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AUSTRALIAN/NEW ZEALAND STANDARD

# Grid connection of energy systems via inverters

## Part 2: Inverter requirements

Superseding AS/NZS 4777.2:2015

AS/NZS 4777.2:2020

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Australian PV Institute
Better Regulation Division – NSW Fair Trading
Clean Energy Council
Clean Energy Regulator
Communications, Electrical and Plumbing Union – Electrical Division
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*This standard was issued in draft form for comment as DR AS/NZS 4777.2:2020.*

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will also remain current for 12 months after the date of publication of this Standard and after this time they will be superseded by AS/NZS 4777.2:[A1] 2020 [A1].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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## 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 ($\varphi$) 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: IEV 192-01-35]

**1.4.5**
**fixed equipment**
equipment fastened to a support, or otherwise secured in a specific location

[SOURCE: IEV 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: IEV 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 ($\varphi$) 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 ($R_{\text{iso}}$ 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<br>kVA | $R_{iso}$ limit<br>kΩ |
|---|---|
| ≤ 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.

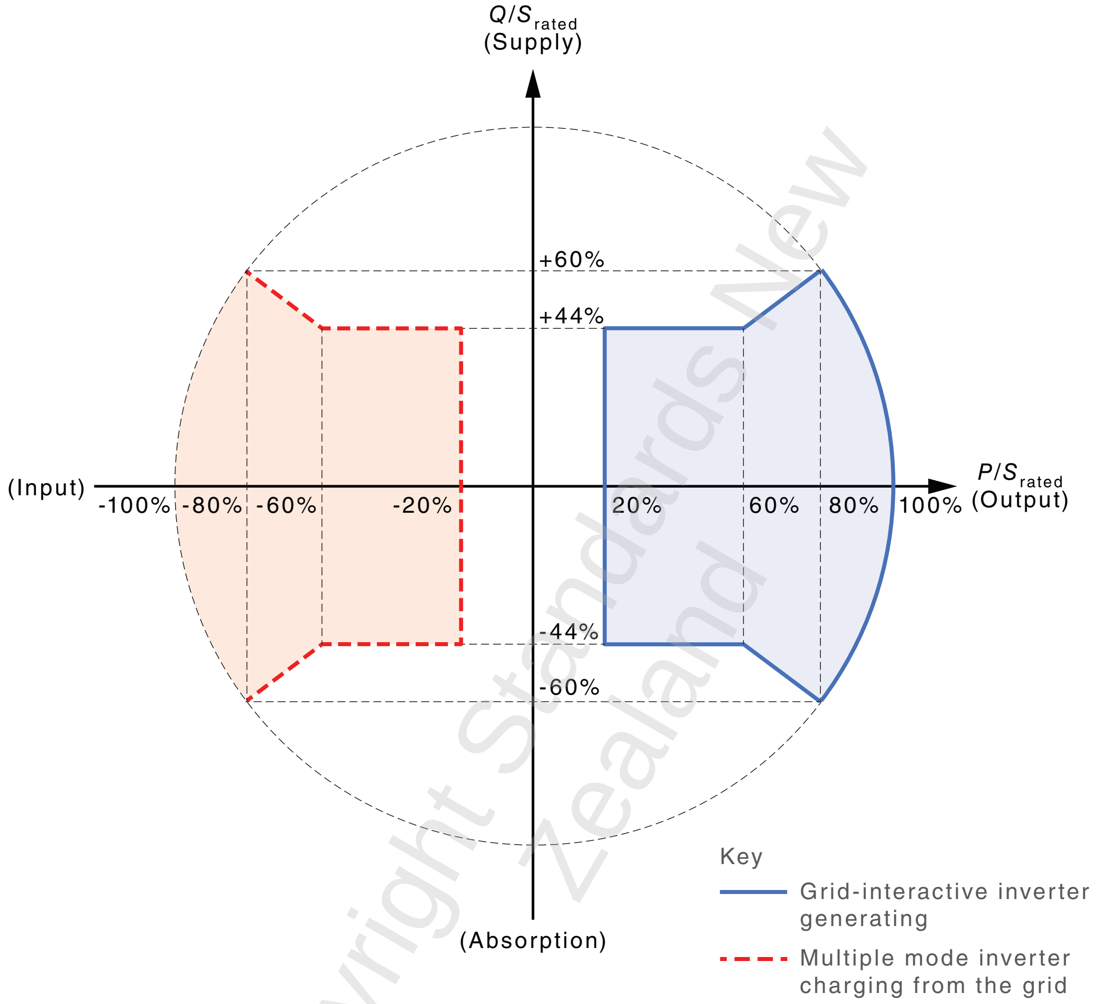



**Figure 2.1 — Minimum reactive power capability**

## 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<br>s | Instantaneous voltage<br>Line-to-neutral<br>V | Instantaneous voltage<br>Line-to-line<br>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 |

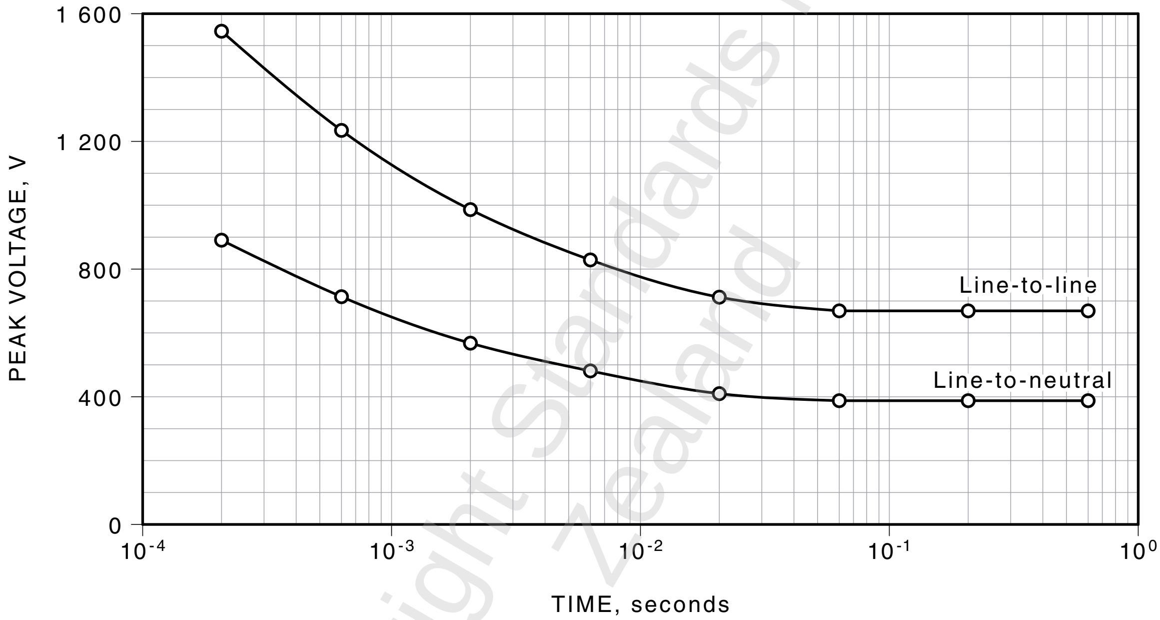



**Figure 2.2 — Voltage-duration curve of transient voltage limits**



## 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 ($I_{\mathrm{the}}$ and $I_{\mathrm{the\ solar}}$) 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 | ±1 % $V_{nominal}$ | 100 ms | 0 to 280 V |
| Frequency | ±10 mHz | 100 ms | 45 to 55 Hz |
| Active power | ±4 % $S_{rated}$ | 200 ms | 0 to 120 % $S_{rated}$ |
| Reactive power | ±4 % $S_{rated}$ | 200 ms | 0 to ± 120 % $S_{rated}$ |
| Apparent power | ±4 % $S_{rated}$ | 200 ms | 0 to ± 120 % $S_{rated}$ |
| 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.<br>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) | ≥ 1 000 | V |
| Insulation resistance (MΩ min 500 V) | ≥ 500 | MΩ |

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 kΩ, the inverter shall fail-safe to DRM 0 asserted.

**Table 3.3 — Method of asserting demand response modes**

| Mode | RJ45 socket Asserted by shorting pins: | | Terminal block 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. | | | |



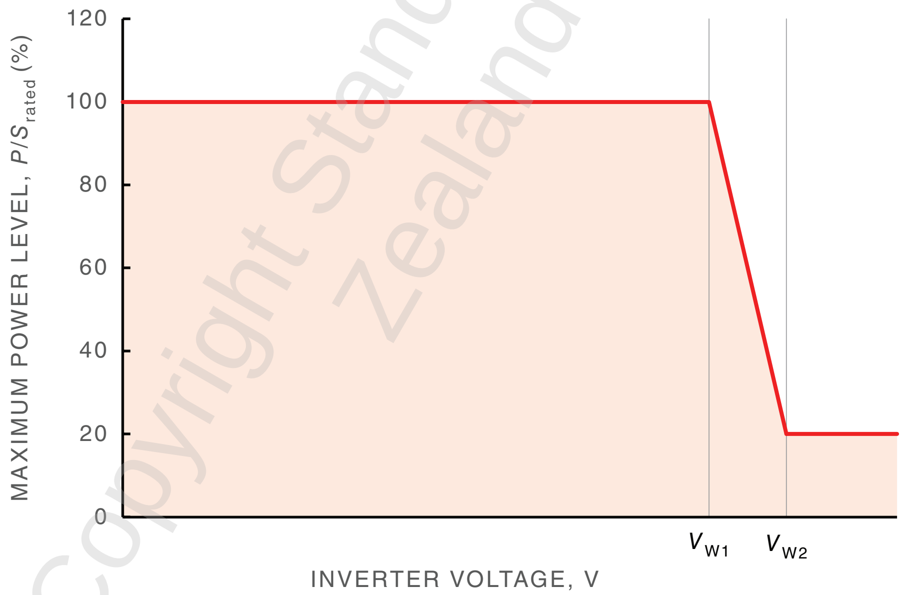



**Figure 3.1 — Example curve for the volt–watt response mode**

### 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.

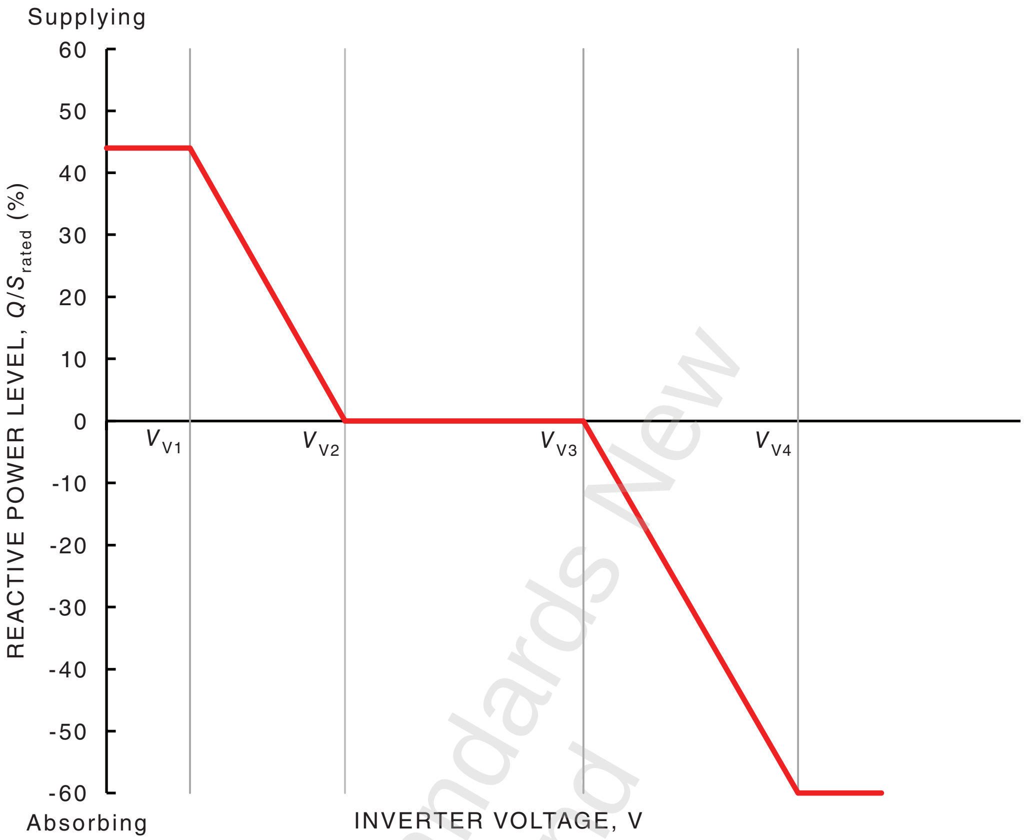



**Figure 3.2 — Example curve for the volt–var control mode**



### 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 ($W_{\mathrm{Gra}}$) 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 ($T_{\mathrm{n}}$) 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.

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

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 ($W_{Gra+}$); and

(b) to rate limit a decrease in power ($W_{Gra-}$).

The default setting of $W_{Gra+}$ and $W_{Gra-}$ 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

$\Delta$ = allowed deviation from the characteristic curve

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



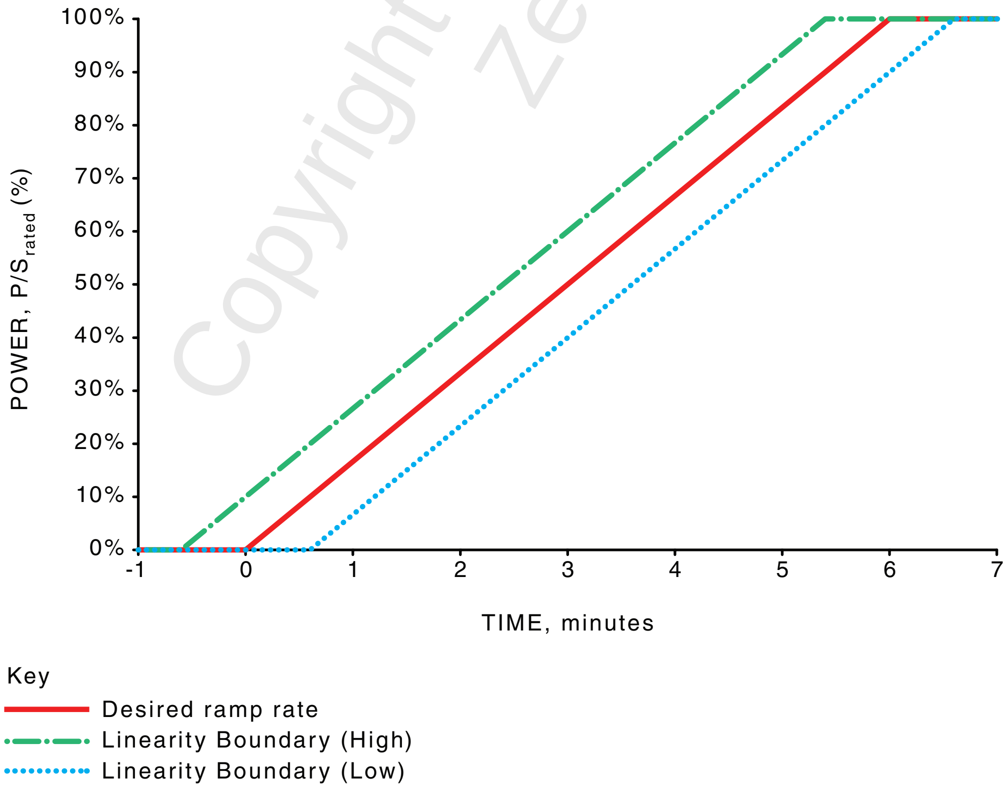



**Figure 3.3 — Nonlinearity of ramp rate ($W_{Gra}$, $T_n$ = default values)**

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

NOTE 1 $P_{charge}$ refers to power input level through the grid-interactive port.

NOTE 2 $P_{rated\text{-}ch}$ refers to the rated active power input through the grid-interactive port used for charging the energy storage.

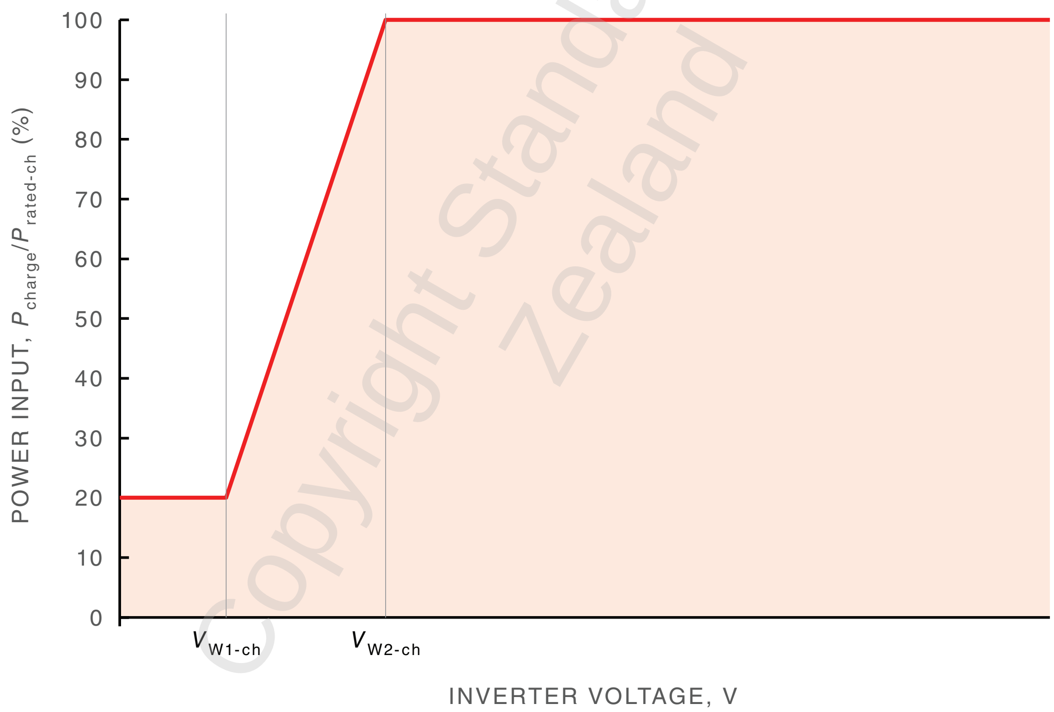



**Figure 3.4 — Example curve for the volt–watt response mode for multiple mode inverters with energy storage when charging**



### 3.4.4 Stand-[A1] alone [A1] 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<br>Hz | Lower limit of continuous operation range ($f_{LLCO}$)<br>Hz | Upper limit of continuous operation range ($f_{ULCO}$)<br>Hz | Increase in frequency response Upper limit<br>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 ($f_{Pmax}$)<br>Hz | Frequency where charging power level is zero (see Note 3) ($f_{stop\text{-}ch}$)<br>Hz | Frequency where discharging power level is zero (see Note 3) ($f_{transition}$)<br>Hz | Frequency where power level is minimum ($f_{Pmin}$)<br>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 ($f_{LLCO} + f_{hyst}$) to ($f_{ULCO} - f_{hyst}$). | |

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:

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

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. $f_{Pmax} \leq f \leq f_{LLCO}$) |

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 ($f_{LLCO}$ + $f_{hyst}$) for at least 20 s, the inverter shall return to continuous operation. Any change in power output level shall be at a rate no greater than the power rate limit ($W_{Gra}$) of Clause 3.3.4.

An example response is shown in Figure 4.1.

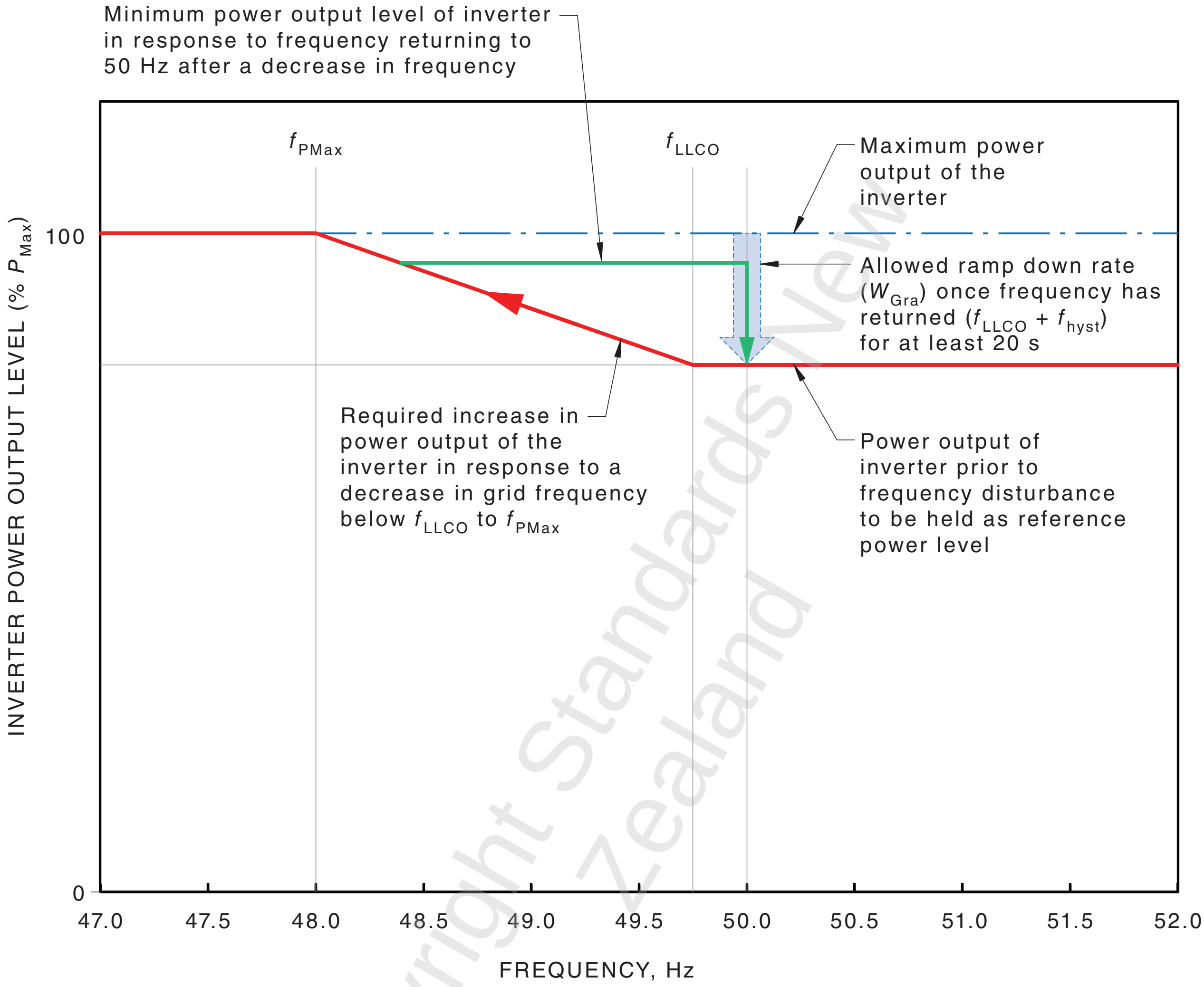



**Figure 4.1 — Example frequency response for a decrease in frequency for an inverter that has a reduced output**

### 4.5.3.2.2 Response to a decrease in frequency for multiple mode inverters with energy storage

The response to a decrease in frequency for multiple mode inverters with energy storage is a two-stage response. The initial stage applies if the energy storage is being charged via the grid-interactive port of the inverter and requires a reduction in the power input level through the grid-interactive port, the second stage requires the inverter to increase power output through the grid-interactive port as the frequency continues to decrease.

When a disturbance results in a decrease in frequency that falls below the continuous operation range ($f_{LLCO}$), and where the multiple mode is generating through the grid-interactive port (from any energy source) it shall maintain at least the same power output level until $f_{stop\text{-}ch}$.

When a disturbance results in a decrease in frequency that falls below the continuous operation range ($f_{LLCO}$), and where the multiple mode inverter is charging the energy storage from the grid-interactive port it shall reduce the power input level linearly with the decrease in frequency until $f_{stop\text{-}ch}$ is reached.

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

The required response is expressed in the equation below:

$$P_{\text{charge}} = P_{\text{ref-ch}}\left[1 - \frac{\left(f_{\mathrm{LLCO}} - f\right)}{\left(f_{\mathrm{LLCO}} - f_{\text{stop-ch}}\right)}\right]$$

where

| | | |
|---|---|---|
| $P_{\text{charge}}$ | = | power input level via the grid-interactive port for a frequency between $f_{\mathrm{LLCO}}$ and $f_{\text{stop-ch}}$ |
| $P_{\text{ref-ch}}$ | = | power input level via the grid-interactive port when the frequency falls below $\mathrm{f}_{\mathrm{LLCO}}$ |
| $f_{\mathrm{LLCO}}$ | = | lower limit of the continuous operation range for frequency |
| $f_{\text{stop-ch}}$ | = | frequency where input power level is zero |
| $f$ | = | frequency between $f_{\mathrm{LLCO}}$ and $f_{\text{stop-ch}}$ (i.e. $f_{\text{stop-ch}} \le f \le f_{\mathrm{LLCO}}$) |

When the frequency falls below $f_{\text{stop-ch}}$, the inverter shall have ceased charging the energy storage via the grid-interactive port (i.e. 0 W).

When a disturbance results in a decrease in frequency that falls below $f_{\text{stop-ch}}$ the multiple mode inverter with energy storage shall increase the power output level through the grid-interactive port linearly with the decrease in frequency until $f_{\mathrm{Pmax}}$ is reached, the maximum discharge rate of the energy storage is reached, or the state of charge of the energy storage is exhausted.

The required response is expressed in the equation below:

$$P_{\text{out}} = \begin{cases} P_{\max}\left[\dfrac{\left(f_{\text{stop-ch}} - f\right)}{\left(f_{\text{stop-ch}} - f_{\mathrm{Pmax}}\right)}\right] & \text{if inverter charging before disturbance} \\ P_{\text{ref}} + \left(P_{\max} - P_{\text{ref}}\right)\left[\dfrac{\left(f_{\text{stop-ch}} - f\right)}{\left(f_{\text{stop-ch}} - f_{\mathrm{Pmax}}\right)}\right] & \text{if inverter generating before disturbance} \end{cases}$$

where

| | | |
|---|---|---|
| $P_{\text{out}}$ | = | required power output level for a frequency between $f_{\text{stop-ch}}$ and $f_{\mathrm{Pmax}}$ |
| $P_{\text{ref}}$ | = | reference power output level when the frequency falls below $f_{\mathrm{LLCO}}$ |
| $P_{\max}$ | = | maximum power output of the inverter |
| $f_{\mathrm{Pmax}}$ | = | frequency where power output level is maximum |
| $f_{\text{stop-ch}}$ | = | frequency where power output level is zero |
| $f$ | = | frequency between $f_{\text{stop-ch}}$ and $f_{\mathrm{Pmax}}$ (i.e. $f_{\mathrm{Pmax}} \le f \le f_{\text{stop-ch}}$) |

The inverter power level shall remain —

(a) at or below the lowest power input level reached in response to the decrease in frequency between $f_{\mathrm{LLCO}}$ and $f_{\text{stop-ch}}$; or

(b) at or above the highest power output level reached in response to the decrease in frequency between $f_{\text{stop-ch}}$ and $f_{\mathrm{Pmax}}$ (unless the state of charge of the energy storage is exhausted).

When the frequency has increased above ($f_{LLCO}$+$f_{hyst}$) for at least 20 s, the inverter shall be returned to continuous operation. This is to provide hysteresis in the control of the inverter. Any change in power level shall be at a rate no greater than the power rate limit ($W_{Gra}$) of Clause 3.3.4.

An example response is shown in Figure 4.2.

