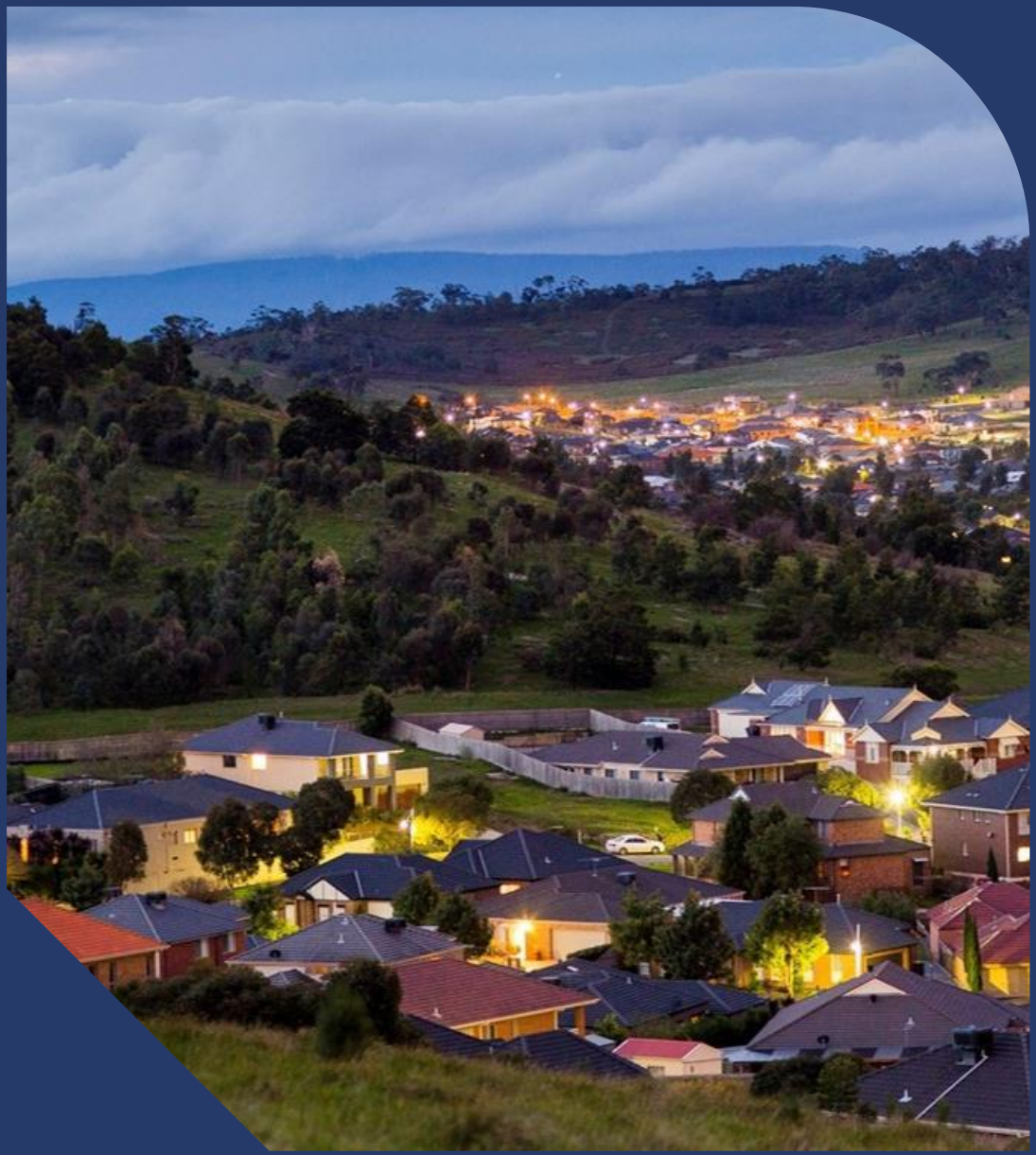
AusNet

Solar PV generator – Power Quality Compliance Requirements

Standard operating procedure



Document number:	SOP 33-08
Issue number:	2
Status:	Approved
Approver:	B Ton
Date of approval:	17 October 2024

AusNet

Table of contents

1. Purpose

The purpose of this document is to detail the **Power Quality requirements** for connecting Solar PV embedded generators.

