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(Incorporating Amendment No. 1)



Australian/New Zealand Standard™

Grid connection of energy systems via inverters

Part 2: Inverter requirements



AS/NZS 4777.2:2020

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- Better Regulation Division — NSW Fair Trading
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- Clean Energy Regulator
- Communications, Electrical and Plumbing Union — Electrical Division
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Australian/New Zealand Standard™

Grid connection of energy systems via inverters

Part 2: Inverter requirements

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-042, Renewable Energy Power Supply Systems and Equipment, to supersede AS/NZS 4777.2:2015, *Grid connection of energy systems via inverters, Part 2: Inverter requirements*. AS/NZS 4777.2:2015 will also remain current for 12 months after the date of publication of this Standard and after this time they will be superseded by AS/NZS 4777.2: ^{A1}2020 ^{A1}. Regulatory authorities that reference this Standard in regulation may apply these requirements at a different time. Users of this Standard should consult with these authorities to confirm their requirements.

^{A1} This Standard incorporates Amendment No. 1 (October 2021). The start and end of changes introduced by the Amendment are indicated in the text by tags including the amendment number 1. ^{A1}

The objective of this Standard is to specify minimum performance and safety requirements for the design, construction and operation of inverters intended for grid connection of energy systems.

This Standard is part of a series on the grid connection of energy systems via inverters. The series is as follows:

AS/NZS 4777.1, *Grid connection of energy systems via inverters, Part 1: Installation requirements*

AS/NZS 4777.2, *Grid connection of energy systems via inverters, Part 2: Inverter requirements* (this Standard)

The differences between this and the previous edition include but are not limited to the following:

- (a) Revision of sustained frequency response.
- (b) Revised set-points and limits to match electricity distributor and grid operator requirements.
- (c) Revision of provisions for demand response and power quality response modes.
- (d) Inclusion of requirements for electrical safety of non-PV energy sources in accordance with IEC 62477-1.
- (e) Inclusion of requirements for improved withstand capabilities including multiple voltage disturbances, rate of change of frequency and voltage phase shift.
- (f) Inclusion of requirements for measurement system accuracy and functional prioritization.
- (g) Inclusion of requirements for stand-alone inverters.
- (h) Inclusion of requirements for generation limit and export limit control function.
- (i) Revised and expanded testing procedures.

The following documents were used for information and guidance in the preparation of this Standard to ensure that features and requirements were aligned with international developments.

IEEE 1547-2018, *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*

VDE-AR-N 4105:2018-11, *Generators connected to the low-voltage distribution network — Technical requirements for the connection to and parallel operation with low-voltage distribution networks*

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The terms “normative” and “informative” are used in Standards to define the application of the appendices to which they apply. A “normative” appendix is an integral part of a Standard, whereas an “informative” appendix is only for information and guidance.

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Australian/New Zealand Standard

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Part 2: Inverter requirements

Section 1 Scope and general

1.1 Scope

This Standard specifies device specifications, functionality, testing and compliance requirements for electrical safety and performance for inverters designed to facilitate connectivity between energy sources and/or energy storage systems and the grid, connected at low voltage. This includes electric vehicles that can operate as an energy source and energy storage system that can supply an electrical installation connected to the grid.

This Standard also applies to stand-alone inverters within an electrical installation that may be connected to the grid at low voltage via an a.c. input port.

General requirements relating to the test methods set out in [Appendices B to L](#) are specified in [Appendix A](#). [Appendix M](#) specifies requirements for stand-alone inverters.

NOTE This Standard does not include the regulatory requirements mandated in Australia by the Australian Communications Media Authority (ACMA) and in New Zealand by Radio Spectrum Management. Refer to ACMA, *Electromagnetic Compatibility—Information for suppliers of electrical and electronic products in Australia and New Zealand*, for guidance.

1.2 Application

This Standard enables the inverters to be installed as part of an inverter energy system (IES) in accordance with the requirements of AS/NZS 4777.1. This Standard applies in conjunction with the requirements of the electricity distributor approving the connection. Relevant legislation and regulations also apply.

1.3 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document.

NOTE Documents referenced for informative purposes are listed in the Bibliography.

AS 60038, *Standard voltages*

AS 60947.3, *Low voltage switch gear and control gear, Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units (IEC 60947-3:2015 (ED. 3.2) MOD)*

AS IEC 62040.3, *Uninterruptible power systems (UPS), Part 3: Method of specifying the performance and test requirements*

AS IEC 62196.2, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles, Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories*

AS/NZS 3000, *Electrical installations (known as the Australian/New Zealand Wiring Rules)*

AS/NZS 3112, *Approval and test specification—Plugs and socket-outlets*

AS/NZS 4777.1, *Grid connection of energy systems via inverters, Part 1: Installation requirements*

AS/NZS 5033, *Installation and safety requirements for photovoltaic (PV) arrays*

AS/NZS 60320.1, *Appliance couplers for household and similar general purposes, Part 1: General requirements (IEC 60320-1 Ed. 2.1 (2007) MOD)*

AS/NZS 61000.3.2, *Electromagnetic compatibility (EMC), Part 3.2: Limits—Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

AS/NZS 61000.3.3, *Electromagnetic compatibility (EMC), Part 3.3: Limits—Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

AS/NZS 61000.3.4, *Electromagnetic compatibility (EMC), Part 3.4: Limits—Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 75 A*

AS/NZS 61000.3.11, *Electromagnetic compatibility (EMC), Part 3.11: Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems—Equipment with rated current less than or equal to 75 A and subject to conditional connection*

AS/NZS IEC 60947.2, *Low-voltage switch gear and control gear, Part 2: Circuit-breakers*

AS/NZS IEC 61000.3.12, *Electromagnetic compatibility (EMC), Part 3.12: Limits—Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase*

AS/NZS IEC 62116, *Utility-interconnected photovoltaic inverters—Test procedure of islanding prevention measures*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements*

IEC 61851-1, *Electric vehicle conductive charging system — Part 1: General requirements*

IEC 62109-1, *Safety of power converters for use in photovoltaic power systems — Part 1: General requirements*

IEC 62109-2, *Safety of power converters for use in photovoltaic power systems — Part 2: Particular requirements for inverters*

IEC 62196-3, *Plugs, socket-outlets, vehicle connectors and vehicle inlets — Conductive charging of electric vehicles — Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers*

IEC 62477-1, *Safety requirements for power electronic converter systems and equipment — Part 1: General*

1.4 Terms and definitions

For the purpose of this document, the following terms and definitions and those of AS/NZS 3000 apply.

1.4.1

active anti-islanding protection

method of preventing islanding by actively varying the output of the inverter

1.4.2

cease power generation

cease active power output and any power quality response while remaining connected to the grid during voltage disturbances

Note 1 to entry: Passive reactive power flow may continue (e.g. due to inverter filter capacitors).

1.4.3

displacement power factor

cosine of the angle (φ) between the fundamental voltage and the fundamental current

1.4.4**firmware**

software contained in a read-only memory device

Note 1 to entry: Firmware, in normal usage, is not intended for modification, and requires the hardware device containing it to be replaced or re-programmed.

[SOURCE: IEC 192-01-35]

1.4.5**fixed equipment**

equipment fastened to a support, or otherwise secured in a specific location

[SOURCE: IEC 826-07-07]

1.4.6**grid**

portion of the electrical distribution system that is operated by an electrical distributor

Note 1 to entry: An alternative term for “grid” is “electricity distribution network”.

1.4.7**grid-interactive inverter**

inverter or inverter function intended to operate in parallel to the grid for export or self-consumption of energy generated by the inverter energy system

1.4.8**grid test voltage**

voltage applied for testing of an inverter

1.4.9**inverter**

device that uses semiconductor devices to transfer power between a d.c. source or load and an a.c. source or load

Note 1 to entry: Inverters include a.c. to a.c. convertors transferring power between non-grid energy sources and an a.c. source or load that use semiconductor devices.

1.4.10**inverter energy system**

system comprising of one or more inverters together with one or more energy sources (which may include batteries for energy storage), and controls, which satisfies the requirements of this Standard

1.4.11**islanding**

any situation where the electrical supply from a grid is disrupted or fails and one or more inverters maintains any form of electrical supply, be it stable or not, to any section of that grid or within the electrical installation

Note 1 to entry: Prevention of the injection of energy and prevention of an unintentional island with the grid or part thereof when supply is disrupted is key to maintaining safety on the grid and within the electrical installation.

1.4.12**may**

indicates the existence of an option

1.4.13**multiple mode inverter**

inverter that operates in more than one mode, for example having grid-interactive functionality when grid voltage is present and in stand-alone mode when the grid is de-energized or disconnected

Note 1 to entry: Inverters with energy storage ports are also deemed to be multiple mode inverters as they have charge and discharge modes.

Note 2 to entry: Vehicle to grid capable electric vehicle supply equipment is a type of multiple mode inverter.

[SOURCE: IEC 62109-2:2014, 3.107, modified and notes added.]

1.4.14**passive anti-islanding protection**

method of preventing islanding based on monitoring the grid

1.4.15**permanently connected**

electrically connected by means which can be detached only by the use of a tool

[SOURCE: IEC 62109-1:2014, 3.53.]

1.4.16**pluggable equipment type A**

equipment which is intended for connection to the building installation wiring via a non-industrial plug and socket-outlet or a non-industrial appliance coupler, or both

[SOURCE: IEC 62109-1:2014, 3.57]

1.4.17**pluggable equipment type B**

equipment which is intended for connection to the building installation wiring via an industrial plug and socket-outlet or an appliance coupler, or both, complying with IEC 60309 or with a comparable national standard

Note 1 to entry: Appliance couplers and connectors within the scope of IEC 60320 or AS/NZS 60320 are not equivalent connectors to those conforming to IEC 60309-1.

Note 2 to entry: PV circuits that use connectors are examples of pluggable type B or fixed equipment.

Note 3 to entry: Electric vehicle connections that use AS IEC 62196.2 or IEC 62196-3 are examples of pluggable equipment type B.

[SOURCE: IEC 62109-1:2014, 3.58 with Note 1 to entry added]

1.4.18**port**

location giving access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

[SOURCE: IEC 62109-1:2014, 3.64.]

1.4.19**portable equipment**

pluggable equipment intended to be moved from place to place

[SOURCE: IEC 62109-1:2014, 3.65.]

1.4.20**rated**

value assigned, generally by a manufacturer, to a specified operating condition of an inverter

[SOURCE: IEC 151-04-03]

1.4.21**rated apparent power**

output apparent power of the inverter which is the product of the rated current and rated voltage

Note 1 to entry: The SI unit is the volt ampere (VA). Typically inverters are rated in kilovolt amperes (kVA).

Note 2 to entry: This is referred to as S_{rated} throughout tables, figures and equations in this Standard.

