:

- Initially working with DNSPs to develop an implementation guideline, based upon the recommended technical requirements and settings. The guideline would provide settings for HV connections relevant to IEC TS 62786-1, and additional settings for those plant 200 kW up to 5 MW for which AS4777.1 would also apply.
- Working with the relevant Australian Standards Committee on the adoption of IEC TS 62786-1 as an Australian standard, with any applicable amendments. Country-specific settings might be agreed within the technical specification or published by AEMO as a separate document.

AEMO will proactively seek to discuss this report with various stakeholder groups. If any party would like to be involved in this collaboration, please contact futureenergy@aemo.com.au.

The consultation process and feedback to the questions posed in this report will inform development of any rule changes and guidelines that will form the basis of AEMO's advice to DNSPs' network connection agreements. Stakeholders are invited to provide responses to this document via futureenergy@aemo.com.au by **30 October 2024**.

[3] Different settings are proposed for synchronous and legacy synchronous generation compared with IES, to account for technology performance characteristics. The legacy plant reference is to cover circumstances where existing back-up generating plant might be connected to the power system.

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Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Term	Definition
AAS	automatic access standard – in relation to a technical requirement of access, a standard of performance, identified in a schedule of Chapter 5 as an automatic access standard for that technical requirement, such that a plant that meets that standard would not be denied access because of that technical requirement
ac	alternating current
BESS	battery energy storage system
dc	direct current
DER	distributed energy resources (generation or storage system connected to the distribution network)
DNSP	distribution network service provider
electrical energy	Average electrical power over a time period, multiplied by the length of the time period.
electrical power	Instantaneous rate at which electrical energy is consumed, generated, or transmitted.
EG	embedded generation – refers to generation in connected in a distribution network
EV	electric vehicle
EVSE	electric vehicle supply equipment
FCAS	frequency control ancillary services – refers to market ancillary services for managing frequency in the NEM
generating capacity	amount of capacity (in kilowatts (kW) or megawatts (MW)) available for generation
generating unit	Power stations may be broken down into separate components known as generating units, and may be considered separately in terms (for example) of dispatch, withdrawal, and maintenance.
GFM inverter	grid forming inverter – a inverter able to operate in the absence of any synchronous generation or synchronous condensers
HV	high voltage – nominal voltage exceeding 1,000 V ac or 1,500 V dc
IES	inverter energy system/s
installed capacity	The generating capacity (in megawatts (MW)) of the following (for example): • A single generating unit. • A number of generating units of a particular type or in a particular area. • All of the generating units in a region. Rooftop PV installed capacity is the total amount of cumulative rooftop PV capacity installed at any given time.
ISP	*Integrated System Plan* – an AEMO planning document that considers a number of forward-looking demand, generation and storage scenarios and associated transmission network augmentations to support them.
LV	low voltage – nominal voltage exceeding 50 V ac/120 V dc but not exceeding 1,000 V ac or 1,500 V dc
MAS	minimum access standard – in relation to a technical requirement of access, a standard of performance, identified in a schedule of Chapter 5 as a minimum access standard for that technical requirement, such that a plant that does not meet that standard will be denied access because of that technical requirement
NEM	National Electricity Market
NER	National Electricity Rules
non-scheduled generation	generation by a generating unit that is not scheduled by AEMO as part of the central dispatch process, and which has been classified as a non-scheduled generating unit in accordance with Chapter 2 of the NER.
OEM	original equipment manufacturer
PV	photovoltaic – refers to solar panels
RoCoF	rate of change of frequency

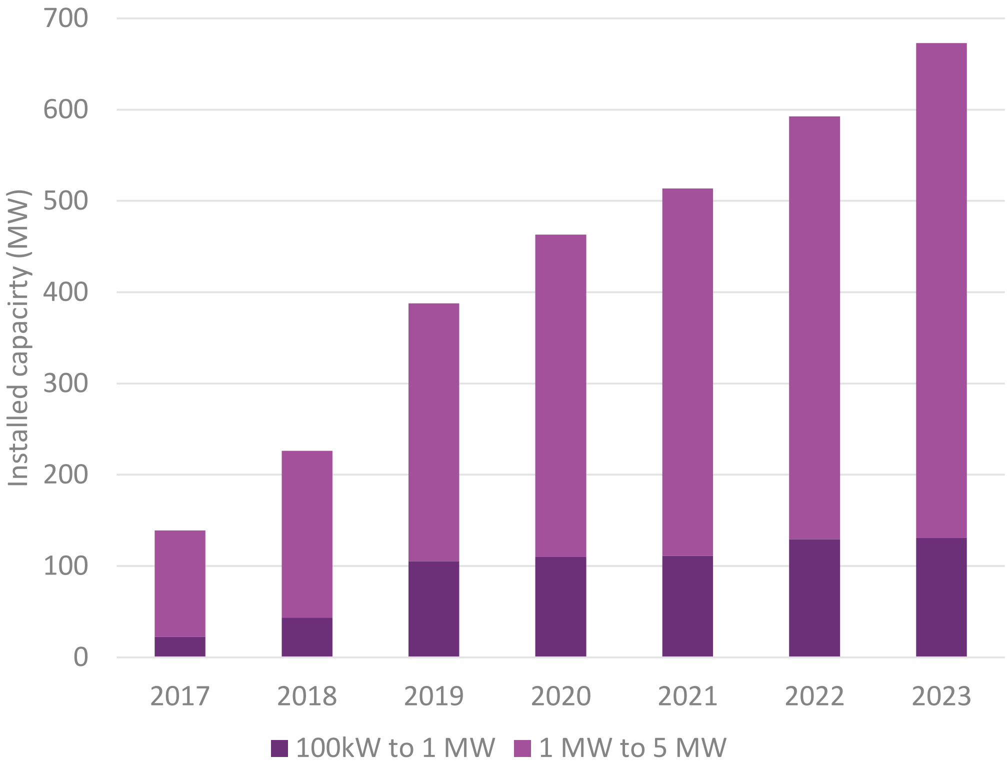
Term	Definition
SCADA	supervisory control and data acquisition

1 Introduction

Recent historical installations of distributed photovoltaic (DPV) resources and battery energy storage systems (BESS) greater than 100 kilowatts (kW) are shown in the figures below[4], highlighting that there has been more than a quadrupling of capacity in the last five years. AEMO's Draft 2024 *Integrated System Plan* (ISP) forecasts the penetration of distributed energy resources (DER) to increase rapidly as the energy transition in the National Electricity Market (NEM) progresses over the next couple of decades[5], with 86 gigawatts (GW) of DPV and 34 GW of residential and commercial batteries forecast installed by 2050[6]. While the largest growth in the last two decades has been predominately small-scale (<100 kW) PV, it is anticipated that there is significant potential in this range, as the current 5 megawatts (MW) threshold for scheduled dispatch arrangements may incentivise participants to remain below this threshold.

Considering the volume of connections being made, as well as those forecast, it is essential that DER will perform in a way that will not adversely impact the security or reliability of the power system. It is also important that performance requirements facilitate plant capabilities and responses that support the integration of these plants into the NEM to maintain and enhance the efficient operation of the NEM.

Figure 1 NEM-wide PV capacity (MW) for connections in the range 100 kW to 5 MW



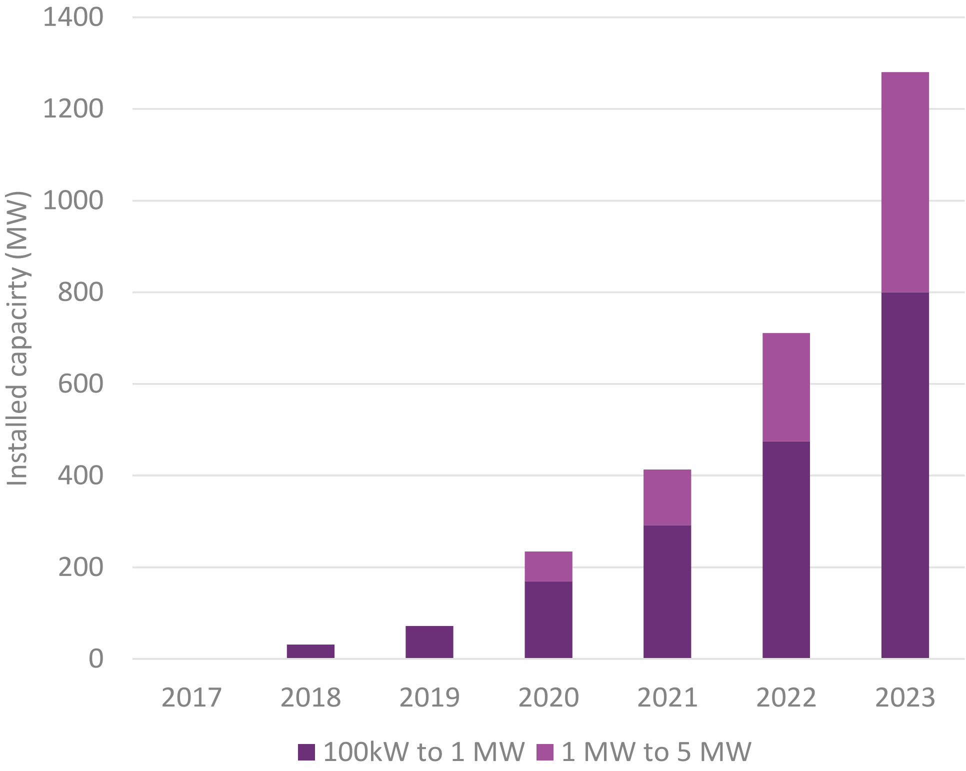
Source: DER Register as of January 2024

[4] Note not all BESS are registered in the DER Register.

[5] *Step Change* scenario; see https://aemo.com.au/consultations/current-and-closed-consultations/draft-2024-isp-consultation.

[6] Installations in the size range considered for this review form a part of those numbers, although a smaller portion than residential PV and BESS

Figure 2 NEM-wide battery energy storage systems capacity for connections in the range 100 kW to 5 MW



Source: DER Register as of January 2024

It has been observed that the aggregate performance of DER can influence the operation of the NEM power system and the efficient operation of the market. This includes:

- The disconnection of photovoltaic (PV) generation within the distribution network following a fault or disturbance in the bulk supply transmission network.
- A rapid change in transmission connection point or regional demand due to price-responsive DER changing its generation responding to price.

1.1 Regulation of sub-5 MW DER

At present, the connection of DER ranging between 200 kW up to 5 MW is currently managed through the distribution network service provider (DNSP) connection process referenced in National Electricity Rules (NER) Chapter 5A. Under Chapter 5A, individual DNSPs set their performance requirements for DER connections in this size range. AEMO does not have a role in the negotiation of the connection agreement between the DNSP and the DER proponent, nor is there an expectation that it should have direct involvement in connections for this size range in the future.

However, AEMO is interested in the cumulative impact of these connections on the bulk power system, and any requirements that may support the continued safety and reliability of the NEM as larger volumes of these systems are installed.

It is important that adequate technical requirements are in place and cover the different types of DER connections and forms of participation across the sub-5 MW size range. These connections vary across several different dimensions, including:

- Connection location within the distribution network – smaller installations within the low voltage (LV) network and larger commercial and industrial installations in the high voltage (HV) network.
- Technology – inverter-based distributed PV (DPV) and BESS, or synchronous generators; also whether it is smaller-scale equipment coupled together, or utility-scale equipment (for example, string inverters versus utility-scale central inverters).
- Mode of operation – such as being paired with local load, or as capacity reserved for local network support or as system services, managed by a retailer or trader.

1.2 Review objectives

AEMO is conducting a review of the technical performance requirements for DER with a particular focus on the size range 200 kW up to 5 MW ("sub-5 MW"). The review includes both DER for generation and storage connected to a DNSP's network, but excludes DER loads.

The purpose of the review is to:

- Understand whether any regulatory gaps exist for technical performance requirements for DER.
- Where gaps might exist, identify consistent and appropriate performance requirements that would assist with the effective management of any risks to the operation of the NEM bulk power system associated with the technical operation of the DER.
- Investigate and propose the most appropriate pathway to implement any performance requirement recommendations.

The review does not expressly include consideration with respect to the compliance management framework that might be required for any proposed performance requirement recommendations. Issues relating to compliance management for the relevant DER reviewed in this report are discussed in Section 5.3.

AEMO's objectives for this review are to:

- Identify and propose technical requirements for DER generation and storage systems from 200 kW up to 5 MW that may affect the performance of the bulk power system, to enable large volumes of such plant to be connected without adversely impacting NEM power system security or reliability of supply; and
- Determine the most effective implementation approach for any recommended technical requirements, in collaboration with DNSPs.

1.3 Scope

AEMO and industry have worked extensively since 2018 to improve the performance standards of residential and small commercial-scale inverter-based DER through Standards Australia's review of AS/NZS 4777.2[7]. This standard describes inverter technical performance requirements, and the companion standard AS/NZS 4777.1 deals with the inverter energy systems (IES), that is, at the facility level. Prior to July 2024, AS/NZ 4777.1 (2016) covered the inverter requirements for DER up to a size of 200 kilovolt amperes (kVA) but contemplated extension to larger plant. The AS/NZS 4777.2 standard deals with LV inverters and has specific requirements about operation in the range 180 to 260 volts (V) alternating current (ac) phase to neutral and three phase equivalent voltages, which are appropriate for LV nominal voltage of 230 V ac single phase or 400 V three phase[8].

Since undertaking the cross-industry review, and since change(s) to AS/NZS4777.2 to manage identified challenges with sympathetic tripping, AEMO identified that this risk of tripping may be applicable for systems that are beyond the scope of the AS4777 suite of standards as well. AEMO also recently completed a review of the access standards in Schedule 5.2 of the NER where recommended updates have been proposed to the performance requirements for registered generation and storage, which are typically above 5 MW[9]. As part of this review, AEMO identified a gap in technical requirements for larger-scale DER between the range of connections covered by AS/NZS 4777 series and the NER schedule 5.2.

This review and the proposed recommendations herein seek to address the risk and gaps identified through both review processes highlighted above.

Further, very recent changes to AS/NZS 4777.1 were adopted by Standards Australia[10] that amended its the scope. Table 1 considers the scope of AS/NZS 4777 as it existed until recently – AS/NZS 4777.1 (2016) – and as amended in the 2024 version[11].

[7] Australian and New Zealand Standard "Grid connection of energy systems via inverters: Part 2 inverter requirements", AS/NZS 4777.2 (2020).

[8] Note that LV is defined as nominal voltages greater than 50 V ac and up to 1,000 V ac (root mean square, phase to phase), and for direct current (dc), 120 V to 1,500 V (ripple free). The term high voltage (HV) is used in Australian standards (including AS/NZS 3000 and AS/NZS 4777.1) to describe nominal voltage above 1,000 V ac.

[9] Under NER 5.2.6A, AEMO reviewed the technical performance requirements in NER S5.2, S5.3 and S5.3a for generation, customer loads and HVDC systems. Further information is at https://www.aemo.com.au/consultations/current-and-closed-consultations/aemo-review-of-technical-requirements-for-connection. Following this review of access standards in Schedule 5.2, AEMO submitted two rule change proposals to implement its recommendations; see https://www.aemc.gov.au/rule-changes/improving-nem-access-standards-package-1 and https://www.aemc.gov.au/rule-changes/improving-nem-access-standards-package-2.

[10] AS/NZS 4777.1:2024 Grid connection of energy systems via inverters, Part 1: Installation requirements, at https://www.standards.org.au/standards-catalogue/standard-details?designation=AS-NZS-4777-1-2024, and AS/NZS 4777.2:2020 Amd 2:2024 Grid connection of energy systems via inverters, Part 2: Inverter requirements, at https://www.standards.org.au/standards-catalogue/standard-details?designation=AS-NZS-4777-2-2020-Amd-2-2024.

[11] AS/NZS 4777.1:2024 Grid connection of energy systems via inverters, Part 1: Installation requirements, at https://www.standards.org.au/standards-catalogue/standard-details?designation=AS-NZS-4777-1-2024.

Table 1 AS/NZS 4777 applicability to various types of distributed energy resources

Description	Connection	Size range	Technical requirements considering AS/NZS 4777.1 2016	Technical requirements considering AS/NZS 4777.1:2024
HV-connected LV inverter-based systems with HV load	DNSP (>1,000 V ac)	< 5 MW	DNSP requirements – AS/NZS 4777 may apply	DNSP requirements – AS/NZS 4777 does not apply
HV-connected LV inverter-based systems (without LV load)	DNSP (>1,000 V ac)	< 5 MW[A]	DNSP requirements – AS/NZS 4777 may apply	DNSP requirements – AS/NZS 4777 does not apply
Other types of generation (including HV inverter systems and synchronous plant)	DNSP (>1,000 V ac)	< 5 MW[A]	DNSP requirements – AS/NZS 4777 does not apply	DNSP requirements – AS/NZS 4777 does not apply
LV inverter-based systems, with LV load, connected at HV	DNSP (>1,000 V ac)	<5 MW[A]	DNSP requirements – AS/NZS 4777 may apply	DNSP requirements – AS/NZS 4777 may apply[B], for 230/400 V IES
LV inverter-based systems, other than 230/400 V, connected at HV	DNSP (>1,000 V ac)	<5 MW	DNSP requirements – AS/NZS 4777 may apply[C]	DNSP requirements – AS/NZS 4777 does not apply
Micro-embedded inverter-based generation, storage and electric vehicle supply equipment (EVSE) (DER)	DNSP (LV)	200 kW – 5 MW	DNSP requirements – AS/NZS 4777 may apply (for EVSE, AS/NZS 4777 may apply to EVSE with vehicle-to-grid (V2G) capability)	AS/NZS 4777 applies for 230/400 V IES[D]
Micro-embedded inverter-based generation, storage (DER)	DNSP (LV)	<200 kW	AS/NZS 4777 applies to all LV-connected inverter-based DER less than or equal to 200 kVA	AS/NZS 4777 applies to inverter based DER systems for 230/400 V IES
EVSE	DNSP (LV)	<200 kW	DNSP requirements – AS/NZS 4777 applies to EVSE with vehicle to grid capability[E]	AS/NZS 4777 applies to all LV connected EVSE capable of reverse power[F]
Synchronous generation	DNSP (LV)	< 5 MW	DNSP requirements – AS/NZS 4777 does not apply	DNSP requirements – AS/NZS 4777 does not apply

A. No lower size limited identified but HV systems are generally larger than 200 kVA and are likely to be larger than about 1 MW.
B. DNSP may apply additional requirements.
C. The 2016 version indicates that it may apply but practically it would be difficult to apply AS/NZS 4777.2 as it has absolute voltages assuming 230/400 V nominal voltage at the inverter.
D. In AS/NZS 4777.2, the inverter requirements appear to be for EVSE with V2G capability (in the sub-200 kW range too).
E. AS/NZS 4777.1 says its object is specify safety and installation requirements for IES intended for the injection of electric power through an electrical installation to the grid. This could include EVSE with capability for injection into the grid.
F. AS/NZS 4777.2 applies to EVSE capable of reverse power and intended for parallel operation as a supplementary supply.

One of the key changes to the standard is the removal of the 200 kVA threshold for general application of AS/NZS 4777.1, however, the standard's scope is explicitly described for 'low voltage systems with nominal values of 230/400 V that conform with AS IEC 60038 for Australia', extending the standard's application to a subset of IES greater than 200 kVA while excluding LV inverters with nominal voltages higher than 230/400V.

The requirements for which the standard may apply have also been subtly changed by the most recent amendments; in particular, the standard 'does not apply to IES connected to dedicated high voltage systems with no local low voltage load'. This means that the standard is not intended to be applied to dedicated HV-connected generation, BESS or electric vehicle supply equipment (EVSE), or to IES connected to HV with (only) HV level load.

