Collaboration on Energy and Environmental Markets

UNSW SYDNEY

10 September 2020

EL-042 Committee
Standards Australia

Dear Committee,

Supporting statement on CEEM's comments regarding the AS4777.2 draft revisions

Thank you for considering our comments on the AS4777.2 draft revisions. Firstly we would like to acknowledge the Committee for your diligent efforts in drafting the revised Standard. We would also like to note our strong support for the proposed requirements to help address the power system security concerns associated with growing distributed resources penetrations. These changes to the Standards are essential in our view, and we appreciate the expedited Standards Australia process to ensure their introduction. Our work on distributed resource responses to major power system voltage and frequency disturbances [1, 2] highlights the need to put these measures in place as quickly as possible, particular the voltage disturbance ride-through requirements.

Our submission focuses, instead, on the proposed changes to the inverter volt-var power quality (PQ) mode. In particular, we wish to encourage more detailed and transparent analysis to support appropriate development of settings for this mode. We note that volt-watt and volt-var PQ modes are likely to play an important role in facilitating high penetration DER in Australia and more fairly distributing curtailment of DER. Indeed, our recent analysis of rooftop PV curtailment suggests that it is highly likely that some degree of DER curtailment due to the operation of these PQ modes will offer the most economically efficient outcome for consumers overall [3]. We also note that these modes may in fact reduce overall DER curtailment, for instance through preventing 'tripping' when over-voltage set points are reached.

However it is possible that the proposed volt-var mode, and its proposed new settings, may result in significant curtailment of DER real power in some circumstances, depending upon a number of factors including the local network conditions and local penetration of DER (particularly legacy DER without PQ response modes enabled). This possible curtailment of real power will have financial impacts for consumers, and in addition, may reduce the opportunities for DER to participate in low-carbon transition of our electricity index.

Given this context, determining appropriate default setpoints for volt-var and volt-watt response modes is complex, and will ultimately require trade-offs and compromise across industry stakeholders. In our view, volt-var and volt-watt set points should be conservative (that is, they only operate near the upper limit of the statutory voltage range), certainly until and unless a robust evidence base is established that suggests otherwise.

We therefore suggest that the current power quality modes as specified in AS4777.2-2015 should be retained under this current revision. However contrary to the current AS4777.2-2015, we suggest that the volt-var mode should be enabled be default. Given that it doesn't seem critical that these PQ response modes are updated under the current revision, we suggest that these modes should instead be reconsidered in the next revision of AS4777.2. We understand that this next revision is intended to run in 2021 with a focus including cyber security requirements.

Please find enclosed a short statement expanding upon these comments. It includes an introduction to our Collaboration on Energy and Environmental Markets (CEEM), a brief overview of some relevant research, and suggested areas for further analysis that could support appropriate determination of PQ response mode set points.

1 The Collaboration on Energy and Environmental Markets (CEEM)

The Collaboration on Energy and Environmental Markets (CEEM) at the University of New South Wales undertakes interdisciplinary research in the design, analysis and performance of energy and environmental markets and their associated policy frameworks.

CEEM's research focuses on the challenges and opportunities of clean energy transition within market oriented electricity industries. Key aspects of this transition are the integration of large-scale renewable technologies and, of greatest relevance here, distributed energy technologies – generation, storage and 'smart' loads – into the electricity industry. Facilitating this integration requires appropriate spot, ancillary and forward wholesale electricity markets, retail markets, monopoly network regulation and broader energy and climate policies. Our work particularly focuses on current and possible future arrangements in the Australian National Electricity Market (NEM).

Distributed Energy Resources (DERs) are a vitally important set of technologies, with vitally important stakeholders, for achieving quick, assured and equitable low carbon energy transition, and CEEM has been exploring the opportunities and challenges they raise for the future electricity industry for over a decade. Relevant contributions that have been made in recent years are detailed below, and included in Section *0 References*. More details of this work on effective, efficient and equitable integration of DER into the Australian NEM can be found at the CEEM website. We welcome comments, suggestions and corrections on this submission, and all our work in this area.

