Compliance of Distributed Energy Resources with Technical Settings: Update

December 2023

Compliance to AS/NZS4777.2:2020

A technical report for Australia

Important notice

Purpose

The purpose of this report is to describe the current state of compliance of Distributed Energy Resources (DER) with technical settings, focusing on compliance of distributed photovoltaic (DPV) inverters with AS/NZS4777.2:2020. The report provides a status update since AEMO's report released in April 2023[1], with insights based on the actions taken by various parties to improve in-field compliance since that earlier report.

AEMO has prepared this report to meet our responsibility under clause 4.3.1 (n) of the National Electricity Rules (NER) to refer to Registered Participants, as AEMO deems appropriate, information of which AEMO becomes aware in relation to significant risks to the power system where actions to achieve a resolution of those risks are outside the responsibility or control of AEMO.

Disclaimer

To inform its review and the findings expressed in this report, AEMO has been provided with data by third parties, including original equipment manufacturers (OEMs) and distribution network service providers (DNSPS), and has also collated information from its own observations, records and systems. This report has been prepared by AEMO using data available and observations made at different times as indicated in the report, and other information available to AEMO as at October 2023.

AEMO has made reasonable efforts to ensure the quality of the information in this report but cannot guarantee its accuracy or completeness. Any views expressed in this report are those of AEMO unless otherwise stated, and may be based on information given to AEMO by other persons.

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[1] AEMO (April 2023) Compliance of Distributed Energy Resources with Technical Settings, https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en&hash=FC30DF5A3B9EF853093709012242D897

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

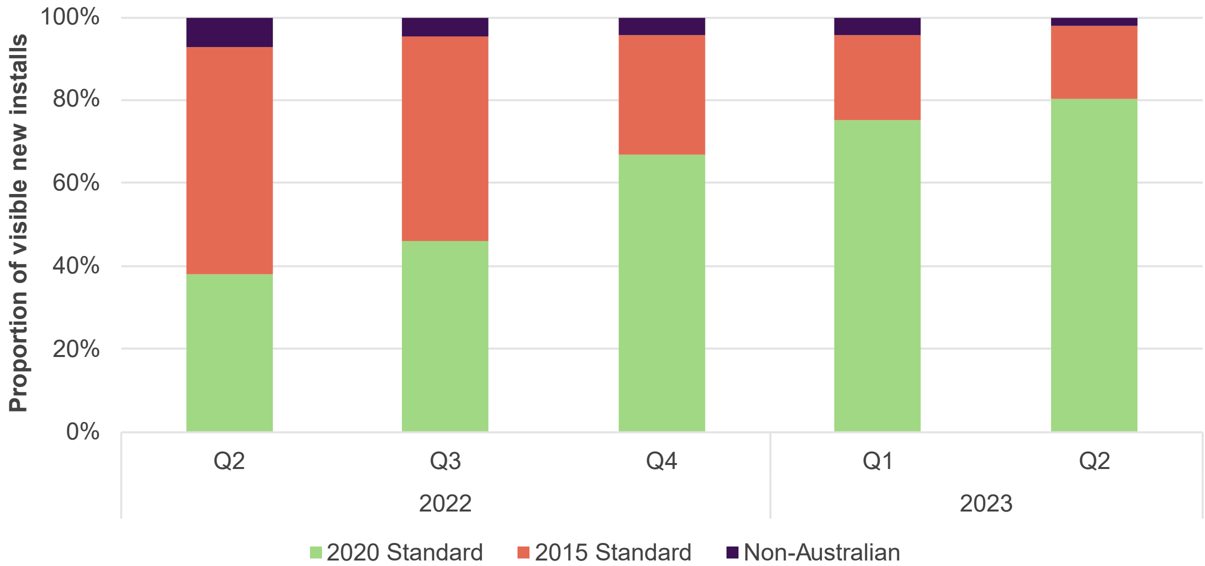
Executive summary

In April 2023, AEMO published a report on compliance of distributed energy resources (DER) with technical settings[2]. All grid-connected inverters installed in Australia after 18th December 2021 are required to comply with AS/NZS4777.2:2020 (the 2020 Standard). However, analysis of distributed PV (DPV) installations in Q1 2022 estimated that only 37% of new installations were being commissioned correctly to the 2020 Standard grid code configuration. The report highlighted significant power system security concerns if this low rate of compliance continued.

Following these findings, AEMO investigated with stakeholders what actions could be taken to improve compliance. Multiple industry stakeholders took proactive actions to innovate and raise compliance. This report provides an update on the actions taken, and their effectiveness in improving 2020 Standard compliance for new DER installations. In this round of analysis, 13 of Australia's largest market share DPV OEMs voluntarily provided data on settings that were being applied to their products in the field. In aggregate, these OEMs comprise over 95% of the market share for new installations[3].

AEMO's analysis found significant improvement in compliance, increasing from just under 40% compliance in early 2022 to an estimated 75-80% compliance in early 2023. Figure 1 shows the evolution of estimated quarterly compliance rates for new DPV installations, scaled by market share. Legacy AS/NZS4777.2:2015 (the 2015 Standard) settings were still being incorrectly applied to 21% of new installs in Q1 2023. The remaining 4% had international grid codes applied. Compliance rates were found to be similar across all Australian regions.

Figure 1 Estimates of quarterly compliance to the AS/NZS4777.2:2020 grid code



[2] AEMO 2023, *Compliance of Distributed Energy Resources with Technical Settings*, available: https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en.

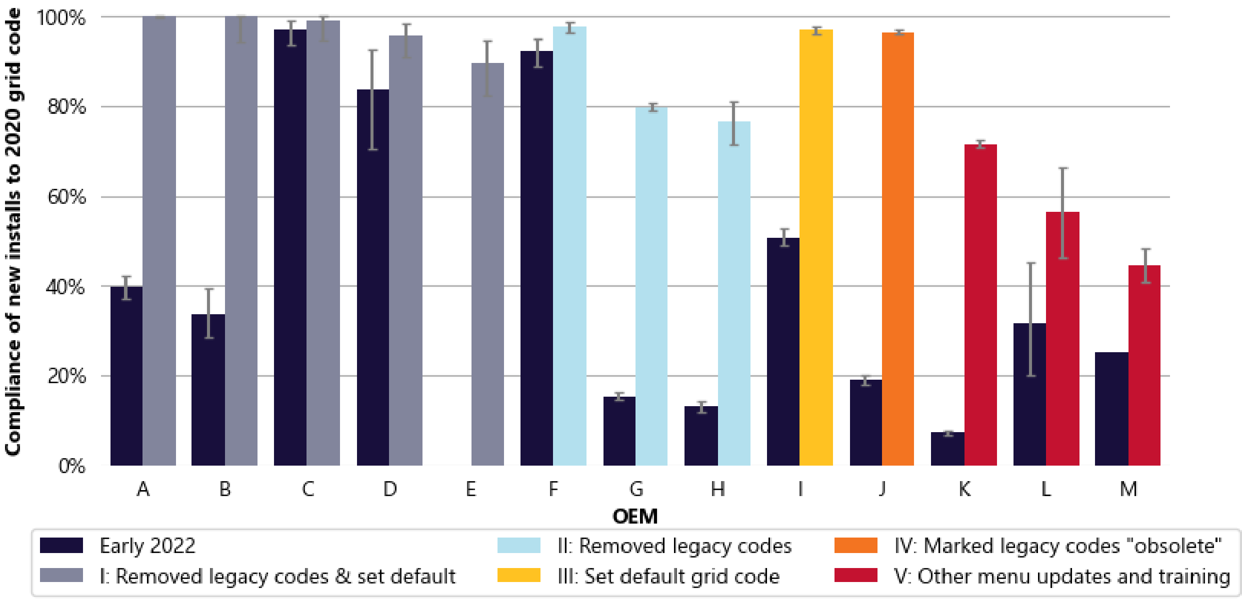
[3] Based on new installations occurring in Q1 2023

AEMO continues to recommend a target of at least **90% of inverters installed from December 2023 compliant to the 2020 Standard**, with further improvement thereafter. Improving compliance mitigates risks to system security and delivers benefits to customers through increased DER hosting capacity (more DER able to be installed) and minimised intervention costs. The findings in this report indicate that proactive actions taken by many stakeholders (particularly by the OEMs who have updated product menus and commissioning processes to better assist installers in selecting the correct grid codes) has made significant progress towards this goal, but further action remains required.

The compliance data suggests that most of the improvement observed to date has been driven by various voluntary OEM actions. Figure 2 shows estimated compliance rates for each OEM for installations in early 2022 (dark blue) compared to compliance rates for installations in early 2023. The colours are indicative of the various significant action(s) reported to have been undertaken by the OEMs. Most OEMs that have updated their product menus and commissioning processes to remove legacy grid codes, set default grid codes, or move legacy grid codes to the bottom of the menu and clearly label them as “obsolete” have seen significant improvements in in-field compliance. In contrast, OEMs that have relied on installer training and more minor menu updates have shown smaller improvements, and their observed rates of compliance remain below the levels required to support system security in the long term. For some OEMs, changes were immediately effective in the majority of new installations (for example, through updates to the OEM’s commissioning app). For other OEMs, changes were only applied to new stock in the factory, so there is a lag in compliance improvements while new stock has been rolled out in the field.

This data indicates the considerable influence that OEMs have over in-field compliance of their products, depending on the design of their product menus and commissioning processes.

Figure 2 Compliance rates of new DPV installations to the 2020 Standard for each OEM showing improvement between early 2022 and early 2023



Compliance rates shown for early 2022 (Q1/Q2, varying by OEM) are in dark blue, and early 2023 (Q1/Q2) in various colours, based on data voluntarily provided by each OEM. Error bars indicate uncertainty related to sample sizes of data provided by OEMs, but do not account for potential bias due to lack of visibility of the non-internet-connected fleet.

AEMO has published this updated report to provide industry and governments with evidence-based options to continue to improve compliance with DER technical standards, and support development of robust long term frameworks for ongoing governance and maintenance of compliance. This report should be considered in the context of the Australian Energy Market Commission's (AEMC) recent market review into consumer energy resources technical standards[4] and the outcomes of the Energy Minister's meeting on 24 November 2023[5], wherein Energy Ministers agreed to consider implementing a national approach to technical regulatory settings for consumer energy resources in 2024.

Data limitations

The data used for this assessment has some important limitations:

- Data was only provided for the internet-connected proportion of OEM fleets. It is estimated that approximately 65% of total installations in Q1 2023 (weighted by market share) are internet connected and visible to OEMs.
- Six OEMs only polled settings on a small sample of 100-200 inverters. These small samples were assumed to be representative of all new installations in the relevant period for these OEMs.
- All data on settings applied on the device is self-reported and voluntarily provided by OEMs.

Given the crucial nature of this data for system security, improved governance arrangements are required to facilitate collection and provision of the necessary data to support compliance monitoring by suitable parties.

Validation against other data sources

Some distribution network service providers (DNSPs) have also been monitoring compliance with the 2020 Standard by measuring whether individual inverters in the field correctly perform the Volt-VAr power quality functions defined in that standard (adjusting reactive power contributions from the inverter as a function of site voltage, to support network voltages). Compliance rates based on OEM self-reported data were compared against the compliance rates estimated from Volt-VAr assessment for each OEM in the CitiPower/Powercor/United Energy (VPN/UE) and South Australia Power Networks (SAPN) networks. In most cases, the compliance rates observed were relatively well aligned across OEM and DNSP Volt-VAr assessments, which provided validation of both methods for estimating overall compliance rates.

For one OEM, their self-reported data indicated close to 100% compliance, while the independent DNSP Volt-VAr assessment indicated compliance of less than 5%. Further investigations indicated that the Volt-VAr response was not enabled by default for this OEM, even if the inverters were set correctly to the 2020 Standard. The OEM has indicated that they are working on a batch firmware upgrade to rectify this issue. This highlights the importance of independent measures of compliance, including direct monitoring of the performance of various functions in the field.

[4] AEMC 2022, *Review into consumer energy resources technical standards*, https://www.aemc.gov.au/market-reviews-advice/review-consumer-energy-resources-technical-standards

[5] Department of Climate Change, Energy, the Environment and Water 2023, *Energy and Climate Change Ministerial Council Meeting*, 24 November, available: https://www.energy.gov.au/sites/default/files/2023-11/ECMC%20Communique_24%20Nov%202023.docx.

Accreditation testing process

Independent laboratory testing of inverters[6] has revealed at least one approved product that does not appear to be delivering the disturbance ride-through behaviours required, even when set correctly to the 2020 Standard. One DNSP also reported a case where an approved inverter was observed not to perform Volt-VAr functions to the level of the 2020 Standard. AEMO is investigating these cases with the stakeholders involved.

These issues suggest a need for improvements to the governance frameworks around product testing, test report checking, and product accreditation.

External devices

For BESS systems, AEMO is aware of several OEMs for which an external device is typically installed with the system on the customer site. These external devices can significantly affect the device and site performance, and in some cases have been observed to disconnect the site from the grid in response to power system conditions. These external devices can affect the delivery of disturbance ride-through behaviours specified in the 2020 Standard. However, it appears that some OEMs have not included these external devices in the standard testing process when testing for accreditation to the 2020 Standard. It is important that the full setup used at the customer site, including any external devices, is tested during this accreditation process to confirm delivery of the necessary disturbance ride-through behaviours. This perhaps indicates a need for test procedures to more clearly specify that any external devices typically used should be tested in conjunction with the inverter, and may also suggest a need for consideration of these installations within the existing and future governance framework to ensure this is checked and confirmed when test results are assessed for accreditation.

Inverter internal settings updates (including firmware and software updates)

Several examples have been identified where OEMs have introduced firmware or software updates that have fundamentally changed the performance and behaviour of inverters in the field. In one case, the issue was identified via DNSP assessments of Volt-VAr delivery in the field. This highlights the importance and value of ongoing, independent direct monitoring and assessments of in-field DER performance, and also suggests a need for improved governance and processes around rollout and testing of the device performance implications of firmware and software updates.

