Jemena Electricity Networks (Vic) Ltd

Connection Guidelines for Inverter Energy Systems
>10 kVA (single phase) and >30 kVA to 200 kVA (three phase)

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History

Rev No	Date	Description of changes	Author
1	26/02/2016	Initial publication	E. Twining
2	12/01/2018	Recommended protection settings revised to align with AS4777.	E. Twining
3	12/11/2021	Recommended protection settings revised to align with the latest AS/NZS 4777.2:2020	K. Combe
4	24/04/2024	Added solar PV emergency backstop enablement	D. Battaglia

Owning Functional Area

Business Function Owner:	Electricity Distribution - Asset and Operations

TABLE OF CONTENTS

GLOSSARY

Connection Point	Point at which the Jemena's service cable or supply main connects to the customer's terminals. Also known as Point of Supply or Point of Connection.
Customer	Owner / operator of the Inverter Energy System.
CSIP-AUS	CSIP-AUS means the Common Smart Inverter Profile Australia, SA HB 218:2023 Handbook, published by Standards Australia on 16 June 2023 and as amended from time to time or if superseded, the document(s) listed by Standards Australia as superseding the SA HB 218:2023 Handbook
Emergency Backstop Enablement	Emergency backstop enablement means, that the IES unit is – a) able to communicate with Jemena's utility server via a communication channel that is compliant to CSIP-AUS; ***AND*** b) connected to the licensee's utility server via the internet – to enable the remote interruption or curtailment of electricity generated by the IES unit;
Inverter Energy System	A system comprising one or more inverters together with one or more energy sources and controls, where the inverter(s) satisfies the requirements of AS/NZS 4777.2.
Point of Common Coupling	Nearest common point in Jemena's distribution network that connection is made between two or more customers' electrical installations.
Service Protection Device	A protection device usually a fuse or circuit breaker which is the isolation point between Jemena's distribution network and the customer main switchboard. Also known as Supply Protection Device.

ABBREVIATIONS

CSIP-AUS	Common Smart Inverter Profile Australia
EBE	Emergency Backstop Enablement
EDCoP	Victorian Electricity Distribution Code of Practice
IES	Inverter Energy System
JEN	Jemena Electricity Networks
LV	Low voltage (i.e. 400 V)
NMI	National Meter Identifier
PV	Photovoltaic
SIR	Victorian Service and Installation Rules
SLD	Single Line Diagram
SPD	Service Protection Device or Supply Protection Device
UPS	Uninterruptable Power Supplies

OVERVIEW

These guidelines provide an overview of the connection process and technical requirements for customers wanting to connect greater than 10 kVA (single phase) and greater than 30 kVA to 200 kVA three-phase Inverter Energy Systems to the JEN distribution network at low voltage (i.e. 400 V) and should be read in conjunction with the requirements of AS/NZS 4777 “Grid connection of energy systems via inverters”.

In all cases, the more onerous of the requirements between these guidelines, the AS/NZS 4777 and other applicable standards shall be applicable.

All requirements relating to emergency backstop enablement apply to all connection applications made from 1 July 2024.

1. INTRODUCTION

These guidelines provide an overview of the connection process and technical requirements for customers wanting to connect Inverter Energy Systems (IES) to the JEN distribution network at low voltage (i.e. 400 V). These guidelines specifically relate to systems that meet the following specifications:

- Generating capacity between 30 kVA and 200 kVA (three phase);
- Generating capacity greater than 10 kVA (single phase);
- Energy source may be solar PV, wind turbine, hydro turbine, battery or fuel cell energy storage; Three-phase low voltage (LV) connection (i.e. 400 V);
- IES will not operate when site is disconnected from the JEN distribution network (i.e. islanded); and
- The inverters used in the IES are AS/NZS 4777 and CSIP-AUS compliant and are on the list of approved inverters published by the Clean Energy Council[1].

These guidelines do not apply to the following embedded generator systems:

- Micro embedded generators (i.e. IES with capacity less than 10 kVA single phase or 30 kVA three phase) - the connection process for these systems is outlined on the Jemena website[2];
- IES with capacity greater than 200 kVA – these guidelines may be used to ascertain the minimum requirements for connection of these systems but additional network studies may be required to identify additional connection requirements to ensure that network safety or performance is not compromised;
- Synchronous and asynchronous generators (e.g. co-generation and tri-generation) – connection requirements for these generators are outlined in “JEN GU 0020 Embedded Generation Guidelines”[3];
- Hybrid systems (e.g. diesel generator / solar PV systems).; and
- Generators that require network augmentation to facilitate connection.

1 http://www.solaraccreditation.com.au/products/inverters/approved-inverters.html

2 https://jemena.com.au/electricity/our-services/solar-and-renewables-for-installers-recs

3 Embedded Generation | Jemena

2. CONNECTION PROCESS

The connection process is detailed in Jemena's "Negotiated Connection Process (Embedded Generation)"[4] and summarised in Figure 2–1.