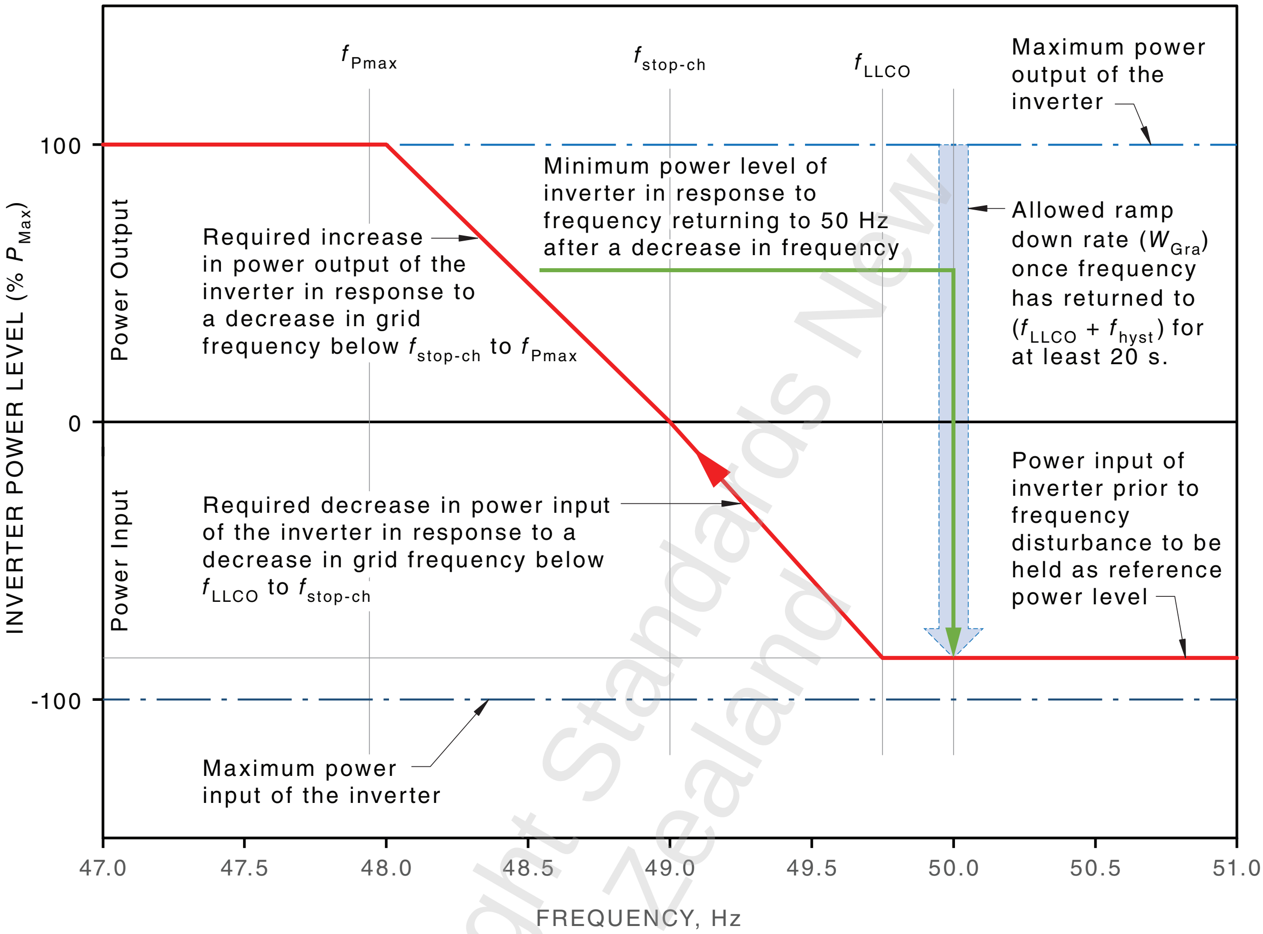



**Figure 4.2 — Example two-stage frequency response for a decrease in frequency for the multiple mode inverter with energy storage with $f_{stop\text{-}ch}$ 49.0 Hz**

### 4.5.3.3 Response to an increase in frequency

#### 4.5.3.3.1 General response to an increase in frequency

When a disturbance results in an increase in frequency that exceeds the continuous operation range ($f_{ULCO}$), the inverter shall reduce the power output linearly with the increase in frequency until $f_{Pmin}$ is reached.

The power output level present at the time the frequency exceeds $f_{ULCO}$ shall be held as the reference power level used to calculate the required response to the increase in frequency.

This is expressed in the equation below:

$$P_{out} = P_{ref}\left[1 - \frac{(f - f_{ULCO})}{(f_{Pmin} - f_{ULCO})}\right]$$

where

$P_{out}$ = required power output level for a frequency between $f_{ULCO}$ and $f_{Pmin}$

$P_{ref}$ = reference power output level when the frequency exceeds $f_{ULCO}$

$f_{ULCO}$ = upper limit of the continuous operation range for frequency

$f_{Pmin}$ = frequency where power output is zero

$f$ = frequency between $f_{ULCO}$ and $f_{Pmin}$ (i.e. $f_{ULCO} \le f \le f_{Pmin}$)

When the frequency exceeds $f_{Pmin}$ the inverter power output shall be ceased (i.e. 0 W).

The inverter power output level shall remain at or below the lowest power output level reached in response to the increase in frequency between $f_{ULCO}$ and $f_{Pmin}$. This is to provide hysteresis in the control of the inverter. When the frequency has decreased below ($f_{ULCO} - f_{hyst}$), for at least 20 s, the inverter shall return to continuous operation. Any change in power output level shall be at a rate no greater than the power rate limit ($W_{Gra}$) of Clause 3.3.4. As shown in Figure 4.3.

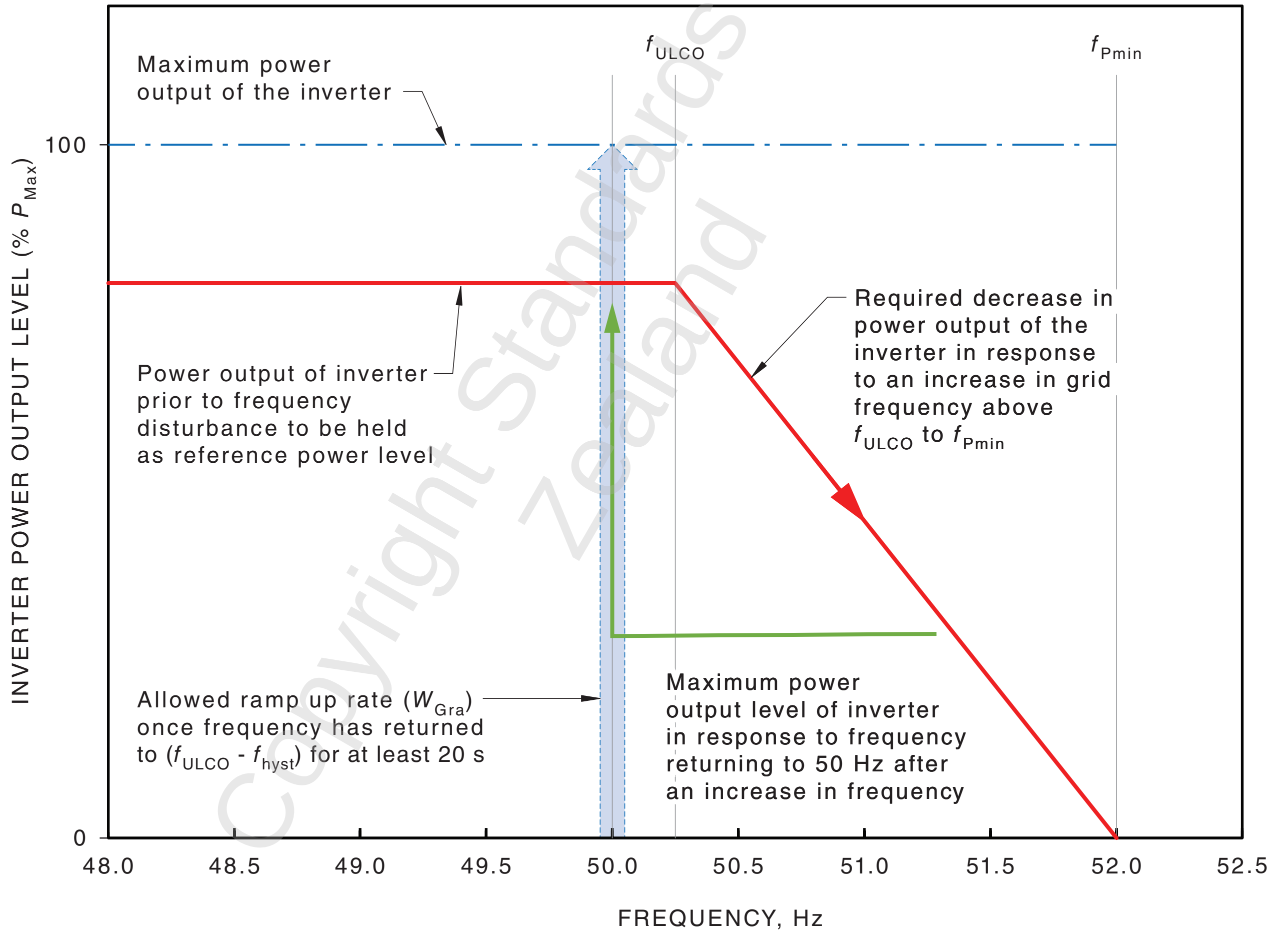



**Figure 4.3 — Example frequency response for an increase in frequency for $f_{Pmin}$ of 52 Hz**

### 4.5.3.3.2 Response to an increase in frequency for multiple mode inverters with energy storage

The response to an increase in frequency for multiple mode inverters with energy storage is a two-stage response. The initial stage is a reduction in the power output level if the inverter is generating, the second stage requires the inverter to increase its power input level through the grid-interactive port as the frequency continues to increase.

When a disturbance results in an increase in frequency that exceeds the continuous operation range of ($f_{\mathrm{ULCO}}$), the multiple mode inverter that is charging the energy storage via the grid-interactive port shall maintain at least the same power input level with the increase in frequency until $f_{\mathrm{transition}}$ is reached.

When a disturbance results in an increase in frequency that exceeds the continuous operation range of ($f_{\mathrm{ULCO}}$), the multiple mode inverter that is generating (from any energy source) shall reduce the power output linearly with the increase in frequency until $f_{\mathrm{transition}}$ is reached. The power output level present at the time the frequency exceeds $f_{\mathrm{ULCO}}$ shall be held as the reference power output level used to calculate the required response to the increase in frequency.

This is expressed in the equation below:

$$P_{\mathrm{out}} = P_{\mathrm{ref}}\left[1 - \frac{(f - f_{\mathrm{ULCO}})}{(f_{\mathrm{transition}} - f_{\mathrm{ULCO}})}\right]$$

where

| | | |
|---|---|---|
| $P_{\mathrm{out}}$ | = | required power output level for a frequency between $f_{\mathrm{ULCO}}$ and $f_{\mathrm{transition}}$ |
| $P_{\mathrm{ref}}$ | = | reference power output level when the frequency exceeds $f_{\mathrm{ULCO}}$ |
| $f_{\mathrm{ULCO}}$ | = | upper limit of the continuous operation range for frequency |
| $f_{\mathrm{transition}}$ | = | frequency where power output level is zero |
| $f$ | = | frequency between $f_{\mathrm{ULCO}}$ and $f_{\mathrm{transition}}$ (i.e. $f_{\mathrm{ULCO}} \leq f \leq f_{\mathrm{transition}}$) |

When the frequency equals $f_{\mathrm{transition}}$ the inverter power output shall be ceased (i.e. 0 W).

When a disturbance results in an increase in frequency that exceeds $f_{\mathrm{transition}}$, the multiple mode inverter shall increase the power input level through the grid-interactive port, linearly with the increase in frequency until $f_{\mathrm{Pmin}}$ is reached, the maximum charge rate of the energy storage is reached, or the state of charge of the energy storage is full.

This is expressed in the equation below:

$$P_{\mathrm{charge}} = \begin{cases} P_{\mathrm{rated\text{-}ch}}\left[\dfrac{(f - f_{\mathrm{transition}})}{(f_{\mathrm{Pmin}} - f_{\mathrm{transition}})}\right] & \text{if inverter generating before disturbance} \\ P_{\mathrm{ref\text{-}ch}} + (P_{\mathrm{rated\text{-}ch}} - P_{\mathrm{ref\text{-}ch}})\left[\dfrac{(f - f_{\mathrm{transition}})}{(f_{\mathrm{Pmin}} - f_{\mathrm{transition}})}\right] & \text{if inverter charging before disturbance} \end{cases}$$

where

| | | |
|---|---|---|
| $P_{\mathrm{charge}}$ | = | required power input level for a frequency between $f_{\mathrm{transition}}$ and $f_{\mathrm{Pmin}}$ |
| $P_{\mathrm{ref\text{-}ch}}$ | = | reference power input level when the frequency exceeds $f_{\mathrm{ULCO}}$ |
| $P_{\mathrm{rated\text{-}ch}}$ | = | rated power input level of the inverter |
| $f_{\mathrm{Pmin}}$ | = | frequency where power input level is maximum |
| $f_{\mathrm{transition}}$ | = | frequency where power input level is zero |
| $f$ | = | frequency between $f_{\mathrm{transition}}$ and $f_{\mathrm{Pmin}}$ (i.e. $f_{\mathrm{transition}} \leq f \leq f_{\mathrm{Pmin}}$) |

The inverter power output level shall remain —

(a) at or below the lowest power output level reached in response to the increase in-frequency between $f_{\mathrm{ULCO}}$ and $f_{\mathrm{transition}}$; or

(b) at or above the highest power input level reached in response to the increase in frequency between $f_{transition}$ and $f_{Pmin}$ (unless the state of charge of the energy storage is full).

This is to provide hysteresis in the control of the inverter. When the frequency has decreased below ($f_{ULCO}$ – $f_{hyst}$), for at least 20 s, the power level of the inverter shall be restored to the pre-disturbance level at a rate no greater than the power rate limit ($W_{Gra}$) of Clause 3.3.4.

An example response is shown in Figure 4.4.

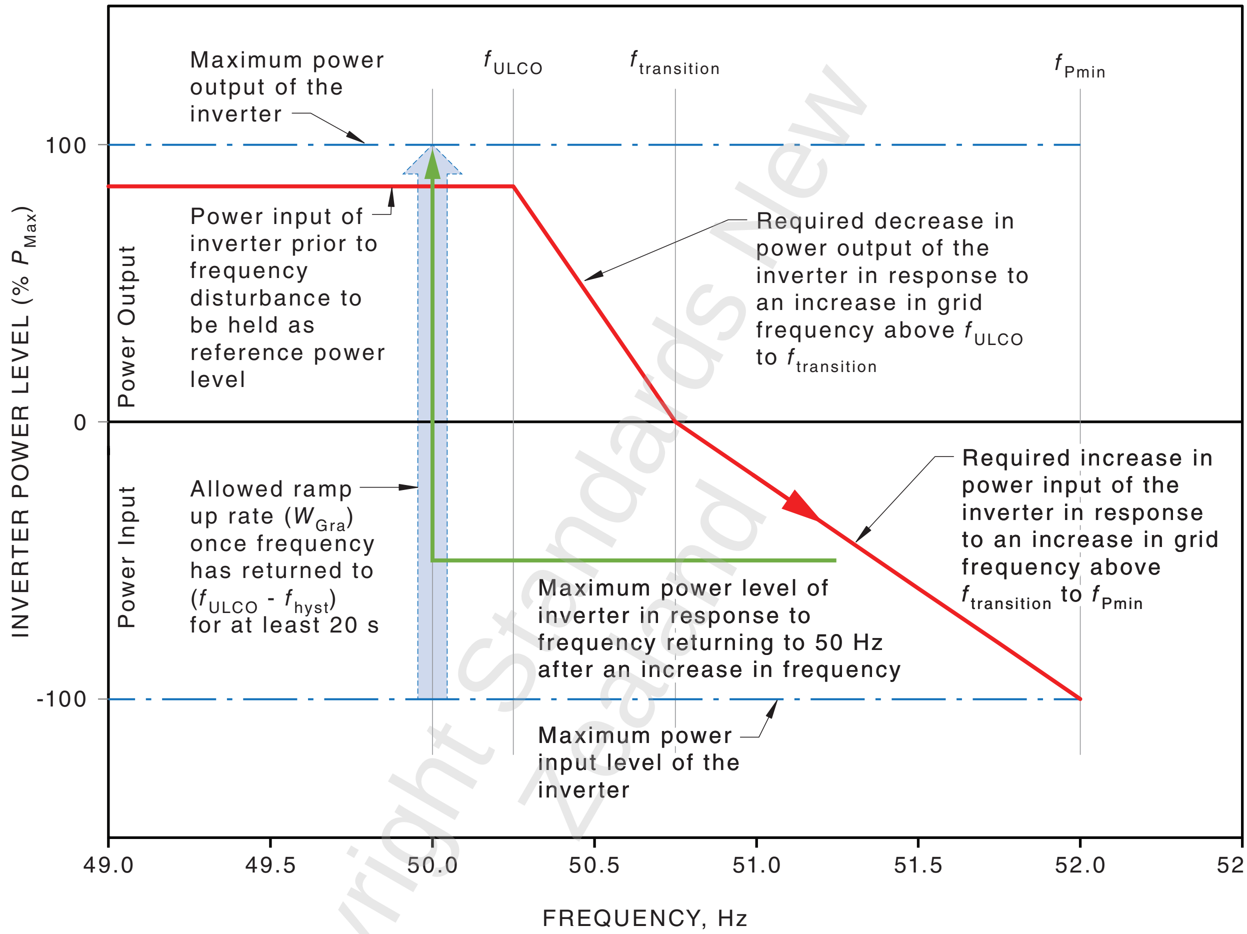



**Figure 4.4 — Example frequency response for an increase in frequency for the multiple mode inverter with energy storage for $f_{transition}$ of 50.75 Hz**

### 4.5.4 Voltage disturbance withstand

#### 4.5.4.1 General

A voltage disturbance is any variation of voltages outside of the voltage limits continuous operation of Table 4.8. The inverter or inverter energy system shall respond as specified in Table 4.8 for voltage disturbances.

**Table 4.8 — Voltage disturbance response**

| Voltage limits | Inverter response |
|---|---|
| > 260 V | Cease power generation |
| 180 V to 260 V | Continuous operation |
| < 180 V | Cease power generation |

The inverter shall cease power generation within 200 ms after the measured voltage falls below or exceeds the continuous operation limits. For voltage disturbances lasting less than the trip delay times in Table 4.1, the inverter shall restore active power output to the pre-disturbance level within 400 ms after the measured voltage has returned to within the continuous operation limits of Table 4.8.

For a three-phase inverter, the inverter shall respond in the event of a voltage disturbance on any of the phases.

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 in place of the cease power generation requirement, provided that when the grid voltage recovers within the voltage requirements of the AS IEC 62040.3 performance classification relevant to the inverter, the inverter shall restore active power output through the grid-interactive port to the pre-disturbance level within 400 ms.

Compliance shall be determined by type testing in accordance with the voltage disturbance withstand test specified in Appendix I.

#### 4.5.4.2 Multiple voltage disturbances

A multiple voltage disturbance event is any number of voltage disturbances as defined in Clause 4.5.4.1 where the cumulative time that the voltage is less than the trip delay time as specified in Table 4.1, provided that each voltage disturbance occurs no more than 15 s since the previous disturbance. After a period of 15 s without a disturbance, any further disturbances shall be treated as a new multiple voltage disturbance event. Refer to Figure 4.5 for example of a multiple voltage disturbance event.

The inverter shall respond in accordance with the requirements of Clause 4.5.4.1 in the event of multiple voltage disturbances. The inverter shall not disconnect for at least two multiple voltage disturbance events. The inverter may disconnect in the event of any further voltage disturbance within the following 20 minute period.

Compliance shall be determined by type testing in accordance with the multiple voltage disturbance withstand test specified in Appendix I.

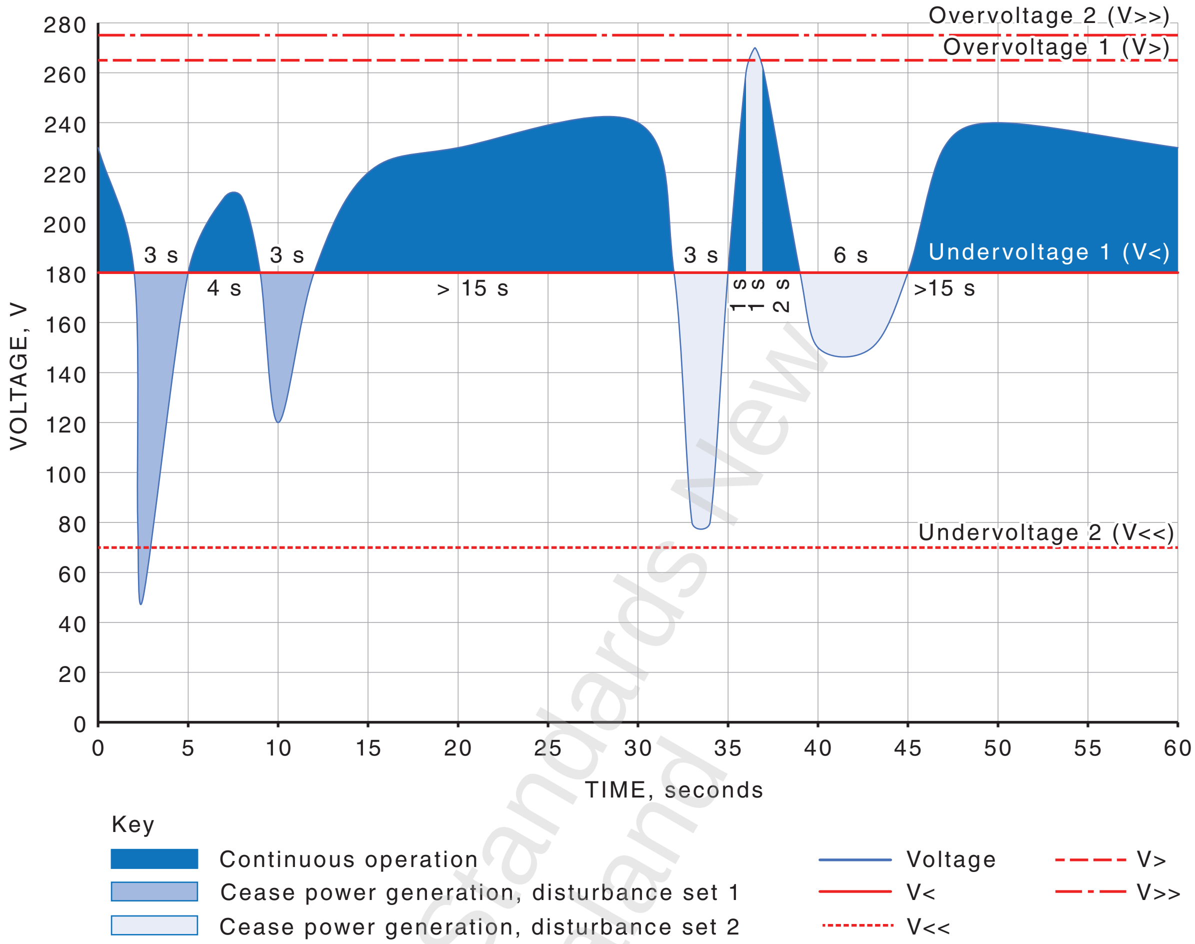



**Figure 4.5 — Example of two multiple voltage disturbance events where the inverter is required to remain in continuous operation**



### 4.5.5 Voltage phase angle shift withstand

The inverter shall remain in continuous operation for a single-phase voltage angle shift within a voltage cycle of at least 60 electrical degrees. In addition, three-phase inverters shall remain in continuous operation for a voltage phase angle shift within a voltage cycle, in the positive-sequence, of at least 20 electrical degrees. Refer to Table 4.9.

**Table 4.9 — Voltage phase angle shift withstand requirements**

| | Single-phase disturbance | Three-phase disturbance |
|---|---|---|
| Single-phase inverter | 60° | — |
| Three-phase inverter | 60° | 20° |

Compliance shall be determined by type testing in accordance with the voltage phase angle shift withstand test specified in Appendix I.

### 4.5.6 Rate of change of frequency

The inverter shall maintain continuous operation for frequency excursions with a rate of change of frequency (ROCOF) that do not exceed ± 4.0 Hz/s for a duration of 0.25 s.

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

## 4.6 Disconnection on external signal

The automatic disconnection device shall incorporate the ability to disconnect on an external signal.

If an external signal or demand response "DRM 0" condition is asserted, the automatic disconnection device shall operate within 2 s.

Compliance shall be determined by type testing as specified in Appendix E.

## 4.7 Connection and reconnection procedure

Only after all of the following conditions have been met shall the automatic disconnection device operate to connect or reconnect the inverter to the grid —

(a) the voltage has been maintained within the utilization limits of AS 60038 (for Australia) or the utilization limits (for New Zealand) for at least 60 s;

(b) the frequency has been maintained within the range 47.5 Hz to 50.15 Hz for at least 60 s;

(c) the inverter and the grid are synchronized and in-phase with each other; and

(d) no external signal is present or DRM 0 asserted requiring the system to be disconnected.

After the automatic disconnection device operates to connect or reconnect the inverter the output shall rate limit increase in power generation to the set power rate limit ($W_{Gra}$) for increase in power of Clause 3.3.4. Unconstrained power operation may recommence after the automatic disconnection device operates to connect or reconnect the inverter, when either the rated power output is reached or the required power output level of the inverter exceeds the available energy source.

Compliance shall be determined by type testing in accordance with the tests as specified in Appendix H and Appendix I.

## 4.8 Security of protection settings

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

The settings, specified in Clause 4.5, shall only be capable of being adjusted within the limits specified in Clause 4.5.

The limit values of the automatic disconnection device, specified in Clause 4.4, shall be secured against changes.

The specific regional settings selected for Australia or New Zealand, once applied or confirmed for each inverter, shall be secured against unauthorized changes.

NOTE Special interface devices and passwords are regarded as tools.

Compliance shall be determined by inspection.

## 4.9 Activation of protection settings

The inverter shall not operate the automatic disconnection device to connect until a regional setting has been selected and activated by an authorized person.

Variations to default regional configuration settings of this Section (4) shall be within the ranges specified within this Section (4).

Where the inverter does not connect due to no selection or activation of a regional configuration, the inverter shall provide a visible alert.

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 regional settings may be displayed via a panel/screen, external device or software interface.

# Section 5 Multiple inverter combinations

## 5.1 General

There are installations where multiple inverter energy systems are used and the electrical installation connects at a single point of supply to the grid. Inverter energy systems are often comprised of multiple inverters used in combination to provide the desired inverter energy system capacity or to ensure that voltage balance is maintained in multiple-phase connections to the grid.

This Section (5) specifies the requirements and tests for inverter energy systems used in such combinations. If a combination is not tested, it should not be used or external devices should be used in accordance with the requirements of AS/NZS 4777.1.

Possible combinations are single-phase inverters used in parallel, single-phase inverters used in multiple-phase installations and three-phase inverters used in parallel.

## 5.2 Inverter current balance across multiple phases

In a multiple-phase inverter energy system comprised of individual single-phase inverters, the a.c. current output should be generated and injected into the multiple-phase electrical installation to minimize current imbalance. The maximum current imbalance in a multiple-phase inverter energy system comprised of either individual single-phase inverters connected on separate phases or a combination of single-phase inverters and multiple-phase inverters shall not exceed 21.7 A for more than 15 s.

NOTE 1 This maximum current imbalance also applies to multiple mode inverters used in a inverter energy system that may have a charging mode.