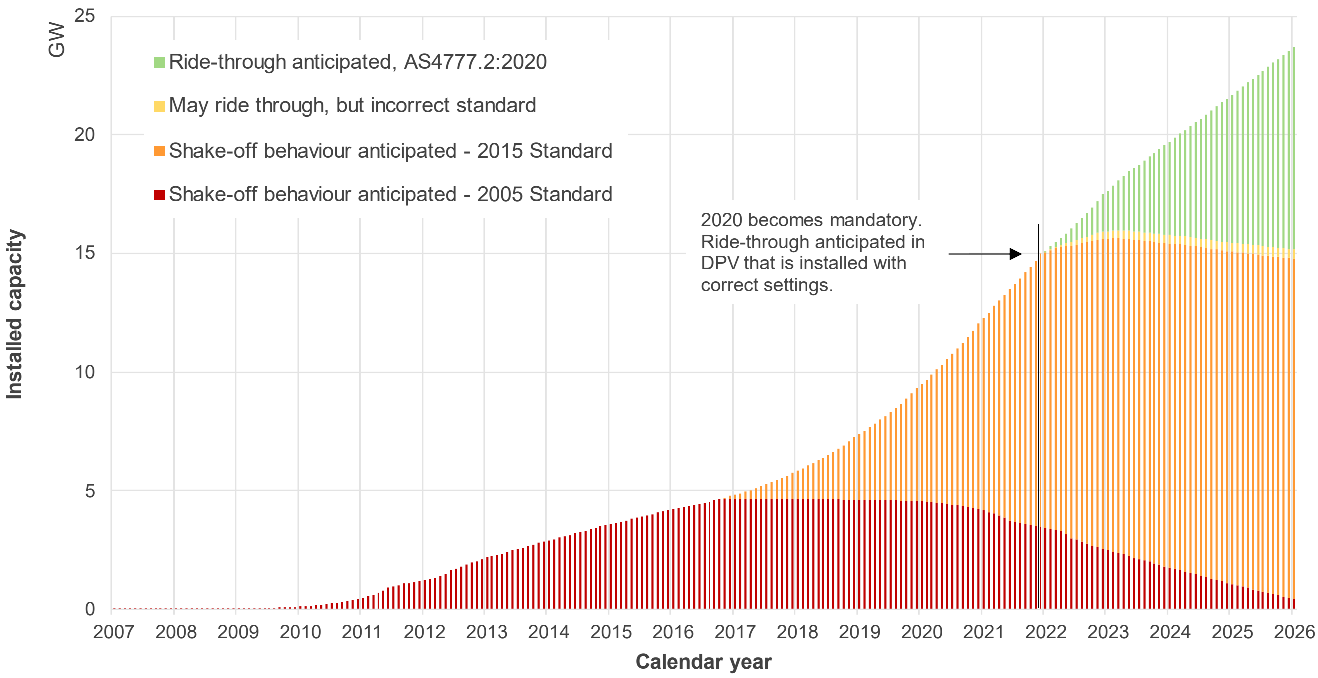
Implications for disturbance ride-through capabilities of the DPV fleet

Figure 3 provides a forward projection of the estimated total fleet capacity of DPV in the NEM that is expected to correctly perform the necessary disturbance ride-through behaviours, based on continued DPV installations as per the AEMO 2023 ISP projections, for the step change scenario[7]. It was assumed that inverters are replaced when they reach a ten-year life.

[6] This testing was conducted by UNSW Sydney as part of the CSIRO Global Power System Transformation (GPST) Research Roadmap, Topic 9, https://www.csiro.au/en/research/technology-space/energy/g-pst-research-roadmap

[7] From 2023 Inputs Assumptions and Scenarios Report, available at: https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-inputs-assumptions-and-scenarios-report.pdf?la=en

Figure 3 Ride-through capabilities of the installed DPV fleet in the NEM (historical and future)



Further improving compliance will minimise the installed capacity that is vulnerable to shake-off in power system disturbances (shown in red and orange in Figure 3), and will therefore increase the DER hosting capacity of the network and minimise the need for costly interventions to maintain system security[8].

Recommendations

AEMO continues to recommend a target of at least 90% of inverters installed from December 2023 set correctly to the 2020 Standard, with further improvement thereafter. Improving compliance mitigates risks to system security and delivers benefits to customers through increased DER hosting capacity (more DER able to be installed while maintaining secure power system operation) and minimised intervention costs. The findings in this report indicate that proactive actions taken by many stakeholders (particularly the OEMs who have made changes to product menus and commissioning processes to better support installers in selecting the correct standard) has made significant progress towards this goal, but further action remains required. Long term governance is also required to maintain compliance at this level.

Detailed recommendations across the industry to improve compliance are summarised in Table 1.

[8] Additional background on how poor inverter compliance leads to increased market costs can be found in Section 3 of this report: AEMO (April 2023) *Compliance of Distributed Energy Resources with Technical Settings*, https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en.

Table 1 Recommendations

Key parties	Proposed actions
OEMs	• **Improve compliance:** Pursue all available short term actions immediately to better support installers in selecting the correct standard. This analysis suggests that the most effective short-term actions have been: – Remove or hide legacy grid codes – Apply location-based default settings (e.g. using geolocation via the commissioning app) – Move legacy grid codes to the bottom of the menu, and clearly label them as "OBSOLETE" – Regularly perform remote updates where possible for all internet connected systems (including rectification of those already installed with incorrect settings) • **Innovation:** OEMs to innovate to improve product menus and commissioning processes to maximise in-field compliance for their devices. • **Data:** – Improve ability to extract and share comprehensive datasets on settings applied to devices in the field, both at the time of installation and for monitoring on an ongoing basis. – Collaborate on the development of standardised dataset formats for settings applied to devices in the field. • **Firmware updates:** Maintain accurate records of firmware updates, including: – What firmware is applied to each device in the field – Expected inverter performance with respect to AS/NZS4777.2:2020 requirements for each firmware version. • **Site inspections:** Support physical site inspections by improving access to information on inverter internal settings and/or Standards so that they can be identified more easily. At present some settings are not visible for a range of reasons (including password protection and site or menu accessibility).
DNSPs	• **Compliance monitoring:** All DNSPs implement programs to monitor in-field compliance in their networks. This could include Volt-Var / Volt-Watt performance assessment becoming standard practice for all DNSPs, as well as exploring other methods (e.g. direct communication with inverters). • **Performance monitoring:** Collaborate with AEMO on a program of continued uplift in tools and capabilities for analysis of inverter performance in the field and event analysis. Including: – Performance monitoring on a representative sample of DER inverters to support in-field assessment of ride-through and power quality performance. – Expansion of high speed (~20ms) data collection in distribution networks, to support model validation and assess aggregate DER performance. • **Improve compliance:** Innovation and collaboration between DNSPs to explore suitable pathways for long-term management of compliance. Possible areas of investigation could include: – **Improve commissioning processes:** Update connection and registration processes to require mandatory commissioning datasheets from installers and/or a digital close-out, including a requirement to confirm selection of AS/NZS4777.2:2020[9]. – **Update Model Standing Offer (MSO)[10]:** to ensure customer consent to make remote changes to inverter settings for the purpose of rectifying compliance. – **Rectification processes[11]:** Work with OEMs, retailers, installers and others[12] to implement processes that rectify incorrect settings, while managing cybersecurity risks, unit corruption failure, or other consequences (such as incorrect firmware creating other unintended consequences).
Installers	• **Complete training on technical settings:** Undertake training on setting new installations to the 2020 Standard, and apply settings correctly.
Clean Energy Regulator (CER) and/or Energy Safety Regulators	• **Improve compliance:** Investigate opportunities to improve compliance in the short-term, possibly leveraging the CER's role in the product listing process, considering incentives and enforcement, and exploring opportunities around training programs for installers.

[9] This could potentially be made a requirement before metering changes, or in collaboration with jurisdictions and regulators, this could also be linked to installer accreditation in the SRES scheme or tied to obligations in state-based schemes.

[10] This may not be applicable across all regions, for example in the South West Interconnected System (SWIS) the MSO is agreed between the energy retailer and the customer.

[11] This may not be applicable across all regions, for example in the SWIS remote communications and monitoring will be effected by Synergy.

[12] For example, DER Integration API Technical Working Group (DERIAPITWG) updates to Common Smart Inverter Profile – Australia (CSIP-Aus).

Key parties	Proposed actions
Jurisdictions	• **Long term governance:** Implement suitable long-term governance frameworks to develop, introduce and implement DER technical standards and address the existing limitations in compliance regulatory frameworks[13]. This could include: – Noting the current inability to regulate the full range of DER parties (including OEMs who have significant influence over DER compliance rates), and seeking pathways to more explicitly recognise these parties as central stakeholders in governance arrangements. – Clarifying which organisations have responsibility for monitoring and enforcing the various elements of compliance at different stages of the life cycle of DER devices (manufacture and supply, installation, and ongoing operations). – Clarifying the datasets that should be collected and made available for assessing ongoing compliance, and the necessary governance arrangements to ensure these datasets are sufficient for enforcement and application of incentives and penalties, and made available to the parties that require them. – Suitable processes for managing impacts of firmware and software updates on technical performance.
All stakeholders	• **Standardised data formats:** Develop standardised dataset formats for settings applied to devices in the field, and explore pathways to facilitate standardised reading and writing of inverter settings[14]. • **DER Register data:** Improve the quality of data uploaded to the DER Register. Consider consolidation of data collection across multiple mechanisms (i.e. integrate data from the SRES program). Consider how to improve data on replacements and retirements and include accurate serial numbers. • **Standardised test reporting:** Develop a standardised test reporting format that all accredited test labs are required to follow and align to. This includes specification of results reporting to ensure that there is consistency in assessment and approval of accredited devices. • **External devices:** Ensure appropriate test procedures and governance arrangements so that any external devices that are typically installed on a customer site with the inverter are included as part of the test setup used for testing accreditation with the 2020 Standard.

AEMO is actively engaging with all the parties noted above on these actions, and will continue to monitor compliance rates based on the datasets available. AEMO is implementing progressive updates to operational processes to reflect the evolution of compliance rates over time. The implementation of suitable long-term governance frameworks to develop, introduce and implement DER technical standards must also be progressed[15].

Collaborators and contributors

Much of the data and evidence noted in this report has been provided to AEMO on a voluntary basis, and AEMO acknowledges the various contributors, particularly the thirteen OEMs who have contributed datasets and assistance, as well as UNSW Sydney, VPN/UE, SAPN, Ausgrid, and the Clean Energy Regulator (CER). In particular, this work was made possible due to the analysis undertaken through Project MATCH[16] which received funding from the Australian Renewable Energy Agency (ARENA).

[13] This recommendation aligns with the findings of the AEMC's Review into consumer energy resources technical standards, its final report can be found here: https://www.aemc.gov.au/sites/default/files/2023-09/RCERTS%20Final%20Report.pdf.

[14] Options such as enhancing CSIP-Aus to define control messages to read and update individual inverter settings or common file formats could be explored.

[15] As per the recommendations outlined in AEMC, Review into consumer energy resources technical standards, https://www.aemc.gov.au/market-reviews-advice/review-consumer-energy-resources-technical-standards

[16] Project MATCH, *Monitoring and Analysis Toolbox for Compliance in a High DER future*, available: https://arena.gov.au/projects/project-match/

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Figures

1 Background

In September 2022, the Australian Energy Market Commission (AEMC) commenced a market review into the Compliance of Distributed Energy Resources with Technical Standards, which considered the governance and regulatory arrangements around technical standards for these devices[17]. This review was part of the AEMC's broader work plan for distributed energy resources technical standards[18].

In April 2023, AEMO published a report on compliance of distributed energy resources (DER) with technical settings[19], which supported and complemented the AEMC's review.

AEMO's report found that only 37% of DER fleet installed in the NEM in Q1 2022 was commissioned with a correct Standard grid code configuration, despite all grid-connected inverters installed in Australia after 18th December 2021 being required to comply with AS/NZS4777.2:2020 (the 2020 Standard). Significant power system security concerns were highlighted, if this low rate of compliance continued.

In light of these findings, AEMO worked with stakeholders to identify actions which could be taken to improve compliance. This included:

- Many inverter original equipment manufacturers (OEMs) implemented various updates to defaults and menus and remotely updated incorrect inverter settings where possible.
- AEMO worked with the Clean Energy Council (CEC), the Clean Energy Regulator (CER) and various Distribution Network Service Providers (DNSPs) to investigate short term options for improving compliance under the present regulatory framework.
- AEMO worked with the AEMC as part of their review into distributed energy resources technical standards to help inform their final recommendations.

This report provides an update on the state of compliance of DER with technical settings, based on the most recent data provided by OEMs for installations in late 2022 and early 2023, with the aim of:

- Estimating current compliance rates, so that likely disturbance ride-through rates for the DER fleet can be estimated more accurately and applied to AEMO's operational processes.
- Assessing the impact of the various actions taken by different stakeholders to improve compliance, to guide further evidence-based efforts on improving compliance, and
- Informing jurisdictional reforms to long-term governance frameworks. The AEMC's review into the Compliance of Distributed Energy Resources with Technical Standards recommended that jurisdictions develop a new national regulatory framework for DER technical standards. On 24 November 2023, Energy Ministers also agreed to give consideration to implementing a national approach to technical regulatory settings for consumer energy resources in 2024[20]. AEMO will aim to support governments and industry in taking the next steps on addressing this important reform.

[17] AEMC 2022, Review into consumer energy resources technical standards, https://www.aemc.gov.au/market-reviews-advice/review-consumer-energy-resources-technical-standards

[18] AEMC 2022, Governance of distributed energy resources, final rule determination, Governance of distributed energy resources technical standards | AEMC

[19] AEMO 2023, *Compliance of Distributed Energy Resources with Technical Settings*, available: https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en.

[20] Department of Climate Change, Energy, the Environment and Water 2023, *Emergy and Climate Change Ministerial Council Meeting*, 24 November, available: https://www.energy.gov.au/sites/default/files/2023-11/ECMC%20Communique_24%20Nov%202023.docx

This analysis has been conducted in collaboration with UNSW Sydney under the ARENA funded Project MATCH[21].

[21] Project MATCH, *Monitoring and Analysis Toolbox for Compliance in a High DER future*, available: https://arena.gov.au/projects/project-match/

2 Compliance estimates

2.1 Approach

OEMs with significant market share were contacted to request data on the standard settings (e.g. 'AS4777.2:2020 Australia A') applied to DER installations that occurred during Quarter 4 (Q4) 2022 and Quarter 1 (Q1) 2023.

Thirteen OEMs voluntarily provided data for some portion of their fleet. In aggregate, these OEMs comprise over 95% of the market share of new installations occurring in Q1 2023[22].

The data has some important limitations:

- Data was only provided for the internet connected proportion of OEM fleets. It is estimated that approximately 65% of total installations in Q1 2023 (weighted by market share) are internet connected.
- Six OEMs only polled settings on a small sample of 100-200 inverters. These small samples were assumed to be representative of the whole fleet for these OEMs.

Further details on the datasets provided and their limitations are outlined in Section 4. The key assumptions applied during the analysis are summarised in Table 2.