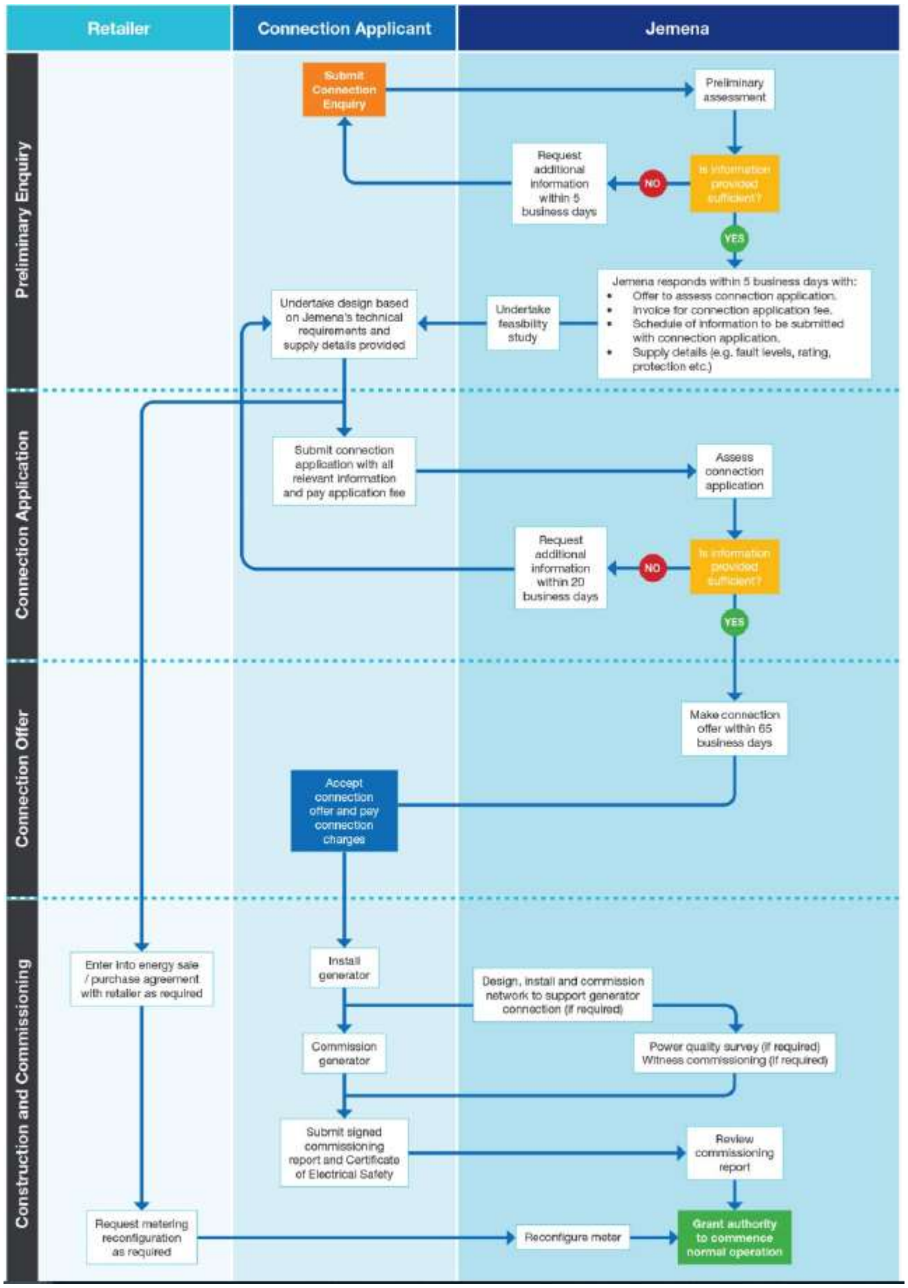

Figure 2–1: Simplified connection process for IES (30 kVA – 200 kVA)

4 Embedded Generation | Jemena

2.1 CONNECTION APPLICATION FEE

The customer is required to pay a *connection application fee* prior to a connection application being assessed. This fee varies and is dependent on the complexity of the connection. It includes:

- Review of technical information;
- Analysis of possible network impacts including assessment of any network augmentation requirements;
- Power quality survey (if required);
- Preparation of the Connection Agreement and Offer to Connect (if required);
- Update of internal systems;
- Attendance at meetings, discussions etc. as required; and
- Witnessing commissioning (if required) and review of test report.

2.2 CONNECTION AGREEMENT

On acceptance of the offer and any final negotiation, Jemena will prepare a Connection Offer and Connection Agreement that will include all technical material, commercial provisions and terms and conditions. These documents will contain any ongoing fees to be paid by the embedded generator or any ongoing payments to be made by Jemena to the customer for services provided. The Connection Agreement must be executed prior to the final commissioning of the IES.

If the customer decides to augment or significantly modify their generating plant after the Connection Agreement is executed, the customer must make an application to modify their plant using the same process described above for the Connection Enquiry and Connection Application stages.

3. SYSTEM CONDITIONS

3.1 OPERATING CONDITIONS

Table 3–1 lists the system conditions at the connection point under which the works must operate satisfactorily.

Table 3–1: Operating conditions

System Condition	Requirement
Nominal voltage	230 V_{rms} (phase to earth) / 400 V_{rms} (phase to phase)
Minimum continuous operating voltage	216 V_{rms} (phase to earth) / 376 V_{rms} (phase to phase)
Maximum continuous operating voltage	253 V_{rms} (phase to earth) / 440 V_{rms} (phase to phase)
Nominal frequency	50 Hz
Normal operating frequency band	49.85 Hz to 50.15 Hz
Fault withstand level	50 kA / 3 s
Lightning impulse withstand level	6.0 kV_p (phase-ground)
Short duration (60 sec) power frequency withstand level	275 V_{rms} (phase-ground)

Source: Electricity Distribution Code of Practice (EDCoP), Frequency Operating Standard

3.2 QUALITY OF SUPPLY

Under the Electricity Distribution Code of Practice (EDCoP), Jemena is required to use best endeavours to maintain the voltage variation, flicker and harmonic voltage distortion levels across JEN within the limits defined in Table 3–2, Table 3–3 and Table 3–4.

Jemena is also required to maintain the negative sequence voltage at the point of common coupling for three phase installations within the limits described by Schedule 5.1a, clause S5.1a.7 of the NER outlined in Table 3–5.

Table 3–2: Standard nominal voltage variations

Voltage Level (kV)	Voltage Range for Time Periods			Impulse Voltage
	Steady State	Less than 1 min	Less than 10 sec	
< 1.0	AS 61000.3.100* +13%, -10%	+13%, -10%	Phase to earth +50% -100% Phase to phase +20% -100%	6 kV peak
1-6.6	±6% (±10% Rural Areas)	±10%	Phase to earth +80% -100% Phase to phase +20% -100%	60 kV peak
11				95 kV peak
22				150 kV peak
66	±10%	±15%	Phase to earth +50% -100% Phase to phase +20% -100%	325 kV peak
*The voltage range for time periods less than 1 minute and 10 seconds do not apply to AS 61000.3.100				

Source: Electricity Distribution Code of Practice (EDCoP) Section 20.4.2

Table 3–3: Flicker limits

Type	Limit for all voltage levels
Short term flicker (P_{st})	1.0
Short term flicker (P_{lt})	0.8

Source: Electricity Distribution Code of Practice (EDCoP) Section 20.10, NER Section S5.1a.5, AS/NZS 61000.3.7:2012 Table 1

Table 3–4: Voltage harmonic distortion limits

Voltage at point of common coupling	Total harmonic distortion	Individual voltage harmonics	
		Odd	Even
< 1 kV	8%	3^{rd} = 5% 5^{th} = 6% 7^{th} = 5%	2^{nd} = 2% 4^{th} = 1% 6^{th} = 0.5%
> 1 kV and ≤ 66 kV		For higher orders refer AS/NZ 61000.3.6:2012	

Source: Electricity Distribution Code of Practice (EDCoP) Section 20.6, NER Section S5.1a.6, AS/NZS 61000.3.6:2012 Table 1

Table 3–5: Voltage unbalance (negative sequence voltage) limits

Voltage	NER		
	30 Min Average	10 Min Average	1 Min average (once per hour)
≤ 10 kV	2.0 %	2.5 %	3.0 %
> 10 kV	1.3 %	2.0 %	2.5 %

Source: Electricity Distribution Code of Practice (EDCoP) Section 20.8, NER Section S5.1a.7

4. TECHNICAL REQUIREMENTS

4.1 STANDARDS AND CODES

All plant and equipment shall be designed, manufactured, installed and tested in accordance with the requirements of all relevant Statutory Authorities and Acts and the latest revision of all relevant Australian / IEC Standards and Codes of Practices including (but not limited to) those listed in Table 4–1.

