INITIAL DISTRIBUTED ENERGY RESOURCE MINIMUM TECHNICAL STANDARDS – FOR CONSULTATION

ISSUES PAPER

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Important notice

PURPOSE

This document outlines the proposed scope and content of an initial distributed energy resource (DER) minimum technical standard ("initial standard") as contemplated in the Australian Energy Market Operator Limited (AEMO) National Electricity Rules (NER) rule change request submitted to the Australian Energy Market Commission: *Electricity Rule Change Proposal, DER Minimum Technical Standards* – https://www.aemc.gov.au/rule-changes/technical-standards-distributed-energy-resources. AEMO is publishing this issues paper for the purpose of gaining feedback from industry to inform drafting of an initial standard. We acknowledge the scope of this document is the subject of consultation. The items contained in this document may form part of the initial standards or inform future considerations as part of future governance arrangements also being considered by the Energy Security Board (ESB).

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VERSION CONTROL

Version	Release date	Changes
# 1	24/08/2020	Original issue

1. EXECUTIVE SUMMARY

Context

In March 2020, the Council of Australian Government Energy Council (COAG EC) tasked the Energy Security Board (ESB) and AEMO to develop a rule change request that establishes in the National Electricity Market[1] (NEM) the initial minimum distributed energy resource (DER) technical standards ("Initial DER Standards") in 2020, and to develop mirror requirements in Western Australia. At the same time, the ESB was also tasked with considering future governance arrangements to coordinate development of DER technical standards moving forward.

The COAG EC agreed to the ESB's recommendation the Initial DER Standards focus on:

1. updates to inverter standard AS/NZS 4777.2; and
2. what interoperability capabilities are available and should be included in the Initial DER Standards.

Operating the power system and market with increasing penetration of DER has implications across the electricity supply chain. To date, DER participation in the NEM has been mostly comprised of the rapid growth of distributed PV (DPV) systems installed on residential and commercial rooftops since 2010. As outlined in AEMO's Renewable Integration Study[2], this growth in DPV generation has begun to pose technical challenges to managing both distribution network and bulk power system operation.

At the bulk power system level, the aggregate contribution of the growing passive DPV fleet impacts all core duties of system operation, including balancing supply and demand, system stability and securely managing the power system following contingency events. High DER penetration has major implications on the maintenance of system security and the ability for returning the power system to a steady state following a contingency event.

The performance of individual DER devices in the aggregate impacts AEMO and DNSPs' ability to main and operate the power system within its technical limits.

AEMO considers that DER will be increasingly diverse and more 'active' compared to the large, predominantly passive DPV fleet today. AEMO's Integrated System Plan projects significant growth in other forms of DER – such as storage, demand response, electric vehicles – into the future, operating both individually and in an aggregated manner. This presents opportunities for flexibility behind-the-meter and within the broader power system but will amount to more complex interactions operationally. A level of standardisation in device level capability and systems level integration will be required to securely operate this future power system and unlock these opportunities.

To better coordinate the technical capability response to this energy transition, and to meet the COAG EC timeframes for a nationally consistent standard to be established this year, market bodies are seeking to collaborate with industry to progress:

1. An AEMC rule change process to enable the enacting of DER Standards;
2. The content of the initial DER Standards (the subject of this paper) to be published with the final Rule determination; and
3. ESB's development of ongoing new governance arrangements for the DER Standards.

This paper introduces the concept of minimum technical standards as the DER Standards. The intent of establishing minimum DER technical standards is to put in place the required capability to underpin power system security and reliability, while allowing for the continued development of other capabilities to deliver benefits beyond the fundamental power system security provisions. A key pillar in defining the minimum

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[1] COAG Energy Council also requested these standards be transitioned into the South West Interconnected System (SWIS).

[2] AEMO 2020, at https://aemo.com.au/en/energy-systems/major-publications/renewable-integration-study-ris

standards is to ensure they do not stifle either technical or competitive innovation. An additional consideration in defining minimum technical standards is that they must be framed to meet the power system security needs, where there is evidence that the capability requirements are ready for implementation. The publication of this Issues Paper commences the first step of a consultation process to develop the Initial DER Standards. The consultation process has been initiated as early as possible and in parallel to the AEMC's rules consultation process to ensure interested parties can consider the broader rule change in the content of the initial standards and to allow full consideration of the proposals and issues. AEMO acknowledges the scope of these initial standards are subject to the AEMC rule change consultation and adaptations to them are required based on the final rule.

Transitioning the power system: benefits and challenges

The increased penetration of DER in the NEM and the Western Australian Wholesale Electricity Market (WEM) and its consequences are well documented[3, 4].The benefit of increased DER penetration to a wide range of companies, individuals and communities both environmentally and economically are also clear.

AEMO's challenge in terms of operating the NEM and WEM power systems, with respect to high DER penetration, relates to managing the power system to withstand contingency events. To maintain power system security and reliability, AEMO requires appropriate visibility and the ability to influence latent DER behaviour.

In the short term, two specific technical issues present with regards to secure and stable operation of the power system:

1. DER inverter capability to withstand power system disturbances

Evidence exists of significant volumes (~40%) of DER disconnecting from the grid in response to short duration (< 1 second) undervoltage disturbances[5]. In order to maintain a secure, safe and reliable power system AEMO strongly recommends DER must be able to withstand such disturbances. The capability to withstand these undervoltage disturbances is referred to as undervoltage disturbance ride-through capability ("VDRT").

Such undervoltage disturbances can, and have been shown to, occur with significant consequential impact to power system operation due to a substantial proportion of DER instantaneously tripping off, causing a given individual premises to switch from net generation to net load instantaneously. At scale this can exacerbate an otherwise manageable undervoltage disturbance to become a significant power system impact.

AEMO's investigations and analysis indicate a significant proportion of inverters already have VDRT capability[6]. However, equally, a significant proportion do not. This may be because some inverters are older technology, or newer technology VDRT capability is insufficiently robust.

AS/NZS 4777.2:2015 has a provision requiring that all inverters have VDRT capability. However, the current standard does not have a test procedure which equipment manufacturers can test against and ensure compliance.

AEMO recommends a change to current applicable test procedures for inverters that would start to address this problem.

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[3] AEMO 2020, at https://aemo.com.au/en/energy-systems/major-publications/renewable-integration-study-ris

[4] https://www.wa.gov.au/government/publications/der-roadmap

[5] AEMO studies include the Renewable Integration Study (2020), Technical Integration of DER (2019), Minimum operational demand thresholds in South Australia (2020)

[6] Ibid.

AEMO has drafted such a test procedure[7] and provided it to the South Australian Government in relation to its SA DER Action Plan. Improvements to VDRT and other disturbance ride-through requirements are also proposed in the current revision to AS/NZS 4777.2 which is presently open for public consultation. This revision will not be finalised until early 2021 with manufacturers provided a 12-month transitional period before inverters must be compliant to the new standard.

AEMO recommends this VDRT test procedure should be included as an Initial DER Standard with effect six months after publication of the Initial Standards. The reason for this accelerated timeframe is simple. DER continues to be deployed at a rapid rate and thus the longer it takes to introduce this test, the greater the risk the DER fleet poses in the event of a undervoltage disturbance. While 12 months will be allowed for inverters to meet a revised AS/NZS 4777.2, this timeframe allows not only for testing to be completed, but also development and implementation of new capability. The revised VDRT test procedure is intended to test for inverter capability that is already defined in AS/NZS 4777.2:2015 and should be implemented.

By introducing this test, DER will contribute to power system security and reliability.

More broadly AEMO recommends AS/NZS 4777.2 should be incorporated into Minimum DER Technical Standards as it enjoys wide support across the Australian electricity sector and would ensure a consistent approach across the NEM and in the WEM as this outcome is replicated in Western Australia.

2. DER Interoperability

DER interoperability, data and communication capabilities are an important part of ensuring:

a) the appropriate parties have aggregate visibility of DER at the appropriate 'level' to understand system performance at any particular moment and plan operational response;

b) active or real-time management of DER is enabled, either directly or, in AEMO's case, indirectly;

c) AEMO and registered participants have the tools and information essential to managing power system supply and demand; and

d) benefits of DER flow to end-use consumers.

Managing power system supply and demand balance

Operating the power system securely and reliably requires that the supply and demand are constantly in balance. This requires a range of techniques and tools – to manage second-by-second incremental variations due to constantly changing loads and generation supply (regulation services), as well as to keep sufficient reserves in place to manage near-instantaneous large changes in supply or demand that can result from faults to loads, generators or parts of the network (contingency services).

Historically, delivering regulation services has been relatively straightforward with small changes to dispatch of generation to respond to reasonably predictable load variations responding to time of day and weather conditions. This task has increased in complexity over time with more flexible demand (changing workplaces and lifestyles), and as a consequence of integrating variable energy sources into the grid. Today, delivering regulation services is further complicated by increasing utilisation of DER which has varying capability around managing energy resources behind the meter. Like regulation services, delivering contingency services has also become increasingly complex. The greater variability in supply sources and demand levels, increasingly "hidden" demand supplied by behind-the-meter DER and more complex energy usage patterns has led to greater uncertainty in operational planning with greater potential contingency sizes.

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[7] AEMO 2020, Short duration undervoltage disturbance ride-through: Inverter conformance test procedure for South Australia, at https://aemo.com.au/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/vdrt-test-procedure

As rooftop solar generation becomes more prevalent, Australia has seen a significant decrease in net demand from the system in the middle of the day meaning that fewer dispatched generating units are required. These generating units also deliver the bulk of balancing services that are required second-to-second and for contingency services essential to respond to significant events. One of the mechanisms power system operators utilise to maintain balance is load shifting (e.g. hot water load), load shedding, or generation shedding. Indeed, in times past, off-peak hot water loads were used to great advantage in this regard (previously minimum demand has occurred during the night and water heating was used to provide additional demand during times these times).

Similarly, today, shifting or controlling load or generation has its place. Whilst the reasons for this are similar to the past, the devices that need to be managed and means of communication need to evolve. Managing the increased complexity of high DER requires both greater visibility of supply and demand across all levels of the power system at any given time, and the ability to accurately and reliably control supply and demand at all levels.

Visibility of DER is intended to provide market participants the ability to engage with the energy market and respond to system needs where practical. It will further inform operators, including AEMO, of the real-time characteristics of the system, enabling better forecasting thereby supporting the maintenance of power system security.

Capabilities to support on-going management of supply and demand

These challenges have given rise to the question posed by COAG EC in the context of this paper, regarding data, communications and interoperability: what interoperability capabilities are available and should be included in the initial standards?

