Review of

AEMO Technical Integration of Distributed Energy Resources

Improving DER capabilities to benefit consumers and the power system - a report and consultation paper (March 2019)

Preliminary Report

Commissioned by the Electricity Engineers' Association of New Zealand

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Executive Summary

AEMO has invited the EEA to review its draft March 2019 report and consultation paper, and intends to submit its report, which calls for a review of AS/NZS 4777.2, to the relevant standard committee.

The EEA is a stake-holder in the AS/NZS 4777 standard series, and provides this review, which is not intended to be comprehensive, to AEMO.

The AEMO report identifies that DER behaviour during power system disturbances in the National Electricity Market (NEM) is already influential in power system security outcomes. The AEMO report has placed initial focus on inverter-connected DER, and therefore the inverter-based performance standards. Areas of incorporation of international standards into AS/NZS 4777.2, and of closer alignment of AS/NZS 4777.2 to these inverter standards, are proposed. A substantial number of proposed parameters for revision or introduction are listed.

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Key areas including disturbance ride-through and grid support are identified and described in detail, supported by compelling arguments including benefits to consumers.

Given that NZ has a very low level of distributed PV, it could be argued that the need to review AS/NZS 4777.2 is less urgent for NZ. However, the penetration level in NZ could rise to be significant over time, and thus the EEA, DNSPs, and other organizations in NZ are planning for this.

There are good reasons to review AS/NZS 4777.2 and to support AEMO's proposed amendments. The benefits, described in the AEMO report, of reviewing AS/NZS 4777.2 are compelling. Keeping AS/NZS 4777.2 relevant and consistent with international practice is important.

Low distributed PV levels in NZ, in fact, present an opportunity to further develop the AS/NZS 4777 series and associated relevant standards, to eventually build a nation-wide distributed PV capacity in which the vast majority of installed inverters operate under the very best international practice.

In conclusion, the EEA welcomes AEMO's DER report and consultation paper, and supports AEMO's submission of this report to the AS/NZS 4777.2 standard committee.

Contents

1 Introduction and summary

AEMO has invited the EEA to review its draft report entitled *Technical Integration of Distributed Energy Resources - Improving DER capabilities to benefit consumers and the power system*. AEMO intends to submit its report, which calls for a review of AS/NZS 4777.2, to the AS/NZS 4777.2 standard committee.

The EEA is a stake-holder in the AS/NZS 4777 standard series, and provides this review, which is not intended to be comprehensive, to AEMO.

The AEMO report identifies that DER behaviour during power system disturbances in the National Electricity Market (NEM) is already influential in power system security outcomes, and that this influence will grow. Extrapolating forward, disconnection of large amounts of DER during disturbances could lead to generation loss exceeding contingency sizes.

To better optimize DER behaviour during disturbances, and to improve levels of grid support from DER at all times, the AEMO report has placed initial focus on inverter-connected DER, and therefore the inverter-based performance standards. Areas of incorporation of international standards into AS/NZS 4777.2, and of closer alignment of AS/NZS 4777.2 to these inverter standards, are proposed. The specific international standards include IEEE Std 1547-2018 (USA), VDE-AR-N 4105 (Germany), and TR 3.2.1 (Denmark). A substantial number of proposed parameters for revision or introduction are listed (in the standards comparison of Appendix A1). Key areas are identified and described in detail, supported by compelling arguments including benefits to consumers. Some of these areas are briefly summarized below:

Disturbance withstand capability

- **Voltage and frequency disturbances.** In particular, consideration to include the passive anti-islanding protective functions *under voltage stage 2*, *over frequency stage 2*, and *under frequency stage 2*.
- **Rate of Change of Frequency (RoCoF).** Not currently included in AS/NZS 4777.2
- **Phase angle jump.** Not currently included in AS/NZS 4777.2.

Grid support

- **Voltage and reactive power control.** Default enablement of Volt-Var functionality, supported by Volt-Watt. Show optimized settings and co-ordinated activation of these two functions in AS/NZS 4777.2.
- **Frequency response.** Specify required response times for Frequency-Watt response.