Table 2 Key assumptions

Assumption	Details
Extrapolation to rest of OEM fleet	These sample datasets were assumed to be unbiased and representative of the entire fleet of installations for each OEM. It is assumed that the compliance rate of an OEM's internet-connected fleet is representative of the compliance rate for an OEM's non-internet connected fleet.
Scaling by market share	The datasets were scaled using market share estimates based on number of installations from the CER[23].
Incorrect region code	An inverter is considered "compliant" if it has the 2020 Standard applied as all inverters installed under this standard are expected to perform the disturbance ride-through behaviours necessary to support power system security. However, the 2020 Standard also contains regional settings (Australia A, B or C) which vary based on the local grid the inverter is connected to. In some cases the inverter has been installed under the 2020 Standard, but with the incorrect A, B or C region setting. In these cases, the inverter will not fully perform the specific frequency and power quality responses required to support the local grid. This is discussed further in Section 3.1.1.
Remote updates	It is assumed that the datasets provided reflect current settings applied at the time when the inverters were polled. For cases where OEMs have completed remote updates these current settings may differ to the installer selected settings. Compliance data presented in this report is at time of polling, which for systems installed in 2023 is typically reflective of compliance at install.
Multiple inverters at the same installation	Compliance rates by inverter are assumed to be the same as compliance rates by installation (there may be multiple inverters at the one installation). Compliance data provided by OEMs is typically based on inverter.
First online date versus installation date	The data available regarding installation date was incomplete in many cases. Where necessary, 'first online date' is used instead. Due to variation in installation process at each site, some inverters may have 'first online' dates that are several months after actual install date.

[22] Based on market share data from the Clean Energy Regulator (CER).

[23] CER 2023, *Postcode data for small-scale installations,* available: https://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations. CER data used in the report is as of April 2023.

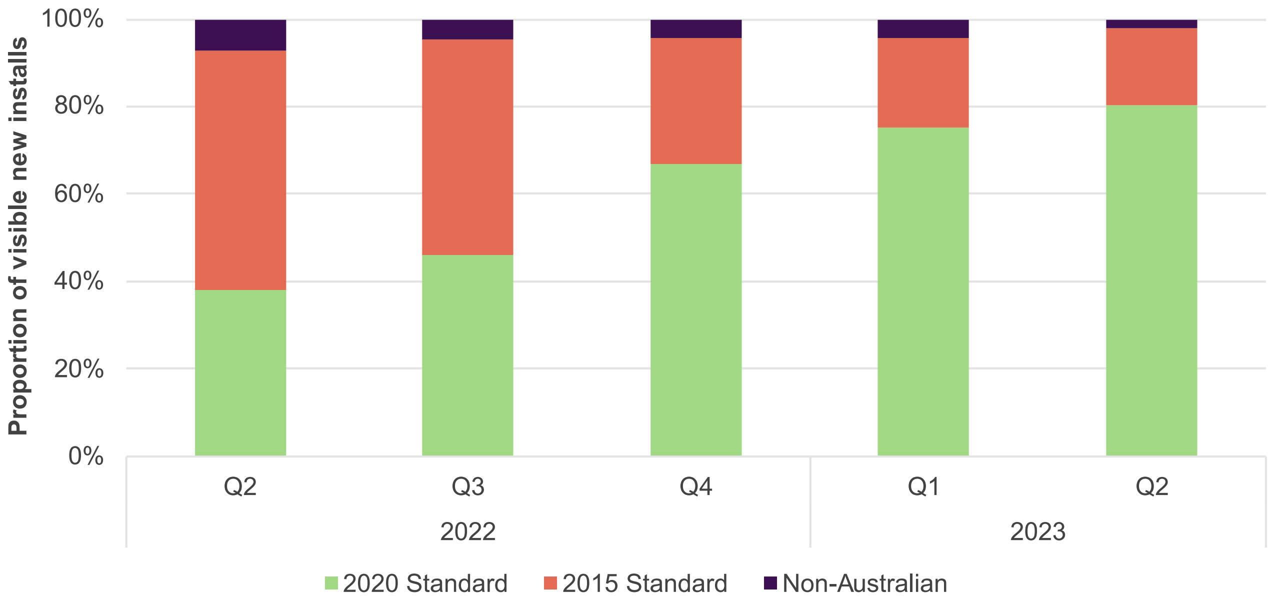
2.2 Fleet compliance rates

The remote inverter survey datasets indicate that around **75% of new inverters installed in Q1 2023 Australia-wide were configured to the 2020 Standard**[24].

Figure 4 shows the evolution of quarterly compliance rates for new installations over time. Significant improvement in compliance is evident, but some inverters continue to be installed with incorrect settings. A significant proportion of the fleet (21% of new installs in Q1 2023) is still being installed with legacy 2015 Standard settings. A much smaller portion of around 4% have international grid codes applied.

For all DER inverters installed between January 2022 and June 2023, it is estimated that ~55% are set to the correct Standard[25].

Figure 4 Estimates of quarterly compliance to the AS/NZS4777.2:2020 grid code



Compliance in each quarter has been estimated based on market share of OEMs who provided information to AEMO. The OEMs included in the aggregation vary by quarter, based on which OEMs responded to the data request. Market coverage varies from 52% to 95%, and internet connectivity is understood to vary between approximately 40-100%. Compliance estimates in this plot are scaled by market share in Q1 2023 and assume the visible portion of the fleet is representative of the entire fleet. Refer to Section 4.1 for further information on data limitations.

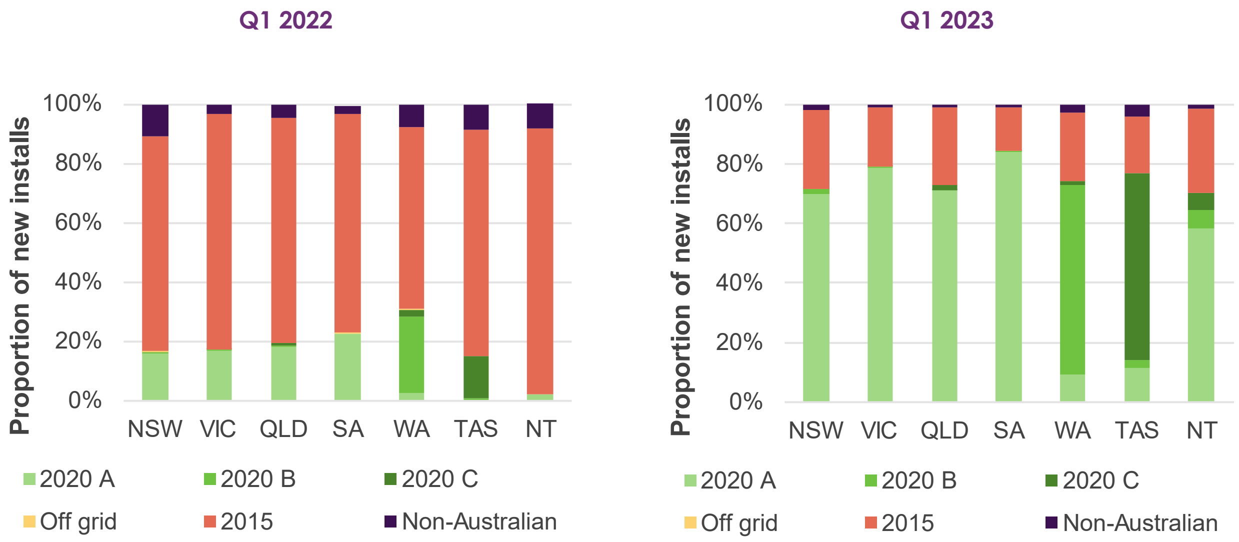
2.2.1 Compliance rates by region

Compliance was found to be broadly similar across regions, as shown in Figure 5. All regions saw the 2020 Standard applied to between 70% and 85% of installations in Q1 2023.

[24] The estimate for Q1 2023 is based on data from thirteen OEMs. Seven OEMs (representing 50% market share) also provided data for Q2 2023, indicating a compliance rate of 80% at that time, but with wider uncertainty than the estimate for Q1 2023.

[25] Accounting for inverters which were remotely updated to the correct standard, where OEMs have provided adequate information to estimate improvement in compliance due to retrospective updates.

Figure 5 Estimated proportions of installations on each setting by region



In Q1 2022, 3 OEMs provided data with regional breakdowns. 7-11 OEMs provided this data in Q1 2023, depending on the state. Regional breakdowns for Q1 2022 were adjusted for all-Australia market share for that quarter, and Q1 2023 data was scaled for state-based market share for that quarter. Data provided was insufficient to separate WA into SWIS and non-SWIS.

The 2020 Standard has three region codes, and installations in each region should be set as follows:

- Australia A: New South Wales, Victoria, Queensland, South Australia (NEM mainland) and Northern Territory[26]
- Australia B: Western Australia South West Interconnected System (SWIS)
- Australia C: Tasmania, Western Australia Horizon network

The datasets indicate reasonable compliance with these localised regional settings, with both Western Australia and Tasmania showing over 80% of installations that were set to the 2020 Standard also set to the correct region. However, 10-15% of installations in these regions were set to Australia A. These installations are expected to correctly perform the required disturbance ride-through behaviours to support system security (these requirements are common to Australia A, B and C), but may not perform the necessary frequency responses or power quality responses to properly support local network needs.

The rate of correct region selection (A, B or C) is influenced by the specific actions taken by each OEM to improve compliance, as elaborated further in Section 3.1.1.

[26] PowerWater, *Inverter-based solar energy system requirements*, available: https://www.powerwater.com.au/customers/power/solar-power-systems/pv-class-requirements.

3 Actions to increase compliance

This section examines the effectiveness of actions taken by various parties to improve compliance.

3.1 Effectiveness of OEM actions

Based on discussions with OEMs, it is understood that the following actions have been taken (with different OEMs undertaking different subsets of these):

- **Removed legacy codes:** pre-commissioning adjustments to product menus to entirely remove legacy grid codes such as AS/NZS4777.2:2015. For some OEMs, this was immediately applied via updates of installation apps, such that changes applied to any new installations from that date. For other OEMs, this was applied only to new products as they left the factory, so uptake in the field showed a delay as older stock with earlier menu options continued to be installed[27].
- **Set default grid code:** setting AS/NZS 4777.2:2020 Australia A as the default standard setting, or a locational-based default that uses geolocation of the inverter (or the device accessing the commissioning app) to set Australia A, B or C as the default. The installer does not need to actively select the standard to be applied at the time of installation (but might have the option to move into deeper menus to select a different standard if desired).
- **Mark legacy codes 'obsolete':** rename legacy grid codes (such as AS4777.2:2015) as 'superseded' or 'obsolete'.
- **Remote updates:** post-commissioning remote updates to settings applied to sites with non-compliant grid codes, either on a repeated or once-off basis.
- **Other menu updates:** Other product menu updates, such as reordering to move the 2020 Standard grid codes to the top of the list or move legacy grid codes to the end of the list.
- **Installer training:** The OEM offered training or other support to installers specific to their product to inform them on correct selection of the new 2020 Standard.

The actions taken by OEMs demonstrate the need to address DER compliance across their lifecycle – i.e., manufacture and supply, installation and ongoing operation. Undertaking a range of actions across different stages increases the effectiveness of compliance measures.

Table 3 summarises the actions that each OEM is understood to have taken. OEMs are grouped into loose categories (Group I, II, III, IV and V), based on similar kinds of actions taken. The improvements in observed compliance rates for each OEM, influenced by the actions taken, are shown in Figure 6.

[27] Some OEMs have expressed concerns that legacy grid codes may be required for like-for-like warranty replacements, and also that AS/NZS4777.2:2015 is required for products commissioned in New Zealand, as the 2020 Standard has not yet been adopted there. It is noted that several DNSPs have implemented technical standards which require like-for-like warranty replacements to meet the 2020 Standard if the capability exists within the replacement inverter (Section 3.2).

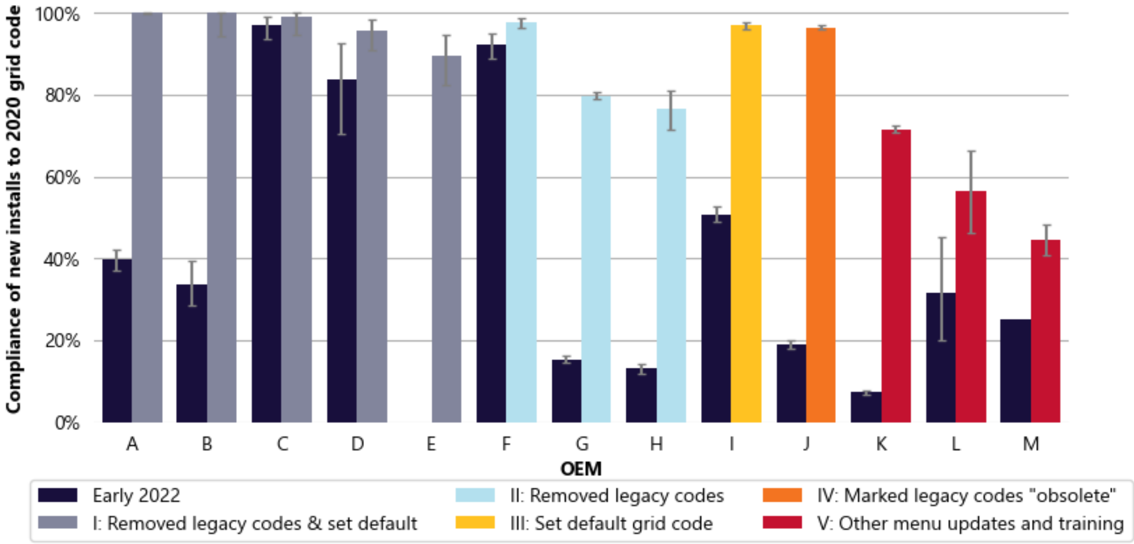
Table 3 Summary of actions taken by OEMs

	OEM	Removed legacy codes	Set default grid code	Other menu updates	Remote updates	Installer training
Group I: **OEMs that have removed legacy grid codes, set the 2020 Standard as the default and may have performed remote updates.**	A	✓	✓	N/A	✓[C]	✓
	B	✓	✓	N/A	✓ Limited[A]	✓
	C	✓	✓	N/A	✗	✓
	D	✓	✓	N/A	✓ Limited[A]	✓
	E	✓	✓	N/A	✗	✗
Group II: **OEMs that have removed legacy grid codes and may have performed remote updates.**	F	✓	✗	N/A	✓	✓
	G	✓	✗	N/A	✗	✓
	H	✓	✗	N/A	✓ Limited[A]	✓
Group III: **OEMs that have set the 2020 Standard as the default grid code for all products shipped to Australia.**	I	✗	✓	N/A	✓Limited[A]	✓
Group IV: **OEMs that have marked legacy codes as 'obsolete' and may have performed remote updates**	J	✗	✗	✓	✓[C]	✓
Group V: **OEMs that have performed other menu updates and implemented installer training**	K	✗	✗	✓[E]	✗	✓
	L	✗	✗	✓[E]	✗	✓[F]
	M	✓ Limited[B]	✗	✓[E]	Limited[D]	✓

✓: OEM reported that action has been implemented.
✓: OEM reported partial implementation.
✗: OEM reported that action has not been implemented.
A: Remote updates on online inverters were performed during 2022 on limited occasions when prompted. It is understood that none of the updates have contributed to the compliance rates shown in Figure 6 (which show the settings applied to new inverters installed after remote updates were performed).
B: OEM reported legacy grid codes have been removed from newly launched products released after December 2021, but remain available for existing product ranges, because these may be required for like-for-like warranty replacements and installations outside Australia.
C: Remote updates performed regularly during 2022. These OEMs have reported substantial increases in compliance at install and are therefore understood to have discontinued regular remote updates.
D: Has technical capability to conduct batch remote updates to the 2020 Standard, but has not yet been carried out across the fleet.
E: 2020 Standard is near the top of the product menu, but legacy standards have not been marked as obsolete.
F: Since 2023 Q3, training on selection of 2020 Standard settings has been targeted towards installers identified as often selecting incorrect settings.

