ESP009 Technical Requirements for Small-Scale Inverter Connected DG

Standard

Table of Contents

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Date for next review	June 2023	

Approved Versions	Date	Revision Notes
1.0	November 2021	First Release. This standard is issued to replace ENS4009 first published in May 2013.

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IV. RELATED DOCUMENTS

Internal Documents	Document Title and Description
ESP005	Technical requirements for connecting distributed generation

External Documents	Document title and description
Electricity (Safety) Regulations	Electricity (Safety) Regulations 2010
AS/NZS 3000:2018	Electrical Installations, known as the Australian / New Zealand Wiring Rules
AS/NZS 4777.1:2016	Grid connection of energy systems via inverters, Part 1: Installation requirements
AS/NZS 4777.2:2015	Grid connection of energy systems via inverters, Part 2: Inverter requirements
AS/NZS 3010:2017	Electrical installations – Generating sets
Vector's Network Connection Standards	Technical requirements for the connection to Vector's electricity network (published on the Vector website)

AS/NZS 61000 / IEC 61000 suite of standards	Electromagnetic compatibility (EMC), Suite of Power Quality Standards
EEA (NZ) Connection of Small-Scale Inverter Based Generation	Guideline for the Connection of Small-Scale Inverter based Distributed Generation
EEA (NZ) Power Quality Guidelines	Guidance and advice on power quality to meet the requirements of Electricity (Safety) Regulations 2010
EEA (NZ) Connection of Generation Plant	Guide for the Connection of Generation Plant
IEC 60255 suite of standards	Measuring relays and protection equipment (All relevant Standards)
IEC 60068 suite of standards	Environmental testing
The Code	Electricity Industry Participation Code 2010

1. INTRODUCTION

1.1 Purpose

The purpose of this standard is to define the technical requirements for connection of small-scale distributed generation to Vector's distribution network using inverters. Typical applications include connection of solar panels, batteries or wind generation in residential dwellings. Distributed generation satisfying the requirements of this standard may apply for connection to the Vector distribution network using the Part 1A process (Schedule 6.1 of the Code).

A distributed generator meeting the minimum requirements as set out in this document does not exempt the distributed generator owner from any statutory responsibilities.

1.2 Scope

The scope of this standard includes:

a) Vector's technical requirements for connection of small-scale distributed generation[1] by inverters of 5kVA single phase or less, or 30kVA three phase or less. This standard applies to the following:

- Distributed generation connected directly to Vector's distribution network or indirectly via customer's installations.
- Distributed generation which is capable but does not export to the grid e.g. generation only used to offset customer's load.
- Intermittent generators (eg. wind generators) that are connected to the distribution network but not always generating.
- Battery energy storage systems connected to the Vector distribution network.
- Generation embedded within third party networks connected to Vector's distribution network.

The following are excluded from the scope of this standard:

a) Connection of distributed generation via inverters with capacities more than 5kVA single phase or 30kVA three phase. The requirements for connection of these distributed generators are addressed in the Vector Standard ESP005.

b) Connection of distributed generation (all sizes) directly (without inverters) to Vector's distribution network.

c) Connection of standby (or backup) generation, as these generation do not normally operate in parallel with Vector's distribution network. The Code excludes generation that is only momentarily synchronised with Vector distribution network from the definition of distributed generation.

[1] Distributed Generation is defined in Section 1.3 of this standard.