This policy does not preclude adherence to any other technical/regulatory obligations such as the customer's compliance with other Standards, the Electricity Distribution Code including Clause 4 and Clause 7, or any other relevant AusNet Services policies or requirements. The customer's electrician has other obligations which impact on network performance and safety, which are included in the installation obligations according to the *Electricity Safety Act 1998*, the Service and Installation Rules and include compliance with AS3000, AS5033 and AS4777.

AusNet Services do not approve individual products and as a result, no list of approved products is published.

It is the customer's responsibility to maintain their system to perform in accordance with the agreed Connection Agreement. Variations from the agreed position could result in the system being 'locked out' or incurring other commercial penalties.

To the maximum extent permitted by law, AusNet makes no representation or warranty (express or implied) as to the accuracy, reliability, or completeness of the information contained in this document, or its suitability for any intended purpose. AusNet (which, for the purposes of this disclaimer, includes all of its related bodies corporate, its officers, employees, contractors, agents and consultants, and those of its related bodies corporate) shall have no liability for any loss or damage (be it direct or indirect, including liability by reason of negligence or negligent misstatement) for any statements, opinions, information or matter (expressed or implied) arising out of, contained in, or derived from, or for any omissions from, the information in this document. AusNet accepts no liability for the operation of any protection devices required by this document.

2. Scope

This policy applies to the connection of Solar PV customers to AusNet Services Low Voltage (400V/230V) network and High Voltage network (ie. 22 kV, 12.7 kV and 6.6 kV). This document is not intended to provide guidance on the design, protection or operation of embedded generators.

3. Abbreviations and definitions

Specific terms and abbreviations used in this document are defined in Table 1.

Table 1 Abbreviations and definitions

TERM	DEFINITION
Approved Inverter	An inverter which complies with AS4777 and listed in Tested and Approved Grid Connected Inverters as in force from time to time and available at http://www.cleanenergycouncil.org.au
DNSP	Distribution Network Service Provider
EDC	Electricity Distribution Code – Victorian
ENR	Energy Network Representative
HV	High Voltage – 22 kV, 6.6 kV, and 11 kV
I	Current
I THD	Current Total Harmonic Distortion
LV	Low Voltage – 230/400V
PCC	Point of Common Coupling – The agreed point of supply established between AusNet Services and the customer.
PQ	Power Quality
PV	Photovoltaic
Solar PV generator Rating (or PV Rating)	Refers to the associated Inverter Rating in kVA.
THD	Total Harmonic Distortion
V	Voltage
V THD	Voltage Total Harmonic Distortion

4. Power quality compliance

Clause 4 of the *Electricity Distribution Code* prescribes the Quality of Supply parameters that must be satisfied by the Distributors and Customers. These parameters include the range of variations to the standard nominal voltages and limits on power factor, voltage harmonics, current harmonics, negative sequence voltage, load balance, voltage fluctuation, and flicker. Table 2 shows the allowable voltage variations.

Table 2 Standard nominal voltage variations

VOLTAGE LEVEL in kV	VOLTAGE RANGE FOR TIME PERIODS			IMPULSE VOLTAGE
	Steady state	Less than 1 minute	Less than 10 seconds	
< 1.0	+ 10% - 6%	+ 14% - 10%	Phase to Earth +50%-100% Phase to Phase +20%-100%	6 kV peak
1-6.6	± 6%	± 10%	Phase to Earth +80%-100%	60 kV peak
11	(± 10%		Phase to Phase +20%-100%	95 kV peak
22	Rural Areas)			150 kV peak
66	± 10%	± 15%	Phase to Earth +50%-100% Phase to Phase +20%-100%	325 kV peak

The standards and codes that are important to managing quality of supply obligations are shown in Section 8.

5. Power quality compliance obligation

The responsibility and obligation to maintain Power Quality (PQ) compliance for various aspects of PQ when connecting Solar PV are detailed in Table 3.