The most recent amendments to the standard make AS/NZS 4777.1 applicable for all 230/400 V LV IES, connected at LV level. Effectively this covers virtually all LV-connected IES, as it would be unlikely for inverters with LV voltages other than 230/400 V ac to connect at LV on the distribution grid[12]. For all other categories, AS/NZS 4777 describes that it is not intended to apply or 'may apply'. The standard does not indicate the basis on which it may be applied, or who makes that decision, but the DNSP would typically have guidelines as to what they require for different connection types. The technical requirements may vary from one DNSP to another. A DNSP may also have requirements additional to what is listed in AS/NZS 4777.1 and AS/NZS 4777.2.

Given the recent changes to the AS/NZS 4777.1 standard and considering other existing regulatory arrangements under the NER for distribution network connections of generation and storage equipment, Table 2 seeks to clarify the scope for this review.

Considering the review's focus on 200 kW to 5 MW DER, the primary area of interest for AEMO is for the types of connections described in Table 2's red-coloured box, as these connection types have no explicit technical requirements associated with them that consider the management of the bulk power system. It is noted that some specifications have been optionally defined by the AS/NZS 4777 series, however these are not consistently applied. Connections of DER to the HV level tend to be larger than LV connections, and there may be a high volume of them (especially connections including inverter-based DER) over the energy transition period.

Additionally, there may be LV-connected IES (orange-coloured box in Table 2) which are in the 200 kW to 5 MW size range of interest. For these connections, along with HV connections to which AS/NZS 4777 may apply, the review's focus is on whether additional functionality may be required beyond the technical requirements specified within the AS/NZS 4777 series. It should be noted that where such functionality considers controls that support system security and emergency operations, specific control strategies have not been considered within the scope of requirements, enabling this to be determined by agreement between proponents and DNSPs.

AEMO recognises that LV synchronous DER is not covered by any specific bulk power system requirements, however it is not expected that connections in this range are likely to have much impact on the operation of the bulk power system given forecast volumes for installation over the energy transition[13].

[12] Since DNSPs in Australia only use nominal voltages at LV of 230 V (single phase)/400 V ac (three phase), step down from a higher LV voltage to 230/400 V would be unlikely to be commercially feasible.

[13] The ISP, for example, does not anticipate significant quantities of LV synchronous generation connections.

Table 2 Summary of existing DER performance standards and regulatory arrangements

Category	Description	Connection	Size range	Technical standards
Utility-scale generation and BESS	Utility-scale generation and storage	TNSP/DNSP	5 MW +	NER S5.2[A]
HV-connected DER	• Synchronous generation with load or stand-alone • Dedicated solar and/or BESS • Load + PV/BESS and other dedicated IBR	DNSP >1,000 V ac	<5 MW	DNSP requirements (AS/NZS 4777 may be applied in a subset of IES cases)
LV-connected inverter-based DER	Micro-embedded generation, storage and EVSE (where V2G capable)	DNSP (low voltage)	< 5 MW	AS/NZS 4777 plus DNSP connection requirements
LV-connected synchronous DER	Synchronous LV-connected generation (with or without load)	DNSP (low voltage)	< 5 MW	DNSP requirements

A. Different requirements may apply if the plant has exemption from registration.

1.3.1 Consistency across the NEM improves predictability

When dealing with connections, historically DNSPs have primarily focused on the impacts to their distribution network – operations, voltage, equipment loading and power quality, protection coordination and line worker safety – with little consideration of the impact on bulk power system security.

More recently, some DNSPs have sought AEMO advice about appropriate levels for performance characteristics of sub-5 MW systems that may affect the broader power system. Additionally, industry and policy officials have indicated the prospect for higher volumes of distributed resources being installed across the NEM needs greater consistency with respect to technical performance requirements to be established.

Establishing consistency across the NEM for sub-5 MW DER can deliver improved predictability of the performance of these systems, which supports positive power system security outcomes.

1.3.2 Impact of market price sensitivity and service opportunities

The review's scope covers sub-5 MW DER, so is effectively focused on commercial resources. Plant greater than 200 kW and connected to the HV system is commercially owned and operated, with developers actively seeking to maximise revenue from their investment. Plant of a size that connects to the HV network is more likely to be spot market exposed (price-sensitive) than small-scale residential solar, however, this plant category is also more likely to participate in providing other market services like frequency control ancillary services (FCAS), where market arrangements and technical requirements permit.

Many plants responding simultaneously and rapidly to market signals can potentially cause a power system disturbance, which could adversely affect local voltages or cause power system circuit overloading.

A key consideration for this review is to identify requirements that would facilitate and incentivise behaviours that support the operation of the power system, while minimising adverse impacts on it, without making the cost of connection prohibitively expensive or the technical requirements significantly arduous as to disincentivise investment.

1.4 Principles and considerations

In undertaking this review, AEMO has applied the following principles and considerations:

- **Facilitate the integration of these plants into the NEM** – the technical requirements should support the operation of the power system for secure and reliable operation and not hinder greater participation of these plant in the market.
- **Provide certainty and consistency for original equipment manufacturers (OEMs) and developers** – these can enable the competitive facilitation of greater volumes of such systems across the NEM. For example:
  - As far as practicably possible, aligning requirements with international standards – this is likely to facilitate more OEMs being able to service the Australian market (without additional development cost), fostering competition in provision of system solutions.
  - Enabling overall functionality to be consistent across the NEM distribution network landscape – this can support efficient development outcomes while balancing the need for settings and enablement of functions to vary in different parts of the network where necessary.
- **Minimise cost of technical requirements and implementation costs** – this would support the potential for greater volume of such systems being installed across the NEM, through:
  - Minimising the need for negotiation (preference for mandatory standards), which is likely to provide for quicker connections and reduce the cost and effort required to process them.
  - Minimising the complexity of connections, avoiding requirements for modelling, which reduces cost and time for connection[14].
  - Avoiding technology-specific requirements that could stifle innovation or limit competition, and that would otherwise increase the cost of connection or even result in sub-optimum performance outcomes.
- **Consider implementation mechanisms to achieve a high level of compliance with the proposed technical requirements.**
- **Recognise that DNSPs may have additional requirements that are outside bulk power system needs** – there may be value in harmonising these requirements across DNSPs, however, it is not an essential requirement of this review to do so. DNSPs may wish to consider further steps towards harmonising their requirements, while it is acknowledged that differences may always remain due to the distinctive technical characteristics of each distribution network.

AEMO also acknowledges that there are other reviews recently completed or being undertaken in parallel with this one, including:

- The Australian Energy Market Commission (AEMC) Review into consumer energy resources (CER) technical standards, published on 21 September 2023[15]. This review, among other things, recommends the establishment of a national regulatory framework for CER technical standards.

[14] AEMO notes that DNSPs may impose their own requirements for modelling. DNSP modelling requirements have not been addressed as part of this review.

[15] At https://www.aemc.gov.au/sites/default/files/2023-09/RCERTS%20Final%20Report.pdf.

- On 24 November 2023, Energy Ministers agreed to consider implementing a national approach to technical regulatory settings for CER in 2024[16]. The federal, state and territory governments are working with market bodies to progress this and other priority CER reforms through a dedicated taskforce that will be supported by a stakeholder reference group[17].
- Guidelines developed by Energy Networks Australia (ENA) for basic micro embedded generation (EG) connections, medium voltage and high voltage EG connections, and low voltage EG connections[18].
- The Australian Renewable Energy Agency (ARENA) Distributed Energy Integration Program[19].
- AEMO's 'Integrating price-responsive resources into the NEM' rule change proposal[20] currently under review by the AEMC.
- AEMO's 'Unlocking CER benefits through flexible trading' rule change proposal[21], also currently under review by the AEMC, with Final Determination to be published on 11 July 2024.

1.5 Approach taken in this review

AEMO's approach for this review brings together information from multiple perspectives. AEMO has:

- Identified the technical requirements that it considers are likely to impact the bulk power system, considering the cumulative impact of a high volume of plant being installed.
- Surveyed and analysed DNSP approaches to connection, to understand the commonalities and differences between them.
- Held discussions with OEMs and developers to understand what aspects of performance or other connection requirements impact the commercial viability or technical feasibility of connections in this size bracket, and to what extent flexibility can be extended to accommodate different operating strategies, and to minimise complexity and cost of connections.
- Investigated the range of international standards that could apply to connections in this size bracket.
- Sought to match the target technical requirements affecting the bulk power system against prospective international standards to potentially identify a preferred standard, as well as working with DNSPs to consider appropriate levels of performance for each of those technical requirements. AEMO has also considered the AS/NZS 4777.2 performance requirements, in light of the needs for the bulk power system, with a view to identifying any additional requirements for plant in the 200 kW to 5 MW range, beyond what is described in that standard.

[16] Energy and Climate Ministerial Council, Meeting Communique Friday 24 November 2023, at https://www.energy.gov.au/sites/default/files/2023-11/ECMC%20Communique_24%20Nov%202023.docx.
[17] Energy and Climate Ministerial Council, Meeting Communique Friday 1 March 2024, at https://www.energy.gov.au/sites/default/files/2024-03/ECMC%20Communique%201%20March%202024.docx.
[18] At https://www.energynetworks.com.au/projects/national-grid-connection-guidelines/.
[19] At https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/.
[20] At https://www.aemc.gov.au/rule-changes/integrating-price-responsive-resources-nem.
[21] At https://www.aemc.gov.au/rule-changes/unlocking-CER-benefits-through-flexible-trading.

- Compared the technical requirements of international standards against the range of requirements for matters outside those of interest to AEMO, but which are of interest to DNSPs to examine whether these would be covered sufficiently by the same standard.

As part of this review process, AEMO has consulted extensively with DNSPs to identify the most effective pathway for implementing any proposed set of technical requirements.

1.6 Report structure

The remainder of this document has been structured as follows:

- Chapter 2 examines which aspects of plant performance are important to the performance of the bulk power system and the efficient operation of the NEM.
- Chapter 3 examines existing performance requirements in the 200 kW up to 5 MW range (referred to as “sub-5 MW”), and OEM and developer experiences with connection.
- Chapter 4 examines options for standards to apply performance settings and alignment with DNSP requirements.
- Chapter 5 describes the prospective implementation plan and associated next steps.

2 Prospective performance requirements

Individual sub-5 MW DER cannot normally impact bulk power system operation, although they may affect the local distribution network. However, when multiple sub-5 MW DER respond in a similar manner simultaneously, the impact on the bulk power system is cumulative, and depending on scale, sufficient volume of response may require active system management options that can mitigate substantive risks. On the other hand, if responses are not triggered simultaneously (in the same direction), the combined impact on the bulk power system will tend to be significantly smaller.

This understanding can be used to identify performance characteristics of DER that will affect the bulk power system. Of particular importance are the ride-through capabilities of sub-5 MW DER for various types of power system disturbances, discussed in Section 2.1 below.

Since DER are expected to play a significant role in the power system of the future – and increasingly, in the power system of the present day – the ability of sub-5 MW DER to support the operation of the power system is also important, especially under emergency conditions where market arrangements alone may not be sufficient and system operations require additional measures to target resilience. Performance requirements that assist in managing abnormal power system conditions are discussed in Section 2.2.

An additional category of consideration for sub-5 MW DER is the market response(s) of these systems. Potentially rapid responses to market signals may assist, or could possibly hinder, the effective operation of the market. Performance requirements related to market interaction(s) are discussed in Section 2.3.

2.1 Ride-through requirements

In response to several power system events across 2017 and 2018[22], AEMO undertook a series of event investigations on DER technical capabilities, with its findings leading to proposals for various changes to the national standard for small-scale IES, AS/NZS 4777.2. AEMO's initiation of a review of AS/NZS 4777.2[23] through Standards Australia to improve disturbance ride-through capabilities for small-scale IES culminated in the publication of AS/NZS 4777.2:2020 on 18 December 2020.

As reported and identified in these previous publications, disturbance ride-through requirements are a significant and imperative need to manage the NEM's operations effectively. Regardless of device or system size, all DER should be required to perform and maintain disturbance ride-through capabilities as specified under the AS/NZ 4777.2:2020 standard. The implications of poor DER compliance – growing the amount of DER installed with poor disturbance ride-through capabilities – are clear, with DER shake-off happening coincident with the trip of a large generating unit, thereby increasing the size of credible contingences that must be managed to maintain power system security.

[22] See, for example, https://www.aemo.com.au/Gas/Gas-Bulletin-Board/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Report-SA-on-3-March-2017.pdf and https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2018/trip-of-rots-bus-on-18-jan-2018---published.pdf?la=en&hash=E87A868BE150309321D9CDFCE7794AD0.

[23] See https://aemo.com.au/-/media/files/electricity/nem/der/2019/technical-integration/technical-integration-of-der-report.pdf?la=en&hash=8A1897A00BABD064CADB590759D682FB.

The consequences of increasing the size of the largest credible contingency include:

- Increasing procurement of frequency control services, which increases market costs and can also become problematic when attempting to operate parts of the grid that can island.
- Increased need for DER curtailment, such as the need to direct network service providers (NSPs) to curtail DPV to maintain power system security, given all other available options are exhausted.
- Reducing network stability limits, such as those related to transient and voltage stability[24], due to DER tripping in response to a fault exacerbating credible contingency events. This can lead to major transmission lines and interconnectors needing to be constrained to lower levels during high DER output conditions, as well as increased market costs.
- Reducing windows for planned network outages, given that network limits such as transient stability are often considerably reduced when there are outages, and thus periods forecast to have high and moderate DER generation are unsuitable for scheduling outages. With the prospect of outages requiring multi-day interruptions, it is increasingly challenging to find suitable windows for works to occur, escalating the risk of sudden unplanned outages associated with operating the network, given the required maintenance and upgrade works could not be undertaken in a timely manner.
- Rising risks for non-credible contingencies due to increasing contingency sizes risking cascading failure and black system associated with non-credible contingency events (such as a simultaneous trip of multiple lines or multiple generating units). As non-credible contingencies are managed by fast, autonomous emergency control schemes such as under frequency load shedding (UFLS), increasing the size of these contingencies risks insufficient resources being available to respond to such non-credible scenarios, leading to potential black system events.

2.1.1 Frequency and rate of change of frequency ride-through

Frequency is a power-system wide characteristic. Tripping of DER generation for low frequency would exacerbate both the frequency deviation and rate of change of frequency (RoCoF), ensuring ride-through capability for frequency excursions and RoCoF are both important requirements that support power system security. Tripping of DER generation at frequency above 50 hertz (Hz) will tend to reduce the frequency excursion; however, if a large amount of generation is tripped, the loss of supply can turn an over-frequency event into an under-frequency event. Tripping of batteries that are charging can also adversely affect a frequency excursion event.

2.1.2 Voltage and phase shift disturbance ride-through

Rapid power system disturbances at transmission level, such as line faults, can be reflected down into the distribution network. If large amounts of DER trip for transmission faults, this can cause voltage disturbances, and changes in power flows that may result in line overloading and supply-demand imbalances that lead to frequency excursions.

Line faults and similar contingency events are often accompanied by network switching (for example, to clear the fault), which is associated with phase shifts on the power system.

[24] For further explanation on stability limits, see AEMO's "Constraint Frequently Asked Questions", at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/congestion-information resource/constraint-faq.

Technical requirements for ride-through for voltage excursions and phase angle shifts[25] are therefore a key consideration for maintaining power system security.

2.1.3 Protection reflecting plant capability

Modern DER are typically quite robust to a range of power system disturbances and may be capable of performance substantially better than mandated ride-through requirements. Where capability exceeds the ride-through requirements, it is beneficial to the bulk power system for the plant to remain connected, as tripping would usually result in a local power system disturbance.

Unless otherwise required by the NSP to trip the plant, protection should be set to maximise plant capability to remain in operation for abnormal power system conditions, subject to safety margins consistent with good engineering practice. AEMO notes that such a recommendation has been made for the access standards in schedule 5.2 of the NER in the recent rule change proposal[26].

2.2 Controls to support system security and emergency operations

2.2.1 Remote active power curtailment

The active power output of DER significantly impacts the supply-demand balance for electricity in the NEM. The extent to which excess supply in one part of the NEM can be used in another part is constrained by the transmission limits between regions (inter-regional limits) and within regions (intra-regional limits). Further, to operate the power system securely, certain (often synchronous) generation may be required to operate at times.

Under high DER generation scenarios, there is the potential for coincident excess distributed generation in multiple regions, contributing to Minimum System Load (MSL) events that require system operators to avoid falling below certain benchmarks or risk widespread power outages. With these conditions, it may be necessary to curtail DER to operate the power system securely.

Device controls, including the means to communicate the action required to the device or system, and monitoring to feed back the response, are potentially important technical requirements for DER.

Where potential curtailment may be required[27] to support bulk power system operation, AEMO anticipates that this would be coordinated through the local DNSP, rather than any direct control being facilitated between AEMO and DER plant.

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[25] For the larger utility-scale plant covered by access standards described in schedule 5.2, these two aspects are covered by S5.2.5.4 for voltage excursions, and S5.2.5.5, which includes contingency response, and therefore covers both phase shifts and voltage shifts associated with faults and other contingency events.

[26] At https://www.aemc.gov.au/rule-changes/improving-nem-access-standards-package-1.

[27] The need to curtail plant can be reduced by building more network to increase power transfer capability. However, this comes at a cost. The National Electricity Objective is met by minimising the overall to cost consumers, factoring in efficient investment and operation as well as the need to maintain power system security and reliability of supply, and meeting greenhouse gas emissions reductions targets. The efficient level of network investment is unlikely to result in an absence of curtailment, so this capability is highly likely to be required in the future. See, for example, Victoria's emergency backstop mechanism for rooftop solar, at https://engage.vic.gov.au/victorias-emergency-backstop-mechanism-for-rooftop-solar.

2.2.2 Frequency responsiveness

If a severe supply-demand mismatch occurs, often due to a power system event (such as the tripping of a large quantity of load or generation), it is highly beneficial that DER provide an automatic active power response that opposes the frequency deviation caused by the event.

The response that AEMO considers would provide most useful capability for system operations would be a frequency droop response, providing an active power response proportional to the frequency deviation. A wide deadband could be nominated to avoid triggering this frequency response unnecessarily (for example, for frequency in the normal operating band).

2.3 Market responses

2.3.1 Alternative frequency response settings

As noted previously, it is attractive for investors and beneficial for the electricity market for sub-5 MW DER to participate in market services. Resources such as solar farms and batteries are well suited to providing fast frequency response and contingency services. They may need to apply different frequency response (frequency droop) settings or ramp rates when they are participating in these services. Any proposed technical requirements should not prevent such arrangements from continuing to be available to such plant.

2.3.2 Ramp rate limits

Some DER, such as batteries, are capable of fast ramping and there can be significant financial rewards to be gained by responding to spot market prices in the NEM. However, if large volumes of non-scheduled plant (<5 MW) ramp rapidly and simultaneously, this can result in adverse impacts on the power system's operation, irrespective of considerations with regards to the market volatility it may also engender.

Rapid ramping of DER – ramping that operates faster than the NEM's 5-minute interval – can introduce mismatches between supply and demand that increase the variability of power system frequency. This could lead to an increased requirement for regulation FCAS and cause the generation and storage systems that provide primary frequency response to operate more often, potentially leading to higher maintenance costs and reduced plant life.

Given this potential impact, AEMO considers it is generally undesirable for non-scheduled plant to ramp at rates faster than a market interval (no greater than 20% per minute[28]). This rate is the effective maximum ramp rate imposed on scheduled generation and is the default limit for smaller DER captured by AS/NZS 4777.2.

Nevertheless, there are prospective situations in which rapid ramping is unlikely to solicit a cumulative impact on the market. Examples where a higher ramp rate may be reasonably supported include:

- To provide fast frequency control services (as described in Section 2.3.1).
- To provide frequency response for large frequency excursions (as described in Section 2.2.2).

[28] This would be 20% of rated export for a generating plant, and 20% of (rated export + rated import) for a BESS.