2 Key observations

Relevant observations as well as findings from some CEEM analyses are summarised here. Please note that the UNSW research discussed below has been undertaken in collaboration with Solar monitoring company Solar Analytics and has received financial support under a number of research projects with funding from a range of sources including the Australian Research Council, ARENA and the Energy Security Board.

Power system security requirements are critical to effectively and efficiently integrate high penetrations of DER

As noted above, we strongly support the immediate introduction of new requirements relating to power system security, and particularly voltage disturbance ride-through requirements. UNSW analysis undertaken in collaboration with Solar Analytics and the Australian Energy Market Operator has highlighted the growing risk posed by DER to power system security [1, 2, 4]. Findings from this analysis have also in included in AEMO reporting [5, 6].

Voltage conditions in NEM LV networks generally sit towards the upper end of the statutory range

Analysis of operating data from over 12,000 distributed PV systems installed across the National Electricity Market has shown that voltage conditions at sites connected to the LV distribution network are towards the upper end of the statutory range (230V +10%/-6%). This is unsurprising given the historic 240V nominal standard, and the need to manage peak demand. We note also that high voltage conditions are not necessarily problematic, however certainly have implications for the operation of DER.

These high LV voltages will likely see a large proportion of DER inverters in volt-var mode for considerable periods under the proposed settings

In particular, we flag that voltage conditions across 98% of the sites studied reported values in excess of 240V (the proposed new setting for volt-var commencement) for 20% of the time. The actual impacts will depend of course on the evolution of network voltages over time under a range of management practices, the potential impact of volt-var itself on reducing voltages, and the specifics inverter locations within the distribution network. Still, it seems possible that volt-var under the proposed new default settings will be enabled for the majority of inverter systems for the majority of the time.

Figure 1 and Figure 2 indicate that the sites studied in [7] reported voltages in excess of 250V relatively infrequently whereas voltages in excess of 240V occurred for a significant proportion of the time. For instance, in South Australia only around 4% of sites experience voltages in excess of 250V for 50% of the time, whereas around 93% of sites experience voltages in excess of 240V for 50% of the time.

Please refer to the report *'Voltage Analysis of the LV Distribution Network in the Australian National Electricity Market'* commissioned by the ESB [7] for full details including limitations regarding our voltage measurement approach. The report also includes a literature review of other voltage assessments to date in Australia that generally report similar findings, including prior work by UNSW [8]. Still, it is clear that further work is required to fully map, present and manage possible future voltage ranges in Australia's LV networks.

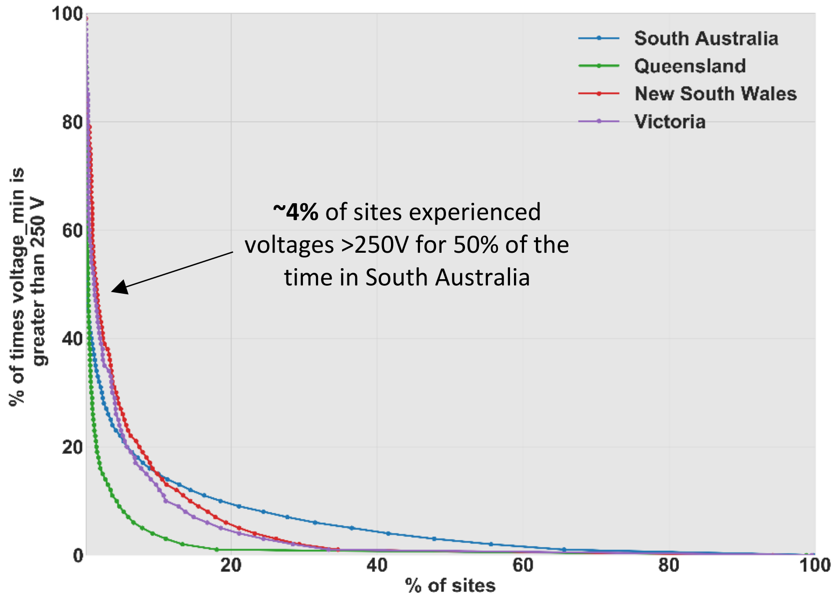

Figure 1- Prevalence of voltages above 250V: the proportion of time sites experienced voltages greater than 250V. Data analysed are minimum voltage measures over 5min intervals (5 sec samples), recorded at the switchboard (i.e. not at the point of network connection)