Protection and control function co-ordination

- **Define measurement accuracy for protection and control functions**
- **Define control system response accuracy and times**

Co-ordination and interoperability

- **Co-ordination of, remote querying, and remote changes to device settings**

Compliance

- **Achieving compliance with relevant standards and required inverter settings**

The EEA realizes that there are both benefits and disadvantages in reviewing AS/NZS 4777.2. With regard to downsides, the standard, published in 2015, is only four years old. Furthermore, the amendments proposed in the AEMO report amount potentially to a substantial over-haul of the standard. In NZ, small-scale inverter-based DER less than 10 kW is almost all solar PV, has a combined capacity of 80.6 MW[2], and has a penetration level of less than 1%. Thus it currently has a minimal impact on the NZ distribution and transmission system. This contrasts greatly in comparison to Australia, as the issues in the AEMO report identify. The impact of distributed PV in NZ is therefore considerably less acute. The AEMO report notes (on page 27) that 70-80% of distributed PV was installed in Australia under the older AS 4777.3(2005) standard, which remained in effect in Australia up to October 2016, and thereby has no inverter ride through capability for over-voltage, under-voltage, and under-frequency disturbances. In NZ, inverters conforming to this standard may still be installed, and thus NZ may have an even higher proportion of these inverters. However, because the penetration level in NZ remains very low, inverter tripping due to these disturbances is not problematic. Therefore, it could be

[2] As of 28 February 2019, see https://www.emi.ea.govt.nz/Retail/Dashboards/

argued that the need to review AS/NZS 4777.2 is less urgent for NZ. However, the penetration level in NZ could rise to significant levels over time, and thus the EEA, DNSPs, and other organizations in NZ are planning for this.

There are also good reasons to review AS/NZS 4777.2 and to support AEMO's proposed amendments. The benefits, described in the AEMO report, of reviewing AS/NZS 4777.2 are compelling. Keeping AS/NZS 4777.2 relevant and consistent with international practice is important. It appears that the international standards, and IEEE Std 1546 - 2018 (USA) in particular, have advanced ahead. Inverters conforming to IEEE Std 1546 may provide better disturbance ride-through and grid support performance, as well as other capabilities, than those that conform to only AS/NZS 4777.2. International inverter manufacturers will be producing inverters to conform to these international standards. If AS/NZS 4777.2 inverter requirements are consistent with those produced for large international markets, both NZ and Australian consumers will benefit from the economies of scale and performance capabilities.

The EEA has published a draft guideline for NZ DNSP's to assist then with the connection of small-scale (<10kW) inverter-based distributed generation in their low voltage networks [1]. This includes technical requirements specified in the AS/NZS 4777 series, and Volt-Var and Volt-Watt curves specifically designed for NZ conditions. It aims to provide both standardization of inverter settings and assessment of connection applications across NZ DNSPs. It was developed in consultation with industry stake-holders, and during this process issues were raised such as the compliance issues identified in the AEMO report. Ensuring installers apply correct and preferably standardized national inverter settings is a compliance issue which has yet to be resolved.

Low penetration levels in NZ, in fact, present an opportunity to further develop the AS/NZS 4777.1 and AS/NZS 4777.2 series and associated relevant standards, to eventually build a nation-wide distributed PV capacity in which the vast majority of installed inverters operate under the very best international practice.

In conclusion, the EEA welcomes AEMO's DER report and consultation paper, and supports AEMO's submission of this report to the AS/NZS 4777 standard committee.

2 Selected technical comments

2.1 Figure 15

Figure 15 shows the response of AS/NZS 4777.2 inverters to the 25 August 2018 over-frequency event in Queensland (note: Figure 15 needs text corrections AS 4777.2:2015 → AS/NZS 4777.2:2015). These inverters do not appear to have had an effect on reducing frequency while curtailed to around 65% of prior power. Perhaps this was due to 80% of the PV being connected prior to October 2016, as noted on page 31, thereby providing no curtailment? Another point of interest is that the curtailment response of the 30-100 kW inverters was poorer than those <30 kW. What would explain this difference? Note that if AS/NZS 4777.1(2016) was a mandatory installation requirement in August 2018, then the 30-100kW inverters would have been required to conform to the additional centralized protection settings of AS/NZS 4777.1 (Table 1) for over-frequency. However, the centralized protection does not require an over-frequency droop response, and the inverters are still required to have the AS/NZS 4777.2 over-frequency droop response.