The questions posed in this paper go to how DER might be managed to ameliorate the aforementioned issues (noting that it would not be AEMO performing any control function; rather, the appropriate participant, under market guidance or instruction from AEMO would undertake this function)[8]. AEMO's expectation is that the existing provisions for informing the market of power system security matters, and issuing instructions and directions where required, as defined within the NER (refer Chapter 4 Power System Security), will facilitate these actions.

To support this outcome, minimum technical standards in communication, data, cybersecurity, and active management and demand response in relation to DER are required. However, these standards either do not currently exist and/or require further industry consultation to agree or develop to a point capable of being enacted in Australia. It is therefore AEMO's position that communications, data and interoperability not be included in the Initial DER Standards at this time. Notwithstanding this, it is AEMO's recommendation that industry jointly address this need as soon as practicable. Over time, various different initiatives to progress a range of matters in relation to this issue have been established and can be built upon, including those developed globally.

Integrating this functionality across the energy supply chain will potentially occur via the smart grid architectural model (SGAM), a commonly applied conceptual framework for understanding the cyber-physical (informational and electrical) interactions within the integrated power system[9]. Standardisation efforts will require extensive coordination and collaboration across industry, informed by a whole-of-system architectural view of the future power system and its key actors, devices and interactions.

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[8] Note that the pathways and circumstances for AEMO exercising this function are not in scope for this consultation.

[9] The SGAM framework was formed in 2012 through the National Institute of Standards and Technology (in the U.S.) Smart Grid Interoperability Panel's development of a 'smart grid architecture conceptual model' defining domains, actors, and stakeholders associated with the integrated power system – then, further refined by the European Smart Grid Coordination Group Reference Architecture Working Group.

This consultation provides an initial opportunity to understand stakeholder perspectives on whether and what device level interoperability and communication capability is required, what these preferred capabilities and protocols are, and whether, as AEMO considers, they best be further developed and potentially adopted in future DER minimum technical standards. Seeking feedback on these matters now will support the future development of these capabilities.

The issues paper presents for industry feedback AEMO's preliminary analysis of the minimum capability needed which can then be utilised to jointly develop a detailed implementation plan.

Recommendations

In summary, and in response to the COAG EC's and ESB's initial brief, AEMO's recommendations are as follows:

1. Incorporate the inverter undervoltage disturbance ride-through conformance test procedure developed for South Australia into the Initial DER Standards as soon as practicable;
2. Consider setting AS/NZS 4777.2 in its entirety as an Initial DER Standard;
3. Develop a coordinated industry consultation / implementation plan regarding DER data, communications and interoperability requirements and standards as soon as practicable. A high-level discussion on these capabilities is included in this issues paper to facilitate development of a detailed workplan.
4. Do not incorporate DER data, communications and interoperability provisions into the Initial DER Standard at this point in time as they are not sufficiently well prepared.

Costs and Benefits of implementing DER device level minimum capabilities

An important step in this consultation will be to understand the costs and benefits of standardising specific capabilities. In progressing the priority capabilities for minimum technical standards, AEMO is conscious of balancing appropriate capability for stable and secure operation of the power system with:

- the delivery of cost-efficient electricity supply for consumers;
- enabling innovation; and
- open market access to deliver value for DER owners.

In power system security terms, the benefits of enhanced testing of disturbance ride-through requirements include:

- Providing power system operators with certainty regarding the performance of connected DER before and after severe disturbances and avoid the need for inefficient operational measures in anticipation of DER loss.
- Avoiding further build-up of inverters that would continue to pose risks to the security and reliability of power supply to electricity customers. Making the changes now will capture more installed, upgraded or replaced DPV generation than would otherwise be captured under business as usual processes and help prevent the issues faced in South Australia from presenting in other jurisdictions.
- Improving resilience of the power system (a key component of reliability) while also meeting distribution network requirements for safety and suitable anti-islanding protection.
- Reducing the potential size of the contingency associated with disconnection of DPV generation via the aggregate response from compliant inverters. This would mitigate potential costs to the broad consumer base in procuring additional reserves required as an alternative risk mitigation measure and result in more efficient operation of the power system and in turn the delivery of more affordable energy to consumers.

Practical implementation of the initial standard

AEMO's rule change request proposes that the Initial DER Standard, in the form of minimum technical standards be implemented in the NEM as a provision via DNSP connection agreements. In practice, DER Standards must not duplicate other standards instruments and there must be a means to maintain consistency and resolve any conflict. These matters are being considered by the AEMC and the ESB, alongside the governance of the minimum standards and their implementation. AEMO's intent is for DER minimum technical standards to provide a NEM-wide consistent base of minimum capabilities, and for DNSPs to retain their existing functions in establishing technical requirements specific to their network.

While the initial DER Standards would apply in the NEM, AEMO is also working in close partnership with the Western Australia Government and Western Power on the implementation of Western Australia's DER Roadmap and a similar DER Standard is envisaged to apply in the WEM.

Stakeholders are invited to submit written responses on the issues and questions identified in this paper by 5:00 pm (AEST) on 29 September 2020, in accordance with the Notice of First Stage of Consultation published with this paper.

CONTENTS

2. STAKEHOLDER CONSULTATION PROCESS

AEMO is consulting on the development of an initial DER minimum technical standard in accordance with the NER consultation process in Rule 8.9. While AEMO is developing the initial standard for the NEM, it is intended the standard be applied, where appropriate, as part of implementing the WA Distributed Energy Resources Roadmap in partnership with the Western Australia Government, Western Power and stakeholders.

AEMO's indicative timeline for this consultation is outlined below. Dates may be adjusted depending on the number and complexity of issues raised in submissions and any meetings with stakeholders.

Deliverable	Indicative date
Issues Paper published	24 August 2020
Submissions due on Issues Paper	29 September 2020
Draft initial standard published	27 October 2020
Submissions due on draft initial standard	11 November 2020
Final initial standard published	23 December 2020**

**Final publication of the standard is dependent upon AEMC considerations of AEMO's DER minimum technical standards Rule change proposal.

Prior to the submissions due date, stakeholders can request a meeting with AEMO to discuss the issues and proposed changes raised in this Issues Paper.

During the consultation process AEMO also intends to hold stakeholder forums (via digital means). Stakeholders who wish to participate in the digital forums to discuss the content of the Issues Paper and related information should provide expressions of interest prior to 7 September 2020 via email - DERProgram@aemo.com.au.

3. BACKGROUND

3.1 NER requirements

On 20 March 2020, the COAG EC tasked the ESB to progress a Rule Change Request putting in place nationally consistent minimum DER technical standards in the NEM by October 2020[10], and to leverage these, where appropriate, to the WEM. The intent of establishing minimum DER technical standards is to put in place the required capability to underpin power system security and reliability, while allowing for the continued development of other capabilities to deliver benefits beyond the fundamental power system security provisions, noting the ESB is also undertaking a review of broader governance of DER technical standards in parallel to the rule change process.

In May 2020, AEMO, in collaboration with the ESB, submitted a rule change request to the AEMC to establish a framework in the NER for the creation of NEM-wide minimum DER technical standards[11]. The intent is also to examine how similar can be achieved in the WEM under the auspices of the WA DER RoadMap. AEMO proposed a rule that sets two key obligations:

- Firstly, an obligation on AEMO to make, publish via a subordinate instrument and, as necessary, amend, initial DER minimum technical standards.
- Secondly, an obligation on DNSPs to ensure that connected DER, either by its own means or by way of a DER control device, meets the initial standards (including, without limitation, through the inclusion of appropriate provisions in connection agreements).

The rule change request was developed as a framework for the implementation of the initial standards set in a subordinate instrument. This approach aims to provide flexibility and allow for timely updating of DER technical capabilities so the performance and capability of DER can better align to power system requirements, and to reflect the evolution of DER technology. The implementation of minimum DER technical capabilities should not conflict with the transition toward a two-sided electricity market, which seeks to enable greater market participation of end users and installed DER.

The proposed rule provides for the obligation to comply with *minimum* DER technical standards. Jurisdictions and DNSPs can require addition complementary standards according to their jurisdictional/network needs.

3.2 Context for this consultation

In the rule change proposal, AEMO committed to working with the AEMC and industry to achieve the introduction of the proposed rule change, together with a nationally consistent[12] initial standard premised on *AS/NZS 4777.2 Grid connection of energy systems via inverters (Inverter requirements)*, by October 2020. To facilitate the October 2020 timeframe, AEMO committed to consult with stakeholders in parallel with the AEMC rule change consultation process, on an initial standard to be published alongside the final rule determination. AEMO intends to follow the *Rules consultation procedures* under Rule 8.9 through this process, noting that these consultations are subject to, and not intended to pre-empt, the outcomes of AEMC's determination on the rule change request.

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[10] COAG Energy Council Communique 20 March 2020, at http://www.coagenergycouncil.gov.au/sites/prod.energycouncil/files/publications/documents/EC%20-%20communique%20-%2020200320.pdf.

[11] AEMO 2020, Electricity Rule Change Proposal, DER Minimum Technical Standards, at https://www.aemc.gov.au/our-work/changing-energy-rules/rule-changes.

[12] AEMO is working with Western Australian regulatory bodies on equivalent requirements for Western Australia.

3.3 AS/NZS 4777.2 review

The Australian Standard AS/NZS 4777.2 defines the safety, performance and functional capability of inverters for grid connection of energy systems to the low voltage network via inverters. In June 2019, following investigations into the response of inverter-based DER (primarily DPV) to power system events, AEMO put forward a proposal to update this Australian Standard, intended to deliver improved performance capabilities (required to underpin system security requirements) as well as enhanced functionality (to improve the potential for distribution networks to host increased DER capacity). The proposal was accepted, and the review is under way, expected to be complete in early 2021.

Considering this approach, AEMO's proposed rule seeks to establish initial standards for the NEM that underpin the existing framework for Australian Standards and function consistently with existing instruments such as AS/NZS 4777.2 and with DNSP technical standards. To maintain consistency, the initial standard is likely to apply until the review of AS/NZS 4777.2 is completed. Following publication of the amended AS/NZS 4777.2, the initial standard should be reviewed and consideration given to applying the amended Australian Standard.

The revised AS/NZ 4777.2 is currently being drafted and consulted by the EL042-03 committee. Standards Australia published the draft standard for public consultation on 9 July 2020[13] and is aiming for final publication of the standard in early 2021. The draft standard indicates that a transitional period of 12 months would apply following final publication of AS/NZS 4777.2 during which the current version of AS/NZS 4777.2 would remain applicable, alongside the new version.