Table 3

#	PQ QUANTITY	LIMIT	RESPONSIBILITY	NOTES
1	Steady State Voltage at PCC	230/400 +10% -6%	AusNet Services	AS 61000.3.100 will be used for checking compliance.
2	Voltage Rise - within complex	2%	Customer	This calculation must be provided to AusNet Services when requested.
3	Load Balance	< 5%	Customer	The net result of load and Solar PV. Unbalance load will contribute to the negative sequence voltage. Solar PV generation must be balanced for 3-phase connections.
4	Negative Sequence Voltage	< 1%	AusNet Services	Customer will also contribute to the negative sequence voltage if its load is not balanced. ie. Net result of load and PV.
5	Current Harmonics	I THD < 5% at LV (Ref EDC for individual limits)	Customer	Inverter must be compliant to AS/NZS 4777.2
6	Voltage Harmonics	V THD < 5% at LV (Ref EDC for individual limits)	AusNet Services	
7	Power Factor (PF)	Up to 100 KVA PF > 0.75 lagging and > 0.8 leading (Ref EDC for other capacities)	Customer	With PV connections, customer's power factor could significantly depart from the code limits during the light load conditions (eg. weekends)
8	Flicker	Based on the installation size	Customer	Inverter must be compliant to AS/NZS 4777.2

6. Solar PV generator connection process

6.1. Solar PV generator < 30 kVA

6.1.1. Preliminary check

All new inverters must be compliant to AS/NZ 4777.1 and AS/NZ 4777.2.

The aggregated PV ratings (kVA) of all PV installations connected to the Distribution Transformer should be less than 30% of the Distribution Transformer rating (kVA).

If the ratio of aggregated PV ratings to Distribution Transformer rating exceeds 30%, an engineering judgment by AusNet Services is required to determine whether the connection can be made without network augmentation, or connection can be made under SOP 33-06 (ie. Limited Export).

Solar PV generators less than 5 kVA will be granted an auto pre-approval via the portal as long as the Customer's inverter is compliant to AS/NZ 4777.1 and AS/NZ 4777.2.

6.1.2. Steady state voltage check

The steady state voltage calculation must be carried out using LV network data and AusNet Services spreadsheet developed for PV connections for greater or equal to 5 kVA. The voltage rise from the Distribution Substation to the Point of Common Coupling (PCC) must be less than 2%. If required corrective actions should be taken to bring the voltage rise within this limit. The Customer will be charged for the proposed corrective actions as part of the connection cost. Regional Energy Network Representatives (ENRs) are responsible for this analysis.

For Solar PV connections ≥ 5 kVA, it is recommended to verify the steady state voltage profile at the metering point for a period of one week (ie. minimum period) using AMI data before PV is connected. It will enable to confirm the expected voltage at the Inverter Terminal as described in Section 6.1.3.

6.1.3. Voltage rise check

The Customer is responsible for checking the voltage rise from PCC to inverter terminals, and the voltage rise should be less than 2%. This analysis should be undertaken by the customer's contractor during the PV installation planning & designing stage. AusNet Services representative could request this calculation and design details prior to energising the new installation, depending on the installation size and location. This information along with AMI data will be used by AusNet Services to verify the expected voltage range at the inverter terminals so that it can operate without tripping.

6.1.4. Negative sequence voltage check

The negative Sequence Voltage measurement is not required. The Customer's load must be balanced so that the Negative Sequence Voltage can be maintained within the EDC limits.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.1.5. Current harmonic check

The Customer is required to satisfy the EDC's current harmonic limits at PCC. However, no compliance measurements are needed prior to energising the new Solar PV connection.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.1.6. Voltage harmonic check

The voltage harmonic measurement is not required. The Customer shall maintain current harmonics within the EDC limits as the deviation from these limits could impact on voltage harmonics.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.1.7. Power factor

Solar PV generator must satisfy the AS/NZ 4777.2 power factor range. Similarly, power factor at the customer's PCC shall be within the EDC limits. However, no compliance measurements are needed prior to energising the new Solar PV generator connection.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.1.8. Voltage fluctuation and flicker check

Solar PV generator must satisfy the AS/NZ 4777.2 voltage fluctuation and flicker limits.
Note: This standard refers to AS/NZ 61000.3.3 and AS/NZ 61000.3.11.
However, no compliance measurements are needed prior to energising the new Solar PV generator connection.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.1.9. Recommendation for connection

The Customer's Solar PV generator can be connected subject to actions outlined in 6.1.1 to 6.1.8. For export limited Solar PV generator connections, the procedure outlined in SOP *33-06 – Export limits for Embedded Generators up to 200 kVA connected at Low Voltage* must be followed including 'commissioning test.'

6.2. 30 kVA < Solar PV generator < 200 kVA (HV – PCC)

6.2.1. Preliminary check

This section covers connections where the PCC is on the **primary side** of the distribution transformer. For the purposes of this guideline, this is referred to as the high voltage side (HV).