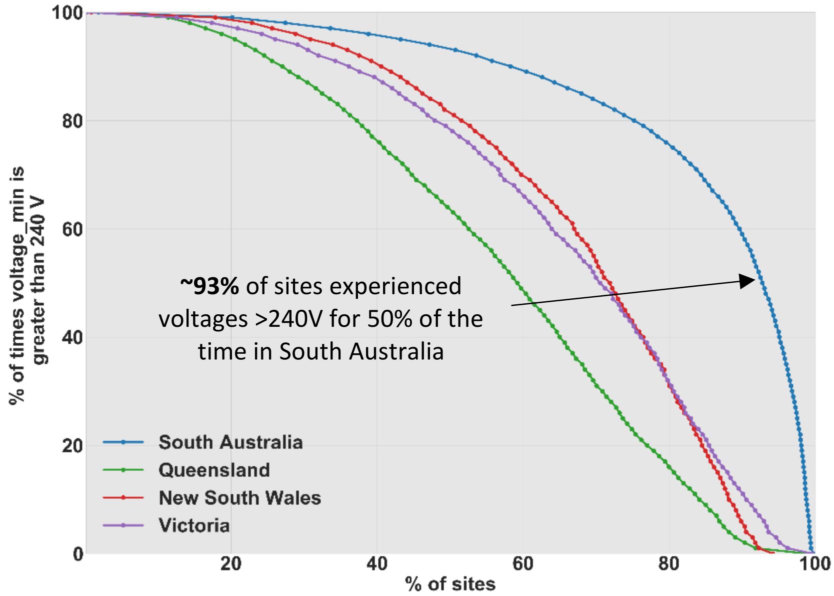

Figure 2 – Prevalence of voltages above 240V: the proportion of time sites experienced voltages greater than 240V. Data analysed are minimum voltage measures over 5min intervals (5 sec samples), recorded at the switchboard (i.e. not at the point of connection)

Volt-var response may adversely impact inverter real power output capabilities.
Given maximum PV inverter VA ratings, significant var requirements may require reductions in inverter real power output at some times (up to 20% reduction from rated capacity for the proposed new requirements under the most extreme conditions). Given:

- The likelihood that high PV power outputs will be increasing voltages,
- Growing DC:AC ratios for distributed PV systems will likely result in longer periods of potential operation at full (real) power output [9], and
- Uncertainties regarding what effectiveness volt-var response on newly installed systems may have on reducing voltages,

- it seems likely that the new volt-var default settings will see potentially significant real power curtailment at some times and locations. We are not aware of any public analysis on this in the Australian context, and are keen to improve our collective understanding of this impact.

Volt-var set points may have implications for consumers and DER integration efforts more broadly
Given the existing voltage conditions, setting the volt-var setpoint Vv3 to 240V has the potential to result in DER sinking vars and experiencing some real-power curtailment a significant proportion of the time in some cases. This possible real power curtailment has direct financial consequences for the owners of new DER. However as noted above, we stress that some PQ mode operation will likely be the most economically efficient outcome for consumers overall, and also likely to more fairly share curtailment.

The requirements set out in AS4777.2 regarding PQ will likely also have implications for broader DER integration. For instance, requiring significant power quality responses may limit the opportunities for DER to provide network services competitively in the future. In addition, it may limit the ability for DER to participate more broadly in the power system, for instance via Virtual Power Plants. We note that these challenges and opportunities are being considered in a number of ongoing processes through the AEMC, AER and AEMO.