3.4 South Australia: Accelerating short duration undervoltage disturbance ride-through requirements

AEMO has observed, through analysis of recent power system events, that a proportion of DPV disconnect in response to short duration transmission undervoltage faults[14] . In South Australia, possible contingency sizes associated with tripping of DPV following a credible fault is estimated to exceed 500 MW by the end of 2020, and this will grow as more DPV is installed. If this eventuates, AEMO will have very few courses of action available for secure operation of the South Australian grid during times that it is separated from the rest of the NEM. Load shedding and resulting customer disruption may be inevitable in response to credible faults, and cascading failure may occur. AEMO has identified that even with an accelerated timeline for the revised AS/NZS 4777.2 to be applicable on all new inverters by early 2022, there are serious risks to the South Australian power system.

In response to the challenges identified in South Australia, in June 2020 AEMO published a test procedure for public consultation with the aim of supporting South Australia to reinforce inverter short duration undervoltage disturbance ride-through capabilities[15]. The test procedure tests for inverter performance that is already captured in AS/NZS 4777.2:2015, but is not explicitly tested for.

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[13] At https://sapc.standards.org.au/sapc/public/listOpenCommentingPublication.action.

[14] AEMO studies include the Renewable Integration Study (2020), Technical Integration of DER (2019), Minimum operational demand thresholds in South Australia (2020)

[15] AEMO 2020, Short duration undervoltage disturbance ride-through: Inverter conformance test procedure for South Australia, at https://aemo.com.au/consultations/current-and-closed-consultations/short-duration-undervoltage-disturbance-ride-through-test-procedure.

4. SCOPE

AEMO's rule change request proposes a new NER framework for incorporation of DER minimum technical standards into DNSP network connection agreements, to support the efficient integration of DER. AEMO's consideration of the content and scope of the initial standard is guided by COAG EC's agreement to put in place DER technical standards by October 2020 with a focus on AS/NZS 4777.2 capabilities and the interoperability capabilities available at this time to integrate DER.

The rule change request includes that AEMO must – and will throughout this process – consider certain factors such as alignment with Australian Standards and DNSP obligations to manage their networks, in making the initial standards. The proposed rule focuses on DER/DER device capability to enable specific system security outcomes. These are minimum standards and are intended to set a baseline of capability to support the power system. They are not designed to limit innovation in expanding DER functionality, particularly in respect of delivering services to new and developing markets.

4.1 Scope of DER

Rather than seeking to define DER the rule change request proposes a broad statement of "DER" as

> *"The types of resources/assets including small and medium scale distributed generation (such as solar PV), energy storage (such as small and medium-scale batteries and electric vehicles that can deliver energy from vehicle to the power system) and controllable loads (such as air conditioners, electric storage hot water systems, pool pumps, and electric vehicle supply equipment) that connect to the distribution system."*

The intention is to identify minimum technical capabilities required to determine or influence DER response to grid conditions and/or control instruction/ commands. Emphasis is placed here on the minimum requirement. The rationale for this approach is to clarify that which AEMO has identified, at a minimum, for operating the power system in a secure, safe and reliable fashion. AEMO's rule change request includes that the specific DER to which a technical standard applies be specified in the standard itself. This issues paper focuses on required DER device capabilities.

4.2 Scope of the initial standard

AEMO has been asked to focus the scope of the initial standard on AS/NZS 4777.2 and consideration of interoperability capabilities available at this time and that should be included in the initial standards.

Operating the NEM with high DER penetration has increased in complexity and has major implications for the maintenance of system security and the ability to return the power system to a steady state following a contingency event. As DER increasingly supplies a greater portion of load its performance in the aggregate can pose considerable risk to AEMO's ability to maintain key operational limits, such as frequency, voltage stability and inertia. The complexity and risks are heightened during periods of low demand and network outages or constraints. When high levels of DER are combined with periods of low demand, network assets require increased management as limitations with respect to voltage, thermal capacity and protection coordination are approached.

This increased complexity requires both greater visibility of supply and demand across all levels of the power system at any given time and the ability to accurately and reliably control them. Standardising minimum inverter capabilities and DER interoperability, data and communication capabilities is needed to help manage this complexity and address these challenges:

Firstly, by standardising an enhanced testing procedure for inverter energy systems to prevent the mass disconnection of DPV. Sensitivity of DPV (inverter energy systems) to short duration transmission undervoltage disturbances[16] is causing large fleets of DPV to suddenly and coincidently disconnect which, at sufficient scale during minimum demand conditions, could lead to cascading failure and a system wide shutdown. This recommendation is discussed in section 5.1.

- As AS/NZS 4777.2 defines the safety, performance and functional capability for grid connection of energy systems to the low voltage network via inverters and has broad consultation and agreement across industry, AEMO is also seeking feedback on setting AS/NZS 4777.2 in its entirety as an initial standard to ensure uniform application of inverter capabilities.

Secondly, by examining and developing an implementation plan to standardise the minimum interoperability, data and communication capabilities that can deliver the information and tools to influence distributed load and generation. This is needed to operate the market effectively and the power system securely. Minimum technical standards in DER communication, data, cybersecurity, and active DER management either do not currently exist or require further industry consultation to develop to a point capable of being implemented in Australia. It is AEMO's view that these capabilities are not ready for inclusion in the initial standards, however they are increasingly important to enable system operators to continue to meet their obligations regarding power system security. These obligations require registered participants (primarily network operators) to maintain facilities for load shedding, to respond to power system needs when the market is unable to provide the required supply services. These challenges arising from unseen and high levels of DER affect the ability of system and network operators to reliably manage load. This is further exacerbated by consequential high load variability across the day and diminishing daytime system demand associated with DPV generation significantly reducing load on the grid.

Section 5.2 discusses the value that DER interoperability capabilities offer in responding to these challenges and the initiatives underway to develop these capabilities. Stakeholder feedback is sought on the standardisation of minimum interoperability capabilities.

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[16] AEMO studies include the Renewable Integration Study (2020), Technical Integration of DER (2019), Minimum operational demand thresholds in South Australia (2020)

5. CHALLENGES TO BE ADDRESSED BY DER STANDARDS

5.1 Mass scale disconnection of DPV (inverter energy systems)

AEMO proposes to uplift the testing of short duration undervoltage ride through capability of all new inverter energy systems connected to the NEM to minimise the risk of mass disconnection of DPV in response to system disturbances. AS/NZS 4777.2:2015 requires voltage disturbance ride through but does not sufficiently test for the behaviour of an inverter during a short duration undervoltage disturbance (less than 1 second). AS/NZS 4777.2 is under review and is expected to address this testing gap but is unlikely to be implemented until early 2022.

AEMO proposes to incorporate into the initial standard a new testing and conformance procedure that tests for inverter capability to stay connected during an undervoltage disturbance for less than 1 second. This would be a new, refined test of the existing inverter capability in AS/NZS 4777.2:2015. The test will demonstrate that an inverter's default settings ensure that it remains connected and in sustained, continuous operation for a short duration transmission undervoltage step reduction (50 V or 20% retained voltage for a duration 220 ms). AEMO has consulted on this test procedure and conformance requirements separately to assist South Australia to fast track this capability by Spring 2020[17] .This capability is critical for the power system to be managed through or recovered following contingency events. Without the changes proposed, the over 2 GW of new rooftop DPV forecast to be installed in the NEM to early 2022[18] would not be required to demonstrate this important capability (noting that the revised AS/NZS 4777.2 is expected to be effective after that time).

5.1.1 Evidence of mass scale disconnection of DPV inverters

AEMO has identified that a large proportion of DPV generation (~40%) has been disconnecting unnecessarily and undesirably in response to transmission faults. This is substantiated by analysis of field data from individual PV inverters during transmission faults, supported through laboratory bench testing of inverters[19] and analysis of data from high-speed event recording devices at the distribution level[20].

Sensitivity of DPV generation to transmission faults means that DPV across a very broad area may be impacted by events that are very remote to the DPV itself. This sensitivity can cause mass disconnection of DPV across a large geographical area, impacting a significant capacity in terms of supply at any one point in time, thereby presenting a material challenge to operating the power system. Detailed analysis in AEMO's Renewable Integration Study (RIS) report[21] points to the potential mass disconnection of DPV generation as impacting the effectiveness of contingency management practices that are critical to power system security and reliability, identifying that the loss of DPV generation might exceed potential load disconnection following plausible transmission disturbances. If coincident with the loss of other generation, this could result in a contingency exceeding the largest credible risk in a region. Eventually, as the capacity

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[17] AEMO 2020, Short duration undervoltage disturbance ride-through: Inverter conformance test procedure for South Australia. Available at: https://aemo.com.au/consultations/current-and-closed-consultations/short-duration-undervoltage-disturbance-ride-through-test-procedure

[18] AEMO 2020 ISP behind the meter rooftop PV forecasts, high scenario, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2019/2019-input-and-assumptions-workbook-v1-3-dec-19.xlsx?la=en.

[19] UNSW Sydney, Addressing Barriers to Efficient Renewable Integration – Inverter Bench Testing Results (Test 27), at http://pvinverters.ee.unsw.edu.au/.

[20] AEMO 2020, Short duration undervoltage disturbance ride-through: Inverter conformance test procedure for South Australia.

[21] AEMO 2020, Renewable Integration Study, at https://aemo.com.au/energy-systems/major-publications/renewable-integration-study-ris.

of DPV generation continues to grow, contingency sizes may become unmanageably large, especially for regions of the NEM that may operate as an island[22].

AEMO's RIS analysis shows mass disconnection of DPV generation is already affecting contingency management in South Australia and is beginning to do so in Victoria and Queensland.

Appendix A provides a case study of observed DPV behaviour during the separation of Queensland from the NEM in 2018.

DPV disconnection behaviour was further investigated by bench testing of individual inverters under laboratory conditions, conducted by UNSW Sydney[23]. This analysis exposed an inverter to a 100 ms duration voltage sag from 230 V to 50 V and returned to above 230 V to simulate a short duration voltage disturbance. In this test, 17 of the 23 inverters tested were developed under the AS/NZS 4777.2:2015 standard; these inverters will form the focus of this consultation as all inverters currently being installed must meet these requirements as a minimum. The results of the testing showed:

- 10 out of the 17 inverters certified/accredited against the 2015 Standard rode-through the voltage sag disturbance without disconnecting.
- 7 out of the 17 inverters certified/accredited against the 2015 Standard, did not demonstrate satisfactory behaviour; their responses varied as below:
- Reduced power output to 0%, 20% or 50% of rated power, and returning after 6-7mins,
- Resulted in control instability, or
- Disconnected completely.

Based on the inverters tested, and extrapolating this out to the broader market, it was determined that approximately two-thirds of the current inverters in the South Australian market would meet this short duration voltage ride-through requirement. As the undervoltage ride-through capabilities are already implied in the existing specifications of AS/NZS 4777.2:2015 and UNSW bench testing indicates many common inverters can already meet this requirement, there is an opportunity to rapidly alleviate growing system security issues through already conforming inverter stock and without significantly impacting consumers or industry installation of additional PV systems. Non-conforming inverters would be impacted.