1.4.22**rated current**

current output of the inverter which can be supplied continuously for 7 h at the rated voltage when the power input to the inverter does not exceed the maximum input limits

Note 1 to entry: For purposes of equipment marking, the maximum continuous current of IEC 62109-1 is equivalent to the rated current.

1.4.23**reactive power**

product of the apparent power and the sine of the angle (φ) between the fundamental voltage and the fundamental current

Note 1 to entry: Reactive power is absorbed from the grid when the inverter acts as an inductive load from the perspective of the grid. Reactive power is supplied to the grid when the inverter acts as a capacitive load from the perspective of the grid.

Note 2 to entry: Reactive power is referred to as Q and the SI unit is volt ampere reactive, written as var.

1.4.24**ripple control**

means of one-way communication based on transmitting audio-frequency electrical signals over a grid

1.4.25**shall**

indicates that a statement is mandatory

1.4.26**should**

indicates a recommendation

1.4.27**single-phase**

connection between the active of an individual phase and the neutral

1.4.28**stand-alone inverter**

inverter intended to supply a.c. power to an electrical installation but not to the grid

Note 1 to entry: Stand-alone inverters are restricted to inverters that may operate in parallel with the grid and do not supply power through the a.c. input port to the grid and electrical installation.

Note 2 to entry: A stand-alone inverter is not a multiple mode inverter that may operate in stand-alone mode ([1.4.29](#)), a multiple mode inverter with stand-alone mode may also be grid-interactive.

[SOURCE: IEC 62109-2:2014, 3.109, modified]

1.4.29**stand-alone mode**

inverter function intended to supply a.c. power to an electrical installation but not to the grid

[SOURCE: IEC 62109-2:2014, 3.109, modified]

1.4.30**three-phase**

system either connected to all phases and neutral (i.e. star connected) or connected between phases (i.e. delta connected)

Section 2 General requirements

2.1 General

This Standard does not prevent the use of materials, methods of assembly, procedures, or additional functions and the like that are not specifically included in the requirements of this Standard, or are not mentioned in it, provided the minimum safety, functional and performance requirements specified herein are met.

2.2 Electrical safety

Inverters for use in inverter energy systems with photovoltaic (PV) arrays and/or batteries shall conform to IEC 62109-1 and IEC 62109-2, and the requirements within this Standard.

Throughout IEC 62109-1 and IEC 62109-2, the term “power conditioning equipment (PCE)” is used. For the purposes of this Standard, “PCE” shall be replaced with the term “inverter”.

Inverters for use in inverter energy systems that have energy storage (batteries) as the only possible energy source shall conform to the electrical safety requirements of IEC 62477-1, and the requirements within this Standard.

Inverters for use in inverter energy systems that incorporate energy sources other than photovoltaic (PV) arrays or batteries shall conform to IEC 62477-1, and the requirements within this Standard.

Throughout IEC 62477-1, the term “power electronic converter system (PECS)” is used. For the purposes of this Standard, “PECS” shall be replaced with the term “inverter”.

NOTE The application of relevant electrical safety standards for energy source types is under consideration. The requirements of IEC 62477-1, IEC 62109-1 and IEC 62109-2 may be of some use in identifying potential hazard and risk mitigation methods.

2.3 Provision for external connections

2.3.1 General

Inverters shall be used and installed as fixed equipment only. Inverters shall not be used as portable equipment.

Where an inverter is integral within an electric vehicle, the inverter shall be connected in accordance with [Clause 2.3.3.2](#).

Inverter provisions for external connection —

- (a) shall be for fixed equipment only; and
- (b) shall provide for safe and reliable connection to any d.c. source or load or any a.c. source or load.

All inverter ports (except communications ports) shall incorporate connection types for either —

- (i) permanently connected equipment (see [Clause 2.3.2](#)); or
- (ii) pluggable type B equipment (see [Clause 2.3.3](#)).

Inverter source or load connections shall not incorporate connection types for pluggable type A equipment.

2.3.2 Permanently connected equipment

Permanently connected inverters shall have terminals for connection to fixed installation wiring.

2.3.3 Pluggable type B equipment

2.3.3.1 General

Pluggable type B equipment shall have one of the following means of connection:

- (a) A non-detachable cord for connection to the electrical installation by means of a connector.
- (b) An appliance inlet that can be connected to a matching connector.

Pluggable type B equipment shall not incorporate —

- (i) a connection by a connector or inlet conforming to any of the dimensional sheets of AS/NZS 60320.1;
- (ii) a connection by a plug conforming to AS/NZS 3112; or
- (iii) a connection by a connector or inlet where hazardous voltages are accessible by the standard test finger.

NOTE The standard test finger is the same as that used in IEC 62109-1.

2.3.3.2 Electric vehicle connections

Pluggable type B equipment for an electric vehicle used in an inverter energy system connected via flexible lead with a plug shall —

- (a) be Mode 3 or Mode 4 in accordance with IEC 61851-1;
- (b) utilize a Case C connection as per IEC 61851-1 between the fixed electric vehicle supply equipment and the electric vehicle; and
- (c) utilize connectors that comply with AS IEC 62196.2 in the case of Mode 3 or IEC 62196-3 in the case of Mode 4.

2.4 Earth fault/earth leakage detection

2.4.1 Photovoltaic (PV) array earth fault/earth leakage detection

For inverter energy systems used with PV array systems that require earth fault detection and residual current detection, either internal or external to the inverter, the type of detection used shall be declared in accordance with IEC 62109-1 and IEC 62109-2.

If an external residual current device (RCD) is required, the manufacturer's installation instructions shall state the need for an RCD and shall specify its rating, type and required circuit location in accordance with [Section 7](#).

Compliance shall be checked by inspection of the inverter's markings and manufacturer's documentation, and testing in accordance with IEC 62109-2.

Where the additional detection for functionally earthed PV arrays, as required by AS/NZS 5033, is present in the inverter, this additional detection shall, before start-up of the system —

- (a) open circuit the functional earth connection to the PV array;
- (b) measure the resistance to earth of each conductor of the PV array;
- (c) if the earth resistance is above the resistance limit (R_{iso} limit) threshold specified in [Table 2.1](#), the system shall reconnect the functional earth and shall be allowed to start; and

- (d) if the earth resistance is equal to or less than the resistance limit (R_{iso} limit) threshold specified in [Table 2.1](#), the inverter shall shut down and initiate an earth fault alarm in accordance with the requirements of IEC 62109-2.

NOTE 1 Direct functional earthing of systems is not recommended. Functional earthing via a resistor is a safer option wherever it is possible.

NOTE 2 R_{iso} limit is the same as in AS/NZS 5033.

Table 2.1 — PV array to earth insulation resistance (R_{iso}) limits for inverter ratings

Inverter rating kVA	R_{iso} limit k Ω
≤ 20	30
> 20 to ≤ 30	20
> 30 to ≤ 50	15
> 50 to ≤ 100	10
> 100 to ≤ 200	7
> 200 to ≤ 400	4
> 400 to ≤ 500	2
> 500	1

2.4.2 Battery Energy Storage System (BESS) earth fault/earth leakage detection

For inverters used with battery systems, the requirements for earth fault alarm monitoring of AS/NZS 5139 may apply..

Where an inverter has a port for connecting a battery system installation that requires an alarm for monitoring of earth faults in conformance to AS/NZS 5139, the inverter should provide an alarm. Where no alarm is provided in the inverter, the inverter documentation shall require the addition of an external alarm and monitoring device.

The inverter documentation should refer to the battery system manufacturer's instructions for earth fault monitoring and earth leakage levels that indicate a fault.

2.5 Compatibility with electrical installation

The inverter shall be compatible with wiring practices for LV electrical installations of AS/NZS 3000 and variations as required in AS/NZS 4777.1. The inverter a.c. voltage and frequency operation shall conform to the limits specified in AS 60038.

NOTE The inverter needs to have a.c. voltage and frequency ratings compatible with Australian and New Zealand electrical supply regulations as a minimum requirement. In Australia, the voltage ranges present on electrical distribution networks may be in accordance with AS 61000.3.100. In New Zealand, the voltage range is specified in Electricity (Safety) Regulations 2010 (NZ) and is less than the limit specified in AS 60038.

2.6 Reactive power capability

The inverter shall be capable of absorbing or supplying at least the specified reactive power of [Clause 3.3](#) down to a power factor of 0.8 for all active power output or input levels above 60 % of rated apparent power. Where the active power output or input level is between 20 % and 60 % of rated apparent power, the inverter shall be capable of absorbing or supplying reactive power of at least 44 % of rated apparent power. Where the active power output or input level is below 20 % of rated apparent power,

reactive power being absorbed or supplied may be reduced due to limitation of inverter power factor capabilities. The minimum reactive power capability requirement is shown in [Figure 2.1](#).

NOTE For inverter active power output or input below 20 % of rated apparent power, the reactive power may be controlled such that the vars supplied or absorbed are less than the amount of vars supplied or absorbed at 20 % of rated apparent power output or input.