We appreciate that integration of high penetration DER remains a relatively new challenge and that methods, evidence and means of communicating findings to the broader industry are still evolving. This is reflected in the CSIRO-CutlerMerz recommendations regarding hosting capacity in their recent report to the AER:

> *'DER integration business cases depend in large part on hosting capacity: the amount of DER a network views its current system can handle, and what it believes it will be able to handle in the future given some investment.*
>
> *There is not a uniform way in which networks conduct hosting capacity assessments today, and stakeholders in the regulatory process have little insight (and poor knowledge of the fundamental challenge) into how networks assess hosting capacity.'* [10]

More detailed and transparent data-driven evidence could therefore be of great value in decision making around PQ modes on inverters

We believe that more detailed and transparent data-driven analysis of DER in the field is necessary to gain an accurate understanding of potential impacts, given the highly diverse fleet of DER (largely distributed PV) in Australia, local LV network conditions and other voltage management efforts underway. While we and other stakeholders have undertaken work on these questions, it remains a limited evidence base for appropriate decision making on these very vexed issues.

Some studies have taken initial steps to quantify the impact of PV on distribution network voltages, and of distribution network voltages on PV, using operational data. However to our knowledge, they have largely been US-focused [11, 12] and due to difference in typical network topology, findings have limited applicability to the Australia context. Notable Australian-based studies include [13, 14], however assessed a limited number of sites. Recent analysis by UNSW suggests that large samples (thousands of sites) are necessary to identify 'edge' cases of high PV curtailment [3]. It is not clear how the proportion of highly impacted 'edge' cases may grow as DER uptake continues and we consider this an important area for further work.

We therefore suggest that further analysis is required to determine the extent and severity of potential curtailment before specifying default set points, other than default set points that are towards the upper end of the statutory voltage range.

3 Proposed changes to the revised AS4777.2

In light of the observations above, we suggest that a further, publicly available evidence base is established to support the identification of appropriate set points. We consider that it is important this evidence base is publicly available and that methods are as transparent as possible given the diversity of the distribution network and DER systems, as well as the diverse stakeholders that may be impacted by PQ requirements.

Specifically, we feel that the following areas of investigation could provide valuable evidence to support appropriate set point development:

- **What is the likely extent and severity of PQ mode operation?**
  Investigate how often and to what extent PQ modes are likely to operate and the

subsequent impact on real power, using real world operating data to assess current PQ mode operation.

- **How will this impact financial outcomes for consumers?**
  Both in terms of real power curtailment and also wear and tear on DER equipment.
- **To what extent is volt-var able to improve voltage conditions?**
  That is, an investigation of whether the benefits of implementing PQ modes outweigh the costs of doing so. In addition, it would be worth investigating potential unintended outcomes where DER such as battery energy storage systems and vehicle to grid electric vehicles may be prevented from operating during periods of high local voltage conditions, despite that this could alleviate conditions.
- **How do these PQ modes interact with other means and efforts to manage voltage?**
  Whilst both minimising costs and managing equity issues.

To enable appropriate development of setpoints, we suggest that this evidence base to be established, including making public any analysis that may already be underway and/or completed. We also suggest that power quality modes are considered under the next revision of AS4777.2 which we understand will occur in 2021 with a preliminary focus on cyber security requirements.

Under the current revision of AS4777.2 we suggest that the power quality modes from AS4777.2-2015 are retained, with the exception that volt-var could be enabled by default.

Thank you for considering our submission, please do not hesitate to contact us if we can provide any further details.

Best regards,

Naomi Stringer, Dr Baran Yildiz, Dr Anna Bruce, A/Prof Iain MacGill*
Collaboration on Energy and Environmental Markets (CEEM)
University of New South Wales Sydney, Australia
*Corresponding author i.macgill@unsw.edu.au

References

[1] N. Stringer, N. Haghdadi, A. Bruce, J. Riesz, and I. MacGill, "Observed behavior of distributed photovoltaic systems during major voltage disturbances and implications for power system security," *Applied Energy,* vol. 260, p. 114283, 2020/02/15/ 2020, doi: https://doi.org/10.1016/j.apenergy.2019.114283.

[2] N. Stringer, N. Haghdadi, A. Bruce, and I. MacGill, "Potential Security Implications of distributed photovoltaics: observed response during major power system frequency and voltage disturbance," *Submitted to Sustainable Energy, Grids and Networks,* 2020.