Figure 6 shows estimated compliance rates for each OEM for the earliest quarter they provided data (Q1 or Q2 2022) (dark blue) compared to compliance rates for the latest quarter (Q1 or Q2 2023). The colours are indicative of the various significant action(s) the OEM is understood to have taken. The improvement in compliance varies significantly on the OEM and the actions taken.

Figure 6 Compliance rates of new installations to the 2020 Standard for each OEM showing improvement between early 2022 and early 2023



Compliance rates shown for earliest quarter in 2022 (dark blue) and most recent quarter in early 2023 (various colours), as provided by each OEM. Error bars indicate uncertainty related to sample sizes of data provided by OEMs, but do not account for potential bias due to lack of visibility of non-internet-connected fleet. Information for OEM E was not available for early 2022.

Based on the data provided, insights are as follows. For new installations (Figure 6):

- **Removal of legacy grid codes** appears to be a highly effective method to increase compliance, with some OEMs showing compliance rates of 95-100% following this action either as a stand-alone action, or in combination with setting a default grid code. A few OEMs still show compliance rates of 70-80% due to legacy grid codes having been removed at a later date, coupled with slow rollout of products in the field (such that some older products with the legacy grid codes remaining are still being installed in mid-2023). This means that this action should ideally be undertaken as early as possible, considering the possibility of long lead times between manufacture and installation. Further details are in Section 3.1.2.
- **Setting the default grid code** to Australia A appears to achieve 90-95% of inverters set to the 2020 Standard, therefore providing the disturbance ride-through behaviours that are essential for power system security. However, this action does not support full compliance in Western Australia and Tasmania with the 2020 Australia B and C grid codes. Further detail is in Section 3.1.1. The appetite amongst OEMs to set Australia A as default will likely vary depending on individual supply chain structures; it is understood that some OEMs manufacture batches of inverters specifically for the Australian market (and therefore can implement defaults for products shipping to the Australian market), whereas others do not. One OEM has developed the capability to set a default grid code based on geolocational information, which appears to support high compliance of 99%, including to the correct local region code.
- **Marking legacy grid codes as outdated,** for instance prefixing superseded standards with the word ‘obsolete’, appears to have been effective for the one OEM that took this action.
- **Other menu updates and training** (such as adding the 2020 Standard at the top of the list and OEM-specific training that specifically addresses correct grid code selection) appears to have somewhat increased compliance rates, however increases vary between the OEMs that took this action. Further details are in Section 3.1.4.

For existing installations, **remote updates** are the primary means available to efficiently increase compliance rates retrospectively (Section 3.1.5).

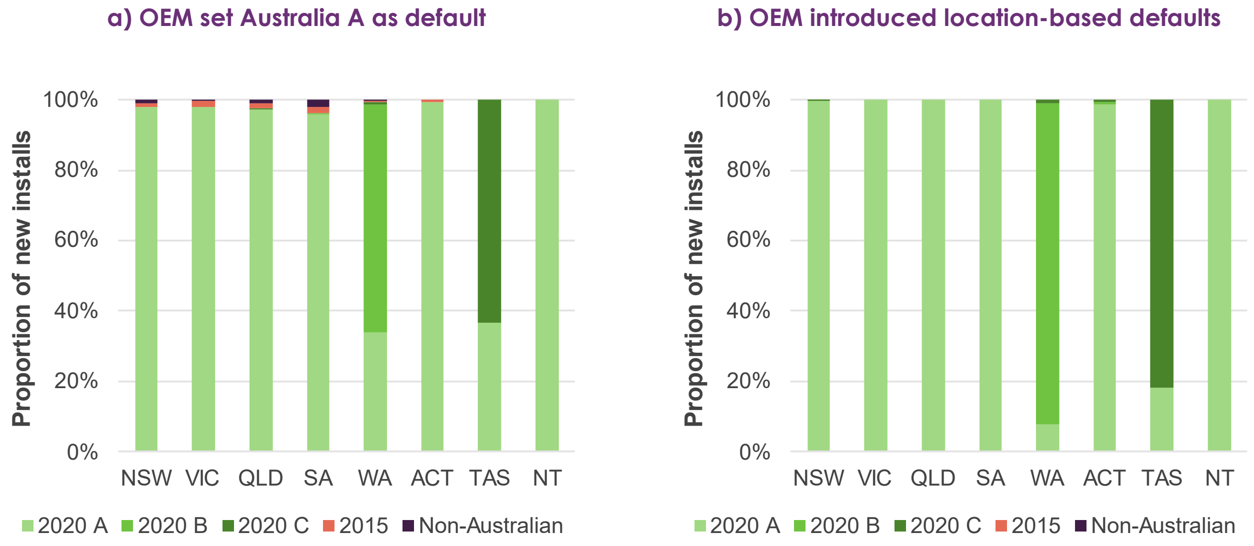
The case studies below provide further details, including observations for individual OEMs.

3.1.1 Default grid codes and implications for region-specific settings

One OEM elected to set the default grid code on their inverters to 2020 Standard Australia A, but did not remove the legacy grid codes. As shown in Figure 7a) this resulted in very high rates of inverters set to the 2020 Standard (almost 100%), but resulted in 30-40% of the installations in Western Australia and Tasmania being set incorrectly to the Australia A region setting. These inverters likely will perform the disturbance ride-through behaviours necessary to support power system security, but will not fully perform the specific frequency and power quality responses required to support those grids.

Another OEM implemented geolocational-based defaults, which use the state of installation to determine the default setting. This OEM reported higher levels of compliance to the appropriate region codes in Western Australia and Tasmania, as shown in Figure 7b), with around 10-20% being set incorrectly to Australia A. The OEM is investigating why this might be the case and ways to reduce this.

Figure 7 Regional compliance rates for two OEMs that set default grid codes



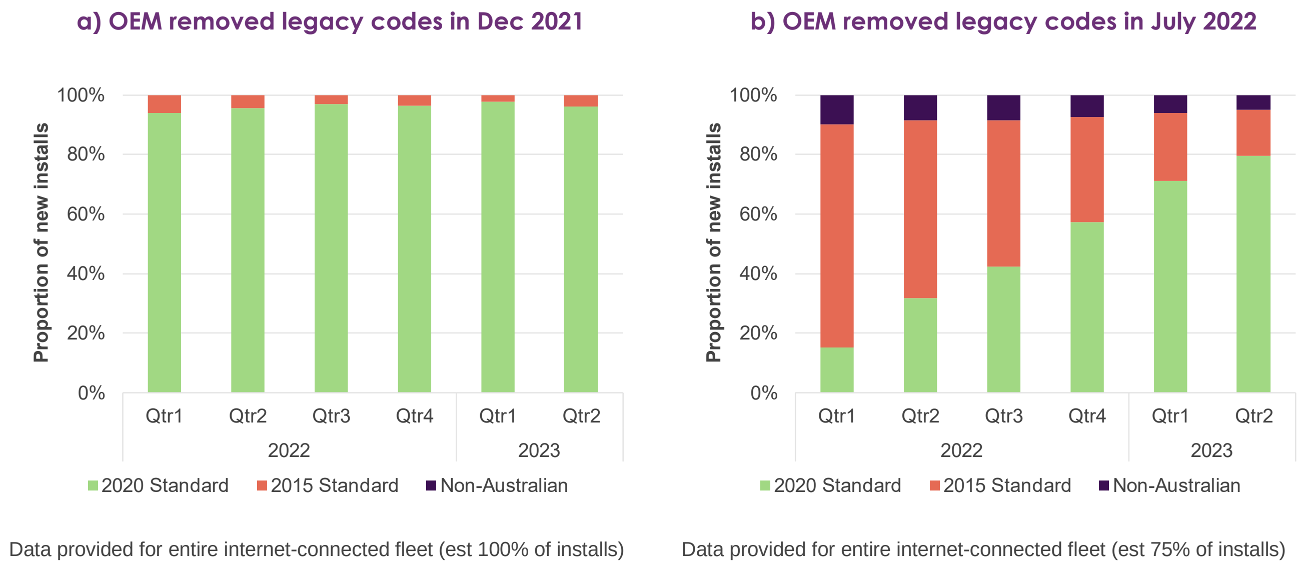
Using a default grid code appears to have been successful in achieving very high compliance with the necessary disturbance ride-through characteristics.

3.1.2 Removal of legacy grid codes: Impact of lead times and remote updates

Figure 8 shows the evolution of compliance rates over time by comparing two OEMs that removed legacy grid codes from their products at different times. The OEM on the left (Figure 8a) removed the option to select legacy grid codes from all their products installed after December 2021, when the 2020 Standard became mandatory, and has also undertaken remote updates to around 20-30% of its fleet installed since Q1 2022. This OEM shows consistently high rates of compliance for installations in 2022 and 2023 (close to 100%).

In contrast, the OEM on the right (Figure 8b) maintained legacy grid codes available in their product menus until July 2022 when they were removed at the point of manufacture. This OEM did not undertake any remote updates. Rates of compliance for this OEM were in the range 10-20% in early 2022, and have increased gradually to achieve approximately 80% compliance in Q2 2023. The gradual improvement reflects the lag between product manufacture and installation, and will be different for each OEM depending on stock flow. It also indicates the benefits of early actions.

Figure 8 Compliance rates over time for two OEMs that removed legacy grid codes



3.1.3 Marking old Standard 'obsolete'

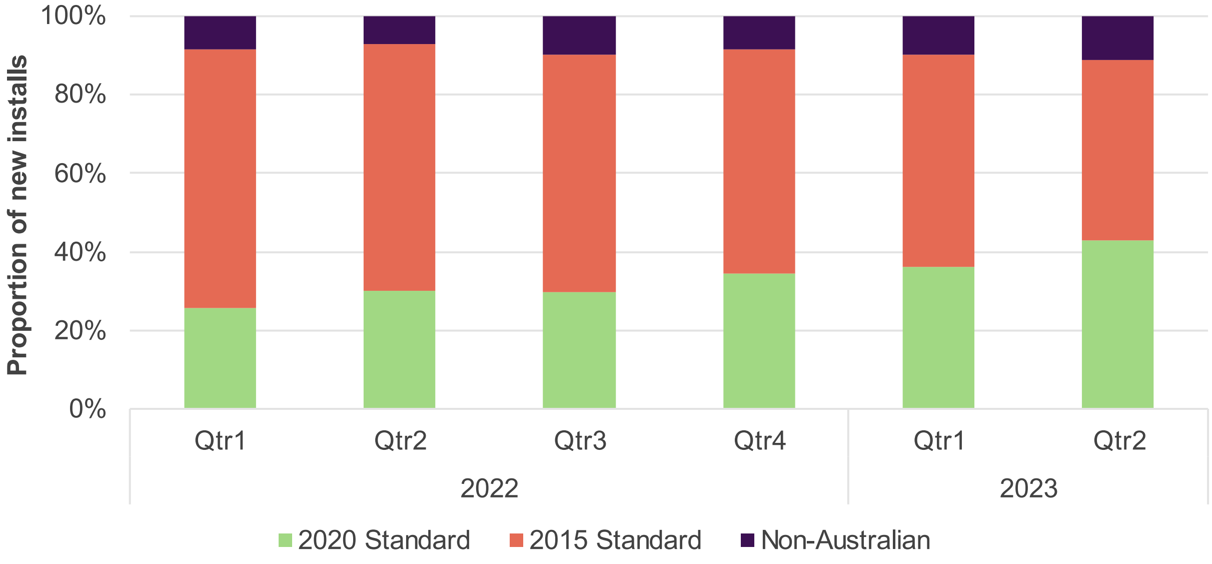
One OEM renamed superseded standards as 'obsolete' and moved them to the bottom of the menu. This appears to have achieved over 90% compliance in Q1 2023 installs. The change was made in the commissioning app in late 2022 and so applied to all new installs, effective immediately.

3.1.4 Other menu updates and installer training

Three OEMs added the 2020 Standard to the top of their product menus and reported providing OEM-specific training and support for their installers. Improvements in compliance for one such OEM are shown in Figure 9. These OEMs show varying levels of improvement in compliance, ranging from 40-70% in mid-2023. This action appears to have some effectiveness at improving compliance rates, however it appears that the specific approach taken can significantly influence outcomes.

Continued low compliance at these rates does not adequately support power system security and will lead to decreased DER hosting capacity (less DER able to be installed on the network while maintaining power system security). To increase the proportion of inverters from these OEMs installed on the correct 2020 Standard, further actions are required (such as those taken by other OEMs noted in previous sections).

Figure 9 Compliance rates over time for one OEM that introduced 2020 Standards at top of menu



Data provided for entire internet connected fleet (~66% of installs)

One OEM identified installers who had either selected the incorrect Standard on their products more than 10 times, or contributed a compliance rate of less than 90% for installations in 2023. This OEM then sent these specific installers a targeted email informing them how to correctly select the 2020 Standard during installation. Since implementing this targeted training in 2023 Q3, this OEM has seen improvement in compliance from 56% in 2023 Q1 to above 70% in 2023 Q3. This represents a significant improvement (although further improvement to above 90% compliance remains required).

3.1.5 Remote updates to existing fleet

Remote updates are the primary method available to efficiently increase compliance rates retrospectively within the existing inverter fleet (the other actions discussed above target new installations only). Remote updates, appear to have been very effective when performed regularly, with OEMs reporting post-update compliance rates of 95 - 100% in their internet connected fleet.