NOTE 2 Provisions for current balance of three-phase inverters are given in Clause 2.11.

## 5.3 Grid disconnection

When any inverter (single-phase or multiple-phase) within a multiple-phase inverter energy system disconnects as required by Section 4, all inverters within the multiple-phase inverter energy system shall disconnect within 2 s of the first inverter disconnecting. This applies to all inverters used in combination for multiple phases.

## 5.4 Grid connection and reconnection

When multiple inverters are used together in a multiple-phase combination, only after all the conditions of Clause 4.7 have been met on all connected phases shall the automatic disconnection device operate to connect or reconnect any inverter of the multiple-phase combination to the grid.

Where any inverter used in a multiple-phase combination has a rated current exceeding 21.7 A per phase, the requirement of Clause 5.2 shall be met when connecting or reconnecting.

## 5.5 Testing combinations

### 5.5.1 Single-phase combinations

Single-phase parallel combinations of inverters shall be tested for combinations with total rated current ($I_{\text{rated}}$) equal to or up to the maximum of 6 A per phase.

To determine the number of inverters to be tested, the following equation shall be used:

$$N = \frac{6}{I_{\text{rated}}}$$

where

| | | |
|---|---|---|
| $N$ | = | number to be tested, rounded up to next whole number |
| $I_{\text{rated}}$ | = | rating of the inverter, in amperes |

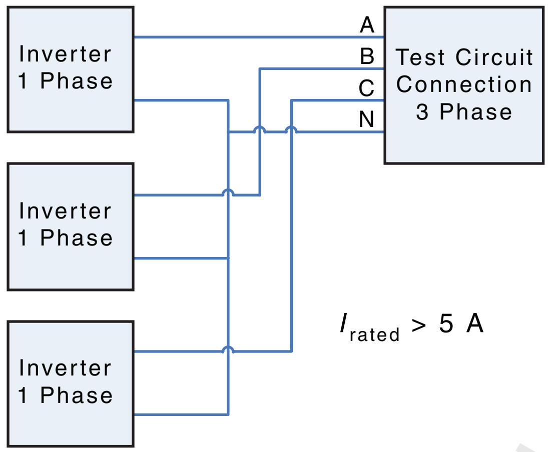
If $N \geq 2$, the minimum number of inverters to be tested shall be $N$. If $N > 6$, the maximum number of inverters to be tested in a combination shall be 6.

### 5.5.2 Single-phase inverters used in three-phase combinations

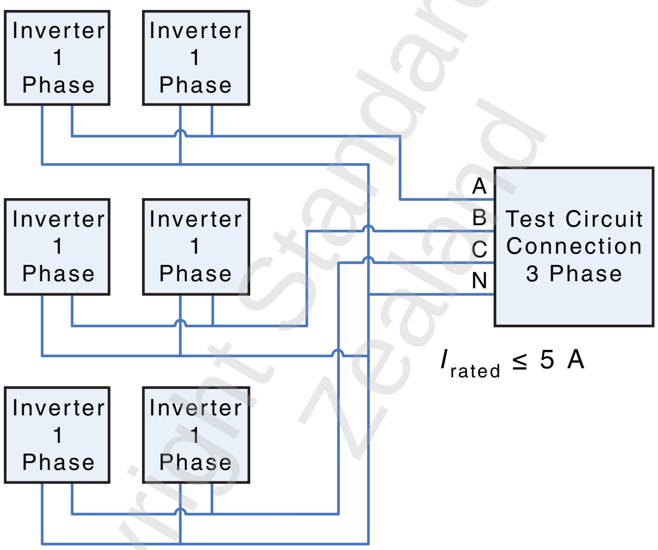
For single-phase inverters with rated current ($I_{\text{rated}}$) greater than or equal to 5 A used in three-phase combinations, three inverters shall be tested in a three-phase arrangement [refer to Figure 5.1(a)].

Single-phase inverters with rated current less than 5 A and to be used in three-phase combinations shall be tested in combination with at least two inverters per phase [refer to Figure 5.1(b)].

NOTE Testing of combinations is not required if the test combination is not allowed by the inverter manufacturer's installation instructions or similar documentation.




(a) Three single phase inverters in three phase arrangement




(b) Six single phase inverters (<5 A) in three phase arrangement



**Figure 5.1 — Single-phase inverters in three-phase combinations**

### 5.5.3 Required tests for multiple inverter combinations

Any single-phase inverter used in a multiple inverter combination shall be tested individually and meet all the requirements of this Standard. Any single-phase inverter that is to be used as part of a multiple inverter combination shall be tested in combination as specified in Clauses 5.5.1 and 5.5.2.

The tests specified in Table 5.1 for multiple inverter combinations shall be performed.

**Table 5.1 — Required tests for multiple inverter combinations**

| Test required | Single-phase combinations (Clause 5.5.1) | Single-phase inverters used in multiple-phase combinations (Clause 5.5.2) |
|---|---|---|
| Active anti-islanding (Clause 4.3 and Appendix H) | Test required | Test required |
| V and freq. limits (Clause 4.4 and Appendix I) | Not required | Test required |
| Balance (Clause 5.2) | Not applicable | Test required |

Compliance shall be determined by type testing as specified in Appendix K.

### 5.5.4 Multiple inverters with one automatic disconnection device

Where the inverter does not have an internal automatic disconnection device, or requires an external automatic disconnection device to provide the required disconnection function, or both, testing shall be conducted with the automatic disconnection device and with either the number of inverters required by Clause 5.5.1 and 5.5.2 or with the automatic disconnection device configured with the number of inverters specified by the manufacturer's instructions.

Compliance shall be determined by performing all of the type tests specified in Clause 5.5.

# Section 6 Generation control function

## 6.1 General

The generation control function is used to control the active or apparent power output levels of an inverter or multiple inverter combination such that it meets a predetermined generation output level that may be less than the total rated apparent power of the inverter or multiple inverter combination. Two generation control functions should be provided as inverter functions, these are —

(a) generation limit control; and

(b) export limit control.

This Section (6) applies to an inverter or multiple inverter combinations that have either or both generation control functions. Where included in the inverter, these generation control functions shall be disabled by default.

The generation control function for an inverter or multiple inverter combination should operate with the following limits:

(i) Soft limit: A limit that will cause the inverter or multiple inverter combination to reduce its output, preventing generation greater than the limit.

(ii) Hard limit: A limit that when activated will cause the inverter or multiple inverter combination to disconnect (e.g. when the soft limit has not been met).

The soft limit may be utilized with the hard limit to minimize the number of disconnections due to exceeding the hard limit. Where both hard and soft limits are used the requirements for hard limit shall take precedence over the soft limit requirements.

The generation control function shall monitor the response of the inverter or multiple inverter combination to the soft limit and hard limit. Where a fault or loss of operability is detected the generation control function shall respond such that on failure of —

(A) the soft limit function, reduce the output of the inverter or multiple inverter combination to zero within 15 s; and

(B) the hard limit function, operate the automatic disconnection device within 5 s.

For multiple-phase systems, the generation control functions shall monitor and control the generation on each phase.

The generation control may use inverter internal measurements or external sensors for measurements. All measurement for generation control functions shall conform to Table 2.5 specifications. The generation control function may be integrated into the inverter or use an external controller.

NOTE The external controller may be another inverter in the multiple inverter combination.

Where an external measurement device or controller is used, any loss of signal or failure of the device shall cause the inverter or multiple inverter combination to operate the automatic disconnection device and disconnect within 5 s, unless the only [A1] generation control function [A1] activated is a soft export limit, in which case the inverter or multiple inverter combination shall reduce active power output to the soft export limit setting as a maximum within 15 s.

The connection to external devices shall be re-established and achieve stable operation for at least 15 s before the inverter or multiple inverter combination reconnects in accordance with Clause 4.7.

Compliance shall be determined by type testing in accordance with the generation control function test specified in Appendix L.

## 6.2 Generation limit control

### 6.2.1 General

The generation limit control function provides control of the apparent power output level of an inverter or multiple inverter combination within an electrical installation. The generation limit control function may be integrated into the inverter or an external device.

The generation limit control for an inverter or multiple inverter combination shall limit the apparent power output level, specified as an apparent power value (VA). The generation limit control function shall have a hard limit and a soft limit specified, where the soft limit coordinates with the hard limit.

Where a generation limit has been applied the generation limit shall be substituted for the inverter or multiple inverter combination rated apparent power for determining the corresponding level of response for the power quality response modes of the inverter or multiple inverter combination. For multiple inverter combinations, including multiple-phase systems, the generation limit shall apply to the net apparent power output at the point of generation.

In multiple-phase systems the apparent power level shall be balanced across the phases.

### 6.2.2 Soft limit

For the generation limit control function a soft limit shall be utilized to control the apparent power output level such that the hard limit is not exceeded.

Where the soft limit is exceeded, the generation limit control function shall operate to reduce the apparent power output of the inverter or multiple inverter combination to less than the soft limit within 15 s.

### 6.2.3 Hard limit

Where the hard limit is exceeded for 15 s the generation limit control function shall operate to disconnect the inverter or each inverter within the multiple inverter combination within 5 s.

## 6.3 Export limit control

### 6.3.1 General

The export limit control function for an inverter is used to control the generation from an inverter or multiple inverter combination to manage the export power level from an electrical installation to the grid. The export limit control function may be integrated into the inverter or an external device.

The export limit control for an inverter or multiple inverter combination shall limit the active power export level, specified as an active power value ($W$). The export limit may be set to allow export to the grid or to provide a minimum import load from the grid.

For inverter or multiple inverter combinations, including multiple-phase systems, the export limit shall apply to the net active power level at the point of supply across all phases.

### 6.3.2 Soft limit

For the export limit control function, where the soft limit is exceeded the export limit control function shall operate to reduce the power output of the inverter or multiple inverter combination such that the export limit of the electrical installation is met within 15 s.

### 6.3.3 Hard limit

For inverter or multiple inverter combination the hard limit may be applied. For the export limit control function, where the hard limit is exceeded the export limit control function shall operate to disconnect the inverter or each inverter within the multiple inverter combination within 5 s.

# Section 7 Inverter marking and documentation

## 7.1 General

The inverter shall conform to the marking and documentation requirements of IEC 62109-1 and IEC 62109-2, as varied by this Section (7).

All markings and documentation shall be in the English language.

NOTE The marking and documentation may be written in other languages in addition to English.

## 7.2 Marking

### 7.2.1 General

The following variations apply to the marking requirements of IEC 62109-1 and IEC 62109-2:

(a) Inverters that are designated for use in inverter energy systems incorporating energy sources other than PV arrays or batteries shall bear additional or alternative markings applicable to the energy source.

(b) Inverters that are designated for use in closed electrical operating areas shall be marked with a warning stating that they are not suitable for installation in households or areas of a similar type or use (i.e. domestic).

NOTE This requirement is derived from the Cooling system failure—Blanketing test of IEC 62109-2. It is intended to ensure that inverters for closed electrical operating areas are not installed in areas where the intended ventilation may be blocked after installation due to shared access and use. For example, an inverter may be installed with correct ventilation in a storage area, but over time the area may become cluttered with material that blocks required ventilation and rests against the heat sink, preventing adequate cooling of the device.

### 7.2.2 Equipment ratings

The inverter shall be marked with its ratings and the ratings of each port, as specified in Table 7.1. Only those ratings that are applicable to the type of inverter are required. The ratings shall be plainly and permanently marked on the inverter, in a location that is clearly visible after installation.

**Table 7.1 — Inverter ratings — Marking requirements**

| Port/General (all that apply) | Parameter | Marking value or symbol | Unit |
|---|---|---|---|
| Photovoltaic | $V_{max}$ PV (absolute maximum) | | d.c. V |
| | $I_{sc}$ PV (absolute maximum) | | d.c. A |
| Wind (a.c. or d.c.) | Voltage (nominal or range) | | a.c V or d.c. V |
| | Rated current (maximum continuous) | | a.c A or d.c. A |
| | Frequency (nominal or range) (a.c. wind only) | | Hz |
| Energy storage ports | Voltage (range) | | d.c. V |
| | Rated current (maximum continuous) | | d.c. A |
| Other energy sources or inputs (a.c. or d.c.) | Voltage (nominal or range) | | a.c V or d.c. V |
| | Rated current (maximum continuous) | | a.c A or d.c. A |
| | Power factor (range) | | |
| | Frequency (nominal or range) (a.c. sources only) | | Hz |
| a.c. output ratings (for each port) | Voltage (nominal or range) | | a.c. V |
| | Rated current | | a.c. A |
| | Frequency (nominal or range) | | Hz |
| | Rated apparent power | | VA |
| | Power factor (range) | | |
| d.c. output ratings | Voltage (nominal or range) | | d.c. V |
| | Rated current | | d.c. A |
| All ports | Protective class (I, II or III)[2] | I, II or III Or symbol | |
| | Over Voltage Category[a] | OVC I, II, III or IV | |
| Inverter topology | Type | Isolated or non-isolated Or symbol | |
| Ingress protection (IP) rating | Rating | IPXX | |

[a] Required for each port.

NOTE Table 7.1 is based on the requirements of IEC 62109-2.

### 7.2.3 Ports

Each port shall be marked with its classification and indicate whether a.c. or d.c. voltage as applicable.

Typical classifications for input, output and communication ports include the following:

(a) PV (photovoltaic).

(b) Wind turbine.

(c) Energy storage.

(d) Battery.

(e) Generator.

(f) Grid-interactive.

(g) Stand-alone.

(h) a.c. input.

(i) Load.

(j) Communications (type).

(k) DRM.

### 7.2.4 External and ancillary equipment

If the inverter requires external or ancillary equipment for compliance with this Standard, the requirement for any such equipment shall be marked on the inverter along with the following or an equivalent statement: Refer to the installation instructions for type and ratings or symbol.

NOTE External or ancillary equipment includes external automatic disconnection devices, external isolation transformers and external RCDs.

Any external or ancillary equipment shall be marked in accordance with this Section (7).

### 7.2.5 Residual current devices (RCDs)

Inverter energy systems used with PV array systems require residual current detection in accordance with IEC 62109-1 and IEC 62109-2. The requirements can be met by the installation of a suitably rated RCD external to the inverter or by an RCMU integral to the inverter.

Where an external RCD is required, the inverter shall be marked with a warning along with the rating and type of RCD required. The warning shall be located in a prominent position and written in lettering at least 5 mm high. It shall contain the following or an equivalent statement:

**WARNING — AN RCD IS REQUIRED ON THE [NAME] PORTS OF THE INVERTER**

If the inverter energy system requires a type B RCD, the inverter shall be marked with a warning. The warning shall be located in a prominent position and written in lettering at least 5 mm high. It shall contain the following:

**WARNING — A TYPE B RCD IS REQUIRED ON THE [NAME] PORTS OF THE INVERTER**

### 7.2.6 Demand response modes

The demand response modes supported by the inverter should be permanently marked on the name plate or on a durable sticker to indicate the demand response modes of which the unit is capable. Where the inverter utilizes a demand response interface port an alternative location for the marking where not on nameplate should be on or near that port.

Figure 7.1 illustrates a permitted form of marking. If this form of marking is used, each box shall contain a tick or a cross (if the inverter has that capability) or remain blank (if it does not have that capability). Alternatively, only the modes supported may be marked.

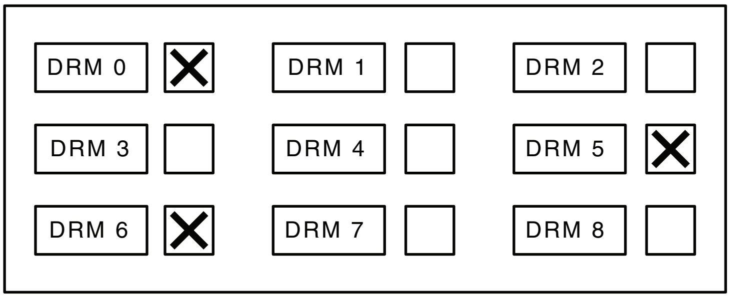



**Figure 7.1 — Example of DRM port marking on inverter**

If the physical interface is a terminal block, then —

(a) the terminals shall be engraved or otherwise durably marked; or

(b) a permanent label with "DRM Port" shall be affixed near the terminal block.

The marking shall indicate which terminal corresponds to which demand response mode. The range of markings is indicated against Pins 1 to 6 in Table 3.4.

The following contractions are permitted:

(i) "DRM" may be omitted, e.g. the terminal corresponding to DRM 1 may be marked "1" and the terminal corresponding to DRM 1/5 may be marked "1/5".

(ii) "Common" may be contracted to "C".

(iii) "RefGen" may be contracted to "Gen".

(iv) "Com/DRM 0" may be contracted to "CD0".

## 7.3 Documentation

### 7.3.1 General

The documentation supplied with the inverter shall provide all information necessary for the correct and safe installation, operation, maintenance and use of the system and any required external devices including information specified in Clause 7.2.

All inverters, including those intended for use in systems incorporating energy sources other than PV arrays or batteries, shall conform to the documentation requirements of IEC 62109-1 and IEC 62109-2.

Inverter documentation shall include a description of the type of inverter as either a grid-interactive or stand-alone inverter, in accordance with the requirements of this Standard. There may be additional descriptions related to the energy source/s or whether it also is a multiple mode inverter with various other modes of operation.

Inverter documentation shall include specification of environmental condition that it is intended for and the rated maximum operating ambient temperature that shall not be less than —

(a) 40 °C for indoor conditioned;

(b) 50 °C for indoor unconditioned;

(c) 50 °C for outdoor unconditioned without solar effects; or

(d) 60 °C for outdoor unconditioned with solar effects.

NOTE Without solar effects means that the inverter is installed in a location not subject to solar radiation as per AS 60947.3.

### 7.3.2 Equipment ratings

The documentation supplied with the inverter shall state the ratings of the inverter and the ratings for each port and parameter listed in Table 7.2. Only those ratings that are applicable to the type of inverter are required.

For equipment with rated current greater than 16 A per phase, additional documentation requirements apply. See Clause 2.8.

**Table 7.2 — Inverter ratings documentation requirements**

| Port (all that apply) | Parameter | Rating | Units |
|---|---|---|---|
| Photovoltaic | $V_{max}$ PV (absolute maximum) | | d.c. V |
| | PV input operating voltage range | | d.c. V |
| | Maximum operating PV input current | | d.c. A |
| | $I_{sc}$ PV (absolute maximum) | | d.c. A |
| | Maximum inverter backfeed current to array | | a.c A or d.c. A |
| Wind (a.c. or d.c.) | Voltage (nominal or range) | | a.c V or d.c. V |
| | Rated current (maximum continuous) | | a.c A or d.c. A |
| | Current (inrush) | | a.c A or d.c. A (peak and duration) |
| | Frequency (nominal or range) (a.c. wind only) | | Hz |
| Energy storage ports | Voltage (nominal or range) | | d.c. V |
| | Nominal battery voltage | | d.c. V |
| | Rated current (maximum continuous) input and output | | d.c. A |
| | Storage type | | |
| Other energy sources or inputs (a.c. or d.c.) | Voltage (nominal or range) | | a.c V or d.c. V |
| | Rated current (maximum continuous) | | a.c A or d.c. A |
| | Power factor (range) | | |
| | Frequency (nominal or range) (a.c. sources only) | | Hz |
| a.c. output ratings (for each port) | Voltage (nominal or range) | | a.c. V |
| | Rated current | | a.c. A |
| | Current (inrush) | | a.c. A (peak and duration) |
| | Frequency (nominal or range) | | Hz |
| | Rated apparent power | | VA |
| | Power factor range | | |
| | Maximum output fault current | | a.c. A (peak and duration) or RMS |
| | Maximum output overcurrent protection | | |
| d.c. output ratings | Voltage (nominal or range) | | d.c. V |
| | Rated current | | d.c. A |
| All ports | Protective class (I, II or III) | I, II or III | |
| | Over voltage category | OVC I, II, III or IV | |
| Inverter topology | Type | Isolated or non-isolated | |
| Active anti-islanding method | Method | Specify type name | |
| Ingress protection (IP) rating | Rating | IPXX | |
| Temperature operating range | Range | Min. to max. | °C |

### 7.3.3 Ports

In addition to the requirements of Clause 7.3.2, the documentation supplied with the inverter shall state the following for each port, as a minimum:

(a) Means of connection.

(b) For pluggable equipment type B, the type of matching connectors to be used.

NOTE 1 For some ports, the specific manufacturer of the connector type may also need to be specified to ensure correct mating connectors.

(c) External controls and protection requirements.

(d) Explanation of terminals or pins used for connection including polarity and voltage.

(e) Tightening torque to be applied to terminals.

(f) Instructions for protective earthing.

(g) Instructions for connection of loads and installation of RCD protection to stand-alone ports.

(h) The decisive voltage class (DVC).

NOTE 2 The DVC is the voltage of a circuit which occurs continuously between any two live parts in the worst-case rated operating condition when used as intended.

In addition to port documentation, where the port has an isolating device as part of and within the inverter as described in Clause 2.12 the following ratings are required —

(i) rated insulation voltage;

(ii) rated impulse withstand voltage;

(iii) suitability for isolation;

(iv) rated operational current;

(v) utilization category and/or PV utilization category;

(vi) rated short-time withstand current ($I_{cw}$);

(vii) rated short-circuit making capacity ($I_{cm}$); and

(viii) rated breaking capacity.

NOTE 3 The definitions for $I_{cw}$ and $I_{cm}$ are the same as used in AS 60947.3.



### 7.3.4 External and ancillary equipment

Where an inverter or multiple inverter combinations requires external or ancillary equipment to achieve functional requirements of this Standard, the documentation shall —

(a) state the requirement for any such equipment;

(b) provide sufficient information to identify the external or ancillary equipment, either by manufacturer and part number or by type and rating; and

(c) specify assembly, location, mounting and connection requirements.

### 7.3.5 Residual current devices (RCDs)

Where an external RCD is required, the following or an equivalent statement shall be included in the documentation: “External RCD required”. The documentation shall also state the rating and type of RCD required and provide instructions for the installation of the RCD.

### 7.3.6 Multiple mode inverters

Where the inverter is capable of multiple mode operation, the documentation shall include the following:

(a) Ratings and means of connection to each source of supply to the inverter or output from the inverter.

(b) Any requirements related to wiring and external controls, including the method of maintaining neutral continuity within the electrical installation to any stand-alone ports as required.

(c) Disconnection means and isolation means.

(d) Overcurrent protection needed.

### 7.3.7 Multiple inverter combinations

Where an inverter has been tested for use in a multiple inverter combination as per Section 5, the documentation shall include the following:

(a) Valid combinations of inverters.

(b) Installation instructions for correct operation as a multiple inverter combination.

### 7.3.8 Firmware

The documentation shall provide instructions for viewing of the inverter firmware version and the selected regional settings and any variations to the default inverter settings in read-only mode. This is to prevent unauthorized modification of inverter settings.

Documentation on the initial configuration and selection of regional settings and other settings at commissioning shall be provided to authorized persons.

Restricted information on accessing and changing the regional settings, other settings and firmware after initial configuration shall be provided to authorized persons only.

# Appendix A
(normative)

# General test and reporting requirements

## A.1 General

This Appendix specifies requirements for the configuration of the equipment under test, the real test grid or simulated test grid, and the reporting of results in test reports.

## A.2 Test conditions

Unless otherwise specified by the test procedure, the testing conditions for each test shall be such that —

(a) the average r.m.s. current on each phase is within ± 5 % of the intended test point;

(b) the average r.m.s. voltage on each phase is within ± 1 % of the grid test voltage; and

(c) a reference to grid source voltage means the r.m.s. voltage measured at the grid-interactive port of the device under test.

In the case of a three-phase supply, the angle between the fundamental voltages of each pair of phases shall be maintained at 120 ± 1.5° unless otherwise specified. The average r.m.s. voltages between each pair of phases shall be maintained within ± 1 %.

The grid test voltage shall be 230 V a.c. phase to neutral, (50 ± 0.1) Hz, unless otherwise specified.

## A.3 Inverter set-up

Each inverter that is to be tested shall have its internal settings and configurations set to the default set-points required by this Standard, as they would be for operation in an installation.

For inverters that have configurations or functionality that can be enabled or disabled, the default enablement shall apply unless otherwise specified in the test procedure.

NOTE This is so that any functionality that is enabled or disabled is proven not to compromise the safe operation of the inverter and that the required prioritization is met.

Each valid configuration that is tested shall be listed in the test report and the test results indicated. This includes testing with different demand response modes enabled and disabled and different power quality response modes enabled and disabled.

If the inverter is required to be used with an external device or devices, such as external automatic disconnection devices or dedicated isolation transformers, the inverter shall be tested in combination with these devices for all tests.

The combinations tested shall be documented in the test report.

Before commencement of the test, all model information and specific information concerning the version of software, firmware and hardware used by the inverter shall be recorded. This information shall be provided in the test report.

Sufficient records shall be kept and photographs taken so that the model can be verified when A1 testing is carried out. A1

Different configurations and default settings are required for regions within Australia and for New Zealand. Testing should be performed for the market intended. This shall be recorded in the test report. The Australia A parameter set shall be tested. Compliance of the limit values and setpoints applicable for each region shall be checked by inspection. The specified ranges shall not be able to be exceeded. Compliance shall be checked by inspection.

## A.4 Grid source

Either a real grid or a simulated test grid shall be used as the grid source in the testing. In some tests the grid source shall be able to be varied to provide the conditions of the test.

Whether a real grid or simulated test grid is used, the impedance of the test point shall be rated consistent with the rating of the inverter or combination of inverters under test. The impedance of the test point should not cause a voltage rise greater than 0.5 % of the grid test voltage at the rated current output of the device under test.

Reference network impedances of the test point specified in Clause A.6 are to be used for specified tests only.

NOTE This is to ensure that the application of the inverter in a customer installation will not adversely affect the quality of supply to the customer.

The type of grid source and the impedance of the test point shall be declared in the test report for each test performed.

During the tests, the steady-state voltage of the real or simulated test grid shall not vary by more than ± 1 % of the grid test voltage. The grid test voltage shall be set as required by each test.

For tests requiring step changes in voltage and/or frequency, the simulated test grid shall be at least capable of being stepped at 0.5 times the smallest step required for testing, to determine the set-points with required accuracy.

The grid source needs to be free from harmonic distortion which could interfere with testing. The voltage harmonic distortions of grid source shall be less than the limits specified in Table B.1 in Appendix B.



## A.5 Energy source

Either a real energy source or a simulated energy source shall be used as the energy source in the testing. The use of a simulated energy source shall not alter the outcome of the test.

The energy source shall be capable of supplying energy within the voltage, current and, where applicable, frequency ratings of the inverter energy source port to enable the inverter to deliver up to its rated current or rated apparent power. It shall be adjustable to other levels as specified by the test.

For photovoltaic input ports a PV array simulator is recommended. Where a PV array simulator is used it shall conform to the requirements of AS/NZS IEC 62116. Where a d.c. power supply with series resistance is used the requirements of AS/NZS IEC 62116 shall be met.

Where a real energy source such as a PV array, wind turbine or fuel cell are used the input electrical conditions at the port shall be monitored and shall not vary by more than 2 % during the duration of the test unless otherwise required.

The inverter under test shall not be modified in order for it to operate correctly with a simulated energy source.

The type of energy source and its ratings shall be declared in the test report for each test performed.

An energy storage port shall be treated as an energy source port. An energy storage device is deemed to be an energy source for the purposes of the tests applicable to energy storage. Where a simulated energy source is used in lieu of a storage battery it shall not limit the current drawn by the inverter energy storage port.

A real or simulated energy storage device shall be capable of absorbing energy at the maximum voltage and current ratings of the inverter energy storage port and where applicable over the rated frequency range of the energy storage port.

## A.6 Reference network impedance

A reference network impedance is required to be used in the testing circuit for the test of Appendix B and as required by the flicker test in Clause 2.8 using AS/NZS 61000.3.11. This reference network impedance simulates the impedance of the grid.

