Title: Australian Guidelines for grid connection of energy systems via inverters.

28 April, 1998

Foreword

The guidelines have been developed by a group of utility, photovoltaic and inverter industry experts coming together under the auspices of the Electricity Supply Association of Australia (ESAA) with the assistance of the Australian Cooperative Center for Renewable Energy (ACRE).

These guidelines address issues related only to the grid connection side of the inverter system. It is envisaged that these guidelines will progress to an Australian Standard and be expanded to cover DC side issues in due course.

Underlying Principles:

The following principles underlie the national guidelines for grid connection of energy systems via inverters.

1. National guidelines provide a uniformity of approach in the context of a national electricity market. They also assist in the formulation of international guidelines for the benefit of all parties. It is anticipated that electricity distributors will use the guidelines as a basis for formulating their specific requirements for grid connection of energy systems via inverters.
2. The guidelines are concerned with the safety of workers on the electricity distribution system and the integrity of that system. Performance and safety of the inverters and associated generation equipment connected to the grid is the responsibility of the owners of such equipment.
3. The guidelines are written from a functional perspective. They are not technology specific, i.e. they do not require specific technologies to be used for connection to the grid. This approach allows for ongoing technology development to continually improve the cost and technical performance of the equipment connected to the grid.

1 Scope

These guidelines apply to any **inverter energy system** as described in Energy Sources, connected to low voltage distribution networks. These inverter energy systems must satisfy the requirements of these guidelines and incorporate an accepted inverter. These guidelines address technical matters only. Commercial matters are outside the scope of these guidelines.

2 Referenced Documents

The following documents are referred to in these guidelines:

AS1931.1 part 1. "High voltage - Test techniques - General definitions & test requirements"

AS 2279 "Disturbances in mains supply networks"

AS2481 "All-or-nothing electrical relays (instantaneous & timing relays)"

AS 3000 "SAA Wiring rules"

AS 3100 "Approval and test specification - General requirements for electrical equipment."

AS 3300 "Approval and test specification - General requirements for household and similar electrical appliances."

IEEE P929 "Recommended Practice for utility Interface of Photovoltaic (PV) Systems."

IEEE 446 "IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications."

3 Definitions

3.1 Energy sources

Grid connected inverter energy systems (excluding motor drive inverters). Single phase systems from 0 to 10kVA, three phase systems from 0 to 30kVA, connected at the nominal interconnection voltage and frequency. Herein referred to as **inverter energy system(s).**

3.2 Nominal Interconnection voltage.

Low voltage ie 240 volts single phase / 415 volts three phase.

This may need to be reviewed in future in accordance with the 230volts IEC based standardisation conversion now underway in Australia under the Standards Association of Australia.

3.3 Nominal Interconnection frequency.

50Hz.

3.4 Accepted inverter

At this stage, until suitable national standards are developed, an accepted inverter is one approved by the relevant electricity distributor for grid connection.

3.5 Lockable switch

Lockable switch means that the switch or circuit breaker must as a minimum have provision for insertion of a wire seal to prevent the switch being closed.

3.6 Electricity Distributor

The owner of the electricity distribution system to which the inverter system is connected. (This may not be the same as the electricity retailer).

3.7 Islanding

Islanding of inverter systems in the context of these guidelines means any situation where the grid fails or is tripped and one or more inverters maintains a supply of any description (be it stable or not) to any section of the distribution network outside the consumers installation (ie on the distribution network side of the point of connection).

4 Connection requirements

4.1 General

Inverter energy systems must satisfy the requirements listed in the subsections below to satisfy these guidelines. The inverter must also be an accepted inverter.

4.2 Power Flow Direction

Both directions of power flow are allowed ie from inverter to grid and from grid to inverter.

4.3 Power Factor

Allowable range is from:

0.8 leading to 0.95 lagging (looking from the grid with the inverter seen as a load on the grid) for outputs from 20% to 100% of rated VA, unless the device is approved by the relevant electricity distributor to control power factor beyond the above range for the purpose of providing voltage support at the point of connection. Alternatively under special circumstances the relevant electricity distributor may require a specific power factor. Note: Lagging power factor is defined to be when VAR flows are from the grid to the inverter.