[3] N. Stringer, N. Haghdadi, A. Bruce, and I. MacGill, "Data driven analysis of network voltage impacts on distributed solar PV curtailment," *Submitted to the Electricity Journal,* 2020.

[4] R. Quint *et al.*, "Transformation of the Grid: The Impact of Distributed Energy Resources on Bulk Power Systems," *IEEE Power and Energy Magazine,* vol. 17, no. 6, pp. 35-45, 2019, doi: 10.1109/MPE.2019.2933071.

[5] AEMO, "Technical Integration of Distributed Energy Resources," April 2019. [Online]. Available: https://www.aemo.com.au/Media-Centre/Technical-Integration-of-Distributed-Energy-Resources-Report

[6] AEMO, "Final Report – Queensland and South Australia system separation on 25 August 2018," 10 January 2019. [Online]. Available: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2018/Qld---SA-Separation-25-August-2018-Incident-Report.pdf

[7] S. Heslop *et al.*, "Voltage Analysis of the LV Distribution Network in the Australian National Electricity Market," Commissioned by the Energy Security Board, 2020. [Online]. Available: https://cloudstor.aarnet.edu.au/plus/s/yXM0UFtPMJmWcLe

[8] N. Stringer, A. Bruce, and I. MacGill, "Data driven exploration of voltage conditions in the Low Voltage network for sites with distributed solar PV," presented at the Asia Pacific Solar Research Conference, Melbourne, December, 2017. [Online]. Available: http://apvi.org.au/solar-research-conference/wp-content/uploads/2018/12/APSRC-2017-Data-driven-exploration-of-voltage-conditions-in-the-LV-network-High-resolution.pdf.

[9] P. Heywood, N. Haghdadi, A. Bruce, I. MacGill, and N. Stringer, "Historical Market Trends of Distributed Photovoltaic Inverters in Australia," presented at the Asia Pacific Solar Research Conference, Canberra, 2019.

[10] CSIRO and CutlerMerz, "Value of Distribtued Energy Resources: Methodology Study: Consultation Draft Report," 7 September 2020. [Online]. Available: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/assessing-distributed-energy-resources-integration-expenditure/consultation

[11] M. Emmanuel, J. Giraldez, P. Gotseff, and A. Hoke, "Estimation of solar photovoltaic energy curtailment due to volt–watt control," *IET Renewable Power Generation*, vol. 14, no. 4*,* pp. 640-646. [Online]. Available: https://digital-library.theiet.org/content/journals/10.1049/iet-rpg.2019.1003

[12] J. Giraldez *et al.*, "Advanced Inverter Voltage Controls: Simulation and Field Pilot Findings," NREL, October 2018.

[13] W. Miller, A. Liu, Z. Amin, and A. Wagner, "Power Quality and Rooftop-Photovoltaic Households: An Examination of Measured Data at Point of Customer Connection," *Sustainability,* vol. 10, no. 4, p. 1224, 2018. [Online]. Available: http://www.mdpi.com/2071-1050/10/4/1224.

[14] Alexander, Wyndham, James, and McIntosh, "Networks Renewed Technical Analysis," 2017.

To submit a comment on a draft open for Public Comment please register with the Standards Hub and submit your comments online. Only registered Standards Hub users can submit comments. Drafts that are open for Public Comment can be accessed here: https://www.hub.standards.org.au/hub/public/listOpenCommentingPublication.action

All comments are required to be submitted online, any comment not submitted online prior to the close of comment date will not be considered for review by the committee.

Please do not modify or change this template, including its table headings, columns or structure, as doing so will result in the system rejecting your comment.

Fields marked with an asterisk (*) are mandatory and if not populated will result in the system rejecting your comment. Any supporting documentation can be updated after the successful submission of comments.

The "Section Identifier" should be laid out as per the examples below. If you use other formats (such as 2-3, 2/3 etc.) the system will reject your comment.

The "Comment Detail" field should describe the issue you feel should be addressed, and a justification for the proposed change.

The "Proposed Change" field should set out the specific text, figured etc. you propose to be added, removed or altered.