For single-phase and three-phase inverters with rated current less than 21.7 A per phase, the impedance of the reference network impedance shall be 0.24 Ω + j0.15 Ω for each phase conductor and 0.16 Ω + j0.10 Ω for the neutral conductor.

For inverters with rated current greater than 21.7 A per phase, the impedance of the reference network impedance shall be 0.15 Ω + j0.15 Ω for each phase conductor and 0.1 Ω + j0.1 Ω for the neutral conductor.

For inverters with rated current greater than 75 A per phase, the source impedance of the network shall be no less than 5 % of the source impedance of the inverter, where the source impedance of the inverter is assumed to be the rated voltage divided by the rated current.

NOTE When using a real test grid, the source impedance of the connection needs to be taken into account when setting up the test circuit with the required reference impedance value.

# Appendix B
(normative)

# Harmonic current limit test

## B.1 Test procedure

The procedure shall be as follows:

(a) The inverter shall be connected into a test circuit equivalent to that shown in Figure B.1.

(b) The energy source shall be varied until the a.c. output of the inverter, measured in amperes, lies in the range (100 ± 5) % of the inverter's rated current output.

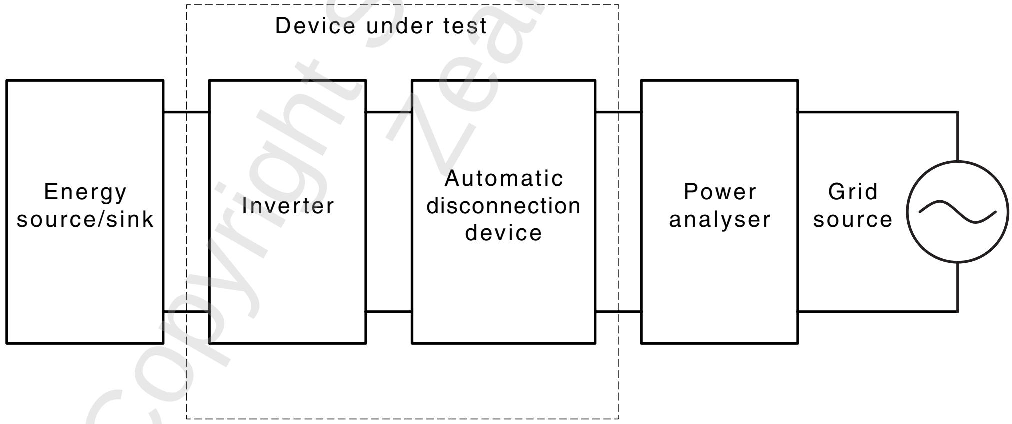
NOTE The required conditions for the grid source are specified in Clause B.3.

(c) The harmonic current content of the inverter output shall be measured and recorded.

(d) The energy source shall be varied until the a.c. output of the inverter, measured in amperes, lies in the range (50 ± 5) % of the inverter's rated current output.

(e) The harmonic current content of the inverter output shall be measured and recorded.

(f) The total impedance of the grid source and reference impedance that simulates a grid shall be in accordance with Appendix A Clause A.6.




NOTE This test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

**Figure B.1 — Circuit for power factor test**



## B.2 Harmonic current limits

When the inverter is tested in accordance with Clause B.1 above, the harmonic currents of the inverter shall not exceed the limits specified in Table 2.2 and Table 2.3 for all points tested.

## B.3 Grid source during harmonic test

While the harmonic current measurements are being made, the test voltage at the grid-interactive port of the inverter shall meet the following requirements:

(a) The test voltage and frequency shall be maintained at the grid test voltage.

(b) In the case of a three-phase supply, the angle between the fundamental voltages of each pair of phases shall be maintained at 120° ± 1.5°.

(c) The impedance of the supply source shall be as specified in Clause A.6.

(d) The harmonic ratios of the grid test voltage shall not exceed the limits specified in Table B.1.

**Table B.1 — Voltage harmonic limits of test grid**

| Harmonic order number | Limit based on percentage of fundamental |
|---|---|
| 3 | 0.9 % |
| 5 | 0.4 % |
| 7 | 0.3 % |
| 9 | 0.2 % |
| Even harmonics 2–10 | 0.2 % |
| 11–50 | 0.1 % |
| Total harmonic distortion (to the 50th harmonic) | 5 % |



## B.4 Test report

The measured values for harmonic current shall be reported in a table format for each point measured. The table shall contain all measured harmonic components as a current reading and as a percentage of the fundamental with a comparison against the limit for the component. Table B.2 is an example.

The test report shall also include —

(a) the reference impedance value used for the test circuit; and

(b) the background voltage harmonics present at the time of the test.

**Table B.2 — Example of table for reporting harmonic limits**

| Component | Limit | 50 % of rated current | | | 100 % of rated current | | |
|---|---|---|---|---|---|---|---|
| | % of fundamental | Value A | Angle degrees | % of fundamental | Value A | Angle degrees | % of fundamental |
| 0 | 0.5 % | | | | | | |
| 1 | 100 % | | | | | | |
| 2 | 1 % | | | | | | |
| 3 | 4 % | | | | | | |
| 4 | 1 % | | | | | | |
| 5 | 4 % | | | | | | |
| 6 | 1 % | | | | | | |
| 7 | 4 % | | | | | | |
| 8 | 1 % | | | | | | |
| 9 | 2 % | | | | | | |
| 10 | 0.5 % | | | | | | |
| 11 | 2 % | | | | | | |
| 12 | 0.5 % | | | | | | |
| 13 | 2 % | | | | | | |
| 14 | 0.5 % | | | | | | |
| 15 | 1 % | | | | | | |
| 16 | 0.5 % | | | | | | |
| 17 | 1 % | | | | | | |
| 18 | 0.5 % | | | | | | |
| 19 | 1 % | | | | | | |
| 20 | 0.5 % | | | | | | |
| 21 | 0.6 % | | | | | | |
| 22 | 0.5 % | | | | | | |
| 23 | 0.6 % | | | | | | |
| 24 | 0.5 % | | | | | | |
| 25 | 0.6 % | | | | | | |
| 26 | 0.5 % | | | | | | |
| 27 | 0.6 % | | | | | | |
| 28 | 0.5 % | | | | | | |
| 29 | 0.6 % | | | | | | |
| 30 | 0.5 % | | | | | | |
| 31 | 0.6 % | | | | | | |
| 32 | 0.5 % | | | | | | |
| 33 | 0.6 % | | | | | | |
| Total harmonic distortion (to 50th component) | | | | | | | |

# Appendix C
(normative)

# Transient voltage limit test

## C.1 General

The purpose of this test is to determine that the inverter complies with the transient voltage limits specified in Clause 2.9 when the grid is disconnected from the inverter.

For inverters with rated apparent power not more than 5 kVA, the test load shall be as described in Figure C.1 with the resistor value (R) indicated. For all other inverters, the resistor value (R) shall be calculated such that the total resistive load connected per phase is equivalent to 0.1 % of the rated apparent power of the inverter.

NOTE When choosing a resistor value, the resistive load may be calculated based on the nearest standard resistor value which results in similar load value, as long as the resistive load is within 20 % of the required value.

## C.2 Test procedure

The procedure shall be as follows:

(a) The inverter shall be placed in a test circuit equivalent to that shown in Figure C.1, with modification of the resistor value (R) if required (see Clause C.1).

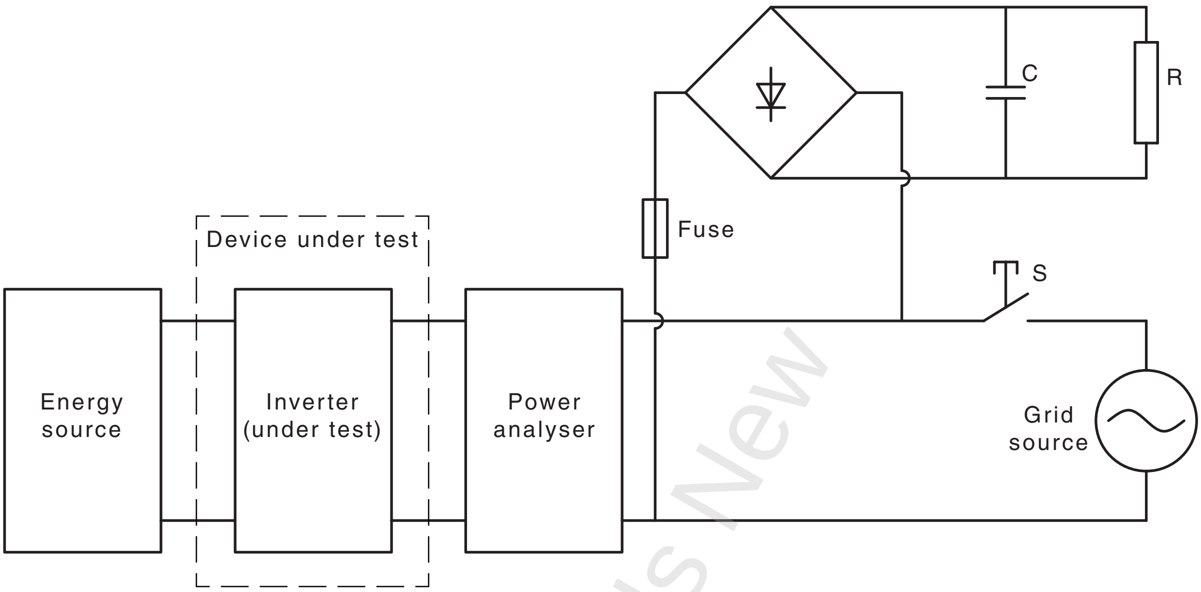
(b) Before the switch is opened, the voltage at the grid-interactive port of the inverter shall be maintained at the grid test voltage.

(c) The energy source shall be varied until the apparent power output of the inverter equals (10 ± 5) % of its rated apparent power.

(d) The switch (S) shall be opened.

(e) The voltage across the grid-interactive port of the inverter shall be recorded at a sample frequency of at least 10 kHz.

(f) Steps (b) to (e) shall be repeated with the inverter operating at (50 ± 5) % and (100 ± 5) % of its rated apparent power.




Key
C = 100 μF
R = 560 kΩ using symbols as shown in Figure

NOTE This test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

**Figure C.1 — Circuit for transient voltage limit test**



## C.3 Transient voltage limits

When tested in accordance with Clause C.2, the voltage-duration curve shall be derived from the measurements sampled for the a.c. voltage at the grid-interactive port.

A voltage-duration curve shall be calculated using the sampled instantaneous voltage over the complete trip time of the inverter. For each voltage (maximum voltage step 10 V), the number of samples greater than that voltage are counted. This number is then multiplied by the sample interval to derive the duration for that voltage. The voltage-duration curve is the locus of all points derived from this process. The inverter is deemed to conform to the transient voltage limit test if the derived voltage-duration curve lies beneath the curve of Figure 2.2 at all points.

The values obtained shall not exceed the limits specified in Table 2.4.

## C.4 Test report

The results recorded shall be provided in tabular and graphical formats.

# Appendix D
(normative)

# DC injection test

## D.1 General

The purpose of this test is to verify that the inverter complies with the d.c. current injection limit specified in Clause 2.10 when it connects to the grid. This test is required for inverters that do not incorporate a mains frequency isolating transformer either internally or externally.

The inverter shall be placed in a test circuit equivalent to that shown in Figure B.1. For three-phase systems, current shall be measured in each phase conductor. For single-phase inverters, either the active or neutral current may be measured.

If used, the simulated test grid shall meet the requirements of Appendix A and shall have negligible d.c. offset before the test commences.



## D.2 Test procedure

The procedure shall be as follows:

(a) Operate the inverter at 20 % of its rated current and at rated power factor. The inverter shall operate for at least 5 min prior to taking any test measurements (or until the inverter temperature stabilizes). The inverter shall operate at the specified current for the period of the measurement

(b) At the inverter output, measure the r.m.s. voltage, r.m.s. current, and d.c. component (frequency less than 1 Hz) of current on all phases. The average value of 180 consecutive readings of the d.c. component with a measurement period of 1 s for each reading shall be calculated. The average of the 180 consecutive readings for the inverter shall be below the limit specified in Clause 2.10. For each 1 s sample, the absolute value (i.e. unsigned value) shall be used to calculate the 180 s average.

(c) Repeat Steps (a) and (b) with the inverter operating at 60 % and 100 % of its rated current.

(d) Divide the calculated average values for the magnitude of the d.c. component of current by the rated current of the inverter and derive the value of the d.c. current injection as a percentage. This shall be done for 3 test points (20 %, 60 % and 100 %) and for each phase and/or neutral measurement. Record the final calculated values as the percentage of d.c. current injection for each phase.

## D.3 DC current limits

All d.c. current injection levels, calculated as percentages, shall be within the limit specified in Clause 2.10.

The resolution of the d.c. component measurement shall be 1 mA or 5 % of the applicable limit, whichever is greater, as specified in Clause 2.10.

## D.4 Test report

The measured values shall be reported in a table format for 20 %, 60 % and 100 % of the rated current. Table D.1 is an example.

**Table D.1 — Example reporting table for d.c. injection test**

| Value | | 20 % | 60 % | 100 % |
|---|---|---|---|---|
| Inverter current, A | Setting | | | |
| | Actual | | | |
| Limit | 0.5 % × $I_{rated}$ | | | |
| Result | A | | | |
| Compliance | (P/F) | | | |

# Appendix E
(normative)

# Demand response mode testing including disconnection on external signal



## E.1 General

The purpose of the tests set out in this Appendix is to verify that the demand response modes respond as required and that the performance of the anti-islanding protection is not affected when these modes are enabled or disabled.

NOTE The Demand Response provisions in this Standard follow the framework in the AS/NZS 4755 series Demand response capabilities and supporting technologies for electrical products.

## E.2 Test procedures

### E.2.1 Test for demand response and disconnection on external signal

The test system shall be as follows:

(a) The inverter shall be connected into a test circuit equivalent to that shown in Figure B.1.

(b) The voltage shall equal the grid test voltage.

(c) The inverter DRED connection (i.e. terminal block or RJ45 socket) shall be connected to a DRED though an auxiliary DRED test circuit, as shown in Figure E.1.

(d) When measured from the inverter DRED connection point, and with less than 30 mA (a.c. or d.c.) current flow, each DRED switch (S1–S8) and auxiliary DRED test circuit switch (S0) shall have a voltage drop of less than 0.1 V when “on”.

(e) When measured from the inverter DRED connection point, and with less than 30 mA (a.c. or d.c.) current flow, the auxiliary DRED test circuit shall have a voltage drop of 1.5–1.6 V (a.c. or d.c.) between terminals REF GEN/0 and DRM1/5 and COM LOAD/0 and DRM1/5, when auxiliary switches S5a and S1a respectively are “on”.

(f) Switch S9 (see Figure E.1) shall be closed prior to the commencement of each of tests in Clauses E.2.2, E.2.3 and E.2.4.

### E.2.2 Test for disconnection at rated power output

The procedure shall be as follows:

(a) The energy source or inverter set-point shall be varied until the a.c. output of the inverter equals (100 ± 5) % of its rated power output.

(b) A signal corresponding to DRM 0 shall be asserted and the time for the device under test to disconnect shall be measured and recorded.

(c) Where the inverter supports the provision of d.c. power to the DRED, power to the DRED shall remain after the automatic disconnection device has operated.

(d) The disconnect signal (DRM 0) shall be removed and the inverter shall be allowed to automatically reconnect (see Clause 4.6).

(e) Switch S9 (see Figure E.1) shall be opened and the time for the device under test to disconnect shall be measured and recorded. See Clause 3.2.2(d).

### E.2.3 Test for standard operation of generator demand response modes

The procedure shall be as follows:

(a) All DRM signals shall be removed and the energy source or inverter set-point shall be varied until the a.c. output of the inverter equals (100 ± 5) % of its rated power output. The DRM 3 and DRM 7 reactive power limits shall be set to their maximum allowed values (see Clause 3.2).

(b) A signal corresponding to DRM 7 shall be asserted and DRM 7 response assessed over a period of 2 min in accordance with the requirements of Table E.1.

(c) A signal corresponding to DRM 6 shall be asserted and simultaneous DRM 6 and DRM 7 response assessed over a period of 2 min in accordance with the requirements of Table E.1.

(d) The DRM 7 signal shall be halted and DRM 6 response assessed over a period of 2 min in accordance with the requirements of Table E.1.

(e) A signal corresponding to DRM 5 shall be asserted and DRM 5 response assessed over a period of 4 min in accordance with the requirements of Table E.1.

(f) All DRM signals shall be removed and the energy source or inverter set-point shall be varied until the a.c. output of the inverter equals (50 ± 5) % of the inverter's rated power output and is in a state able to respond to DRM 8.

(g) A signal corresponding to DRM 8 shall be opened and DRM 6 response assessed over a period of 2 min in accordance with the requirements of Table E.1.



### E.2.4 Test for standard operation of load demand response modes (such as for battery charging)

The procedure shall be as follows:

(a) All DRM signals shall be removed and the energy source or inverter set-point shall be varied until the a.c. draw of the inverter equals 100 % of the inverter's rated power input. DRM 3 and DRM 7 reactive power limits shall be set to their maximum allowed values (see Clause 3.2).

(b) A signal corresponding with DRM 3 shall be asserted and DRM 3 response assessed over a period of 2 min in accordance with the requirements of Table E.1.

(c) A signal corresponding with DRM 2 shall be asserted and simultaneous DRM 2 and DRM 3 response assessed over a period of 2 min in accordance with the requirements of Table E.1.

(d) The DRM 3 signal shall be halted and DRM 2 response assessed over a period of 2 min in accordance with the requirements of Table E.1.

(e) A signal corresponding with DRM 1 shall be asserted and DRM 1 response assessed over a period of 4 min in accordance with the requirements of Table E.1.

(f) All DRM signals shall be removed and the energy source or inverter set-point shall be varied until the a.c. draw of the inverter equals (50 ± 5) % of the inverter's rated power input and is in a state able to respond to DRM 4.

(g) A signal corresponding with DRM 4 shall be opened and DRM 4 response assessed over a period of 7 min in accordance with the requirements of Table E.1.

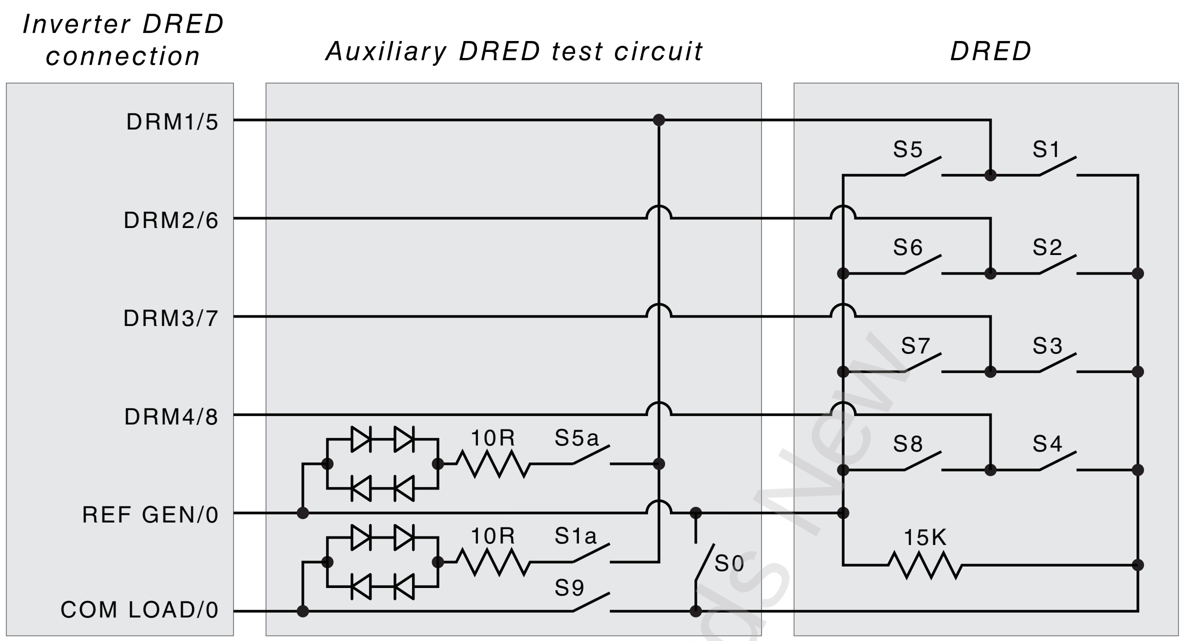



**Figure E.1 — DRED connection circuit**

## E.3 Demand response mode limits

When tested in accordance with Clause E.2, the inverter shall not exceed the active power limits, reactive power limits, or switching time limits specified in Table E.1.

The inverter does not satisfy this test if it —

(a) fails to respond to a DRM instruction of which it is claimed to be capable within the switching time limit;

(b) does not operate in accordance with the requirements for the DRM of Clause 3.1; or

(c) responds to a DRM instruction of which it is not claimed to be capable.

**Table E.1 — Power and switch time limits for DRM compliance**

| Demand response mode | Active power limit (referenced to inverter rated apparent power) | Reactive power limit (referenced to inverter rated apparent power) | Response initiation time |
|---|---|---|---|
| DRM 0 | 0 | 0 | 2 s |
| DRM 1 | Import = 0 | 0 | 2 s |
| DRM 2 | Import < 50 % | As per Clauses 2.5, 3.2 and DRM 3 and DRM 7 | 2 s |
| DRM 3 | Import < 75 % | Within 4 % of set-point per Clause 3.2 | 2 s |
| DRM 4 | Not limited | As per Clauses 2.5, 3.2 and DRM 3 and DRM 7 | 2 s |
| DRM 5 | Generate = 0 | 0 | 2 s |
| DRM 6 | Generate < 50 % | As per Clauses 2.5, 3.2 and DRM 3 and DRM 7 | 2 s |
| DRM 7 | Generate < 75 % | Within 4 % of set-point per Clause 3.2 | 2 s |
| DRM 8 | Not limited | As per Clauses 2.5, 3.2 and DRM 3 and DRM 7 | 2 s |

NOTE 1 For DRM 0, DRM 1 and DRM 5, current draw due to sensing and DRED circuits is allowable (see Clause 4.2).

NOTE 2 The "Response initiation time" is the maximum time the inverter may take to initiate entering a demand response mode after a switch has been asserted. For testing purposes an active power ramp should commence within this time, however the inverter may take several minutes to complete the response due to the power rate limit requirements of Clause 3.3.4.

## E.4 Test report

The measured values for switching times and per phase active and reactive power shall be reported in a table format for each stage of the test. See example in Table E.2.



**Table E.2 — Demand response mode reporting table**

| Demand response test | Active power | Reactive power | Switching time | Pass/Fail |
|---|---|---|---|---|
| DRM 0 at 100 % | | | | |
| DRM 7 | | | | |
| DRM 6 and DRM 7 | | | | |
| DRM 6 | | | | |
| DRM 5 and DRM 6 | | | | |
| DRM 8 | | | | |
| DRM 3 | | | | |
| DRM 3 and DRM 2 | | | | |
| DRM 2 | | | | |
| DRM 1 and DRM 2 | | | | |
| DRM 4 | | | | |

# Appendix F
(normative)

# Fixed power factor mode and reactive power mode test

## F.1 Test procedure

### F.1.1 Fixed power factor mode

The procedure shall be as follows:

(a) Connect the inverter into a test circuit equivalent to that shown in Figure B.1. Set the grid source voltage to the grid test voltage.

(b) Enable the power factor mode.

(c) Set the displacement power factor of the inverter to unity power factor.

(d) Vary the energy source until the a.c. output of the inverter equals (100 ± 5) % of its rated current output.

(e) Record the active power, reactive power and displacement power factor of the inverter output.

(f) Repeat Steps (d) and (e) with the inverter operating at (75 ± 5) %, (50 ± 5) % and (25 ± 5) % of its rated current output.

(g) Set the displacement power factor of the inverter to the limit for supplying maximum reactive power (0.8 power factor or less to the capability of the inverter).

(h) Vary the energy source until the a.c. output of the inverter equals (100 ± 5) % of its rated current output.

(i) Record the active power, reactive power and displacement power factor of the inverter output.

(j) Repeat Steps (h) and (i) with the inverter operating at (75 ± 5) %, (50 ± 5) % and (25 ± 5) % of its rated current output.

(k) Set the displacement power factor of the inverter to the limit for absorbing maximum reactive power (0.8 power factor or less to the capability of the inverter).

(l) Vary the energy source until the a.c. output of the inverter equals (100 ± 5) % of its rated current output.

(m) Record the active power, reactive power and displacement power factor of the inverter output.

(n) Repeat Steps (l) and (m) with the inverter operating at (75 ± 5) %, (50 ± 5) % and (25 ± 5) % of its rated current output.

### F.1.2 Fixed reactive power mode

The procedure shall be as follows:

(a) Connect the inverter into a test circuit equivalent to that shown in Figure B.1. Set the grid source voltage to the grid test voltage.

(b) Enable the fixed reactive power mode.

(c) Set the fixed reactive power level of the inverter so that it absorbs 60 % reactive power as a percentage of rated apparent power.

(d) Vary the energy source until the active power output level of the inverter equals (80 ± 5) % of its rated apparent power.

(e) Record the fixed reactive power level of the inverter output.

(f) Repeat Steps (d) and (e) with the inverter active power output level operating at (60 ± 5) % and (20 ± 5) % of its rated apparent power.

(g) Set the fixed reactive power level of the inverter so that it supplies 60 % reactive power as a percentage of rated apparent power.

(h) Vary the energy source until the active power output level of the inverter equals (80 ± 5) % of its rated apparent power.

(i) Record the fixed reactive power level of the inverter output.

(j) Repeat Steps (h) and (i) with the inverter active power output level operating at (60 ± 5) % and (20 ± 5) % of its rated apparent power.

## F.2 Criteria for acceptance

When tested in accordance with Clause F.1, the displacement power factor and reactive power of the device under test shall conform to the ranges specified in Clause 3.3.3 and the minimum reactive power capability specified in Clause 2.6.

The required accuracy for the measurement and reporting of results shall conform to the measurement accuracy specified in Table 2.5. For testing at power factor limits, results shall be ± 0.01 of the required limit. For example, for a limit of 0.80, values between 0.79 and 0.81 are acceptable.

## F.3 Test report

The measured values for the displacement power factor and reactive power shall be reported in a table format for each point measured and for each mode of operation. Tables F.1 and F.2 are examples.

**Table F.1 — Displacement power factor reporting table**

| Power factor (PF) setpoint | Measurement | Current output as a percentage of rated current output | | | |
|---|---|---|---|---|---|
| | | 25 % | 50 % | 75 % | 100 % |
| Unity | Power (watt) | | | | |
| | Reactive power (var) | | | | |
| | PF cos (phi) | | | | |
| | Supply/absorb | | | | |
| PF limit absorb (0.8) | Power (watt) | | | | |
| | Reactive power (var) | | | | |
| | PF cos (phi) | | | | |
| PF limit supply (0.8) | Power (watt) | | | | |
| | Reactive power (var) | | | | |
| | PF cos (phi) | | | | |

**Table F.2 — Fixed reactive power reporting table**

| Reactive power setpoint (% var/$S_{rated}$) | Measurement | Active power output as a percentage of rated apparent power | | |
|---|---|---|---|---|
| | | 20 %[a] | 60 %[a] | 80 % |
| 60 % absorb | Power (watt) | | | |
| | Reactive power (var) | | | |
| | Reactive power (% $S_{rated}$) | | | |
| 60 % supply | Power (watt) | | | |
| | Reactive power (var) | | | |
| | Reactive power (% $S_{rated}$) | | | |

[a] Inverter reactive power output measurements that meet or exceed the minimum capability of Figure 2.1 are acceptable.

