



AS/NZS 4777.2: 2015

Revisions to the Grid-Connected PV Systems: Design and Installation Training Manual, 8th Edition

Following is the summary of changes to the information within Grid-Connected PV Systems Design and Installation Manual 8th Edition (GSES), regarding the current **AS/NZS 4777**.

Please Note: The following content is not included in the 8.1 manual but will be included in the 8.2 Edition. Please note that these are subject to change.

Chapter 7

7.6 Demand Response Management (DRM)

Demand Response Management is defined as being the automated alteration of an electrical product's normal mode of operation in response to an initiating signal originating from or defined by a remote agent. This allows for the despatch of stored energy from grid-connected Electrical Energy Storage (EES) systems and other despatchable types of energy in a variety of ways as shown below in Table 5 from **AS/NZS 4777.2:2015**. The minimum functionality required for all grid-connected inverters is DRM0, i.e. operate the automatic disconnection device and the detection and response to the DRM signal by the inverter must occur within 2 seconds. In effect this is adding a remote shut-down capability to the inverter in addition to grid failure, over/under frequency and over/under voltage and anti-islanding protection that were called for under the previous version of **AS/NZS4777.2**. Additional functionality may be present in some inverters including power output limitation, production of reactive power (i.e. generate inductive or capacitive VARs) etc, for grid support and power quality improvement.

AUSTRALIAN STANDARDS

AS/NZS 4755 series of standards provides full details on the various Demand Response Modes for various equipment, **AS/NZS 4755.3** in particular deals with Energy Storage Systems and DR **AS/NZS4755.6** covers the requirements for Demand Response Enabling Devices. **AS/NZS4777.2** Section 6 covers the operational mode requirements for grid-connected inverters or the grid-connected port of multiple mode inverters

Table 7.3: Copy of Table 5 from **AS/NZS 4777.2:2015**

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 source 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 sink reactive power if capable.
DRM 8	Increase power generation (subject to constraints from other active DRMs)

7.7 Demand Response Enabling Device

A Demand Response Enabling Device (DRED) acts to provide the interface between the remote agent (i.e. the grid) and the demand controller built into the inverter.

DREDs must be connected to the DRM port of the inverter as per the manufacturer's guidelines. In some of the cases where a DRM port is not available, DREDs should be installed according to manufacturer's specifications. The communication cabling for such devices shall be protected and isolated from other cables.

EES System
DRC DRED
connection

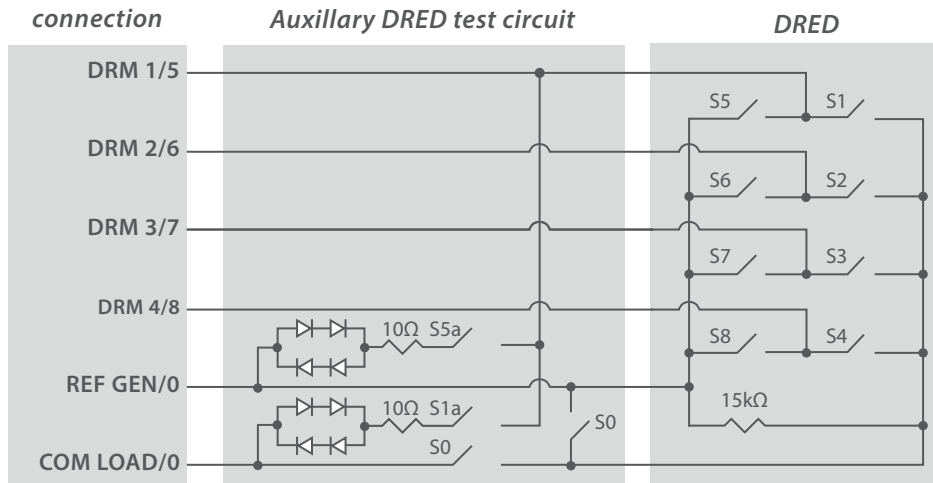


Figure 7.37: extract from AS/NZS 4755.3:2016 Appendix F

7.7.1 Automatic Disconnection Device

The automatic disconnection device must be able to inhibit the power from entering into the point of supply or grid to avoid the formation of islanding with the grid. These devices must operate:

- In the event of disrupted supply from the grid.
- When the grid operates outside the preset parameters.
- When demand response mode DRM 0 is activated. (a new function in AS/NZS 4777.2:2015)

7.8 Inverter Power Quality Response Mode

Inverters may be capable of providing support to the grid by working outside the typical operating characteristics of an inverter. There various operating modes may be enabled or disabled in the inverter and may include following:

- i. Volt response modes;
- ii. Fixed power factor or reactive power mode;
- iii. Power response mode;
- iv. Power rate limit.

7.8.1 Volt Response Modes

This mode responds to voltage changes at the inverter terminals and helps to increase the number of systems that can be connected at a point on the grid without affecting the voltage within an electrical installation. Each of the voltage response modes may be programmed for different response values from the other modes, thus allowing for different response curves in different modes to suit local distributor requirements.

Table 7.4: AS/NZS 4777.2 - Table 9: Volt Response Reference Values

Reference	Australian Default Value (V)	Range (V)
V1	207	NA
V2	220	216 to 230
V3	250	235 to 255
V4	265	244 to 265

Volt Watt Response Mode

In this mode, the output power of the inverter is varied in response to terminal voltage. If this mode is available, it shall be enabled by default. The table below shows the maximum set point values for reference voltages.

Table 7.5: AS/NZS 4777.2 - Table 10: Volt-Watt Response Maximum Setpoint values for Reference Values

Reference	Maximum Value (P/P _{rated}), %
V1	100%
V2	100%
V3	100%
V4	20%

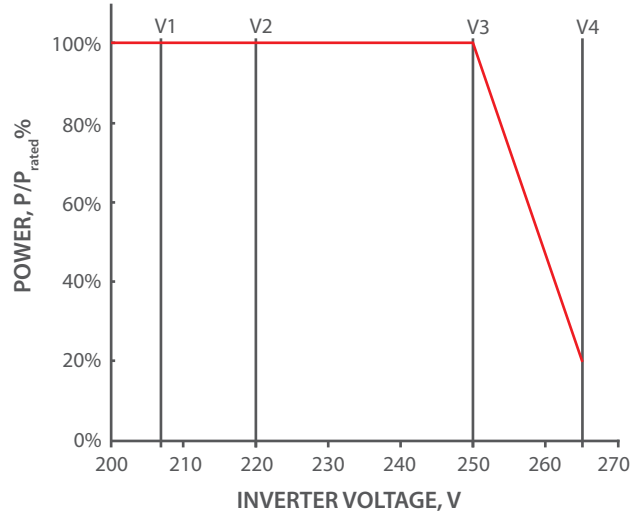


Figure 7.38: Example Curve for a Volt-Watt Response Mode (Australia).
AS/NZS 4777.2:2015 Figure 2(A)

Volt-VAr Response Mode

In this mode, the reactive power output of the inverter is varied in response to the voltage at its grid interactive port. Some inverters include an optional Volt VAr response capability which is disabled by default.

Table 7.6: AS/NZS 4777.2:2015 Table 11: Volt-VAr response set-point values for reference voltages

Reference	Default values for VAr level (VAr % rated VA)	Minimum Range
V1	30% leading	0 to 60% leading
V2	0%	0%
V3	0%	0%
V4	30% lagging	0 to 60 % lagging