5.1.2 Short duration under voltage disturbance ride-through capability

Short duration undervoltage disturbance ride-through refers to the capability of inverters used to connect DPV generation to the grid to ride-through short duration disturbance where the normal supply is recovered within 1 second, without unnecessarily or unexpectedly tripping off and disconnecting from the grid. Short duration disturbances are more typically associated with transmission level faults where very fast protection systems are used to identify and isolate faults quickly. Distribution level protection systems tend to be slower to operate and one of the primary functions inbuilt in inverters is to identify these longer duration voltage disturbances as potential unintended island situations and disconnect for these, providing passive anti-islanding protection in the event of low voltage feeder faults. It is important that DPV generation does not disconnect for transmission level events that can affect very large areas and consequently significant capacity of DPV systems while continuing to deliver the requisite protection for local disturbances.

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[22] Islanded or islanding: In relation to an inertia sub-network or a combination of two or more inertia subnetworks, is the temporary loss of synchronous connection to all adjacent parts of the national grid (the National Electricity Rules, Chapter 10).

[23] UNSW Sydney, Addressing Barriers to Efficient Renewable Integration – Inverter Bench Testing Results, at http://pvinverters.ee.unsw.edu.au/.

5.1.3 Existing undervoltage disturbance ride-through specifications

AS/NZS 4777.2:2015 already includes a specification which requires the capability for inverters to ride-through short duration undervoltage disturbance. The existing specifications require that an inverter has a trip delay time of 1 second once the voltage falls and remains below 180 V (see Figure 1 and as per Table 13 of AS/NZS 4777.2:2015). The intention of this provision is to provide protection against formation of an unintentional island within a distribution network, should the undervoltage event extend beyond 1 second (indicating a local fault), while at the same time ensuring stable operation for short-duration events that are cleared from the system by remote protection, returning the network to its normal operating state within less than 1 second. An additional note in Section 7.4 specifies that when the voltage falls below the undervoltage limit it is permissible to continue, reduce, or stop the inverter output during the trip delay time and if voltage returns above the limit during the trip delay it may resume normal operation. This suggests that an undervoltage event should not result in the inverter activating the automatic disconnection device. Such behaviour is consistent with AEMO's expectations that supply from DPV across a large geographical area should not be interrupted following short duration transmission level events.

Figure 1 AS/NZS 4777.2 passive anti islanding set point values

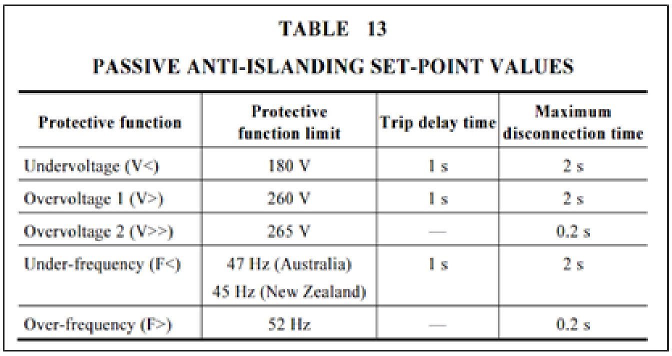
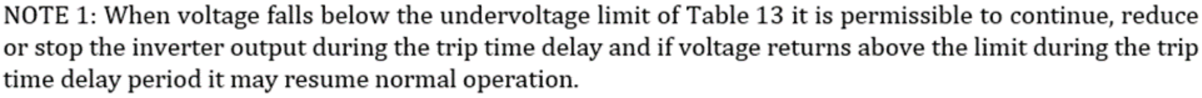


TABLE 13

PASSIVE ANTI-ISLANDING SET-POINT VALUES

Protective function	Protective function limit	Trip delay time	Maximum disconnection time
Undervoltage (V<)	180 V	1 s	2 s
Overvoltage 1 (V>)	260 V	1 s	2 s
Overvoltage 2 (V>>)	265 V	—	0.2 s
Under-frequency (F<)	47 Hz (Australia) 45 Hz (New Zealand)	1 s	2 s
Over-frequency (F>)	52 Hz	—	0.2 s



NOTE 1: When voltage falls below the undervoltage limit of Table 13 it is permissible to continue, reduce or stop the inverter output during the trip time delay and if voltage returns above the limit during the trip time delay period it may resume normal operation.

However, the testing procedure in AS/NZS 4777.2:2015 Appendix G.2 of the Standard only tests to confirm that an inverter trips after one second for incremental voltage reductions (in steps of less than 1 V from 182.5 V to 177.5 V, with a dwell time of 5 seconds for each voltage step). The test process has been designed to accurately ascertain the tripping voltage and trip time, but does not sufficiently test for the behaviour of an inverter during the short duration undervoltage disturbance described above. This identifies a gap in the current test procedure for the desired behaviours and has allowed inverters to be marked as compliant without meeting this response requirement. Therefore, manufacturers may not have prioritised designing inverters that deliver this capability, and the tests for compliance with AS/NZS 4777.2:2015 do not identify whether inverters meet this requirement.

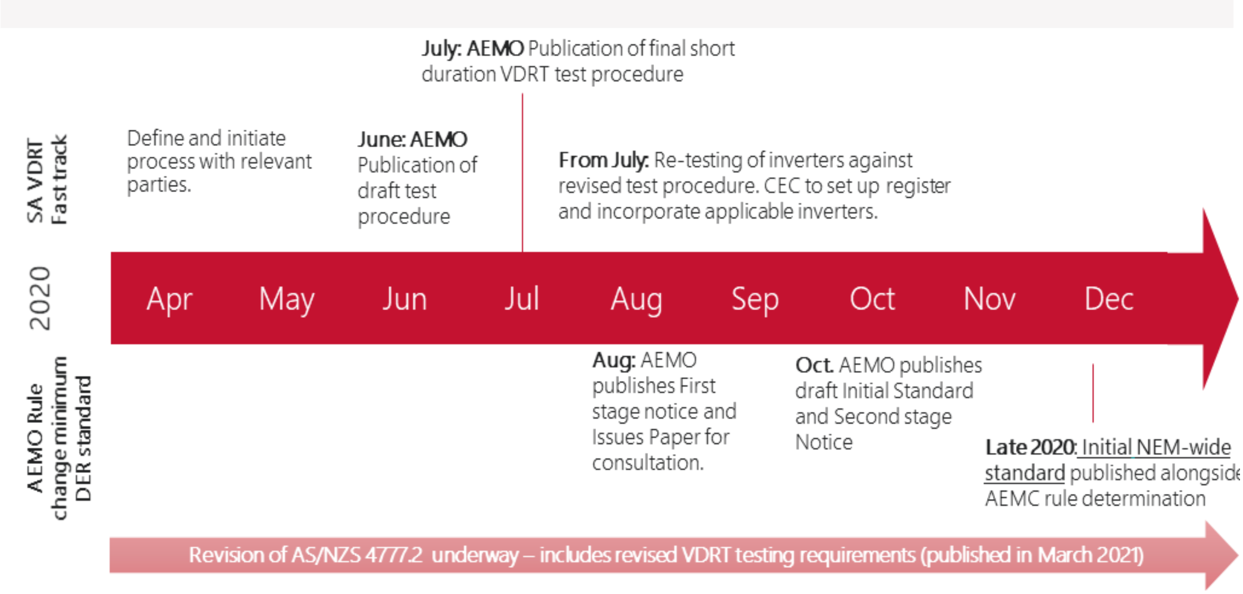
5.1.4 Short duration undervoltage disturbance ride-through – proposed requirements

AEMO proposes that with the volume of DPV being installed daily on Australian homes and businesses it is prudent to ensure as soon as practicable that all new inverters installed across the NEM incorporate the short duration voltage disturbance ride through capability. AEMO is already working with the South Australian Government and SAPN to uplift testing of short duration undervoltage disturbance ride-through capability in all new DPV inverters. AEMO has published a short duration voltage disturbance ride-through (VDRT) test procedure in July 2020, to apply initially in South Australia.

Noting the rate at which DPV continues to be installed by Australian households and businesses, AEMO is seeking to align this test procedure and conformance process for short duration undervoltage disturbance ride-through across the NEM to prevent the further installation of inverters that trip off in response to short duration transmission undervoltage faults. Taking action now could capture an additional 6 to 12 months of DPV installations and help to 'head off' in other jurisdictions the emergence of issues similar to those arising in South Australia.

In practical terms, this would allow inverter manufacturers approximately 11 months from July 2020 (when the AEMO test procedure was published) to test inverters in readiness to comply with the initial standard (for the NEM) (see Figure 2 below and section 6 on proposed implementation of the initial standard). The proposed test procedure (see section 7) maps closely to the existing AS/NZS 4777.2:2015 compliance and testing process, and therefore should be able to be implemented reasonably rapidly by organisations that already have suitable experience in similar roles.

Figure 2 Transition timeline for VDRT test and conformance procedure



Beyond this timeframe, it is expected that inverter manufacturers will need to undertake redesign and testing of their products to meet the revised AS/NZS 4777.2. Inverter compliance to the revised AS/NZS 4777.2 requirements will require testing in accordance with the revised version, and in time for the expiry of AS/NZS 4777.2:2015 (notionally in early 2022), which will be an additional cost to manufacturers. This is because the review of AS/NZS 4777.2 is considering additional functionality that interplays with the short duration under voltage ride through requirement.

Consistency with the National Electricity Objective

The NEO is to promote efficient investment in, and efficient operation and use of electricity services for the long-term interests of consumers of electricity with respect to:

(a) price, quality, safety, reliability and security of supply of electricity, and

(b) the reliability, safety and security of the national electricity system.

Implementing the proposed testing and conformance procedure will:

- Provide power system operators with certainty regarding the performance of connected DER before and after severe disturbances and avoid the need for inefficient operational measures in anticipation of DER loss.
- Avoid further build-up of inverters that would continue to pose risks to the security and reliability of power supply to electricity customers. Making the changes now will capture more installed, upgraded

or replaced DPV generation than would otherwise be captured under business as usual processes and help prevent the issues faced in South Australia from presenting in other jurisdictions, and

- Improve resilience of the power system (a key component of reliability) while also meeting distribution network requirements for safety and suitable anti-islanding protection.
- Reduce the potential size of the contingency associated with disconnection of DPV generation via the aggregate response from compliant inverters. This would mitigate potential costs to the broad consumer base in procuring additional reserves required as an alternative risk mitigation measure, and result in more efficient operation of the power system and in turn the delivery of more affordable energy to consumers.