2.2 Table 6 - Default enablement of Volt-Var functionality supported by Volt-Watt

The AEMO report proposes the default enablement of Volt-Var functionality supported by Volt-Watt. This is in alignment with the EEA Connection Guide [1], which specifies enablement of the Volt-Var response mode supported by Volt-Watt if these functions are available.

The EEA Connection Guide applies a tiered system of inverter requirements for connection to the grid. This consists of two export power thresholds: a lower threshold of export power below which the applicant's inverter does not require Volt-Var functionality; and an upper threshold above which Volt-Var and Volt-Watt functionality may not be sufficient, requiring manual assessment of the connection application. This is similar to the two export power threshold system of connection requirements applied, for example, by Queensland's Energex and Ergon[3]. However, a difference is that the EEA Connection Guide proposes that the two export power thresholds are either calculated or estimated[4] specifically for each low voltage network. This

[3] See https://www.energex.com.au/__data/assets/pdf_file/0016/340603/Connection-Standard-for-Micro-Embedded-Generating-Units-up-to-30kVA-docx.pdf

[4] The Electric Power Engineering Centre has developed a tool called DGHost™ which estimates the export power capacity or hosting capacity of a low voltage network. This requires a minimal number of input parameters, thereby making the determination of hosting capacity straightforward. Further information is at https://www.canterbury.ac.nz/epecentre/research-and-innovation/dghost/

allows connection requirements to be tailored to individual low voltage networks. Fixed thresholds for all the low voltage networks of the DNSP can also be implemented, as practised by Energex/Ergon.

The regulatory process for connection of distributed generation in New Zealand is described in the Electricity Industry Participation Code. This does not mandate the use of Volt-Var and Volt-Watt functionality, but this is presently being reviewed by the Electricity Authority for one of the regulatory pathways to apply for connection. Also note that, unlike Australia, AS/NZS 4777.2 is not required to be adhered to in NZ.

Presently in NZ, any requirement for Volt-Var and Volt-Watt functionality is left at the discretion of DNSPs to apply via network connection agreements.

The EEA would need to consult with stakeholders before advocating for or against Volt-Var and Volt-Watt and other advanced non-mandatory inverter functionality described in AS/NZS 4777.2 being made mandatory. This decision would require an assessment of the additional inverter cost in relation to benefit for consumers, as currently in many instances as a result of NZ’s low level of distributed PV penetration, this advanced functionality would not be necessary.

2.3 Voltage response on pages 43-45

The EEA agrees that the activation thresholds of the example curves for Volt-Watt and Volt-Var in Figures 2(A) and 3 respectively in AS/NZS 4777.2 should not be drawn to coincide. This may require the V3 and V4 reference values in Figure 3 to be lowered below the Australian default values used in the curve, which are shown in Table 9 of the Standard. The EEA has designed specific Volt-Watt and Volt-Var curves for NZ conditions, which have separate activation zones as suggested, but still use volt response reference values within the range permitted by Table 9 of the Standard. The EEA’s recommended Volt-Watt and Volt-Var curves for NZ are described in Section 2.3.4.2.1 of the EEA Connection Guide [1].

2.4 A1.1 Table 9 disturbance withstand

This table lists AS/NZS 4777.2 passive anti-islanding set-point values found in Table 13 of the standard. Both Trip Delay Times and Maximum Disconnection Times are listed in the standard. It appears that Table 9 lists the Trip Delay Times, i.e. ride-through times, of the standard. In this case, there are two errors in Table 9: Over voltage stage 2 should be 0s, not 0.2s; and Over frequency stage 1 should be 0s, not 1s.

The 10 minute average voltage threshold for disconnection $V_{nom-max}$ described in Section 7.5.2 of the standard should also be listed in Table 9. Note that $V_{nom-max}$ corresponds to 1.08 pu, and if Over-voltage stage 1 was lowered from 1.13 pu to 1.10 pu to bring it into line with international standards, then it would be very close to $V_{nom-max}$ and possibly trip the inverter before $V_{nom-max}$ might otherwise do so. The EEA suggests that $V_{nom-max}$ should be removed or amended lower if Over-voltage stage 1 was lowered.

3 References

[1] "Interim draft: Guideline for the connection of small-scale inverter-based distributed generation," Electricity Engineers' Association, July 2018, Wellington. Available at https://www.eea.co.nz/tools/products/details.aspx?SECT=publications&ITEM=2917