# Appendix G
(normative)

# Power quality (voltage) response mode testing

## G.1 General

This test is used to verify the volt-watt and volt-var response modes of Clause 3.3.2 and the volt-watt response mode for charging of inverters with energy storage of Clause 3.4.3 as follows:

(a) Time to respond to a change in voltage.

(b) Correct response to a change in voltage.

(c) Correct prioritization of responses.

This test is also used to verify the default settings listed in Table 3.6 (volt-watt), Table 3.7 (volt-var) and Table 3.8 (volt-watt for charging).

For each of these tests the inverter and automatic disconnection device shall be connected into a test circuit equivalent to that shown in Figure B.1.

For each recording step in the test procedure, the relevant voltage level, timing, active power, reactive power and apparent power output of the device under test shall be measured and recorded. The apparent power level may be measured or calculated from the active and reactive power measurements.



## G.2 Test procedure

### G.2.1 Volt-watt response mode

The procedure shall be as follows:

(a) Enable the volt-watt response mode and disable all other power quality modes.

(b) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output.

(c) Adjust the grid source voltage to equal $V_{W1}$.

(d) Increase the voltage by five equal voltage steps between $V_{W1}$ and ($V_{W2}$ – 1.0) V, remaining at each voltage level for at least 20 s.

(e) At each voltage step record the voltage, the time taken for the active power output level to stabilize and the stable active and reactive power output levels of the device under test.

(f) Decrease the voltage by five equal voltage steps between $V_{W2}$ and $V_{W1}$, remaining at each voltage level for at least 20 s.

(g) At each voltage step, record the voltage, the time taken for the active power output level to stabilize and the stable active and reactive power output levels of the device under test.

(h) Increase the voltage to equal ($V_{W2}$ – 1.0) V.

(i) Record the voltage, the time taken for the power output of the device under test to respond, the time taken for the active power output level to stabilize and the stable active and reactive power output levels of the device under test.

(j) Summarize the results in a table for each voltage step, from initial to final voltage value, showing voltage, apparent power, active power, reactive power and time to reach the stable power output level. Plot the results on a graph of voltage versus apparent power, active power and reactive power output.

NOTE See example table for results at Table G.1.

### G.2.2 Combined volt-var and volt-watt response modes

The procedure shall be as follows:

(a) Enable the volt-watt and volt-var response modes.

(b) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (100 ± 5) % of its rated active power output.

(c) Adjust the grid source voltage to equal $V_{V3}$.

(d) Increase the voltage by five equal voltage steps between $V_{V3}$ and $V_{V4}$, remaining at each voltage level for at least 20 s.

(e) At each voltage step, record the voltage, the time taken for the reactive power output level to stabilize and the stable active and reactive power output levels of the device under test.

(f) Decrease the voltage by five equal voltage steps between $V_{V4}$ and $V_{V3}$, remaining at each voltage level for at least 20 s.

(g) At each voltage step, record the voltage, the time taken for the reactive power output level to stabilize and the stable active and reactive power output levels of the device under test.

(h) Adjust the grid source voltage to equal $V_{V2}$.

(i) Decrease the voltage by five equal voltage steps between $V_{V2}$ and $V_{V1}$, remaining at each voltage level for at least 20 s.

(j) At each voltage step, record the voltage, the time taken for the reactive power output level to stabilize and the stable active and reactive power output levels of the device under test.

(k) Increase the voltage by five equal voltage steps between $V_{V1}$ and $V_{V2}$, remaining at each voltage level for at least 20 s.

(l) At each voltage step, record the voltage, the time taken for the reactive power output level to stabilize and the stable active and reactive power output levels of the device under test.

(m) Increase the voltage to ($V_{W2}$ − 1.0) V.

(n) Record the voltage, the time taken for the reactive power output of the device under test to respond, the time taken for the reactive power output level to stabilize and the stable active and reactive power output levels of the device under test.

(o) Summarize results in a table from initial value to final voltage value showing voltage, apparent power, active power, reactive power and time to reach required reactive power level for each voltage step. Plot results on a graph of voltage versus apparent power, active power and reactive power.

NOTE See example table for results at Table G.2.

### G.2.3 Volt-watt mode for charging of multiple mode inverters with energy storage

The procedure for testing volt-watt response mode for charging of multiple mode inverters with energy storage shall be as follows:

(a) Enable the volt-watt mode and the volt-var response modes.

(b) Set the grid source equal to the grid test voltage. Adjust the power input level of the inverter to at least 75 % of its rated power input level ($P_{\text{rated-ch}}$).

(c) Decrease the grid source voltage to equal $V_{\text{W2-ch}}$.

(d) Decrease the voltage by four equal voltage steps between $V_{\text{W2-ch}}$ and $V_{\text{W1-ch}}$, remaining at each voltage level for at least 20 s.

(e) At each voltage step, record the voltage, the time taken for the active power input level to stabilize and the stable active and reactive power input levels of the device under test.

(f) Increase the voltage by four equal steps between $V_{\text{W1-ch}}$ and $V_{\text{W2-ch}}$, remaining at each voltage level for at least 20 s.

(g) At each voltage step, record the voltage, the time taken for the active power input level to stabilize and the stable active and reactive power input levels of the device under test.

(h) After 90 s, decrease the voltage to ($V_{\text{W1-ch}}$ − 1.0) V.

(i) Record the voltage, the time taken for the power input of the device under test to respond to the voltage step, the time taken for the active power input level to stabilize and the stable active and reactive power input levels of the device under test.

(j) Summarize the results in a table for each voltage step, from initial to final voltage value, showing voltage, apparent power, active power, reactive power and time to reach the stable power input level. Plot the results on a graph of voltage versus apparent power, active power and reactive power input.

NOTE See example table for results at Table G.3

## G.3 Criteria for acceptance

When tested in accordance with Clauses G.2.1 and G.2.2, the volt response shall be linear and conform to Clause 3.3.2. For inverters with energy storage, when tested in accordance with Clause G.2.3, the volt response shall be linear and conform to Clause 3.4.3.

## G.4 Test report

The graphs specified in Clauses G.2.1 and G.2.2 shall be included in the test report. In addition, for inverters with energy storage, the graphs specified in Clause G.2.3 shall be included in the test report.

The summary tables specified in Clauses G.2.1 and G.2.2 shall be presented with a result for each step performed, comparing actual test values against set-point values. In addition, for inverters with energy storage, the summary tables specified in Clause G.2.3 shall be presented with a result for each step performed, comparing actual test values against set-point values.

**Table G.1 — Example table for Clause G.2.1 volt-watt response mode test**

| Voltage<br>V | Time for output to stabilize<br>s | Stable reactive power output<br>% $S_{rated}$ | Stable active power output<br>% $S_{rated}$ | Expected active power output Australia A<br>% $S_{rated}$ |
|---|---|---|---|---|
| 253 | — | | | 100 % |
| 254.2 | | | | 86 % |
| 255.4 | | | | 73 % |
| 256.6 | | | | 59 % |
| 257.8 | | | | 45 % |
| 259 | | | | 31 % |
| 257.8 | | | | 45 % |
| 256.6 | | | | 59 % |
| 255.4 | | | | 73 % |
| 254.2 | | | | 86 % |
| 253 | | | | 100 % |
| 259 | | | | 31 % |

**Table G.2 — Example table for Clause G.2.2 V-var and volt-watt response modes test**

| Voltage<br>V | Time for output to stabilize<br>s | Stable reactive power level<br>% $S_{rated}$[a] | Typical reactive power level Australia A<br>% $S_{rated}$ | Stable active power output<br>% $S_{rated}$ | Expected active power output Australia A<br>% $S_{rated}$ |
|---|---|---|---|---|---|
| 240 | — | | 0 % | | 100 % |
| 243.6 | | | −12 % | | 99 % |
| 247.2 | | | −24 % | | 97 % |
| 250.8 | | | −36 % | | 93 % |
| 254.4 | | | −48 % | | 84 % |
| 258 | | | −60 %[a] | | 43 % |
| 254.4 | | | −48 % | | 84 % |
| 250.8 | | | −36 % | | 93 % |
| 247.2 | | | −24 % | | 97 % |
| 243.6 | | | −12 % | | 99 % |
| 240 | | | 0 % | | 100 % |
| 220 | — | | 0 % | | 100 % |
| 217.4 | | | 9 % | | 100 % |
| 214.8 | | | 18 % | | 98 % |
| 212.2 | | | 26 % | | 96 % |
| 209.6 | | | 35 % | | 94 % |
| 207 | | | 44 % | | 90 % |
| 209.6 | | | 35 % | | 94 % |
| 212.2 | | | 26 % | | 96 % |
| 214.8 | | | 18 % | | 98 % |
| 217.4 | | | 9 % | | 100 % |
| 220 | | | 0 % | | 100 % |
| 259 | | | −60 %[a] | | 31 % |

[a] Inverter reactive power output measurements that meet or exceed the minimum capability of Figure 2.1 are acceptable.

**Table G.3 — Example table for Clause G.2.3 volt -watt response mode for inverters with energy storage test**

| Voltage<br>V | Time for output to stabilize<br>s | Stable reactive power supplied<br>% $S_{rated}$ | Typical reactive power supplied Australia A<br>% $S_{rated}$ | Stable active power input<br>% $S_{rated}$ | Expected active power input Australia A<br>% $S_{rated}$ |
|---|---|---|---|---|---|
| 215 | — | | 17 % | | 99 % |
| 213 | | | 24 % | | 80 % |
| 211 | | | 30 % | | 60 % |
| 209 | | | 37 % | | 40 % |
| 207 | | | 44 % | | 20 % |
| 209 | | | 37 % | | 40 % |
| 211 | | | 30 % | | 60 % |
| 213 | | | 24 % | | 80 % |
| 215 | | | 17 % | | 99 % |
| 206 | | | 44 % | | 20 % |

# Appendix H
(normative)

## Active anti-islanding test

The active anti-islanding protection test of AS/NZS IEC 62116 shall be used for testing to confirm conformance with active anti-islanding requirements of Section 4.

For PV array inverters and battery inverters AS/NZS IEC 62116 is applicable without further technical factors.

NOTE AS/NZS IEC 62116 specifies test procedures for inverters used with PV arrays and battery systems. AS/NZS IEC 62116 scope statement permits application of the test procedure to other types of grid connected systems.

For inverters intended for use with energy sources other than PV arrays and batteries, Clause A.5 shall be applied in place of AS/NZS IEC 62116:2020 Clause 5.2 “DC power source”.

# Appendix I
(normative)

# Voltage and frequency limits tests

## I.1 General

Voltage and frequency limits which provide passive anti-islanding protection, and the voltage and frequency limits for connection and reconnection and the ramp rate upon reconnection shall be assessed by means of the following tests.

NOTE Each test in this Appendix should be repeated three times to confirm compliance of the limit.

## I.2 Undervoltage and overvoltage trip settings and reconnection test

### I.2.1 General

This test is used to verify —

(a) the overvoltage trip delay time and maximum disconnection times specified in Table 4.1;

(b) the undervoltage trip delay times and maximum disconnection times specified in Table 4.1;

(c) the voltage limits and set power rate limit ($W_{\mathrm{Gra}}$), following connection or reconnection, specified in Clause 4.7; and

(d) the nonlinearity requirements of Clause 3.3.4.4.

For three-phase inverters, the following tests shall be performed for a single-phase voltage disturbance on each phase.

For each of these tests the inverter and automatic disconnection device shall be connected into a test circuit equivalent to that shown in Figure B.1.

### I.2.2 Overvoltage 2 (*V* > > ) test

The trip voltage and disconnection time for the protective function overvoltage 2 (V > > ) of Table 4.1 for a voltage step and the reconnection time of Clause 4.7 shall be confirmed in the following steps. In addition, the ramp rate on connection or reconnection shall be confirmed to meet the requirements of Clause 3.3.4.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power.

NOTE 1 For three-phase inverter combinations, the required inverter output is based on the per phase inverter rating.

(b) For steps that test overvoltage limits the voltage at the grid-interactive port should be maintained for a continuous period exceeding 10 min to ensure that the average voltage for that 10 min period is equal to the grid test voltage.

NOTE 2 The 10 min interval is set so that the output level reaches the required limit and the inverter's internal measurements for sustained overvoltage approach approximately 230 V. The overall time for the test needs to be taken into account to ensure that the sustained overvoltage limit does not trip the automatic disconnection device.

(c) Set the grid source equal to 2.5 V less than the overvoltage 1 ($V >$) limit specified in Table 4.1.

(d) Step the grid source voltage to 2.5 V above the overvoltage 2 ($V > >$) limit specified in Table 4.1 with the voltage step completed within 2 ms and occurring at the zero crossing. Record the time interval between the start of the voltage step and the device under test disconnecting from the grid source.

NOTE 3 For testing of the disconnection time for overvoltage 2 ($V > >$), the time to perform the test needs to be such that the sustained overvoltage protection and the protective function overvoltage 1 ($V >$) of Table 4.1 does not cause the automatic disconnection device to trip prior to reaching the overvoltage 2 ($V > >$) protection function limit.

(e) Adjust the grid source to return the voltage to the grid test voltage. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

(f) Record the active power output at intervals of no more than 15 s until the active power output has stabilized at (100 ± 4) % of rated apparent power to confirm that the ramp rate on connection or reconnection meets requirements of Clause 3.3.4.

### I.2.3 Undervoltage 2 ($V < <$) test

The delay and disconnection times for the protective function undervoltage 2 ($V < <$) of Table 4.1 for a voltage step and the reconnection time of Clause 4.7 shall be confirmed in the following steps.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated apparent power.

NOTE 1 For three-phase inverter combinations, the required inverter output is based on the per phase inverter rating.

(b) Step the grid source voltage to 2.5 V below the undervoltage 2 ($V < <$) limit specified in Table 4.1 with the voltage step completed within 2 ms and occurring at the zero crossing of the grid source voltage. Record the time interval between the start of the voltage step and the device under test disconnecting from the grid source.

(c) Adjust the grid source to return the voltage to the grid test voltage. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

(d) Re-establish the conditions of Step (a).

(e) Record the stabilized active power output.

(f) Step the grid source voltage to 50 V with the voltage step completed within 2 ms and occurring at the zero crossing of the grid source voltage, remain at 50 V for 900 ms. Increase the grid source voltage to the grid test voltage with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage. Record the time duration that voltage lies below the undervoltage 2 ($V < <$) limit specified in Table 4.1. The device under test shall remain connected for the duration of this period.

NOTE 2 Where the device under test is a multiple mode inverter meeting the performance classification for output requirements of AS IEC 62040.3, it may disconnect the grid-interactive port during this step, with reconnection when the grid voltage recovers within the voltage requirements of the AS IEC 62040.3 performance classification relevant to the inverter.

(g) After 400 ms record the active power output and confirm it is equal to that recorded before at Step (e) ± 4 %.

### I.2.4 Undervoltage 1 ($V<$) test

The trip voltage, delay and disconnection times for the protective function undervoltage 1 ($V<$) limit of Table 4.1 for a voltage sag, and the reconnection time of Clause 4.7 shall be confirmed in the following steps. In addition, the minimum voltage for reconnection of the automatic disconnection device shall be confirmed as in accordance with Clause 4.7.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated apparent power.

NOTE 1 For three-phase inverter combinations, the required inverter output is based on the per phase inverter rating.

(b) Set the grid source equal to 2.5 V above the undervoltage 1 ($V<$) limit specified in Table 4.1.

(c) Decrease the grid source voltage in steps of less than 1 V to 2.5 V below the undervoltage 1 ($V<$) limit specified in Table 4.1, with a dwell time at each voltage step of 15 s. Record the time interval between the start of a voltage step and the device under test disconnecting from the grid source, and the grid source voltage at which it disconnects.

(d) Set the grid source equal to the 203 V. Maintain the grid source voltage at this level for a period of two (2) times the reconnection time measured in Clause I.2.3. The device under test shall not reconnect for the duration of this period.

NOTE 2 203 V is 2 V below the lowest utilization voltage of AS 60038.

(e) Adjust the grid source to increase the voltage by 4 V. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

### I.2.5 Overvoltage 1 ($V>$) test

The trip voltage, delay and disconnection times for the protective function overvoltage 1 ($V>$) of Table 4.1 and the reconnection time of Clause 4.7 shall be confirmed in the following steps. In addition, the maximum voltage for reconnection of the automatic disconnection device shall be confirmed as in accordance with Clause 4.7.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated apparent power.

NOTE 1 For three-phase inverter combinations, the required inverter output is based on the per phase inverter rating.

(b) Set the grid source equal to 2.5 V below the overvoltage 1 ($V>$) limit specified in Table 4.1.

(c) Increase the grid source voltage in steps of no more than 1 V to 2.5 V above the overvoltage 1 ($V>$) limit specified in Table 4.1, with a dwell time at each voltage step of 5 s. Record the time interval between the start of a voltage dwell time and the device under test disconnecting from the grid source, the grid source voltage at which the device under test disconnects.

NOTE 2 For testing of the overvoltage 1 ($V>$) disconnection time, the time to perform the test needs to be such that the sustained overvoltage protection does not cause the automatic disconnection device to trip prior to reaching the overvoltage ($V>$) protection function limit.

(d) Set the grid source equal to 255 V. Maintain the voltage at this level for a period of two (2) times the reconnection time measured in Clause I.2.2. The device under test shall not reconnect for the duration of this period.

NOTE 3 255 V is 2 V above the highest utilization voltage of AS 60038.

(e) Adjust the grid source to reduce the voltage by 4 V. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

### I.2.6 Test report

The recorded trip times, response times, reconnection times and active power output levels shall be recorded in a table. An example table is shown in Table I.1.

**Table I.1 — Example table for undervoltage and overvoltage trip settings and reconnection test**

| Clause I.2 voltage tests | Description | Minimum value | Maximum value | Test resolution | Units |
|---|---|---|---|---|---|
| Overvoltage 2 (*V*> >) | When stepping the grid source voltage to 2.5 V above the overvoltage 2 (*V*> >) limit in Table 4.1 (2 ms), the time taken from the start of the step and the device under test disconnecting [I.2.2(d)] | 0.0 | 0.2 | | s |
| | The reconnect time after decreasing grid source voltage to grid test voltage [I.2.2(e)] | 60.0 | — | | s |
| | The measured ramp rate after restoration in I.2.2 (e). Provide test data in a graphical and tabular form showing active power output measured at 15 s intervals until power output has stabilized at (100 ± 4) % of rated apparent power [I.2.2(f)] | According to [A1] Figure 3.3 [A1] | According to [A1] Figure 3.3 [A1] | | %/min |
| Undervoltage 2 (*V*< <) | When stepping the grid source voltage to 2.5 V below the undervoltage 2 (*V*< <) limit in Table 4.1 (2 ms), the time taken from the start of the step and the device under test disconnecting [I.2.3(b)] | 1.0 | 2.0 | | s |
| | The reconnect time after increasing grid source voltage to grid test voltage [I.2.3(c)] | 60.0 | — | | s |
| | The stabilized active power output after restoration of grid voltage [I.2.3(e)] | | | | W |
| | When stepping the grid source voltage to 50 V (2 ms), holding for 900 ms then returning to grid test voltage (2 ms). The time taken between first and second points where the voltage passes through the undervoltage 2 (*V*< <) limit in Table 4.1[I.2.3 (f)] | | | | ms |
| | The device remained connected at all times for Step I.2.3(f) | | | | Y/N |
| | OR<br><br>If the device under test is a multiple mode inverter meeting the performance classification for output requirements of AS IEC 62040.3 the inverter reconnected within 400 ms when the grid voltage recovered to within the voltage requirements of the relevant AS IEC 62040.3 performance classification. | | | | Y/N |
| | The real power output 400 ms after restoration of grid test voltage [I.2.3(g)] | | I.2.3(e) value above ± 5 %. | | W |
| Undervoltage 1 (*V*<) | When stepping the grid source voltage in < 1 V steps with a dwell time of 15 s to 2.5 V below the undervoltage 1 (*V*<) limit in Table 4.1, the time taken from the start of a voltage step and the device under test disconnecting [I.2.4(c)] | 10.0 | 11.0 | | s |
| | Grid source voltage recorded when device under test disconnected [I.2.4(c)] | | | | V |

**Table I.1** *(continued)*

| Clause I.2 voltage tests | Description | Minimum value | Maximum value | Test resolution | Units |
|---|---|---|---|---|---|
| | When the grid source voltage was set to 203 V, the device under test remained disconnected for two times the reconnection time in I.2.3 (c) [I.2.4(d)] | | | | Y/N |
| | When increasing the grid source voltage by 4 V, the time taken from the start of a voltage step and the device under test reconnecting [I.2.4(e)] | 60 | — | | s |
| Overvoltage 1 ($V>$) | When stepping the grid source voltage in < 1 V steps with a dwell time of 15 s to 2.5 V above the overvoltage 1 ($V>$) limit in Table 4.1, the time taken from the start of a voltage step and the device under test disconnecting [I.2.5(c)] | 1.0 | 2.0 | | s |
| | The grid source voltage recorded when device under test disconnected [I.2.5(c)] | | | | V |
| | When the grid source voltage was set to 255 V, the device under test remained disconnected for two times the reconnection time in I.2.2 [I.2.5(d)] | | | | Y/N |
| | When decreasing the grid source voltage by 4 V, the time taken from the start of a voltage step and the device under test reconnecting [I.2.5(e)] | 60 | — | | s |

### I.2.7 Criteria for acceptance

When tested in accordance with Clause I.2, the device under test shall conform to the following:

(a) The limits specified in Table 4.1.

(b) The measured voltage of each limit shall conform to the measurement accuracy specified in Table 2.5.

(c) The disconnection time shall be greater than the trip delay time and less than the maximum disconnection time of Table 4.1 unless the device under test is 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.

(d) The device under test shall remain connected for an undervoltage step of less than trip delay time of Table 4.1 unless the device under test is 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.

(e) The connection or reconnection time and behaviour shall conform to Clause 4.7.

(f) The active power output for each interval recorded as part of the steps in Clause I.2.2 shall conform to the nonlinearity requirements of Clause 3.3.4.4 and the default ramp rate of Clause 3.3.4.2.

(g) Where the device under test is a multiple mode inverter meeting the performance classification for output requirements of AS IEC 62040.3, it may disconnect the grid-interactive port during this step. The inverter shall reconnect within 400 ms when the grid voltage recovers within the voltage requirements of the AS IEC 62040.3 performance classification relevant to the inverter.

## I.3 Voltage disturbance withstand tests

### I.3.1 Test procedure

The purpose of this test is to verify the inverter behaviour required in Clause 4.5.4.

For three-phase inverters, the following tests shall be performed for a single-phase voltage disturbance on each phase.

The procedure shall be as follows:

(a) Connect the inverter and automatic disconnection device into a test circuit equivalent to that shown in Figure B.1.

(b) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated apparent power. Record the active power level.

NOTE 1 For three-phase inverter combinations, the required inverter output is based on the per phase inverter rating.

(c) Increase the voltage to overvoltage 1 ($V >$ ) of Table 4.1 plus 2.5 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage.

(d) Record the active power level 200 ms after the voltage step change.

(e) Within 1 s of Step (c), decrease the voltage to the grid test voltage with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage.

(f) Record the stabilized active power level 400 ms after the voltage step change.

NOTE 2 For testing of the upper cease power generation threshold, the time to perform the test needs to be such that the sustained overvoltage protection and the protective function overvoltage 1 ($V >$ ) of Table 4.1 does not cause the automatic disconnection device to trip.

(g) After 2 s, decrease the grid source voltage to 50 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage.

(h) Record the active power level 200 ms after the voltage step change.

(i) Within 1 s of Step (g), increase the grid source voltage to 150 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source.

(j) Record the active power level 200 ms after the voltage step change.

(k) After 8 s, increase the grid source voltage to the grid test voltage with the step change completed within 2 ms and occurring at the zero crossing of the grid source.

(l) Record the active power level 400 ms after the voltage step change.

(m) After at least 15 s, decrease the grid source voltage to 50 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage.

(n) Record the active power level 200 ms after the voltage step change.

(o) After 0.5 s, increase the grid source voltage to the grid test voltage with the step change completed within 2 ms and occurring at the zero crossing of the grid source.

(p) Record the active power level 400 ms after the voltage step change.

(q) After 2 s, decrease the grid source voltage to 100 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source.

(r) Record the active power level 200 ms after the voltage step change.

(s) After 4.5 s, decrease the grid source voltage to 50 V with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage.

(t) Repeat Steps (n) to (r)

(u) After 4.5 s, increase the grid source voltage to the grid test voltage with the step change completed within 2 ms and occurring at the zero crossing of the grid source

(v) Record the active power level 400 ms after the voltage step change.

An example of a table is shown in Table I.2.

### I.3.2 Test report

The recorded active power output levels at each voltage step shall be recorded in a table.

The active power output level and voltage shall be plotted on a graph against time.

**Table I.2 — Example table for voltage disturbance withstand test**

| Clause I.3 test report | Description | Minimum value | Maximum value | Test resolution | Units |
|---|---|---|---|---|---|
| Cease power generation and multiple voltage disturbance test I.3.1 | The active power level after the device under test has been set to (50 ± 5) % of its rated apparent power [I.3.1(b)] | | | | W |
| | When the grid source voltage is raised from grid test voltage to 267.5 V [2 ms — I.2.5(c)], record the power level 200 ms after the voltage step change [I.3.1(d)] | | | | W |
| | When after < 1 s the grid source voltage is decreased to the grid test voltage (2 ms), record the stabilized power level 400 ms after the voltage step change [I.3.1(f)] | | | | W |
| | When after 2 s the grid source voltage is decreased to the 50 V (2 ms), record the stabilized power level 200 ms after the voltage step change [I.3.1(h)] | | | | W |
| | When after < 1 s the grid source voltage is increased to 150 V (2 ms), record the stabilized power level 200 ms after the voltage step change [I.3.1(j)] | | | | W |
| | When after 8 s the grid source voltage is increased to the grid test voltage (2 ms), record the stabilized power level 400 ms after the voltage step change [I.3.1(l)] | | | | W |
| | When after > 15 s the grid source voltage is decreased to the 50 V (2 ms), record the stabilized power level 200 ms after the voltage step change [I.3.1(n)] | | | | W |
| | When after 0.5 s the grid source voltage is increased to the grid test voltage (2 ms), record the stabilized power level 400 ms after the voltage step change [I.3.1(p)] | | | | W |
| | When after 2 s the grid source voltage is decreased to the 100 V (2 ms), record the stabilized power level 200 ms after the voltage step change [I.3.1(r)] | | | | W |
| | When after 4.5 s the grid source voltage is decreased from 100 V to the 50 V (2 ms), record the stabilized power level 200 ms after the voltage step change [I.3.1(t)] | | | | W |
| | When after 0.5 s the grid source voltage is increased to the grid test voltage (2 ms), record the stabilized power level 400 ms after the voltage step change [I.3.1(t)] | | | | W |

**Table I.2** *(continued)*

| Clause I.3 test report | Description | Minimum value | Maximum value | Test resolution | Units |
|---|---|---|---|---|---|
| | When after 2 s the grid source voltage is decreased to the 100 V (2 ms), record the stabilized power level 200 ms after the voltage step change [I.3.1(t)] | | | | W |
| | When after 4.5 s the grid source voltage is increased to the grid test voltage (2 ms), record the stabilized power level 400 ms after the voltage step change [I.3.1(v)] | | | | W |

### I.3.3 Criteria for acceptance

The device under test shall —

(a) remain connected for the duration of the test unless the device under test is 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; and

(b) conform to the voltage disturbance withstand behaviour of Clause 4.5.4.1.

## I.4 Under-frequency and over-frequency trip settings and reconnection test

### I.4.1 General

This test is used to verify —

(a) the under-frequency and over-frequency trip delay and maximum disconnection times specified in Table 4.2; and

(b) the frequency limits and time for reconnection, specified in Clause 4.7.