Additional benefits

The ability for DPV to ride through short duration voltage is expected to realise the following additional benefits:

- At individual consumer level, DPV will remain connected and generating, delivering direct benefits to the owner, either via reduced demand or exported energy.
- The aggregate response will reduce the size of the contingency associated with disconnection of DPV generation. This avoids potential costs to the broad consumer base in procuring additional reserves required as an alternative risk mitigation measure. Thus power system operation efficiency increases and so to the provision of more affordable energy to consumers.
- Consumers should continue to have access to a wide range of market options for inverters, as many inverters already satisfy the desired behaviour without requiring changes to the inverter design[24] and manufacturers will have had the opportunity to test and establish conformance through the SA fast track process (see below).

Questions

1. What are the costs and benefits of implementing enhanced testing for short duration undervoltage disturbance ride-through in the initial standard? (Noting that these would likely be superseded upon the publication of the AS/NZS 4777.2).
2. What are the implications of mandating in the initial standard for additional testing to confirm that inverters can meet the short duration voltage ride-through test procedure, including in relation to DNSP obligations to manage their network safety, power quality and reliability?
3. To operate the power system securely, a level of certainty is required to ensure new installs can satisfactorily withstand a transmission level fault of this nature. Are there other cost-efficient solutions available that provide a high level of certainty in achieving this objective? What considerations need to be made for small DER businesses, manufacturers and consumers?

5.1.5 Aligning inverter capabilities with power system security

AEMO's RIS and *Technical Integration of DER*[25] reports also point to further inverter capabilities that are important enablers for increased DER integration into the power system. While the undervoltage

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[24] inverters selected for bench testing as part of the UNSW Sydney work were based on those with the greatest number of installs across the NEM.

[25] AEMO 2019, Technical integration of distributed energy resources, at https://aemo.com.au/-/media/files/electricity/nem/der/2019/technical-integration/technical-integration-of-der-report.pdf?la=en.

disturbance ride-through requirement is already in AS/NZS 4777.2:2015, AEMO considers that additional capabilities, highlighted below, that form part of the AS/NZS 4777.2 revision recommendation from AEMO in 2019 should be considered for future iterations of the initial DER standard once the current Standards Australia review process is complete.

- Disturbance ride-through capability, such as
  - Protective function limits and zones of operation;
  - Performance and withstand requirements for multiple voltage disturbances, rate of change of frequency events, and voltage phase angle jump conditions;
- Grid integration capability through:
  - Voltage response modes;
  - Frequency response modes; and
  - Testing procedures that better demonstrate when an inverter is performing as required.
- Measurement and control accuracy

AEMO is seeking stakeholder views on the DER minimum technical standards incorporating AS/NZS 4777.2 in full. The amended AS/NZS 4777.2 is expected to deliver improved performance capabilities to better manage power system security as well as enhanced functionality to enable greater DER hosting capability for distribution networks. Formally establishing this standard as minimum capability across the NEM would also aim to improve industry certainty and long-term efficiency across the supply and installation chains, acknowledging that some DNSPs or jurisdictions will need to set additional requirements for their circumstances.

It is AEMO's view that expedited action is required in respect of the identified shortfall in short duration undervoltage ride-through, via the initial standard which will provide an avenue to address relevant power system functionality at the device. This will ensure that despite the fast-moving pace of DER, that it is integrated into the power system whilst continuing to support power system security and maintaining consistency with respect to the existing agreed device level standard (AS/NZS 4777.2).

Questions

4. Should this or a future version of the DER minimum technical standard incorporate AS/NZS 4777.2 and/or the revised version, following its publication (expected to be in early 2021)? What are the benefits and risks in doing this?

5.2 Integrating high levels of DER

5.2.1 Challenges to managing the supply and demand balance

Under the NER, AEMO is responsible for continuously balancing supply and demand, maintaining the power system in a secure operating state. In doing so, AEMO may intervene in the spot market for electricity and issue directions to participants, under certain conditions and where necessary to maintain or re-establish a secure and reliable power system[26]. In undertaking these obligations, AEMO must forecast demand, accept bids for supply and dispatch energy sources according to the dispatch rules. Secure and reliable system operation requires real-time monitoring of the state of the power system and its needs, and

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[26] National Electricity Rules c. 4 Available at: https://www.aemc.gov.au/regulation/energy-rules/national-electricity-rules/current

assessment of the impact of disturbances – to ensure plausible faults and unexpected events do not result in supply disruption.

Operating the power system securely and reliably requires that the supply and demand are constantly in balance. This necessitates a range of operational tools and processes to manage variability and uncertainty in generation and load, and unexpected events, including:

- Regulation services: balancing second-by-second incremental variations due to constantly changing loads and generation supply. Historically, provision of regulation services has been relatively straightforward via small changes to the dispatch of centralised generation in response to reasonably predictable variations, given the time of day, season and prevailing and weather conditions. Today, delivering regulation services is complicated by increasing utilisation of DER, which is decreasing the utilisation of utility generating plant which typically provide this service and which have varying capability around managing energy resources behind-the-meter.
- Contingency services: sufficient reserves in place to manage near-instantaneous large changes in supply or demand that can result from faults impacting loads, generators or parts of the transmission network. Like regulation services, delivering contingency services has also become increasingly complex. The greater variability in supply sources and demand levels, increasingly "hidden" demand supplied by behind-the-meter DER and more complex energy usage patterns has led to greater uncertainty in operational planning with greater potential contingency sizes.
- Non-market intervention: directions or instructions to participants, under certain conditions and where necessary to maintain or re-establish a secure and reliable power system. One of the types of instructions that AEMO may make to intervene in the market when market responses are not sufficient is to instruct load shedding. This action is taken when supply is insufficient to meet forecast demand. These instructions may only be taken as the last step in a process intended to inform the market of a forecast shortfall and to allow the market to either deliver sufficient reserves, or to reduce demand.

The integration of higher levels of DER into the market presents increased complexity in this process, and also extends potential shortcomings from lack of supply to lack of demand.

The issue with lack of demand derives from the relatively uncontrolled nature of DER generation together with coincident production during middle of the day from DPV systems, driving new minimum demand conditions. Managing the power system during times of very low demand is as complex as during high demand and AEMO foresees that it will be necessary to apply similar responses to low demand as high demand to ensure that the system remains resilient to potential disturbances.

In terms of load shedding, the invisible impact of DER on underlying demand means that operators are unable to differentiate demand and supply at feeder level. The resulting lack of clarity around the true nature of load that is connected at any given time impedes operational assessments regarding the level of supply reserves and system services that are needed to maintain power system security.

Minimum operational demand in South Australia

South Australia is an example of where this operational complexity is currently playing out. Increasing DPV generation is significantly reducing system load in the daytime. AEMO's *Renewable Integration Study*[27] also demonstrates this trend across the NEM with minimum operational demand projected to occur in the daytime in all mainland regions by 2025. This reduction is now

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[27] AEMO 2020, Renewable Integration Study (RIS) & RIS Appendix A Distributed Solar PV, at https://aemo.com.au/en/energy-systems/major-publications/renewable-integration-study-ris & https://aemo.com.au/-/media/files/major-publications/ris/2020/ris-stage-1-appendix-a.pdf?la=en.

materially impacting system security in South Australia[28] and is also projected to do so in other mainland NEM regions within the next few years. AEMO is undertaking further detailed analysis on the timing and impact of minimum demand in Queensland, Victoria and NSW, but considers it important to commence this discussion with industry early to enable timely development of mitigation measures.

If certain rare, abnormal events were to occur – such as the outage or reduced availability of inter-regional transfer capacity – during high DPV generation, low underlying demand periods, this can result in insufficient load in a region to match the minimum output of the generating units needed to provide balancing services essential to operate the system. AEMO's *Minimum operational demand thresholds in South Australia* report examines in some detail the power system challenges associated with securely managing the South Australian system under such extreme, abnormal system conditions. As noted, AEMO is currently studying system security challenges associated with reducing minimum operational demand in other NEM regions.

Generally, large-scale generation output is controllable and is therefore able to assist with securely managing the supply-demand balance if necessary, as a last resort. AEMO considers this control capability needs to evolve at the level of DPV, given DPV supplies an increasing proportion of generation at times. This capability would provide the operational levers to manage the power system securely through extreme abnormal system events during high DPV generation, low underlying demand periods such as those presenting in South Australia. While abnormal system events are exceedingly rare, if they were to occur during such periods the consequence would be significant (potentially widespread and prolonged supply disruption) and the extent of the risk is increasing as DPV growth continues. It would also allow for higher levels of DPV generation in the bulk power system on a daily basis, and less conservative system management of the potential risks associated with such rare events in the power system.

5.2.2 Challenges to transmission network operation

For transmission network service providers, the connection of increasing levels of DER initially has limited impact. However, at the levels experienced currently and forecast into the future, planning and operational challenges are emerging. Erosion of system strength and fault levels through lesser dispatch of synchronous generation (due to lower demand levels and alternative energy sources) impacts the operation of protection systems.

Reverse flow of energy from distribution networks into transmission networks was once a rare phenomenon but is increasing in magnitude and occurrence with increased DER generation and requires more adaptable systems in place to manage line flows and voltage control. Similar to all levels of power system operation, the lack of clarity around underlying and measured demand, and the drivers behind load levels presents challenges in load forecasting - both for near term operational purposes and for long term planning and investment purposes.

5.2.3 Challenges to distribution network operation

Distribution network operators are at the forefront of DER integration and have been managing a range of localised issues for some time. As DER penetration rates increase, the extent and type of issues presented continues to evolve and needs to be managed across systems rather than at feeder level as may have previously been done. DNSPs are contending with greater variability in load levels, which challenges in supplying electricity within required voltage ranges, excessive loading of feeders, particularly during

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[28] AEMO 2020, Minimum operational demand in South Australia Available At: https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/sa_advisory/2020/minimum-operational-demand-thresholds-in-south-australia-review.pdf?la=en

daytime due to export from DER systems, and reverse power flows on low voltage and medium voltage feeders and now progressing as far as transmission nodes.

Reverse power flows can have a detrimental impact not only on voltage control but also on operation of protection systems. Finally, as with transmission systems, the lack of information regarding demand and supply needs across distribution networks impacts both operational and investment planning.

This increased complexity of power system and network operation requires greater visibility of supply and demand across all levels of the power system at any given time as well as the ability to accurately and reliably control (turn them on and off and adjust) them.

5.2.4 Challenges to DER optimisation

A key component of achieving the productive and efficient integration of DER into the power system is to ensure that customers and service providers to them are engaged. Energy retailers and aggregators or service providers need to be able to deliver products to their customers and their customers need to derive benefits from these. Foundational to engagement, delivery and receipt of service is information. AEMO expects that data and information regarding needs (demand), opportunities (supply), services, and potential forms of flexibility and other innovations will drive successful partnerships between customers and their suppliers.