- Where the plant is part of a hybrid system, being any combination of load and generation and storage, where the plant is controlling the net import or export at the connection point, and the ramp rate limit is applied to the net import or export, but the plant may be permitted to have a higher individual ramp rate.
- Where the plant is a battery storage system and a higher ramp rate may be permitted at low charge level, to avoid having to reduce output early to manage battery voltage. The prospect has been raised that a "baseline" low charge threshold level be nominated as part of any proposed requirement, to avoid the setting of arbitrary limits by operators or OEMs, however, it is not clear that the cumulative effect of this exemption would impact system security and thus it may be best left to DNSPs to manage local network circumstances.
- Where the plant is operating in an islanded condition (for example, back up generation or 'edge of grid' operation to maintain supply to an islanded part of the distribution system).
- Where a generator run-back scheme may be agreed with the DNSP.

AEMO considers the above situations as potential exemptions from any ramp rate limit requirements.

2.3.3 Monitoring

The ability to predict change in load and non-scheduled generation is key to forecasting for market dispatch and an input into planning power system operation in the short term, and power system augmentation in the longer term. Forecasting for all these timescales relies on quality data. Of particular interest for forecasting are insights such as active power output and curtailment status (curtailed/not curtailed) or an equivalent quantity.

Feedback of active power and other quantities such as connection point voltage or reactive power output may also be important for distribution management systems and might be required by DNSPs.

AEMO acknowledges that the provision of remote monitoring is a likely cost imposition on connections, which may be an impediment for small projects to proceed to completion. However, it is also understood that HV connections are most often associated with larger load or DER, for which a remote monitoring requirement is less likely to be a prohibitive cost.

It is important to note that any requirement for monitoring is not expected to result in signals being transmitted to AEMO directly, rather that such signals would be directed to the relevant DNSP.

2.3.4 System strength services

In future, a portion of DER connections are likely to include grid-forming (GFM) capabilities. In the short term this is most likely to be BESS in larger size projects. Some developers have expressed interest in GFM inverters in the sub-5 MW range of equipment. Some DNSPs are also exploring the possibilities for GFM technologies to support the local grid in abnormal power system conditions, including islanding of part of a distribution system.

The requirements to support the bulk power system, described in the previous sections, can be equally met by GFM inverters and the more common grid-following inverter technologies. For GFM inverters, consideration would need to be given to protection system design for low fault level conditions, and whether anti-islanding should apply. These design elements would affect the bulk supply system operation only if they impinge on the plant's capability to ride through power system disturbances and there is some interaction between the plant and other plant that results in a cumulative impact.

2.4 Requirements that support the bulk power system

The discussion in the preceding sections outlines requirements which AEMO considers are important to support the operation of the bulk power system for DER in the sub-5 MW range, namely:

- Frequency ride-through.
- RoCoF ride-through.
- Voltage excursion ride-through.
- Phase angle shift ride-through.
- Active power curtailment, by remote signal.
- Ramp rate limit.
- Frequency response (with a deadband).
- Remote monitoring.
- Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements.

Some of the above requirements will also be of importance to DNSPs, particularly those affecting voltage in the local network.

2.5 Other prospective technical requirements

As part of this review, AEMO considered other prospective technical requirements for sub-5 MW DER, in addition to those identified in Section 2.4.

After analysis, AEMO considered that a range of requirements, while of interest to DNSPs for their local networks, were not likely have sufficient impact on the bulk power system to warrant a determination by AEMO for a specific requirement to support the power system. These requirements include:

- Reactive power capability.
- Reactive power control.
- Volt-watt characteristics.

In addition, DNSPs will continue to specify requirements for communications (and associated protocols) from their control centres to plant in accordance with licence conditions and obligations under the *Security of Critical Infrastructure Act 2018*. Plant operator and other third-party remote interactions with plant are outside the scope of this review.

Further, other national efforts are currently underway (or soon to be undertaken) that will likely be the primary channels for identifying standards and roles for managing CER cyber security risks in the Australian energy system[29].

[29] Standards Australia and the Department of Climate Change, Energy, the Environment and Water (DCCEEW) Roadmap for CER cybersecurity, at https://www.standards.org.au/documents/roadmap-for-cer-cybersecurity-report. DCCEEW and Standards Australia are

Consultation questions: Scope of technical requirements

AEMO welcomes stakeholder feedback. In particular, AEMO is interested in understanding:

- Has the scope of prospective requirements for sub-5 MW DER been clearly defined?
- Is the reasoning behind including those focus areas for AEMO to consider specifying technical requirements (summarised in Section 2.4) clear and reasonable?
- Should AEMO also consider any or all of the requirements outlined in Section 2.5 (identified by AEMO as being of interest to DNSPs only)?
- Should AEMO consider other requirements not outlined here?

currently preparing a proposal to develop a technical specification on cybersecurity for consumer energy devices to provide guidance for the Australian market. In addition, the Minister for Climate Change and Energy has submitted a rule change to the AEMC that seeks to provide AEMO with a coordinating role for cyber security, including providing advice to government and industry; see https://www.aemc.gov.au/rule-changes/cyber-security-roles-and-responsibilities.

3 Existing performance requirements

As part of this review, AEMO held discussions with DNSPs, OEMs and industry participants such as DER developers on current connection practices for sub-5 MW DER. The feedback from these consultations is summarised in this chapter and has informed the proposed recommendations outlined in subsequent sections.

3.1 Current approach for DER technical requirements

As part of this review, AEMO surveyed existing DNSP requirements for generation and BESS connections for the sub-5 MW category. Appendix A3 has a summary of each DNSP's specifications. While the results show commonality in the type of technical requirements applied, the performance levels vary across DNSPs.

Consistency in approach between DNSPs is scattered, with some of the differences being attributable to differences in the characteristics of the DNSPs' networks.

Two main approaches were observed:

- Extension of the AS/NZS 4777.2 requirements beyond its intended coverage to inverters connected at HV level and/or greater than 200 kVA in size, sometimes with additional requirements.
- Extension of the access standards in schedule 5.2 of the NER down to plant below sub-5 MW, often with some simplifications.

The following section considers these broad approaches and their implications. While, intuitively, the technical requirements for sub-5 MW DER should fall between AS/NZS 4777.2 requirements (applicable to <200 kVA plant) and those specified in NER Schedule 5.2 (applicable to >5 MW plant), it is worth considering how these differ for the technical requirements identified in Section 2.4.

Consideration also needs to be given to the effect of recent changes to AS/NZS 4777.1, described in Section1.3, which, by removing the existing 200 kVA threshold, extend the mandatory application of AS/NZS 4777.1 to all LV-connected IES. Further, consideration needs to be paid to the AS/NZS 4777 amendments which describe conditions where the standard is not applicable, potentially resulting in changes to some DNSP technical requirements for connections, compared with their historical approaches.

3.1.1 Technical requirements for Utility scale generation

The process and requirements for connecting new utility generating systems are defined in NER Chapter 5. In particular, the technical requirements for connecting utility generating systems are prescribed in the access standards in NER S5.2. The requirements in NER S5.2 are generally described by automatic access standards (AAS) and minimum access standards (MAS). For each technical requirement, a performance standard is agreed, which either meets or exceeds the automatic access standard or is a negotiated level between the minimum and automatic access standard levels. There are also some general requirements associated with particular access standards which apply to all plant connecting under NER S5.2.

Generation and storage systems equal to or >5 MW, unless exempted, are required to be registered with AEMO, and this includes the performance standards. Compliance with performance standards is also required over the life of the plant.

As the access standards are formulated as minimum and automatic levels, there is no one mandated standard that applies in all cases. Generally, the range of technical requirements is aligned with those described in Section 2.4 . Two significant matters of note are:

- The under-voltage ride-through requirements in S5.2.5.4 AAS and MAS only specify performance down to 70% of normal voltage.
- The phase shift requirement is only specified as a MAS not to have any (vector shift or similar) protection that could trip the plant for phase angle changes less than 20 degrees at the connection point.

However, NER S5.2 includes broader ride-through requirements in NER S5.2.5.5 for contingency events that include a wide range of single and multiple fault conditions, which would typically encompass conditions that required ride-through for lower voltages than 70% and contingencies that result in phase angle shifts, which may differ from one connection location to another. The assessment of such a broad technical requirement requires the use of extensive wide area modelling, the cost of which would be difficult to justify for small distribution connections.

AEMO considers it would be more appropriate for these connections to specify the voltage profile ride-through and phase shift requirements by reference to an existing international standard.

3.1.2 Low voltage inverter-based DER

The standard AS/NZS 4777.2 'Grid Connection of energy systems via inverters Part 2: Inverter requirements' specifies device specifications, functionality, testing and compliance requirements for electrical safety and performance, taking into account the proposed 2024 amendments, low voltage inverters with nominal voltage of 230/400 V that conform with AS IEC 60038, including:

- Energy sources.
- Energy storage systems.
- Electric vehicles (EVs) and EVSE that can operate as an energy source and storage system that can supply an electrical installation connected to the grid.
- Inverters within an electrical installation capable of operating in an island mode that may be connected to the grid at low voltage via an ac input port.

Whereas NER S5.2 is largely written for performance at the connection point, technical requirements in AS/NZS 4777.2 are largely at the inverter level. AS/NZS 4777.2 enables the inverters to be installed as part of an IES in accordance with the requirements of AS/NZS 4777.1, which deals with installation requirements. AS/NZS 4777.2 also contemplates additional requirements of the electricity distributor approving the connection.

This standard is referenced in the NER under the definition of DER technical standards, which apply to embedded generating units. The DER technical standards are defined as:

> The requirements for *embedded generating units* under Australian Standard AS/NZS 4777.2:2020 as in force from time to time.

An embedded generating unit is a *generating unit* connected with a *distribution system* and not having direct access to the *transmission network*. The 'Integrating Energy Storage Systems (IESS) into the NEM' rule, commencing 3 June 2024, extends application to distribution-connected bidirectional units. For a basic micro DER connection service, a model standing offer must require embedded generating units to meet the DER Technical Standards.

Micro DER connection is defined in chapter 5A to mean:

> a *connection* between *a distribution connected unit* and a *distribution network* of the kind contemplated by Australian Standard AS 4777 (Grid connection of energy systems via inverters).

AS/NZS 4777 includes both AS/NZS 4777.1 and AS/NZS 4777.2.

AS/NZS 4777.2 covers the types of technical requirements identified in Section 2.42.4 of this report, except that it specifically requires the plant to trip for under- and over-voltages outside specified ranges (although these are after reasonable time delays), and it also defines voltage ranges (<180 V and >260 V) for which it is required to cease power generation after 200 milliseconds (ms).

Some requirements might not be at a level that is desirable for larger IES. For example, an inverter conforming to this standard is required to be able to operate a disconnection device, but other levels of curtailment (such as not consume power more than 50% or not generate power more than 50%) are not mandatory for this standard – it permits the NSP flexibility to override default parameters.

As noted previously, recent amendments to AS/NZS 4777.1 remove a 200 kVA threshold for IES for which the standards apply, thereby extending it and the technical requirements in AS/NZS 4777.2 to all LV-connected IES.

3.1.3 DNSP approaches for HV connections in the sub-5 MW range

As noted earlier, AEMO's consultation with DNSPs as part of this review identified that there are two main approaches undertaken by DNSPs for technical requirements for sub-5 MW plant, namely:

- Applying requirements of AS/NZS 4777.2-2020, and extending them up to HV connections, or
- Applying requirements of NER schedule 5.2 and extending them down to smaller size equipment.

Where schedule 5.2 is applied, is it usually with some simplification of the requirements.

Typically, plants in the sub-5 MW category would be connected under chapter 5A of the NER, although proponents may elect to use chapter 5 instead[30]. Under chapter 5A, the DNSP has the discretion over the choice of technical requirements[31].

The NER do not prevent AS/NZS 4777.2 application to facilities connected at HV level. However, AS/NZS 4777.2 contains voltage requirements specifying LV quantities, so would not be directly applicable unless the inverters had LV 230/400 V ac terminal voltages, and the recent amendments to AS/NZS 4777.1 also refer to this limitation of scope. AS/NZS 4777.1 permits its application to HV connections where there is also LV load.

[30] AEMO understand that proponents of sub-5 MW plants rarely, if ever, elect to use Chapter 5.

[31] The NER also permit a person to elect to apply NER 5.3A instead of chapter 5A, in which case NER S5.2 access standards apply. Furthermore, for a negotiated connection (which would be more typical for a commercial/industrial-scale connection), the DNSP can specify technical requirements that may include elements of NER S5.2.

Key observations from AEMO's survey of DNSP requirements for sub-5 MW inverters, a summary of which is provided in Appendix A3, include:

- While DNSPs usually specify most of the requirements identified in Section 2.4, specific requirements vary significantly between DNSPs.
- DNSPs often specify different technical requirements for IES sub-5 MW, based either on size or connection voltage. For example, some DNSPs have different requirements based on LV-connected or HV connections. Other DNSPs may have a size threshold at 1 MW or 1.5 MW with different requirements applying above and below the threshold.

Typically, smaller plant would be expected to connect at LV and larger plant at HV, because of capacity limitations at LV connections, but there may be circumstances in which smaller plant connect at HV level, for example, as part of a larger facility that includes load and generation.

The use of the term HV is not universal either – some DNSPs refer to connections above LV as medium voltage connections.

3.2 OEM and developer feedback

As a part of this project, AEMO held discussions with a number of OEMs and developers who are active in the connection of sub-5 MW DER in the NEM. Key feedback and insights from these discussions include:

- DNSPs varied, and differing requirements for connections makes it difficult to standardise offerings and adds greater cost than would otherwise be necessary under a scenario where a NEM-wide standard was applicable and enforced. Some developers called for existing requirements to be "harmonised" across the NEM.
- Ramp rate limits can impact the business case of a project, particularly where a key proposed revenue stream was the ability for the plant to respond to a market price faster than within a single market interval.
  - AEMO outlines in Section 2.3.2 a discussion on different scenarios and conditions under which fast ramping (that is, responding within a market interval) would not adversely affect the market operation.
- Modelling requirements can be burdensome and do not seem to add much value to the connection process. Examples of site-specific modelling leading to nearly identical outcomes were provided.
- Requiring SCADA for plants less than 1 MW is burdensome and might affect the commercial viability of the project.
- Requiring technical standards (as per the NER chapter 5 process for larger plant) for sub-5 MW DER is excessive.

Feedback from OEMs and developers suggested a high level of existing compliance with AS/NZS 4777.2, although AEMO analysis indicates ride-through performance is not uniformly satisfactory across different connection sizes. In general, OEMs supported the use of a common standard that might be used internationally, in comparison to specifying bespoke requirements, but there was no single standard specified by all those interviewed.

4 Proposed performance requirements

This section includes considerations about:

- Options for meeting the technical requirements identified in Section 2.4 (requirements that support the bulk power system).
- Proposed detailed requirements for AEMO's areas of interest, compared with the technical requirements outlined in IEC TS 62786-1 and IEEE 1547.
- Proposed technical settings for potential requirements.
- How IEC TS 62786-1 covers other requirements that may be of importance to DNSPs.

4.1 Options for specifying the technical requirements

The potential options available for AEMO to specify technical requirements for sub-5 MW HV-connected DER are to adopt one of:

- AS/NZS 4777.
- NER schedule 5.2.
- A different international standard.
- A bespoke set of requirements.

The following table compares the advantages and disadvantages of these options.

Table 3 Options to define technical requirements

Option	Advantages	Disadvantages
Extend AS/NZS 4777.2 to HV DER sub-5 MW range	• LV inverters used for the <200 kVA range have already been certified against this standard – the standard is fairly mature. • Defined performance at inverter level – easy to apply settings on the inverter and to confirm the settings. • Does not require modelling to determine settings. • Less complex connections, because settings are not bespoke. • Already applied by some DNSPs to HV connections using 230/400 V ac inverters. • Flexible in some requirements, such as ramp rate limits. • Covers all the requirements listed in Section 2.4 other than protection settings to be set to maximise capability.	• AS/NZS 4777 is designed primarily for LV inverters and LV connections. This series of standards does not apply across the entire sub-5 MW landscape, although AS/NZS 4777.1 does permit application to HV connections for some types of connections. • HV inverters are not covered and only a limited range of LV inverters is covered; AS/NZS 4777.2 has 230/400 V ac settings specified in absolute voltages for some requirements. • Connection point performance is not defined (mainly an issue for HV connections). Some requirements may be affected by presence of a transformer, for example, phase shift and voltage ride-through settings. Performance will be different compared with requirements at the connection point; for example, for single phase voltage dips, transformer impedance and phase shift lead to different voltage and angle at inverter compared with connection point. • Inverters are required to cease generation for high and low voltages for deep voltage dips. This does not make best use of available capability from inverters, and for cumulative impacts of multiple systems could cause a bulk power system disturbance. • AS/NZS 4777 series is specifically for inverter-based equipment and cannot be used for other technologies.

Option	Advantages	Disadvantages
		• Pre-defined settings that relate to other NEM settings (such as the Frequency Operating Standards (FOS)) can become outdated. • Some default settings are quite onerous and may result in curtailment of active power more than is necessary in all circumstances.
Extend schedule 5.2 requirements down to the HV connected sub-5 MW range	• Requirements of plants just below 5 MW would be the same as or similar to those above 5 MW – consistency is enhanced. • No limitations on the size or connection voltage of plant that can apply these requirements. • Proposed changes to technical standards (currently being reviewed by the AEMC) include that protection settings to be set to maximise capability.	• Schedule 5.2 is written as AAS and MAS requirements – not fixed values; negotiation and modelling costs which may not be efficient use of time and resource for small plant connections. • Voltage ride-through only goes down to 70% of nominal. Contingency ride-through captures lower voltages – site-specific and requires detailed dynamic modelling. • Phase shift ride-through captured through contingency ride-through – requires detailed dynamic modelling, which would be inefficient use of resource for sub-5 MW plant. • Some requirements of schedule 5.2 are more onerous than necessary for small plant and require detailed modelling, such as continuous uninterrupted operation requirements within ride-through clauses. Relaxing these requirements would effectively just create another level of bespoke requirements. • Detailed dynamic modelling to meet these standards would add cost and time to the connection process for this size of plant, which might be an impediment to connection.
An international standard, with defined settings, separate to the standard	• More products will likely be assessed for compliance with an international standard than a standard only applying in one country, and compliance costs will be spread over a wider base. Potentially leads to lower costs and more competition in the Australian market. • Can be flexible enough to cover the requirements listed in Section 2.4, as the standards often allow ranges of settings that can be set for the relevant jurisdictions. • Performance may be specified at the connection point – consistent with larger plant. • Can be flexible enough to cover other multiple generation technologies, storage and EVSE. • If the standard includes ranges of settings, it is relatively easy to update settings requirements for new plant over time, while still requiring certification to the same standard. • Potentially less work than developing a standard in Australia[A]. • Can benefit from international experience and work done internationally to keep the standard up to date with technology changes.	• Would be a third set of technical requirements for Australian developers to navigate for connections. • International standards can get out of synch with Australian needs – might resolve this by adopting a particular version. Then subsequent versions will need to be reviewed as well. • Settings often need to be specified separately, as the standard allows a range of performance requirements. There is some extra work to determine the settings and establish a process for maintaining them into the future. • Performance may be specified at the connection point – more work to determine settings at the inverter level.
A bespoke standard (a new Australian standard or amendment/addition to the current standard, or technical requirements	• Could be set to be between AS/NZS 4777.2 and schedule 5.2 levels – very flexible. • May be structured with a range of settings that then is able to be modified or defined in DNSP requirements.	• Does not make use of existing certification processes – more costly and reduces competition compared with use of an existing standard. • Could be an impediment to investment. • Much more time consuming to develop and have approved. Would not be available in short term. • [External standards] can get out of synchronism with the NEM requirements.

Option	Advantages	Disadvantages
within the rules), with defined settings		• If settings are defined within the standard or the rules (as per AS/NZS 4777, they cannot quickly be updated).