For each of these tests the inverter and automatic disconnection device shall be connected into a test circuit equivalent to that shown in Figure B.1.

### I.4.2 Under-frequency 1 ($F <$ ) test

The trip frequency, delay and disconnection times for the protective function under-frequency 1 ($F <$ ) of Table 4.2 of the automatic disconnection device shall be confirmed in the following steps. In addition the reconnection time specified in Clause 4.7 shall be confirmed

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated current output or 10 A, whichever is the lesser.

NOTE For three-phase inverters, the required output is based on the per phase rating. For larger inverters, if 10 A is too low for stable operation, the minimum stable power output level of the inverter may be used.

(b) Slowly decrease the frequency of the grid source until the device under test disconnects from the grid source. Record the frequency at which disconnection occurs.

(c) Increase the frequency of the grid source to (50 ± 0.1) Hz. Record the time taken for the device under test to reconnect to the grid source.

(d) Set the frequency of the grid source to the under-frequency 1 ($F <$ ) limit, as recorded at Step (b), plus 0.1 Hz. Decrease the frequency by at least the rate of change of frequency (df/dt) as specified in Clause 4.5.6. Record the time interval between the frequency passing through the frequency measured at Step (b) and the device under test disconnecting from the grid source.

(e) Increase the frequency of the grid source to 47.4 Hz. Maintain the frequency at this level for a period of two (2) times the reconnection time measured at Step (c). The device under test shall not reconnect for the duration of this period.

(f) Increase the frequency of the grid source to 48.0 Hz. Record the time taken for the device under test to reconnect to the grid source.

### I.4.3 Over-frequency 1 ($F >$ ) test

The trip frequency and the disconnection time for the protective function over-frequency 1 ($F >$ ) limit of Table 4.2 of the automatic disconnection device shall be confirmed in the following steps.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated current output or 10 A, whichever is the lesser.

NOTE 1 For three-phase inverters, the required output is based on the per phase rating. For larger inverters, if 10 A is too low for stable operation, the minimum stable power output level of the inverter may be used.

(b) Slowly increase the frequency of the grid source until the device under test disconnects from the grid source. Record the frequency at which disconnection occurs.

NOTE 2 For testing of the over-frequency 1 ($F >$ ) limit, the behaviour of the inverter for sustained over-frequency operation needs to be taken into account; the output of the inverter before the automatic disconnection device operates may be close to zero, so verification of the disconnection may not be detected by recording the inverter output.

(c) Decrease the frequency of the grid source to (50 ± 0.1) Hz. Record the time taken for the device under test to reconnect to the grid source.

(d) Set the frequency of the grid source to the over-frequency 1 ($F >$ ) limit, as recorded at Step (b), less 0.1 Hz. Increase the frequency as rapidly as possible but at least the rate of change of frequency (df/dt) as specified in Clause 4.5.6. Record the time interval between the frequency passing through the frequency measured at Step (b) and the device under test disconnecting from the grid source.

(e) Reduce the frequency of the grid to 50.2 Hz. Maintain the frequency at this level for a period of two (2) times the reconnection time measured at Step (c). The device under test shall not reconnect for the duration of this period.

(f) Decrease the frequency of the grid source to 50.1 Hz. Record the time taken for the device under test to reconnect to the grid source.

### I.4.4 Test report

The recorded trip times, response times, reconnection times and active power output levels shall be recorded in a table. An example of a table is shown in Table I.3.

**Table I.3 — Example table for under-frequency and over-frequency trip settings and reconnection test**

| Clause I.4 frequency tests | Description | Minimum value | Maximum value | Test results | Units |
|---|---|---|---|---|---|
| Under-frequency 1 ($F<$) I.4.2 | When decreasing the frequency of the grid source from (50 ± 0.1) Hz, the frequency at which the device under test disconnects [I.4.2(b)] | Table 4.2 | | | Hz |
| | When increasing the frequency of the grid source to (50 ± 0.1) Hz., the time taken for the device under test to reconnect [I.4.2(c)] | 60.0 | | | s |
| | When the frequency of the grid source is reduced from the under-frequency 1 ($F<$) limit frequency in Table 4.2 and measured in I.4.2(b) plus 0.1 Hz by at least the rate of change of frequency (d$f$/d$t$) as specified in Clause 4.5.6, the time taken from when the frequency measured in I.4.2(b) is passed through and the device under test disconnecting [I.4.2(d)] | | | | s |
| | When the frequency of the grid source is increased to 47.4 Hz and held for at least twice the time measured in I.4.2(c), the device under test remains disconnected [I.4.2(e)] | | | | Y/N |
| | When increasing the frequency of the grid source to 48.0 Hz., the time taken for the device under test to reconnect [I.4.2(f)] | 60 | | | s |
| Over-frequency 1 ($F>$) I.4.3 | When increasing the frequency of the grid source from (50 ± 0.1) Hz, the frequency at which the device under test disconnects [I.4.3(b)] | Table 4.2 | | | Hz |
| | When decreasing the frequency of the grid source to (50 ± 0.1) Hz., the time taken for the device under test to reconnect [I.4.3(c)] | 60.0 | | | s |
| | When the frequency of the grid source is increased from the over-frequency 1 ($F>$) limit frequency in Table 4.2 measured in I.4.3(b) minus 0.1 Hz by at least the rate of change of frequency (df/dt) as specified in Clause 4.5.6, the time taken from when the frequency measured in I.4.3(b) is passed through and the device under test disconnecting [I.4.3(d)] | 0 | 0.2 | | s |
| | When the frequency of the grid source is reduced to 50.2 Hz and held for at least twice the time measured in I.4.3(c), the device under test remains disconnected [I.4.3(e)] | | | | Y/N |
| | When the frequency of the grid source is reduced to 50.1 Hz., the time taken for the device under test to reconnect [I.4.3(f)] | 60.0 | | | s |

### I.4.5 Criteria for acceptance

When tested in accordance with Clause I.4, the device under test shall conform to the following:

(a) The limits specified in Table 4.2.

(b) The measured frequency of each limit shall conform to the measurement accuracy specified in Table 2.5.

(c) The disconnection time shall be greater than the trip delay time and less than the maximum disconnection time of Table 4.2.

(d) The connection or reconnection time and behaviour shall conform to Clause 4.7.

## I.5 Voltage phase angle shift test

### I.5.1 General

The purpose of this test is to verify that the inverter complies with the voltage phase angle shift withstand requirements specified in Clause 4.5.5.

This test may be conducted via either of two methods. The first method applies where the voltage angle of a single-phase may be shifted, either by a grid source capable of independent phase angle change or by switching to a second grid source operating at a different voltage phase angle. The second method applies where a phase-phase fault condition is applied to effect the required voltage phase angle shift. This method applies for single-phase inverter testing only.

For three-phase inverters, the voltage phase angle shift shall be applied to each phase in a sequence, and then to all phases simultaneously.

For each voltage phase angle shift, a step of either positive or negative (leading or lagging) relative to the initial voltage phase angle shall be made.

For each of these tests the inverter and automatic disconnection device shall be connected into a test circuit equivalent to that shown in Figure B.1



### I.5.2 Test procedure

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated current output.

(b) Record the active power output.

(c) Step the relative angle of phase-a voltage by 60° ± 3° with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage. Maintain the phase shift for 500 ms.

(d) Step the relative angle of phase-a voltage back to the initial phase angle with the step change completed within 2 ms and occurring within 45° of the peak or trough of the voltage waveform.

(e) After 400 ms record the active power output.

(f) For three-phase inverters only, repeat Steps (c), (d) and (e) for phases b and c

(g) For three-phase inverters only, step the voltage angles of phases a, b and c by 20° ± 3° with the step change completed within 2 ms and occurring at the zero crossing of the grid source voltage. Maintain the phase shift for 60 s.

(h) For three-phase inverters only, step the voltage angles of phases a, b and c back to the initial voltage angle with the step change completed within 2 ms and occurring within 45° of the peak or trough of the voltage waveform.

(i) For three-phase inverters only, after 400 ms record the active power output.

### I.5.3 Test report

The active power output levels following the completion of each voltage phase angle shift shall be recorded in a table.

An example of a table is shown in Table I.4.

**Table I.4 — Example table for voltage phase angle shift test**

| Clause I.5 test report | Description | Minimum value | Maximum value | Test results | Units |
|---|---|---|---|---|---|
| Voltage phase angle shift test | The active power level after the device under test has been set to (50 ± 5) % of its rated current output [I.5.2(b)] | | | | W |
| | The active power level 400 ms after the relative angle of phase-a has been shifted by 60° ± 3° and been restored [I.5.2(e)] | I.5.2(b) – 4 % | I.5.2(b) + 4 % | | W |
| | The active power level 400 ms after the relative angle of phase-b has been shifted by 60° ± 3° and been restored [I.5.2(e)] | I.5.2(b) – 4 % | I.5.2(b) + 4 % | | W |
| | The active power level 400 ms after the relative angle of phase-c has been shifted by 60° ± 3° and been restored [I.5.2(e)] | I.5.2 (b) – 4 % | I.5.2 (b) + 4 % | | W |
| | The active power level 400 ms after the voltage angles of all three phases have been shifted by 20° ± 3° and been restored [I.5.2(i)] | I.5.2 (b) – 4 % | I.5.2 (b) + 4 % | | W |

### I.5.4 Criteria for acceptance

When tested in accordance with Clause I.5.2, the device under test shall conform to the following:

(a) The device under test shall remain connected for the duration of this test.

(b) The active power output recorded at Steps (e) and (i) shall be equal to that at Step (b) ± 4 %.

# Appendix J
(normative)

# Sustained operation test procedures



## J.1 General

The limits for sustained operation are as specified in Clause 4.5. The purpose of the tests set out in this Appendix is to demonstrate the performance of the inverter in terms of accuracy of set-points and control of output in response to a variation in the grid voltage and frequency.

The inverter and automatic disconnection device shall disconnect correctly in response to the limits and in such a way that no interference with the anti-islanding protection of the inverter occurs.

## J.2 Sustained operation for voltage variations

### J.2.1 General

When tested in accordance with the following procedure, the device under test shall demonstrate a satisfactory response to a sustained overvoltage event and then a controlled return to normal operation after the voltage has been maintained within the limits of AS 60038 (for Australia) or New Zealand for at least 60 s.

### J.2.2 Test procedure for voltage variations

The sustained operation over-voltage limit ($V_{\text{nom-max}}$) as specified in Clause 4.5.2, shall be confirmed. The procedure shall be as follows:

(a) Connect the inverter and automatic disconnection device into a test circuit equivalent to that shown in Figure B.1.

(b) Set the grid source equal to the grid test voltage for a period of 10 min. Vary the energy source until the a.c. output of the device under test equals (50 ± 5) % of its rated apparent power.

(c) Adjust the grid source to a voltage equal to the $V_{\text{nom-max}}$ setting less 1 V. Maintain this voltage level for 5 min.

(d) Adjust the grid source to increase the voltage by 2 V (i.e. $V_{\text{nom-max}}$ setting plus 1 V).

(e) Record the average voltage at the grid-interactive port of the device under test such that the average value for the preceding 10 min can be calculated when the device under test disconnects. Record the voltage at least every 3 s to calculate the average value over 10 min.

NOTE 1 The disconnection can be determined by the device under test ceasing output and the automatic disconnection device operating (and/or an indication of the automatic disconnection device operating).

(f) Adjust the grid source to the grid test voltage. Maintain this voltage level for 10 min.

NOTE 2 Steps (b) to (e) should be repeated at least three times to confirm the set-point.

(g) After the set-point has been determined, set the grid source voltage equal to the $V_{\text{nom-max}}$ setting. Maintain this voltage level for 10 min.

(h) Increase the grid source voltage by 1.5 V (i.e. $V_{\text{nom-max}}$ setting plus 1.5 V). Record the time to disconnect.

(i) Adjust the grid source to the grid test voltage. Record the time to reconnect.

### J.2.3 Criteria for acceptance

When tested in accordance with Clause J.2.2, the device under test shall conform to the setpoints specified in Table 4.3. The measured voltage of $V_{\text{nom-max}}$ shall conform to the measurement accuracy specified in Table 2.5. The time to detect a sustained overvoltage and disconnect as recorded in Step (h) shall be less than 30 s. The time to reconnect recorded in Step (i) shall conform to that specified in Clause 4.7.

### J.2.4 Test report

A summary table shall be presented with a result for each step performed, comparing actual test values against set-point values.

## J.3 Sustained operation for frequency variations

### J.3.1 General

When tested in accordance with the following procedure, the device under test shall demonstrate a satisfactory response as required by Clause 4.5.3, Clause 2.14 and Clause 4.5.6 to —

(a) a sustained increase in frequency event;

(b) a sustained decrease in frequency event;

(c) a controlled return to normal operation after the frequency returns to 50 Hz;

(d) prioritize sustained operation for frequency disturbances over volt response modes; and

(e) withstand a rate of change of frequency event.

This test is also used to verify the default settings listed in Table 4.4 and Table 4.5.

For each of these tests the inverter and automatic disconnection device shall be connected into a test circuit equivalent to that shown in Figure B.1.

The accuracy of the response to each of an increase in frequency and decrease in frequency event shall be measured at 50 % of the rated apparent power. There shall be a tolerance on the output of ± 5 % of the starting apparent power for each test.

### J.3.2 Test procedure for an increase in frequency for inverters without energy storage

The frequency response for sustained operation during an increase in frequency event, as specified in Clause 4.5.3.3.1 and withstand to a rate of change of frequency event as specified in Clause 4.5.6, shall be confirmed.

This test comprises two parts to confirm the inverter's response to Clause 4.5.3.3.1 and Clause 4.5.6. The first part increases frequency until frequency approaches a level where the inverter power output level is zero, the second part increases frequency to a level where the inverter power output level is partially reduced. This second part is to verify that on return to nominal frequency the hysteresis function holds the power output of the inverter at the minimum power output level required by the increase in frequency event as the frequency is returned to 50 Hz and that the inverter will withstand the rate of change of frequency of Clause 4.5.6.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. power output of the device under test equals (50 ± 5) % of its rated apparent power.

(b) Maintain the output voltage and frequency of the grid source for 5 min. Record the average inverter power over this period, this is the reference power level ($P_{ref}$) when the frequency exceeds $f_{ULCO}$.

(c) Increase he output frequency of the grid source by 0.20 Hz and remain at that level for at least 20 s.

(d) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test.

(e) Repeat Steps (c) and (d) until the ($f_{Pmin}$ − 0.2) Hz is reached.

(f) Decrease the frequency every 20 s in 0.20 Hz decrements until the frequency is 50.2 Hz.

(g) Record the frequency and power output.

(h) After 20 s, decrease the frequency to 50 Hz.

(i) Maintain the voltage and frequency for 10 min or until the inverter reaches the maximum power output available. Monitor and record the increase in power output every 30 s to determine if the change in power output conforms to the power rate limit ($W_{Gra}$) of Clause 3.3.4.2.

(j) Part two commences. Increase the frequency to 51.0 Hz in a ramp, with a rate of change of frequency of at least 4.0 Hz/s.

(k) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test. Maintain the frequency at 51.0 Hz for 60 s.

(l) Repeat Steps (f), (g) and (h).

(m) Maintain the voltage and frequency for 10 min or until the inverter reaches the maximum power output available. Monitor and record the increase in power output every 30 s to determine if the change in power output conforms to the power rate limit ($W_{Gra}$) of Clause 3.3.4.2.

NOTE An example of a table is shown in Table J.1.

### J.3.3 Criteria for acceptance

When tested in accordance with Clause J.3.2, the device under test shall —

(a) respond to the increase in frequency condition linearly and in accordance with Clause 4.5.3;

(b) stabilize the output power level after a frequency disturbance within the response completion time specified in Table 4.6; and

(c) maintain continuous operation for a rate of change of frequency event in accordance with Clause 4.5.6.

The results recorded in J.3.2 shall be graphed on an x-y-axis graph, where the x-axis is frequency and the y-axis is power output.

The results recorded in Steps (i) and (m) shall be graphed with respect to time. The rate of increase in power output shall not exceed the power rate limit ($W_{Gra}$) and shall conform to the nonlinearity of power limit changes of Clause 3.3.4.4.

### J.3.4 Test procedure for a decrease in frequency for inverters without energy storage

The frequency response for sustained operation during a decrease in frequency event, as specified in Clause 4.5.3.2.1, prioritization of sustained response to frequency over volt response modes of Clause 3.3.2, and withstand to a rate of change of frequency event as specified in Clause 4.5.6, shall be confirmed.

This test comprises two parts to confirm the inverter's response to Clause 4.5.3.2.1, Clause 2.14 and Clause 4.5.6. The test commences with the volt-var and volt-watt response modes of Clause 3.3.2 responding with inverter power output level reduced. The first part of the test decreases frequency until the frequency is below a level where the inverter power output level is at its maximum, above the level otherwise required by the volt response modes specified in Clause 3.3.2. This second part of the test is to verify that on return to nominal frequency the hysteresis function holds the power output of the inverter at the maximum power output level required by the decrease in frequency event as the frequency is returned to 50 Hz and that the inverter will withstand the rate of change of frequency of Clause 4.5.6.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. power output of the device under test equals (100 ± 5) % of its rated apparent power.

(b) Increase the grid source voltage to the midway point between $V_{W1}$ and $V_{W2}$ set-points of the volt-watt response mode.

(c) Maintain the output voltage and frequency of the grid source for 5 min. Record the average inverter power over this period, this is the reference power level ($P_{ref}$) when the frequency falls below $f_{LLCO}$. Confirm $P_{ref}$ is equal to (60 ± 10) % of rated apparent power.

(d) Decrease the output frequency of the grid source by 0.20 Hz and remain at that level for 20 s.

(e) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test.

(f) Repeat Steps (d) and (e) until the ($f_{Pmax}$ - 0.2) Hz is reached. At this frequency, the inverter active power output shall be equal to (100 ± 5) % of its rated apparent power.

(g) Increase the frequency every 20 s in 0.20 Hz increments until the frequency is 49.8 Hz.

(h) Record the frequency and power output.

(i) After 20 s, increase the frequency to 50 Hz.

(j) Maintain the voltage and frequency for 10 min or until the inverter reaches the reference power level. Monitor and record the decrease in power every 30 s to determine if the change in power conforms to the power rate limit ($W_{Gra}$) of Clause 3.3.4.2.

(k) Part 2 commences. Decrease the frequency to 49.0 Hz in a ramp, with a rate of change of frequency of at least 4.0 Hz/s.

(l) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test. Maintain the frequency at 49.0 Hz for 60 s.

(m) Repeat Steps (g), (h) and (i).

(n) Maintain the voltage and frequency for 10 min or until the inverter reaches the reference power level. Monitor and record the decrease in power every 30 s to determine if the change in power output conforms to the power rate limit ($W_{Gra}$) of Clause 3.3.4.2.

NOTE An example of a table is shown in Table J.2.

### J.3.5 Criteria for acceptance

When tested in accordance with Clause J.3.4, the device under test shall —

(a) respond to the decrease in frequency condition linearly and in accordance with Clause 4.5.3;

(b) stabilize the output power level after a frequency disturbance within the response completion time specified in Table 4.6; and

(c) maintain continuous operation for a rate of change of frequency event in accordance with Clause 4.5.6.

The results recorded in J.3.4 shall be graphed on an x-y-axis graph, where the x-axis is frequency and the y-axis is power output.

The results recorded in Steps (j) and (n) shall be graphed with respect to time. The rate of change in power output shall not exceed the power rate limit ($W_{Gra}$).

### J.3.6 Test procedure for an increase in frequency for inverters with energy storage

The frequency response for sustained operation during an increase in frequency event, as specified in Clause 4.5.3.3.2, and withstand to a rate of change of frequency event as specified in Clause 4.5.6, shall be confirmed, shall be confirmed.

This test comprises two parts to confirm the inverter's response to Clause 4.5.3.3.2 and Clause 4.5.6. The first part increases frequency above the level where inverter power output ceases, approaching a frequency where the inverter power input level is at its maximum. The second part increases frequency to a level where the inverter power input level is partially increased. This second part is to verify that on return to nominal frequency the hysteresis function holds the power input of the inverter at the level required by the increase in frequency event as the frequency is returned to 50 Hz, and that the inverter will withstand the rate of change of frequency of Clause 4.5.6.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Vary the energy source until the a.c. power output of the device under test equals (50 ± 5) % of its rated apparent power.

NOTE 1 Where an energy storage element is used, its state of charge should be at a level to allow it to charge at 100 % of $P_{rated\text{-}ch}$ for the duration of the test.

(b) Maintain the output voltage and frequency of the grid source for 5 min. Record the average inverter power recorded over this period, this is the reference power level ($P_{ref}$) when the frequency exceeds $f_{ULCO}$.

(c) Increase the output frequency of the grid source by 0.20 Hz and remain at that level for at least 20 s.

(d) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test.

(e) Repeat Steps (c) and (d) until the $f_{transition}$ is reached. At this frequency, the power output of the device under test shall be 0 W.

(f) Repeat Steps (c) and (d) shall be repeated until the ($f_{Pmin}$ - 0.2) Hz is reached.

(g) Decrease the frequency every 20 s in 0.20 Hz decrements until the frequency is 50.2 Hz.

(h) Record the frequency and power output.

(i) After 20 s, decrease the frequency to 50 Hz.

(j) Maintain the voltage and frequency for 10 min or until the inverter reaches the reference power level. Monitor and record the change in power every 30 s to determine if the change in power conforms to the power rate limit ($W_{\mathrm{Gra}}$) of Clause 3.3.4.2.

(n) Part two commences. Increase the frequency to 51.0 Hz in a ramp, with a rate of change of frequency of at least 4.0 Hz/s.

(k) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test. Maintain the frequency at 51.0 Hz for 60 s.

(l) Repeat Steps (g), (h), (i) and (j).

NOTE 2 An example of a table is shown in Table J.3.

### J.3.7 Criteria for acceptance

When tested in accordance with Clause J.3.6, the device under test shall —

(a) respond to the increase in frequency condition linearly and in accordance with Clause 4.5.3;

(b) stabilize the output power level after a frequency disturbance within the response completion time specified in Table 4.6; and

(c) maintain continuous operation for a rate of change of frequency event in accordance with Clause 4.5.6.

The results recorded in Clause J.3.6 shall be graphed on an x-y-axis graph, where the x-axis is frequency and the y-axis is power output.

The results recorded in Steps (j) and (l) shall be graphed with respect to time. The rate of increase in power output shall not exceed the power rate limit ($W_{\mathrm{Gra}}$).

### J.3.8 Test procedure for a decrease in frequency for inverters with energy storage

The frequency response for sustained operation during a decrease in frequency event, as specified in Clause 4.5.3.2.2, prioritization of sustained response to frequency over volt response modes of Clause 3.3.2, and withstand to a rate of change of frequency event as specified in Clause 4.5.6, shall be confirmed.

This test comprises two parts to confirm the inverter's response to Clause 4.5.3.2.2, Clause 2.14 and Clause 4.5.6. The first part of the test decreases frequency until the frequency is below a level where the inverter power output level is at its maximum, above the level otherwise required by the volt response modes specified in Clause 3.3.2. The second part of the test decreases frequency to a level where the inverter power input is partially reduced. This second part is to verify that on return to nominal frequency the hysteresis function holds the power output of the inverter at the minimum power input level required by the decrease in frequency event as the frequency is returned to 50 Hz, and that the inverter will withstand the rate of change of frequency of Clause 4.5.6.

The procedure shall be as follows:

(a) Set the grid source equal to the grid test voltage. Where the charge rate of the storage element can be externally controlled, adjust the power input level of the inverter to (50 ± 5) % of the rated power input level ($P_{\mathrm{rated\text{-}ch}}$). Otherwise set the initial power input level of the inverter to at least 45 % of the rated power input level. Record the initial power input level for each test.

NOTE 1 Where an energy storage element is used, its state of charge should be at a level to allow it to discharge at 100 % of $P_{max}$ for the duration of the test.

(b) Increase the grid source voltage to the midway point between $V_{W1}$ and $V_{W2}$ set-points of the volt-watt response mode.

(c) Maintain the output voltage and frequency of the grid source for 5 min. Record the average charge rate over this period, this is the reference charge rate ($P_{ref\text{-}ch}$) when the frequency falls below $f_{LLCO}$.

(d) Decrease the output frequency of the grid source by 0.20 Hz and remain at that level for 20 s.

(e) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test.

(f) Repeat Steps (d) and (e) until the $f_{stop\text{-}ch}$ is reached. At this frequency, the charge rate of the storage element shall be 0 W.

(g) Repeat Steps (d) and (e) until the ($f_{Pmax}$ − 0.2) Hz is reached.

(h) Increase the frequency every 20 s in 0.20 Hz increments until the frequency is 49.8 Hz.

(i) Record the frequency and power output.

(j) After 20 s, increase the frequency to 50 Hz.

(k) Maintain the voltage and frequency for 10 min or until the charge rate of the storage element reaches the reference charge rate. Monitor and record the decrease in power output and increase in charge rate every 30 s to determine if the change in power conforms to the power rate limit ($W_{Gra}$) of Clause 3.3.4.2.

(l) Part 2 commences. Decrease the frequency to 49.2 Hz in a ramp, with a rate of change of frequency of at least 4.0 Hz/s.

(m) Record the frequency, the time taken for the power output of the device under test to respond to the frequency step, the time taken for the power output level to stabilize and the stable power output level of the device under test. Maintain the frequency at 49.2 Hz for 60 s.

(n) Repeat Steps (h), (i) and (j).

(o) Maintain the voltage and frequency for 10 min or until the power input level of the storage element reaches the reference power level. Monitor and record the change in every 30 s to determine if the change in power conforms to the power rate limit ($W_{Gra}$) of Clause 3.3.4.2.

NOTE 2 An example of a table is shown in Table J.4.

## J.3.9 Criteria for acceptance

When tested in accordance with Clause J.3.8, the device under test shall —

(a) respond to the decrease in frequency condition linearly and in accordance with Clause 4.5.3;

(b) stabilize the output power level after a frequency disturbance within the response completion time specified in Table 4.6; and

(c) maintain continuous operation for a rate of change of frequency event in accordance with Clause 4.5.6.

The results recorded in Clause J.3.8 shall be graphed on an x-y-axis graph, where the x-axis is frequency and the y-axis is charge rate.

The results recorded in Steps (k) and (o) shall be graphed with respect to time. The rate of change in power output shall not exceed the power rate limit ($W_{Gra}$).

### J.3.10 Test report

The graphs specified in Clauses J.3.2, J.3.4, J.3.6 and J.3.8 (as applicable) shall be included in the test report.

A summary table shall be presented with a result for each step performed, comparing actual test values against set-point values.