Seven OEMs, representing approximately 50% of new installations, have undertaken some form of remote updates, whereby the grid code at specific inverters was identified as not having been correctly set, and was changed to 2020 Standard Australia A, B or C by the OEM via an online interface. The means by which the incorrectly set inverters were identified varies:

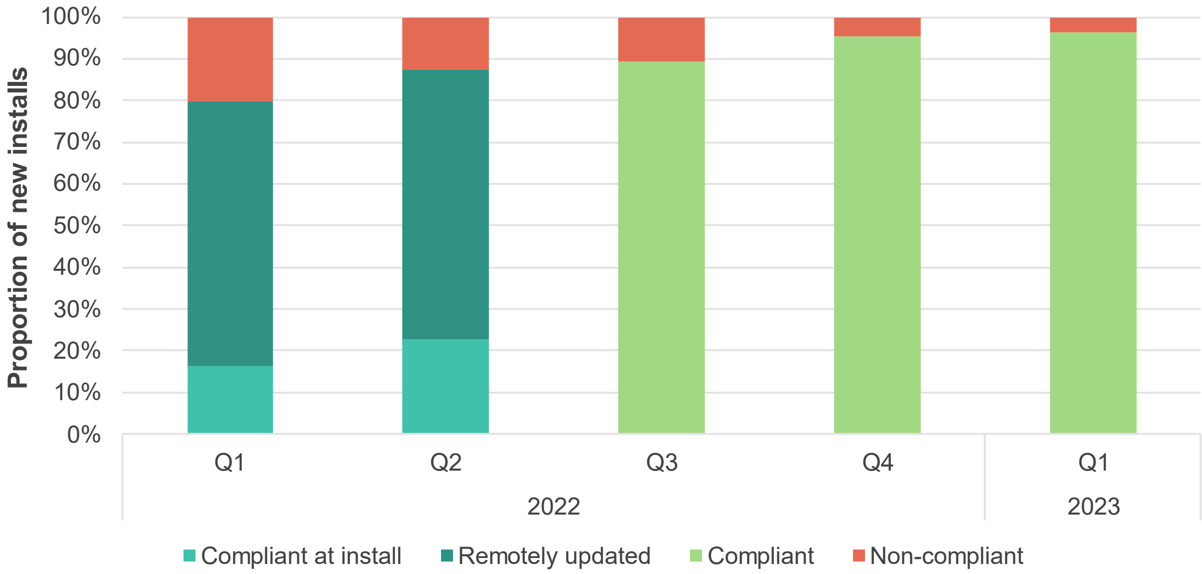
- Some were identified directly by the OEM by querying online inverters in their fleet installed since the 2020 Standard came into effect.
- In some cases, AEMO identified serial numbers for installations manufactured by the OEM from the DER Register, and requested that the OEM query those serial numbers in their own database and update to the correct grid code if required.
- Some were identified by DNSPs through analysis of power quality functions (see Section 5.1).

The ease of completing remote updates varies between OEMs. One OEM indicated the process is streamlined and can be completed quickly, whereas other OEMs reported needing to manually change the settings for each individual inverter in a resource-intensive process.

A case study for one OEM is shown in Figure 10. This OEM undertook a substantial work program to remotely update its inverters installed between January and October 2022. The remote updates made by this OEM have increased compliance for Q1 and Q2 2022 installs from around 15-20% at the point of installation to 80-85% post updates. It is understood that this process was resource intensive, but has achieved an immediate and significant improvement in compliance for a large proportion of the existing installed fleet.

From Q3 2022, this OEM updated their commissioning app (applicable to all new installs effective immediately) to rename superseded standards as "obsolete" and move them to the bottom of the menu. As noted in the previous sections, this appears to have achieved over 90% compliance in new installs. This has significantly reduced the need for further remote updates, since the majority of installations were set correctly at the time of commissioning.

Figure 10 Compliance rates over time for one OEM applying remote updates



AEMO together with the OEM compared data provided by this OEM in mid-2022 with updated grid codes information provided in 2023 to identify sites that had been remotely updated to a 2020 region code. However, this OEM has advised that it did not record all sites that were remotely updated, and so the datasets available do not capture the full extent of remote updates from Q3 2022 onwards.

Some additional considerations relating to remote updates include:

- In the absence of other actions to improve compliance at the point of installation, remote updates must be performed on an ongoing basis to ensure compliance remains high. Some OEMs have done regular voluntary remote updates while others are doing this on a limited basis only when prompted, and some require provision of a list of serial numbers in order to roll out the update. Correct serial numbers are only available for a proportion of installations[28].
- The process of undertaking remote updates can be resource intensive for OEMs, and with existing tools and processes may require each individual inverter to be manually updated.
- Not all OEMs are technically able to remotely update their inverters at this time.

[28] The data available in the DER Register only includes correct serial numbers for 75-85% of installations.

- Remote updates can only be applied to the internet-connected portion of an OEM's fleet (estimated to be between 40% - 100%, depending on the OEM). Connectivity rates are estimated to be higher for the OEMs that require internet connection as part of the commissioning process.
- Some OEMs did not consider they had the authority to undertake remote updates on customer devices, even where the setting had been applied incorrectly at the time of commissioning.

3.2 DNSP and regulator actions to monitor and improve compliance

Some DNSPs and regulators are implementing programs of work to increase monitoring of compliance, and attempting to actively improve compliance. AEMO is aware of the actions listed in Table 4.

Table 4 DNSP and regulator actions to monitor and improve compliance

Action	Description	Regions where this has been implemented
Commissioning sheets or reports	Require that installers provide mandatory commissioning datasheets or reports on installation and/or a digital close-out, *including a requirement to confirm selection of the 2020 Standard on close-out.*	• Vic (VPN/UE) [29,30] • SA (SAPN)[31]: SmartInstall • Qld (EQL): For systems >30kVA[32]
Commissioning process	Network connection approvals	• SA (SAPN): Traffic light approach adopted with SmartInstall and SmartApply system[33]
Updates to MSO	Updated model standing offer (MSO) to ensure customer consent to make remote changes to inverter settings (via the OEM).	• Vic (VPN/UE[34], Jemena[35], Ausnet[36])
Physical inspections	Conducted on-site inspections of inverters[A]	• TAS (Tasmanian Government electrical safety inspection service) • Australia (CER inspections of 1-2% of systems) • VIC (Solar Victoria, 5% of systems in Solar Homes Program) • Non-SWIS WA (Horizon Power, 2-5% of DPV systems)

[29] Citipower Powercor, 2022. Smart Inverter settings. https://www.powercor.com.au/industry-partners/connections/solar-connections/smart-inverter-settings/

[30] United Energy, 2022. Smart inverter settings. https://www.unitedenergy.com.au/partners/solar-installers/smart-inverter-settings/

[31] SAPN 2023, *Changes are coming to SmartApply and SmartInstall to help improve compliance*, https://www.sapowernetworks.com.au/data/314512/changes-are-coming-to-smartapply-and-smartinstall-to-help-improve-compliance/.

[32] These systems require a Registered Professional Engineer of Queensland to confirm compliance with the 2020 Standard.

[33] SAPN, *Distributed Energy Resource Compliance*, available: https://www.talkingpower.com.au/69013/widgets/359673/documents/222449.

[34] CitiPower, Powercor, and United Energy Model Standing offer for basic connection services for retail customers who are micro embedded generators. March 2022. See Clause 39. Available at: https://media.powercor.com.au/wp-content/uploads/2022/04/04172452/CPPALUE-MSO-for-EG-version-3-AER-approved13317322.1.pdf

[35] Jemena 2022, *MSO for Micro Embedded Generator Basic Connection Services*, Section 5.7, available: https://www.jemena.com.au/documents/electricity/embedded-generation/mso-basic-electricity-connection-micro-eg-v5_from.aspx.

[36] Ausnet 2022, Model Standing Offer for Basic Connection Services Basic Micro Embedded Generation (Inverter Energy System – Battery, Solar, Wind), Section 8.3, available: HYPERLINK "https://www.ausnetservices.com.au/-/media/project/ausnet/corporate-website/files/solar/up-to-30kw/basic-mso-effectivefrom-18-dec-2021-final.pdf"https://www.ausnetservices.com.au/-/media/project/ausnet/corporate-website/files/solar/up-to-30kw/basic-mso-effectivefrom-18-dec-2021-final.pdf

Action	Description	Regions where this has been implemented
Warranty replacements	Technical standards require like-for-like warranty replacements to meet the latest (2020) Standard if the capability exists within the replacement inverter.	• SA (SAPN)[37] • TAS (TasNetworks)[38] • NSW (Evoenergy - ACT)[39]
Volt-VAr monitoring and testing	Introducing processes to analyse and test Volt-VAr responses of inverters in the field, using advanced metering infrastructure (AMI) data	• Vic (VPN/UE) • SA (SAPN) • NSW (Ausgrid, Endeavour, Essential Energy) • WA (Western Power – limited on a small sample) • Qld (EQL) - Pending[B]
OEM remote update requests	Contacted OEMs to request remote updates for devices which did not provide the expected Volt-VAr response	• Vic (VPN/UE) • SA (SAPN) • WA (Western Power – limited on a small sample, Horizon Power) • NSW (Ausgrid)

[A] The inspections are intended to identify noncompliance with the mandated Australian Standard. Physical inspection of whether the inverter is set to the 2015 Standard or 2020 Standard Australia A, B, or C is challenging as it often requires specialised firmware, passwords, or equipment to access the portal. Further discussion is in Section 5.2.
[B] AMI data has been received but not yet analysed.

These audits and increased monitoring of compliance rates by DNSPs, the CER and other parties have provided an important cross-check of the datasets provided voluntarily by OEMs (outlined further in Section 5). The other actions listed also lay an important foundation for further activities to improve compliance and collect accurate data for ongoing compliance monitoring.

The data available suggests that DNSPs have been taking targeted actions to improve compliance. Launching a comprehensive compliance program will likely allow DNSPs to better leverage the effectiveness of actions to improve compliance across their networks. Some recommendations are outlined in Section 7 for consideration.

DNSPs continue to raise concerns that they may not have sufficiently comprehensive governance frameworks to efficiently support and coordinate required actions to achieve and maintain high rates of compliance.

3.2.1 Non-specific installer training courses

AEMO, the Clean Energy Council (CEC) and the Victorian Government collaborated to roll out a voluntary training course developed by AEMO to the CEC installer base. The course informs installers about the mandatory AS/NZS4777.2:2020 Standard, and emphasises the importance of selecting the correct standard at the time of installation. This course is available to installers via the CEC free of charge. At 10 November 2023 (approximately 18-months after the course became available), approximately 68% of installers had completed the course.

It is difficult to assess how much this action has improved compliance, although the variability between compliance outcomes for different OEMs suggests that OEM actions have had a more significant influence on improving compliance rates. The CEC generic installer training may have contributed to the recent improvement in compliance rates, in addition to the device-specific training provided by those OEMs. In the absence of other actions, installer training does not appear to be sufficient in isolation to bring compliance levels to 90% or higher.

[37] SAPN 2021, *TS129 Small EG Connections Technical Requirements – Capacity not exceeding 30kVA*, Section 4.3.1, available: https://www.sapowernetworks.com.au/public/download.jsp?id=318532.

[38] TasNetworks 2023, *Basic Mirco EG Connection Technical Requirements*, Section 4.4.1, available: https://www.tasnetworks.com.au/config/getattachment/52bb97ef-b872-4c17-b394-12cbb38ac55a/tasnetworks-basic-micro-eg-connection-technical-requirements-v3-2.pdf.

[39] EvoEnergy 2022, *Evoenergy Micro Embedded Generation Technical Requirements*, Section 4.11.1, available: https://www.evoenergy.com.au/-/media/evoenergy/documents/emerging-technology/po0845-evoenergy-micro-embedded-generation-technical-requirements.pdf.

4 Datasets

4.1 Data limitations

The OEMs that responded to the data request represent 95% of overall installations in Q1 2023[40]. It is noted that these datasets were provided voluntarily. There are currently no obligations for OEMs to collect data on compliance of their product settings in the field, or to provide this data to external parties. Given the importance of these datasets for monitoring compliance over time, and the implications of DER compliance for power system security[41], the governance arrangements around collection and provision of this data should be reviewed.

The datasets that were provided for this assessment have several important limitations, discussed below.

4.1.1 Data bias based on internet connectivity

OEMs are only able to provide data for inverters that are internet connected. Anecdotal discussions with OEMs suggest that internet-connected devices may exhibit higher compliance rates compared with non-internet connected devices due to the ability for OEMs to remotely update the inverters (these interventions are not always fully accounted for in the OEM datasets provided), as well as likely increased care taken by installers during commissioning for this subset of inverters. Connectivity rates vary significantly between OEMs and many OEMs were not able to provide robust quantitative estimates of the proportion of their fleet that is not internet connected[42].

Figure 11 illustrates the data available for this assessment, for the DER fleet installed during Q1 2023, weighted by market share. It is estimated that approximately 65% of the DER fleet installed in Q1 2023 is internet connected and visible to OEMs[43], and therefore informs the compliance estimates presented in this report. Of the 65% that was internet connected and visible to OEMs, approximately one-third had data provided for a limited sample size. Compliance rates observed for each OEM in their online inverters were assumed to apply to their entire fleet.

[40] Based on CER data.

[41] AEMO (April 2023) Compliance of Distributed Energy Resources with Technical Settings, Section 3, https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en&hash=FC30DF5A3B9EF853093709012242D897

[42] Some OEMs may have internet connectivity rates as low as 40%.

[43] Eleven OEMs provided estimates of internet connectivity rates for their fleet. For two OEMs who have not provided internet connectivity rates, the average of the other OEMs was assumed.

Figure 11 Visibility of the Q1 2023 inverter installations provided by OEM datasets

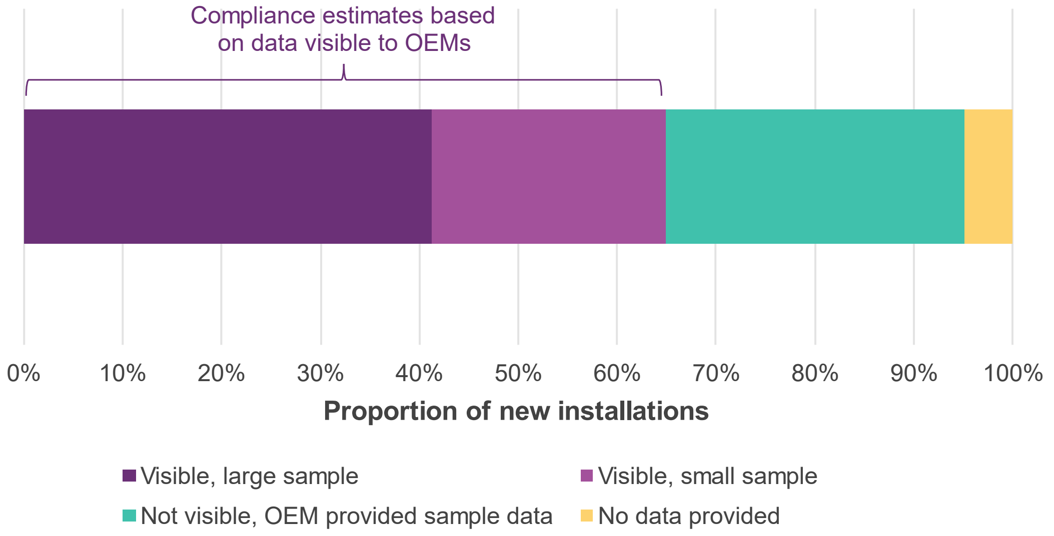
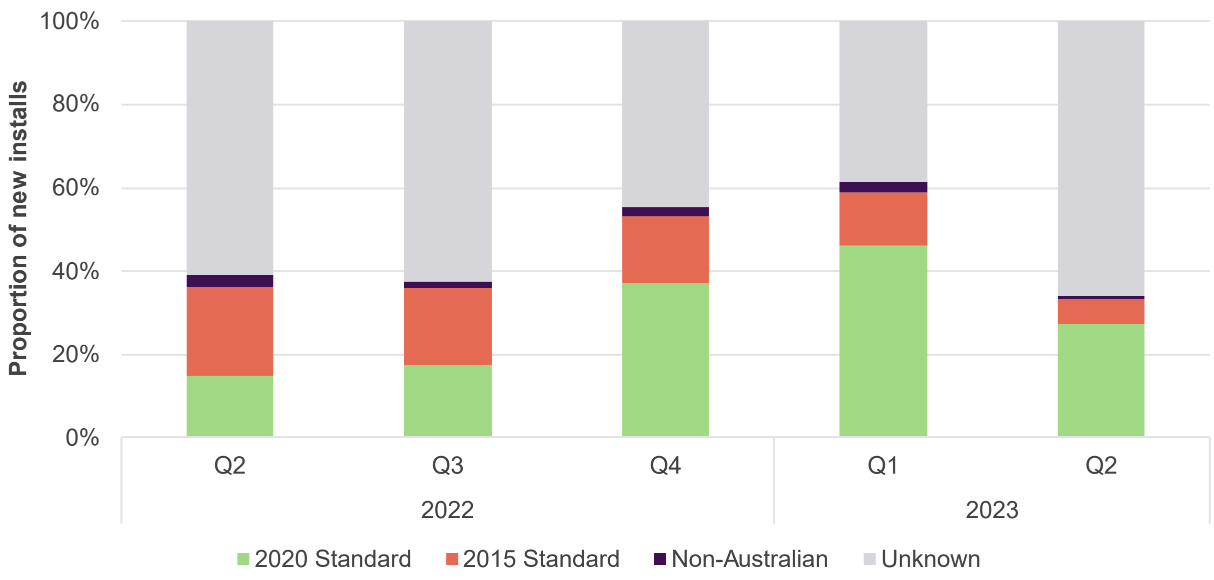


Figure 12 illustrates in grey as "unknown" the proportion of the fleet for which there was no direct visibility of the settings applied from OEM datasets (either because it is not internet connected, or no data was supplied for the OEM). For the assessments in this report, it has been assumed that the visible proportion of each OEM's fleet provides a representative sample reflective of general settings applied across their whole fleet.