4.4 Harmonics

General

The inverter system shall at full load have harmonic currents less than the limits specified in table 1

Current Harmonic Number	Limit based on % of fundamental
3 – 9th	<4%
11 – 15th	<2%
17 – 21st	<1.5%

23 – 33rd	<0.6%
above 33rd	<0.3%
Even harmonics	< 25% of equivalent odd harmonics
THD	<5%

Table 1. Current Harmonic limits

This table was extracted from IEEE Draft P929.

IEEE Draft P929 standard implements a limit based on % of the fundamental which differs from the AS2279.1 which specifies harmonic current limits in amps.

The installation must conform to all relevant Australian standards and codes i.e. AS2279 and the new draft National Electricity Code. These documents are under revision at the time of this draft.

4.5 High Frequency Noise

Equipment must conform to Australian Communications Authority "Electromagnetic Compatibility Framework"

4.6 Voltage Flicker

Equipment must conform to limits as per AS2279 part 4 section 6.

4.7 Protection

A minimum requirement to facilitate the prevention of islanding is that the **inverter energy system** protection operates and isolates the inverter energy system from the grid if:

- operating voltage is greater than 270V phase to neutral
- operating voltage is less than 200V phase to neutral
- operating frequency is greater than FreqMAX
- operating frequency is less than FreqMIN

FreqMAX will be in the range 50 to 52Hz.

FreqMIN will be in the range 48 to 50Hz.

Both these limits may be either factory set or site programmable. The values of these limits will be negotiated with the relevant electricity distributor within the range noted preceding. The protection voltage operating points may be set in a narrower band if required, e.g. 220V to 260V.

In addition to the passive protection detailed above, and to prevent the situation where islanding may occur because multiple inverters provide a frequency reference for one another, inverters must have an accepted active method of islanding prevention following grid failure, e.g. frequency drift. This function must operate to force the inverter output outside the protection tolerances specified previously, thereby resulting in isolation of the inverter energy system from the grid. The maximum combined operation time of both passive and active protections will be 2 seconds after grid

failure under all local load conditions (See compliance test requirements.). If frequency shift is used, it is recommended that the direction of shift be down. (This appears to be the general consensus internationally) The inverter energy system must remain disconnected from the grid until the reconnection conditions are met (see section 4.14).

If the **inverter energy system** does not have the above frequency features the manufacturer must demonstrate an alternate anti-islanding protection feature that is acceptable to the relevant electricity distributor.

If the protection function above is to be incorporated in the inverter it must be type tested for compliance with these requirements and accepted by the relevant electricity distributor. Otherwise other forms of external protection relaying are required which have been type tested for compliance with these requirements and approved by the relevant electricity distributor.

4.7.1 Security of Protection Settings

Where the inverter energy system has protection settings that may be changed via a keypad or switches, adequate security must be employed to prevent any tampering or inadvertent / unauthorized changing of these settings. A suitable lock or password system should be used. The relevant electricity distributor must approve any setting changes.

4.8 Voltage Limits

When the grid is disconnected from the inverter system and before the inverter isolates itself from any local load, the voltage shall be within the limits specified by the curves in Figure 1 for voltage and time.