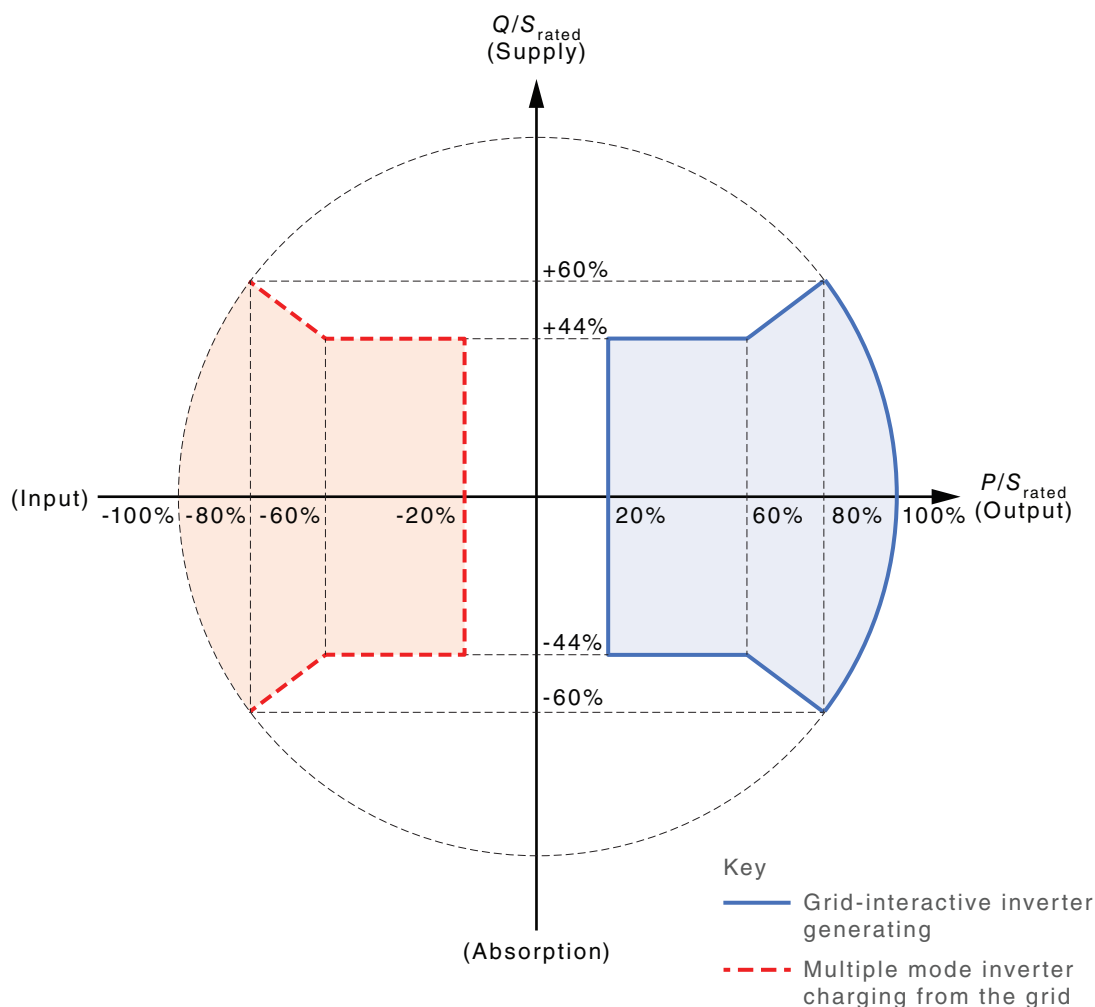


Figure 2.1 — Minimum reactive power capability

2.7 Harmonic currents

The harmonic currents of the inverter shall not exceed the limits specified in [Tables 2.2](#) and [2.3](#) and the total harmonic current distortion (I_{THD}) to the 50th harmonic shall be less than 5 %.

Compliance shall be determined by type testing in accordance with the harmonic current limit test specified in [Appendix B](#).

NOTE The inverter should not significantly radiate or sink frequencies used for ripple control by the local electrical distributor. The distributor should be consulted to determine which frequencies are used. Fitting of additional filtering components may be required in some grid areas.

Table 2.2 — Odd harmonic current limits

Odd harmonic order number	Limit for each individual odd harmonic based on percentage of fundamental
3, 5 and 7	4 %
9, 11 and 13	2 %
15, 17 and 19	1.0 %
21, 23, 25, 27, 29, 31 and 33	0.6 %

Table 2.3 — Even harmonic current limits

Even harmonic order number	Limit for each individual even harmonic based on percentage of fundamental
2, 4, 6 and 8	1 %
10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30 and 32	0.5 %

2.8 Voltage fluctuations and flicker

The inverter shall conform to the voltage fluctuation and flicker limits specified in AS/NZS 61000.3.3 for equipment with rated current less than or equal to 16 A per phase (a.c.).

For equipment with rated current greater than 16 A per phase (a.c.), if the inverter cannot meet the requirements of AS/NZS 61000.3.3, the maximum permissible connection point impedance ($Z_{\max}$) shall be determined such that the voltage fluctuation and flicker limits specified in AS/NZS 61000.3.3 can be met. The impedance shall be determined in accordance with the methods given in AS/NZS 61000.3.11. The values of P_{st} and P_{lt} , when tested using Z_{ref} , and the network impedance value ($Z_{\max}$ or Z_{ref}) required for compliance shall be included in the inverter documentation.

NOTE Definitions of P_{st} and P_{lt} and the value of Z_{ref} are given in AS/NZS 61000.3.3.

Compliance shall be determined by testing in accordance with the relevant Standard. The inverter shall remain connected throughout the test and the automatic disconnection device shall not operate.

2.9 Transient voltage limits

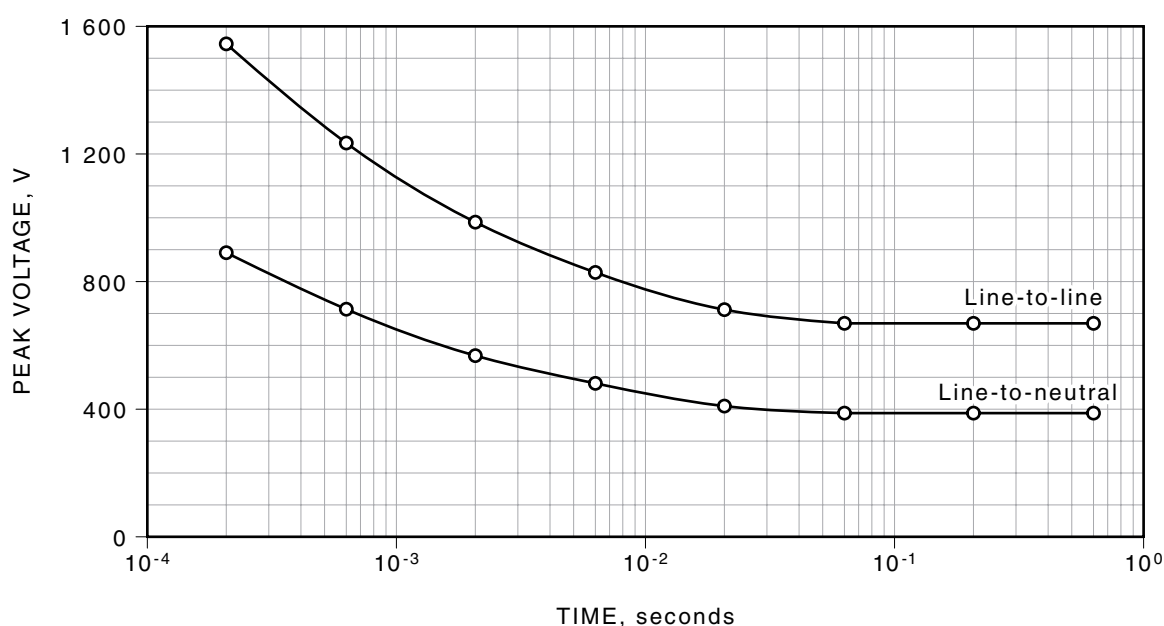
To prevent damage to electrical equipment connected to the same circuit as the inverter, disconnection of the inverter from the grid shall not result in transient overvoltages beyond the limits specified in [Table 2.4](#).

Compliance shall be determined by type testing in accordance with the transient voltage limit test specified in [Appendix C](#). The voltage-duration curve is derived from the measurements taken at the grid-interactive port of the inverter.

The transient voltage limits listed in [Table 2.4](#) are graphically illustrated in [Figure 2.2](#).

Table 2.4 — Transient voltage limits

Duration s	Instantaneous voltage	
	Line-to-neutral V	Line-to-line V
0.000 2	910	1 580
0.000 6	710	1 240
0.002	580	1 010
0.006	470	810
0.02	420	720
0.06	390	670
0.2	390	670
0.6	390	670

**Figure 2.2 — Voltage-duration curve of transient voltage limits**

2.10 DC current injection

In the case of a single-phase inverter, the d.c. current output of the inverter at any a.c. port including the grid-interactive and/or stand-alone port shall not exceed 0.5 % of the inverter's rated current or 5 mA, whichever is the greater.

In the case of a three-phase inverter, the d.c. current output of the inverter at any a.c. port, including the grid-interactive and/or stand-alone port, measured in each of the phases, shall not exceed 0.5 % of the inverter's per-phase rated current or 5 mA, whichever is the greater.

If the inverter does not incorporate a mains frequency isolating transformer or is not used with a dedicated external isolation transformer, it shall be type tested to ensure the d.c. current output at any a.c. port of the inverter is below the limits specified above at all current output levels.

Compliance shall be determined by type testing in accordance with the d.c. current injection test specified in [Appendix D](#).

NOTE For any inverter capable of injecting d.c. fault current into the electrical installation the selection of an RCD, where required, needs to be such that the RCD operates correctly with the level of d.c. fault current being injected.

2.11 Current balance for three-phase inverters

In the case of a three-phase inverter the a.c. current output shall be generated and injected into the three-phase electrical installation as a three-phase balanced current.

Compliance shall be determined by type testing in accordance with the following requirement. The a.c. current output for each phase for three-phase balanced current shall be within 5 % of the measured value of the other phases at rated current when injected into a balanced three-phase voltage.

Inverters which can be used in a voltage balance mode, as defined in [Clause 3.3.2.4](#), are allowed to generate unbalanced currents.

2.12 Isolation of energy sources

2.12.1 General

Where an energy source port has a load break switching device that is part of and within the inverter and is part of the method for isolating the energy source, the load break switching device/s shall —

- (a) have a voltage rating equal to or greater than the inverter's maximum voltage rating for that port;
- (b) interrupt all live conductors simultaneously;
- (c) be able to be secured in the open position and only secured when the main contacts are in the open position;
- (d) be either a switch disconnector that conforms to [Clause 2.12.2](#) or a circuit breaker that conforms to [Clause 2.12.3](#);
- (e) conform to additional requirements of [Clause 2.12.4](#) for PV array energy source;
- (f) conform to additional requirements of [Clause 2.12.5](#) for battery system energy sources; and
- (g) for all energy sources other than those listed in Items (e) and (f) be rated for a.c. or d.c. operation per the port type, and if d.c. rated be a non-polarized type.

Where a load break switching device is part of and within the inverter, and forms part of the method for isolating the energy source/s, there shall be a warning label to isolate energy source/s prior to removal of any cover for maintenance or repair.

Documentation of permitted and safe access (including isolation) to inverters for maintenance and repair shall be included in manuals.

Combination fused switch disconnectors or fused circuit breakers shall not be used as the load break switching device as part of or within the inverter.

Where any load break switching device is part of and within the inverter and does not meet the requirements of this [Clause \(2.12.1\)](#) a warning label shall be used to indicate that an additional external load break switching device is required. Documentation for an inverter that requires an external load break switching device shall include the requirement of an additional external load break switching device that conforms to the requirements AS/NZS 4777.1.

NOTE Use of terminology such as AC-21B, DC-21B, and DC-PV1 are from AS 60947.3.