**Table J.1 — Example table for Clause J.3.2 sustained operation for increase in frequency test**

| Frequency<br>Hz | Time for initial response<br>s | Time for output to stabilize<br>s | Stable active power output<br>% $S_{rated}$ | Expected active power output Australia A<br>% $S_{rated}$ |
|---|---|---|---|---|
| 50 | — | | | 50 % |
| 50.2 | — | | | 50 % |
| 50.4 | — | | | 46 % |
| 50.6 | — | | | 40 % |
| 50.8 | — | | | 34 % |
| 51 | — | | | 29 % |
| 51.2 | — | | | 23 % |
| 51.4 | — | | | 17 % |
| 51.6 | — | | | 11 % |
| 51.8 | — | | | 6 % |
| 51.6 | — | — | — | — |
| ... | — | — | — | — |
| 50.4 | — | — | — | — |
| 50.2 | — | — | | 6 % |
| 50 | — | — | — | — |
| ... | — | — | — | — |
| 50 | — | — | | 50 % |
| 51 | | | | 29 % |
| 50.8 | — | — | — | — |
| 50.6 | — | — | — | — |
| 50.4 | — | — | — | — |
| 50.2 | — | — | | 29 % |
| 50 | — | | | 50 % |

**Table J.2 — Example table for Clause J.3.4 sustained operation for decrease in frequency test**

| Frequency<br>Hz | Time for initial response<br>s | Time for output to stabilize<br>s | Stable active power output<br>% $S_{rated}$ | Expected active power output Australia A<br>% $S_{rated}$ |
|---|---|---|---|---|
| 50 | — | | | 60 % |
| 49.8 | — | | | 60 % |
| 49.6 | — | | | 63 % |
| 49.4 | — | | | 68 % |
| 49.2 | — | | | 73 % |
| 49 | — | | | 77 % |
| 48.8 | — | | | 82 % |
| 48.6 | — | | | 86 % |
| 48.4 | — | | | 91 % |
| 48.2 | — | | | 95 % |
| 48 | — | | | 100 % |
| 47.8 | — | | | 100 % |
| 48 | — | — | — | — |
| ... | — | — | — | — |
| 49.6 | — | — | — | — |
| 49.8 | — | | | 100 % |
| 50 | — | — | — | — |
| ... | — | — | — | — |
| 50 | — | — | | 60 % |
| 49 | | | | 77 % |
| 49.2 | — | — | — | — |
| 49.4 | — | — | — | — |
| 49.6 | — | — | — | — |
| 49.8 | — | — | | 77.1 % |
| 50 | — | | | 60.0 % |

**Table J.3 — Example table for Clause J.3.6 sustained operation for increase in frequency for inverters with energy storage test**

| Frequency<br>Hz | Time for initial response<br>s | Time for output to stabilize<br>s | Stable active power output<br>% $S_{rated}$ | Expected active power output Australia A<br>% $S_{rated}$ |
|---|---|---|---|---|
| 50 | — | | | 50 % |
| 50.2 | — | | | 50 % |
| 50.4 | — | | | 35 % |
| 50.6 | — | | | 15 % |
| 50.8 | — | | | −4 % |
| 51 | — | | | −20 % |
| 51.2 | — | | | −36 % |
| 51.4 | — | | | −52 % |
| 51.6 | — | | | −68 % |
| 51.8 | — | | | −84 % |
| 51.6 | — | — | — | — |
| ... | — | — | — | — |
| 50.4 | — | — | — | — |
| 50.2 | — | — | | −84 % |
| 50 | — | — | — | — |
| ... | — | — | — | — |
| 50 | — | — | | 50 % |
| 51 | | | | −20 % |
| 50.8 | — | — | — | — |
| 50.6 | — | — | — | — |
| 50.4 | — | — | — | — |
| 50.2 | — | — | | −20 % |
| 50 | — | | | 50.0 % |

**Table J.4 — Example table for Clause J.3.8 sustained operation for decrease in frequency for inverters with energy storage test**

| Frequency | Time for initial response | Time for output to stabilize | Stable active power output | Expected active power output Australia A |
|---|---|---|---|---|
| Hz | s | s | % $S_{rated}$ | % $S_{rated}$ |
| 50 | — | | | −50 % |
| 49.8 | — | | | −50 % |
| 49.6 | — | | | −40 % |
| 49.4 | — | | | −26 % |
| 49.2 | — | | | −13 % |
| 49 | — | | | 0 % |
| 48.8 | — | | | 20 % |
| 48.6 | — | | | 40 % |
| 48.4 | — | | | 60 % |
| 48.2 | — | | | 80 % |
| 48 | — | | | 100 % |
| 47.8 | — | | | 100 % |
| 48 | — | — | — | — |
| ... | — | — | — | — |
| 49.6 | — | — | — | — |
| 49.8 | — | — | | 100 % |
| 50 | — | — | — | — |
| ... | — | — | — | — |
| 50 | — | — | | −50 % |
| 49.2 | | | | −13 % |
| 49.4 | — | — | — | — |
| 49.6 | — | — | — | — |
| 49.8 | — | — | | −13 % |
| 50 | — | | | −50 % |

# Appendix K
(normative)

# Multiple inverter testing

## K.1 General

When multiple inverters are to be used in combination with other inverters to meet the needs of the consumer and provide the desired inverter energy system capacity, they are required to be tested together in combination, as specified in Section 5. This is to ensure that the operation of the inverters in combination does not compromise inverter performance or safety.

For all tests performed in combination, each inverter in the combination shall have a current output that is equal, within 5 %, to the other inverters in the combination.

## K.2 Test procedures

### K.2.1 Test for single-phase combinations

The procedure shall be as follows:

(a) Determine the number of inverters to be tested in combination in accordance with Clause 5.5.1.

(b) Perform the active anti-islanding test of Appendix H. The test shall be performed in accordance with the correct number of paralleled single-phase inverters instead of a single inverter.

### K.2.2 Test for single-phase inverters used in three-phase combination

#### K.2.2.1 Test procedure

The procedure shall be as follows:

(a) Determine the number of inverters to be tested in combination in accordance with Clause 5.5.2.

(b) Perform the voltage and frequency limits tests for the inverter combination in accordance with Appendix I. The tests shall be performed such that when any change on any one phase trips any inverter in the combination, all of the other inverters trip within the trip time required by Clause 5.3 (i.e. 2 s). Changes to voltage shall be applied to a single-phase whereas changes to frequency shall be applied to all phases.

(c) Perform the active anti-islanding test for the inverter combination in accordance with Appendix H. The test shall be performed such that when any one phase trips any inverter in the combination, all other inverters trip within the trip time required by Clause 5.3 (i.e. 2 s).

(d) The response of the inverters in a three-phase combination system to a change of output in a single-phase inverter shall be tested by reducing the energy source input on one inverter in the combination to 0 % and maintaining the energy source input for the other inverters in the combination at full input. The inverters shall limit the imbalance to 21.7 A between any combination of phases or disconnect all inverters, in accordance with the requirements of Clause 5.2.

## K.3 Test report

For each test performed, the results specified in the relevant appendix shall be recorded in the test report for the inverter combination tested.

# Appendix L
(normative)

# Generation control function testing

## L.1 General

The generation control function (Section 6) introduces two important concepts. The underlying concept is similar to PV array (or other energy source) oversizing on the energy source port, in this case permitting both energy source and inverter oversizing but establishing generation limit and export limit, both soft and hard limits.

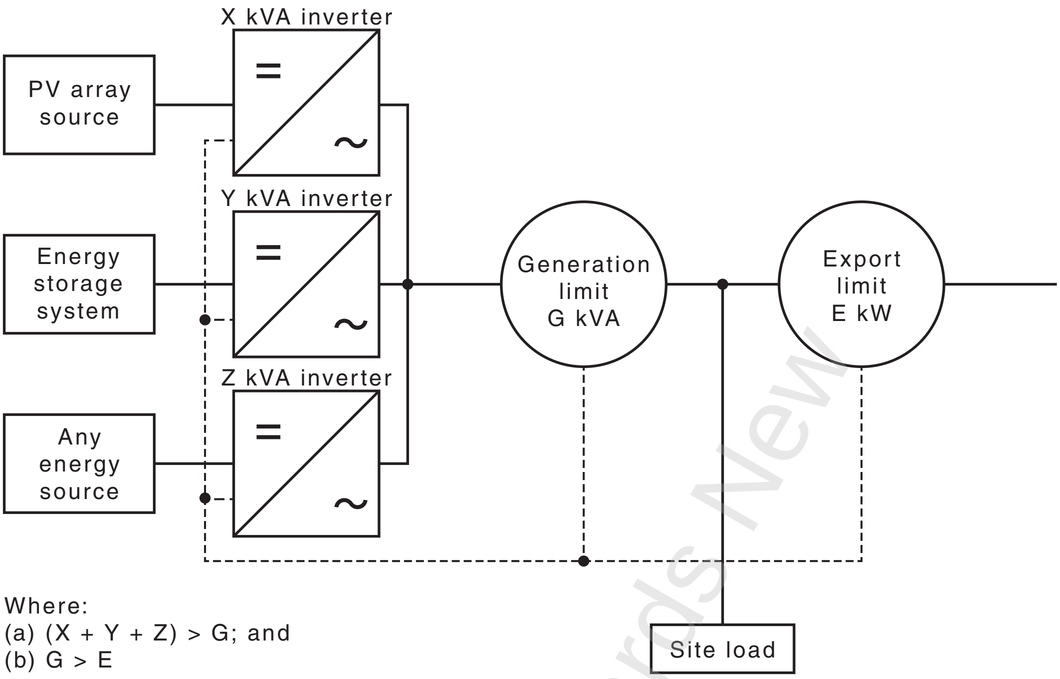
## L.2 Generation limit control

The generation limit in apparent power (kVA), with the use of a control system enables the maximum rating of an inverter or multiple inverter combination greater than the limit that can be connected at any one time within an installation. The generation limit control may be used to maximize an energy source size while meeting the electrical constraints within an electrical installation. The limit may also be used where multiple energy sources are maximized within a site using multiple inverters and may typically operate independently, however, when concurrently operating need to be limited to not exceed any installation ratings or other specified limits. This provides for inverters with same or different energy sources may be used to optimize operation like one inverter. i.e. a separate battery inverter and PV inverter with a generation limit will ensure that it will operate similar to a multiple mode inverter rated at the same value as the generation limit. Refer to Figure L.1 for multiple inverter combinations and Figure L.2 for multiple mode inverters.

For generation limit by control, the generation limit value and the possibility that it may be able to be remotely set has been included to indicate a future functionality requirement that the Committee EL-042 is considering. This functionality would be particularly useful for charging and discharging storage systems and maximizing solar system production across full sunlight hours.

## L.3 Export limit control

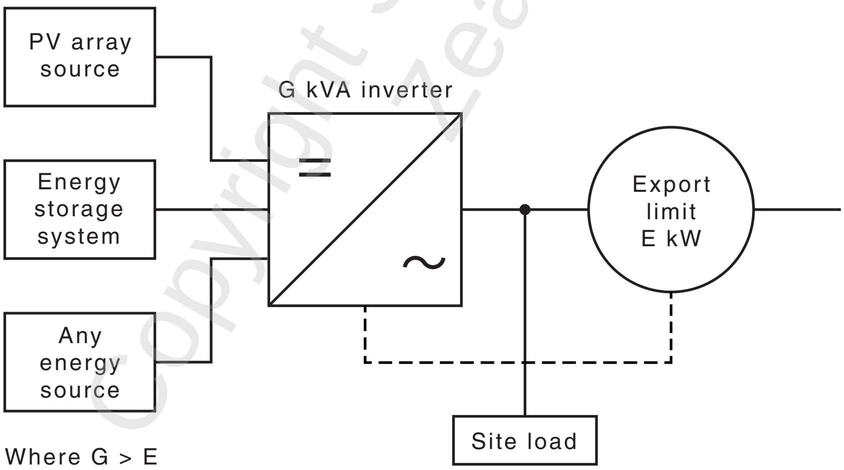
Export limit from the installation is simply the limit determined by the electricity distributor and can have a soft and/or hard limit applied. Currently this function is generally a fixed limit, but future development of inverter interoperability could become a dynamic limit. This equipment Standard defines the functional and conformance requirements when the export limit control is managed by the inverter or multiple inverter combination.




NOTE 1 The generation limit may be a single value representing both soft and hard limits. Whereas export limit typically may use a single soft limit. However, a separate hard limit may be specified at times.

NOTE 2 This test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

**Figure L.1 — Multiple inverter combination with generation limit and export limit control**




NOTE This test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

**Figure L.2 — Multiple mode inverter with generation limit and export limit control**

## L.4 Testing requirements

### L.4.1 General

This test is used to verify the generation limit and export limit control functions specified in Section 6 —

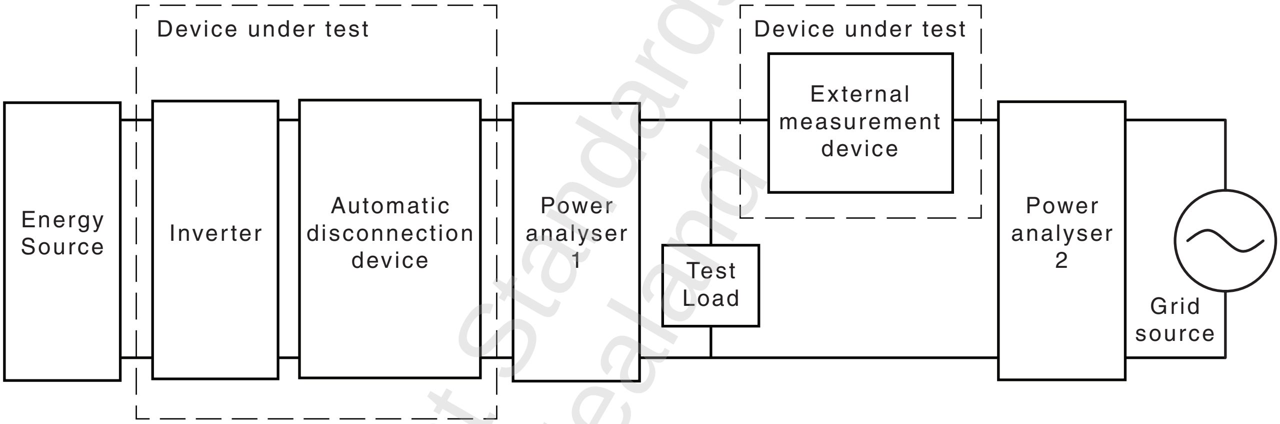
(a) time to fully respond to a change in load or generation;

(b) correct response to a change in load or generation; and

(c) correct response to loss of communication with external measurement device.

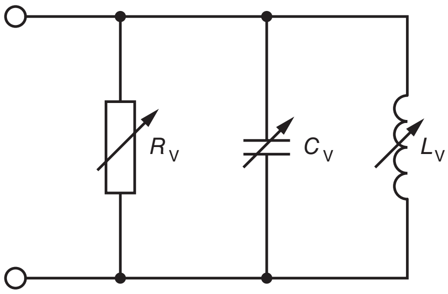
For each recording step in the test procedure, the relevant timing, active power, reactive power and apparent power output of the device under test shall be measured and recorded. The apparent power level may be measured or calculated from the active and reactive power measurements.

For the export limit control test, the inverter, automatic disconnection device and external measurement device shall be connected into a test circuit similar to that of Figure L.3. The test load shall be a variable load similar to that of Figure L.4.




NOTE The above test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

**Figure L.3 — Test circuit for export limit control**




NOTE The above test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

**Figure L.4 — Test load**

For the generation limit control test, the inverter, automatic disconnection device and external measurement device shall be connected into a test circuit similar to that of Figure L.5. The secondary a.c. source shall be a controllable a.c. source capable of synchronizing with the grid.

NOTE The a.c. source may be an inverter conforming to AS/NZS 4777.2 (this version or a previous version).

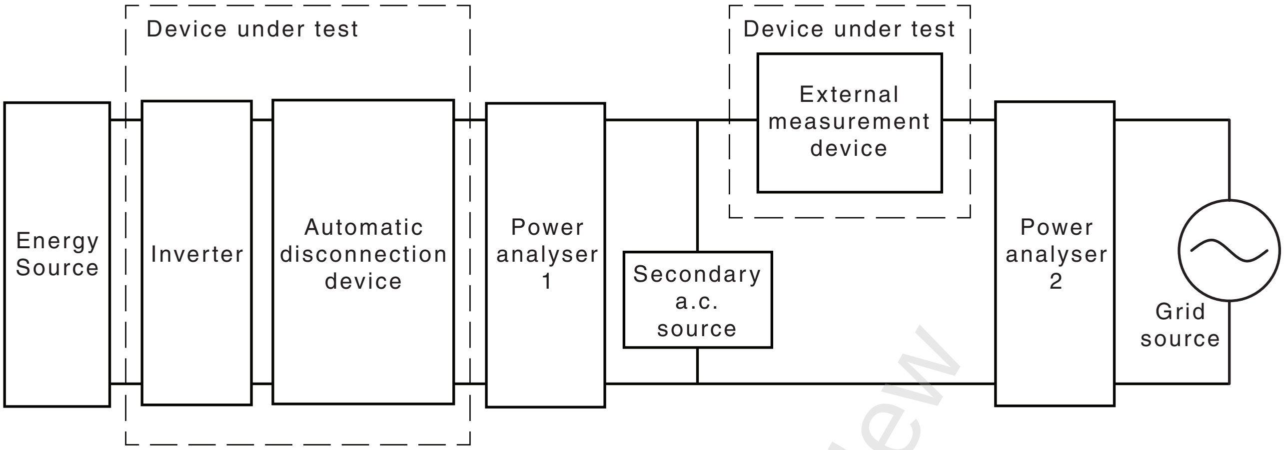



**Figure L.5 — Test circuit for generation limit control**

## L.4.2 Test procedure

### L.4.2.1 Soft export limit control

The procedure for testing soft export limit control shall be as follows:

(a) Enable the soft export limit and set to 25 % of the rated apparent power output of the device under test.

(b) Set the grid source equal to the grid test voltage.

(c) Set the test load equal to the rated apparent power output of the device under test with a unity power factor by adjusting the resistive element.

(d) Vary the energy source until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output. Record the active power to the grid source, which shall be no more than 5 % of the device's rated apparent power output.

(e) Adjust the test load by adding an inductive element equal to 20 % of the rating of the inverter.

(f) Record the stable active and reactive power output levels to the grid source.

(g) Adjust the test load by reducing the resistive element to 50 % of the rated apparent power output of the device under test.

(h) After 20 s, record the time taken for the active power output level to stabilize and the stable active and reactive power output levels to the grid source.

(i) Adjust the test load by disconnecting the resistive element so the test load is solely inductive.

(j) Repeat Step (h).

(k) Adjust the test load by connecting the resistive element equal to the rated apparent power output of the device under test.

(l) Repeat Step (h).

(m) Disconnect or disable the communication path between the inverter and the external measurement device.

(n) Repeat Step (h)

(o) Reconnect or re-enable the connection path between the inverter and the external measurement device.

(p) Record the active power output at intervals of no more than 15 s until the active power output has stabilized at (100 ± 4) % of rated apparent power to confirm that the ramp rate on connection or reconnection meets requirements of Clause 3.3.4.2.

(q) Adjust the soft export limit to 0 % and repeat Step (f) to (l).

(r) Summarize the results in a table for each test load, from initial to final load value, showing active power, reactive power and time to reach the stable power output level. Also record power ramp after communication path failure.

NOTE An example table is shown in Table L.1.

### L.4.2.2 Hard export limit control

The procedure for testing hard export limit control shall be as follows:

(a) Enable the hard export limit and set to 50 % of the rated apparent power output of the device under test.

(b) Set the grid source equal to the grid test voltage.

(c) Set the test load equal to the rated apparent power output of the device under test with a unity power factor by adjusting the resistive element.

(d) Vary the energy source until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output. Record the active power to the grid source, which shall be no more than 5 % of the device's rated apparent power output.

(e) Adjust the test load by adding a capacitive element equal to 20 % of the rating of the inverter.

(f) After 20 s, record the stable active and reactive power output levels to the grid source.

(g) Adjust the test load by reducing the resistive element to 55 % of the rated apparent power output of the device under test.

(h) Repeat Step (f).

(i) Reduce the resistive element of the test load in steps of no more than 2.5 % of the rated apparent power output of the device under test, with a dwell time at each load step of 20 s, until the automatic disconnection device operates.

(j) Record the time interval between the start of the final load step dwell time and the device under test disconnecting from the grid source, and the active and reactive power output levels of the device under test.

(k) Adjust the test load by increasing the resistive element to 100 % of the rated apparent power output of the device under test.

(l) Record the reconnection time (the time taken for the device under test to reconnect to the grid source after disconnecting).

(m) Record the active power output at intervals of no more than 15 s until the active power output has stabilized at (100 ± 4) % of rated apparent power to confirm that the ramp rate on connection or reconnection meets requirements of Clause 3.3.4.2.

(n) Disconnect or disable the communication path between the inverter and the external measurement device. Record the time until the device under test disconnects from the grid source.

(o) Reconnect or re-enable the connection path between the inverter and the external measurement device. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

(p) Adjust the hard export limit to 5 % and repeat Steps (i) and (j).

(q) Summarize the results in a table for each test load, showing active power and reactive power. Also record disconnection times, reconnection times and power ramp after reconnection.

NOTE An example table is shown in Table L.2.

### L.4.2.3 Generation limit control

The procedure for testing generation limit control shall be as follows:

(a) Enable the hard and soft generation limits and set both to 100 % of the rated apparent power output of the device under test.

(b) Set the grid source equal to the grid test voltage.

(c) Set the secondary a.c. source to an active power output of 25 % of the rated apparent power output of the device under test.

(d) Vary the energy source until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output. Record the active, reactive and apparent power output to the grid source. It shall be 125 ± 5 % of the device's rated apparent power output.

(e) After 20 s, record the time taken for the active power output level to stabilize and the stable active, reactive and apparent power output levels to the grid source.

(f) Adjust the secondary a.c. source to an active power output of 75 % of the rated apparent power output of the device under test.

(g) Repeat Step (e).

(h) Adjust the secondary a.c. source to an active power output of 95 % of the rated apparent power output of the device under.

(i) Repeat Step (e).

(j) Increase the active power output of secondary a.c. source in steps of no more than 2.5 % of the rated apparent power output of the device under test, with a dwell time at each generation step of 30 s, until the automatic disconnection device operates.

(k) For each step, record the time taken for the active power output level to stabilize and the stable active, reactive and apparent power output levels to the grid source.

(l) Record the time interval between the start of the final generation step dwell time and the device under test disconnecting from the grid source, and the active, reactive and apparent power output levels to the grid source at which the device under test disconnects.

(m) Adjust the secondary a.c. source to an active power output of 25 % of the rated apparent power output of the device under test.

(n) Record the reconnection time (the time taken for the device under test to reconnect to the grid source after disconnecting).

(o) Record the active power output at intervals of no more than 15 s until the active power output has stabilized at (100 ± 4) % of rated apparent power to confirm that the ramp rate on connection or reconnection meets requirements of Clause 3.3.4.2.

(p) Disconnect or disable the communication path between the inverter and the external measurement device. Record the time until the device under test disconnects from the grid source.

(q) Reconnect or re-enable the connection path between the inverter and the external measurement device. Record the reconnection time (the time taken for the device under test to reconnect to the grid source).

(r) Summarize the results in a table for each level of secondary a.c. source generation, showing active power, reactive power, apparent power and time to reach the stable power output level. Also record disconnection times, reconnection times and power ramp after reconnection.

(s) Perform the test specified in Clause L.4.2 with the secondary a.c. source operating with an active power output of 25 % and 75 % and unity power factor.

NOTE An example table is shown in Table L.3.

### L.4.3 Criteria for acceptance

When tested in accordance with Clauses L.4.2.1 and L.4.2.2, the response to exported active power shall be in accordance with Clause 6.3. When tested in accordance with Clauses L.4.2.3, the response to generated apparent power shall be in accordance with Clause 6.2. In addition, the disconnection and reconnection associated with a loss of signal from the external measurement device shall be in accordance Clause 6.1.

### L.4.4 Test report

A summary table shall be presented with a result for each step performed, comparing actual test values against expected values.

**Table L.1 — Example table for Clause L.4.2.1 soft export limit control test**

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| Soft export limit control with limit set to 25 % [L.4.2.1] | The stabilized active power output to the grid source with the soft export limit set to 25 % after Steps [L.4.2.1(a) to (e)] | | | | W |
| | The stabilized reactive power output to the grid source [L.4.2.1(f)] | | | | var |
| | When the test load resistive element has been reduced to 50 % of the rated apparent power of the device under test, the time taken for the active power to stabilize [L.4.2.1(h)] | | 15 s | | s |
| | When the test load resistive element has been reduced to 50 % of the rated apparent power of the device under test, after 20 s the stable active power output to the grid source [L.4.2.1(h)] | | | | W |
| | When the test load resistive element has been reduced to 50 % of the rated apparent power of the device under test, after 20 s the stable reactive power output to the grid source [L.4.2.1(h)] | | | | var |
| | When the test load resistive element has been disconnected so the test load is solely inductive, the time taken for the active power to stabilize [L.4.2.1(j)] | | 15 s | | s |

**Table L.1** *(continued)*

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| | When the test load resistive element has been disconnected so the test load is solely inductive, after 20 s the stable active power output to the grid source [L.4.2.1(j)] | | | | W |
| | When the test load resistive element has been disconnected so the test load is solely inductive, after 20 s the stable reactive power output to the grid source [L.4.2.1(j)] | | | | var |
| | When the test load is connected to a resistive load equal to the apparent rated power output of the device under test, the time taken for the active power to stabilize [L.4.2.1(l)] | | 15 s | | s |
| | When the test load is connected to a resistive load equal to the apparent rated power output of the device under test, after 20 s the stable active power output to the grid source [L.4.2.1(l)] | | | | W |
| | When the test load is connected to a resistive load equal to the apparent rated power output of the device under test, after 20 s the stable reactive power output to the grid source [L.4.2.1(l)] | | | | var |
| | When the communication path is disconnected or disabled between the inverter and the external measurement device, the time taken for the active power to stabilize [L.4.2.1(n)] | | 15 s | | s |
| | When the communication path is disconnected or disabled between the inverter and the external measurement device, after 20 s the stable active power output to the grid source [L.4.2.1(n)] | | | | W |
| | When the communication path is disconnected or disabled between the inverter and the external measurement device, after 20 s the stable reactive power output to the grid source [L.4.2.1(n)] | | | | var |
| | When the communication path is reconnected or re-enabled between the inverter and the external measurement device, the ramp rate obtained by measuring active power output at intervals ≤ 15 s until active power output has stabilized at (100 ± 4) % of rated apparent power [L.4.2.1(p)] | According to A1 Figure 3.3 A1 | According to A1 Figure 3.3 A1 | | %/min |
| Soft export limit control with limit set to 0 % [L.4.2.1] | The stabilized active power output to the grid source with the soft export limit set to 0 % after Steps [L.4.2.1(q), (b) to (e)] | | | | W |
| | The stabilized reactive power output to the grid source [L.4.2.1(f)] | | | | var |
| | When the test load resistive element has been reduced to 50 % of the rated apparent power of the device under test, the time taken for the active power to stabilize [L.4.2.1(h)] | | 15 s | | s |

**Table L.1** *(continued)*

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| | When the test load resistive element has been reduced to 50 % of the rated apparent power of the device under test, after 20 s the stable active power output to the grid source [L.4.2.1(h)] | | | | W |
| | When the test load resistive element has been reduced to 50 % of the rated apparent power of the device under test, after 20 s the stable reactive power output to the grid source [L.4.2.1(h)] | | | | var |
| | When the test load resistive element has been disconnected so the test load is solely inductive, the time taken for the active power to stabilize [L.4.2.1(j)] | | 15 s | | s |
| | When the test load resistive element has been disconnected so the test load is solely inductive, after 20 s the stable active power output to the grid source [L.4.2.1(j)] | | | | W |
| | When the test load resistive element has been disconnected so the test load is solely inductive, after 20 s the stable reactive power output to the grid source [L.4.2.1(j)] | | | | var |
| | When the test load is connected to a resistive load equal to the apparent rated power output of the device under test, the time taken for the active power to stabilize [L.4.2.1(l)] | | 15 s | | s |
| | When the test load is connected to a resistive load equal to the apparent rated power output of the device under test, after 20 s the stable active power output to the grid source [L.4.2.1(l)] | | | | W |
| | When the test load is connected to a resistive load equal to the apparent rated power output of the device under test, after 20 s the stable reactive power output to the grid source [L.4.2.1(l)] | | | | var |