5.2.5 Interoperability between DER devices and systems

'Interoperability' refers to the extent to which different devices and systems can interact together for a particular purpose. In the power system context, this corresponds to the chain of communication, data exchange and controllability across different components and systems necessary for system and market operation. Increasing decentralisation, in particular increasing levels of actively managed DER, will mean the power system must support devices and systems developed and operated by many different utilities and solution providers, and millions of industrial, business and residential end users.

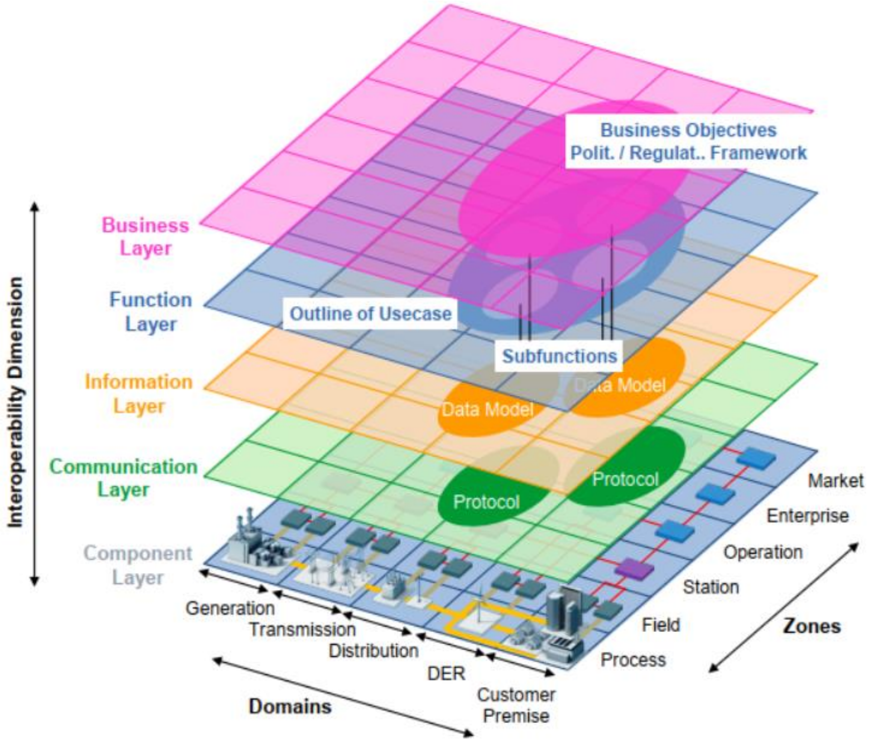
A level of standardisation will be required to enable the scalable and secure data and information exchange necessary to achieve this. Standardisation efforts will require extensive coordination and collaboration across industry, informed by a whole-of-system architectural view of the future power system and its key actors, devices and interactions.

Interoperability can currently be delivered by a range of systems and devices but is a fast-developing area where the future state provides increased value and opportunity. Given the immature state of this aspect of DER, a staged approach to standardisation is prudent.

5.2.6 Interoperability dimensions

The smart grid architectural model (SGAM) is a commonly applied conceptual framework for understanding the cyber-physical (i.e. informational and electrical) interactions within the integrated power system.[29] The SGAM framework presents interactions between components of the electricity supply chain, which SGAM references as the 'Domains' and the necessary systems and processes – the 'Zones' – within each Domain. Overlaid on this are several dimensions relating to interoperability between Domains.

Figure 3 Smart grid architecture model (SGAM) conceptual framework for the integrated power system



Interoperability within the integrated power system refers to interactions between the Domains – the extent to which this 'system of systems' can work together. Interoperability dimensions in the context of DER integration can be interpreted as follows:

- **Business layer**: business models and regulatory requirements specifying consumer participation, as well as the scope and purpose of interactions with DER devices.
- **Function layer**: functions and applications (the use cases) applying to DER and the relationship with Business layer needs, as well as the circumstances under which they would be called upon – by whom and for what.
- **Information layer**: data and information that needs to be exchanged between parties to achieve these functions and how this should be structured, consistent with communication protocols.
- **Communication layer**: protocols and mechanisms for how this information is exchanged between parties, between parties and devices and between devices in the Component layer.
- **Component layer**: physical power system and information and communications technology (ICT) devices delivering Functions, hosting Information and means of Communication.

Cyber security is an important consideration across all interoperability layers and the overall system architecture.

The focus of the initial standard and associated rule change is to put in place standards for DER devices in the Component layer. Interoperability decisions at the device level cannot be considered in isolation as they are intrinsically linked with requirements across the higher levels of the interoperability chain. Devices will need to be able to be communicated with in a scalable, secure way to deliver the agreed upon functions and services.

5.2.7 Realising the value of DER through interoperability

DER interoperability, as well as the data and information exchange necessary to deliver it, is an important lever to addressing these challenges. It is important also for the development of products and retail offerings empowering consumer participation. The value of interoperability is that it offers:

1. Real-time information re supply/export to grid which can inform AEMO and NSPs about the underlying demand for operations and network and system planning.

2. Real-time information of status – to help determine whether there is a problem.

3. Information that may be integrated into the DER register and used for audit purposes, where audits can be conducted remotely to support monitoring and compliance.

4. Active management of export/energy services (load shifting/energy management) – as either a response to market pricing or an instruction.

Through DNSPs, active management capabilities can enable AEMO to manage the emerging power system complexity and challenges presented by high DER in certain extreme conditions. These functions are necessary to securely manage the supply-demand balance and prevent widespread and prolonged supply disruption under such circumstances.

Active DER management does not (today at least) play a major role in the operation of the NEM and power system or in the way consumers' benefit from their DER. Active management of DER can bring significant opportunities for a range of market participants including, but not limited to, AEMO, NSPs, retailers, aggregators and end-use customers, as well as improved power system and market outcomes. The capabilities encompass:

- Management of DER devices at given locations through home, building and facility-level energy management systems (HEMS, BEMS, FEMS).
- Management of DER devices at several locations (often through site-specific energy management systems) referred to as DER management systems (DERMS). DERMS implementations include:
  - DNSP management: coordination of DER to maintain power flows within the secure technical operating envelope of their LV networks and the capability to respond to AEMO instructions.
  - Third party aggregation: coordinating DER across a wide area for the provision of an aggregated service such as energy or ancillary services in the bulk power system.
  - Microgrids: interconnected electrical networks linking end users, potentially operating in both 'islanded' and 'connected' (if embedded within the distribution network) modes.

Achieving this at scale will require deep and careful integration within both power system and market operations.

5.2.8 Future capabilities to deliver interoperability

Data and information models

Data and information are critical across the spectrum of DER integration. Market participants, consumers and system operators all require data to make informed decisions.

Consistent representation of DER within data models allows the variety of data users to access and utilise the components of data relevant to them. For the network operator use case, location at the appropriate 'nodal' level in the physical distribution network will be increasingly important for the scalable integration of increasing levels of aggregated DER within DERMS. This will be a necessary prerequisite for secure distribution network and bulk power system operation, representation within system studies, the defining of operating envelopes for DER orchestration, and communication of network and system limits.

AEMO is engaging with industry on the potential development of implementation guidance (as has taken place in Texas and other jurisdictions internationally) for the adoption of the IEC Common Information Model (CIM) series of standards for this purpose.

Communication protocols

Communication protocol standards are fundamental to enabling interoperability at the inter-device level and will help facilitate the development of management platforms and ecosystems that can integrate a diverse range of products within site-specific EMSs, and across different locations through DERMS implementations.

A future revision project for AS/NZS 4777.2 must consider how to specify secure, consistent, standardised protocols at device level, to facilitate DER interoperability. The 2018 update to the U.S. national standard for DER connection (IEEE 1547) requires DER devices to be compatible with instructions from a communication interface in at least one of three specified protocols able to support common smart inverter function (IEEE 1815/DNP3, IEEE 2030.5 and SunSpec Modbus). During development of IEEE 1547 it was acknowledged that multiple options could leave both utilities and manufacturers uncertain about which interface to use and what to expect, the optionality was driven by differences in stakeholder preferences and different needs for various DER sizes. Moving forward, this needs to be considered in the context of the Australian market and system characteristics.

The Internet of Things (IoT) leverages sensors and internet-based communication for connectivity between devices. This can provide interoperability pathways for active management of DER enabling a range of services through process intelligence informed by the real time monitoring of devices. Challenges associated with IoT solutions include reliable end-to-end architectural design given the range of diverse technologies, data and systems integration between IoT devices and between IoT and other DER devices, standardisation in information models and communication protocols, as well as cyber security and data privacy.

Various standards exist for the 'group management' of DER devices within DERMS, in addition to the smart inverter protocols listed above, including OpenADR, IEC 61850. California has mandated IEEE 2030.5 as the default application protocol (transport over the internet through TCP/IP) for distribution network utility communication with individual DER devices, facility EMSs, and aggregator DERMS. Details of the IEEE 2030.5 profile are defined in the California IEEE 2030.5 Implementation Guide[30]. Other Application Level protocols may be used by mutual agreement, including IEEE 1815/DNP3 for SCADA real-time monitoring and control and IEC 61850.

Aggregators, DNSPs and other parties are currently collaborating through the API Working Group to develop an Australian Implementation Guide for IEEE 2030.5, specifying how different IEEE 2030.5 function sets should be applied for different mutually agreed DERMS use cases.

Device level control capability

Aligned to data and communications is the control or dispatch response from DER and its standardisation. A standardised response provides control rooms with predictability and allows modelling of the power system to ensure system security is maintained. Today large generators have predictable and consistent ramp rates in response to dispatch instructions, as well as set minimum times to deliver or reduce their

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[30] Common Smart Invert Profile Working Group 2018, Common Smart Inverter Profile, IEEE 2030.5 Implementation Guide for Smart Inverters, at https://sunspec.org/wp-content/uploads/2018/03/CSIPImplementationGuidev2.003-02-2018-1.pdf.

output into the system. As DER standards continue to develop it is critical that this minimum functionality required to balance supply and demand is consistent across millions of generation and load side devices.

Currently, one standard that provides these control modes is AS 4755. This standard provides an important minimum technical framework for demand response capable electrical products such as air conditioners, pool pumps, electric storage water heaters, electric energy storage systems and inverter energy systems, defining the basic minimum capabilities for demand response in these DER. The current AS 4755 suite of standards requires the installation of the DRED at a location to communicate with the electrical product physically via standard RJ45 port. This device could be located close to the electrical equipment with a DRED per electrical product arrangement, although there are no barriers to a central DRED device controlling several electrical devices.