1.3 Definitions

Table 1: List of Definitions

Term	Description
Active Anti Islanding protection	Is a method used to detect a network island when the network load matches the generator output (or multiple generators) output. AS/NZS 4777.2 describes three methods.
Distributed Energy Resources	A Distributed Energy Resource (DER) is any device connected to the distribution network that generates (produces), stores or consumes electricity and can be controlled locally or remotely to alter its electricity production, storage or consumption pattern.
Distributed Generation	Distributed generation as defined in the Code means generating plant connected to a distribution network or to a consumer installation that is connected to a distribution network. Distributed generation excludes generating plants that are not normally connected or prevented from connecting to the distribution network or are only momentarily synchronised with the distribution network. For the purposes of this document distributed generation includes traditional synchronous or asynchronous generation and inverter connected generation.
Non-Exporting Generation	Generation connected to and operated in parallel with the distribution network used to offset customer load but that does not export electricity into Vector's distribution network.
High Risk Generation	Is any generation connected to Vector's network that has the potential (including combined with existing generation) to sustain a network island on any part of Vector's overhead network for longer than 2 seconds.
Network island or islanding	A condition in which a portion of the Vector's network while electrically isolated from the rest of the Vector's distribution network remains energised by one or more generators.
Point of supply	Is the point at which the distributed generator is connected into Vector's distribution network.
ROCOF	Rate of Change of Frequency protection similar to Vector Shift.
Synchronised or Synchronising	Synchronised is when two network points have the same voltage magnitude and frequency and zero phase difference. Synchronising is the act of bringing two separated points of the network into synchronism.

2. HEALTH, SAFETY AND ENVIRONMENT

No distributed generation shall be connected to Vector's distribution network, including temporary connection, addition of capacity to exiting generation without the prior written approval of Vector. Distributed generation connected to Vector's distribution network (either directly or via an inverter) poses a public safety risk and could potentially damage other customers' equipment.

The responsibility for safe generation operation and avoiding damages to Vector's network remains that of the distributed generation owner. All distributed generation owners need to be aware of their responsibility regarding public safety and potential damage to other customers' equipment.

Directly connected rotating distributed generation (i.e. Synchronous or Asynchronous machines) poses a significantly higher risk than equivalent size inverter connected generation due to generator inertia and the significantly higher fault current contribution. Inverter connected distributed generation meeting AS/NZS 4777.2 requirements have active anti islanding protection that conventional generation do not have thereby providing an additional risk mitigation factor.

2.1 Public Safety Risk

The potential for distributed generation to continue to energise Vector's distribution network (particularly a faulted network) after Vector's upstream circuit breaker has opened (or tripped) creates a potential public electrocution risk. This risk is higher on overhead networks. The following risk factors need to be evaluated for each prospective distributed generation connection and mitigation measures implemented:

a) Public safety (downed conductor) risk for distributed generation connected to Vector's overhead network (includes upstream overhead, and likely back-feed overhead).

b) Sustained Network Islanding risk. If the distributed generation or the distributed generation in combination with other network generation can sustain an island on part of Vector's distribution network.

c) A combination of the above two factors poses increased risk.

2.2 Customer Equipment Damage Risk

Should a distributed generator (or a distributed generator in combination with a cluster of other distributed generation) not trip out immediately following the onset of a network island, a resultant unchecked extreme over-voltage transient could result in widespread equipment damage to customers connected to Vector's network in the immediate vicinity of the generator.

The following are risk factors for distributed generation output (or the combination of a cluster of generation output) that may result in network over-voltages:

a) Over-voltage due to large distributed generation connected to rural overhead 11kV networks particularly during low network load periods.

b) Large solar generation connected to the network during an unusually low network midday summer load (too low to offset the generation output) e.g. during holidays.

Growth of inverter based generation connected to Vector's network is anticipated, particularly solar generation and battery storage. Therefore, when evaluating a distributed generator's ability to sustain a network island, allowance must be made for the addition of future generation and prudent future proofing measures should be included to safeguard against a significant future risk.

Table 2: Summary of risks addressed in this Standard

Lifecycle Stage	Risk	Risk Rating	Control	Section Ref
Operational	Generation continues energising a downed conductor. Public electrocution risk.	Very High	Ensure adequate dual independent protection. Vector independent protection and SCADA required for the point of supply circuit breaker. Ensure residual voltage protection. Ensure robust commissioning and ongoing maintenance of the Protection and Control systems.	3.7 3.8 4 5
Operational	Generator causes transient over-voltage during onset of a network island. Customer equipment damaged by network transient over-voltage.	High	Ensure fast main and fast backup tripping of the generator for severe over-voltages. Ensure robust commissioning and ongoing maintenance of the Protection and Control systems.	3.7 4 5
Operational	Generators continue exporting unconstrained power and reactive power output during a network sustained elevated voltage resulting in the local network voltage exceeding regulatory maximum limits and the sustained over-voltage causing customer equipment failure and complaints.	High	Ensure sustained over-voltage tripping is implemented in independent protection systems. Ensure generators have Volt-VAr (Voltage influence) and Volt-Watt (Over-voltage load curtailment) controls enabled and correctly configured.	3.7 4 5
Operational	Out of Sync closing damaging Vector network equipment and generation.	Low (low risk to Vector, high risk to the generator owner)	Ensure the generator site has robust and documented operational procedures to connect generation to Vector's network and robust interlocking systems to prevent out of sync closing.	3.4