2.12.2 Switch-disconnector

Where a load break switching device that is part of or within the inverter is a switch-disconnector, it shall —

- (a) be rated for independent manual operation;

- (b) be classified as suitable for disconnection and be marked with the following symbol:



- (c) have a utilization category of at least DC-21B where the port is suitable for a d.c. energy source;
- (d) have a utilization category at least AC-21B where the port is suitable for an a.c. energy source;
- (e) conform to relevant switch-disconnector standards as specified for the port and rating criteria in [Clauses 2.12.4](#) or [2.12.5](#);
- (f) have a current rating where rated operational current (I_e) and $I_{(make)}$, and $I_{c(break)}$ rated current are rated such that the disconnector is capable of interrupting the maximum rated normal and fault current for that port as specified in the inverter documentation; and
- (g) have a current rating for the thermal current (I_{the} and $I_{the\ solar}$) rated for the installation environment specified by the manufacturer.

2.12.3 Circuit breaker

Where a load break switching device that is part of or within the inverter is a circuit breaker, it shall —

- (a) conform to AS/NZS IEC 60947.2; and
- (b) be classified as suitable for isolation and be marked with the following symbol:



2.12.4 PV array ports

For inverters with an apparent power rating of less than 30 kVA the isolating devices for PV array ports that are part of or within the inverter shall conform to the requirements of AS 60947.3 for switch-disconnectors for photovoltaic (PV) d.c. applications.

For inverters with an apparent power rating of 30 kVA or more the isolating devices for PV array ports as a part of or within the inverter shall conform to AS 60947.3 for switch-disconnectors for photovoltaic (PV) d.c. applications with the following modifications:

- (a) have a minimum utilization category of DC-PV1;
- (b) for inverters with IP6x or greater, have at least pollution degree 2; and
- (c) where the utilization category is DC-PV1, have a continuous backfeed current as tested by IEC 62109-1 of less than 0.3 A.

2.12.5 Battery system ports

Isolating devices for battery system ports that are part of or within the inverter shall meet the following additional requirements:

- (a) Shall conform to AS 60947.3.
- (b) Shall be of the non-polarized type.
- (c) Shall have a current rating equal to or greater than the maximum rated d.c. current for the battery system port.
- (d) Shall have a utilization category of at least DC-21B.

NOTE Other d.c. energy ports may be treated the same as a battery system port.

2.13 Measurement accuracy

To ensure the stable and reliable operation of the inverter protective functions and all modes of operation, the inverter shall conform to or exceed the measurement and calculation accuracy requirements specified in [Table 2.5](#). Where the inverter utilizes an external measurement device, the measurement and calculation accuracy of the system (including the combination of the inverter and external measurement device) shall conform to the measurement and calculation accuracy requirements specified in [Table 2.5](#).

Table 2.5 — Specification for measurement and calculation accuracy

Quantity	Measurement accuracy	Measurement time	Measurement range
Voltage	$\pm 1 \% V_{\text{nominal}}$	100 ms	0 to 280 V
Frequency	$\pm 10 \text{ mHz}$	100 ms	45 to 55 Hz
Active power	$\pm 4 \% S_{\text{rated}}$	200 ms	0 to 120 % S_{rated}
Reactive power	$\pm 4 \% S_{\text{rated}}$	200 ms	0 to $\pm 120 \% S_{\text{rated}}$
Apparent power	$\pm 4 \% S_{\text{rated}}$	200 ms	0 to $\pm 120 \% S_{\text{rated}}$
NOTE For the purposes of measurement accuracy, V_{nominal} refers to 230 V of AS 60038.			

Voltage at the grid-interactive port shall not be conditioned by an external device such that the voltage measured at the grid interactive port does not reflect the grid voltage.

2.14 Prioritization of protection and operational modes

Inverters responding to abnormal voltage or frequency conditions shall meet the prioritization levels of [Table 2.6](#).

Table 2.6 — Specification for prioritization of inverter functions

Prioritization level	Description
1	All disturbance withstand limits described in Section 4 while abnormal conditions prevail and until the duration exceeds the time limits of the passive anti-islanding settings in Clause 4.4 .
2	All requirements to operate the automatic disconnection device.
3	Generation control function of Section 6 .
4	Sustained operation for frequency disturbances of Clause 4.5.3 .
5	Inverter demand response mode of Clause 3.2 and power quality modes of Clauses 3.3.2 and 3.3.3 (see Note 1).
6	Power rate limit of Clause 3.3.4 .
NOTE 1 The prioritization requirements for the power quality modes is defined in Clause 3.3 .	
NOTE 2 The performance of the inverter when responding to demand response commands is defined in Clause 3.2.1 .	

2.15 Firmware

The inverter firmware determines the functioning of an inverter as well as responses required by this Standard. The functions may be spread over multiple programmable devices. The inverter firmware may change over the life of a specific inverter model.

The inverter firmware version shall be reported in testing. The inverter firmware version identifier shall be accessible for inspection. Inverter firmware version information may be displayed via a panel/screen, external device or software interface.

The inverter firmware shall be secured against inadvertent or unauthorized changes. Changes to the inverter firmware shall require the use of a tool and special instructions not provided to unauthorized personnel.

NOTE Special interface devices and passwords are regarded as tools.

Inverter firmware changes and updates shall conform to the requirements of this Standard. Where an inverter firmware update affects any of the provisions specified in [Sections 2, 3, 4](#) and [5](#) conformance with this Standard shall be determined.

Section 3 Operational modes and multiple mode inverters

3.1 General

Unless otherwise stated, the modes in the following Clauses are for the grid-interactive port of the inverter.

3.2 Inverter demand response modes (DRMs)

3.2.1 General

The inverter shall support the demand response mode DRM 0 of [Table 3.1](#). The inverter should support the other demand response modes of [Table 3.1](#).

NOTE 1 The only mandatory demand response mode is DRM 0. Support for other demand response modes is optional.

The inverter shall detect and initiate a response to all supported demand response commands within 2 s. The inverter shall continue to respond while the mode remains asserted.

The inverter shall conform to the relevant requirements of [Section 2](#) and this [Section \(3\)](#), and with all of the requirements of [Section 4](#), while any demand response mode is asserted and following the cessation of a demand response command.

The inverter shall be capable of responding to demand response commands via a demand response enabling device (DRED) as defined in [Clause 3.2.2](#).

Compliance shall be determined by testing as specified in [Appendix E](#).

NOTE 2 The demand response modes may be provided via an integrated device or an external device, where DRM 0 meets the requirements of [Clause 4.1](#). Only integrated devices and external devices providing DRM 0 are applicable for testing in this Standard.

Table 3.1 — Demand response modes (DRMs)

Mode	Requirement
DRM 0	Operate the disconnection device
DRM 1	Do not consume power
DRM 2	Do not consume at more than 50 % of rated power
DRM 3	Do not consume at more than 75 % of rated power AND supply reactive power if capable
DRM 4	Increase power consumption (subject to constraints from other active DRMs)
DRM 5	Do not generate power
DRM 6	Do not generate at more than 50 % of rated power
DRM 7	Do not generate at more than 75 % of rated power AND absorb reactive power if capable
DRM 8	Increase power generation (subject to constraints from other active DRMs)
NOTE Demand response modes of Table 3.1 are as described in AS/NZS 4755.3 series of Standards.	

3.2.2 Interaction with demand response enabling device (DRED)

The inverter shall have a means of connecting to a DRED. This means of connection shall include a terminal block or RJ45 socket. The terminal block or RJ45 socket shall conform to the minimum

electrical specifications in [Table 3.2](#). The terminal block or RJ45 socket may be physically mounted in the inverter or in a separate device that remotely communicates with the inverter.

NOTE 1 In the absence of a DRED, the inverter may be fitted with a DRED bypass device.

NOTE 2 RJ45 is the common name for the 8P8C modular connector specified in ISO/IEC 8877, which is generally used to terminate communications cables.

NOTE 3 Where a separate device that remotely communicates with the inverter is used then other methods are possible using a range of different communications systems and protocols in the inverter or external. Provided that this still allows the inverter to interact with the DRED.

Table 3.2 — RJ45 socket and terminal block specifications

Property	Value	Symbol
Current rating	≥ 1.5	A
Voltage rating (V d.c.)	≥ 125	V
Dielectric strength (V r.m.s. 50 Hz, 1 min)	$\geq 1\ 000$	V
Insulation resistance (M Ω min 500 V)	≥ 500	M Ω

The DRED asserts demand response modes by shorting together terminals or pins as specified in [Table 3.3](#). In detecting the state of the DRED, the inverter shall conform to the following requirements:

- (a) The inverter shall not inject more than 30 mA (d.c. or a.c.) into —
 - (i) terminals “DRM1/5”, “DRM2/6”, “DRM3/7” or “DRM4/8”, where a terminal block is used; or
 - (ii) pins 1, 2, 3 or 4, where an RJ45 socket is used.
- (b) The inverter shall allow for a drop of up to 1.6 V across the DRED and associated wiring when nominally shorted.
- (c) The inverter shall not supply more than 34.5 V (d.c. or a.c.) to any terminal of the terminal block or RJ45 socket.
- (d) If the impedance between pins 5 and 6 is detected to be above 20 k Ω , the inverter shall fail-safe to DRM 0 asserted.

Table 3.3 — Method of asserting demand response modes

Mode	RJ45 socket		Terminal block	
	Asserted by shorting pins:		Asserted by shorting terminals marked:	
DRM 0	5	6	“REF GEN/0” or “RG/0”	“COM LOAD/0” or “CL/0”
DRM 1	1	6	“DRM1/5” or “1/5”	“COM LOAD/0” or “CL/0”
DRM 2	2	6	“DRM2/6” or “2/6”	“COM LOAD/0” or “CL/0”
DRM 3	3	6	“DRM3/7” or “3/7”	“COM LOAD/0” or “CL/0”
DRM 4	4	6	“DRM4/8” or “4/8”	“COM LOAD/0” or “CL/0”
DRM 5	1	5	“DRM1/5” or “1/5”	“REF GEN/0” or “RG/0”
DRM 6	2	5	“DRM2/6” or “2/6”	“REF GEN/0” or “RG/0”
DRM 7	3	5	“DRM3/7” or “3/7”	“REF GEN/0” or “RG/0”
DRM 8	4	5	“DRM4/8” or “4/8”	“REF GEN/0” or “RG/0”

The RJ45 socket pin assignments for demand response modes are as specified in [Table 3.4](#).

Table 3.4 — RJ45 socket pin assignment

Pin	Assignment for inverters capable of both charging and discharging
1	DRM 1/5
2	DRM 2/6
3	DRM 3/7
4	DRM 4/8
5	REF GEN/0
6	COM LOAD/0
7	V+
8	V-

The DRED may assert more than one DRM at a time, in which case the requirements of every active DRM that is supported by the inverter shall be simultaneously satisfied.

The inverter shall detect the assertion of any combination of DRMs which result in terminal 5 and 6 being shorted simultaneously as assertion of DRM 0.

Where DRM 3 or DRM 7 are supported, the reactive power set-point shall be set by default to operate at unity power factor. The reactive power set-point should be adjustable up to a minimum of 60 % of the inverter's kVA rating.