AS 4755.2 is a new standard to remove the need for a physical DRED to activate these same Demand Response Modes in the device via APIs and other communication means. AEMO continues to drive and support the review of AS 4755.2 which is in its final editorial review stage prior to public consultation. AS 4755.2 promotes interoperability as it describes the remote communication requirements to enable DER response from remote agents' commands and the minimum performance for the response for DER. The communication requirements describe the minimum information required in a command and the overall cybersecurity principles required to maintain security. It is critical for interoperability that AS/NZS 4777.2 is developed on the same footing and the Demand Response Modes are consistent across the suite of AS 4755 standards. As trials and guidelines continue to develop, a key aspect for interoperability is minimum data and control standard which will be reviewed following this initial review.

The next revision to AS/NZS 4777.2 is likely to consider interoperability provisions for inverters. This may include communication protocols and data exchange requirements that would apply to facilitate smarter inverter operation.

5.2.9 Industry activities and initiatives

Engagement across industry towards consensus-driven decisions on the different interoperability dimensions for our system and market is well underway. Consolidation of learnings and experiences from technology trials, use case mapping for the end-to-end consideration of future grid architecture, and close collaboration across industry will be critical for this.

Pathways might include revisions to existing or the development of new local technical requirements, or the adoption of international standards. Effective adoption will require collaborative development of implementation guidance to institutionalise new norms across actors, systems and devices within our integrated power system and market.

Distributed Energy Integration Program

An ARENA funded initiative the Distributed Energy Integration Program (DEIP) is a collaboration of government agencies, market authorities, industry and consumer associations aimed at maximising the value of DER for all energy users. The forum supports DER information exchange regarding DER projects across the sector, driving collaboration and research to identify knowledge gaps and priorities to help accelerate reforms in the interest of customers. DEIP has four key work streams: Access and Pricing, Market Development, Standards, Data and Interoperability, Market Development and Electric Vehicles.

Stakeholder feedback is sought on utilising the DEIP Standards, Data and Interoperability stream to continue working across industry to progress DER capability develop while the ESB's broader DER governance structure is established, and then transition this progress into that framework.

SA Power Networks Flexible Export Program

SA Power Networks (SAPN) in its 2020-2025 regulatory proposal received AER approval to develop a flexible DER export program for new connections within this time period. The program aims to enable 'real-time' management of DER export via aggregators/VPPs to manage location specific distribution network constraints. Modelling undertaken for SAPN indicates that managing network constraints in this manner provides a better long-term economic outcome for all customers (both with and without DER) than investing in new network capacity or managing DER through fixed export limits, under a wide range of possible future scenarios. This is because it enables DER to continue to connect, export energy and contribute to the energy system as a whole while avoiding the need for expensive network upgrades. To enable this platform SAPN is seeking to utilise the IEEE 2030.5 Australian Implementation Guide.

DER Visibility and Monitoring Best Practice Guide

The DER industry has developed a DER Visibility and Monitoring Best Practice Guide[31] establishing a common static and dynamic (near) real time data set collected for new DER installed behind the meter on the low voltage electricity network. The voluntary guide aims to provide the consistent data required from the device to support and evaluate optimal system operation, increase network hosting capacity for DER and provide consumers with a more granular level of information to make more informed decisions about the energy use – through the provision of this real time system performance data to DER customers and their authorised industry entities.

The guide is complete and its stated purpose is to undergo a trial and then transition into a national industry standard. Stakeholder views are sought on transitioning this or future versions of this guideline, potentially enhanced under the ESB governance DER standards governance structure, into a future 'DER minimum technical standard'.

DER Register

The DER Register stores the static information about a DER device installed on-site at a residential or business location. This information is requested by DNSPs via qualified electrical contractors and solar installers at the time of the DER installation. This information improves the planning, design and operation of the power system, with enhanced load forecasting and modelling capability reducing the need for conservative system operating decisions.

Australian Implementation Guide: IEEE 2030.5-2018: IEEE Standard for Smart Energy Profile Application Protocol

This standard defines the application layer with TCP/IP providing functions in the transport and Internet layers to enable utility management of the end user energy environment, including demand response, load control, time of day pricing, management of distributed generation, electric vehicles, etcetera. An industry working group has been established to develop an Australian Implementation Guide for the IEEE 2030.5 at the 'market participant' level – i.e. a use case and data exchange standard that is utilising the relevant sections of IEEE 20230.5, for application in Australia, to support aggregated management of the DER fleet. While the guideline may not be ready in time for consideration in the initial standard, stakeholder views are sought on transitioning this guideline into a future 'DER minimum technical standard'.

Questions

5. What are the technical challenges faced by each industry sector in integrating DER?
6. What interoperability functions are needed to help address the challenges and realise the value of DER?

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[31] Available at https://www.dermonitoring.guide/

7. What interoperability capabilities are available now for consideration in DER minimum technical standards? What capabilities will be required in the future?
8. What are the priority interoperability capabilities to be taken forward in minimum standards over the next 2 years?
9. Should the DER Visibility and Monitoring Best Practice Guide developed by a sector of industry participants be utilised as a basis for review and inclusion in future minimum DER technical standards, and if not what other options should be considered?
10. What developments exist in communications, data and interoperability systems, for consideration in future DER minimum technical standards?
11. Should the Australian Implementation Guide for IEEE 2030.5 currently under development by a sector of industry participants be utilised as a basis for review and inclusion in future minimum DER technical standards, and if not what other options should be considered?

6. IMPLEMENTATION OF THE INITIAL STANDARD

Publication and implementation of the initial standards are being considered by AEMC as part of the Rule change consultation process. AEMO has proposed that each standard stipulate its publication and implementation date, and these be considered as part of consultations. This is similar to the approach taken with Australian Standards. Stakeholders are encouraged to engage in the AEMC Rule change consultation process to put forward their views on the transitional arrangements for the initial standard.

AEMO proposes a NEM-wide implementation period for the short duration undervoltage disturbance ride-through requirements of 6 months - noting that bench testing indicates approximately 60% of commonly used inverters can already provide the desired capabilities, and that through the South Australia fast track process manufacturers will have the opportunity to test inverters in readiness for this timeframe. Should the rule change proceed on time, publication of the initial standard in late 2020 would result in an implementation date set at the end of quarter two calendar 2021.

An alternative approach could be to stage implementation across jurisdictions based on greatest urgency, system security risk or other suitable consideration. This approach suggests implementation occur first in South Australia, followed by Queensland and Victoria with greater flexibility in New South Wales and Tasmania. The risks to this approach include:

- A significant amount of installed DPV could be missed, diluting the effectiveness of the response. According to AEMO's ISP high scenario forecast[32], Queensland and New South Wales are expected to host the largest increases in new rooftop PV capacity in 2020-21 and 2021-22.
- Inverters identified (by bench testing) as not meeting the VDRT requirements (roughly 40% of common inverters) are likely to be redeployed to jurisdictions that implement later, which could reduce proportionately the levels of compliance of new installations in those states.

Questions

12. If an implementation date were to be set in the initial standard, what is an appropriate implementation date for the short duration voltage disturbance ride through requirements?
13. What are the benefits and risks/costs of staging implementation of the initial standard across jurisdictions?

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[32] AEMO 2019, ISP behind the meter rooftop PV forecasts, high scenario, at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/inputs-assumptions-methodologies/2019/2019-input-and-assumptions-workbook-v1-3-dec-19.xlsx?la=en.

7. DRAFTING REQUIREMENTS

To help stakeholders and other interested parties respond to this Issues Paper, AEMO has published for consultation a draft of key content AEMO proposes to include in the initial standard. A draft initial standard will be published following consultation on this issues paper.

7.1 Voltage disturbance ride-through requirements

Drafting of the initial standard is expected to directly reference the relevant clauses of AS/NZS 4777.2:2015 - Section 7.4 Table 13 and Note - with respect to undervoltage ride-through requirements.

7.2 Short duration undervoltage disturbance response test

AEMO has defined a compliance test for inclusion in the initial standard that determines whether an inverter can meet the short duration undervoltage ride-through provisions in AS/NZS 4777.2:2015. This test procedure, which is outlined below, has been consulted on and determined through a separate process to enable accelerated adoption in SA[33]. AEMO's intention is to enable accelerated adoption of these requirements in SA whilst ensuring the final interim test procedure is consistent across the NEM. Stakeholders are encouraged to provide feedback on the test procedure.

The test will demonstrate that an inverter's default settings ensure that it remains connected and in sustained, continuous operation for a short duration transmission undervoltage step reduction (50 V or 20% retained voltage for a duration 220 ms). The values selected are based on the protection clearance times applicable to high voltage distribution and transmission networks and as such represent the minimum technical requirement, not the full requirement of AS/NZS 4777.2:2015.

The test report would seek to confirm two aspects of the inverter's behaviour:

- Inverter remains connected during an event where the voltage reduces to below 180 V and consequently returns above 180V within less than one second,
- Inverter disconnects after one second following a sudden event where the voltage reduces and remains below 180 V.

The draft test procedure is designed to align closely to existing test procedures within AS/NZS 4777.2:2015. The applicable test body accreditation and conformance processes are defined in the test procedure.

7.3 General test and reporting requirements

7.3.1 General

The intention of this test procedure is to confirm the behaviour of an inverter energy system during a short-duration voltage disturbance. The inverter should sufficiently demonstrate the ability to remain in continuous operation through a 220 ms duration voltage dip to 50V. This test should be applied in conjunction with existing product certification testing for compliance with AS/NZS 4777.2:2015, and has been developed as a supplementary test. All definitions throughout are according to AS/NZS4777.2.

Where possible the undervoltage (V<) trip level from the original AS/NZS 4777.2:2015 certification should be noted. If this value is not available, then the undervoltage (V<) test as described in AS/NZS 4777.2:2015 Appendix G2.2 should be performed to determine the value.

This test is used to verify –

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[33] AEMO 2020, Short duration undervoltage disturbance ride-through: Inverter conformance test procedure for South Australia

- The undervoltage trip delay and maximum disconnection time for a short-duration undervoltage event, and
- The withstand capability for a short duration undervoltage event that occurs within the trip delay time.

This test shall be repeated three times to confirm requirements in Section 7.4.4 are met.

7.3.2 Test Conditions

Unless otherwise specified by the test procedure, the testing conditions for each test shall be such that —

a) the average r.m.s. current on each phase is within ±5 % of the intended test point; and

b) the average r.m.s. voltage on each phase is within ±1 % of the grid test voltage.

In the case of a three-phase supply, the angle between the fundamental voltages of each pair of phases shall be maintained at 120 ± 1.5°. The average r.m.s. voltages between each pair of phases shall be maintained within ±1 %.