**Table L.2 — Example table for Clause L.4.2.2 hard export limit control test**

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| Hard export limit control with limit set to 50 % [L.4.2.2] | When the energy source is varied until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output, the active power to the grid source [L.4.2.2(d)] | | 0 ± 5 % of $S_{\text{rated}}$ | | W |
| | When a capacitive element equal to 20 % of the rating of the device under test is added to the load, after 20 s the stable active power output to the grid source [L.4.2.2(f)] | | | | W |
| | When a capacitive element equal to 20 % of the rating of the device under test is added to the load, after 20 s the stable reactive power output to the grid source [L.4.2.2(f)] | | | | var |
| | When the test load resistive element has been reduced to 55 % of the rated apparent power of the device under test, after 20 s the stable active power output to the grid source [L.4.2.2(h)] | | | | W |
| | When the test load resistive element has been reduced to 55 % of the rated apparent power of the device under test, after 20 s the stable reactive power output to the grid source [L.4.2.2(h)] | | | | var |
| | When the test load resistive element is reduced in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 20 s, the time taken from the last dwell step and the device under test disconnecting from the grid source [L.4.2.2(j)] | | [A1]5 s[A1] | | s |
| | When the test load resistive element is reduced in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 20 s, the active power output to the grid source after the automatic disconnection device operates [L.4.2.2(j)] | | | | W |
| | When the test load resistive element is reduced in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 20 s, the reactive power output to the grid source after the automatic disconnection device operates [L.4.2.2(j)] | | | | var |
| | When the test load resistive element is increased to 100 % of the rated apparent power of the device under test, the time taken for the device under test to reconnect the grid source [L.4.2.2(l)] | 60 s | | | s |
| | When the test load resistive element is increased to 100 % of the rated apparent power of the device under test, the ramp rate obtained by measuring active power output at intervals ≤ 15 s until active power output has stabilized at (100 ± 4) % of rated apparent power [L.4.2.1(p)] | According to [A1]Figure 3.3[A1] | According to [A1]Figure 3.3[A1] | | %/min |
| | When the communication path is disconnected or disabled between the inverter and the external measurement device, the time taken for the device under test to disconnect from the grid source [L.4.2.2(n)] | | [A1]5 s[A1] | | s |

**Table L.2** *(continued)*

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| | When the communication path is reconnected or re-enabled between the inverter and the external measurement device, the time taken for the device under test to reconnect from the grid source [L.4.2.2(o)] | 60 s | | | s |
| Hard export limit control with limit set to 5 % [L.4.2.2(p)] | After adjusting the hard export limit to 5 %, the test load resistive element is reduced in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 20 s, the time taken from the last dwell step and the device under test disconnecting from the grid source [L.4.2.2(p)] | | A1⟩5 s⟨A1 | | s |
| | After adjusting the hard export limit to 5 %, the test load resistive element is reduced in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 20 s, the active power output to the grid source after the automatic disconnection device operates [L.4.2.2(p)] | | | | W |
| | After adjusting the hard export limit to 5 %, the test load resistive element is reduced in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 20 s, the reactive power output to the grid source after the automatic disconnection device operates [L.4.2.2(p)] | | | | var |

**Table L.3 — Example table for Clause L.4.2.3 generation limit test**

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| Generation limit control with hard and soft limits set to 100 % [L.4.2.3] | When the secondary a.c. source is set to 25 % and energy source is varied until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output, the active power to the grid source [L.4.2.3(d)] | | 125 ± 5 % of $S_{\text{rated}}$ | | W |
| | When the secondary a.c. source is set to 25 % and the energy source is varied until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output, the reactive power to the grid source [L.4.2.3(d)] | | 125 ± 5 % of $S_{\text{rated}}$ | | var |
| | When the secondary a.c. source is set to 25 % and the energy source is varied until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output, the apparent power to the grid source [L.4.2.3(d)] | | 125 ± 5 % of $S_{\text{rated}}$ | | VA |
| | When the secondary a.c. source is set to 25 % and the energy source is varied until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output, after 20 s the time taken for the active power output level to stabilize [L.4.2.3(e)] | | 15 s | | s |
| | When the secondary a.c. source is set to 25 % and the energy source is varied until the a.c. output of the device under test equals (100 ± 5) % of its rated apparent power output, after 20 s the power to the grid source [L.4.2.3(e)] | **Active power** | **Reactive power** | **Apparent power** | |
| | | | | | W<br>var<br>VA |
| | When the secondary a.c. source is adjusted to 75 % rated apparent power output of the device under test, after 20 s the time taken for the active power output level to stabilize [L.4.2.3(g)] | | 15 s | | s |
| | When the secondary a.c. source is adjusted to 75 % rated apparent power output of the device under test, after 20 s the active power to the grid source [L.4.2.3 (g)] | **Active power** | **Reactive power** | **Apparent power** | |
| | | | | | W<br>var<br>VA |
| | When the secondary a.c. source is adjusted to 95 % rated apparent power output of the device under test, after 20 s the time taken for the active power output level to stabilize [L.4.2.3(i)] | | 15 s | | s |
| | When the secondary a.c. source is adjusted to 95 % rated apparent power output of the device under test, after 20 s the power to the grid source [L.4.2.3(i)] | **Active power** | **Reactive power** | **Apparent power** | |
| | | | | | W<br>var<br>VA |

**Table L.3** *(continued)*

| Clause L.4.4 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| | When the active power output of secondary a.c. source is increased from 95 % in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 30 s, the power output to the grid source after the automatic disconnection device operates [L.4.2.2(k)] | **Active power** | **Reactive power** | **Apparent power** | |
| | | Record each step | Record each step | Record each step | W<br>var<br>VA |
| | When the active power output of secondary a.c. source is increased from 95 % in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 30 s, the time taken for the active power output level to stabilize [L.4.2.2(k)] | Record time for each step | | | s |
| | When the active power output of secondary a.c. source is increased from 95 % in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 30 s, the time taken from the last dwell step and the device under test disconnecting from the grid source [L.4.2.2(l)] | 15 s | [A1] 20 s [A1] | | s |
| | When the active power output of secondary a.c. source is increased from 95 % in steps ≤ 2.5 % of the rated apparent power of the device under test with a dwell time of 30 s, the power output to the grid source after the automatic disconnection device operates [L.4.2.2(l)] | **Active power** | **Reactive power** | **Apparent power** | |
| | | | | | W<br>var<br>VA |
| | When the secondary a.c. source active power is set to 25 % of the rated apparent output power of the device under test, the time taken for the device under test to reconnect to the grid source [L.4.2.3(n)] | 60 s | | | s |
| | When the secondary a.c. source active power is set to 25 % of the rated apparent output power of the device under test, the ramp rate obtained by measuring active power output at intervals ≤ 15 s until active power output has stabilized at (100 ± 4) % of rated apparent power [L.4.2.3(o)] | **Min. value** | **Max. value** | **Test resolution** | |
| | | According to [A1] Figure 3.3 [A1] | According to [A1] Figure 3.3 [A1] | | %/min |
| | When the communication path is disconnected or disabled between the inverter and the external measurement device, the time taken for the device under test to disconnect from the grid source [L.4.2.3(p)] | | [A1] 5 s [A1] | | s |
| | When the communication path is reconnected or re-enabled between the inverter and the external measurement device, the time taken for the device under test to reconnect from the grid source [L.4.2.3(q)] | 60 s | | | s |

# Appendix M
(normative)

# Stand-alone inverters

## M.1 General

This Appendix specifies the requirements for stand-alone inverters with an a.c. input port that can be connected to the grid.

Compliance shall be determined by type testing the inverter and where required any external devices.

## M.2 Stand-alone inverter requirements

### M.2.1 How to apply this document to stand-alone inverters

Where a stand-alone inverter has an a.c. input port, it shall conform to the requirements of this document by direct reference or as modified in this Clause (M.2) as follows:

(a) Where a stand-alone inverter is required to conform to an unmodified Clause, the Clause in the main body of this Standard shall be followed.

(b) Where a stand-alone inverter is required to conform to a modified requirement, the complete requirement included in this Appendix M shall replace the requirement in the corresponding clause in Sections 2, 3 and 4.

### M.2.2 General requirements

#### M.2.2.1 Application

Stand-alone inverters —

(a) shall conform to Clauses 2.2, 2.3, 2.4, 2.5, 2.8, 2.13 and 2.15;

(b) are not required to conform to Clauses 2.6, 2.9 and 2.10; and

(c) shall conform to modified requirements for Clauses 2.7, 2.11, 2.12 and 2.14 as defined in Clauses M.2.2.2, M.2.2.3, M.2.2.4 and M.2.2.5 respectively.

#### M.2.2.2 Modified requirements for harmonic currents

Replace Clause 2.7 “Harmonic currents”, including Tables 2.2 and 2.3, with the following:

The stand-alone inverter a.c. input port shall conform to the harmonic current emission requirements of —

(a) AS/NZS 61000.3.2 for equipment rated up to 16 A per phase;

(b) AS/NZS IEC 61000.3.12 for equipment rated greater than 16 A and up to 75 A per phase; or

(c) AS/NZS 61000.3.4 for equipment rated greater than 75 A per phase.

#### M.2.2.3 Modified requirements for current balance for three-phase inverters

Replace Clause 2.11 "Current balance for three-phase inverters" with the following:

Where a three-phase stand-alone inverter is in charging operation through the a.c. input port, the a.c. current input shall be balanced within 5 % of the rated input.

#### M.2.2.4 Modified requirements for isolation of energy sources

Stand-alone inverters with a.c. input ports that have an integrated isolating device shall conform to Clause 2.12 "Isolation of energy sources" for all energy source ports, including the a.c. input port.

NOTE The grid may be treated as an energy source for a stand-alone inverter.

#### M.2.2.5 Modified requirements for prioritization of protection and operational modes

Replace Clause 2.14 "Prioritization of protection and operational modes" with the following:

Stand-alone inverters with a.c. input ports shall prioritize Clause M.2.4 over Clause M.2.3.

### M.2.3 Operational modes and multiple mode inverters

#### M.2.3.1 Application

For stand-alone inverters with an a.c. input port where the modes in Section 3 refer to the grid-interactive port of the inverter the modes shall apply to the a.c. input port.

Stand-alone inverters —

(a) shall conform to Clauses 3.4.2 and 3.5;

(b) are not required to conform to Clauses 3.2 and 3.3; and

(c) shall conform to modified requirements for Clauses 3.4.1 and 3.4.3 as defined in Clauses M.2.3.2 and M.2.3.3 respectively.

#### M.2.3.2 Modified requirements for multiple mode inverters

Replace Clause 3.4.1 "Multiple mode inverter operation — General" with the following:

(a) When the stand-alone inverter is disconnected from the grid any stand-alone port shall ensure that all active conductors are also isolated from the a.c. input port.

(b) Stand-alone 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 disconnects 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 a.c. input port and stand-alone ports when the inverter ceases to operate.

(c) Stand-alone inverters shall be arranged such that only the allowed installation methods of AS/NZS 3000 and AS/NZS 4777.1 can be used.

(d) When the stand-alone inverter is operating 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.

#### M.2.3.3 Modified requirements for volt-watt response

Stand-alone inverters with a.c. input ports shall either —

(a) conform to Clause 3.4.3 “Volt–watt response mode for inverters with energy storage when charging”; or

(b) disconnect the a.c. input port (via the automatic disconnection device) when grid voltage falls below the limit $V_{\text{W2-ch}}$ in Table 3.8.

### M.2.4 Protective functions for connection to electrical installations and the grid

#### M.2.4.1 Application

For stand-alone inverters with an a.c. input port, where the requirements in Section 4 refer to the grid-interactive port of the inverter, these requirements shall apply to the a.c. input port of the stand-alone inverter.

Stand-alone inverters shall conform to modified requirements for Clauses 4.1, 4.2, and 4.3, 4.4, 4.7, 4.8 and 4.9 as defined in Clauses M.2.4.2, M.2.4.3, M.2.4.4, M2.4.5, M2.4.6, M2.4.7 and M2.4.8 respectively.

Stand-alone inverters are not required to conform to Clauses 4.5 and 4.6.

#### M.2.4.2 Modified requirements for protective functions general

Replace Clause 4.1 “Protective functions for connection to electrical installations and the grid — General” with the following:

(a) There shall be an automatic disconnection device on the a.c. input port to isolate installation and inverter from the grid.

(b) The automatic disconnection device shall operate —

   (i) if supply from the grid is disrupted; and

   (ii) when the grid goes outside preset limits (e.g. undervoltage/overvoltage, under-frequency/over-frequency).

(c) 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.

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

(e) Where a separate automatic disconnection device is used, the specific device used shall be tested with the inverter and documented in the test report. Testing of one combination of inverter and automatic disconnection device may not be taken as verification for any other combination of inverter and/or automatic disconnection device.

#### M.2.4.3 Modified requirements for automatic disconnection device

Stand-alone inverters with an a.c. input port shall conform to the Clause 4.2 “Automatic disconnection device”, for the a.c. input port.

#### M.2.4.4 Modified requirements for active anti-islanding protection

Replace Clause 4.3 “Active anti-islanding protection” with the following:

The automatic disconnection device shall operate within 200 ms to disconnect the a.c. input port whenever active power output is detected.

#### M.2.4.5 Modified requirements for voltage and frequency limits (passive anti-islanding protection)

Stand-alone inverters with a.c. input ports shall conform to Clause 4.4 “Voltage and frequency limits (passive anti-islanding protection)”, except replace Table 4.1 with limits in Table M.1, and replace Table 4.2 with limits in Table M.2.

**Table M.1 — Voltage protection limit values for stand-alone inverters**

| Protective function | Protective function limit | Maximum disconnection time, s |
|---|---|---|
| Undervoltage 1 (V < ) | 207 V | 2 |
| Overvoltage 1 (V > ) | 253 V | 2 |

**Table M.2 — Frequency protection limit values for stand-alone inverters**

| Protective function | Protective function limit | Maximum disconnection time, s |
|---|---|---|
| Under-frequency 1 ($F <$ ) | 49 Hz | 2 |
| Over-frequency 1 ($F >$ ) | 52 Hz | 2 |

#### M.2.4.6 Modified requirements for connection and reconnection procedure

Replace Clause 4.7 “Connection and reconnection procedure” with the following:

Only after all the following conditions have been met shall the automatic disconnection device operate to connect or reconnect the inverter to the grid —

(a) the voltage has been maintained within the supply voltage limits of AS 60038 (for Australia) or for New Zealand for at least 60 s; and

(b) the frequency has been maintained within the range 49.85 Hz to 51 Hz for at least 60 s.

#### M.2.4.7 Modified requirements for security of protection settings

Replace Clause 4.8 “Security of protection settings” with the following:

Where the stand-alone inverter a.c. input port is connected to the grid, the settings of the automatic disconnection device shall conform to the requirements of this Standard and be secured against inadvertent or unauthorized changes. Changes to the settings shall require the use of a tool and special instructions not provided to unauthorized personnel.

#### M.2.4.8 Modified requirements for activation of protection settings

Replace Clause 4.9 “Activation of protection settings” with the following:

The stand-alone inverter shall not operate the automatic disconnection device to connect to the grid until the grid settings have been selected and activated by an authorized person.

#### M.2.4.9 Modified requirements for multiple inverter combinations

Stand-alone inverters are not required to conform to Section 5 “Multiple inverter combinations”.

#### M.2.4.10 Modified requirements for generation control function

Stand-alone inverters are not required to conform to Section 6 “Generation control function”.

#### M.2.4.11 Requirements for inverter marking and documentation

Stand-alone inverters shall conform to Section 7 "Inverter marking and documentation".

## M.3 Stand-alone inverter a.c. input port testing requirements

### M.3.1 General

This test is used to verify the stand-alone inverter a.c. input port functions as specified in Clause 3.4.4, and charging is in accordance with the Clause M.2.3.3 —

(a) does not output active power through the a.c. input port; and

(b) reduces power input between $V_{W2\text{-ch}}$ and $V_{W1\text{-ch}}$, or disconnects below $V_{W2\text{-ch}}$.

NOTE 1 Stand-alone inverters may be built with a range of topologies while achieving the functionality specified in Clause 3.4.4. Some of these will not have the capability to output power through the a.c. input port but the test in Clause M.3.3.1 is intended to apply irrespective of topology to confirm this requirement. Operation of the automatic disconnection device on the a.c. input port is a permitted means of achieving this performance.

For the a.c. input port test, the stand-alone inverter and automatic disconnection device shall be connected into a test circuit, similar to that of Figure M.1. The automatic disconnection device on the a.c input port shall be closed at the commencement of the test. The stand-alone inverter shall be in a state the requires it to reconnect when a grid source is available. The stand-alone test load shall be a variable resistor, similar to that of Figure M.2. The RLC load shall be in accordance with Clause M.3.2, similar to that of Figure M.3.

NOTE 2 This test circuit applies to a single-phase system. To test a three-phase system, an equivalent three-phase circuit is required.

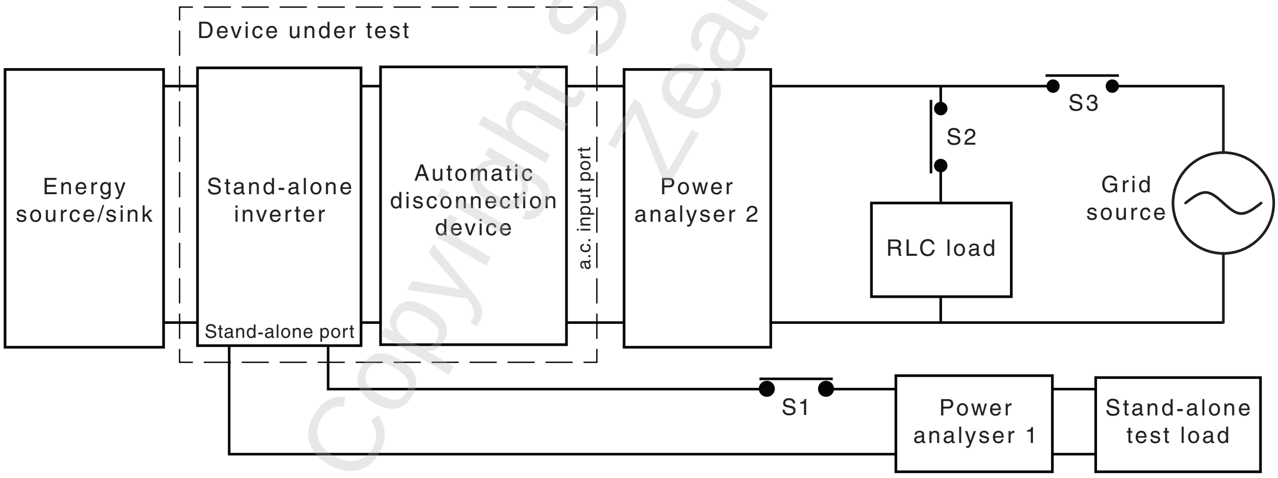



**Figure M.1 — Test circuit for a stand-alone inverter a.c. input port test**

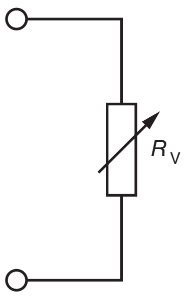



**Figure M.2 — Stand-alone test load for an a.c. input port test**

### M.3.2 RLC load

An additional fixed resonant load shall be chosen that has an inductive load such that it absorbs reactive power from the grid and a capacitive load such that it supplies reactive power to the grid. The fixed resonant load shown in Figure M.3 shall be a separate load included in addition to the variable resistor ($R_V$)for achieving required load power match conditions for the test.

The value of the capacitive and inductive parts of the resonant load shall be increased based on the apparent power rating of the inverter per phase in accordance with Table M.3.

**Table M.3 — Resonant load selection of var (Q) values**

| Apparent power rating/phase<br><br>kVA | Reactive power rating/phase ($Q_C = Q_L$)<br>kvar |
|---|---|
| ≤ 5 | 100 |
| ≤ 10 | 200 |
| ≤ 20 | 400 |
| ≤ 30 | 600 |
| ≤ 40 | 800 |
| ≤ 50 | 1 000 |
| ≤ 100 | 2 000 |
| > 100 | 3 000 |

For the fixed resonant load, values for $L$ and $C$ can be calculated using the values for $Q_C$ and $Q_L$ in Table M.3 and the following equations:

$$L = \frac{V^2}{2\pi f \times Q_L}$$

$$C = \frac{Q_C}{2\pi f \times V^2}$$

where

$V$ = grid test voltage = 230 V

$f$ = grid frequency = 50 Hz

$C$ = capacitance

$L$ = inductance

To determine that the resonant load is correctly established for each of the chosen test values, the resonant load shall be tested connected to a voltage equal to the grid test voltage and then disconnected by a switch. The resonant load shall meet the following criteria:

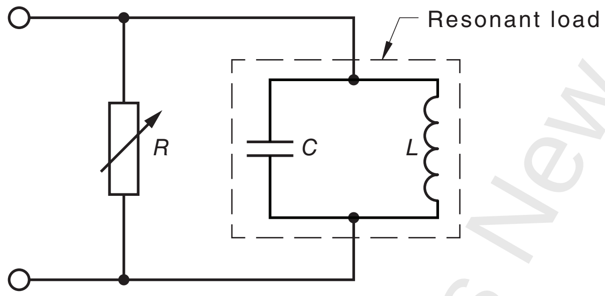
(a) There shall be a minimal internal resistance such that the resonant load has an underdamped resonant behaviour.

(b) The voltage seen at the resonant load terminal after the switch disconnects it from the grid test voltage shall oscillate at the resonant frequency $50^{+0.25}_{-2.0}$ Hz.

NOTE As the resonant frequency is dependent on inductors and capacitors, the allowable range for the measured resonance after disconnection is 48 Hz to 50.25 Hz.

(c) When the resonant load is tested with no other loads or sources, after the switch disconnects the resonant load the measured peak voltage value of the second peak shall be more than 90 % of the measured first peak value cycle after the resonant load is disconnected from a source set at the grid test voltage.

The load and resonant load are based on the per phase rating of the inverter and the load conditions for a three-phase system are the same as for a single-phase system. The resonant load shall be connected between the neutral and active terminals of the grid source.




NOTE 1 This load applies to a single-phase system. To test a three-phase system, an equivalent three-phase load is required.

NOTE 2 The capacitance (C) and inductance (L) form a resonant load where the reactive power of each component is as specified in Table M.3.

**Figure M.3 — RLC load for an a.c. input port test**

## M.3.3 Test procedure

### M.3.3.1 Output from a.c. input port

The procedure for testing the a.c. input port of a stand-alone inverter shall be as follows:

(a) Connect the energy source to the device under test.

NOTE 1 Where an energy storage element is used, its state of charge should be at a level to allow it to discharge at 100 % of the stand-alone port's rating to the test load for the duration of the test. The energy storage element should be the primary source of energy for the test load.

(b) Close the switch S1 and set the stand-alone test load equal to 100 % of the rated apparent power output of the device under test by adjusting the resistive element.

(c) Ensure switch S2 is open, set the grid source equal to the grid test voltage and close switch S3.

(d) Record the stable active and reactive power input levels from the grid source.

(e) Disconnect the test load by opening switch S1.

(f) Monitor the active and reactive power levels at the a.c. input port for at least 10 s, commencing 1 s before the load disconnection.

(g) Repeat Step (d).

(h) Close switch S1.

(i) Connect the RLC load between the neutral and active terminals of the grid source by closing switch S2.

(j) The resistive load (R) shall be increased or decreased until the active power consumption of the RLC load matches 100 % of the rated output of the stand-alone port of the device under test.

(k) Repeat Step (d).

(l) Disconnect the test load and the grid source by opening switches S1 and S3 simultaneously.

(m) Repeat Step (f).

(n) Reconnect the test load and grid source by closing switches S1 and S3.

(o) Record the reconnection time (the time taken for the automatic disconnection device to reconnect to the grid source).

(p) Repeat Step (d).

(q) Summarize the results in a table for each step, showing apparent power, active power and reactive power levels. Also record any steps that resulted in operation of the automatic disconnection device.

NOTE 2 An example table is shown in Table M.4.

### M.3.3.2 Volt-watt mode for charging of stand-alone inverters

Complete the test procedure described in Clause G.2.3 replacing only Step (a) with the following step:

(a) Enable the volt-watt mode for charging of inverters with energy storage if available.

If the automatic disconnection device operates when the voltage falls below $V_{W2\text{-ch}}$ the rest of the test procedure shall be followed to confirm reconnection only occurs when voltage returns to $V_{W2\text{-ch}}$.

## M.4 Criteria for acceptance

When tested in accordance with Clause M.3.3.1, no power output shall be observed from the a.c. input port for more than 200 ms. The connection or reconnection time and behaviour shall conform to Clause M.2.4.5.

When tested in accordance with Clause M.3.3.2, the response to the voltage at the a.c. input port shall be linear and in accordance with Clause 3.4.3 or shall result in operation of the automatic disconnection device when the voltage falls below $V_{W2\text{-ch}}$. The connection or reconnection time and behaviour shall conform to Clause M.2.4.5.

## M.5 Test report

The summary tables specified in Clauses M.3.3 shall be presented with a result for each step performed.

**Table M.4 — Example table for Clause M.3.3.1 output from a.c. input port test**

| Clause M.5 test report | Description | Minimum value | Maximum value | Test result | Units |
|---|---|---|---|---|---|
| Output from a.c. input port M.3.3.1 | The stabilized active power input level from the grid source after Steps M.3.3.1(a) to(c) [M.3.3.1(d)] | | | | W |
| | The stabilized reactive power input level from the grid source after Steps M.3.3.1(a) to(c) [M.3.3.1(d)] | | | | var |
| | When the load is disconnected (switch S1), monitor from 1 s before till 10 s after the stabilized active power output from the grid source [M.3.3.1(f)] | | | | W |
| | When the load is disconnected (switch S1), monitor from 1 s before till 10 s after the stabilized reactive power input level from the grid source [M.3.3.1(f)] | | | | var |
| | When the load is disconnected (switch S1), after 10 s the stabilized active power output from the grid source [M.3.3.1(g)] | | | | W |
| | When the load is disconnected (switch S1), after 10 s the stabilized reactive power input level from the grid source [M.3.3.1(g)] | | | | var |
| | When the load is reconnected (switch S1), an RLC load connected across the grid source and adjusted to 100 % of the rated output of the device under test, the stabilized active power input level from the grid source [M.3.3.1(l)] | | | | W |
| | When the load is reconnected (switch S1), an RLC load is connected across the grid source and adjusted to 100 % of the rated output of the device under test, the stabilized reactive power input level from the grid source [M.3.3.1(l)] | | | | var |
| | When the load (switch S1) and grid source (switch S2) are disconnected simultaneously, monitor from 1 s before till 10 s after the stabilized active power input level from the grid source [M.3.3.1(n)] | | | | W |
| | When the load (switch S1) and grid source (switch S2) are disconnected simultaneously, monitor from 1 s before till 10 s after the stabilized reactive power input level from the grid source [M.3.3.1(n)] | | | | var |
| | When the load (switch S1) and grid source (switch S2) are connected simultaneously, the time taken for the device under test to reconnect to the grid source [M.3.3.1(p)] | 60 s | | | s |
| | The stabilized active power input level from the grid source [M.3.3.1(q)] | | | | W |
| | The stabilized reactive power input level from the grid source [M.3.3.1(q)] | | | | var |

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AS IEC 62040-2, *Uninterruptible power systems (UPS), Part 2: Electromagnetic compatibility (EMC) requirements*

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ISO/IEC 8877, *Information technology — Telecommunications and information exchange between systems — Interface connector and contact assignments for ISDN Basic Access Interface located at reference points S and T*

ACMA, *Electromagnetic Compatibility—Information for suppliers of electrical and electronic products in Australia and New Zealand*

# Amendment control sheet

## AS/NZS 4777.2:2020

## Amendment No. 1 (October 2021)

### Correction amendment

Summary: This amendment applies to the Preface, Contents, Clauses 2.3.1, 3.4.4, 6.1, Tables I.1, L.1, L.2 and L.3 and Appendix A.3.

Published on 1 October 2021.

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