A. Australia might need to participate actively in international efforts to update and improve the standard over time, however would also benefit from input provided by other international experts.

While the application of the existing Australian Standard to the sub-5 MW category would be desirable, it contains requirements that are targeted to LV connections of relatively small size plant. Key impediments to adopting the Standard are requirements in AS/NZS 4777.2 that are specifically written for LV connections and the technology-specific nature of the standard. Other requirements, such as those requiring plant to cease generation for high and low voltages, are not suitable for plant up to 5 MW, but different requirements could be written for HV inverters, and larger HV connections that could be added to the standard, if desired. Nevertheless, considering that the current requirements are quite explicitly targeted to 230/400 V ac inverters, it would take significant time and effort to extend the current standard. Use of an existing international standard or specification is expected to require less complexity and could be achieved in a shorter timeframe.

The NER's schedule 5.2 requirements are designed for much larger plant, with bespoke requirements for Australian conditions, and an expectation of a negotiation process over the level of performance. In some technical requirements the minimum standards are much more onerous than required by the AS/NZS 4777 series[32]. The performance standards cannot be determined without reference to extensive dynamic modelling. The cost of modelling, assessment and negotiation, in general, does not seem warranted for connections sub-5 MW in size, and would not be consistent with efficient investment in the NEM required by the National Electricity Objective (NEO). In addition, the performance standards regime includes compliance requirements that would be difficult to manage for small plant.

4.1.1 Connection point versus terminal quantities

The table above refers to assessment at the connection point as both an advantage and disadvantage. Having performance requirements at the inverter level is simpler, because settings can be directly applied to the plant, and OEMs can make those settings selectable as a set. Moreover, inverter level settings assist with type testing which provide DNSPs some level of comfort that the plant is capable of achieving the required level of performance without additional modelling or commissioning works. For example, in the AS/NZS 4777 series, there are region-based settings, which set the technical requirements associated with that region.

When the connection is at HV level, there will typically be a transformer between the inverter and the connection point, which will have impedance and often introduces a phase shift in voltages between the connection point and the plant's terminals. The transformer tap ratio may also change the voltage at the equipment terminals relative to the connection point voltage. These factors mean that voltages (magnitude and phase) seen at the terminals will differ from the connection point values. To achieve a level of performance at the connection point requires translation of connection point requirements into inverter level settings. This is particularly important for voltage disturbances. Some control modes may also cause the plant to respond to voltage disturbances in a way that opposes the disturbance (such as volt-var control), in which case the response of the plant also influences the

[32] However, some requirements of AS4777.2 2020 exceed the requirements of the NER S5.2.

plant's ability to remain in operation for disturbances. Voltage relationships between the plant terminals and the connection point can be determined approximately with a steady-state Root Mean Squared (RMS) model of the plant (load flow). More precise assessment would need to consider dynamic models, which are more complex and therefore expensive to establish.

4.1.2 Application to electric vehicle charging equipment

The complication here is that for ac chargers the inverters are in the EVs, while in dc chargers the inverters are in the stationary charging equipment. The technical capability of a connection may depend on what is connected to the chargers at the time.

This current review does not extend to EVSE technology, but EVSE projects of the size covered by this project will become more common and will need to be considered for inclusion in technical requirements in future. The solution that is selected to address technical requirements for connections in HV-connected sub-5 MW segment should therefore not preclude extension to EVSE in the future.

4.1.3 Application to technologies other than inverter-based resources

There may be technologies other than inverter-based plant that connect in the sub-5 MW category. This could include, for example, small synchronous generators such as small run of river hydro or synchronous co-generation plant. In principle, the technical requirements for sub-5 MW connections should not need to be technology-specific. However, AEMO notes that in some technical performance characteristics, inverter-based plant can be more capable than synchronous generators – for example, in frequency range for operation. These differences might need to be allowed for with flexibility to allow different settings, although the focus areas for performance would be the same.

As noted above, the AS/NZS 4777 series is specific to inverter-based equipment.

4.1.4 Options for international standards

AEMO identified that the options for standards consideration for the HV connected sub-5 MW range included IEEE 1547-2018 *Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* and IEC TS 62786-1 2023 *Distributed energy resources connection with the grid Part 1 General Requirements*. The latter is a new technical specification, rather than a standard, and only the first version has been published, so it can be considered relatively immature compared with the IEEE standard. The IEEE 1547 standard on the other hand, has been around for six years, and the current version may be outdated, compared with current understanding of performance characteristics.

These two publications are described in more detail in the following sections.

IEEE 1547-2018

IEEE 1547-2018 is the first of a series of standards. The remaining standards are supporting documents covering testing, an application guide, guidance on monitoring information exchange and control, guidance on design operation, best practice for interconnecting DER with electric distribution secondary networks, and guidance on conducting distribution impact studies for DER interconnection. The IEEE 1547-2018 standard is oriented towards requirements for the United States of America, and describes, for example, frequencies reflecting a 60 Hz power system nominal frequency. However, the standard does make provision for 50 Hz systems (by means of a footnote). As it is used in the United States of America (although not universally) and has been around for several years, there is likely to be a large variety of DER that can meet this standard.

The IEC 1547-2018 standard is technology-neutral and is intended to apply to connections to the distribution network below sub-transmission level. Its application is not restricted by connection size.

IEEE 1547-2018 specifies most requirements at the connection point level (using the Australian NER concept of connection point, which is equivalent to point of common coupling (PCC) in the standard), except where specifically indicated in the requirement. Some exceptions to this apply, including:

- Where for the connection zero sequence continuity applies between the connection point and the plant, and one of the following two conditions applies:
  - Aggregate DER nameplate rating of equal to or less than 500 kVA.
  - Annual average load demand of greater than 10% of the aggregate DER nameplate rating and where the connection is not capable of or is prevented from exporting more than 500 kVA for longer than 30 seconds (s).
- Where zero sequence continuity does not apply, but the connection meets one or other of the two conditions above, the requirements except short circuit fault or open phase on the distribution network circuit supplying the connection[33] for voltage trip and voltage ride-through requirements[34], the reference point of applicability is the terminals of the DER.
- Where the DNSP and the DER operator can agree another location for the reference point of applicability between the connection point and the DER terminals, instead of at the DER terminals.

The standard provides default values for many functional settings, although where the requirements are at the connection point, voltage-related requirements will not translate one-for-one on to the equipment settings. The standard also allows for different DER categories, which have different technical requirements such as for voltage ride-through. Like AS/NZS 4777 this standard includes must-trip requirements.

IEEE 1547 specifies two categories for performance requirements related to reactive power capability and voltage regulation, Category B having higher requirements than Category A, and three categories related to ride-through performance, abnormal operating performance Category I, II and III (with Category I being lowest and III being highest). In addition to ride-through requirements, this standard also includes mandatory trip conditions and may trip conditions which differ according to the category.

IEC TS 62786-1 2023

The IEC TS 62786 is a series of technical specifications[35] (TS) with IEC TS 62786-1 providing common requirements supplemented by other parts of the series including:

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[33] Section 6.2 of IEEE 1547.

[34] Section 6.4 of IEEE 1547.

[35] A technical specification is similar to an international standard in terms of detail and completeness but has not yet passed through all approval stages, either because consensus has not been reached or standardisation is seen to be premature. This explanation is at

- IEC TS 62786-2 Part 2 Additional requirements for PV generation (proposed to be published in May 2026 – a draft has been published).
- IEC TS 62786-3 Part 3 Additional requirements for stationary battery energy storage system (recently published).

Part 3 also notes that mobile energy storage devices (EVs) are under consideration for future editions.

The series applies to DER including distributed generation and electrical energy storage systems and covers all types of synchronous generators, asynchronous generators, power converters (except EVs at this stage) connected to the HV or LV networks.

The requirements are intended to be applied at the connection point. However, IEC TS 62786-1 also notes that in some situations, the requirements can be applied at the AC terminals of the generator.

4.1.5 Use of size or voltage thresholds for different levels of performance

The focus areas of interest to AEMO, identified in Section 2.4, were selected because they were areas where there was a likelihood that small plants would respond simultaneously to conditions on the power system or in the market in a way that would have a cumulative effect on the performance of the bulk power system, or would provide a benefit to the operation of the power system (for example, monitoring would assist forecasting for dispatch and longer-term planning). In addition, it was noted previously that currently there are no defined bulk power system requirements, and that this has resulted in different requirements being applied by different DNSPs. Therefore, it is necessary to have defined requirements that support the operation of the power system and desirable to have consistency across the NEM.

However, AEMO recognises that some requirements might have greater financial consequences for smaller projects than larger ones. The application of requirements at the connection point, for instance, may require additional analysis to be undertaken both in the design and in the assessment of projects, with associated cost and time implications. As described in Section 4.1.1, when the connection is at LV, the terminal and connection point performance will typically be more similar than if the connection is at HV and the terminal voltage is at LV. The AS/NZS 4777.1 standard contemplates that it may be applied for 230/400 V ac IES, with LV load on the same HV connection. To simplify the complexity and cost of connection for smaller connections it might be reasonable to apply the AS/NZS 4777 requirements to smaller size connections of this type, or connections that have a small net impact on the power system (considering the size of the load and generation combined)[36].

As observed in Section 3.1.3, some DNSPs split requirements by size threshold, which reflects the level of impact of the plant on their network, as well as the cost of connection. Monitoring is one area in which it might be possible to take a more light-handed approach for smaller plants, commensurate with the size of the plant, or commensurate with DNSP requirements.

https://www.iec.ch/publications/specifications#:~:text=A%20technical%20specification%20approaches%20an,is%20seen%20to%20be%20premature.

[36] It might also be reasonable for the framework to support some level of flexibility for DNSPs to apply site specific requirements for brownfield applications with existing load.

4.2 Proposed performance levels and alignment with international standards

In Table 4 below, AEMO proposes performance levels for each of the focus areas identified in Section 2.4 and then examines applying these requirements using the IEC TS 62786 2023 TS and the IEEE 1547 2018 standard. In the case of the key areas of frequency ride-through, RoCoF ride-through and voltage ride-through, separate proposed performance levels have been defined for:

- Inverter-based plant including generation and storage.
- Synchronous generation.
- Legacy plant such as existing standby generation that negotiates to be able to synchronise with the DNSP network.

Table 4 Comparison between proposed requirements of IEC TS 62786-1 2023 and IEEE 1547 2018

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
Frequency ride-through	**IBR plant** Align with AS/NZS 4777.2 45 Hz to 52 Hz full output 49.5 Hz to 55 Hz multiple mode inverters with energy storage, must be capable of charging **Synchronous generation** Align frequency and duration with Frequency Operating Standards (FOS) for islanded conditions. (Frequency ranges differ between Mainland and Tasmania.) Mainland: 49.5 to 50.5 Hz, continuously Tasmania: 49.0 to 51 Hz, continuously Mainland: 49.0 to 49.5 and 50.5 to 51.0 Hz, for at least 10 min Tasmania: 48.0 to 49.0 Hz and 51 to 52.0 Hz, for at least 10 min Mainland: 47.0 to 49.0 Hz and 51 to 52.0 Hz, for at least 2 mins Tasmania: 47.0 to 49.0 Hz and 51 to 55.0 Hz for at least 2 min **Legacy plant**	For DER with rated power > Pth-fd • f < fmin2 and f> fmax2, instantaneous disconnection permitted • fmin2 ≤ f ≤ fmin1 and • fmax1 ≤ f ≤ fmax2, operate for at least Tf1 • fmin1 ≤ f ≤ fmax1, continuous operation where • continuous operation range can be set between fmin1: 48.5 – 48.85 Hz[39] to fmax1 50.15 – 51.0 Hz • Tf1 can be set between 2 s and 90 min • fmin2 can be set between 47 – 49.8 Hz • fmax2 can be set between 50.2 – 52 Hz[40]	Frequency ride-through is not required for some specified conditions of intentional islanding or combined load-generation tripping. The frequency ride-through requirements in this standard are written for 60 Hz power systems, but the standard allows conversion to 50 Hz system frequency, which is provided here: • f > 51.67 Hz, No ride-through requirement applies[41] • 51 < f ≤ 51.5 Hz, mandatory operation, for at least 299 s • 49 ≤ f ≤ 51 Hz, continuous operation (for V/f ≤ 1.1) • 47.5 ≤ f ≤ 49 Hz, mandatory operation, for at least 299 s • f < 47.5 Hz, No ride-through requirement applies. .

[37] These requirements have been summarised using terminology that is more recognisable for Australian readers and consistent with the NER terminology. Readers are encouraged to consult the original document if the summary is unclear.

[38] For the purpose of this table, the highest performance category III for disturbance ride through has been assumed. Category III is intended for situations with high DER penetration levels, and provides increased bulk power system security by reducing the potential loss of DER during bulk system disturbance events. AEMO considers this level of performance to be consistent with its goal to address the cumulative impact of DER in this size range on the power system

[39] This upper limit on the range is slightly lower than the FOS requirements for mainland and Tasmania, but operating with this setting would not have an adverse impact and could increase resilience.

[40] This TS defines one short term ride-through range below nominal frequency and one above nominal, whereas the FOS defines two short-term ranges below and above nominal frequency. The highest frequency range is 52 Hz, which is less than Tasmania's 55 Hz in the FOS.

[41] The upper and lower limits on ride-through frequencies are not consistent with the proposed requirements. The ride-through durations for the mandatory levels are also not consistent with the proposed duration in the 48-49 Hz and 51-55 Hz ranges for Tasmania

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
	Performance to be agreed with DNSP based on plant capability with appropriate safety margins.		
Rate of change of frequency ride-through	**IBR plant** Align with AS/NZS 4777.2 ±4 hertz per second (Hz/s) for duration of 250 ms plus the FOS requirement for ±1 Hz/s over any 500 ms period **Synchronous generation** Align with FOS Mainland: ±1 Hz/s over any 500 ms, ±3 Hz/s over any 300 ms Tasmania: ±3 Hz/s over any 250 ms **Legacy plant** Performance to be agreed with DNSP based on plant capability with appropriate safety margins.	This TS allows thresholds to be specified by the grid operator. The following is an example of form. Other specification forms are permitted: • ROCOFhi for the first $t_{ROCOFhi}$ seconds and • ROCOFlo to the first $t_{ROCOFlo}$ seconds where • ROCOFhi > ROCOFlo and • $t_{ROCOFhi} < t_{ROCOFlo}$ There are no default values. The TS also allows for a ride-through requirement for a step change in frequency to be specified (to cater for auto-reclose of a transmission line)	The standard specifies ride-through (Category III) of 3.0 Hz/s average over at least 0.1 s[42].
Voltage excursion ride-through	**IBR plant** Align with system standard for over-voltage in NER S5.1a.4 and the AS/NZS 4777.2 protection time delays for passive anti-islanding for undervoltage. Note: The AS/NZS 4777.2 requirements to cease generation for voltage less than 78% after 400 ms is not appropriate for larger plant and has not been included in this proposed specification. Remain in operation for the following voltages: • Unless disconnection is required or allowed by the DNSP*, up to 130% for up to 60 ms • Unless disconnection is required or allowed by the DNSP*, up to 125% for up to 100 ms	For plant with a rated power exceeding Pth-vd the TS describes withstand requirements as follows: • Continuous operating voltage range Umin1 ≤ U ≤ Umax1 with default values 0.9 pu to 1.1 pu at the POC, and • Limited operating voltage ranges with recommended ranges that the plant must withstand: – Umin2: 0.85 to 0.9 pu for Tu1 10 – 180 s and – Umax2: 1.1 to 1.2 pu for Tu2 Tu1 (ov) 10 –180 s 0.0 s Disconnection permitted U > Umax2 and U < Umin2 in Tu2	For a short circuit fault on the circuit to which the DER is connected, the plant must cease to energy and trip, unless otherwise specified by the DNSP. The DER shall cease to energise and trip all phases for an open phase condition occurring directly at the reference point of applicability[46]. All requirements related to delivery of active power shall be subject to the availability of the DER's primary energy source. Abnormal voltage and frequency conditions shall not result in unavailability of the DER's primary source of energy. The actual field applied trip settings shall be specified by the DNSP. If not specified, the default settings shall be used.

[42] The duration of the ride-through requirement is not consistent with the proposed requirement.

[46] This is the connection point for plant rated more than 500 kVA or connected through a transformer with a non-continuous zero sequence path. Otherwise it can be the plant terminals. For more detail see Section 4.1.4.

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
	• Up to 120% for up to 350 ms • Up to 115% for up to 900 ms • Continuously 90 - 110% • Down to 78% for up to 10000 ms • Down to 70% for up to 2000 ms • Down to 30% for up to1000 ms • At connection point for HV connections. * *The DNSP may require disconnection of the inverters between 120% and 130% of nominal voltage* **Synchronous generation and legacy plant** Performance to be agreed with DNSP based on plant capability with appropriate safety margins.	Tu2 recommended value 0 s. The TS also defines an under- voltage profile at the POC for which the plant must remain connected with up to 6 voltages and associated times. The TS allows flexibility for setting U1 to U6. The following are the recommended values, but can be changed, and must be coordinated with the limited operating voltage range and time (above)[43,44]. • U1 0.05 to 0.70 pu for 0.0 to 0.25 s • U2 0.30 to 0.85 pu for 0.0 to 0.3 s • U3 0.70 to 0.85 pu for 0.0 to 10.0 s • U4 0.85 to 0.90 pu for 0.0 to 10 s • U5 0.85 to 0.90 pu for 0.0 to 180 s • U6 0.85 to 0.90 pu for 0.0 to 180 s Likewise, the TS defines an over-voltage profile at the POC for which the plant must stay connected with up to 6 voltages and associated times[45]. • U1 1.25 to 1.32 pu for 0.0 to 0.10 s • U2 1.20 to 1.30 pu for 0.0 to 2.0 s • U3 1.15 to 1.25 pu for 0.0 to 5.0 s • U4 1.10 to 1.20 pu for 0.0 to 10 s • U5 1.10 to 1.15 pu for 0.0 to 180 s • U6 1.10 to 1.15 pu for 0.0 to 180 s	The DER settings shall be field adjustable for adjustable parameters specified in this clause and adjustability may be required by communication (if specified by the DNSP). The standard includes specific exclusions from ride-through requirements for specific load and generation output conditions for an intentional island or if load and generation is shed within 0.1 s of each other[47]. The following performance is specified (for Category III)[48]: • V >120% cease to energise (within 0.16 s) • 1.10 < V ≤ 1.20 pu momentary cessation[49] • 0.88 pu < V ≤ 1.10 pu continuous operation • 0.7 ≤ V ≤ 0.88 pu mandatory operation for at least 20 s • 0.5 ≤ V ≤ 0.7 pu mandatory operation for at least 10 s • V < 0.5 pu momentary cessation. The 0.5 pu threshold in the list above may be altered by mutual agreement of the DER operator and the DNSP. For voltages in the continuous operation region the plant must continue to deliver available active power at least as much as the pre-disturbance level prorated by the per-unit voltage level of the least phase voltage, if less than nominal. Temporary deviations of active power up to 0.5 s shall be allowed. The plant may cease to energise and trip if the negative phase sequence component of the applicable voltage is greater than 5% of nominal voltage for greater than 60 s or greater than 3% for greater than 300 s, provided the voltage unbalance is neither caused nor aggravated by unbalanced currents of the connection.

[43] The proposed 50% for 1.0 s does not fall in this default range (compare with U2 above), but this does not prevent the proposed setting from being applied, by adjustment of other parameters.

[44] The standard deliberately duplicates or overlaps some ranges to allow different profiles to be flexibly set.

[45] The proposed standard falls within the recommended envelop of operation for overvoltages.

[47] See section 6.4.2.1 of the standard for detail

[48] The standard includes must trip and momentary cessation requirements that are not consistent with the proposed ride through requirements).

[49] Momentary cessation means that the plant is temporarily required to cease to energise with the capability to restore output of operation when the applicable voltages and system frequency return to within defined ranges.