The grid test voltage shall be 230 V a.c. phase to neutral, 50 ± 0.1 Hz.

7.3.3 Inverter setup

Each inverter that is to be tested shall have its device settings and configurations set to the default set-points required by AS/NZS 4777.2:2015, as they would be for operation in an installation. Once the default settings are selected, the power quality response mode settings should be set according to the Energy Networks Australia[34] recommended default power quality response modes Tables 4a, 4b and 4c..

If the inverter is required to be used with an external device or devices, such as external automatic disconnection devices or dedicated isolation transformers, the inverter shall be configured in combination with these devices for all tests. The combinations tested shall be documented in the test report.

Before commencement of the test, all model information and specific information concerning the version of software, firmware and hardware used by the inverter shall be recorded. This information shall be provided in the test report.

High speed monitoring data records shall be kept and archived; photographs taken to be included in the test report such that the model tested can be verified. The test data and information shall be made available upon request.

7.3.4 Grid source

Either a real grid or a simulated test grid shall be used in the testing.

Whether a real grid or simulated test grid is used, the impedance of the test point shall be rated appropriate to the rating of the inverter or combination of inverters under test. The impedance of the test point should not cause a voltage rise greater than 0.5 % of the grid test voltage at the rated current output of the device under test.

NOTE: This is to ensure that the application of the inverter in a customer installation will not adversely affect the quality of supply to the customer.

The type and impedance of the source shall be declared in the test report for each test performed.

During the tests, the steady-state voltage of the real or simulated test grid shall not vary by more than ±1 % of the grid test voltage. The grid test voltage shall be set as required by each test.

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[34] ENA Power Quality Response Mode Settings, at https://www.energynetworks.com.au/miscellaneous/power-quality-response-mode-settings/.

For tests requiring step changes in voltage, the simulated test grid shall be capable of being stepped at least 0.5 times the smallest step required for testing, to determine the set-points with required accuracy.

The real grid or a simulated test grid should be free from harmonic distortion which could interfere with testing. The voltage harmonic distortions of the real or simulated test grid shall be less than the limits specified in the table below.

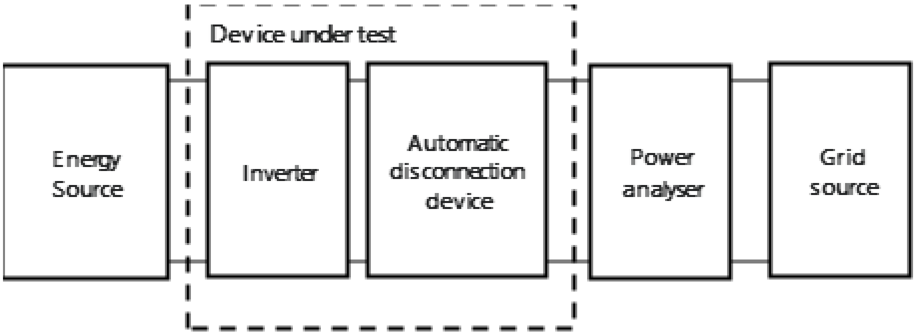
Harmonic order number	Limit based on percentage of fundamental
3	0.9 %
5	0.4 %
7	0.3 %
9	0.2 %
Even harmonics 2–10	0.2 %
11–50	0.1 %
Total harmonic distortion (to the 50th harmonic)	5 %

7.4 Test procedure

7.4.1 General

The following test procedure steps should be completed sequentially. For each of these tests the inverter and automatic disconnection device shall be connected into a test circuit equivalent to that shown in Figure 4.

Figure 4 Test circuit for voltage limits



NOTE: The above test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

7.4.2 Undervoltage (V<) disconnection test in response to event duration exceeding trip delay time

The disconnection time for the protective function undervoltage (180 V) for a voltage step shall be confirmed. The procedure shall be as follows:

(c) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals 50 ± 5 % of its rated current output.

NOTE: For three-phase inverters or inverter combinations, the required inverter output is based on the per phase inverter current rating.

(d) Step the grid source voltage down to 177.5 V (2.5 V below 180 V) with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage. Record the time interval between the start of the voltage step and the device under test disconnecting from the grid source.

NOTE: For three phase systems, the test shall be conducted at the zero-crossing for each phase individually, and additionally for all three phases stepped together at the zero-crossing for one of the phases.

(e) Adjust the grid source to return the voltage to the grid test voltage. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

7.4.3 Undervoltage (V<) withstand test in response to event duration of less than trip delay time

The trip delay requirement for the protective function undervoltage 1 (V <) of 180 V for a voltage step shall be confirmed. The procedure shall be as follows:

(f) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals 50 ± 5 % of its rated current output.

NOTE: For three-phase inverters or inverter combinations, the required inverter output is based on the per phase inverter current rating.

(g) Record the stabilised active power output.

(h) Step the grid source voltage down to 50 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage, remain at 50 V for 220 ms. Increase the grid source voltage to the grid test voltage with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage. Record the time interval between each voltage step passing through 180 V (i.e. the duration for which voltage lies below 180 V).

NOTE: For three phase systems, the test shall be conducted at the zero-crossing for each phase individually, and additionally for all three phases stepped together at the zero-crossing for one of the phases.

(i) After 1 second, record the active power output and confirm it is equal to that recorded at Step (e) ± 4 %.

NOTE: There is no defined behaviour of the inverter during the simulated fault. Monitor and recording at this stage is to better understand the anticipated inverter response.

7.4.4 Criteria for acceptance

(1) The disconnection time recorded at Step (c) shall be greater than the trip delay time of AS/NZS 4777.2:2015 of 1 s and less than the disconnection time of AS/NZS 4777.2:2015 of 2 s.

(2) The device under test shall remain connected for the duration of Step (f).

(3) At Step (g) the device under test shall have recovered its active power output to that recorded at Step (e) ± 4 % within 1 second.

7.4.5 Test report specifications

For each test performed, the results specified in the test procedure and criteria for acceptance shall be recorded and displayed in the test report. The report shall include time-series plots that shows the instantaneous and RMS voltage waveform and the power output of the device under test over the duration of each test (A1.5.2 and A1.5.3). The presented waveforms shall demonstrate that the inverter appropriately disconnected after 1 second, and that the inverter remained connected and recovered to a stable output for a disturbance of less than 1 second. The test report should clearly indicate whether the inverter met or failed each acceptance criteria.

7.5 Accreditation

The testing facility must have the technical competence to undertake the test and be accredited by either:

- The Australian National Association of Testing Authorities (NATA), or
- The International Accreditation New Zealand (IANZ); or
- By accreditation bodies that are signatories to the International Laboratory Accreditation Cooperation Mutual Recognition Arrangements (ILAC MRA).

7.6 Conformance

Once the testing is complete, the test report is to be provided to the CEC for conformance approval and listed on to CEC Approved Inverter Listing[35].

Questions

14. Do you suggest any changes to the proposed test procedure? What and why?

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[35] https://www.cleanenergycouncil.org.au/industry/products/inverters/approved-inverters

APPENDIX A – DPV MASS DISCONNECTION CASE STUDY

Separation event 25 August 2018[36]

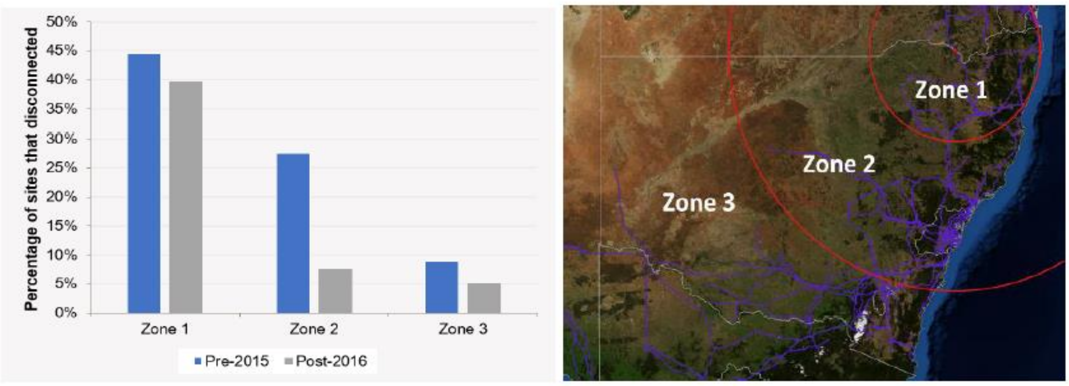
At 1:11 pm on Saturday 25 August 2018, a fault resulted from a lightning-induced flashover along the Queensland – New South Wales interconnector (QNI). This initially caused separation of Queensland from the NEM, with further control system action subsequently separating South Australia, leading to a range of frequency disturbances across the separated regions. This case study focuses on the impacts of the voltage disturbance in NSW caused by the fault at QNI.

Solar Analytics provided data from approximately 5,000 monitoring devices at sites with DPV, recording generation at one-minute intervals. The research team at UNSW Sydney collaborated with AEMO to analyse the data[37].

Figure 5 shows the spatial distribution of observed reduction to zero of DPV generation at sites monitored by Solar Analytics in New South Wales. Affected DPV sites were concentrated around the zone closest to QNI. In Zone 1, closest to the fault, almost 45% of monitored inverters installed prior to October 2015 were observed to reduce generation to zero. In contrast, in Zone 3, furthest from the fault (and not experiencing a significant voltage dip), less than 10% of monitored inverters were impacted. This response may also have been partially due to the subsequent frequency disturbance that resulted from the transmission line switching required to isolate the fault.

Inverters installed under the current Australian Standard (effective from 2016) do show improvement in response during this event, compared with inverters installed under the older standard (pre-2016), demonstrating the value of incrementally improving voltage disturbance withstand requirements. In the zone nearest the fault, inverters installed after 2016 (under the latest standard) were still significantly affected, with almost 40% of monitored systems in Zone 1 reducing output to zero. Zone 1 has a radius of around 240 km.

Figure 5 Inverters reducing output to zero and geographic distribution of monitored PV system sites in New South Wales during the 25 August 2018 event



This geographic distribution of reduced generation also reinforces that incrementally improving voltage disturbance withstand capabilities for DER will reduce the amount of DER lost during disturbances. The analysis found that the severity of the voltage dip experienced by DER systems reduces at more distant locations and concluded that incrementally improving the ability of DPV to remain operational, limits the impact of a fault to a smaller zone which will become increasingly important as DER levels grow.

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[36] AEMO 2019, Technical Integration of Distributed Energy Resources.

[37] UNSW Sydney, Addressing Barriers to Efficient Renewable Integration – Inverter Bench Testing Results, at http://pvinverters.ee.unsw.edu.au/.