Table 4–1: Standards and Codes

Publisher	Title
Australian Energy Market Commission (AEMC)	National Electricity Rules (NER)
Essential Services Commission (ESC)	Victorian Electricity Distribution Code of Practice (EDCoP)
	Electricity Customer Metering Code
Victorian Electricity Distributors	Victorian Service & Installation Rules (SIR)
Victorian Electricity Supply Industry (VESI)	Electrical Safety Rules for Victorian Distribution Networks (Green Book)
IEC 60255	Requirements applicable to measuring relays and protection equipment
Standards Australia	AS/NZS 4777.1: 2016 Grid connection of energy systems via inverters - Installation requirements
	AS/NZS 4777.2: 2020 Grid connection of energy systems via inverters - Inverter requirements
	AS/NZS 3000 Electrical installations (Wiring Rules)
	AS/NZS 5033 Installation and safety requirement for photovoltaic (PV) arrays
	AS 60044.1 – Instrument Transformers – Part 1: Current Transformers
	AS 60044.12 – Instrument Transformers – Part 2: Inductive voltage transformers
	AS/NZS CSIP-AUS – Common Smart Inverter Profile Australia
	All other Australian Standards relevant to equipment being installed.

4.2 MAXIMUM GENERATION CAPACITY

The maximum allowable capacity of the Inverter Energy System (IES) will be limited by either the size of the customer's electrical installation (wiring) or the capacity of the JEN distribution network infrastructure (e.g. distribution substation transformer or LV circuit). The general guideline Jemena applies for the assessment of multiple IES generators connected to a shared LV distribution network is 30% allowable export of customer's maximum demand to align with network asset capacity i.e. when the total inverter export exceeds 30% of customer's maximum demand, a detailed evaluation is required to confirm that additional IES connections will not adversely impact the network or other customers.

4.3 NETWORK CONNECTION AND ISOLATION

Every distribution network LV connection (load or generator) must have a service protection device installed in accordance with the SIR. For low voltage connections, the service protection device shall be installed between the point of supply and the meter. The service protection device can be either fuse or circuit breaker. The distributor must be provided with access to operate or work on the service protection devices at all times and must be able to lock the device in the open position. The customer can only authorise a person to operate a circuit breaker used as a service protection device if it is not sealed or locked off by the distributor.

All IES must have a pad-lockable isolating device owned and operated by the customer. While the isolating device should only be operated by the customer, Jemena may insert their own padlock or similar locking device to lock the isolator in the open position when undertaking works on the distribution network or at the customer connection point. This device may isolate just the IES (single or multiple IES) or may isolate the whole installation (i.e. main switch). Where practicable, the connection of multiple IES (new and existing) should be made at the main switchboard and controlled using one single main switch. Where there are multiple IES intended to be directly connected to an individual switchboard, there shall only be one single main switch.

4.4 EARTHING

The customer is required to ensure that their IES has an effective earthing system to limit step and touch earth potential rise to safe values and ensure compliance with the requirements of Australian Standards.

4.5 PROTECTION

4.5.1 GENERAL PRINCIPLES

Electrical protection shall be provided to ensure the safety, integrity and power quality of the electricity distribution network is not in any way compromised by the connection and operation of the IES.

All electrical faults within the IES installation shall be automatically detected and rapidly isolated from the electricity distribution network. All plausible electrical faults on the electricity distribution network (external to the generator installation) shall also be automatically detected and the generator contribution is to be rapidly interrupted. The IES shall incorporate primary protection (i.e. inverter integrated) and backup protection (i.e. central protection relay). These protection devices shall be configured to trip either the connection point main circuit breaker and/or the generator circuit breaker(s).

Whenever network supply is lost, the IES must disconnect as quickly as possible to avoid islanding and shall not reclose (i.e. a generator shall not attempt to reconnect to the distribution network if the network is not within the normal operating range under any circumstances). The IES can only reconnect to the network once the network connection is restored to normal operating conditions (as defined in Table 3–1) for at least 60 seconds. This allows time for multiple feeder recloses and ensures that the reclose was successful and has stabilised before attempting to reconnect the IES.

The IES designer must consider the impact of failure of any protection component would have on the operation of the protection system. The designer shall incorporate fail-safe features that disconnect the entire IES from the distribution system in the event that the central protection relay has an internal fault or power supply failure or is not in service for any other reason.

4.5.2 SHORT CIRCUIT PROTECTION

Any short circuit fault within a customer's installation must be detected and disconnected from the distribution network as quickly as possible. This includes three phase, phase to phase and phase to ground faults. It is important that the protection used to detect and clear short circuit faults within the customer's installation grades with the protection on the distribution network so that the customer's protection clears the fault before the distribution network protection acts. This limits the impact of the fault on other network users. It is recommended that the IES designer undertake an overcurrent protection grading study to ensure that the IES protection grades with all upstream network protection.

4.5.3 INVERTER PROTECTION

4.5.3.1 Passive anti-islanding and limits for sustained operation

During commissioning of an AS/NZS 4777.2:2020 compliant inverter, the correct region setting is required to be selected and configured. The required region setting and corresponding inverter protection functionality and settings are summarised in Table 4–2. These settings align with those recommended in AS/NZS 4777.2:2020.

Table 4–2: Inverter protection functionality (Region: Australia A)

Region: Australia A			
Protection function	**Protective Function Limit**	**Trip delay time**	**Maximum disconnection time**
Undervoltage 1 (V<)	180 V (ph-n)	10 s	11 s
Undervoltage 2 (V<<)	70 V (ph-n)	1 s	2 s
Overvoltage 1 (V>)	265 V (ph-n)	1 s	2 s
Overvoltage 2 (V>>)	275 V (ph-n)	-	0.2 s
Sustained Overvoltage (10 minutes)	258 V (ph-n)		3 s
Under-frequency (F<)	47 Hz	1 s	2 s
Over-frequency (F>)	52 Hz	-	0.2 s
Active anti-islanding	(3)	-	2 s
Voltage phase angle shift withstand	60° (1), 20° (2)		2 s
Rate of Change of Frequency (ROCOF)	4.0 Hz/s	-	0.25 s
Reconnection delay	60 sec		

Notes:
(1) 60° - Single phase disturbance
(2) 20° - Three phase disturbance
(3) The method used to provide active anti-islanding protection shall be as per AS/NZS 4777.2:2020 Section 4.3

Source: AS/NZS 4777.2:2020 Table 4.1 “Passive anti-islanding voltage limit values”, Table 4.2 “Passive anti-islanding frequency limit values”, Table 4.3 “Settings for $V_{nom-max}$, Table 4.9 “Voltage phase angle shift withstand requirements”, and Section 4.5.6 “Rate of change of frequency”.

The maximum output fault current shall be provided for the IES[5].

[5] AS/NZS 4777.2:2020 Table 7.2

The IES shall maintain continuous operation for frequency variations within the limits specified in Table 4–3 and Table 4–4.

Table 4–3: Frequency variation withstand limits

Region: Australia A			
Decrease in frequency response lower limit [Hz]	Lower limit of continuous operation range (f_{LLCO}) [Hz]	Upper limit of continuous operation range (f_{ULCO}) [Hz]	Increase in frequency response upper limit [Hz]
47	49.75	50.25	52

Source: AS/NZS 4777.2:2020 Section 4.5.3 “Sustained operation for frequency variation”.