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
		If requested by the DNSP the plant must provide reactive current to support the power system during disturbance. The DNSP is required to specify the settings. Note: The voltage and times specified above define a curve. For undervoltage the area above the curve defines conditions for which the plant must stay connected. Likewise, for the overvoltage, the plant must stay connected for conditions under the curve. These requirements apply to all types of short circuit faults. For three phase DER, the lowest phase-to-phase voltage shall be used. Depending on local system requirements, the lowest phase-to-neutral voltage may be used instead. Active power recovery After the fault is cleared the DER should recover (at least) a specified proportion of its output power Srec within a specified time Trec after stable network conditions are detected (as shown in figure 6 of the technical schedule).	The standard also includes specification of multiple ride-through requirements.
Phase angle shift ride-through	Align with AS/NZS 4777 Single-phase disturbance, 60 degrees Three phase disturbance, 20 degrees Note: in AS/NZS 4777 the requirements are at inverter terminal level, but this standard only applies to LV connections, so is approximately the same phase angle as the connection point.	Recommended immunity threshold levels[50]: • 60 degrees for single phase fault • 20 degrees for three phase fault. These values are referenced to connection point voltage[51].	Multiphase DER shall ride-through for positive sequence phase angle changes within a sub-cycle to cycle time frame of the applicable voltage of less than or equal to 20 electrical degrees. In addition, multi-phase DER shall remain in operation for change in the phase angle of individual phases less than 60 electrical degrees, provide that the positive sequence angle does not exceed 20 degrees.

[50] The TS describes the recommended requirements in terms of a fault condition, but AEMO would prefer them to reference unbalanced voltage disturbance and balance voltage disturbance as phase shifts are not necessarily caused by faults, but phase shifts may be caused by other phenomena such as line switching and trip of load or generation. The plant should also be required to ride through two phase faults, not just single and three phase. The example of phase shift provided in the standard is for a phase to phase fault, implying the intention is for ride through to apply in this situation as well as for single phase faults.

[51] By default, the requirements are at the connection point, but there is some flexibility to apply requirements elsewhere in some conditions (not specified in this part 1 of the TS). Where the connection is at HV level and there is a transformer with a phase shift between the HV connection point and the LV plant terminals, there will be a phase shift introduced for unbalanced faults, between HV and LV. This phase shift will need to be taken into account for compliance.

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
			Active and reactive current oscillations in post disturbance that are positively damped or momentary cessation of the DER having a maximum duration of 0.5 s shall be acceptable in response to phase angle changes. The applicable voltage is normally (with some exceptions[52]) defined at the connection point.
Active power curtailment, by remote signal	DNSP can curtail active power or disconnect plant, through remote control	The TS specifies the active power curtailment requirements as follows: Generating plants connected to a HV network and those connected to a LV network with a rated power exceeding the power threshold for disconnection Pth-dis (defined by country) shall have the capability to be disconnected or curtailed, locally or remotely. The maximum active power output should not exceed the value determined by the system operator.	The standard specifies that DER shall be capable of limiting active power as a percentage of the nameplate active power rating, within the greater of 30 s or the time it takes for the primary energy source to reduce its active power output to achieve the setpoint. In cases where the DER is supplying loads (within the connection) the active power limit may be implemented as a maximum active power export limit. The DER may be required by the local DNSP to reduce active power below the level of the load (ie net import). The DER shall be capable of responding to external inputs, including being capable of tripping within 2 s. The standard describes a cease to energise state, which requires active power to be ceased at unit terminal level. For systems with aggregate DER rating less than 500 kVA, the reactive power exchange shall be less than 10% of the nameplate rating and shall exclusively result from passive devices. If requested by the DNSP the DER operator shall provide the reactive susceptance that remains connected to the power system in a cease to energise state. In a cease to energise state import of active power is only permitted for DER housekeeping and auxiliary loads. Alternatively, the requirements for cease to energise may be met by disconnecting the local power system or a portion of the local power system from the area power system. The DER may continue to deliver power to the portion of the local power system that is disconnected from the area power system.

[52] See Section 4.1.4 of this document in the IEEE 1547 description for more detail on where the requirements apply, or see the IEEE 1547 2018 section 4.2.

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
			This provision allows an islanded system to operate within part of a DNSP's network or in a private network.
Remote monitoring	Active power level and Active power curtailment status (active/ inactive) Implementation method to be agreed with the DNSP. Propose to apply to systems 200 kW and above.	Monitoring and control capability is required for HV connected DER and LV connected DER above a threshold Pth-inf defined by country[53]. Required capability includes information sent from the DER and to the DER to accept control and regulation instructions sent by the system operator[54].	The limit active power parameters that the system must provide include: • Limit active power enable (on/off). • Maximum active power (the maximum permitted active power). Active power is also available through monitoring. The information read response time is ≤ 30 s. The information shall be the latest value that has been measured within the require response time (which differs from one parameter to another, and is often settable)
Ramp rate limit	Ramp rate limited to 20% of rated power/min except for specific exempted conditions (described in Section 2.3.2).	For generating plants connected to HV network and those connected to LV network with rated power exceeding the power threshold for disconnection Pth-dis, the maximum rate of active power change should not exceed the value determined by the system operator[55].	The standard contemplates ramp rate limits for entering service (or return to service), but not in general.[56]
Frequency response (with a deadband)	5% Frequency droop response with deadband of: • 49.5 – 50.5 Hz (mainland) • 49.0 – 51.0 Hz (Tasmania) A lower (more aggressive) droop may be agreed with the DNSP when the IES is offering FCAS) (aligns with S5.2.5.8 for over frequency)	All HV connected DER and LV connected with rating exceeding Pth-apc defined by the country shall have active power – frequency response. Defined as a P vs f curve with deadbands: • Δf' for underfrequency and Δf for overfrequency, in Hz and • gradients, expressed as per-unit of DER active power per Hz: – G'pu for underfrequency – Gpu for overfrequency	The DER (Category III) shall have mandatory operation with frequency droop during low-frequency ride-through and high frequency ride-through. A DER low frequency response may be subject to available active power (in NER terminology, equivalent to energy source availability). The standard allows for a deadband and output limited by pmin and pmax. The default droop is 5% with an allowable range of 2% to 5%. Deadbands for over and under-frequency have default settings of 0.03 Hz[57] (when converted to 50 Hz power

[53] Note: All HV systems have the requirement not limited by active power threshold. This differs slightly from the proposed requirement.

[54] Note: time resolution not mentioned. Active power curtailment status is not mentioned, but not precluded.

[55] Exceptions are not specifically mentioned, but not precluded.

[56] This is inconsistent with the proposed requirement for ramp rate limits.

[57] The maximum allowable deadband is slightly lower than the proposed range, with much tighter default values.

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
		When network frequency exceeds nominal value (fn) by more than ∆f, DER should reduce their active power output with a gradient Gpu. When the network frequency is below nominal value (fn) by more than ∆f' and if active power increase is possible, DER should increase their active power output with a gradient G'pu. Note: IEC TS 62786-3 for BESS requires frequency response while charging as well as while generating.	system equivalent values) corresponding to 49.97 to 50.03 with allowable range 0.0142 to 0.8333 Hz. The DER is not required to change its active power output at a rate greater than 20% of nameplate rating per minute to meet the response requirement if the primary source is physically unable to provide a greater response rate. Inertial response is not required but is permitted.
Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements	Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements for voltage, frequency and RoCoF, within safe operating limits consistent with good engineering practice	The section on protection functions refers to IEC 60255-127 for over- and under-voltage protection and IEC 60255-181 for over-frequency, under-frequency and ROCOF[58].	The standard specifies mandatory tripping for over-voltage and under-voltage conditions as follows (Category III)[59]: Overvoltage: • 1.20 pu in 0.16 s, (fixed voltage and clearance time). • Default 1.10 pu with clearing time 13.0 s with range settable within 1.10 to 1.20 pu and clearance time 1.0 – 13 s. Undervoltage: • Default 0.88 pu with clearing time 21s with range settable within 0.0 – 0.88 pu and clearance time 21.0 -50 s. • Default 0.5 pu with clearing time 2.0 s with range settable within 0.0 – 0.5 pu and clearance time 2.0 – 21 s. The standard specifies mandatory tripping for over- and under-frequency conditions with a range of allowable settings. The standard describes the settings for a 60 Hz system but allows them to be converted to 50 Hz equivalents, which are provided here. • Default 51.67 Hz with clearance time 0.16 s with a range settable within 51.5 – 55 Hz and clearance time 0.16 – 1,000 s.

[58] The standard does not specifically include the principle of maximising capability, within safe operating limits.

[59] Mandatory tripping for voltage and frequency is not consistent with the principle of maximising capability within safe operating levels.

Focus Area	Proposed performance level	IEC TS 62786-1 2023 coverage	IEEE 1547 2018[37,38] coverage
			• Default 51 Hz with clearance time 300 s with a range settable within 50.83 – 55 Hz and clearance time 180 – 1000 s. • Default 48.75 Hz for 300 s, with a range settable within 41.67– 49.17 Hz and clearance time 180 – 1,000 s. • Default 47.08 Hz for 0.16 s with a range settable within 41.67 – 47.5 Hz and clearance time 0.16 – 1,000 s.

The comparison shown in Table 4 above indicates that the IEC 62786 TS more closely aligns with the proposed performance requirements for this category of plant. The IEEE standard is generally more detailed and prescriptive than the IEC TS, but its prescriptions are lower for key ride-through requirements for frequency, ROCOF and voltage, and also contain some must-trip requirements not consistent with the proposed performance requirements. Note that the requirement for mandatory tripping is not consistent with a principle of maximising capability to operate within safe operating limits.

The IEC TS is flexible, typically allowing the country or the local network operator to specify settings and, in some cases, the form of the requirement as well. Many types of requirements have size thresholds based on active power rating of the plant. Other exceptions to requirements could potentially be agreed for NEM use, as appropriate (for example regarding application of ramp rate limits).

4.3 Proposed settings

AEMO has proposed technical settings for sub-5 MW plant, considering the permitted values within the IEC TS 62786-1 2023, and provided these in Appendix A1. The appendix demonstrates that the IEC TS 62786-1 covers the performance levels identified in Section 4.2 with minor modifications only. These minor differences are not likely to have a material adverse impact on the performance of the power system, compared with the proposed settings.

For requirements not covered by those described in Appendix A1, AEMO proposes to allow DNSPs to establish their own technical requirements for DER connections connected at HV level, as they currently do now. For 230/400 V ac IES connected at HV level, this may at the DNSP’s discretion, including the application of the requirements of AS/NZS 4777.2 as applicable.

The proposed split between AS/NZS 4777 and IEC TS 62786-1 allows for less complex connection requirements for connections that will have a net impact on the power system of less than 1.5 MW, should they ‘cease generation’ for under-voltage or over-voltage conditions.

4.4 Application of IEC TS 62786-1 to other technical requirements

While the focus for this review has been those aspects of technical performance most likely to impact the operation of the bulk power system, DNSPs are likely to have specific requirements for aspects of performance that impact the operation of their networks. The DNSPs may also have overlapping interests in the areas identified by AEMO to be of interest and may have additional requirements in some cases. For example, some DNSPs may require additional SCADA quantities beyond those proposed. Section 2.5 identified some other technical requirements that are likely to be of interest to DNSPs (which should not be considered exhaustive). As would be expected from a modern technical specification, the IEC TS 62786-1 covers these areas of performance.

The requirements for control modes and ranges appear to be quite flexible and can be set to meet local or country-defined requirements. In such cases, a level of coordination would be required by DNSPs to agree a NEM-wide (or country-wide) threshold for application.

AEMO encourages DNSPs to evaluate the permitted performance ranges for their own requirements. It may also be of value to industry for DNSPs to consider whether common settings within the standard can be agreed across the range of requirements, which would enhance the efficiency of connections across the NEM (or Australia, were Western Australia and the Northern Territory to be included).

4.5 Application of proposed AS/NZS 4777.2-2020 to LV IBR larger than 200 kVA

As discussed in Section 3.1.2, the AS/NZS 4777.2-2020 Standard includes technical performance requirements for low voltage inverters with nominal voltage of 230/400 V that conform with AS IEC 600038, and proposed changes to the Standard mean it shall apply to systems larger than 200 kVA. This section seeks to compare AEMO's recommended technical requirements for sub-5 MW DER with the requirements in place with the AS/NZS 4777.2-2020 standard.

Appendix A2 outlines a comparison between the proposed performance level for each of the key focus areas described in Section 2.4 with the requirements under AS/NZS 4777.2-2020. In summary:

- The proposed performance levels for frequency ride-through, RoCoF ride-through and phase angle shift ride-through are to align with AS/NZS 4777.2-2020. Thus, the performance of LV-connected DER larger than 200 kVA is as proposed. Note that the recent changes to AS/NZS 4777.2-2020 do not alter this.
- The proposed performance level for voltage ride-through is that the inverters would meet the continuous uninterrupted operation[60] requirements for a range of voltage disturbances, while the requirement from AS/NZS 4777.2-2020 is that LV-connected DER is required to cease generation for over-voltages above 260 V and under-voltages below 180 V. This is discussed further in Section 4.5.1.
- The proposed requirement to be able to curtail active power is an inherent control capability required under AS/NZS 4777.2-2020. In addition, the required demand response modes (DRM) interface provides a coarse level of active power control, including disconnection. However, AS/NZS 4777.2 does not explicitly require the active power control functionality and DRM control requirements to operate remotely. Therefore, to implement remote active power curtailment or DRM may necessitate the installation of additional systems, specified by the DNSP, commensurate with its needs.
- The proposed requirement to remotely monitor active power is not explicitly required under AS/NZS 4777.2-2020, although it does require local monitoring. Therefore, to facilitate remote active power monitoring may necessitate the installation of additional systems, specified by the DNSP.
- The proposed requirement to limit the ramp rate to 20% per minute is supported under AS/NZS 4777.2-2020, as the standard requires the ramp rate limit to be settable in the range of 5% to 100% per minute, with a default ramp rate limit of 16.67% per minute. The AS/NZS 4777.2 is therefore more onerous, by default, but settings may be changed. However, AS/NZS 4777.2-2020 does not contemplate the exceptions to ramp rate limits described in Section 2.3.2.
- The proposed requirement to provide frequency response is supported under AS/NZS 4777.2-2020, although the specification of the requirement is different. This difference is unlikely to lead to a material change in system security and would be the same as the response of smaller DER under the standard.

[60] Continuous uninterrupted operation is defined in Chapter 10 of the NER.

- The proposed requirement to have protection systems that maximise capability beyond ride-through requirements is not included in AS/NZS 4777.2-2020.

The AS/NZS 4777.1:2024 standard allows for additional requirements to be imposed by the DNSP. To achieve better alignment with the proposed performance designed in Section 4.3, the following additional requirements are proposed for inverter-based plant larger than 200 kVA and smaller than 1.5 MW for which AS4777 applies:

- Remotely control and remotely monitoring of the active power; and
- Consideration of setting the ramp rate to 20% per minute.

4.5.1 Voltage ride-through requirements for LV inverters

The proposed performance requirement for voltage ride-through is for the IES to remain in operation, which supports the frequency of the bulk power system, while AS/NZS 4777.2-2020 requires the IES to cease power generation for voltages above 260 V and below 180 V, which is intended to assist the management of the network voltage.

In general, a requirement for IES to remain in operation during voltage disturbances is desirable for the security of the bulk power system and is the proposed performance requirement. However, LV networks are more resistive (having a lower X/R ratio), which causes the voltage to rise when active power is injected. This is managed in AS/NZS 4777.2-2020 by including both:

- A volt-watt characteristic to reduce the maximum active power injection from 100% at 253 V to 20% at 260 V; and
- A requirement for IES to cease power generation above 260 V or below 180 V within 200 ms.

This requirement should be retained for LV-connected IES, including HV connections with LV inverters where there are local loads, to reduce the likelihood of damage to LV loads due to over-voltages. AEMO considers that the impact on the frequency of the bulk power system of a reduction in active power from LV inverters is unlikely to be significant compared to the risk of damage to LV load equipment.

However, in the case of HV-connected IES with LV inverters and no LV loads, the risk of damage to LV loads is removed and the IES should be required to remain in operation for voltage disturbances. This would be the case because these inverters would not be covered by AS/NZS 4777.

4.5.2 Requirements specific to independent systems (non-aggregated)

As identified in Section 2, when multiple sub-5 MW DER respond in a similar manner simultaneously, the impact on the bulk power system is cumulative, and depending on scale, sufficient volume of response may require active system management options that can mitigate substantive risks.

AEMO considers the proposed performance requirements outlined in Appendix A1 to be applicable to solutions intended to be operated and managed independently. Where proponents wish to aggregate multiple sub-5MW DER into a larger capability or fleet, given the potential impact on both the bulk power system and the affected networks, AEMO considers the assessment of network and system risks for such aggregation scenarios requires investigation on a case-by-case basis. In cases where multiple sub-5MW units are intended to operate in a co-ordinated manner and effectively connect to a common connection point (e.g. multiple dedicated feeders connecting to a sub-station busbar), the aggregated system may meet the criteria of a generating system or integrated resource system (being comprised of multiple generating units) and would therefore be required to register as a Generator or Integrated Resource Provider and be subject to the technical requirements of NER Schedule 5.2.5 technical requirements.

4.6 Comparison of current DNSP requirements and proposed settings

As discussed previously, DNSPs currently apply different technical performance requirements for sub-5 MW DER based on specifications that may be outlined in the NER Schedule 5.2, AS/NZS 4777, and/or their own requirements. Therefore, if DNSPs adopt the proposed settings and requirements for sub-5 MW DER related to the security of the bulk power system (as outlined in Appendix A1), they may need to consider changes to the requirements they currently impose on connecting IES.

Table 5 provides an overview of the range of current DNSP requirements and approaches for each of the focus areas and identifies areas where change might be required if the DNSP was to become consistent with AEMO's proposed settings. The table differentiates between HV-connected IES and those covered by AS/NZS 4777.2.

Table 5 Proposed settings considering IEC TS 62786

Focus Area	HV IES		LV IES	
	DNSP existing requirements	Extent of change required	DNSP Existing approaches	Extent of change required
Frequency ride-through	Many DNSPs apply NER S5.2.5.3. Some DNSPs apply AS/NZS 4777.2. One DNSP had no requirement.	Not a significant change required as NER S5.2.5.3 and AS/NZS 4777.2 have similar requirements.	Many DNSPs apply AS/NZS 4777.2 Some DNSPs may apply NER S5.2.5.3. One DNSP had no requirement.	Not a significant change required as NER S5.2.5.3 and AS/NZS 4777.2 have similar requirements. Also LV equipment will meet AS/NZS 4777.
RoCoF ride-through	Many DNSPs apply NER S5.2.5.3. Some DNSPs apply AS/NZS 4777.2. Some have different or no requirements.	Not a significant change required as NER S5.2.5.3 and AS/NZS 4777.2 have similar requirements.	Many DNSPs apply AS/NZS 4777.2. Some have different or no requirements.	Not a significant change required as LV equipment will meet AS/NZS 4777.
Voltage excursion ride-through	Many DNSPs apply NER S5.2.5.4. Some have bespoke requirements of a form similar to NER S5.2.5.4. One DNSP had no requirement.	Not a significant change required for most DNSPs as the proposed settings are of a similar form to NER S5.2.5.4 and the bespoke standards. One DNSP will need to start requiring voltage ride-through capability.	Many DNSPs apply AS/NZS 4777.2. Some DNSPs apply NER S5.2.5.4.	Not a significant change required as NER S5.2.5.3 and AS/NZS 4777.2 have similar requirements. Also, LV equipment will meet AS/NZS 4777. One DNSP will need to start requiring voltage ride-through capability.
Phase angle shift ride-through	Many do not impose any requirements. Some DNSPs apply AS/NZS 4777.2.	Many DNSPs will need to start requiring phase angle shift requirements.	Many do not impose any requirements. Some DNSPs apply AS/NZS 4777.2.	Not a significant change required as NER S5.2.5.3 and AS/NZS 4777.2 have similar requirements. LV equipment will meet AS/NZS 4777.
Active power curtailment, by remote signal	Half DNSPs require active power control. Some implement this on case-by-case basis, such as a run-back scheme. Small number do not require.	The majority either already require this, at least for some sites. Some may need to implement systems to control the active power remotely. A small number have no requirements.	Many DNSPs working towards this requirement for IES larger than 200 kVA.	Not a significant change required as LV equipment will meet AS/NZS 4777 which requires active power control and DRM. Some DNSPs will need develop systems to implement remote curtailment.
Remote monitoring of active power	Typically require SCADA or integration into a DER Management System (DERMS) above 1.0 or 1.5 MW. Some require SCADA or remote monitoring for exporting systems above	The majority either already require this, at least for some sites. Some may need to implement systems to monitor the active power remotely.	Many DNSPs working towards this requirement for IES larger than 200 kVA.	Some DNSPs will need develop systems to implement remote monitoring.