3. COMPLIANCE

The design, installation and operation shall comply with the latest editions of the following regulations, codes, standards and guides listed below.

Table 3: List of Standards

REFERENCE No	DESCRIPTION
Electricity (Safety) Regulations	NZ Electricity (Safety) Regulations
AS/NZS 3000:2018	Electrical Installations, known as the Australian / New Zealand Wiring Rules
AS/NZS 4777.1:2016	Grid connection of energy systems via inverters, Part 1: Installation requirements
AS/NZS 4777.2:2015	Grid connection of energy systems via inverters, Part 2: Inverter requirements
AS/NZS 3010:2017	Electrical installations – Generating sets
Vector's Network Connection Standards	Technical requirements for the connection to Vector's electricity network (published on the Vector website)
AS/NZS 61000 / IEC 61000 suite of standards	Electromagnetic compatibility (EMC), Suite of Power Quality Standards
EEA (NZ) Connection of Small-Scale Inverter Based Generation	Guideline for the Connection of Small-Scale Inverter based Distributed Generation
EEA (NZ) Power Quality Guidelines	Guidance and advice on power quality to meet the requirements of Electricity (Safety) Regulations 2010
EEA (NZ) Connection of Generation Plant	Guide for the Connection of Generation Plant
IEC 60255 suite of standards	Measuring relays and protection equipment (All relevant Standards)
IEC 60068 suite of standards	Environmental testing
The Code	Electricity Industry Participation Code 2010

4. TECHNICAL REQUIREMENTS

All distributed generation connected to or proposed to be connected to Vector's distribution network via inverters (5kVA or smaller single phase or 30kVA or smaller three phase) shall comply with the requirements of this standard and Vector's Network Connection Standards.

Distributed generation connected via inverters (single phase inverter >5kVA and three phase inverter >30kVA) shall comply with Vector standard ESP005 "Technical requirements for connecting distributed generation". This standard is published on the Vector website.

All distributed generation must meet all relevant statutory requirements including all applicable safety regulations, codes and standards.

4.1 Inverter and Installation Standards

Regulation 60 of the Electricity (Safety) Regulations 2010 requires installation of low voltage mains parallel generation systems to comply with AS/NZS 3000, AS/NZS 3010 and AS 4777.1:2005. The AS 4777 suite of standards have been updated and published as AS/NZS 4777.1:2016 and AS/NZS 4777.2:2015. These updated standards, however, have not yet been cited in the Electricity (Safety) Regulations. Until these standards are gazetted, Vector will continue to accept inverter connections designed and installed to AS 4777.1 provided that the protection settings of the distribution generation system comply with the Vector voltage and protection settings as specified in section 4.3 of this document.

Inverters configured to the New Zealand settings in accordance with AS/NZS 4777.2 2015 will be accepted for connection to Vector's network. Inverters configured to Australia-only settings are unacceptable.

4.1.1 AS 4777.1:2005 Grid connection of energy systems via inverters – Part 1: installation requirements

AS 4777.1:2005 "Grid connection of energy systems via inverters – Part 1: Installation requirements" has been gazetted under the Electricity (Safety) Regulations[2]. Compliance with this standard is deemed to have satisfied the safety requirements of this standard. However as AS 4777.1 is an Australian standard, there are features in this standard that are incompatible with the New Zealand power supply environment. The Vector requirements to enable this standard to satisfy New Zealand conditions are included in this technical standard.