Table 4–4: Frequency response limits

Region: Australia A			
Frequency where power output level is maximum (f_{Pmax}) [Hz]	Frequency where charging power level is zero ($f_{stop\text{-}ch}$)NOTE 1 [Hz]	Frequency where discharging power level is zero ($f_{transition}$)NOTE 1 [Hz]	Frequency where power level is minimum (f_{Pmin}) [Hz]
48	49	50.75	52
NOTE 1: This refers to IES with energy storage			

Source: AS/NZS 4777.2:2020 Section 4.5.3.2 “Response to a decrease in frequency” & Section 4.5.3.3 “Response to an increase in frequency”.

Where a frequency variation results in frequency to be outside the continuous operation range, the inverter shall respond according to the default characteristics outlined in AS/NZS 4777.2:2020 and shall respond within the specified times of Table 4–5.

Table 4–5: Frequency response – Maximum Response times

Region: Australia A		
Response commencement time	Response completion time	f_{hyst}
1 s	10 s	0.1 Hz

Source: AS/NZS 4777.2:2020 Table 4.6 and Table 4.7 Section 4.5.3 Sustained operation for “frequency variations”.

4.5.3.2 Power Quality Response Modes

The IES should have the following power quality response modes enabled as default:

- Volt-var response mode; and
- Volt-watt response mode.

The volt-watt and volt-var response modes shall be able to operate concurrently when active.

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 required settings are defined in Table 4–6.

Table 4–6: Volt-watt response default set-point values

Region: Australia A		
Reference	**Voltage (V)**	**Inverter maximum active power output level (P) % of S_{rated}**
V1	253 V	100 %
V2	260 V	20 %

Source: AS/NZS 4777.2:2020 Table 3.6 Section 3.3.2.2 “Volt-watt 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 required settings are defined in Table 4–7.

Table 4–7: Volt-var response default set-point values

Region: Australia A		
Reference	**Voltage (V)**	**Inverter reactive power level (Q) % of S_{rated}**
V1	207 V	44 % supplying (export VAr)
V2	220 V	0 %
V3	240 V	0 %
V4	258 V	60 % absorbing (import VAr)

Source: AS/NZS 4777.2:2020 Table 3.7 Section 3.3.2.3 “Volt-var response mode”.

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 shall have this volt-watt response mode. This volt-watt response mode is only active when energy storage charges and the required settings are defined in Table 4–8.

Table 4–8: Volt-watt response default set-point values for IES with energy storage when charging

Region: Australia A		
Reference	**Voltage (V)**	**$P_{charge}/P_{rated\text{-}ch}$ %**
V1	207 V	20 %
V2	215 V	100 %

Source: AS/NZS 4777.2:2020 Table 3.8 Section 3.4.3 “Volt-watt response mode for inverters with energy storage when charging”.

4.5.4 CENTRAL PROTECTION RELAY

The central protection relay shall be installed as close to the main switch of the customer's electrical installation as practicable. There should be a single central protection relay (master) which controls a slave contactor to trip multiple IES (new and existing) simultaneously. The voltage reference of the master central protection relay shall be as close to the main switch of the customer's electrical installation as practicable to create a common reference point for multiple IES (new and existing).

The protection functions provided by this relay, as detailed in Table 4–9, are in addition to and separate from the inverter protection. The central protection shall respond to the parameter settings in Table 4–9 by disconnecting all IES (new and existing IES) from the installation by automatic operation of a disconnect device.

Table 4–9: Central protection relay functionality[6]

Protection function	Recommended settings	Maximum disconnection time
Sustained over voltage (based on average value over a 10 min period)	258 V (ph-n)	3 s
Over voltage 1 (V>)	265 V (ph-n)	2 s
Over voltage 2 (V>>)	275 V (ph-n)	0.2 s
Under voltage 1 (V<)	180 V (ph-n)	11 s
Under voltage 2 (V<<)	70 V (ph-n)	2 s
Over frequency (F>)	52 Hz	2 s
Over frequency (F<)	47 Hz	2 s
Vector shift	20°	2 s
Rate of change of frequency (ROCOF)	4 Hz/s	0.25 s
Reconnection delay NOTE 1	–	60 s
Current unbalance NOTE 2	21.7 A	2 s

NOTES

1. Inverter can only be reconnected to grid when voltage and frequency have been maintained within specified limits for at least 60 seconds.
2. Current unbalance protection only required if this is not inverter integrated.

Source: AS/NZS 4777.2:2015 Table 1 "requirements for inverter integrated protection and central protection functions" and Table 2 "Passive Central voltage and frequency protection set points".

[6] AS/NZS 4777.1: 2016 Grid connection of energy systems via inverters - Installation requirements, Section 3.4.4.3 Central voltage and frequency protection requirements

4.6 VOLTAGE RISE

The overall voltage rise from the *connection point* to the inverter a.c. terminals shall not exceed 2% of the nominal voltage at the point of supply (i.e. 8 V). The value of the current used for the calculation of voltage rise shall be the rated current of the IES.

All cabling should be sized so that the maximum voltage rise from the Main Switch (inverter supply) to the inverter a.c. terminals does not exceed a 1% maximum voltage rise.

Jemena will review and assess the voltage rise impacts of the IES on its network. In certain cases this may limit how the generator operates or how much it can export (refer Section 4.8 for more details).

4.7 HARMONIC INJECTION LIMITS

In addition to the inverter harmonic current limits specified in AS4777.2:2020[7], the customer must keep harmonic currents at the Point of Common Coupling below the limits defined in the EDCoP, as reproduced in Table 4–10. The limits for even harmonics are limited to 25% of those for the odd harmonics and the limits vary according to the ratio of the short current level (I_{SC}) and the load current (I_L).

Table 4–10: Harmonic current distortion limits

I_{SC}/I_L	Maximum harmonic current distortion in percent of I_L					
	Individual harmonic order "h" (odd harmonics)					Total Harmonic Distortion
	< 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	
<20*	4.0%	2.0%	1.5%	0.6%	0.3%	5.0%
20<50	7.0%	3.5%	2.5%	1.0%	0.5%	8.0%
50<100	10.0%	4.5%	4.0%	1.5%	0.7%	12.0%
100<1000	12.0%	5.5%	5.0%	2.0%	1.0%	15.0%
>1000	15.0%	7.0%	6.0%	2.5%	1.4%	20.0%

Source: Electricity Distribution Code of Practice Clause 20.6.3

4.8 EXPORT CONTROL

In most cases, the generator will be allowed to operate at unity power factor and maximum output. However, there are some operating scenarios where the output of the generator may need to be constrained because:

- The thermal rating of the local JEN distribution network infrastructure (e.g. distribution substation transformer or LV circuit) is not sufficient to accommodate the maximum level of generation export;
- Power export into the JEN distribution network is likely to compromise quality of supply for other customers i.e. operate outside of limits defined in Section 3.