Focus Area	HV IES		LV IES	
	DNSP existing requirements	Extent of change required	DNSP Existing approaches	Extent of change required
	200 kVA. Half DNSPs require active power control.			
Ramp rate limit	Some DNSPs do not impose a ramp rate limit. Most require 16.67 or 20% per minute or similar. One required a limit of 50 kW/s (3 MW/min). Some allow exemptions such as for providing FCAS or run back.	The majority either already require this, at least for some sites. This would be a relatively easy requirement to set and forget.	Some DNSPs do not impose a ramp rate limit. Most require 16.67 or 20% per minute or similar. One required a limit of 50kW/s (3 MW/min) Some allow exemptions such as for providing FCAS, run back etc.	Not a significant change required as LV equipment will meet AS/NZS 4777 which requires a ramp rate limit capability. May require a change of a default of 16.67%.
Frequency response (with a deadband)	Some DNSPs apply AS/NZS 4777 and about half apply NER S5.2.5.11 (negotiated or MAS). One DNSP had no requirement.	Most DNSPs already require a form of frequency response. Some may need to change the specification.	Most DNSPs apply AS/NZS 4777. One DNSP had no requirement.	Not a significant change required as LV equipment will meet AS/NZS 4777 which requires a suitable frequency response.
Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements	Generally, DNSPs do not consider, but protection settings need to support ride-through requirements.	DNSPs will need to consider how to require IES to consider this.	Generally, DNSPs do not consider, but protection settings need to support ride-through requirements.	DNSPs will need to consider how to require IES to consider this.

Consultation questions: Proposed performance requirements

AEMO is interested in understanding:

- Have the proposed performance requirements for sub-5MW DER been clearly outlined?
- What are stakeholder perspectives on the application of the proposed settings within the framework of IEC TS 62786-1 technical specification for sub-5MW HV connected DER?
- What are stakeholder perspectives on the application of AS/NZS 4777.1 and AS/NZS 4777.2 region-based requirements, for 230/400 V ac IES, less than 1.5 MW aggregate rated capacity, connected to the HV distribution network with LV load?
- Should AEMO consider other references for its technical performance settings? For example, EN 50549-2:2019, which specifies the technical requirements for the protection functions and the operational capabilities for generating plant intended to operate in parallel with MV distribution networks.

5 Options for implementation

AEMO's proposed approach to implementing its recommendations for performance requirements for sub-5 MW HV-connected DER is outlined in this section.

Stakeholder feedback is sought on recommendations made in this report:

- The key focus areas for DER technical performance in relation to the security of the bulk power system (discussed in Section 2.4).
- The recommendation to adopt the IEC TS 62786-1 technical specification as the basis for implementing the proposed technical settings for the key focus areas (outlined in Section 4.2)
- The recommended settings for each focus area (discussed in Section 4.3 and more comprehensively in Appendix A1).
- The proposed approach to adopting the recommended settings for each focus area.

5.1 Proposed approach

After receiving and incorporating stakeholder feedback in the recommendations, AEMO proposes to implement the specified performance requirements using the approach outlined below.

5.1.1 Develop a guideline to introduce the recommended settings

AEMO proposes to work with DNSPs to develop a guideline to detail and introduce the recommended settings for each of the key focus areas.

This guideline would be published to enable DNSP connection arrangements to refer to it and be used to inform their connection negotiations with all sub-5 MW HV-connected DER proponents. The guideline would detail the recommended settings for HV connections relevant to IEC TS 62786-1, and any additional settings for plant 200 kW to <5 MW for which AS4777.1 would apply.

By adopting this approach, AEMO and DNSPs can identify and clarify any issues of concern in relation to the proposed performance requirements, including considerations about, where relevant, potential exemptions might be made available, and issues such as compliance monitoring and management.

At a minimum, the guideline could be revised from time to time to reflect the evolving nature of DER technology, the challenges associated with managing the bulk power system with a high penetration of DER, and the landscape of international and national standards applicable to this DER category.

5.1.2 Adoption of IEC TS 62786-1 by Standards Australia

AEMO recommends that Standards Australia commence a consultation on the adoption of IEC TS 62786-1 *Distributed energy resources connection with the grid Part 1 General Requirements* as an Australian standard or technical specification for application to sub-5 MW HV-connected DER. Adopting it with some modification might be the required approach that would see it converted from a Technical Specification to an Australian Standard.

AEMO intends to work with the Australia Standards Committee EL-064 to initiate this consultation on the adoption of the IEC technical specification. Adoption in Australia would require country specific settings to be defined across the different areas of IEC TS 62786-1, by either:

- Linking the Australian adopted version to the guideline described in Section 5.1.1; or
- Including the country-specific settings within the Australian adopted version of IEC TS 62786-1.

5.1.3 Prospective rule change for link with Chapter 5A DER connection process

If Standards Australia adopts AEMO's recommendation and makes the IEC technical specification an Australian Standard, a rule change proposal may be needed to amend Chapter 5A of the NER to link to the new Standard, including the country specific settings.

Further, the potential rule change proposal might also address the broader NER issues described in the section below (5.2).

5.2 NER implications of the proposed changes to AS/NZ 4777.1

There are currently two NER references to the AS/NZS 4777 standard in the definition of micro EG connection in Chapter 5A and *DER Technical Standards* in the chapter 10 glossary. These definitions (and some related ones) are:

> **DER Technical Standards** (NER chapter 10 glossary definition)
>
> The requirements for embedded generating units under Australian Standard AS4777.2:2020 as in force from time to time
>
> **micro DER connection** (chapter 5A definition)
>
> means a connection between a distribution connected unit and a distribution network of the kind contemplated by Australian Standard AS 4777 (Grid connection of energy systems via inverters)
>
> **basic micro DER connection service** (chapter 5A definition)
>
> means a basic connection service for a retail customer who is a micro resource operator
>
> **micro DER connection** (NER chapter 10 glossary definition)
>
> has the meaning given in clause 5A.A.1
>
> **micro resource operator**
>
> a small customer, large customer or SRA customer who operates, or proposes to operate, a distribution connected unit for which a micro DER connection is appropriate

As discussed in Section 1 of this report, the revision to AS/NZS 4777.1 removes the 200 kVA threshold for the Standard and thus removes any ambiguity that may have existed about the interpretation of all LV-connected 230/400 V IES as *micro DER connections* and *distribution connected generators*. This could reduce the resilience of the power system, with AS/NZS 4777.2 requiring the IES to cease power generation for voltages above 260 V and below 180 V (while returning to generation within 400 ms when the voltage returns to the range 180 V to 260 V).

AS/NZS 4777.1 contains some ambiguity about whether some HV connections of LV IES could be classed as *micro DER connections* and *distribution connected generators*. It is likely that DNSPs will be making that decision, and therefore, impacting the rule definition.

The changes to the Australian Standard also mean that any LV-connected EVSE must comply with AS/NZS 4777 (including the technical requirements of AS/NZS 4777.2). This will have implications for consumer EVSE products that can be sold in Australia and connected to the NEM.

Another implication of removing the 200 kVA threshold in the proposed standard is that the definitions of *micro DER connection* and *basic micro DER connection service* are used in Chapter 5A for many non-technical purposes, in particular the terms and conditions for any *basic connection services* detailed within the connection agreement between the DNSP and the embedded generator. In addition, the Australian Energy Regulator (AER) may need to review the model basic connection services associated with *micro DER* connections.

In its final determination for the *Technical standards for distributed energy resources* rule change, the AEMC indicated, regarding the definition of *micro DER connection,* that:[61]

> This definition necessarily includes the connection of an embedded generating unit of the kind contemplated by Australian Standard AS 4777 (Grid connection of energy systems via inverters) currently up to 200kVA and connected to a distribution network. Using this definition, rather than specifying 200kVA, enables the application of the final rule to change without the need for a rule change if the size recognised by AS 4777 changes in the future.

The AEMC's comments above suggest a recognition that the prospect of a change to the current 200 kVA limit within the Standard may occur at some point in the future. However, it is unclear whether the entire removal of the limit itself was ever envisaged at the time of the rule change's implementation.

An analysis of the operation of Chapter 5A may be required if generating systems greater than 200 kVA are captured by the definition of *micro DER connections* and *basic micro DER* connection service.

5.3 Compliance management

This review has sought to detail recommended technical performance requirements for sub-5 MW DER, given its potential influence on the bulk power system's security and operation.

As part of its initial consultations, various stakeholders have raised concerns around the management of compliance with any set of prospective standards that AEMO may wish to recommend.

While the issue of compliance is a critical consideration, it was not within the scope of this review to determine the appropriate compliance framework to use for any recommended technical requirements it may wish to propose.

As highlighted in Section 2.1, AEMO has long had a significant engagement with respect to the compliance of small-scale IES. Its investigations and reports into these systems[62] have consistently highlighted their compliance challenges, and promoted the importance of ensuring there are appropriate governance systems and processes

[61] At the time of the final determination on "Technical standards for distributed energy resources" rule change assessment *micro DER connections* were referred to as *micro EG connection*. See https://www.aemc.gov.au/rule-changes/technical-standards-distributed-energy-resources.

[62] For example, see https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/compliance-of-der-with-technical-settings.

in place to support a high level of compliance with relevant standards. The same compliance governance framework concerns hold true for sub-5 MW DER.

AEMO notes the activities proceeding (or likely to proceed) below, and expects that the compliance management framework for sub-5 MW DER will be resolved through their fulfilment:

- **National CER Roadmap** – as mandated by the Energy and Climate Change Ministerial Council (ECMC) in November 2023, the Roadmap includes a key work stream seeking to implement a national approach to technical regulatory settings for consumer energy resources[63]. It is unclear at present whether the proposed framework that will emanate from this effort will seek to cover the entire sub-5 MW landscape (or whether it may be limited to small-scale systems only).
- **Guideline development** – as the proposed approach to implement this review's recommendations, AEMO will seek to collaborate with DNSPs to introduce, as part of the Guideline development, systems and processes that may be required to facilitate a high degree of compliance with the Guideline's technical requirements. This is also likely to be informed by the activity undertaken in the first point above.
- **Standards development** – as a further step beyond the initial Guideline with DNSPs, AEMO proposes to work with Standards Australia to institute the adoption of the IEC TS 62786-1 as an Australian standard or technical specification for application to sub-5 MW HV-connected DER. It is expected that further detailed considerations such as measurement accuracy, prioritisation of protection and operational modes, and even some discussion of firmware/operational codes (and their associated reporting) may be considered as part of this standard development (if not already addressed within the Guideline mentioned above). It is anticipated that the compliance management framework for the standard will be a key consideration prior to its introduction.

5.4 Next steps

The recommendations in this report were developed through consultation with the DNSPs in the NEM, AEMO subject matter experts, and a range of DER proponents and OEMs. These recommendations include:

- Proposed settings for each of the key focus technical performance areas.
- Adopting the IEC TS 62786 technical specification that was published in November 2023 as the basis for these proposed settings for each of the key focus areas.
- Adopting a proposed regulatory pathway for implementing the performance requirements as outlined.

AEMO intends to undertake a public consultation on these recommendations as well as on the most appropriate and effective approach for them to be implemented. All stakeholders are encouraged to provide their input as part of this consultation.

[63] As outlined in the ECMC Communique, at https://www.energy.gov.au/energy-and-climate-change-ministerial-council/meetings-and-communiques.

Consultation questions: Implementation approach

AEMO welcomes stakeholder feedback. In particular, AEMO is interested in understanding:

- Is initially introducing the proposed recommended settings via a guideline with DNSPs the most effective approach?
- Should the recommended settings be established as an Australian Standard?

6 Summary of issues for consultation

AEMO welcomes comment and feedback on the recommendations in this report, and specifically on the following matters:

Section		Questions
2	**Scope of technical requirements**	• Has the scope of prospective requirements for sub-5 MW DER been clearly defined? • Is the reasoning behind including those focus areas for AEMO to consider specifying technical requirements (summarised in Section 2.4) clear and reasonable? • Should AEMO also consider any or all of the requirements outlined in Section 2.5 (identified of interest to DNSPs only)? • Should AEMO consider other requirements not outlined here?
4	**Proposed performance requirements**	• Have the proposed performance requirements for sub-5 MW DER been clearly outlined? • What are stakeholder perspectives on the application of the proposed settings within the framework of IEC TS 62786-1 technical specification for sub-5 MW HV-connected DER? • What are stakeholder perspectives on the application of AS/NZS 4777.1 and AS/NZS 4777.2 region-based requirements, for 230/400 V ac IES, less than 1.5 MW aggregate rated capacity, connected to the HV distribution network with LV load? • Should AEMO consider other references for its technical performance settings? For example, EN 50549-2:2019, which specifies the technical requirements for the protection functions and the operational capabilities for generating plant intended to operate in parallel with medium voltage distribution networks.
5	**Options for implementation**	• Is initially introducing the proposed recommended settings via a guideline with DNSPs the most effective approach? • Should the recommended settings be established as an Australian Standard?

Stakeholders are invited to provide responses via futurenergy@aemo.com.au by **30 October 2024**.

A1. Proposed settings

The IEC TS 62786 settings described below are recommended for HV generation and storage connections, except 230 V single phase and 400 V three phase inverter systems greater than or equal to 1.5 MW and less than 5 MW, connected with LV load. They apply to HV-connected synchronous plant less than 5 MW. They may also be applied to LV-connected synchronous generation at the DNSP's discretion. For legacy plant, the existing plant capabilities will need to be taken into account when establishing requirements. Nevertheless, consideration may be given to whether protection settings, for example, maximise the capability of the plant to ride through disturbances, within the plant's capability and appropriate safety margins.

AS/NZS 4777.2 requirements are recommended to apply for systems less than:

- 230 V single phase/400 V three phase IES, connected at LV level.
- 230 V single phase/400 V three phase IES connected at HV level, less than or equal to 1.5 MW where the connection includes LV load.

Table 6 Proposed settings considering IEC TS 62786

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
Frequency ride-through	**IBR plant** Align with AS/NZS 4777.2 45 Hz to 52 Hz full output 49.5 Hz to 55 Hz multiple mode inverters with energy storage, must be capable of charging **Synchronous generation** Align frequency and duration with FOS for islanded conditions. (Frequency ranges differ between Mainland and Tasmania.) Mainland: 49.5 to 50.5 Hz, continuously	For DER with rated power > Pth-fd • f < fmin2 and f> fmax2, instantaneous disconnection permitted • fmin2 ≤ f ≤ fmin1 and • fmax1 ≤ f ≤ fmax2, operate for at least Tf1 • fmin1 ≤ f ≤ fmax1, continuous operation where • continuous operation range can be set between fmin1: 48.5 – 48.85 Hz[64] to fmax1 50.15 – 51.0 Hz • Tf1 can be set between 2 s and 90 min • fmin2 can be set between 47 – 49.8 Hz	Pth-fd = 0 kW (applies to whole range) **IBR plant** fmin 2 = 47 Hz fmin1 = 47 Hz fmax1 = 52 Hz fmax2 = 52 Hz Tf1 =90 min *Note: This is broader than the system standards and S5.2.5.3 AAS but not as wide as AS/NZS 4777.2. The fmax2 value is also not as high as the FOS for Tasmania. Maximum value of Tf1 has been used to maximise*

[64] This upper limit on the range is slightly lower than the FOS requirements for mainland and Tasmania, but operating with this setting would not have an adverse impact and could increase resilience.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
	Tasmania: 49.0 to 51 Hz, continuously Mainland: 49.0 to 49.5 and 50.5 to 51.0 Hz, for at least 10 min Tasmania: 48.0 to 49.0 Hz and 51 to 52.0 Hz, for at least 10 min Mainland: 47.0 to 49.0 Hz and 51 to 52.0 Hz, for at least 2 mins Tasmania: 47.0 to 49.0 Hz and 51 to 55.0 Hz for at least 2 min **Legacy plant** Performance to be agreed with DNSP based on plant capability with appropriate safety margins.	• fmax2 can be set between 50.2 – 52 Hz[65]	*capability, but the IEC TS 62786 allows for instantaneous disconnection for frequency above fmax2.* **Synchronous generation**: Mainland fmin2 = 47 Hz fmin1 = 49.5 fmax1 = 50.5 fmax2 = 52 Tf1 = 2 min Tasmania and Western Australia fmin2 =47 Hz fmin1 =49 Hz fmax1= 51 Hz fmax2 = 52 Hz Tf1 = 2 min **Legacy Plant** For Legacy plant, settings should reflect plant capability with appropriate safety margins, targeting as close as possible to the relevant technology setting. *Note: if this standard is adopted as an Australian standard, consideration could be given to extending the upper frequency limit to 55 Hz, for Tasmania and Western Australia. This would represent an amendment to the standard, compared with what is in the current version.*
RoCoF ride-through	**IBR plant** Align with AS/NZS 4777.2 ±4 Hz/s for duration of 250 ms	This technical schedule allows thresholds to be specified by the grid operator. The following is an example of form. Other specification forms are permitted: • ROCOFhi for the first $t_{ROCOFhi}$ seconds and	**IBR Plant** RoCoFhi: ±4 Hz/s $t_{ROCOFhi}$: 0.25s.