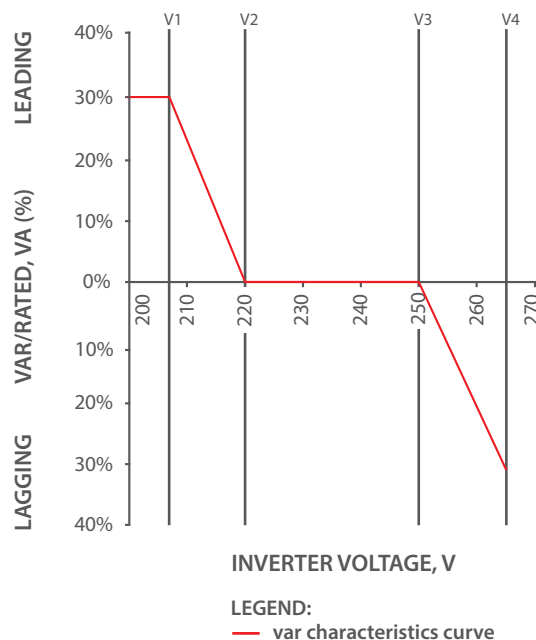


Figure 7.39: Example curve for a possible Volt-Var control mode (Australia)
AS/NZS 4777.2:2015 Figure 3

Voltage balance modes

Voltage balancing mode is where a three-phase inverter or single-phase inverters used in a three-phase combination are used to balance the voltages between phases on a customer's installation by injecting unbalanced three-phase currents into the installation. For example if "A" phase is more heavily loaded than "B" and "C" phases, the voltage on "A" phase would normally drop in comparison to "B" and "C" phases. By injecting more current into the "A" phase than into the "B" and "C" phases the heavier load is offset and the installation voltage is balanced.

The voltage balance mode must be able to detect faults and either:

- i. operate correctly with a single fault applied;
- ii. disconnect the inverter from the electrical installation; or
- iii. for three phase inverters, force the inverter to revert to injecting current into the three phase electrical installation as a three phase balanced current.

7.8.2 Fixed power factor mode and reactive power mode

The fixed power factor mode and the reactive power mode may be required in some situations by the electrical distributor to meet local grid requirements. These modes shall be disabled by default. If the inverter is capable of operating with reactive power mode, the maximum ratio of reactive power (VAr) to rated apparent power (VA) should be 100%. The reactive power modes may be required to be fixed at a constant reactive power by the electrical distributor. If the inverter is capable of operating with fixed power factor mode, the minimum range of settings should be 0.8 leading to 0.8 lagging. The fixed power factor mode is for control of the displacement power factor over the range of inverter power output.

7.8.3 Power Rate Limit:

The power rate limit for an inverter is a power quality response mode which states that inverter shall have the capability to rate limit changes in power generation through grid interactive mode. The power rate limit does not apply when the inverter disconnection device is required to operate. The power rate limit causes the inverter power output to either ramp up or ramp down smoothly as it transitions from one power output level to another power output level. These changes in power output level are constrained by several factors such as the type of energy source connected, energy storage and operating state of the inverter. Ramp rates are adjustable between 5% and 100% of rated power per minute and may be different for ramp up to that for ramp down.

Limits for Sustained Operation:

The inverter must disconnect from the grid within 3 seconds if the average voltage for a 10 minute period exceeds the nominal maximum voltage setting (default of 255V and maximum of 258V in Australia). This minimises the risk of damage to other equipment within the installation due to sustained high voltages from the inverter.

7.9 Frequency Shifting:

7.9.2 Response to increase in frequency:

The inverter shall be capable of supplying rated power between 47 Hz and 50.25 Hz for Australia. An inverter shall reduce the power output linearly with increase in the frequency of the grid. The Power level present at the time that frequency reaches or exceeds 50.25Hz shall be used as reference power level used to calculate the required response to the increasing frequency. The object of this mode is to avoid forcing up the grid frequency by continuing to supply power into the grid during over-frequency events whilst still allowing the inverter to remain connected to the grid.

$$P_{out} = P_{ref} \left[1 - \frac{(f - 50.25)}{(f_{stop} - 50.25)} \right]$$

Where:

- P_{OUT} = required output for a frequency between 50.25 Hz and f_{STOP}
- P_{REF} = reference power level when the frequency reaches or exceeds 50.25 Hz
- f = frequency between 50.25 Hz and f_{STOP}