[7] AS/NZS 4777.2:2020 Clause 2.7.

Typical scenarios where an IES output may need to be constrained include:

- The network asset already has a high level of solar PV penetration and the actual and forecast export exceeds the asset export rating;
- The proposed site export exceeds 30% of the customer's maximum demand;
- The connection is located in a weak part of the network e.g. at the end of a long, weak LV high impedance circuit; and
- The voltage rise from the substation to the Point of Common Coupling exceeds 2%.

The requirement for constrained generation will be identified at the assessment stage of a connection application and a solution will be negotiated with the customer. Possible solutions include:

- Network augmentation (e.g. upgrades to the LV circuit or distribution substation transformer);
- Implementation of export control either integrated into the inverter or within the central protection device to limit export into the JEN distribution network during periods of light load;
- Enabling inverter power factor / reactive power mode[8] – inverter operates at a fixed leading / lagging power factor or reactive power output in order to increase / decrease the voltage at the point of connection.

Where an export limit is applied, the implementation of how the export is limited shall be described.

4.9 METERING

The metering standards that apply for load connections to the Jemena network also apply for generator connections. However active power can be bi-directional and this requires metering that can accurately measure energy flow in both directions. The energy that flows in each direction must be stored in separate registers.

In both cases it is necessary to obtain the approval from Jemena to avoid the need to install bi-directional energy metering. If changes are required to existing metering arrangements, this should be co-ordinated with the customer's retailer and meter provider.

4.10 REMOTE COMMUNICATION

The customer is responsible for equipping the generator connection with remote interruption or curtailment capabilities as specified by Jemena. Compliance with Jemena's designated communication protocols and effective emergency backstop enablement (EBE) implementation is mandatory and must be integrated into the installation's design. Please refer to "Installer CSIP-AUS Commissioning Test Procedure"[9] for further information.

Jemena will evaluate the communication strategy, design, and integration with its utility server during the application review process. Additional subsequent testing and commissioning will be determined and outlined at that time.

Ongoing operational verification will be necessary as detailed in section 5.4.

[8] AS4777.2 Clause 3.3.3

[9] This document will be replaced with CSIP-AUS Handbook in the future.

NOTE: CSIP-AUS compliant communication and control is the required method to enact EBE functionality for all IESs. However, due to other specific constraints, which the customer will need to adequately note and justify, Jemena may review and approve designs for alternate methods of control available as outlined in "Embedded Generation Backstop Guideline (Above 30kVA) – DoE Over SCADA and Generator Monitoring Meter Methods"[10].

10 Embedded Generation | Jemena

5. COMMISSIONING AND MAINTENANCE

5.1 COMMISSIONING REQUIREMENTS

Generators are required to undertake suitable testing to confirm compliance with the connection agreement including the intended design of all safety, protection, control, metering, monitoring systems associated with the IES, together with the electrical integrity of all primary circuit equipment.

A testing and commissioning program shall be submitted to Jemena for review as part of the connection application. The program should include the final protection settings as agreed with Jemena and should be of sufficient detail to allow Jemena to understand what is being tested and the pass/fail criteria for each test. The testing and commissioning program shall detail testing methodology and test equipment which will be used. Jemena will identify any additional requirements or request any adjustment on proposals from the generator.

The customer shall provide an opportunity for Jemena to witness any tests and to request any tests to be repeated if the test results do not demonstrate compliance with the agreed access standard. The tests shall be performed by suitably competent testing personnel with appropriately calibrated test equipment. Upon completion of all tests, a copy of all test results in the form of a test report shall be submitted to Jemena.

5.1.1 POWER QUALITY SURVEY

Jemena may require a power quality survey to be undertaken both prior to and following connection of the IES, particularly in cases where the connection to the JEN distribution network is in an area which already has:

- high solar PV penetration;
- a known power quality issue; or
- high supply impedance (i.e. weak connection point).

The requirement for a power quality survey will be determined on a case-by-case basis and will be undertaken by Jemena's power quality team. The fee for this service will be advised during the connection application assessment and the customer will be notified of the requirement at this stage.

In cases where a power quality survey has been deemed necessary, Jemena will require at least one month notice prior to commencement of testing and commissioning. The power quality team will co-ordinate site access with the customer as required.

5.1.2 INVERTER TESTING

Jemena does not require additional testing of AS/NZS 4777.2:2020 compliant inverters. However, where the inverter settings have changed and do not align with AS/NZS 4777.2:2020 Australia A settings, evidence should be provided to confirm settings have been set as agreed with Jemena during the technical assessment (an attached configuration file or screen shots are acceptable).

5.1.3 EMERGENCY BACKSTOP CAPABILITY COMMISSIONING TESTING

Inverters installed using CSIP-AUS to enable the emergency backstop functionality shall undergo capability commissioning tests to ensure that the device is able to communicate with Jemena's utility server and that Jemena can confirm that the curtailment functionality available under CSIP-AUS can be performed successfully.

Refer to ”Installer CSIP-AUS Commissioning Test Procedure”[11] for more details.

NOTE: Where an alternate method to enact EBE functionality has been approved by Jemena, similar commissioning tests shall be conducted to ensure that all IES can be successfully interrupted or curtailed by Jemena. Refer to ”Embedded Generation Backstop Guideline (Above 30kVA) – DoE Over SCADA and Generator Monitoring Meter Methods”[12] for more details.

5.1.4 CENTRAL PROTECTION RELAY TESTING

Secondary injection testing of the central (or back up) protection relay is required to confirm that all required set points and trip timing are as agreed with Jemena. Protection functions to be tested include:

- Under / over voltage;
- Sustained over voltage (10 minutes);
- Under / over frequency;
- Vector shift (forward and reverse);
- ROCOF (ramp up / ramp down);
- Reconnection delay;
- Current unbalance (if enabled);
- Overcurrent (if enabled);
- Power export limit and loss of communication (if enabled); and
- Voltage response / power factor profile (if response mode is enabled).

In addition to the testing of protection functions, the fail-safe operation of the protective device shall be tested. The testing shall demonstrate evidence that the disconnection device shall operate to isolate the generators from the Jemena grid when there is:

- Loss of power to the central protection;
- Loss of control signal from the central protection;
- An internal fault in the central protection; and
- When any equipment in the tripping circuit is deenergised or becomes faulty. Separate test cases should be included for each equipment in the tripping circuit and for each failure mode (including the loss of communication if applicable).

Note that bench testing of central protection relay is acceptable providing end-to-end functionality is confirmed on site with a loss of mains (anti-islanding) test. The following IES anti-islanding and reconnection tests shall be performed and recorded:

- Operate the main switch (inverter supply) and verify that the connection time is greater than 60 s; and

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[12] Embedded Generation | Jemena

- Isolate the main switch (mains supply) and verify that the disconnection time is less than 2 s[13].

The testing of the relay should as a minimum include tests either side of the set point (operation/no operation tests) with a sufficiently small step size to prove the set point operation with required accuracy. Event logging should be enabled within the relay so that Jemena can access event records if required. The test results should be shown for each of the three phases (under / over voltage etc.) where applicable.