[65] This standard defines one short term ride-through range below nominal frequency and one above nominal, whereas the FOS defines two short-term ranges below and above nominal frequency. The highest frequency range is 52 Hz, which is less than Tasmania's 55 Hz in the FOS.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
	plus the FOS requirement for ±1 Hz/s over any 500 ms period **Synchronous generation** Align with FOS Mainland: ±1 Hz/s over any 500 ms, ±3 Hz/s over any 300 ms Tasmania: ±3 Hz/s over any 250 ms **Legacy plant** Performance to be agreed with DNSP based on plant capability with appropriate safety margins.	• ROCOFlo to the first $t_{ROCOFlo}$ seconds where • ROCOFhi > ROCOFlo and • $t_{ROCOFhi} < t_{ROCOFlo}$ There are no default values. The technical schedule also allows for a ride-through requirement for a step change in frequency to be specified (to cater for auto-reclose of a transmission line)	RoCoFlo: ±1 Hz/s $t_{ROCOFlo}$ 0.5s, *Note: The way the IEC TS specifies the time is slightly different from the system standard and the AS/NZS 4777.2, in that the former refers to 'the first' time period of the disturbance whereas the other two documents allow for the specified RoCoF to occur any time. Practically a high RoCoF is most likely to occur at the start of a disturbance, if the frequency is going to recover from it, or at the end if the system is heading for a blackout. The early period is therefore the most important consideration. In the recommended settings above, the high RoCoF has been taken from the AS/NZS 4777.2, but combined with the low RoCoF requirement and longer duration of the system standard.* *These settings should be practically achievable for an IBR plant.* **Synchronous generation** Requirement: Remain in operation for at least RoCoFhi: ±3 Hz/s $t_{ROCOFhi}$: 300 ms period. RoCoFlo: ±1 Hz/s $t_{ROCOFlo}$ 500 ms period, Note that the Tasmanian system standard requirement is a subset of the ±3 Hz/s over any 300 ms requirement, so is not separately required. **Legacy Plant**

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
			For Legacy plant, settings should reflect plant capability with appropriate safety margins, targeting as close as possible to the relevant technology setting.
Voltage excursion ride-through	**IBR plant** Align with system standard for over-voltage in NER S5.1a.4 and the AS/NZS 4777.2 protection time delays for passive anti-islanding for undervoltage. Note: The AS/NZS 4777.2 requirements to cease generation for voltage less than 78% after 400 ms is not appropriate for larger plant and has not been included in this proposed specification. Remain in operation for the following voltages Unless disconnection is required by the DNSP*, up to 130% for up to 60 ms Unless disconnection is required or allowed by the DNSP*, up to 125% for up to 100 ms Up to 120% for up to 350 ms Up to 115% for up to 900 ms Continuously 90 - 110% Down to 78% for up to 10000 ms Down to 70% for up to 2000 ms Down to 30% for up to1000 ms At connection point for HV connections At unit terminals or connection point for LV connections * The DNSP may require disconnection of the inverters between 120% and 130% of nominal voltage.' **Synchronous generation and legacy plant**	For plant with a rated power exceeding Pth-vd the technical schedule describes withstand requirements as follows: • Continuous operating voltage range Umin1 ≤ U ≤ Umax1 with default values 0.9 pu to 1.1 pu at the POC, and • Limited operating voltage ranges with recommended ranges that the plant must withstand: – Umin2: 0.85 to 0.9 pu for Tu1 10 – 180 s and – Umax2: 1.1 to 1.2 pu for Tu1 (ov) 10 –180 s Disconnection permitted U > Umax2 and U < Umin2 in Tu2 Tu2 recommended value 0 s. The technical schedule also defines an under- voltage profile at the POC for which the plant must remain connected with up to 6 voltages and associated times. The technical schedule allows flexibility for setting U1 to U6. The following are the recommended values, but can be changed, and must be coordinated with the limited operating voltage range and time (above)[66] [67]. • U1 0.05 – 0.70 pu for 0.0 to 0.25 s • U2 0.30 – 0.85 pu for 0.0 to 0.3 s • U3 0.70 – 0.85 pu for 0.0 to 10.0 s • U4 0.85 – 0.90 pu for 0.0 to 10 s • U5 0.85 – 0.90 pu for 0.0 to 180 s • U6 0.85 – 0.90 pu for 0.0 to 180 s	Settings for withstand: Pth-vd = 0 kW (ie apply in whole range) Continuous operation range: A DER with rated power exceeding the power threshold for a voltage deviation P th-vd should provide capability of withstanding voltage deviations at the connection point, in the continuous range (0.9 pu to 1.1pu), continuously. Umin1 0.9 pu Umax1 1.1 pu Limited operating voltage range The DER is permitted to disconnect, where necessary for the safe operation of the plant, for voltage at the connection point: 0.85 pu ≤ U < 0.90 pu at the connection point, after 60 s: Umin2 = 0.85 Tu1 = 60s Tu2 = Not specified The DER is permitted to disconnect, where necessary for the safe operation of the plant, for voltage at the connection point: 1.1 ≤ U < 1.17 pu at the connection point after 1.7s: Umax2 1.17 pu Tu1(ov) = 1.7 s Tu2(ov) = Not specified (consistent with the system standards). Note: if applying this specification to a GFM plant that is intended to remain connected, the NSP and the developer

[66] The proposed 50% for 1.0 s does not fall in this default range (compare with U2 above), but this does not prevent the proposed setting from being applied, by adjustment of other parameters.

[67] The TS deliberately duplicates or overlaps some ranges to allow different profiles to be flexibly set.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
	Performance to be agreed with DNSP based on plant capability with appropriate safety margins.	Likewise, the technical schedule defines an over-voltage profile at the POC for which the plant must stay connected with up to 6 voltages and associated times[68]. • U1 1.25 to 1.32 pu for 0.0 to 0.10 s • U2 1.20 to 1.30 pu for 0.0 to 2.0 s • U3 1.15 to 1.25 pu for 0.0 to 5.0 s • U4 1.10 to 1.20 pu for 0.0 to 10 s • U5 1.10 to 1.15 pu for 0.0 to 180 s • U6 1.10 to 1.15 pu for 0.0 to 180 s If requested by the DNSP the plant must provide reactive current to support the power system during disturbance. The DNSP is required to specify the settings. Note: The voltage and times specified above define a curve. For undervoltage the area above the curve defines conditions for which the plant must stay connected. Likewise, for the overvoltage, the plant must stay connected for conditions under the curve. These requirements apply to all types of short circuit faults. For three phase DER, the lowest phase-to-phase voltage shall be used. Depending on local system requirements, the lowest phase-to-neutral voltage may be used instead. Active power recovery After the fault is cleared the DER should recover (at least) a specified proportion of its output power Srec within a specified time Trec after stable network conditions are detected (as shown in figure 6 of the technical schedule).	may need to consider alternative disconnection arrangements. This disconnection specification is permissive rather than restrictive. The DNSP will also have to separately agree with the developer the protection trip times for anti-islanding protection which need to respect the ride-through requirements described in this section. Transient voltage ride-through If voltage drops below Umin2 (0.85 pu), undervoltage ride-through requirements below apply. If voltage exceeds Umax2 (1.17 pu) overvoltage ride-through requirements below apply. **Undervoltage ride-through requirements**: (voltages in pu of nominal at connection point, time in seconds) The DER shall maintain connection with the network if the voltage drop at the connection point is within the “stay connected” area (defined by the area above the voltage-time curve (as illustrated in figure 5 of the technical schedule), which connects the following points: U1 = 0.3 pu t1 = 1.0 s U2 = 0.3 pu t2 = 1 s U3 = 0.70 pu t3 = 2.3s U4 = 0.78 pu t4= 10s U5 = 0.80 t5= 20s

68 The proposed standard falls within the recommended envelop of operation for overvoltages.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
			U6 0.85 pu t6= 60s After the fault is cleared the DER should recover (at least) the specified proportion of its output power Srec within a specified time Trec after stable network conditions are detected (as shown in figure 6 of the technical schedule). Srec = 80% of pre-disturbance active power Trec = 1 second *Note: An inverter's capability is proportional to voltage. The equivalent wording in AS/NZS 4777.2 says that the inverter's active power must recover to the predisturbance level within 400 ms of the voltage recovering to the continuous operation range, which is above 180 V. Full output at 180 V is impractical, for two reasons. Firstly, inverter capability is proportional to voltage, so will be reduced to 78% at 180 V. Secondly, the reactive power is likely to be prioritised over active power at such a low voltage, in which case active power is likely to be further reduced. The wording in the IEC TS is not significantly better, because it doesn't specify the voltage at the time the recovery is supposed to commence, but only refers to "stable network conditions".* **Overvoltage ride-through requirements**: (voltages in pu of nominal at connection point, time in seconds) If the voltage at the POC is within "stay connected" area, DER shall maintain the connection with the network. If the voltage at the POC moves out of "stay connected" area, DER may be disconnected. The points below describe the curve. The "stay connected" area is below and to the left of the curve as illustrated in figure 7 of the technical schedule. U1 = 1.30 pu t1 = 0.06 s U2 = 1.30 pu

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
			t2 = 0.06 U3 = 1.25 pu t3 = 0.1s U4 = 1.20 pu t4= 0.35 s U5 = 1.15 pu t5 = 1.7s U6 = 1.15 pu t6= 1.7s The DNSP may, at its discretion, reduce or omit the requirement for remaining in operation above 1.20 pu of nominal voltage. This can be achieved by setting U3, U2 and U1 to 1.20 pu and t3, t2, and t1 to 0.35 s. Application to LV settings: For HV connections, voltage requirements can be translated to LV level settings using steady state modelling (loadflow) taking account of the operating mode, impedances and tap ratio. If the plant is incapable of riding through the settings calculated by this method (in compliance with this technical schedule), a dynamic model can be used along with reactive current injection /absorption to support the unit level voltages to achieve required ride-through performance. Dynamic modelling should only be required where simpler methods are not sufficient. A single-machine infinite bus study with an RMS model would be sufficient for this purpose. As required by section 4.7.6.1 of the technical schedule, any reactive current settings for additional reactive current response during disturbances shall be nominated by the DNSP, and shall be field adjustable. Alternatively, industry may prefer to adopt an amendment to this technical specification to apply the settings at the inverter level. There may be a small difference in the voltage at the connection point and the inverter level, considering the transformer between the connection point

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
			and the plant for HV connections, and the control mode of the plant. A pragmatic approach might be to apply the values to the inverter directly, ignoring the voltage difference, which would simplify the connection and the process of confirming that the expected values are applied. It is noted that the proposed voltage levels are wider (at least at the undervoltage levels above 0.7 pu) than required by Schedule 5.2 for larger plant, considering connection point values, so taking this pragmatic approach would be expected to provide acceptable overall performance. Multiple voltage disturbances Note that the IEC TS does not specifically deal with multiple voltage disturbances. However, the plant would be required to stay connected for any complex shaped disturbance that fell within the magnitudes and durations described, and there is no limit on the number or proximity of disturbances that a plant is expected to ride through.
Phase angle shift ride-through	Align with AS/NZS 4777 Single-phase disturbance, 60 degrees Three phase disturbance, 20 degrees Note: in AS/NZS 4777 the requirements are at inverter terminal level, but this standard only applies to LV	Recommended immunity threshold levels[69]: • 60 degrees for single phase fault • 20 degrees for three phase fault These values are referenced to connection point voltage[70].	Recommended immunity threshold levels: 60 degrees for unbalanced voltage disturbance 20 degrees for balanced voltage disturbance. *Note: the reference to balanced and unbalanced is different from the recommendation in the standard. With*

[69] The TS describes the recommended requirements in terms of a fault condition, but AEMO would prefer them to reference unbalanced voltage disturbance and balance voltage disturbance as phase shifts are not necessarily caused by faults, but phase shifts may be caused by other phenomena such as line switching and trip of load or generation. The plant should also be required to ride through two phase faults, not just single and three phase. The example of phase shift provided in the specification is for a phase to phase fault, implying the intention is for ride through to apply in this situation as well as for single phase faults.

Depending on the configuration of their windings, transformers can introduce phase shift in voltages on one side of the transformer compared with other, so that a single phase fault on the connection point can result in multiple phases shifting at the unit terminals. This also makes specification of phase shift requirement in terms of "balanced" and "unbalanced disturbance more desirable" Note that the AS/NZ 4777.2 also specifies the phase shift requirement as single phase and three phase. Consequently, the AS/NZ 4777.2 also has the same problems with its phase shift ride through requirement when applied to HV-connected IES.

[70] By default, the requirements are at the connection point, but there is some flexibility to apply requirements elsewhere in some conditions (not specified in this part 1 of the standard). Where the connection is at HV level and there is a transformer with a phase shift between the HV connection point and the LV plant terminals, there will be a phase shift introduced for unbalanced faults, between HV and LV. This phase shift will need to be taken into account for compliance.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
	connections, so is approximately the same phase angle as the connection point.		*this change it should be possible to specify the impact at the plant terminals rather than the connection point, which would facilitate equipment level testing and certification. This change might require an amendment to the standard where adopted, although the immunity thresholds are only described as "recommended".*
Active power curtailment, by remote signal	DNSP can curtail active power or disconnect plant, through remote control[71].	The standard specifies the active power curtailment requirements as follows: Generating plants connected to a HV network and those connected to a LV network with a rated power exceeding the power threshold for disconnection Pth-dis (defined by country) shall have the capability to be disconnected or curtailed, locally or remotely. The maximum active power output should not exceed the value determined by the system operator.	Pth-dis = 0 kW (ie applies to the whole range)
Remote monitoring	Active power level and Active power curtailment status (active/ inactive) Implementation method to be agreed with the DNSP Propose to apply to systems 200 kW and above.	Monitoring and control capability is required for HV connected DER and LV connected DER above a threshold Pth-inf defined by country[72]. Required capability includes information sent from the DER and to the DER to accept control and regulation instructions sent by the system operator[73].	Monitoring and control capability is required for HV connected DER above a threshold Pth-inf defined by country. Includes info sent from the DER and to the DER to accept control and regulation instructions sent by the system operator. Recommend: Pth-inf = 200 kW Minimum requirements, with implementation method to be specified by the NSP: • Active power level • Active power curtailment status

[71] This includes curtailment on the instruction of AEMO such as during a system restoration.

[72] Note: All HV systems have the requirement not limited by active power threshold. This differs slightly from the proposed requirement.

[73] Note: time resolution not mentioned. Active power curtailment status is not mentioned, but not precluded.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
Ramp rate limit	Ramp rate limited to 20% of rated power/min except for specific exempted conditions (described in section 2.3.2).	For generating plants connected to HV network and those connected to LV network with rated power exceeding the power threshold for disconnection Pth-dis, the maximum rate of active power change should not exceed the value determined by the system operator.[74]	For generating plants connected to HV network and those connected to LV network with rated power exceeding the power threshold for disconnection Pth-dis, the maximum rate of active power change should not exceed the value determined by the system operator. Pth-dis = 0 kW Ramp rate limit 20% of rated power/minute Permitted exceptions: • Fast frequency response (FCAS) • PFR response outside deadband • Low charge condition less than 20% in a BESS when exporting • When net output of a hybrid plant is being controlled at the connection point • When operating in an intentional island (and frequency control is required)
Frequency response (with a deadband)	5% Frequency droop response with deadband of: • 49.5 – 50.5 Hz (mainland) • 49.0 – 51.0 Hz (Tasmania) A lower (more aggressive) droop may be agreed with the DNSP when the IES is offering FCAS) (aligns with S5.2.5.8 for over frequency)	All HV connected DER and LV connected with rating exceeding Pth-apc defined by the country shall have active power – frequency response. Defined as a P vs f curve with deadbands: • Δf' for underfrequency and Δf for overfrequency, in Hz and • gradients, expressed as per-unit of DER active power per Hz: – G'pu for underfrequency – Gpu for overfrequency When network frequency exceeds nominal value (fn) by more than Δf, DER should reduce their active power output with a gradient Gpu. When the network frequency is below nominal value (fn) by more than Δf' and if active power increase is possible,	All HV connected DER and those connected to LV network with a rated power exceeding the power threshold for active power control Pth-apc, shall have active power control capability. They shall adjust their active power output in response to frequency deviation (power-frequency response), ensuring the secure operation of the network. Pth-apc = 0 kW (ie applies to whole range) Deadband: Δf = Δf' = 0.5 H(1 Hz Tasmania) which gives an overall deadband 49.5 – 50.5 Hz (49.0 – 51.0 Hz (Tasmania) Gradient: Gpu = G'pu = 0.5 pu/Hz (which gives a 4% droop) When network frequency exceeds nominal value (fn) by more than Δf, DER should reduce their active power output with a gradient Gpu.

[74] Exceptions are not specifically mentioned, but not precluded.

Focus Area	Proposed performance level (repeated from Table 4)	IEC TS 62786 requirement (repeated from Table 4)	Proposed settings
		DER should increase their active power output with a gradient G'pu. Note: IEC TS62786-3 for BESS requires frequency response while charging as well as while generating.	When the network frequency is below nominal value (fn) by more than ∆f' and if active power increase is possible, DER should increase their active power output with a gradient G'pu.
Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements	Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements for voltage, frequency and RoCoF, within safe operating limits consistent with good engineering practice.	The section on protection functions refers to IEC 60255-127 for over- and under-voltage protection and IEC 60255-181 for over-frequency, under-frequency and ROCOF[75].	Protection to be set to maximise capability to ride through voltage and frequency disturbances, subject to DNSP requirements and operation of the plant within safe operating limits.

[75] The standard does not specifically include the principle of maximising capability, within safe operating limits.

A2. Gap analysis: AS/NZS 4777.2 and recommended settings for sub-5 MW DER

AS/NZS 4777.2 defines the inverter requirements, including technical performance requirements, for grid-connected energy systems via inverters. Since the standard's inception, these requirements have applied to inverters below 200 kVA, however, under recent changes (see Section 1.4) they apply to all IBR installations at the LV level, with the explicit context being IES supplying ac power at mains voltage (230 V phase to neutral/400 V phase to phase).

The table below compares the proposed performance requirement for each of the key focus areas of this review with the requirements under the revised AS/NZS 4777.2-2020. Note that for each focus area the performance under AS/NZS 4777.2-2020 applies at the inverter terminals, including where the energy system is HV connected.

Table 7 Comparison of proposed settings: IEC TS 62786 and AS/NZS 4777.2:2020

Focus Area	Proposed performance level (as outlined in Table 4Table 4)	Settings AS/NZS 4777.2-2020
Frequency ride-through	**IBR plant** Align with AS/NZS 4777.2 45 Hz to 52 Hz full output 49.5 Hz to 55 Hz multiple mode inverters with energy storage, must be capable of charging	Proposed settings align with AS/NZS 4777.2 No change to Clause 4.5.3. Passive anti- islanding (clause 4.4): • Disconnect below 47 Hz with trip delay of 1 second and maximum disconnection time of 2 seconds • Disconnect above 52 Hz with maximum disconnection time of 0.2 seconds
RoCoF ride-through	**IBR plant** Align with AS/NZS 4777.2 ±4 Hz/s for duration of 250 ms Plus the FOS requirement for ±1 Hz/s over any 500 ms period	Proposed settings align with AS/NZS 4777.2 No change to Clause 4.5.6.
Voltage excursion ride-through	**IBR plant** Align with system standard for over-voltage in NER S5.1a.4 and the AS/NZS 4777.2 protection time delays for passive anti-islanding for undervoltage.	Passive anti-islanding (clause 4.4): • Disconnect below 70 V with trip delay of 1 second and maximum disconnection time of 2 seconds

Focus Area	Proposed performance level (as outlined in Table 4Table 4)	Settings AS/NZS 4777.2-2020
	Note: The AS/NZS 4777.2 requirements to cease generation for voltage less than 78% after 400 ms is not appropriate for larger plant and has not been included in this proposed specification. Remain in operation for the following voltages Unless disconnection is required or allowed by the DNSP*, up to 130% for up to 60 ms Unless disconnection is required or allowed by the DNSP*, up to 125% for up to 100 ms Up to 120% for up to 350 ms Up to 115% for up to 900 ms Continuously 90 - 110% Down to 78% for up to 10000 ms Down to 70% for up to 2000 ms Down to 30% for up to 1,000 ms At connection point for HV connections At unit terminals or connection point for LV connections * The DNSP may require disconnection of the inverters between 120% and 130% of nominal voltage.'	• Disconnect below 180 V with trip delay of 10 seconds and maximum disconnection time of 11 seconds • Disconnect above 265 V with trip delay of 1 second and maximum disconnection time of 2 seconds • Disconnect above 275 V with no trip delay time and maximum disconnection time of 0.2 seconds Sustained over-voltage (Clause 4.5.2) • Disconnected within 3 seconds when the average voltage for a 10 minute period exceeds 258 V. • Voltage disturbance response (Clause 4.5.4) Cease power generation within 200ms when above 260 V • Continuous operation between 180 V and 260 V • Cease power generation within 200ms when below 180 V The requirement to cease power generation for over and under voltages is different to the proposed performance level.
Phase angle shift ride-through	Align with AS/NZS 4777 Single-phase disturbance, 60 degrees Three phase disturbance, 20 degrees Note: in AS/NZS 4777 the requirements are at inverter terminal level, but this standard only applies to LV connections, so is approximately the same phase angle as the connection point.	Proposed settings align with AS/NZS 4777.2 No change to Clause 4.5.5.
Active power curtailment, by remote signal	DNSP can curtail active power or disconnect plant, through remote control	Standard includes inverter demand response modes (DRM) in Clause 3.2: • DRM 0 – operate the disconnection device • DRM 1 – Do not consume power • DRM 2 – Do not consume at more than 50% power • DRM 3 – Do not consume at more than 75% power AND supply reactive power if capable • DRM 4 – Increase power consumption (subject to constraints from other active DRMs)