Figure 12 Estimates of quarterly compliance to the 2020 Standard, accounting for non-internet connected fleet



The OEMs included in the aggregation vary by quarter, based on which OEMs responded to the data request. Market coverage varies from 52% to 95%, and internet connectivity is understood to vary between approximately 40-100%. Proportions are scaled by market share in Q1 2023 and estimated internet connectivity. "Unknown" indicates an estimate of the non-internet connected portion of the fleet, and limited market coverage due to the available OEM datasets.

4.1.2 Small sample sizes

Seven OEMs provided relatively complete datasets for the majority of installations over the period of interest. Six OEMs provided only small samples of 100-200 installations per quarter. For some OEMs, the data extraction was manual and they were therefore only able to provide this information on a limited sample of inverters. Small samples increase uncertainty in the overall compliance estimate.

Three OEMs required a list of serial numbers in order to extract the necessary data, because they did not have information on the installation location of their inverters and therefore could not identify those installed in Australia. AEMO and DNSPs have some data on serial numbers from the DER Register, but this information is incomplete and of low quality since in most cases installers need to manually enter the serial numbers, a highly error prone process. Of the installations in the DER Register, only 75-85% were found to have valid serial numbers (that OEMs could correctly match with actual serial numbers in their databases).

4.1.3 Regional information

Not all datasets provided by OEMs contained regional information (e.g. state or postcode). For the datasets that did contain regional information, often not all regions were covered. Regional data was available in the data sets provided by three OEMs in Q1 2022 and seven to eleven OEMs in Q1 2023 (depending on the region).

Locational data is required to assess the correct application of the regional settings (Australia A, B or C).

4.1.4 Challenges in data consistency and handling

Preparing this analysis involved considerable efforts by OEMs to extract and share data, and by AEMO and UNSW to clean and analyse the data. Many OEMs did not have simple processes implemented to extract these datasets in bulk, and the datasets provided were not in standardised formats, and were of varying quality. Collating the data and ensuring accurate understanding of all actions taken is resource intensive work, and would not be possible without extensive voluntary engagement of OEMs.

4.2 Recommendations on data

It is recommended that:

- OEMs improve their processes and tools for efficiently collecting, storing and extracting data on the technical settings applied to their products in the field (including software and firmware updates), both at the time of installation and on an ongoing basis.
- OEMs collaborate to develop and apply standardised formats for these datasets, and standardised processes for collecting and sharing the data.
- Governance frameworks are improved to require that this data is accurately collected, stored, and can be provided regularly to AEMO and NSPs to monitor rates of compliance of the settings applied to devices in the field, both at the time of installation and on an ongoing basis. This data is critical for AEMO to estimate credible contingency sizes and maintain the power system within a secure technical envelope.
- The processes by which the DER Register is populated are improved, to facilitate accurate data collection, including data on:
  - Technical settings
  - Serial numbers
  - Replacements and retirements of devices.

- DNSPs develop systems and tools to monitor performance of various functions in-field, to provide an ongoing cross-check of device performance. This includes:
  - Volt-Var / Volt-Watt performance assessment to become standard practice for all DNSPs.
  - Developing tools and monitoring systems to directly assess performance of as many other functions as possible, such as disturbance ride-through, frequency-watt modes, ramp rate limitations, export limitations, and so on.

5 Other measures of compliance

5.1 Volt-VAr assessment

Some DNSPs[44] have undertaken analysis of Volt-VAr compliance of inverters in the field. This approach uses advanced metering infrastructure (AMI) data to observe the reactive power contributions of inverters when grid voltages at the site are in a range that a response should be observable if the inverter is set correctly to the 2020 Standard region code that applies to the DNSP's network (with relatively wide error margins applied, allowing for measurement uncertainty). Further details are outlined in AEMO's April report[45].

Overall, in-field Volt-VAr compliance rates observed in SAPN, Endeavour Energy and VPN/UE's networks for Q1 2023 installs were measured at around 60-85%, which roughly aligns with estimated compliance based on OEM data (Section 2.2 and Figure 13). This helps to confirm the validity of the OEM voluntarily provided datasets, and the extrapolation approaches applied. Some New South Wales DNSPs have indicated they believe compliance is somewhat lower in their networks; AEMO is working with them to understand differences in the datasets and analysis methods.

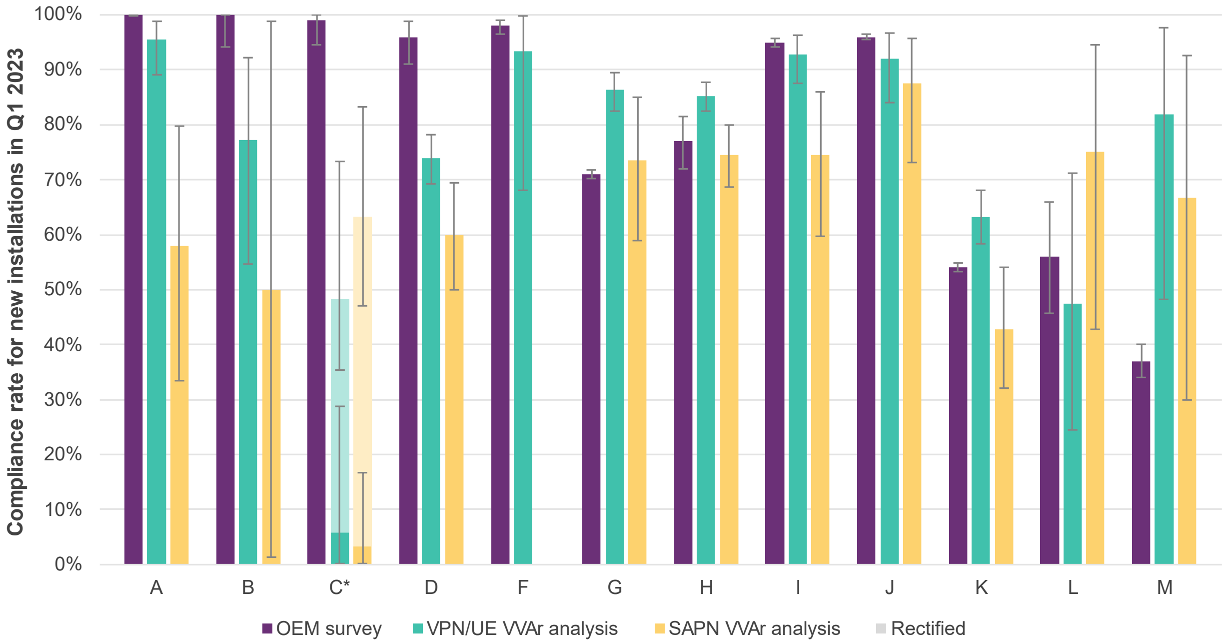
Figure 13 compares the compliance rates based on OEM self-reported data, against the compliance rates estimated from Volt-VAr assessment for each OEM individually in the VPN/UE and SAPN Volt-VAR datasets. In most cases, these are relatively well aligned (accounting for small sample sizes in some cases), which provides validation of both methods for estimating compliance.

For one OEM, their self-reported data indicated the selection of the 2020 Standard was close to 100%, while the Volt-VAr assessment indicated compliance of less than 5%. This issue is in the process of being rectified. The case study in Section 5.1.1 provides more details.

[44] AEMO is aware of VPN/UE, SAPN, Western Power, Ausgrid and Endeavour Energy to date.

[45] AEMO, April 2023, *Compliance of Distributed Energy Resources with Technical Settings*, Section 2.4, available: https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en.

Figure 13 Comparison of OEM self-reported compliance rates against AMI Volt-VAr assessment



Error bars indicate uncertainty related to the sample sizes of the data. OEM E has been removed from this plot due to small sample sizes. OEM F was not included in SAPN's analysis.
*OEM C has been working with VPN/UE and SAPN to rectify Volt-VAr response on their inverters, and has seen improved Volt-VAr compliance in Q4 2023. See case study in Section 5.1.1.

5.1.1 Case study: Ausgrid

Ausgrid has also used AMI data to assess Volt-VAR compliance in their network. Ausgrid applied a somewhat different methodology to SAPN and VPN/UE, which resulted in a much lower compliance estimate. When applying the identical Volt-VAr compliance analysis approaches taken by SAPN and VPN/UE to the Ausgrid AMI data for Q1 2023 installations, compliance rates were estimated at 50-60%, slightly lower than the rate reported by other networks.

State-based OEM data also indicates slightly lower compliance in New South Wales compared to South Australia and Victoria for 2023 Q1 (~70% in NSW, vs 80-85% in Victoria and SA, as shown in Figure 5). AEMO is working with Ausgrid to investigate possible causes for this slightly lower compliance rate.

Based on the evidence available at present, AEMO has assumed that the ~70% compliance rate reported by OEMs for New South Wales is reflective of compliance with disturbance ride-through requirements, and that the 50-60% compliance rate for Volt-VAr in Ausgrid's network reflects poorer compliance to the Volt-VAr requirements under the 2020 Standard.

This case study highlights the importance of using multiple datasets across a range of regions to analyse compliance, as well as the importance sharing learnings across DNSPs and having consistent approaches to analysing Volt-Var compliance.

5.1.2 Case study: Incorrect implementation of Volt-VAr despite correct Standard selection

The data provided to AEMO by OEM C for installations during Q1 2023 indicated that nearly 100% of their inverters were set correctly to the 2020 Standard. However, both VPN/UE and SAPN observed that only around 5% of inverters from this OEM were correctly delivering the specified Volt-VAr functions. Further investigations have indicated that the Volt-VAr response was not enabled by default for this OEM's inverters, even though the inverters were set to the 2020 Standard Australia A. The OEM indicated that they have started rolling out a batch firmware upgrade to rectify this issue.

Figure 13 illustrates that the compliance rates for a sample of the OEM's 2023 Q1 installs have improved due to their recent rectification actions. SAPN repeated their Volt-VAr assessment for a selection of inverters and found that compliance had increased to 63%, noting retrospective rectification by OEMs relies on installers providing accurate serial numbers to DNSPs post installation, inverter internet connectivity, and the ability to perform remote updates. Technical capabilities in these areas vary across DNSPs and OEMs.

This case study highlights the importance of independent measures of compliance, including direct monitoring of performance of functions such as disturbance ride-through and Volt-VAr response. A variety of metrics and data sources to confirm performance in the field are essential.

5.2 Physical site inspections

Physical inspection programs are undertaken by a range of organisations across Australia. These provide another important cross-check against other measures of compliance.

5.2.1 CER SRES audits

The CER's physical inspection program is undertaken as part of its administration of the Small-scale Renewable Energy Scheme (SRES)[46]. 1-2% of DPV installations across Australia where STCs have been created are selected randomly from those completed in the previous 12-18 months on a rolling basis[47]. Outcomes from previous rounds of the CER audits were summarised in AEMO's April report[48].

In the latest FY22-23 round of audits, the CER looked at installations from January 2021 to September 2021 (prior to the December 2021 requirement for systems to be on the 2020 Standard). New data for FY23-24 will be available next year and will analyse compliance with the 2020 Standard.

5.2.2 Solar Victoria – Solar Homes Program audits

In Victoria, 5% of systems installed under the Solar Homes Program are selected for a safety audit[49]. Solar Victoria have recently conducted a trial where inverter technical settings are checked as part of this audit.

The audit targeted sites which had been analysed by VPN/UE for Volt-VAr compliance, allowing a cross-check of these compliance monitoring methods. Physical audits were conducted at 164 sites with inverters from four different OEMs. Key findings included:

[46] Discussed further in Section 2.2 of AEMO's April 2023 report, *Compliance of Distributed Energy Resources with Technical Settings*, available: https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en. Further information on the SRES scheme is available at: http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Agents-and-installers/Small-scale-Renewable-Energy-Scheme-inspections.

[47] This time delay is to allow for STCs to be claimed.

[48] AEMO (April 2023) Compliance of Distributed Energy Resources with Technical Settings, Section 2.2, https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en&hash=FC30DF5A3B9EF853093709012242D897

[49] Solar Victoria, *Safety audit for your solar system*, available: https://www.solar.vic.gov.au/safety-audit-your-solar-system.

- Of the sites listed by the DNSP as adequately delivering the Volt-VAr functions, 58% were set to the 2020 Standard.[50]
- Of the sites listed by the DNSP as not adequately delivering the Volt-VAr functions, 91% were not set to the 2020 Standard. One particular model of inverter by an OEM was set to the 2020 Standard but did not appear to be performing Volt-VAr to the expected level.

Previous analysis of Volt-VAr data against inverter technical settings found similar outcomes[51]. These findings indicate that Volt-VAr assessment method is a good starting point for DNSPs to identify non-compliances and may serve as a means to select key sites to begin addressing issues. However, the method cannot be relied on as the sole approach for detecting non-compliant installations.