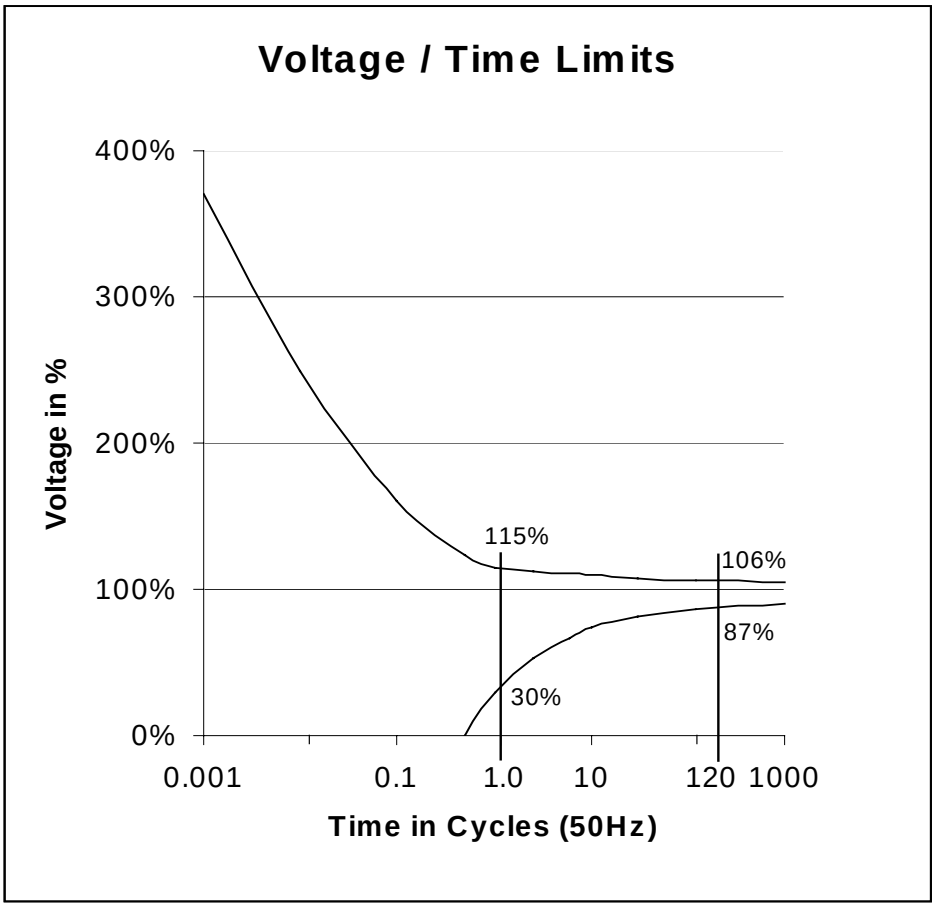

Figure 1 Voltage/time limits. (Voltage must remain in area between curves.) (Extract from IEEE Std 446)

The main issue here is to prevent damage to electronic equipment, which is in a circuit connected to the inverter when the grid is tripped. See Appendix B B.1.4 for test conditions.

4.9 Maintenance and Routine Testing

Maintenance and routine testing requirements (if any) are to be agreed between the relevant electricity distributor and the owner of the inverter energy system.

4.10 DC Injection Prevention

A transformer shall be installed at the point of connection on the AC side to prevent DC from entering the grid. The transformer can be omitted when a DC detection device is installed at the point of connection on the AC side. This detection device may be incorporated in the inverter provided that its performance has been type tested and approved for compliance with these guidelines. The limit on DC current injection

will be such that the injected DC current will not exceed 5 milli-Amps. Guidance can be obtained from AS3300 on DC current limitations for continuously operated devices.

4.11 Connection Point

It is preferable that **inverter energy system(s)** be connected directly to the main switchboard. In installations where this is not possible/desirable the nearest distribution board shall be used and all switchboards between the inverter energy system and the main switchboard including the main switchboard shall be labelled. See section on labelling.

The **inverter energy system** must be connected to a dedicated circuit. The rating of the inverter circuit cables and all the cables between any distribution boards and the main switchboard which carry inverter output must be rated for at least the full output of the inverter. See AS3000.

4.12 External Disconnect Switch

The main issue here is one of personnel safety when working on electrical systems both within a customer's installation, which contains an inverter energy system(s), and on the grid adjacent to a customer that has an **inverter energy system**. To address these issues it is required that there be a visible and accessible method of ensuring that the **inverter energy system** is disconnected from the grid and disconnected from the customer's installation.

Where the **inverter energy system** is connected directly to the main switchboard these requirements may be met by a single lockable switch appropriately labelled.

In installations where the **inverter energy system** is connected at a distribution board other than the main switchboard then two lockable switches must be provided.

(1) The switch located on the main switchboard which controls the sub-circuit of the distribution board to which the **inverter energy system** connects must be lockable to be used as isolation for utility staff working on the grid.

(2) The other lockable switch must be located at the distribution board from where the **inverter energy system** sub-circuit emanates to provide isolation for electrical contractors working on the customer's installation.