Focus Area	Proposed performance level (as outlined in Table 4Table 4)	Settings AS/NZS 4777.2-2020
		• DRM 5 – Do not generate power • DRM 6 – Do not generate at more than 50% power • DRM 7 – Do not generate at more than 75% power AND absorb reactive power if capable • DRM 8 – Increase power generation (subject to constraints from other active DRMs) DRM 0 is mandatory, but the others are optional. In each case the response time is 2 seconds. The inclusion of DRM 5, 6 ,7 and 8 provide some ability to implement generator curtailment, but it is not very granular. In addition, these modes do not appear to be able to regulate the import or export from a site. Clause 6 describes the control functionality. This includes generation limit and export limit controls, with both soft and hard limits. A SCADA remote terminal unit (RTU) or similar would likely be required to allow remote control of active power.
Remote monitoring	Active power level and Active power curtailment status (active/ inactive) Implementation method to be agreed with the DNSP Propose to apply to systems 200 kW and above.	Clause 6 describes the control functionality. This includes monitoring of the active power response to the operation of the soft and hard limits. A SCADA RTU or similar would likely be required to allow remote monitoring of active power.
Ramp rate limit	Ramp rate limited to 20% of rated power/min except for specific exempted conditions (described in Section 2.3.2).	Clause 3.3.4.2 specifies that the default power rate limit for increase and decrease shall be 16.67% of rated power per minute which gives a nominal ramp time of 6 minutes. A ramp rate of 20% of rated power per minute could be used instead of the default to be consistent with the proposed performance level for DER. However, the slower ramp rate of 16.67% of rated power per minute is likely to marginally reduce FCAS costs.
Frequency response (with a deadband)	5% Frequency droop response with deadband of: • 49.5 - 50.5 Hz (mainland) • 49.0 – 51.0 Hz (Tasmania) A lower (more aggressive) droop may be agreed with the DNSP when the IES is offering FCAS.	Clause 4.5.3 specifies an active power response to support the power system frequency. Features include: • Maximum output below f_{Pmax} set between 47 and 49 Hz (default 48 Hz) • Increase in generation below $f_{stop\text{-}ch}$ set between 48 and 49.5 Hz (default 49 Hz) • Deduction in generation above $f_{transition}$ set between 50.5 and 2 Hz (default 50.75 Hz)

Focus Area	Proposed performance level (as outlined in Table 4Table 4)	Settings AS/NZS 4777.2-2020
	(aligns with S5.2.5.8 for over frequency)	• Minimum output above f_{Pmin} set between 51 and 53 Hz (default 52 Hz) – for generation plant • Zero output at $f_{transition}$ and maximum consumption at f_{Pmin} – for storage plant • Hysteresis to sustain the increase for decrease in generation for 20 seconds once the frequency returns to 50.0 Hz This is broadly consistent with the proposed performance levels in Table 4.
Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements	Subject to DNSP requirements, protection settings to maximise capability beyond ride-through requirements for voltage, frequency and RoCoF, within safe operating limits consistent with good engineering practice.	The standard is silent on this.

A3. DNSP access requirements

This section contains a summary of current DNSP access requirements for 200 kW-5 MW DER for those focus areas relevant to bulk power system and NEM market operations considered as part of this review.

While every effort has been made to ensure the quality of the information provided herein, AEMO cannot guarantee its accuracy or completeness, and it should not be relied on as a substitute for obtaining detailed advice directly from the relevant DNSP.

Table 8 SA Power Networks: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Assumes that the principles of AS/NZS 4777 will be met but no specific ride-through requirement are spelt out and checked. For HV and LV connected systems, anti-islanding requires disconnection: • Below 47 Hz after 1 second. • Above 52 Hz.
RoCoF ride-through	As per AS4777.2:2020 part 4.5.6: ±4 Hz/s for 0.25 seconds
Voltage ride-through	Assumes that the principles of AS/NZS 4777 and Electricity (General) Regulations 2012 requirements for UVRT will be met but no specific ride-through requirement are spelt out and checked. For HV connected systems, anti-islanding requires disconnection: • Below 30% nominal voltage after 1 second. • Below 78% nominal voltage after 10 seconds. • Above 115% nominal voltage after 1 second. • Above 120% nominal voltage. For LV connected systems, anti-islanding requires disconnection: • Below 70 volts after 1 second. • Below 180 volts after 10 seconds. • Above 265 volts after 1 second. • Above 275 volts.
Active power control	SCADA controls for generating systems exporting 200 kW or more. The three control capabilities that are mandated are: • Permissive Signalling – applies to the whole generating system. • Generation Dispatch Limiter – applies at the generating system terminals. • Net Export Limiter – applies at the connection point.
Active power ramp rate	Applies the AS4777.2-2020 recommended default ramp rate of 6 minutes. Considering changing for HV systems to better align with NEM dispatch requirements of 5 minutes. The ramping requirements may be overridden under contingent scenarios such as: • Generator runback for overload scenarios. • Compliance with site export/import limits. • Delivery of frequency responses (PFR, C-FCAS). • Responding to power quality demand response modes (Volt-VAr, Volt-Watt). Also trialling allowance of faster ramp rates for internal load following applications (e.g. supporting motor starts, peak lopping etc.) provided the customer can demonstrate that the voltage fluctuations / impact seen at the connection point does not get worse with the BESS ramping faster for load matching applications.

Item	DNSP requirement
Phase angle shift ride-through	Assumes that the principles of AS/NZS 4777 will be met but no specific ride-through requirement are spelt out and checked. Requires that any form of phase angle protection be disabled.
Frequency control	No specific requirements for sub 5 MW generating systems other than the standard AS/NZS 4777 requirements. Additional requirements for those systems intending to provide FCAS.
Monitoring and control	SCADA monitoring and control for all generating systems exporting 200kW or more. Note this requirement is based on export capabilities and not the capability of behind the meter systems. The standard quantities include: • Connection point voltages, currents, active power, reactive power and power factor. • Generating system controls (such as permissive signalling, GDL, net export limiter, power factor controls).
Protection settings reflecting capability	Protection settings for generating system connections are set to coordinate with generating system capability/requirements but often set right at the limit without additional safety margin (for excample, RoCoF protection set at ±4 Hz @ 250 ms delay).

Table 9 Tas Networks: Access requirements (200 kW – 5M W)

Item	DNSP requirement
Frequency ride-through	For MV systems have: • Passive anti-island settings are 45Hz (for 1 second) and 53Hz; and • Shall not disconnect for frequency in the range of 47.0 Hz - 52.0 Hz (unless anti-islanding protection operates). For LV EG – Passive anti-islanding for outside the range 47.0 – 53.0 Hz for 2 seconds. Otherwise, AS 4777.2 region "Australia C" responses.
RoCoF ride-through	RoCoF ride-through is not explicitly stated, although ROCOF-based protection is not allowed. AS4777 is most likely applied.

Voltage ride-through	For MV systems <5 MW shall not disconnect for faults within 150 ms of any voltage disturbance; plus CUO for
	• A minute:
	  – 90-110% (below 33kV).
	  – 85-115% (33kV and above).
	• 10 seconds:
	  – 0-150% phase to earth (33 kV and above).
	  – 0-180% phase to earth (less than 33kV).
	  – 0-150% phase to phase.
	Passive anti-islanding protection requirements:
	• Over Voltage (V>) 115% 3.0 second.
	• Over Voltage (V>>) 130% 0.1 second.
	• Under Voltage (V<) 90% 20.0 second.
	• Under Voltage (V<<) 75% 1.0 second.
	• Over Frequency (F>) 52 Hz 0.1 second.
	• Under Frequency (F<) 47 Hz 1.0 second.
	Active anti-islanding protection also required. In addition, communication based active anti-islanding protection is required when it is deemed that the system can form an island.
	No requirement for LV systems. Active anti-islanding is required as per AS 4777.2:2020 and passive anti-islanding is required as per Australia Region C in AS 4777.2:2020.

Active power control	Active power control for curtailment is not required.

Item	DNSP requirement
Active power ramp rate	No requirement specified.
Phase angle shift ride-through	The MAS of S5.2.5.16 is expected for MV connected systems. There is no specification for LV-connected systems. No vector shift projection is allowed for anti-islanding protection.
Frequency control	MV connected systems should have a frequency droop of 4%. These units should comply with the MAS of S5.2.5.11 and should be adequately damped. No requirement specified for LV connected systems.
Monitoring and control	Monitoring typically required above 200 kVA. Monitored quantities vary, but generally include voltage and current at the resolution of the connection point recloser, and communications integrity monitoring.
Protection settings reflecting capability	Not considered.

Table 10 United Energy, Powercor, CitiPower: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Apply the requirements of NER S5.2.5.3.
RoCoF ride-through	Allow for the requirements in S5.2.5.3 which will have the AAS, MAS ride-through requirements as well.
Voltage ride-through	Protection is set based on AS4777.2:2020 for low voltage. For high voltage, the Victorian distribution code is used to define the minimum access standard. That is: • 110% to 120% 10.0 s. • 90% to 110% continuously. • 80% to 90% 5.0 s. • 70% to 80% 2.0 s. • Requirements of MAS in NER S5.2.5.5 for contingency events.
Active power control	Required for all sub-5 MW from 1 July 2024. Remote control capability. Linear increase or reduction for HV-connected.
Active power ramp rate	Apply AS4777.2-2020 below 1 megavolt ampere (MVA) and apply 100% ramping over 5 minutes for systems larger than 1 MVA.
Phase angle shift ride-through	AS4777.2-2020 is applied.
Frequency control	Applies NER S5.2.5.11.
Monitoring and control	Active power monitoring required for all Sub 5MW from 1st July 2024.. Generators above 1 MW incorporated into the HV DERMS. • Control of reactive power and active power. • Monitoring active power, reactive power, current , voltage. Further details provided in our technical standards. Link to: https://media.powercor.com.au/wp-content/uploads/2022/01/25094028/HV-Generator-Performance-Standard-Guideline-For-Sub-5MW-Generators.pdf https://media.unitedenergy.com.au/factsheets/UE-ST-2008.2-LV-EG-Network-Access-Standard_2023.pdf https://media.unitedenergy.com.au/factsheets/UE-ST-2008.3-HV-EG-Network-Access-Standard_2023.pdf

Item	DNSP requirement
Protection settings reflecting capability	For LV-connected generation AS4777.2 setting are adopted. For >1 MVA generation the customer equipment capability will be considered by customer during their protection study.

Table 11 Jemena: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	No specific contingency events are included in the requirement.
RoCoF ride-through	No specific contingency events are included in the requirement.
Voltage ride-through	No specific contingency events are included in the requirement.
Active power control	Requires the DER with size 200 kW and above requires to either active power control to curtail its generation to zero, or a level specified by DNSP, or instantaneous disconnection from the network for minimum demand event as required/directed by AEMO.
Active power ramp rate	Requires non-scheduled DER to have active power ramp rate below 50kW/s unless negotiated and agreed with DNSP.
Phase angle shift ride-through	No specific contingency events are included in the requirement.
Frequency control	No specific contingency events are included in the requirement.
Monitoring and control	Requires DER with size 200 kW and above to have active power monitoring at connection point and at aggregate of the generator terminals. Other quantities monitored are voltage and reactive power at the connection point and if available, at aggregate of the generator terminals.
Protection settings reflecting capability	Not considered.

Table 12 AusNet: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Follow the MAS in the NER.
RoCoF ride-through	Follow the MAS in the NER.
Voltage ride-through	Generally follow the MAS of the NER S5.2.5.4 and S5.2.5.5 for the most part. However, more lenient on recovery timing and damped responses. Require current injection during faults, but do not stringently evaluate it. If someone would prefer to block during a fault, we would allow it, as most of the network's fault current still comes from the transmission network.
Active power control	Want the option to control active power via remedial action scheme for DER larger than 1.5 MW. Used to run back their active power as per our command when there's a network constraint. Also intend to require DER to interface with ADMS/DERMS system. This is voluntary at the moment, with the incentive being that when there's a network constraint, instead of being runback to 0 MW you'll be runback to a non-zero value.
Active power ramp rate	1 MW/minute for normal operation, to provide enough time for the voltage regulators to operate and keep voltages within limits. There is an exception for FCAS and responses to runback schemes must result in a ramp-back to 0 MW within 20 seconds.

Item	DNSP requirement
Phase angle shift ride-through	Not explicitly evaluated. However it must be coordinated with the anti-islanding protection relay.
Frequency control	We follow the MAS. Would settle for "Just don't go the wrong way for a frequency excursion".
Monitoring and control	DER larger than 1.5 MVA is in the SCADA system. Request compatibility with our upcoming ADMS/DERMS system which will have the ability to apply dynamic operating constraints. Currently monitor active and reactive power, phase current and phase voltage at the connection point.
Protection settings reflecting capability	Not considered.

Table 13 EVO Energy: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Applies settings equivalent to AS4777-2:20-20 for LV connections. Do not apply a ride-through requirement for HV but rather require disconnection: • Above 50.5 Hz (10-minute average) after 0.2 second delay. • Above 52 Hz instantaneously. • Below 49.5 Hz (120-minute average) after 2 second delay. • Below 47 Hz instantaneously.
RoCoF ride-through	Requires for ROCOF protection is 1Hz/s for 2s.
Voltage ride-through	Applies settings equivalent to AS4777-2:20-20 for LV connections. Do not apply a ride-through requirement for HV but rather require disconnection: • Above 12.21 kV after 1 second delay. • Above14.3 kV instantaneously. • Below 8.8 kV after 2 second delay. • Below 4.43 kV instantaneously.
Active power control	Do not have any requirements for sub-5 MW systems.
Active power ramp rate	Do not have any requirements for sub-5 MW systems.
Phase angle shift ride-through	Do not apply a ride-through requirement but requires vector shift protection is set to 10 deg instantaneous for LV and 12 deg with 2 second delay for HV.
Frequency control	No specific requirement.
Monitoring and control	Exporting systems over 200 kVA currently require SCADA which gives visibility of voltage and current readings as well as remote disconnect and a close inhibit for when the central protection trips (call control room to reset).
Protection settings reflecting capability	Not considered.

Table 14 Ausgrid: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Apply AAS and the MAS in NER S5.2.5.3, depending on the circumstances.
RoCoF ride-through	Apply AAS and the MAS in NER S5.2.5.3, depending on the circumstances.
Voltage ride-through	Apply the MAS om NER S5.2.5.4 and NER S5.2.5.5.
Active power control	Apply MAS in NER S5.2.5.14.
Active power ramp rate	Do not impose an active power ramp rate for this category of generators.

Item	DNSP requirement
	Are reviewing whether/when to impose a ramp rate limit.
Phase angle shift ride-through	Do not impose a voltage phase shift ride-through requirements for this category of generators.
Frequency control	Apply MAS in NER S5.2.5.14.
Monitoring and control	Typical connection includes a controllable circuit breaker at the point of connection which would offer a full suite of metrics.
Protection settings reflecting capability	Not considered.

Table 15 Endeavour: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Compliance with AS4777.2:2020.
RoCoF ride-through	Compliance with AS4777.2:2020.
Voltage ride-through	Compliance with AS4777.2:2020.
Active power control	Working towards export active power control, including curtailment, and SCADA for systems larger than 200 kW.
Active power ramp rate	Compliance with AS4777.2:2020. Exemptions are allowed for participation in FCAS.
Phase angle shift ride-through	Compliance with AS4777.2:2020.
Frequency control	Compliance with AS4777.2:2020.
Monitoring and control	For systems larger than 2 MVA, often on a case-by-case basis, including circuit breaker status, circuit breaker fail to trip alarm, MW and megavolt amperes reactive (MVAr) analogue signals. Are developing a SCADA system and will require SCADA for DER systems in the range of 200kW to 5MW which will be more specific about monitoring requirements.
Protection settings reflecting capability	Not considered.

Table 16 Essential Energy: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	LV (typically <1.5 MW): as per AS4777. MV (typically >1.5 MW): as per S5.2.5.3 of the NER (do not require full CUO). Anti-islanding requirements typically satisfied with under/over-voltage and under/over-frequency protection.
RoCoF ride-through	LV (typically <1.5 MW): as per AS4777. MV (typically >1.5 MW): RoCoF ride-through not specifically assessed however any RoCoF protection to lie outside NER requirements.
Voltage ride-through	LV (typically <1.5 MW): as per AS4777. MV (typically >1.5 MW): required to ride through a 2 second faults. Generating systems are to maintain active and reactive current through the fault (where possible). Anti-islanding requirements typically satisfied with under/over-voltage and under/over-frequency protection. SMIB voltage disturbance assessments are included in these requirements.
Active power control	LV (typically <1.5 MW): as per AS4777. MV (typically >1.5 MW): only when runback schemes required to manage network constraints.
Active power ramp rate	LV (typically <1.5 MW): as per AS4777.

Item	DNSP requirement
	MV (typically >1.5 MW): ramping from P_{min} to P_{max} (and P_{max} to P_{min}) over 5 minutes (where P_{min} could be negative for grid-charging batteries). Ramping requirements only relaxed for runback schemes, FCAS operation and zero export systems as required.
Phase angle shift ride-through	LV (typically <1.5 MW): as per AS4777. MV (typically >1.5 MW): Not specifically assessed however any vector shift protection to lie outside NER requirements.
Frequency control	LV (typically <1.5 MW): as per AS4777. MV (typically >1.5 MW): disabled in generating systems (except for FCAS participation).
Monitoring and control	LV (typically <1.5 MW): no specific monitoring requirements. MV (typically >1.5 MW): exporting systems require connection point recloser measuring kW, kVAr, Amps and Volts and power quality (harmonics, flicker, unbalance). Non-exporting systems: No specific monitoring requirements.
Protection settings reflecting capability	Protection settings to lie outside NER frequency, voltage and vector shift CUO requirements.

Table 17 Energy Queensland: Access requirements (200 kW – 5 MW)

Item	DNSP requirement
Frequency ride-through	Applies AS4777.2:2020 for inverter-based generation smaller than 1.5 MVA. Rotating machines smaller than 1.5 MVA will generally not have any performance defined beyond machine response. Generation 1.5-<5 MVA have a negotiated performance standard based on NER S5.2.5.3.
RoCoF ride-through	Applies AS4777.2:2020 for inverter-based generation smaller than 1.5 MVA. Rotating machines smaller than 1.5 MVA will generally not have any performance defined beyond machine response. Generation 1.5-<5 MVA have a negotiated performance standard based on NER S5.2.5.3.
Voltage ride-through	Generation 1.5-<5 MVA have a negotiated performance standard based on NER S5.2.5.3. Anti-islanding is managed through a grid protection relay /network owned recloser at the connection point, and in some cases additional interlocking.
Active power control	Site-specific, SCADA-based curtailment schemes may apply. Have commencing rolling out dynamic export limits for LV connections.
Active power ramp rate	Applies AS4777.2:2020 for inverter-based generation smaller than 1.5 MVA. Do not include a requirement for rotating machines under 1.5 MVA. A 5-minute ramp rates applies to systems 1.5-<5 MVA, but will also accept a 6 minute ramp in line with AS4777.2:2020, as negotiated.
Phase angle shift ride-through	Not specified.
Frequency control	Inverter-based generation less than 1.5 MVA refers back to AS4777.2:2020. Rotating machines less than 1.5 MVA not have any additional requirements defined. Generation 1.5-<5MVA have a negotiated performance standard based on NER S5.2.5.11.
Monitoring and control	SCADA monitoring for systems above 1.5 MVA Note that we are also starting to roll out dynamic export limits for LV connections, which will include some feedback to the DERMS in terms of compliance.
Protection settings reflecting capability	Not considered.