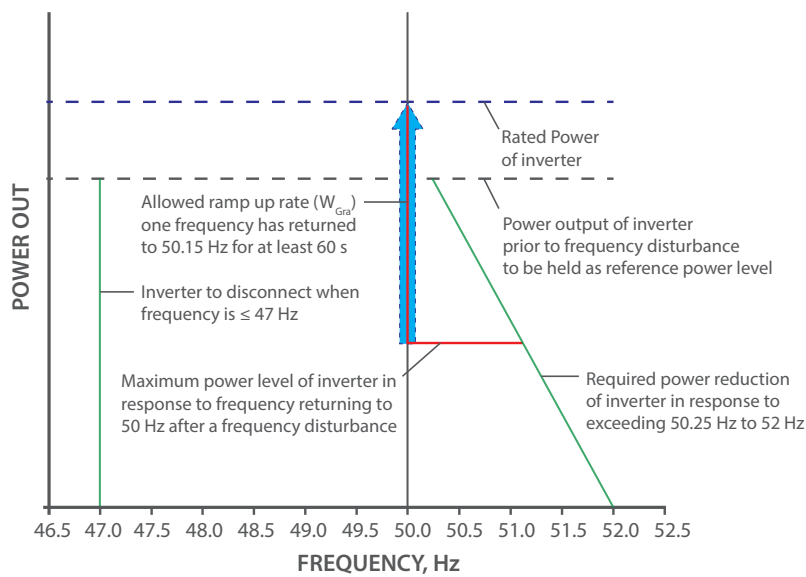


Figure 7.40: Example frequency response for over-frequency conditions for f_{STOP} of 52 Hz. Figure 7(A) from AS/NZS 4777.2:2015

7.9.2 Response to grid frequency:

This requirement is applicable only to the inverter with energy storage capabilities. The inverter shall be capable of charging the energy storage between 49.75 Hz and 52.0 Hz. An inverter with energy storage which is charging from the grid port should reduce the power input for charging linearly with a decrease of frequency until Frequency Stop Charging ($f_{stop-CH}$) is reached, where $f_{stop-CH}$ lies in the range 47–49 Hz. The Power level present at the time the frequency reaches or falls below 49.75Hz shall be used as reference charge rate used to calculate the required response to the decreasing frequency.

This is expressed in the equation below:

$$P_{charge} = P_{ref} \left[1 - \frac{(49.75 - f)}{(49.75 - f_{stop-CH})} \right]$$

Where:

- P_{charge} = charge rate of the storage element for a frequency between 49.75 Hz and $f_{stop-CH}$
- P_{ref-CH} = charge rate of the storage element when the frequency reaches or falls below 49.75 Hz

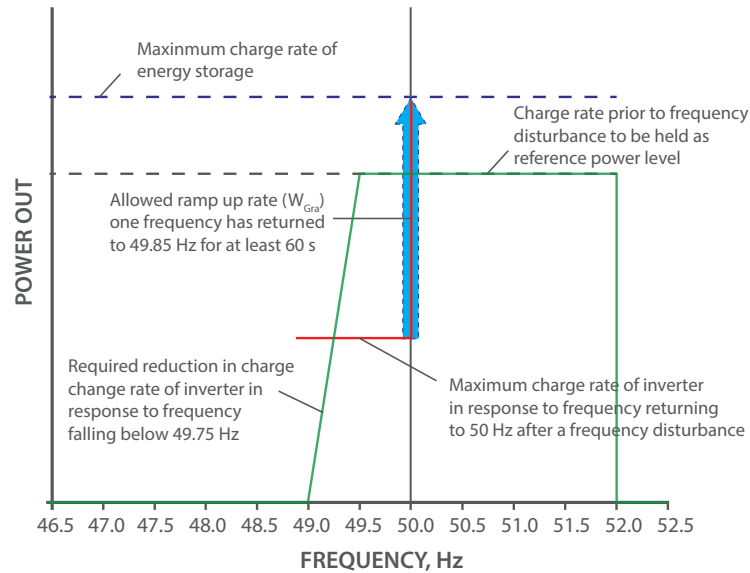


Figure 7.41: Example frequency response for under frequency conditions for $f_{stop-ch}$ of 49 Hz. Figure 7(B) from AS/NZS 4777.2:2015