Example: How to complete the comment form:

*Sect./ Subsect.[1]	*Sect. ID	Para./Table /Fig./Comm ./Note	*Page No.	*Comment Type[2]	*Comment Detail	*Proposed Change
Clause	2.3	Table 1	16	Editorial	"diagram" incorrectly spelt	Correct spelling error
Appendix	C15.6		62	Technical	AS 5100.7 incorrectly referenced	Reference should be AS 5100.2

[1] Options include: Clause, Title, Table of Contents, Preface, Foreword, Introduction, Appendix, Bibliography or Index.

[2] Options include: Editorial, General or Technical.

*Section[1]	*Section Identifier	Paragraph/ table/ figure/ commentary/ note	*Comment Type[2]	*Page No	*Comment Detail	*Proposed Change
Section 3	3.3.2.3 Volt-var response mode		General	20	Comments submitted on behalf of the Collaboration on Energy and Environmental Markets (CEEM), UNSW Sydney: The draft states that the volt-var mode shall be enabled by default and sets out the response curve in table 3.7. Determining appropriate default setpoints for volt-var and volt-watt response modes is complex and impacts on a diverse range of electricity industry stakeholders, and will ultimately require trade-offs across effectiveness, efficiency and equity grounds. In our view, volt-var and volt-watt set points should be conservative (that is, they only operate near the upper limit of the statutory voltage range) until and unless a robust evidence base is established that argues otherwise. We therefore suggest that the current power quality modes as specified in AS4777.2-2015 should be retained under this current revision. However contrary to the current AS4777.2-2015, we suggest that the volt-var mode should be enabled be default. Given that it doesn't appear critical that these PQ response modes are updated under the current revision, we suggest that these modes could instead be reconsidered in the next revision of AS4777.2. We understand that this next revision is intended to run in 2021 with a focus including cyber security	We propose retaining the current volt-var set points as set out in AS4777.2-2015, however suggest making the volt-var response enabled by default.

[1] Options include: Clause, Title, Table of Contents, Preface, Foreword, Introduction, Appendix, Bibliography or Index.
[2] Options include: Editorial, General or Technical.

*Section[1]	*Section Identifier	Paragraph/ table/ figure/ commentary/ note	*Comment Type[2]	*Page No	*Comment Detail	*Proposed Change
					requirements. Please refer to the attached letter for background and further detail.	
Section 3	3.3.2.3 Volt-var response mode	Table 3.7	General	21	Comments submitted on behalf of the Collaboration on Energy and Environmental Markets (CEEM), UNSW Sydney: The volt-var response mode parameter Vv3 for Australia A is currently set to 240V in the revised standard. As above, determining appropriate default setpoints for volt-var and volt-watt response modes is complex given the range of stakeholders, high present uncertainties and need for trade-offs across effectiveness, efficiency and equity. In our view, volt-var and volt-watt set points should be conservative (that is, they only operate near the upper limit of the statutory voltage range) until and unless a robust evidence base is established. We therefore suggest that the current power quality modes as specified in AS4777.2-2015 should be retained under this current revision. However contrary to the current AS4777.2-2015, we suggest that the volt-var mode should be enabled be default. Given that it doesn't seem critical that these PQ response modes are updated under the current revision, we suggest that these modes should instead be reconsidered in the next revision of AS4777.2. We understand that this next revision is intended to run in 2021 with a focus including cyber security	We propose retaining the current volt-var set points as set out in AS4777.2-2015, however suggest making the volt-var response enabled by default.

*Section[1]	*Section Identifier	Paragraph/ table/ figure/ commentary/ note	*Comment Type[2]	*Page No	*Comment Detail	*Proposed Change
					requirements. Please refer to the attached letter for background and further detail.	
Section 4	Section 4 Protective functions for connection to electrical installations and the grid		General	30	Comments submitted on behalf of the Collaboration on Energy and Environmental Markets (CEEM), UNSW Sydney: We strongly support measures to improve the aggregate bulk power system impacts of distributed inverter connected generators. In particular, the introduction of withstand requirements given the immediate risks that distributed PV systems can pose to power system security. These requirements should be put in place as a matter of urgency.	No changes required.