The inverter may provide a power supply for use by the DRED. If included this shall be d.c. and of a voltage less than 34.5 V.

Where an RJ45 socket is used, pins 7 and 8 may be utilized as positive and negative DRED power supply pins respectively. The power supply shall be capable of delivering at least 0.5 A at a minimum of 6 V d.c., otherwise the inverter shall short pins 7 and 8 together.

Where a terminal block is used, only those terminals needed for the supported DRMs are required.

3.3 Inverter power quality response modes

3.3.1 General

The inverter shall have the following power quality response modes:

- (a) Volt-var response mode ([Clause 3.3.2](#)).
- (b) Volt-watt response mode ([Clause 3.3.2](#)).
- (c) Fixed power factor ([Clause 3.3.3](#)).
- (d) Reactive power mode ([Clause 3.3.3](#)).
- (e) Power rate limit ([Clause 3.3.4](#)).

The inverter may have the Voltage balance mode ([Clause 3.3.2.4](#)).

For each of the power quality response modes available in the inverter, the inverter shall conform to the relevant requirements of this [Section \(3\)](#) and [Section 2](#), and all of the requirements of [Sections 4](#) and [5](#), when these modes are enabled or disabled.

Compliance shall be determined by type testing as specified in [Appendix F](#), [Appendix G](#) and [Appendix J](#).

If these power quality response modes of operation are controlled by an external device, the external device shall not interfere with the inverter conforming to the relevant requirements of this [Section \(3\)](#).

and [Section 2](#), and all of the requirements of [Section 4](#) and [5](#), when the external device is controlling these modes.

The required characteristics of the power quality response modes are specified below in [Clauses 3.3.2, 3.3.3](#) and [3.3.4](#).

NOTE Additional requirements in [Clause 3.4.3](#) are for multiple mode inverters with energy storage and when operating in charging modes.

3.3.2 Volt response modes

3.3.2.1 General

The volt-watt and volt-var response modes specified in [Clause 3.3.2.2](#) and [Clause 3.3.2.3](#) shall be able to operate concurrently when both modes are active.

For three-phase inverters, the inverter shall use the average of the three single-phase voltages as the reference voltage to determine the corresponding volt response action.

The volt-watt mode ([Clause 3.3.2.2](#)) may be used with the volt-var mode ([Clause 3.3.2.3](#)), fixed power factor mode ([Clause 3.3.3](#)), or fixed reactive power mode ([Clause 3.3.3](#)).

The volt-var mode may be used with the volt-watt mode ([Clause 3.3.2.2](#)).

Where a power quality response mode is enabled the inverter shall commence and complete the required response according to the defined characteristics of [Clause 3.3.2](#) within the relevant times specified in [Table 3.5](#), starting from the time the voltage is measured as deviating by 1 V from the 10 s average. Response times faster than the maximum times in [Table 3.5](#) are permitted, and commencement and completion of the inverter response should not be unnecessarily delayed or slowed.

Table 3.5 — Power quality response modes — Maximum response times

Region	Response commencement time	Response completion time
All	1 s	10 s

Compliance shall be determined by type testing in accordance with the power quality (voltage) response mode tests specified in [Appendix G](#).

3.3.2.2 Volt-watt response mode

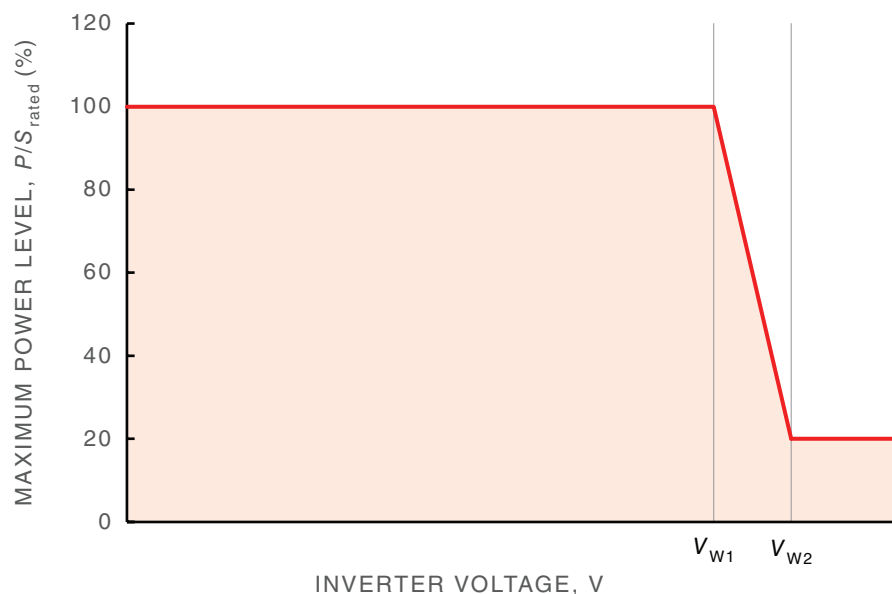
The volt-watt response mode varies the maximum active power output level of the inverter in response to the voltage at its grid-interactive port. The volt-watt response mode shall be enabled by default.

The response curve required for the volt-watt response mode is defined by two volt response reference values and corresponding maximum active power output levels, the default values are listed in [Table 3.6](#). Above V_{W2} , the maximum active power output shall not exceed the limit specified at V_{W2} . An example volt-watt response mode is shown in [Figure 3.1](#).

Table 3.6 — Volt-watt response default set-point values

Region	Default value	V_{W1}	V_{W2}
Australia A	Voltage	253 V	260 V
	Inverter maximum active power output level (P) % of S_{rated}	100 %	20 %
Australia B	Voltage	250 V	260 V
	Inverter maximum active power output level (P) % of S_{rated}	100 %	20 %
Australia C	Voltage	253 V	260 V
	Inverter maximum active power output level (P) % of S_{rated}	100 %	20 %
New Zealand	Voltage	242 V	250 V
	Inverter maximum active power output level (P) % of S_{rated}	100 %	20 %
Allowed range	Voltage	235 to 255 V	240 to 265 V
	Inverter maximum active power output level (P) % of S_{rated}	100 %	0 % to 20 %

NOTE Australia C parameter set is intended for application in isolated or remote power systems.

**Figure 3.1 — Example curve for the volt-watt response mode**

3.3.2.3 Volt-var response mode

The volt-var response mode varies the reactive power absorbed or supplied by the inverter in response to the voltage at its grid-interactive port. The volt-var response mode shall be enabled by default.

The response curve required for the volt-var response is defined by four volt response reference values and corresponding reactive power levels, the default values are listed in [Table 3.7](#). Below V_{V1} , reactive power shall be maintained at the level specified for V_{V1} . Above V_{V4} , reactive power shall be maintained at the level specified for V_{V4} . An example volt-var response mode is shown in [Figure 3.2](#).

Where the inverter apparent power rating is reached, active power level shall be reduced to stay within the inverter apparent power rating while meeting the volt-var mode reactive power requirements of this [Clause \(3.3.2.3\)](#). This behaviour is intended to provide reactive power priority.

Table 3.7 — Volt-var response set-point values

Region	Default value	V_{V1}	V_{V2}	V_{V3}	V_{V4}
Australia A	Voltage	207 V	220 V	240 V	258 V
	Inverter reactive power level (Q) % of S_{rated}	44 % supplying	0 %	0 %	60 % absorbing
Australia B	Voltage	205 V	220 V	235 V	255 V
	Inverter reactive power level (Q) % of S_{rated}	30 % supplying	0 %	0 %	40 % absorbing
Australia C	Voltage	215 V	230 V	240 V	255 V
	Inverter reactive power level (Q) % of S_{rated}	44 % supplying	0 %	0 %	60 % absorbing
New Zealand	Voltage	207 V	220 V	235 V	244 V
	Inverter reactive power level (Q) % of S_{rated}	60 % supplying	0 %	0 %	60 % absorbing
Allowed Range	Voltage	180 to 230 V	180 to 230 V	230 to 265 V	230 to 265 V
	Inverter reactive power level (Q) % of S_{rated}	30 to 60 % supplying	0 %	0 %	30 to 60 % absorbing
NOTE 1 Inverters may operate at a reactive power level with a range up to 100 % supplying or absorbing.					
NOTE 2 Australia C parameter set is intended for application in isolated or remote power systems.					

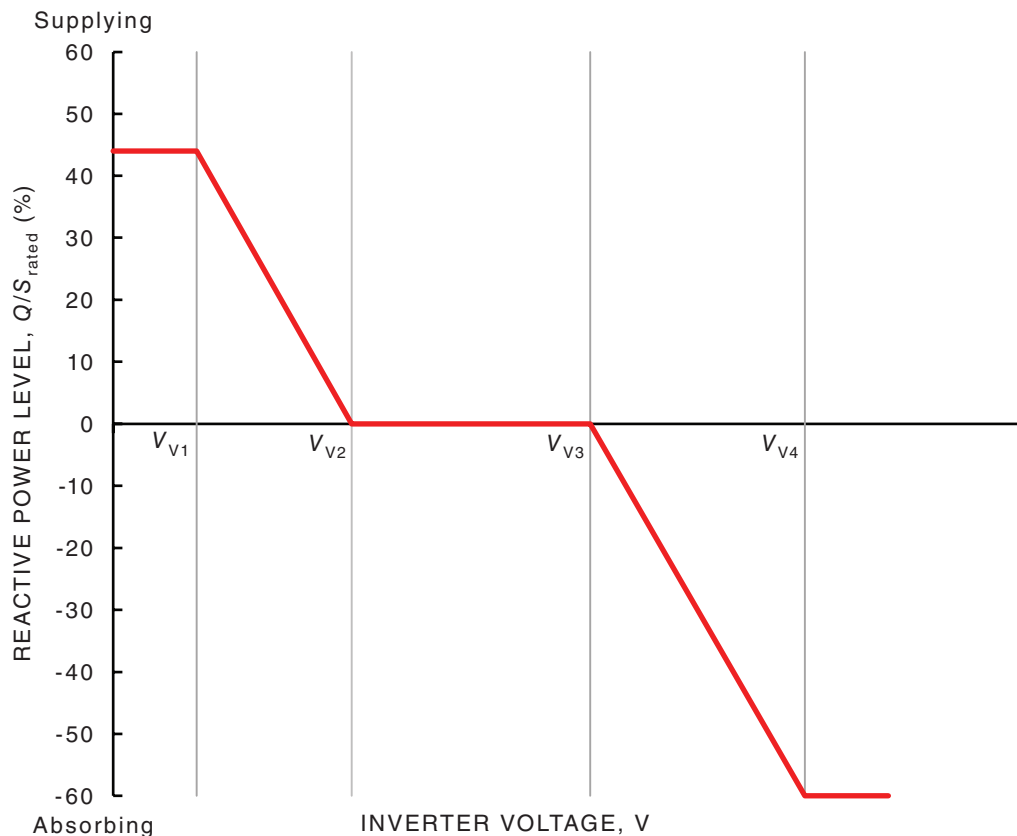


Figure 3.2 — Example curve for the volt-var control mode

3.3.2.4 Voltage balance modes

A voltage imbalance between phases may occur in an electrical installation that presents a load that is not balanced across the phases. Three-phase inverters, or single-phase inverters used in a three-phase combination may be used for voltage balancing between phases by injecting unbalanced three-phase currents into the electrical installation.