Irrespective of where the **inverter energy system** circuit emanates from, the controlling device will be installed to the requirements governing main switches in AS3000.

4.13 Labelling / Signage

The inverter **energy system** installation must include warning signage. Signage should as a minimum be placed:

- On the switchboard or distribution board that has the **inverter energy system** connected to it.

- On all switchboards including main switchboard and distribution board(s) between the main switchboard and the board that has the **inverter energy system** connected to it.

Signage should describe the actual **type** of generation source installed because particular generation sources, such as photovoltaic or wind, have varied electrical characteristics.

The owner of the **inverter energy system** shall make arrangements to supply and install appropriate signage on the installation, in accordance with requirements outlined in appendix A.

The materials for the labelling / signage must comply with AS 3100.

4.14 Reconnection Procedure

Automatic reconnection of **inverter energy system(s)** onto the grid will only occur if the voltage is within the range 200V to 270V phase to neutral and the frequency is within the range FreqMIN to FreqMAX, (as per section 4.7) and these conditions have been maintained for a minimum of 1 minute.

4.15 Short Circuit Capacity

Must comply with AS3000.

4.16 Cables and Wires

The following are minimum requirements. The installation must comply with all appropriate local and Australian Standards including but not limited to:

- AS3000 for all wiring
- AS 3100 for equipment requirements.

4.17 Metering

Metering is the responsibility of the relevant electricity distributor.

5 Authorisation

For Suggested Compliance Testing see appendix B.

6 APPENDIX A

6.1 Sample Signage

This is only a sample of appropriate signage. It is indicative of the type of appropriate signage required at the various locations specified.

Note: Words in italic would change to describe the type of generation (e.g. photovoltaic, induction generator, synchronous generator, alternative, renewable, etc.)

Size specifications are a minimum size.

6.1.1 Location

6.1.1.1 Main switchboard and distribution board(s) upstream of distribution board where the inverter energy system is connected.

Qty: 1

Lettering: 4mm, 8mm "WARNING"

Colour: Red, white letters

Size: **120 * 60 mm**

WARNING

***SOLAR* GENERATION PLANT CONNECTED**

ISOLATE *SOLAR* GENERATION PLANT AT (appropriate distribution board)

6.1.1.2 Main switchboard or distribution board where the inverter energy system is connected.

Qty: 1

Lettering: 4mm, 8mm "WARNING"

Colour: Red, white letters

Size: **120 * 60 mm**

WARNING

DUAL SUPPLY

ISOLATE BOTH NORMAL AND *SOLAR* SUPPLIES BEFORE WORKING ON THIS SWITCHBOARD

Normal supply main switch

Qty: 1
Lettering: 5mm
Colour: White, black letters
Size: **75 * 30 mm**

NORMAL SUPPLY MAIN SWITCH

Solar generator main switch
Qty: 1
Lettering: Title 5mm, words 4mm
Colour: White, black letters
Size: **75 * 30 mm**

***SOLAR* SUPPLY MAIN SWITCH**
***SOLAR* GENERATOR LOCATED IN**
(location of *solar* generator)

7 APPENDIX B

7.1 Testing for compliance with these guidelines

Compliance testing is based on type testing of each type of **inverter energy system** requiring approval.

7.1.1 Power Factor

The output power factor of the inverter energy system will be tested to be within the guidelines.

7.1.2 Automatic Reconnection

The inverter energy system will be tested by operation into a variable frequency, variable voltage test supply system. One variable will be changed at any time while the other variable remains within the normal operating range. Tests will be carried out to confirm that there is a minimum time delay (as specified in the guidelines) before the inverter energy system is automatically reconnected onto the grid after the grid has returned to nominal voltage and frequency.

7.1.3 Anti islanding protection

7.1.3.1 Over / under frequency and voltage trip settings.

The inverter energy system will be tested by operation into a variable frequency, variable voltage test supply system. The setpoints for over and under voltage at which the inverter system disconnects from the supply will be established by varying the supply voltage. The setpoints for over and under frequency at which the inverter system disconnects from the supply will be established by varying the supply frequency. These setpoints will be compared with the guideline requirements.