5.1.5 FIRMWARE

The inverter firmware version shall be reported in design documents and 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. Inverter firmware changes and updates shall conform to the requirements of the AS/NZS 4777.2:2020.

5.2 MAINTENANCE REQUIREMENTS

The generator proponent is to prepare and keep active a 5-year forward maintenance program. Jemena may request access to the maintenance program and maintenance and test reports for the purpose of review and to establish generator compliance with the program. Maintenance records should be maintained for at least 7 years.

5.3 ASSET REPLACEMENT, MODIFICATIONS OR UPGRADES

No modification that might reasonably be considered to impact the compliance of the IES with the technical requirements outlined in Section 4, may be undertaken without prior approval from Jemena. Jemena may require the customer to conduct a test to demonstrate that the unit has been modified in accordance with the proposal and remains compliant with the technical requirements.

No changes are permitted to tested protection, control, metering and monitoring systems without consultation with Jemena. Consultation will determine whether retesting is a requirement in the event of change.

Modifications which do not require prior approval from Jemena are:

- Like for like replacement of the inverter (i.e. same model, capacity, manufacturer and protection settings);
- Like for like replacement of solar panels (i.e. no increase in rating);
- Replacement of an isolator/switch with an equivalent isolator/switch.

5.4 ON-GOING OPERATIONAL VERIFICATION REQUIREMENTS

The emergency backstop functionality (i.e. remote interruption or curtailment) for each IES connection must be verified regularly to ensure it operates correctly when needed. Compliance with Jemena's verification processes is mandatory.

[13] AS/NZS 4777.1:2016 Grid connection of energy systems via inverters, Part 1: Installation requirements, Section 7.6 “Commissioning”

If the remote control / design method effectively verifies EBE functionality, Jemena may conclude that annual testing may not be necessary to ensure verification compliance. Jemena is open to considering alternative verification methods proposed by customers that could eliminate the requirement for annual testing.

Refer to ”Embedded Generation Emergency Backstop Requirements”[14] for more details.

14 Embedded Generation | Jemena

6. INFORMATION TO BE SUBMITTED BY CUSTOMER

The following sections detail the information to be submitted by customer at each stage of the connection process.

6.1 CONNECTION ENQUIRY

At the connection enquiry stage, the customer must provide the following:

- Completed connection enquiry details including:
  - Customer / applicant details;
  - Address of Solar PV installation;
  - National Meter Identifier (NMI);
  - Generation capacity;
  - Number and rating of inverters;
  - Expected maximum export; and
  - Maximum / minimum site load.
- Initial concept Single Line Diagram (if available).

6.2 CONNECTION APPLICATION

At the connection application stage, the customer must provide the following:

- Completed connection application form[15];
- Detailed Single Line Diagram (SLD) including inverters, central protection relay and connection to Jemena network. The SLD should clearly label the pad-lockable generator isolating device. (Refer to Appendix A for example SLD and required information);
- Protection Schematic (Refer to Appendix B for requirements);
- Site layout diagram highlighting location of panels, inverters and pad-lockable generator isolating device (Refer to Appendix B for requirements);
- Design report including:
  - Inverter, CSIP-AUS Gateway (if applicable) and central protection relay manufacturer and model details;
  - Proposed inverter and central protection relay protection settings including settings calculations and operate times;
  - Intended system communication method including, but not limited to;
    - Communication Type (i.e. CSIP-AUS)

[15] https://myservices.jemena.com.au/edp/login/auth

    - Is there internet connectivity with utility server?
    - Subsequent export limit chosen – refer to "Embedded Generation Emergency Backstop Requirements"[16]
  - Maximum export to JEN network;
- Voltage rise / drop calculations between inverters, main switchboard, and point of supply; and
- Commissioning program.

6.3 COMMISSIONING

Following commissioning of the IES, the customer must submit the following:

- Signed and dated commissioning report (including EBE commission testing);
- Test software generated original test report of the secondary injection test (if available);
- Screenshot of the export limit settings used in the export energy smart meter and commissioning report showing export limit test results (if applicable);
- Completed Electrical Works Request (EWR); and
- Certificate of Electrical Safety (CES) to demonstrate that the generator installation has been inspected by a licensed electrical inspector.

[16] Embedded Generation | Jemena

APPENDIX A: SINGLE LINE DIAGRAM REQUIREMENTS

A Single Line Diagram (SLD) shall be submitted as part of the connection application and is required for all Negotiated Embedded Generation Connections.

The agreed SLD will be included in the Connection Agreement and Offer Schedule.

What is not Acceptable?

The following are not acceptable forms of Single Line Diagram:

- Hand drawn sketches;
- Incorrect SLD's referring to incorrect addresses, previous projects and incorrect details (solar panel / inverter model numbers);
- SLD's which do not align with the information on the online application form;
- SLD's which do not meet Jemena requirements; and
- Non electrical layout drawings.

SLD Requirements

The SLD shall meet the following requirements as a minimum:

- Include a title block containing
  - Drawing name
  - Unique drawing number
  - Version number
  - Designer and authoriser including CEC accreditation number (if available)
  - Date
  - NMI and Address
- SLD shall represent the full system (existing plus new system);
- SLD shall be in electronic CAD format (not hand drawn sketch);
- Preferably use symbols which comply with AS/NZS 3000 Appendix J Figure J1;
- Ensure all application details match up with the SLD (Total system size, no. panels, no. inverters, no. batteries, model numbers etc.);
- Show current and fault rating of all devices from the point of supply;
- Show cable length and cable type for all sections of cable from the point of supply to the inverter;
- Include the wiring from the panels to the connection point or supply meter;
- Show symbol of point of supply/boundary to Jemena network and supply meter;
  - Identify and name each switchboard / distribution board (MSB, DB, PVDB, etc.);

- Show indicative customer load circuits when present;
- Ensure main solar switch and main battery switch are 'pad-lockable' and both are labelled;
- Identify phases involved in the proposed system and total phases at each switchboard (single phase, three phase);
- Show the full connection and implementation of the system within the site, including all CT/VT connections, contactors, circuit breakers, isolators, sub boards, communication links, energy management system connections, and export limit control measurement and connections, etc;
- Include monitoring and communication links to link the export of the system (if applicable);
- Show the manufacturer and model of each inverter, panels, relay, generator etc;
- Show central protection relay and inverter protection settings;
- Show system voltage rise on SLD (Show voltage rise information in a table format with all the cable details, how many conductor per phase, % voltage rise for each section of cable from point of supply to inverter, and total % voltage rise at each inverter);
- Show the capacity of the battery inverter in kVA and kWh;
- Display the total export limit of the site, export limit of solar inverters, export limit of battery inverters, etc; and
- Label what is existing solar/battery installation and what is new solar/battery installation.

An example SLD is shown below.