If the voltage balance mode is available, the following requirements apply:

- (a) The voltage balance mode shall be disabled by default.
- (b) For single-phase inverters used in a three-phase combination, the requirements of [Clause 5.2](#) apply.
- (c) The voltage balance mode shall be able to —
 - (i) operate correctly with a single fault applied to the voltage balance control system;
 - (ii) detect the fault or loss of operability and cause the inverter to revert to injecting current into the three-phase electrical installation as a three-phase balanced current; or
 - (iii) detect the fault or loss of operability and disconnect the inverter from the electrical installation.

3.3.3 Fixed power factor mode and reactive power mode

The fixed power factor mode or the reactive power mode may be enabled in some situations by the electrical distributor to meet local grid requirements, one of these modes shall be enabled if the volt-var mode is disabled. These modes shall be disabled by default.

For the fixed power factor mode, the minimum range of settings shall be 0.8 to 1.0 supplying reactive power, and 1.0 to 0.8 absorbing reactive power, the default power factor setting shall be 1.0. The fixed power factor mode is for control of the displacement power factor over the range of inverter power output.

The volt-watt mode and fixed power factor mode shall be able to operate concurrently.

For the fixed power factor mode, the measurement of power factor shall be the displacement power factor of the inverter treated as a load from the perspective of the grid.

For the reactive power mode, the minimum setting range for ratio of reactive power (vars) to rated apparent power shall be at least 60 % absorbing to 60 % supplying, the default reactive power setting shall be 0 %.

The volt-watt mode and reactive power mode shall be able to operate concurrently.

Where the inverter apparent power rating is reached, active power output level shall be reduced to meet the inverter apparent power rating while meeting the fixed power factor mode or reactive power requirements of this [Clause \(3.3.3\)](#). This behaviour is intended to provide reactive power priority.

NOTE Refer to [Clause 2.6](#) for reactive power capability.

Compliance shall be determined by type testing in accordance with the fixed power factor mode and reactive power mode test specified in [Appendix F](#).

3.3.4 Power rate limit

3.3.4.1 General

The power rate limit for an inverter is a power quality response mode. The inverter shall have the capability to rate limit changes in power generation through the grid-interactive port. Inverters capable of multiple mode operation shall have the capability to rate limit changes in power level (for example increasing/decreasing of charging rates of connected energy storage).

The power rate limit only applies to the changes in power level specified in [Clause 3.3.4.3](#).

The power rate limit does not apply when the automatic disconnection device is required to operate (i.e. to disconnect).

NOTE The power rate limit causes the inverter power level to either ramp up or ramp down smoothly as it transitions from one power level to another. Changes in power level may be constrained by several factors such as the type of energy source connected, energy storage and operating state of the inverter. For example, an inverter without energy storage may not be able to ramp down when required if the energy source ceases suddenly or conversely may not be able to ramp up if the energy source is not able to deliver more power. Likewise, when the inverter is generating maximum power, it can ramp down but cannot ramp up, while a multiple mode inverter with a completely charged storage system may ramp up (discharge power) but cannot ramp up consumption of power (charge power).

Compliance shall be determined by type testing in accordance with the reconnection test specified in [Appendix I](#) and the sustained operation for frequency disturbance test in [Appendix J](#).

3.3.4.2 Gradient of power rate limit

The power rate limit (W_{Gra}) is the ramp rate of active power output in response to changes in power and is defined as a percentage of rated power per minute. The nominal ramp time (T_n) is the nominal

time for a 100 % change in power output with a power rate limit of W_{Gra} . An inverter shall have an adjustable power rate limit (W_{Gra}) which limits the change in power output to the set power rate limit. The default setting for the power rate limit (W_{Gra}) for increase and decrease shall be 16.67 % of rated power per minute which is a nominal ramp time of 6 min.

$$W_{\text{Gra}} = \frac{100 \%}{T_n}$$

where

T_n = nominal ramp time in minutes (default value is 6 min)

100 % = total change from no output to rated power output or from rated power output to no output.

The power rate limit (W_{Gra}) shall be adjustable within the range 5 % to 100 % of rated power per minute. It is permitted to have two separate power rate limits for increase and decrease in power level, as follows:

- (a) to rate limit an increase in power ($W_{\text{Gra+}}$); and
- (b) to rate limit a decrease in power ($W_{\text{Gra-}}$).

The default setting of $W_{\text{Gra+}}$ and $W_{\text{Gra-}}$ shall be the same as W_{Gra} .

3.3.4.3 Power rate limit modes

3.3.4.3.1 General

The inverter power rate limit (W_{Gra}) is applicable to operate in the following modes:

- (a) Soft ramp up after connect, reconnect or soft ramp up/down following a response to frequency disturbance.
- (b) Changes in a.c. operation and control.
- (c) Changes in energy source operation.

The following clauses provide operation information for each mode.

3.3.4.3.2 Soft ramp up after connect, reconnect or soft ramp up/down following a response to frequency disturbance

All inverters shall have this mode. This mode shall be enabled as per [Clause 4.7](#) and for the change in power required by [Clause 4.5.3](#) after frequency has been restored to within the required limits.

3.3.4.3.3 Changes in a.c. operation and control

If available, this mode shall be enabled for a change in a demand response mode of [Clause 3.2](#) (except for DRM 0). When a demand response mode of [Clause 3.2](#) (except for DRM 0) is asserted or unasserted the power rate limit (W_{Gra}) shall apply to the increase or decrease in power generation or consumption and the transitions between power levels.

NOTE Changes in DRM modes (except for DRM 0) are dependent on the availability of the energy source or energy storage to respond. For example an increase in power is not possible if the required increase cannot be met by the available energy resource situation.

3.3.4.3.4 Changes in energy source operation

This mode only applies to multiple mode inverters with energy storage. It operates when there is a change in the energy resource available to the inverter, which causes a change in power through the grid-interactive port. For this mode the power rate limit (W_{Gra}) should apply to the increase or decrease in power generation or consumption, and to the transitions between power levels. For this mode, the power rate limit (W_{Gra}) should be able to be enabled or disabled. The power rate limit shall be disabled by default. The increase or decrease for transitions between power levels is contingent on external situations (such as amount of available solar energy, wind energy or discharge capacity). Only for increases or decreases in the power level which are faster than the power rate limit (W_{Gra}) does a control action to limit the ramp rate apply.

3.3.4.4 Nonlinearity of power rate limit changes

The nonlinearity (NL) of the power rate limit (W_{Gra}) in response to a change of the inverter power level, as defined by the characteristic curve depicted in [Figure 3.3](#), shall be less than 10 %.

The following equation shall be used to calculate the maximum nonlinearity:

$$NL = \frac{(100 \times \Delta)}{T_n}$$

where

NL = maximum nonlinearity

Δ = allowed deviation from the characteristic curve

T_n = nominal ramp time ($= 1/W_{Gra}$)

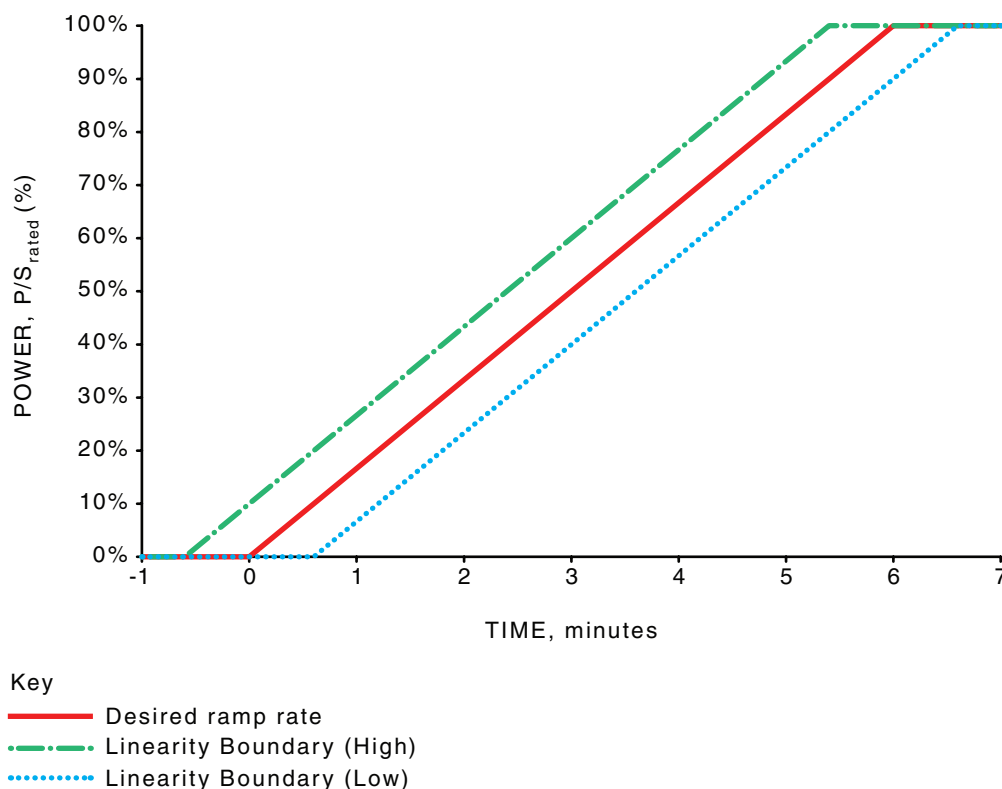


Figure 3.3 — Nonlinearity of ramp rate (W_{Gra} , T_n = default values)

3.4 Multiple mode inverter operation

3.4.1 General

The requirements in this Clause for multiple mode inverters are in addition to the requirements for inverters.

Multiple mode inverters operating in charging mode through the grid-interactive port shall conform to the requirements of [Clause 3.3.2.3](#).

When the multiple mode inverter is operating in stand-alone mode and disconnected from the grid all active conductors of the stand-alone port shall be isolated from the grid.

Multiple mode inverters in stand-alone mode may utilize the grid-interactive port as the stand-alone port or may utilize a separate stand-alone port.

Multiple mode inverters shall be arranged to ensure that the continuity of the neutral conductor to the load from the electrical installation is not interrupted when the inverter is operating in stand-alone mode, disconnected from the grid and supplies a load via the stand-alone port.