The time to trip will be verified to be less than the time required by the guidelines.

7.1.3.2 Tests under actual grid trip conditions

Tests are to be carried out to establish the performance of the inverter energy system under actual grid failure conditions. In order to test a reasonable range of conditions the inverter energy system is to be connected to a local load (at the inverter output terminals) and a switch placed between the local load and the grid (see fig B1).

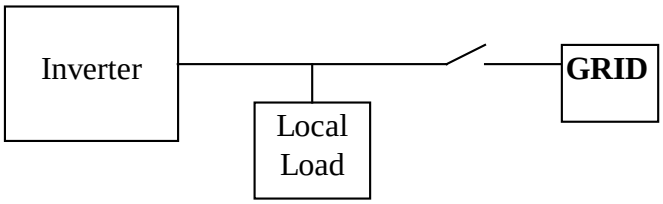

Figure B1 Circuit for Tests under actual grid trip conditions

The inverter energy system is to be tested at three output powers and 3 possible local load conditions giving nine tests in all (see Table 1)

Local Load ⇒ Inverter output ⇓	open circuit	Load Match	10% greater than load match
10%	◊	◊	◊
50%	◊	◊	◊
100%	◊	◊	◊

Table 1 Tests under actual grid failure conditions

Load match conditions are defined as being when the current from the inverter energy system meets the requirements of the local load ie. there is no export of current to the grid and no import of current from the grid.

It is assumed that the local load will be mostly resistive as the power factor allowed under these guidelines is restricted to close to unity. If other power factors are allowed these tests would have to be modified depending on the controllability of the inverter.

The tests will record the inverter output voltage and frequency from at least 2 cycles before the switch is opened until the inverter protection system operates and isolates the inverter from the grid. The time from the switch opening until the protection isolation occurs is to be measured and must comply with the guidelines under all conditions of output power and local load.

In the case where frequency drift is the main active protection scheme then the direction of frequency drift should be verified to be in the down direction under all situations where the output from the inverter extends over multiple cycles after the grid has been tripped. (In situations where the inverter disconnects very rapidly it will be impossible to determine the frequency drift direction effectively.)

7.1.4 Voltage Limits

During the grid trip tests carried out in section 7.1.3.2 “Tests under actual grid trip conditions” the voltage output from the inverter should be checked in order to verify that it remains within the envelope set out in the Voltage Limits section of the guidelines. This should be done for all tests except the no load test as this test would be unnecessarily severe. Instead of no load a load which consists of a full wave rectifier and 100 microfarad capacitor should be used as a local load to simulate the sort of load that a small electronic appliance may present. See fig B2.

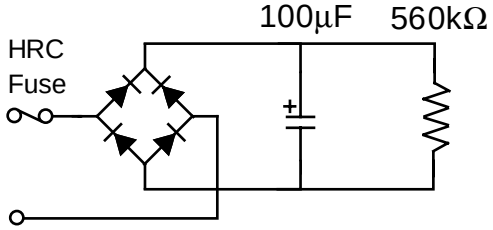

Figure B2 Inverter Load for Voltage Limit test to replace no load conditions.

The voltage rating of the capacitor should be of the order of 800V to cover the situation where an inverter does not control its overvoltage. The diodes should have a reverse rating of at least 1000V. It should also be noted that the capacitor will remain charged for a period after the test and should be enclosed in a box in case of capacitor failure.

7.1.5 Harmonics:

Harmonic measurement of inverter output at full load. Harmonic measurements must be less than those figures specified in the guidelines for the appropriate type of inverter.

7.1.6 High Frequency Noise:

Complying with ACA requirements.

7.1.7 Voltage Flicker:

As indicated by AS2279 Part 4 Section 6.

7.1.8 Impulse Protection:

Must withstand Standard Lightning Impulse of 0.5 Joule, 5kV, 1.2/50 waveform to AS1931.1 part 1.

7.1.9 DC Injection:

As indicated by AS3300 for continuously energized appliances.

7.1.10 Insulation tests

To relevant parts of AS3100.

7.1.11 Earthing tests

To relevant parts of AS3100.