5.2.3 Horizon Power audits

In Western Australia, Horizon Power (DNSP for non-SWIS areas of the network) inspects 2-5% of their DPV sites to check they meet technical requirements. The inspection includes confirming the 2020 Standard settings (Australia C), as well as other internal settings.

5.2.4 Tasmanian Government electrical safety inspections

The Tasmanian Government's electrical safety inspection service[52] conducts onsite inspections of notifiable electrical installation work, which cover the entire system including the roof top installation of the solar panels, inverter, switchboard connections and interconnecting wire systems. To date, this inspection program has focused on safety.

5.2.5 Difficulties identifying the Standard in site audits

Contractors in the CER inspection program have consistently been unable to confirm which internal settings and/or Standard were applied for approximately 50% of inverters inspected. The Tasmanian Government's on-site electrical safety inspection service and Solar Victoria's safety audit have also noted similar challenges in identifying inverter settings during physical inspections. It is possible that some settings are not visible for a range of reasons, including password protection and accessibility of the interface.

OEMs could consider updating their product menu designs to improve access to information on inverter internal settings, without requiring passwords or complex accessibility requirements. This would improve visibility during physical site inspections and allow more robust data collection.

5.3 Laboratory bench testing of inverters

AEMO is collaborating with researchers at UNSW Sydney and University of Wollongong to perform laboratory bench testing of individual inverters and loads, to investigate potential risks related to their performance under

[50].Volt-VAr became mandatory for new installations in Victoria in November 2019. Hence some sites on the 2015 Standard are expected to have Volt-Var enabled.

[51] Details in Section 2.4.2 and Table 9 of AEMO's April 2023 report, *Compliance of DER with technical settings*, available: https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en.

[52] Tasmanian Government, *Electrical safety inspection service*, available: https://www.cbos.tas.gov.au/topics/technical-regulation/electrical-standard-safety/electrical-safety-inspection-service-techsafe-australia.

various grid conditions[53,54]. The project includes undertaking a suite of laboratory tests to confirm the behaviour of off-the-shelf inverters set to the 2020 Standard, testing their responses to various types of power system disturbances (e.g., voltage dips, frequency changes, phase angle jumps, and so on), to determine possible impacts on power system security.

To date, 52 inverters have been tested against a wide suite of possible disturbances. The majority of inverters have performed the ride-through behaviours as desired, indicating that the standard test procedures defined in the 2020 Standard are broadly sufficient to specify and test for the necessary ride-through behaviours.

For two OEMs,, the laboratory bench testing has indicated that some of their products deviate from the requirements of the 2020 Standard, and in some cases do not demonstrate adequate disturbance ride-through behaviours as defined in the 2020 Standard. This perhaps indicates a flaw in the governance process for inverter testing, and for checking test results to support inclusion on the list of approved inverters for sale in Australia. AEMO is in discussions with these OEMs and also with the CEC and CER on these findings. Investigations are continuing[55].

This issue indicates the importance of independently testing a sample of inverters to confirm that products accredited against the Australian Standards behave as required to support system security.

5.4 Inverter internal configuration updates

OEMs develop and release updates to their fleet of inverters for many reasons, including addressing identified cyber security vulnerabilities. Updates to inverter internal configurations have been observed to present certain challenges for maintaining 2020 Standard compliance.

Updates can change fundamental performance properties of an inverter, and may change the behaviour of an inverter in the tests involved in accreditation with the 2020 Standard. Across a range of OEMs, DPV inverters of the same make and model on different firmware versions have been observed to exhibit different behaviours, both in-field and in bench tests. Some observed behaviours were non-compliant with Volt-VAr or disturbance ride-through requirements of the 2020 Standard, even though the 2020 Standard had been selected for these products.

Updates are rolled out and implemented at the discretion of OEMs, installers and consumers who own DER assets. Some updates are critical for other reasons, e.g., cyber security. At present, these updates are a ‘black box’, and there are no governance arrangements in place to assess their potential impact on the power system. There is no clear guidance on when an OEM should repeat accreditation testing, and how to confirm and check that any firmware or software updates do not fundamentally change performance of the device.

Furthermore, update versions may be heterogenous across an OEM fleet. Fleet-wide updates are usually pushed via the internet, meaning non-internet connected inverters are likely to be on older versions which may respond differently to power system disturbances. Further, not all OEMs have the ability to remotely contact large numbers of their inverter fleet, which may mean that firmware and settings vary depending on when an inverter was

[53] Funded through the CSIRO Global Power System Transformation (GPS-T) consortium, Topic 9, https://www.csiro.au/en/research/technology-space/energy/g-pst-research-roadmap

[54] All results available at: http://pvinverters.ee.unsw.edu.au/Summary

[55] Until the issue is resolved, for all analysis AEMO is assuming that a subset of products from this OEM which do not ride through disturbances in bench tests will not perform disturbance ride-through behaviours, even if set to the 2020 Standard.

commissioned. In most cases, there is little data available to assess or track the firmware and settings operating on each device in the field. This makes prediction of fleet-wide inverter behaviour challenging.

Firmware updates which cause issues in inverter behaviour that impact power system security may not be diagnosed until unexpected in-field performance occurs. At present, observations of in-field inverter behaviour are patchy and limited to areas where there is AMI data or other metering devices. Assessing in-field behaviours of inverters is therefore becoming increasingly important as levels of DER continue to grow.

5.4.1 Case study: Firmware settings non-compliant with 2020 Standard

As noted in Section 5.1, one OEM did not have Volt-VAr response enabled by default in their firmware for their fleet of recently installed inverters, even though these inverters were set to the 2020 Standard. This resulted in OEM-reported compliance rates being much higher than in-field Volt-VAr observations. SAPN and VPN/UE are currently in discussion with the relevant OEM. The OEM has indicated that they are rolling out a batch firmware update to rectify this issue for internet-connected sites. Further details are in Section 5.1.1.

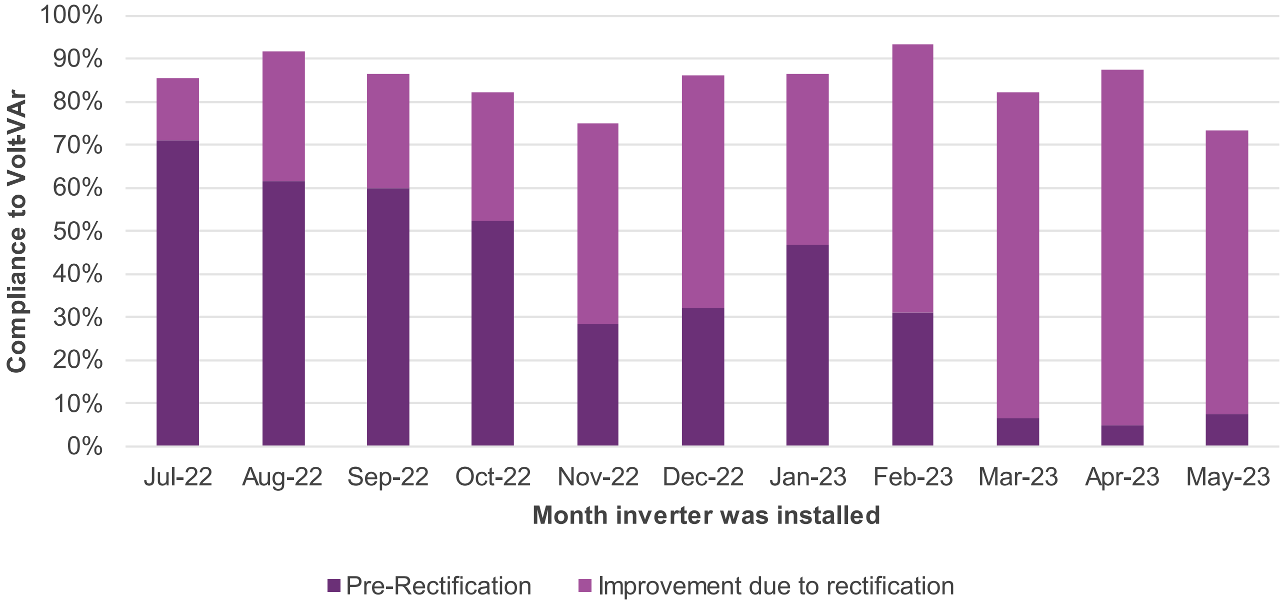
5.4.2 Case study: Batch settings incorrect in shipment

In May 2023, VPN/UE detected a noticeable drop in compliance in their Volt-VAr compliance assessments for a specific series of inverters produced by one OEM, while compliance remained steady across other series manufactured by the same OEM. The networks worked with the OEM to address compliance and the OEM discovered that they had incorrectly applied the Volt-VAr settings for this inverter series.

12,500 inverters (with a total rated capacity of 60 MW) were estimated to have been impacted. Within a few weeks, the OEM performed a remote firmware update on 75% (10,000) of affected inverters throughout Australia. 15% (2,400) of affected inverters were offline and could not be updated. The OEM has informed VPN/UE that the new firmware would fix the Volt-VAr response curve as per the 2020 Standard, and confirmed that future inverters would have the new firmware.

Figure 14 shows remote rectification increased compliance on the inverter series to above 70%. A greater proportion of inverters installed in April-May 2023 were affected, which meant more sites needed rectification to bring compliance up to the level of the earlier installations.

Figure 14 VPN/UE analysis of the proportion of sites of one OEM series correctly delivering Volt-VAr functions in their network, pre- and post-rectification



5.4.3 Importance of in-field performance monitoring

These case studies highlight that there may be inconsistencies in inverter settings (software or firmware) which can impact inverter response to power system events, but are challenging to detect without in-field measurements of compliance. Ongoing performance monitoring is vital in identifying and rectifying compliance issues.

5.5 Customer complaints

In their investigation of customer complaints, several DNSPs have observed that many inverters associated with customer complaints are on the incorrect standard (e.g. the 2015 Standard instead of the 2020 Standard), or have incorrect technical settings (e.g. Volt-VAr or Volt-Watt disabled on an inverter that was set to the 2020 Standard). Ausgrid has observed that 80% of their customer complaints can be resolved by reconfiguring inverters to the correct 2020 Standard settings.

6 Implications for disturbance ride-through capabilities

6.1 Significance of disturbance ride-through capabilities

Poor compliance with the 2020 Standard means that DPV may demonstrate shake-off behaviours in power system disturbances. DPV shake-off behaviours increase the size of the largest credible contingency. This has a series of flow-on consequences, including:

- Increased requirements for frequency control services
- Increased need for DPV curtailment
- Reducing network stability limits
- Reducing windows for planned network outages
- Increased risks for non-credible contingencies

These factors increase the need for market intervention, increase system costs, and decrease the DER hosting capacity of the network. Further detail is elaborated in AEMO's April report[56].

AEMO needs to quantify the size of the total DPV fleet that may demonstrate shake-off behaviours, to ensure suitable operational arrangements are in place to maintain the power system within a secure technical envelope.

This section provides an estimate of the ride-through capability of the DPV fleet, based on compliance observations. This provides an input to operational processes that account for DPV ride-through behaviours.

6.2 Projection of continued compliance improvements

Figure 15 provides an estimated trajectory for likely further improvements in compliance for new installations, accounting for observed impacts of ongoing OEM activities (for example, assuming continued improvement for certain OEMs as menu updates roll out in the field) and any further activities that OEMs have agreed to take at this time. Based on actions already underway and committed, this suggests compliance for new installations improving from ~80% in Q2 2023 to just under 90% at the end of 2025, and plateauing thereafter in the absence of any further actions.

[56] AEMO (April 2023) Compliance of Distributed Energy Resources with Technical Settings, Section 3, https://aemo.com.au/-/media/files/initiatives/der/2023/compliance-of-der-with-technical-settings.pdf?la=en&hash=FC30DF5A3B9EF853093709012242D897

Figure 15 Estimates of compliance for new installations

6.3 DPV growth rates and replacement rates

DPV installation rates in Australia started reaching meaningful levels during the period 2010-2013 (with approximately 3 GW of DPV installed in Australian grids by the end of 2013). Based on an inverter life-cycle duration of approximately 10-15 years, this means that some of the new installations occurring in the NEM will now be replacements. These replacements should be installed with the 2020 Standard applied, and therefore will reduce the stock of legacy inverters that demonstrate DPV shake-off behaviours in power system disturbances.

Minimal data is available on DPV replacements. Given this will be a critical input to operational processes (to estimate the total size of the DPV fleet, and the proportion of the inverter fleet that may demonstrate shake-off behaviours), improved data is required for estimation of replacement rates.

For this analysis, an assumption of inverter replacement after 10 years of operation was applied.

Historical DPV installation data was sourced from the APVI[57]. Forecast growth rates for DPV for the NEM were assumed as per the AEMO 2023 ISP projections, for the step change scenario[58]. This scenario projects DPV installed capacity in the NEM growing from just under 20 GW at the start of 2024 to 25 GW in 2026. For WA growth rates were based on the AEMO 2023 WEM Electricity Statement of Opportunities[59].

[57] https://pv-map.apvi.org.au/analyses

[58] AEMO (2023) Inputs Assumptions and Scenarios Report, https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-inputs-assumptions-and-scenarios-report.pdf?la=en

[59] AEMO (August 2023) 2023 Wholesale Electricity Market Electricity Statement of Opportunities, https://aemo.com.au/-/media/files/electricity/wem/planning_and_forecasting/esoo/2023/2023-wholesale-electricity-market-electricity-statement-of-opportunities-wem-esoo.pdf?la=en

6.4 Projection of disturbance ride-through capabilities

Figure 16 provides a forward projection of the estimated proportion of the total DPV fleet in the NEM that is expected to correctly perform the necessary disturbance ride-through behaviours (based on the assumptions outlined above). This has been estimated as follows:

- DPV inverters set to the 2020 Standard are assumed to perform disturbance ride-through (with the exception of one model which has demonstrated poor behaviour in laboratory testing, as discussed in section 5.3).
- Three OEMs have said that inverters on the 2020 firmware will ride-through even if the 2015 Standard is selected. These are included as “may ride through, but incorrect standard”. It is noted that this behaviour has not been validated in the field or with any evidence of laboratory testing provided, and is based on self-reporting.
- All other DPV inverters that are not configured to the 2020 Standard are assumed to have disturbance ride-through characteristics similar to inverters under the older 2015 Standard (and therefore will demonstrate shake-off behaviours in disturbances in a similar manner to these legacy inverters). In power system studies, AEMO will assume that non-compliant inverters demonstrate shake-off behaviour as per the power system models calibrated based on measurements of these legacy inverters[60].

OEM compliance rates are weighted by state-based market share in Q1 2023 (with this market share assumed to remain stable over time).