All new inverters must be compliant to AS/NZ 4777.2.

Relative Voltage Change (d):

$d = PV\ Rating_{kVA} / Fault\ Level_{kVA}$[1]

Where: PV Rating is the total (new and existing) PV at the site and Fault Level is the three-phase to ground fault level at the PCC.

[1] Fault Level (kVA) = 1.7321 x V_{L-L} x I where V_{L-L} = Line to Line voltage in kV and I = Fault Current in Amp

If the relative voltage changes **(d) < 4%** then it is expected the new Solar PV generator connection would not cause noticeable voltage fluctuations or inconvenience to HV customers at the PCC.

If the relative voltage change test is **not satisfied**, then further advice should be sought from the AusNet Services' Regional Planning Engineer in the Networks Planning team.

Typical solutions include:

(a) reduce Solar PV generator size

(b) change to a different point of connection, and

(c) network augmentation.

Power Quality measurements before and after Solar PV generator connection for a period of one week each (or an agreed period) may also be required. This is to be undertaken by AusNet Services or customer's nominated contractor. If the measurements are to be undertaken by AusNet Services, the appropriate charge will be applied to the Customer's connection cost.

AusNet Services could also request a comprehensive system study to be undertaken by the customer to assess the suitability of the new connection.

6.2.2. Steady state voltage check

The steady state voltage check is not required as the PCC is on HV side of the Customer's transformer. However, HV voltage must be within ±6% (± 10% rural areas) of the nominal voltage.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.2.3. Voltage rise check

The Customer is responsible for the voltage rise check (ie. from transformer secondary side) to be undertaken so that the Solar PV generator can operate safely and without tripping due to over voltage at the inverter terminals.

Transformer tap position shall be determined by the customer's electrician to maintain the Inverter terminal voltage within operating limits.

6.2.4. Negative sequence voltage check

The Customer's load must be balanced so that the Negative Sequence Voltage can be maintained within the EDC limits.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.2.5. Current harmonic check

The Customer is required to satisfy the EDC's current harmonic limits at PCC. However, no compliance measurements are needed prior to energising the new Solar PV generator connection.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.2.6. Voltage harmonic check

The Voltage Harmonic measurement is not required. The Customer shall maintain current harmonics with the EDC limits as the deviation from these limits could impact on voltage harmonics.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.2.7. Power factor

Solar PV generator must satisfy the AS/NZ 4777.2 power factor range. Similarly, power factor at the customer's PCC shall be within the EDC limits. However, no compliance measurements are needed prior to energising the new Solar PV generator connection.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.2.8. Voltage fluctuation and flicker check

Solar PV generator must satisfy the AS/NZ 4777.2 voltage fluctuation and flicker limits.
Note: This standard refers to AS/NZ 61000.3.3 and AS/NZ 61000.3.11.
However, no compliance measurements are needed prior to energising the new Solar PV generator connection.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.2.9. Recommendation for connection

6.2.9.1. Relative voltage test passed

The Customer's Solar PV generator can be connected subject to actions outlined in Section 6.2.1 and Section 6.2.9.

6.2.9.2. Relative voltage test failed

If the test specified in Section 6.2.1 is not satisfied, the AusNet Services' Regional Planning Engineer could request PQ measurements to be undertaken with and without Solar PV generator for a specified period. These PQ measurements should include:

(a) steady-state voltage

(b) negative sequence voltage

(c) current harmonics

(d) voltage harmonics

(e) power factor (or real and reactive power), and

(f) flicker.

These measurements will enable AusNet Services to advise the customer of required corrective actions and also allow AusNet Services to understand its quality of supply performance.

If the customer is required to take corrective actions, the timing of those corrective measures can be negotiated with the AusNet Services' Regional Energy Network Representatives.

For export limited Solar PV generator connections, the procedure outlined in *SOP 33-06 – Export limits for Embedded Generators up to 200 kVA connected at Low Voltage* must be followed including 'commissioning test.'

6.3. 30 kVA < Solar PV generator < 200 kVA (LV – PCC)

6.3.1. Preliminary check

This section covers when the PCC is on the secondary side of the distribution transformer. For the purposes of this guideline, this is referred to as the low voltage side (LV).

All new inverters must be compliant to AS/NZ 4777.2.