NOTE The requirements for the automatic disconnection device in [Clause 4.2](#) are intended to ensure that at least basic insulation or simple separation is maintained between the energy source port, the grid-interactive port and stand-alone ports when the inverter ceases to operate.

Multiple mode inverters shall be arranged such that only the allowed installation methods of AS/NZS 3000 and AS/NZS 4777.1 can be used.

When the multiple mode inverter is operating in stand-alone mode and is disconnected from the grid, the stand-alone port shall conform to the requirements for d.c. current injection (refer to [Clause 2.10](#)) into the connected load circuits. The type of RCD compatible with and for use on the stand-alone mode outputs shall be declared.

3.4.2 Sinusoidal output in stand-alone mode

The a.c. output voltage waveform of a stand-alone port of a multiple mode inverter operating in stand-alone mode, shall conform to the requirements of this [Clause \(3.4.2\)](#). The a.c. output voltage waveform of a stand-alone mode shall have a voltage total harmonic distortion (THD) not exceeding 5 % and no individual harmonic at a level exceeding 5 %.

Compliance shall be checked by measuring the THD and the individual harmonic voltages with the inverter delivering 5 % power or the lowest continuous available power output greater than 5 %, and 50 % and 100 % of its continuous rated power, into a resistive load, with the inverter supplied with nominal d.c. input voltage. The THD measuring instrument shall measure the sum of the harmonics from $n = 2$ to $n = 50$ as a percentage of the fundamental ($n = 1$) component at each load level.

3.4.3 Volt-watt response mode for inverters with energy storage when charging

The volt-watt response mode for charging of energy storage varies the maximum active power input of the inverter from the grid in response to the voltage at its grid-interactive port. An inverter with energy storage that can be charged through the grid-interactive port shall have this volt-watt response mode. This volt-watt response mode is only active when energy storage charges through the grid-interactive port. The volt-watt response mode for charging of energy storage shall be enabled by default.

The response curve required for the volt-watt response is defined by two volt response reference values and corresponding maximum power input levels through the grid-interactive port, the default values are listed in [Table 3.8](#). Example response modes are shown in [Figure 3.4](#).

The inverter shall commence and complete any required volt-watt response for charging according to the defined characteristics of this [Clause 3.4.3](#) within the relevant times specified in [Table 3.5](#).

Table 3.8 — Volt-watt response set-point values for multiple mode inverters with energy storage when charging

Region	Default value	V_{W1-ch}	V_{W2-ch}
Australia A	Voltage	207 V	215 V
	$P_{charge}/P_{rated-ch}$	20 %	100 %
Australia B	Voltage	195 V	215 V
	$P_{charge}/P_{rated-ch}$	0 %	100 %
Australia C	Voltage	207 V	215 V
	$P_{charge}/P_{rated-ch}$	20 %	100 %
New Zealand	Voltage	216 V	224 V
	$P_{charge}/P_{rated-ch}$	20 %	100 %
Allowed Range	Voltage	180 to 230 V	180 to 230 V
	$P_{charge}/P_{rated-ch}$	0 to 20 %	100 %

NOTE 1

P_{charge} refers to power input level through the grid-interactive port.

NOTE 2

$P_{rated-ch}$ refers to the rated active power input through the grid-interactive port used for charging the energy storage.

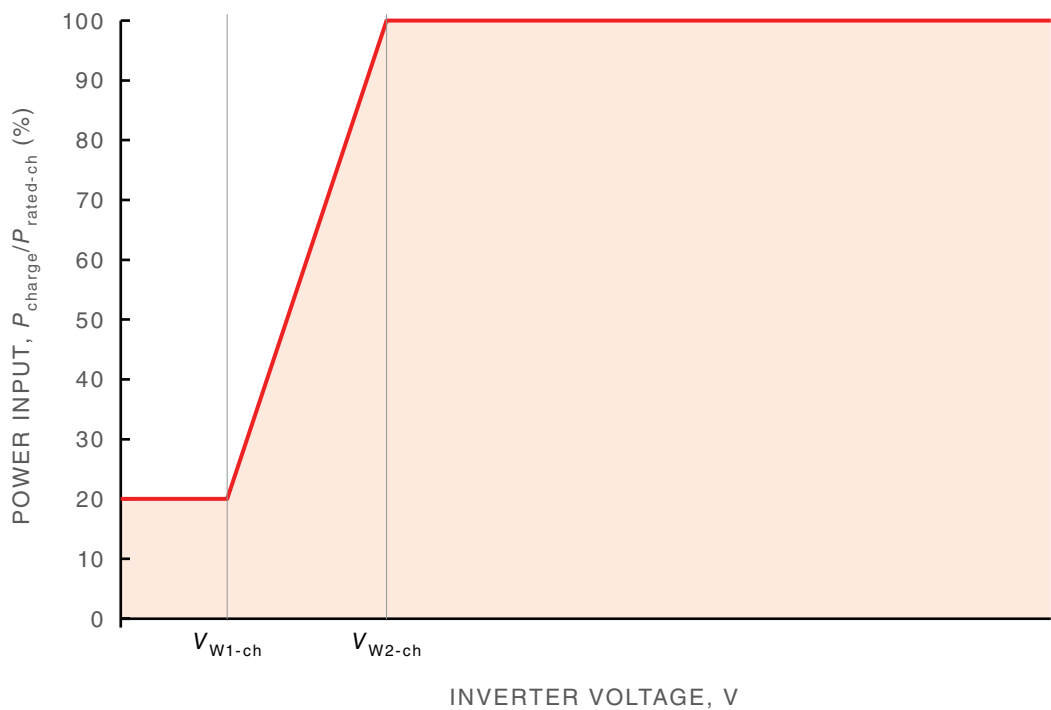


Figure 3.4 — Example curve for the volt-watt response mode for multiple mode inverters with energy storage when charging

3.4.4 Stand-alone inverters

There are a variety of stand-alone inverters, which are intended for supply of 230 V a.c. power to loads within the electrical installation only, with energy provided from batteries, solar arrays and/or other d.c. sources. These inverters have a stand-alone port for supplying the loads within the electrical installation separate to the a.c. input port. These inverters also have an a.c. input port that can be directly connected to either a grid or an independent a.c. energy source such as a diesel generating set. A stand-alone inverter is a type of multiple mode inverter.

Any inverter that is not a grid-interactive inverter but is an uninterruptible power system (UPS) that is in accordance with AS 62040.1, AS IEC 62040.2, AS IEC 62040.3 and IEC 62040 series is not considered a stand-alone inverter for the purposes of this Standard.

The a.c. input port of a stand-alone inverter, means a port provided to support the energy source, such as —

- (a) charging the system batteries when other energy sources are unavailable;
- (b) providing direct supply to site loads, bypassing the inverter completely, when local generation such as from solar and batteries is insufficient; or
- (c) providing supplementary supply to site loads (in parallel with the inverter output) when local generation is insufficient to supply the entire load.

Stand-alone inverters shall not output power from the a.c. input port during normal operation or fault conditions.

The stand-alone port of a stand-alone inverter shall be separate to the a.c. input port.

Where the a.c. input port can be connected to the grid the inverter shall have settings to conform to this Standard for connection to the grid.

A stand-alone inverter with an a.c. input port that is connected to a grid, shall conform to the requirements of this Standard with modifications as described in [Appendix M](#).

NOTE The arrangement covered by this Clause is for where the a.c. input will use the grid as an alternative/back up energy source for the stand-alone system to supply energy to the installation.

3.5 Security of operational settings

The settings of the demand response or power quality response modes of the inverter shall be secured against inadvertent or unauthorized change. Changes to the settings shall require the use of a tool and special instructions not provided to unauthorized personnel.

NOTE Special interface devices and passwords are regarded as tools.

The settings shall be capable of only being adjusted within the values specified in this [Section \(3\)](#).

Compliance shall be determined by inspection.

The inverter settings shall be able to be viewed in read-only mode for verification. A set of operational instructions for viewing inverter regional setting shall be available. Inverter operational settings information may be displayed via a panel/screen, external device or software interface.

Section 4 Protective functions for connection to electrical installations and the grid

4.1 General

There shall be an automatic disconnection device to prevent injection of energy into the point of supply and prevent the formation of an unintentional island with the grid or part thereof when supply from the grid is disrupted.

NOTE This includes preventing the formation of an island within any part of the electrical installation, which is normally connected to the grid.

The automatic disconnection device shall operate —

- (a) if supply from the grid is disrupted;
- (b) when the grid goes outside preset limits (e.g. undervoltage/overvoltage, under-frequency/over-frequency); or
- (c) when the demand response mode DRM 0 (see [Clause 3.2](#)) is asserted.

For inverter energy systems connected to multiple phases the automatic disconnection device shall operate if any of the above conditions is met on any phase.

The automatic disconnection device may be within the inverter or a separate device.

Compliance shall be determined by type testing the automatic disconnection device within the inverter or combined with the inverter. Where the automatic disconnection device is separate to the inverter (or inverters), the inverter (or inverters) and the automatic disconnection device shall be tested together as though they are one inverter. Compliance of one combination of inverter and automatic disconnection device does not ensure compliance of either device as part of a different combination. Specific requirements are specified in [Clauses 4.2 to 4.8](#).

4.2 Automatic disconnection device

The automatic disconnection device shall prevent power (both a.c. and d.c.) from entering the grid when the automatic disconnection device operates.

The automatic disconnection device shall provide isolation in all live conductors.

NOTE 1 The automatic disconnection device need not disconnect sensing and control circuits.

Automatic disconnection devices for isolation shall conform to the following requirements:

- (a) They shall be capable of withstanding an impulse voltage for at least over voltage category III, and have an adequate contact gap.
- (b) They shall not be able to falsely indicate that the contacts are open.
- (c) They shall be designed and installed so as to prevent unintentional closure, such as might be caused by impact, vibration or the like.
- (d) They shall be devices that disconnect all live conductors (active and neutral) of the inverter from the grid-interactive port.

Exception: For multiple mode inverters with stand-alone mode, which conform to IEC 62477.1, the automatic disconnection device for isolation shall be a device that disconnects active conductors of the multiple mode inverter from the grid-interactive port.

- (e) They shall be such that with a single fault applied to the automatic disconnection device or to any other location in the inverter, at least basic insulation or simple separation is

maintained between the energy source port and the grid-interactive port when the means of disconnection is intended to be in the open state.

- (f) They shall be such that with a single fault applied to the automatic disconnection device or to any other location in the inverter, power is prevented from entering the grid.