4.1.2 AS/NZS 4777.2:2015 Grid connection of energy systems via inverters – Part 1: inverter requirements

The Electricity Authority has amended the Electricity Industry Participation Code (EPIC) to adopt AS/NZS 4777.2:2015 "Grid connection of energy systems via inverters – Part 2: Inverter requirements" as of 20 October 2016[3] for the Part 1A DG connection application process. Although this standard is still to be gazetted under the Electricity (Safety) Regulations compliance with this standard will meet Vector's technical requirements for connection.

[2] Refer to Schedule 2 of the Electricity (Safety) Regulations

[3] https://www.ea.govt.nz/assets/dms-assets/21/21271EIPCA-Inverter-Standard-for-Distributed-Generation-2016.pdf

4.1.3 AS/NZS 4777.1:2016 – Grid connection of energy systems via inverters - Part 1: Installation requirement

AS/NZS 4777.1:2016 "Grid connection of energy systems via inverters – Part 1: Installation requirements" was published on the 30 September 2016 to replace AS 4777.1:2005[4]. This standard specifies the New Zealand and Australian voltage and frequency differences, and compliance with the New Zealand requirements of this standard will meet Vector's requirements

4.1.4 Inverters conforming to European standards

Vector envisages imported inverters pre-set to the default settings specified in EN 50438 may be easier for prospective distributed generation applicants to comply with Vector's protection settings. Inverters compliant with European standard EN 50438 will be accepted on Vector's network.

4.2 Network Capacity Headroom to host New or Increase Generation

Additional distributed generation may be connected if the required network capacity to host (support) the distributed generation is available. As a minimum, the following criteria must be met:

a) Maximum network design fault ratings are not exceeded.

b) Equipment fault ratings are not exceeded.

c) Equipment thermal ratings are not exceeded.

d) Connection will not result in over-voltage causing problems to the Vector distribution network and its customers.

The assessment of headroom capacity to host the distributed generation is the first step in approving a distributed generator connection. For the majority of the small-scale distributed generation, Vector has developed a congestion model to identify any congestion due to voltage constraints. This model will facilitate the Vector Connection Team to assess if there is voltage constraints limiting the capacity to host the connection. Depending on the size of the distributed generation, a further detailed capacity study may be required to look at options for connection.

Should reinforcement or changes to Vector's distribution network be required to allow the connection of the distributed generation the distributed generator owner may be required to bear the cost of these changes.

[4] AS/NZS 4777.1: 2016 "Grid connection of energy systems via inverters – installation requirements" has a six months transition period from the date of publication.

4.3 Voltage and Frequency Settings

The Inverter voltage and frequency settings should comply with the appropriate AS/NZS 4777.2:2015 standards.

4.4 Network Islanding

The inverter must disconnect the distributed generator from the part of the distribution network which is disconnected from the rest of Vector's distribution network or disconnected from Transpower's grid. The distributed generation may remain operating as an island to supply the customer's internal load, but only after any connection with Vector's distribution network is disconnected and remain disconnected and locked out for the duration when the customer's installation is operated in an island mode.

4.5 Power Quality

The distributed generator shall not cause voltage fluctuation and flicker levels greater than the emission level allocations based on AS/NZS 61000 suite of standards including AS/NZS 61000 technical reports. The capacity of the distributed generator shall be considered as the equivalent load capacity for the purposes of applying these standards.

The harmonic currents of the inverter shall not exceed the limits specified in tables 2 and 3 of section 5.6 of AS/NZS 4777.2:2015. The total harmonic current distortion (I_{THD}) to the 50th harmonics shall be less than 5%.

4.6 Phase Imbalance

To ensure any voltage imbalance that may be introduced into the Vector distribution network is kept to an acceptable level, the capacity for single phase distributed generators (including the capacity of the connecting inverter) connected to the Vector network shall be limited to 5kW. Three phase distributed generators shall have a balanced output with respect to its capacity with a tolerance of no more than 5kW imbalance between any phases.

Distributed generators that do not satisfy the requirements of this section are not eligible to apply for connection using the Part 1A process (Schedule 6.1 of the Code).

4.7 Volt Response

The risk of the low voltage network voltage exceeding the statutory limit of 6% above nominal voltage levels is increasing likely as more distributed generation is connected to the distributed network. For inverter connected distributed generation, implementing Volt-VAr and Volt-Watt response modes provide a means of mitigating the localised excessive voltage during times of high production and low usage while allowing production at other times. This facilitates connection of generation without compromising upper voltage limits.