Equipment Schedule

Total System Capacity (kVA):
(Rating of all inverters)
Total Export Capacity (kVA):

PV Inverter Details
Manufacturer:
Model Name:
Model Number:
Rating (kVA):
Total Number of Inverters:

Battery Inverter Details
Manufacturer:
Model Name:
Model Number:
Rating (kVA):
Total Number of Inverters:
Export capability: yes/no

PV Panel Details
Manufacturer:
Model Name/Number:
Total Number of PV Panels:
Individual Panel Rating (Watts):

Battery Details
Manufacturer:
Model Name/Number:
Rating (kWh):

Export Limit Device
Manufacturer:
Model Name:
Model Number:

Central Protection Relay Details
Manufacturer:
Model:

Central Protection Relay Settings

Protection Function	Recommended Settings	Maximum Disconnection Time
Sustained over voltage (10 min average)	258 V (ph-n)	3 s
Over voltage 1 (V>)	265 V (ph-n)	2 s
Over voltage 2 (V>>)	275 V (ph-n)	0.2 s
Under voltage 1 (V<)	180 V (ph-n)	11 s
Under voltage 2 (V<<)	70 V (ph-n)	2 s
Over frequency (F>)	52 Hz	2 s
Over frequency (F<)	47 Hz	2 s
Vector shift	20°	2 s
Rate of change of frequency (ROCOF)	4 Hz/s	0.25 s
Reconnection delay (1)	–	60 s
Current unbalance (2)	21.7 A	2 s

NOTE 1 Inverter can only be reconnected to grid when voltage and frequency have been maintained within specified limits for at least 60 seconds.

NOTE 2 Not applicable when using ONLY AS4777 approved three phase inverters

Inverter Protection Settings: **Region Australia A**

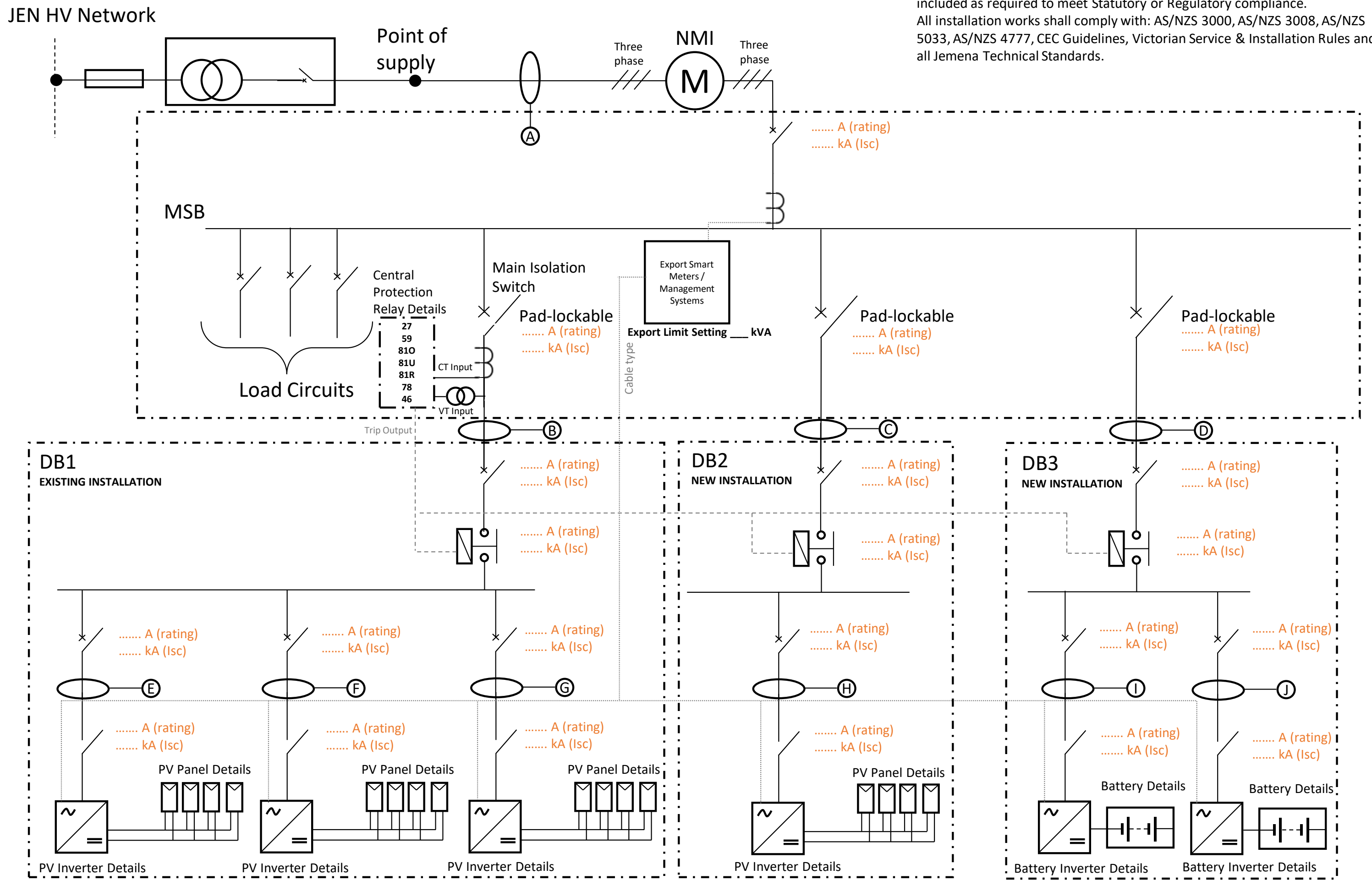
Protection Function	Protection Function Limit	Trip Delay time	Max Disconnection Time
Undervoltage 1 (V<)	180 V (ph-n)	10 s	11 s
Undervoltage 2 (V<<)	70 V (ph-n)	1 s	2 s
Overvoltage 1 (V>)	265 V (ph-n)	1 s	2 s
Overvoltage 2 (V>>)	275 V (ph-n)	-	0.2 s
Sustained Overvoltage (10 minutes)	258 V (ph-n)		3 s
Under-frequency (F<)	47 Hz	1 s	2 s
Over-frequency (F>)	52 Hz	-	0.2 s
Active anti-islanding	-	-	2 s
Voltage phase angle shift withstand	60° (1), 20° (2)		2 s
Rate of Change of Frequency (ROCOF)	4.0 Hz/s	-	0.25s
Reconnection delay	60 sec		

NOTE 1: 60° - Single Phase disturbance.

NOTE 2: 20° - Three Phase disturbance.

Detailed SLD – **Example** Single Line Diagram

Note: This Single Line Diagram is for Jemena purposes only. It is not intended for any other purposes and no liability is accepted for any items included or not included as required to meet Statutory or Regulatory compliance.
All installation works shall comply with: AS/NZS 3000, AS/NZS 3008, AS/NZS 5033, AS/NZS 4777, CEC Guidelines, Victorian Service & Installation Rules and all Jemena Technical Standards.