7.10 Multiple Inverter Combinations

Where multiple inverters are used in combination to provide the desired inverter capacity or to maintain voltage balance to the grid e.g. single phase inverters in parallel, single phase inverters in multiple phase combinations or three phase inverters in parallel, these combinations must be tested together by the manufacturer or an external protection device used. It should be noted that this could have significant cost implications for people wanting to upgrade existing installations by adding additional capacity in parallel with their existing inverters as external protection devices will most likely be required, particularly with older inverters.

7.11 Signage

Where an external RCD is required for an inverter, warning signs are required indicating the requirement for, type of and rating of the RCD required.

The installer should ensure that appropriate DRM labelling is either already provided on the inverter by the manufacturer, or is applied to the inverter as required. This label shall indicate the demand response modes of which the unit is capable. It shall indicate on the label which functions have been connected and enabled.

DRM 0	<input type="checkbox"/>	DRM 1	<input type="checkbox"/>	DRM 2	<input type="checkbox"/>
DRM 3	<input type="checkbox"/>	DRM 4	<input type="checkbox"/>	DRM 5	<input type="checkbox"/>
DRM 6	<input type="checkbox"/>	DRM 7	<input type="checkbox"/>	DRM 8	<input type="checkbox"/>

Figure 7.42: Figure 9 from AS/NZS 4777.2:2015 – sample DRM labelling.

AUSTRALIAN STANDARDS

In Australia and New Zealand refer to **AS/NZS 4777.2** Clause 9.2.5 for detailed information related to warning labels where external RCD's are required by an inverter.

AUSTRALIAN STANDARD

AS/NZS 4777.2:2015 Section 8 sets out the requirements for testing of multiple inverter combinations.

Chapter 13

13.7 Residual Current Device (RCD)

A current-imbalance activated device (typically a miniature circuit breaker) used to isolate supply to protected circuits, socket terminals or other electrical equipment under earth fault conditions.

The main purpose of an RCD is to disconnect the active and neutral conductors from the incoming supply in the event that an earth fault greater than a set value should occur (e.g. current flowing to earth through a person who has come into contact with an energised part of the installation), thus eliminating a potentially lethal shock hazard.

If an inverter does not use a mains frequency isolation transformer (either incorporated in the inverter or externally connected) the possibility of d.c. current injection into the mains exists under fault conditions. As such, any RCD selected for use with that inverter will need to be capable of operating correctly with the level of d.c. fault current that could be injected into the mains. This is also of particular importance on multimode inverters with a stand-alone port. Importantly, the common Type AC RCD's often found at electrical wholesalers are not suitable for use on systems where pulsating d.c. or constant d.c. injection are present. Typically a Type A or Type B RCD will be required.

If the inverter system requires the installation of an external RCD then this must be installed according to the manufacturer's instructions. A warning sign must be located on the port of the inverter containing the type and rating of the RCD. The inverter installation documentation must include the rating, type of RCD and required circuit location.

AUSTRALIAN STANDARDS

As per **AS/NZS 3000:2007** Clause 1.4.80: A device intended to isolate supply to protected circuits, socket outlets or electrical equipment in the event of a current flow to earth that exceeds a predetermined value.

AS/NZS 3000:2007 sets out the required trip times and current values for various installations in Australia and New Zealand.

AUSTRALIAN STANDARDS

In Australia and New Zealand, **AS/NZS 4777.2** outlines the requirements around the use of an RCD with an inverter energy system. In particular see Clauses 5.3, 5.9, 9.2.5 and 9.3.5 for details.