NOTE 2 In the case of a non-isolated inverter, the prevention of power entering the grid can be achieved by two mechanical automatic disconnection devices in series in each live conductor. In the case of an isolated inverter, the prevention of power entering the grid can be achieved by a single mechanical automatic disconnection device and a semiconductor device (or semiconductor devices) in each live conductor. The control of the two automatic disconnection devices can be achieved by two independent control circuits to satisfy the single fault requirements in Items (e) and (f) consistent with principals of IEC 62109-2.

The automatic disconnection device shall be capable of interrupting at least the rated current.

A semiconductor (solid-state) device shall not be used for isolation purposes.

4.3 Active anti-islanding protection

The combination of the inverter and the automatic disconnection device shall incorporate at least one method of active anti-islanding protection.

NOTE 1 Examples of such methods include —

- (a) shifting the frequency of the inverter away from nominal conditions in the absence of a reference frequency (frequency shift);
- (b) allowing the frequency of the inverter to be inherently unstable in the absence of a reference frequency (frequency instability);
- (c) periodically varying the power output of the inverter (power variation); and
- (d) monitoring for sudden changes in the impedance of the grid by periodically injecting a current pulse (current injection).

The method used to provide active anti-islanding protection shall be declared in documentation.

NOTE 2 Active anti-islanding protection is required in addition to the passive anti-islanding protection specified in [Clause 4.4](#) to prevent a situation where islanding may occur because multiple inverters and/or other generators are providing a frequency and voltage reference for one another and/or because load and generation is balanced.

To prevent islanding, the active anti-islanding protection system shall operate the automatic disconnection device (see [Clause 4.2](#)) within 2 s of disruption to the power supply from the grid.

Compliance shall be determined by type testing in accordance with the active anti-islanding test specified in [Appendix H](#).

4.4 Voltage and frequency limits (passive anti-islanding protection)

The combination of the inverter and the automatic disconnection device shall incorporate the following forms of passive anti-islanding protection:

- (a) Undervoltage and overvoltage protection.
- (b) Under-frequency and over-frequency protection.

For sustained variation of the voltage and frequency beyond each limit specified in [Table 4.1](#) and [Table 4.2](#), the automatic disconnection device (see [Clause 4.2](#)) shall operate no sooner than the required trip delay time and before the maximum disconnection time.

The inverter shall remain in continuous operation for voltage and frequency variations with a duration shorter than the trip delay time specified in [Table 4.1](#) and [Table 4.2](#). The inverter shall remain in continuous operation and operate, as required by [Clauses 4.5.4](#), [4.5.5](#) and [4.5.6](#), for voltage and frequency variations with a duration shorter than the trip delay time specified in [Table 4.1](#) and [Table 4.2](#).

Table 4.1 — Passive anti-islanding voltage limit values

Protective function	Protective function limit	Trip delay time	Maximum disconnection time
Undervoltage 2 ($V < <$)	70 V	1 s	2 s
Undervoltage 1 ($V <$)	180 V	10 s	11 s
Overvoltage 1 ($V >$)	265 V	1 s	2 s
Overvoltage 2 ($V > >$)	275 V	—	0.2 s
NOTE Refer to Table 2.5 for the measurement specifications.			

Table 4.2 — Passive anti-islanding frequency limit values

	Region	Australia A	Australia B	Australia C	New Zealand
Under-frequency 1 ($F <$)	Protective function limit value	47 Hz	47 Hz	45 Hz	45 Hz
	Trip delay time	1 s	1 s	5 s	1 s
	Maximum disconnection time	2 s	2 s	6 s	2 s
Over-frequency 1 ($F >$)	Protective function limit value	52 Hz	52 Hz	55 Hz	55 Hz
	Trip delay time	—	—	—	—
	Maximum disconnection time	0.2 s	0.2 s	0.2 s	0.2 s
NOTE Refer to Table 2.5 for the measurement specifications.					

Each protective function limit shall be preset and secured against change on selection of the specific region.

For a multiple mode inverter meeting the performance classification for output requirements of AS IEC 62040.3 that provides an operational mode to supply load continuously during grid disruption, the inverter may disconnect the grid-interactive port within the trip delay time, provided that when the grid voltage recovers within the voltage requirements of the AS IEC 62040.3 performance classification within the trip delay time the inverter shall reconnect within 400 ms.

Compliance shall be determined by type testing in accordance with the voltage and frequency limits tests specified in [Appendix I](#).

4.5 Limits for sustained operation

4.5.1 General

The inverter or inverter energy system shall remain in continuous operation over the range of voltages and frequencies that it is required to be compatible with. Refer to [Clause 2.5](#).

4.5.2 Sustained operation for voltage variations

The inverter shall operate the automatic disconnection device (see [Clause 4.2](#)) within 3 s when the average voltage for a 10 min period exceeds the $V_{\text{nom-max}}$ specified in [Table 4.3](#).

The sustained operation for voltage variations shall not interfere with the active and passive anti-islanding requirements of [Clauses 4.3](#) and [4.4](#).

Table 4.3 — Settings for $V_{\text{nom-max}}$

Region	Default setpoint
Australia A	258 V
Australia B	258 V
Australia C	258 V
New Zealand	249 V
Allowable range	244 V to 258 V

The 10 min average value shall be compared against the limit $V_{\text{nom-max}}$ at least every 3 s to determine when to disconnect.

NOTE The 10 min average value needs to be calculated for the preceding 10 min based on measurements at the inverter's terminals.

Compliance shall be determined by type testing in accordance with the sustained operation for voltage variations test specified in [Appendix J](#).

4.5.3 Sustained operation for frequency variations

4.5.3.1 General

The inverter shall be capable of supplying rated power between 45 Hz and 52 Hz.

Where the inverter is a multiple mode inverter connecting an energy storage system it shall be capable of charging the energy storage from the grid-interactive port between 49.5 Hz and 55 Hz.

The inverter shall maintain continuous operation for frequency variations within the limits specified in [Table 4.4](#) and respond as defined in [Table 4.5](#).

Table 4.4 — Frequency variation withstand limits

Inverter response	Decrease in frequency response Lower limit Hz	Lower limit of continuous operation range (f_{LLCO}) Hz	Upper limit of continuous operation range (f_{ULCO}) Hz	Increase in frequency response Upper limit Hz
Range	—	49.5 – 49.9	50.1 – 50.5	—
Australia A	47	49.75	50.25	52
Australia B	47	49.85	50.15	52
Australia C	45	49.5	50.5	55
New Zealand	45	49.8	50.2	55

Table 4.5 — Frequency response limits

Inverter response	Decrease in frequency response limits (see Note 1)		Increase in frequency response limits (see Note 2)	
	Frequency where power output level is maximum (f_{Pmax}) Hz	Frequency where charging power level is zero (see Note 3) ($f_{stop-ch}$) Hz	Frequency where discharging power level is zero (see Note 3) ($f_{transition}$) Hz	Frequency where power level is minimum (f_{Pmin}) Hz
Range	47 to 49	48 to 49.5	50.5 to 52	51 to 53
Australia A	48	49	50.75	52
Australia B	48	49	50.75	52
Australia C	47	48.25	51.75	53
New Zealand	48	49	51	52
NOTE 1 For decrease in frequency response refer to Clause 4.5.3.2 .				
NOTE 2 For increase in frequency response refer to Clause 4.5.3.3 .				
NOTE 3 This refers to multiple mode inverters with energy storage.				

Where a frequency variation results in frequency to be outside the continuous operation range, the inverter shall respond according to the defined characteristics of [Clause 4.5.3.2](#) and [Clause 4.5.3.3](#).

The inverter shall commence its response within the specified time of [Table 4.6](#), starting from the time the frequency is measured as crossing the continuous operation threshold (either f_{LLCO} or f_{ULCO}). The inverter shall complete its response within the specified time of [Table 4.6](#), starting from the time the frequency reaches its maximum deviation. Response time faster than the maximum times in [Table 4.6](#) are permitted, and commencement and completion of the inverter response should not be unnecessarily delayed or slowed.

Table 4.6 — Frequency response — Maximum response times

Region	Response commencement time	Response completion time
All	1 s	10 s

Where a frequency variation results in a change of power level of an inverter, the inverter power shall remain at the required level, until the frequency is maintained within the continuous operating region (less the hysteresis margin) for a period of 20 s. [Table 4.7](#) provides values for hysteresis margin (f_{hyst}) for each region.

Table 4.7 — Frequency response — Values for hysteresis margin (f_{hyst})

Region	f_{hyst}
Australia A	0.1 Hz
Australia B	0.1 Hz
Australia C	0.05 Hz
New Zealand	0.1 Hz
NOTE The frequency range for returning to continuous operation is within the range $(f_{\text{LLCO}} + f_{\text{hyst}})$ to $(f_{\text{ULCO}} - f_{\text{hyst}})$.	

When the conditions for returning to continuous operation defined in [Clause 4.5.3.2](#) and [4.5.3.3](#) have been met, any change in power level shall be at a rate no greater than the power rate limit (W_{Gra}) of [Clause 3.3.4](#).

Compliance shall be determined by type testing in accordance with the sustained operation for frequency variations test specified in [Appendix J](#).

4.5.3.2 Response to a decrease in frequency

4.5.3.2.1 General response to a decrease in frequency

The inverter shall not reduce power output through the grid-interactive port in response to a decrease in frequency.

In addition, when a disturbance results in a decrease in frequency below the continuous operation range (f_{LLCO}) and where the inverter has a reduced output due to a power quality response mode or demand response mode, the inverter shall increase the power output linearly with the decrease in frequency until the lower limit frequency range (f_{Pmax}) is reached.

The power output level present at the time the frequency falls below f_{LLCO} shall be held as the reference power output level used to calculate the required response to the decrease in frequency.

This is expressed in the equation below:

$$P_{\text{out}} = P_{\text{ref}} + \left[(P_{\text{max}} - P_{\text{ref}}) \left(\frac{(f_{\text{LLCO}} - f)}{(f_{\text{LLCO}} - f_{\text{Pmax}})} \right) \right]$$

where

P_{out} = required power output level for a frequency between f_{LLCO} and f_{Pmax}

P_{max} = maximum power output of the inverter

P_{ref} = reference power output level when the frequency falls below f_{LLCO}

f_{LLCO} = lower limit of continuous operation range for frequency

f_{Pmax} = frequency where power output level is maximum

f = frequency between f_{LLCO} and f_{Pmax} (i.e. $f_{\text{Pmax}} \leq f \leq f_{\text{LLCO}}$)

When the frequency equals f_{Pmax} the inverter power output level shall be the maximum power output level (P_{max}). The power output level reached may be limited by the energy source availability.

The inverter power output level shall remain at or above the highest power output level reached in response to the decrease in frequency between f_{LLCO} and f_{Pmax} . This is to provide hysteresis in the control of the inverter. When the frequency has increased above $(f_{\text{LLCO}} + f_{\text{hyst}})$ for at least 20 s, the