The aggregated PV ratings (kVA) of all PV installations connected to the Distribution Transformer should be less than 30% of the Distribution Transformer rating (kVA). Higher Solar PV generator penetration up to 50% is allowed if the distribution transformer is dedicated to the customer. If the ratio of aggregated PV ratings to Distribution Transformer rating exceeds 30%, an engineering judgment by AusNet Services is required to determine whether the connection can be made without network augmentation, or connection can be made under SOP 33-06 (ie. Limited Export).

Relative Voltage Change (d):

$d = \text{PV Rating}_{kVA} / \text{Fault Level}_{kVA}$

Where: PV Rating is the total (new and existing) PV at the site and Fault Level is the three-phase to ground fault level at the PCC.

If the relative voltage changes **(d) < 4%** then it is expected the new Solar PV generator connection would not cause noticeable voltage fluctuations or inconvenience to HV customers at the PCC.

If the relative voltage change test is **not satisfied**, then further advice should be sought from the AusNet Services' Regional Planning Engineer in the Networks Planning team.

Typical solutions include:

(a) reduce Solar PV generator size

(b) change to a different point of connection, and

(c) network augmentation.

Power Quality measurements before and after Solar PV generator connection for a period of one week each (or an agreed period) may also be required. This is to be undertaken by AusNet Services' contractor or Customer's nominated contractor. If the measurements are to be undertaken by AusNet Services, the appropriate charge will be applied to the Customer's connection cost.

AusNet Services could also request a comprehensive system study to be undertaken (ie. steady-state studies, not dynamic studies) by the customer to assess the suitability of the new connection.

6.3.2. Steady state voltage check

The steady state voltage calculation must be carried out using LV network data and AusNet Services' spreadsheet developed for PV connections for greater than 5 kVA. The voltage rise from the Distribution Substation to the Point of Common Coupling (PCC) must be less than 2%. If required corrective actions should be taken to bring the voltage rise within this limit. The Customer will be charged for the proposed corrective actions as part of the connection cost. Regional Energy Network Representatives (ENRs) are responsible for this analysis.

It is recommended to verify the steady state voltage profile at the metering point utilising AMI data for a period of one week (ie. minimum period) before PV is connected. It will enable to confirm the expected voltage at the Inverter Terminal as described in Section 6.3.3.

6.3.3. Voltage rise check

The Customer is responsible for checking the voltage rise from PCC to inverter terminals, and the voltage rise should be less than 2%. This analysis should be undertaken by the customer's contractor during the PV installation planning & designing stage. AusNet Services' representative could request this calculation and design details prior to energising the new installation, depending on the installation size and location. This information along with AMI data will be used by AusNet Services to verify the expected voltage range at the inverter terminals so that it can operate without tripping.

6.3.4. Negative sequence voltage check

The Customer's load must be balanced so that the Negative Sequence Voltage can be maintained within the EDC limits.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.3.5. Current harmonic check

The Customer is required to satisfy the EDC's current harmonic limits at PCC. However, no compliance measurements are needed prior to energising the new Solar PV generator connection if the tests identified in Section 6.3.1 are satisfied.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.3.6. Voltage harmonic check

The Voltage Harmonic measurement is not required. The Customer shall maintain current harmonics with the EDC limits as the deviation from these limits could impact on voltage harmonics.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions

6.3.7. Power factor

Solar PV generator must satisfy the AS/NZ 4777.2 power factor range. Similarly, power factor at the customer's PCC shall be within the EDC limits. However, no compliance measurements are needed prior to energising the new Solar PV generator connection if the tests identified in Section 6.3.1 are satisfied.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.3.8. Voltage fluctuation and flicker check

Solar PV generator must satisfy the AS/NZ 4777.2 voltage fluctuation and flicker limits.
Note: This standard refers to AS/NZ 61000.3.3 and AS/NZ 61000.3.11.
However, no compliance measurements are needed prior to energising the new Solar PV generator connection if the tests identified in Section 6.3.1 are satisfied.

AusNet Services will undertake these measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.3.9. Recommendation for connection

6.3.9.1. Relative voltage test passed

The Customer's Solar PV generator can be connected subject to actions outlined in Section 6.3.1 and Section 6.3.8. The Customer is required to provide 'steady state voltage' measurements over a period of two hours with Solar PV generator and further over two hours without Solar PV generator. These measurements can be undertaken at the time of commissioning or within **two weeks** of commissioning. Measurements must be taken at **10 minute** intervals.