Volt-Watt and Volt-VAr response modes shall be set on all distributed generators newly connected to the Vector distribution network. The settings are described in section 6.3 of AS/NZS4777.2:2015 and the Vector requirements are provided in Sections 4.7.1 and 4.7.2 below.

The Volt-Watt response mode varies the output power of the inverter in response to the voltage at the point of connection.

Volt-VAr response modes shall be sufficiently smooth so as not to cause voltage fluctuations or voltage flicker. During increasing voltage events distributed generators shall endeavour to supress the high voltage by importing reactive power (VAr), this will enable more generation capacity to be connected to Vector's distribution network.

4.7.1 Volt-Watt control

The settings for the Volt-Watt control are provided in Table 4 and Table 5 below. Figure 1 provides a visual representation of the controller action.

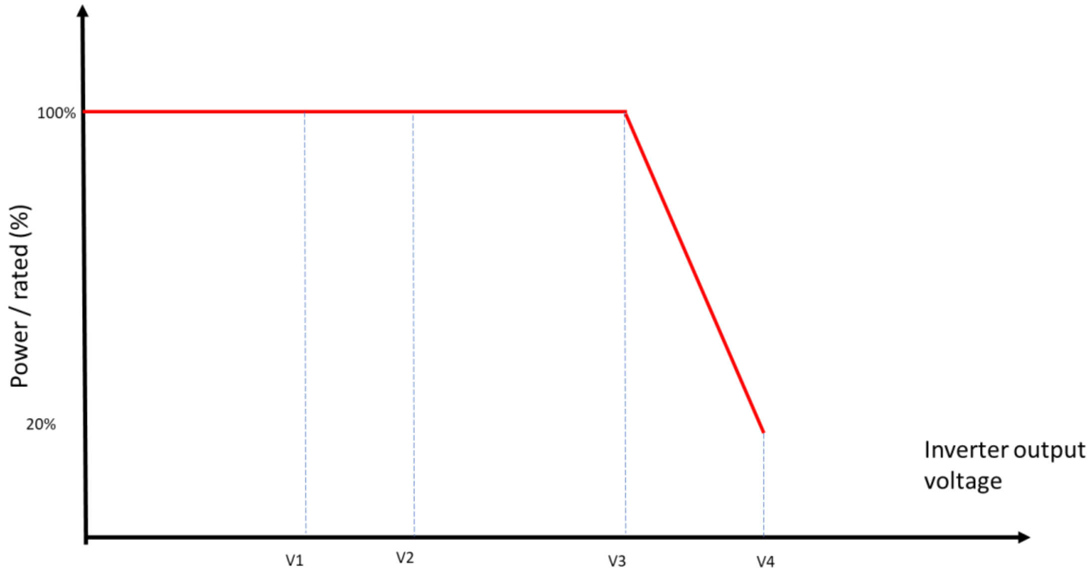
Table 4: Voltage reference values for setting Volt-Watt response modes

Reference	Volts (single phase)	Volts (three phase)
V1	207	360
V2	220	383
V3	244	423
V4	255	442

Table 5: Power reference values for setting Volt-Watt response modes

Reference	Power (kW) Control
V1 to V3	No power output restriction (stays at 100%)
V3 to V4	Shall decrease power output from 100% down to 20% of generator rating
>V4	Power output limited to maximum 20% of generator rating

Figure 1: Visual representation of the Volt-Watt response settings



4.7.2 Volt-VAr control

The settings for the Volt-VAr control are provided in Table 6 and Table 7 below. Figure 2 provides a visual representation of the controller action.