Figure 16 Ride-through capabilities of the installed DPV fleet in the NEM (historical and future)

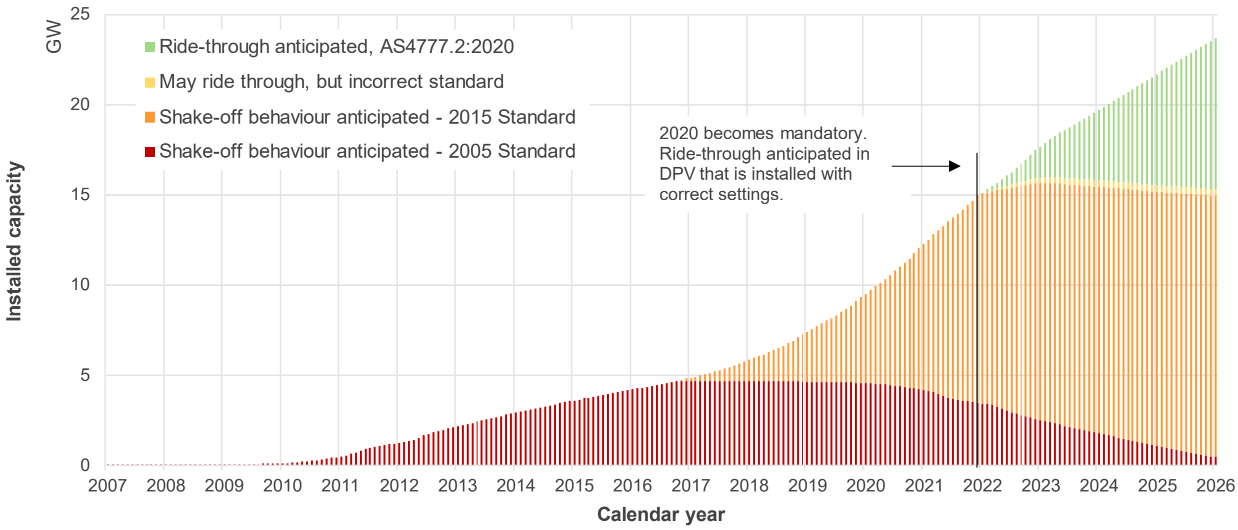
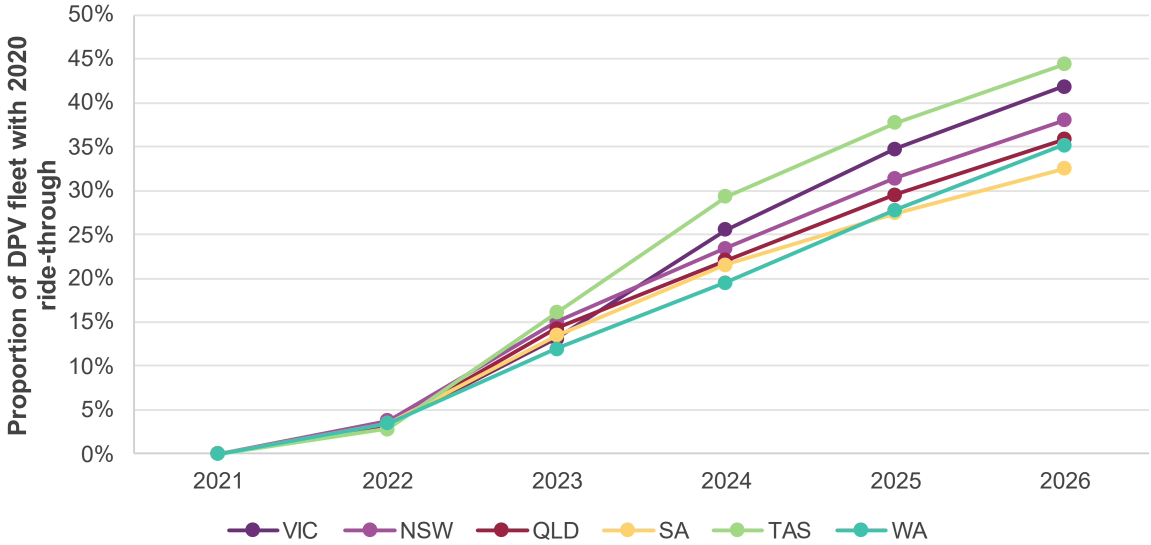


Figure 17 illustrates the region-by-region proportion of the total DPV fleet expected to deliver disturbance ride-through behaviours as per the 2020 Standard. As of June 2023 approximately 15% of the total NEM fleet (3GW) are estimated to have this capability. This is forecast to approach 40% of the fleet (10GW) in 2026. Projections of fleet capacities, based on assumed annual replacements and annual compliance rates is supplied in Appendix A1.

[60] AEMO (November 2022) PSSE models for load and distributed PV in the NEM, https://aemo.com.au/-/media/files/initiatives/der/2022/psse-models-for-load-and-distributed-pv-in-the-nem.pdf?la=en

Figure 17 Region by region ride-through capabilities of the installed DPV fleet



7 Next steps and recommendations

Recommended target of >90% compliance for inverters installed from December 2023

AEMO continues to recommend a target of at least **90% of inverters installed from December 2023 compliant to the 2020 Standard**, with further improvement thereafter. Improving compliance mitigates risks to system security and delivers benefits to customers through increased DER hosting capacity (more DER able to be installed) and minimised intervention costs. The findings in this report indicate that proactive actions taken by many stakeholders (particularly by the OEMs who have updated product menus and commissioning processes to better assist installers in selecting the correct grid codes) has made significant progress towards this goal, but further action remains required.

Detailed recommendations to help achieve this goal are summarised in Table 5.

Table 5 Recommendations

Key parties	Proposed actions
OEMs	• **Improve compliance:** Pursue all available short term actions immediately to better support installers in selecting the correct standard. This analysis suggests that the most effective short-term actions have been: – Remove or hide legacy grid codes – Apply location-based default settings (e.g. using geolocation via the commissioning app) – Move legacy grid codes to the bottom of the menu, and clearly label them as "OBSOLETE" – Regularly perform remote updates where possible for all internet connected systems (including rectification of those already installed with incorrect settings) • **Innovation:** OEMs to innovate to improve product menus and commissioning processes to maximise in-field compliance for their devices. • **Data:** – Improve ability to extract and share comprehensive datasets on settings applied to devices in the field, both at the time of installation and for monitoring on an ongoing basis. – Collaborate on the development of standardised dataset formats for settings applied to devices in the field. • **Firmware updates:** Maintain accurate records of firmware updates, including: – What firmware is applied to each device in the field – Expected inverter performance with respect to AS/NZS4777.2:2020 requirements for each firmware version. • **Site inspections:** Support physical site inspections by improving access to information on inverter internal settings and/or Standards so that they can be identified more easily. At present some settings are not visible for a range of reasons (including password protection and site or menu accessibility).

<table>
<tr><th>Key parties</th><th>Proposed actions</th></tr>
<tr><td>DNSPs</td><td>Compliance monitoring: All DNSPs implement programs to monitor in-field compliance in their networks. This could include Volt-Var / Volt-Watt performance assessment becoming standard practice for all DNSPs, as well as exploring other methods (e.g. direct communication with inverters).
Performance monitoring: Collaborate with AEMO on a program of continued uplift in tools and capabilities for analysis of inverter performance in the field and event analysis. Including:
– Performance monitoring on a representative sample of DER inverters to support in-field assessment of ride-through and power quality performance.
– Expansion of high speed (~20ms) data collection in distribution networks, to support model validation and assess aggregate DER performance.
Improve compliance: Innovation and collaboration between DNSPs to explore suitable pathways for long-term management of compliance. Possible areas of investigation could include:
– Improve commissioning processes: Update connection and registration processes to require mandatory commissioning datasheets from installers and/or a digital close-out, including a requirement to confirm selection of AS/NZS4777.2:2020[61].
– Update Model Standing Offer (MSO)[62]: to ensure customer consent to make remote changes to inverter settings for the purpose of rectifying compliance.
– Rectification processes[63]: Work with OEMs, retailers, installers and others[64] to implement processes that rectify incorrect settings, while managing cybersecurity risks, unit corruption failure, or other consequences (such as incorrect firmware creating other unintended consequences).</td></tr>
<tr><td>Installers</td><td>Complete training on technical settings: Undertake training on setting new installations to the 2020 Standard, and apply settings correctly.</td></tr>
<tr><td>Clean Energy Regulator (CER) and/or Energy Safety Regulators</td><td>Improve compliance: Investigate opportunities to improve compliance in the short-term, possibly leveraging the CER's role in the product listing process, considering incentives and enforcement, and exploring opportunities around training programs for installers.</td></tr>
<tr><td>Jurisdictions</td><td>Long term governance: Implement suitable long-term governance frameworks to develop, introduce and implement DER technical standards and address the existing limitations in compliance regulatory frameworks[65]. This could include:
– Noting the current inability to regulate the full range of DER parties (including OEMs who have significant influence over DER compliance rates), and seeking pathways to more explicitly recognise these parties as central stakeholders in governance arrangements.
– Clarifying which organisations have responsibility for monitoring and enforcing the various elements of compliance at different stages of the life cycle of DER devices (manufacture and supply, installation, and ongoing operations).
– Clarifying the datasets that should be collected and made available for assessing ongoing compliance, and the necessary governance arrangements to ensure these datasets are sufficient for enforcement and application of incentives and penalties, and made available to the parties that require them.
– Suitable processes for managing impacts of firmware and software updates on technical performance.</td></tr>
</table>

[61] This could potentially be made a requirement before metering changes, or in collaboration with jurisdictions and regulators, this could also be linked to installer accreditation in the SRES scheme or tied to obligations in state-based schemes.

[62] This may not be applicable across all regions, for example in the South West Interconnected System (SWIS) the MSO is agreed between the energy retailer and the customer.

[63] This may not be applicable across all regions, for example in the SWIS remote communications and monitoring will be effected by Synergy.

[64] For example, DER Integration API Technical Working Group (DERIAPITWG) updates to Common Smart Inverter Profile – Australia (CSIP-Aus).

[65] This recommendation aligns with the findings of the AEMC's Review into consumer energy resources technical standards, its final report can be found here: https://www.aemc.gov.au/sites/default/files/2023-09/RCERTS%20Final%20Report.pdf.

Key parties	Proposed actions
All stakeholders	• **Standardised data formats:** Develop standardised dataset formats for settings applied to devices in the field, and explore pathways to facilitate standardised reading and writing of inverter settings[66]. • **DER Register data:** Improve the quality of data uploaded to the DER Register. Consider consolidation of data collection across multiple mechanisms (i.e. integrate data from the SRES program). Consider how to improve data on replacements and retirements and include accurate serial numbers. • **Standardised test reporting:** Develop a standardised test reporting format that all accredited test labs are required to follow and align to. This includes specification of results reporting to ensure that there is consistency in assessment and approval of accredited devices. • **External devices:** Ensure appropriate test procedures and governance arrangements so that any external devices that are typically installed on a customer site with the inverter are included as part of the test setup used for testing accreditation with the 2020 Standard.

AEMO is actively engaging with all the parties noted in the table above and will continue to monitor compliance rates with the 2020 Standard based on the datasets available. AEMO is implementing progressive updates to operational processes to reflect the evolution of compliance rates over time.

Stakeholders may contact DERdata@aemo.com.au for any queries or feedback on this report.

[66] Options such as enhancing CSIP-Aus to define control messages to read and update individual inverter settings or common file formats could be explored.

A1. Disturbance ride-through estimates

The assumptions applied to the forward projections of disturbance ride-through of the DER fleet in each region are provided here for reference.

Table 6 VIC

	2021-22	2022-23	2023-24	2024-25	2025-26
Total installed capacity (MW)	3,673	4,201	4,916	5,559	6,201
Annual replacements (MW)	159	168	153	171	146
New installs with ride-through	16%	62%	81%	83%	84%

Table 7 NSW

	2021-22	2022-23	2023-24	2024-25	2025-26
Total installed capacity (MW)	5,098	6,076	6,700	7,372	8,044
Annual replacements (MW)	110	140	154	198	175
New installs with ride-through	19%	65%	84%	86%	88%

Table 8 QLD

	2021-22	2022-23	2023-24	2024-25	2025-26
Total installed capacity (MW)	4,976	5,702	6,140	6,646	7,152
Annual replacements (MW)	284	390	224	218	187
New installs with ride-through	16%	58%	81%	84%	86%

Table 9 SA

	2021-22	2022-23	2023-24	2024-25	2025-26
Total installed capacity (MW)	2,065	2,330	2,461	2,615	2,768
Annual replacements (MW)	163	111	138	72	67
New installs with ride-through	16%	65%	81%	83%	83%

Table 10 TAS

	2021-22	2022-23	2023-24	2024-25	2025-26
Total installed capacity (MW)	238	277	302	337	371
Annual replacements (MW)	11	26	29	12	11
New installs with ride-through	15%	59%	80%	82%	84%

Table 11 WA

	2021-22	2022-23	2023-24	2024-25	2025-26
Total installed capacity (MW)	2,204	2,472	2,673	2,917	3,163
Annual replacements (MW)	103	82	73	99	110
New installs with ride-through	18%	63%	83%	84%	85%

A2. Glossary

Term	Definition
2005 Standard	AS4777.3:2005 Australian Standard
2015 Standard	AS/NZS4777.2:2015 Australian Standard
2020 Standard	AS/NZS4777.2:2020 Australian Standard
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AMI	Advanced Metering
API	Application Programming Interface
ARENA	Australian Renewable Energy Agency
AS/NZS47777.2	Australian Standard – Grid Connection of energy systems via inverters: Inverter requirements. In this document this refers to either the 2015 or 2020 editions of the Standard.
CEC	Clean Energy Council
CER	Clean Energy Regulator
VPN/UE	Victoria Power Networks and United Energy (CitiPower, Powercor and United Energy)
CSIP	Common Smart Inverter Profile
DER	Distributed Energy Resources
DERIAPITWG	Distributed Energy Resources Integration Application Programming Interface Technical Working Group
DNSP	Distribution Network Service Provider
DPV	Distribution network-connected, Solar Photovoltaic
FCAS	Frequency Control Ancillary Services
GW	Gigawatt, a unit of active power
ISP	Integrated System Plan
MSO	Model Standing Offer
MW	Mega Watt, a unit of active power
NEM	National Electricity Market
NSP	Network Service Provider
OEM	Original Equipment Manufacturer
PV	Photovoltaic
SA	South Australia
SAPN	South Australian Power Networks
SRES	Small-scale Renewable Energy Scheme
STC	Small-scale Technology Certificate
SWIS	South West Interconnected System
UE	United Energy
UNSW	University of New South Wates
VA	Volt Amperes, a unit of apparent power
Volt-VAr	Response settings applied in the inverter that varies its reactive power output in response to the voltage at its grid-interactive port

Term	Definition
Volt-Watt	Response settings applied in the inverter that varies its output power in response to the voltage at its grid-interactive port
VPN	Victoria Power Networks
VPP	Virtual Power Plant
WA	Western Australia
WEM	Wholesale Electricity Market