As noted in previous sections, AusNet Services will undertake PQ measurements at a future date or if a customer complaint is received due to the new connection. The Customer will be advised to take corrective actions as appropriate and is responsible for the costs of such corrective actions.

6.3.9.2. Relative voltage test failed

If the test specified in Section 6.3.1 is not satisfied, the AusNet Services' Regional Planning Engineer will determine the action needs to be taken for the connection. This could include requesting a comprehensive system study by the Customer and also requesting PQ measurements to be undertaken with and without Solar PV generator for a specified period.

These PQ measurements should include:

(a) steady-state voltage

(b) current harmonics

(c) voltage harmonics

(d) negative sequence voltage

(e) flicker, and

(f) power factor (or real and reactive power).

These measurements will enable AusNet Services to advise the customer of required corrective actions and also allow AusNet Services to understand its quality of supply performance.

If the customer is required to take corrective actions, the timing of those corrective measures can be negotiated with the AusNet Services' Regional Energy Network Representatives.

For export limited Solar PV generator connections, the procedure outlined in *SOP 33-06 – Export limits for Embedded Generators up to 200 kVA connected at Low Voltage* must be followed including 'commissioning test.'

6.4. Solar PV generator > 200 kVA

6.4.1. Recommendation for connection

For Solar PV generator > 200 kVA, it is recommended that these connections are treated as special connections and seek the AusNet Services' Regional Planning Engineer's advice.

It is expected that comprehensive system studies along with PQ measurements would be required for these connections. However, it will be determined by the AusNet Services' Regional Planning Engineer considering factors such as:

- Solar PV generator size (rating)
- Connection location
- Fault Levels
- Existing disturbing and sensitive loads nearby (ie. to PCC)
- Future network configuration/augmentation etc.

7. Legislative references

STATE	REGULATOR	REFERENCE
ALL	Energy Networks Australia	ENA Guideline – 2014 Power Quality Guideline for inverter energy systems for connection to low-voltage distribution networks
ALL	Standards Australia	AS 61000.3.100 – 2011 Steady State Voltage Limits in public electricity systems.
ALL	Standards Australia	AS/NZ 3000:2007 Wiring Rules
ALL	Standards Australia	AS/NZ 61000.3.11:2002 Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage power supply systems – Equipment with rated current less than 75A and subject to conditional connection.
ALL	Standards Australia	AS/NZ 61000.3.2:2013 Limits for harmonic current emissions (equipment input current ≤ 16A per phase).
ALL	Standards Australia	AS/NZ 61000.3.3:2012 Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage power supply systems for equipment with rated current ≤ 16A per phase and not subject to conditional connection.
ALL	Standards Australia	AS/NZ 61000.3.5:1998 Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16A **Note**: This standard is superseded by SA/SNZ TS IEC 61000.3.5:2013.
ALL	Standards Australia	AS/NZS 4777.1:2024
ALL	Standards Australia	AS/NZS 4777.2:2020
ALL	Standards Australia	IEC TS 61000.3.5:2013 Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 75A.
ALL	Standards Australia	TR IEC 61000.3.6:2012 Guideline for Power Quality: Harmonics (Previous edition AS/NZS 61000.3.6:2001)
ALL	Standards Australia	TR IEC 61000.3.7:2012 Guideline for Power Quality: Flicker (Previous edition AS/NZS 61000.3.7:2001)
VIC	Essential Services Commission	EDC Electricity Distribution Code of Practice Version 8

8. Resource references

DOCUMENT ID	DOCUMENT TITLE
SOP 11-16	Standard Operating Procedure 11-16: Protection Requirements of Embedded Generators less than 5 MVA (LV + HV up to 22 kV)
SOP 33-06	Standard Operating Procedure 33-06: Export limits for Embedded Generators up to 200kVA connected at Low Voltage

9. Appendices

None.

10. Schedule of revisions

ISSUE	DATE	AUTHOR	DETAILS OF CHANGE
1	20/3/2017	M Wickramasuriya	Solar PV generator – Power Quality Compliance Requirements
2	17/9/2024	R Muneer	Updated references to AS 4777.1

AusNet Services

Level 31
2 Southbank Boulevard
Southbank VIC 3006
T +613 9695 6000
F +613 9695 6666
Locked Bag 14051 Melbourne City Mail Centre Melbourne VIC 8001
www.AusNetservices.com.au

Follow us on

@AusNetServices
@AusNetServices
@AusNet.Services.Energy

AusNet