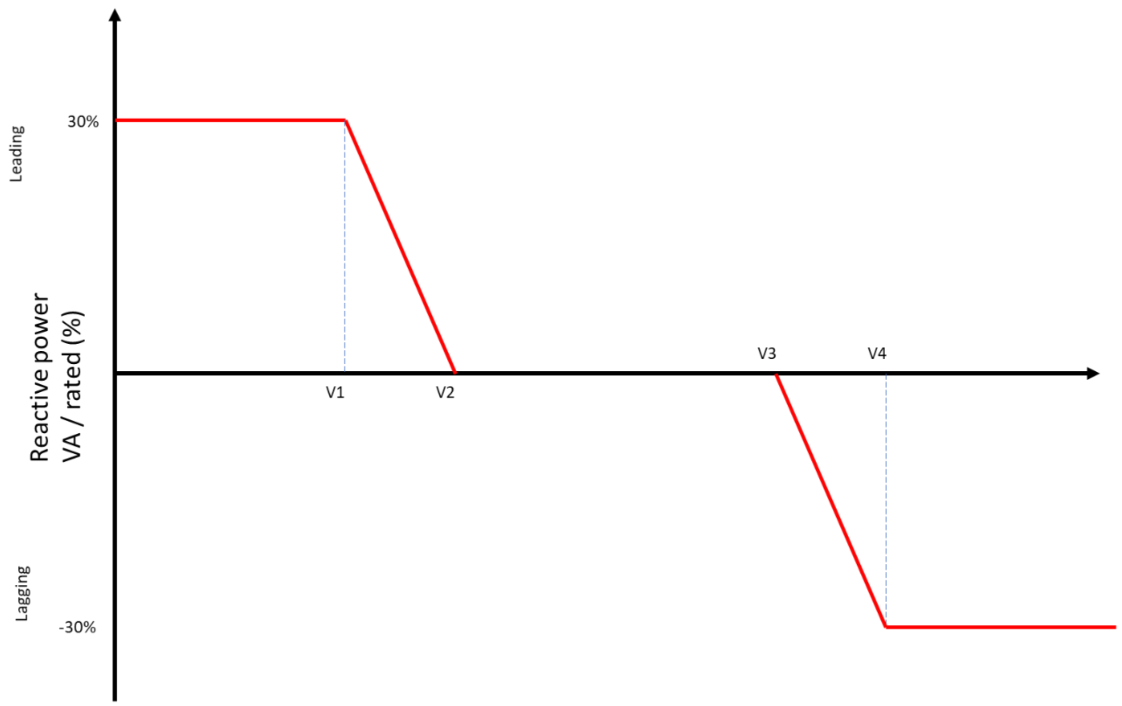
Table 6: Voltage reference values for setting Volt-VAr response modes

Reference	Volts (single phase)	Volts (three phase)
V1	207	360
V2	220	383
V3	235	409
V4	244	424

Table 7: Reactive Power reference values for setting Volt-VAr response modes

Reference	Reactive Power Control
<V1	30% of generator VA rating (Capacitive)
V1 to V2	Shall ramp smoothly from unity to V1 setpoint
V2 to V3	Shall operate at unity power factor
V3 to V4	Shall ramp smoothly from unity to V4 setpoint
>V4	-30% of generator VA rating (Inductive)

Figure 2: Visual representation of the Volt-VAr response settings



5. PRE-COMMISSIONING (PRE-CONNECTING) REQUIREMENTS

Vector may decline connection of distributed generator to Vector's distribution network if the equipment does not meet the specified technical requirement (as stated in this document).

The distributed generator owner shall provide Vector full details of the protection settings to be applied in the application form.

All testing and associated costs are the responsibility of the distributed generator owner.

Vector or Vector's representative reserves the right to witness the testing.

The distributed generator shall use a contractor who is experienced and qualified in installation and commissioning distributed generation systems.

6. POST-COMMISSIONING AND ONGOING MAINTENANCE REQUIREMENTS

Within one week of commissioning of the distributed generation system, copies of the Certificate of Compliance and Record of Inspection for the installation of the distributed Generation system shall be sent to Vector for records.

Distributed generator owners shall ensure that all associated protection equipment meet the below requirements.

a) Protection equipment should be available at all times.

b) If the protection becomes unavailable, the distributed generation should immediately be taken out of service.

c) The protection equipment should regularly be maintained in accordance with good electrical industry practice.

d) The protection settings shall be password protected against inadvertent changes.

e) No changes (including settings changes) shall be made to the generator protection without notifying Vector.