Cable Schedule										
Section	J	I	H	G	F	E	D	C	B	A
Description	IES to DB3	IES to DB3	IES to DB2	IES to DB1	IES to DB1	IES to DB1	DB3 to MSB	DB2 to MSB	DB1 to MSB	MSB to PoS
Cable Size (mm²) / Details										
Longest Run (m)										
Voltage Rise(%)										
Total Voltage Rise (%)										

Notes:
1. The central protection relay (CPR) shall respond to the parameter settings in Table by disconnecting all IES (new and existing IES) from the installation by automatic operation of a disconnect device.
2. The CPR shall be installed as close to the main switch (grid supply) of the customer's electrical installation as practicable as outlined in AS/NSZ 4777.1:2016 providing a common point of measurement for the entire IES.
3. All IES shall be isolated by a single pad-lockable isolating device. Where there are multiple IES intended to be directly connected to an individual switchboard, there shall only be one main switch (inverter supply) as outlined in AS4777.1:2016.
4. Voltage response modes volt-var and volt-watt shall be enabled and align with Region Australia A settings as outlined in AS/NZS 4777.2:2020.
5. During commissioning of an AS/NZS 4777.2:2020 compliant inverter, Region Australia A is required to be selected and configured.

Installation Company:
Address:
Contact Number:
Email:
CEC Designer and Accreditation Number:

Project Name:
Customer Name:
Supply Address:
NMI:

Prepared	Reviewed	Approved

Drawing No.	Date:	Rev.

Equipment Schedule

Total System Capacity (kVA):
(Rating of all inverters)
Total Export Capacity (kVA):

PV Inverter Details
Manufacturer:
Model Name:
Model Number:
Rating (kVA):
Total Number of Inverters:

Battery Inverter Details
Manufacturer:
Model Name:
Model Number:
Rating (kVA):
Total Number of Inverters:
Export capability: yes/no

PV Panel Details
Manufacturer:
Model Name/Number:
Total Number of PV Panels:
Individual Panel Rating (Watts):

Battery Details
Manufacturer:
Model Name/Number:
Rating (kWh):

Export Limit Device
Manufacturer:
Model Name:
Model Number:

Central Protection Relay Details
Manufacturer:
Model:

Central Protection Relay Settings

Protection Function	Recommended Settings	Maximum Disconnection Time
Sustained over voltage (10 min average)	255 V (ph-n)	15 sec
Over voltage (V>)	260 V (ph-n)	2 sec
Under voltage (V<)	180 V (ph-n)	2 sec
Over frequency (F>)	52 Hz	2 sec
Over frequency (F<)	47 Hz	2 sec
Vector shift	8°	2 sec
Rate of change of frequency (ROCOF)	1 Hz/s	2 sec
Reconnection delay (1)	–	60 sec
Current unbalance (2)	21.7 A	2 sec

NOTE 1 Inverter can only be reconnected to grid when voltage and frequency have been maintained within specified limits for at least 60 seconds.

NOTE 2 Not applicable when using ONLY AS4777 approved three phase inverters

Inverter Protection Settings: **Region Australia A**

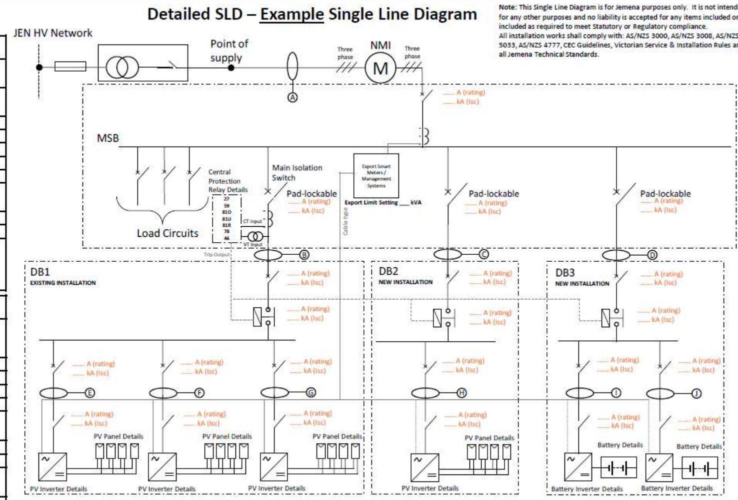
Protection Function	Protection Function Limit	Trip Delay time	Max Disconnection Time
Undervoltage (V<)	180 V (ph-n)	10 s	11 s
Undervoltage (V<<)	70 V (ph-n)	1 s	2 s
Overvoltage 1 (V>)	265 V (ph-n)	1 s	2 s
Overvoltage 2 (V>>)	275 V (ph-n)	-	0.2 s
Sustained Overvoltage (10 minutes)	258 V (ph-n)		3 s
Under-frequency (F<)	47 Hz	1 s	2 s
Over-frequency (F>)	52 Hz	-	0.2 s
Active anti-islanding (loss of mains)	-	-	2 s
Vector shift	60° (1), 20° (2)		2 s
Rate of Change of Frequency (ROCOF)	4.0 Hz/s	-	0.25s
Reconnection delay	60 sec		

NOTE 1: 60° - Single Phase disturbance.

NOTE 2: 20° - Three Phase disturbance.

Detailed SLD – <u>Example</u> Single Line Diagram

Note: This Single Line Diagram is for Jemena purposes only. It is not intended for any other purposes and no liability is accepted for any items included or not included as required to meet Statutory or Regulatory compliance.
All installation works shall comply with: AS/NZS 3000, AS/NZS 3008, AS/NZS 5033, AS/NZS 4777, CEC Guidelines, Victorian Service & Installation Rules and all Jemena Technical Standards.



Cable Schedule

Section	J	I	H	G	F	E	D	C	B	A
Description	IES to DB3	IES to DB3	IES to DB2	IES to DB1	IES to DB1	IES to DB1	DB3 to MSB	DB2 to MSB	DB1 to MSB	MSB to PoS
Cable Size (mm²) / Details										
Longest Run (m)										
Voltage Rise(%)										
Total Voltage Rise (%)										

Notes:
1. The central protection relay (CPR) shall respond to the parameter settings in Table by disconnecting all IES (new and existing IES) from the installation by automatic operation of a disconnect device.
2. The CPR shall be installed as close to the main switch (grid supply) of the customer's electrical installation as practicable as outlined in AS/NSZ 4777.1:2016 providing a common point of measurement for the entire IES.
3. All IES shall be isolated by a single pad-lockable isolating device. Where there are multiple IES intended to be directly connected to an individual switchboard, there shall only be one main switch (inverter supply) as outlined in AS4777.1:2016.
4. Voltage response modes volt-var and volt-watt shall be enabled and align with Region Australia A settings as outlined in AS/NZS 4777.2:2020.
5. During commissioning of an AS/NZS 4777.2:2020 compliant inverter, Region Australia A is required to be selected and configured.

Installation Company:
Address:
Contact Number:
Email:
CEC Designer and Accreditation Number:

Project Name:
Customer Name:
Supply Address:
NMI:

Prepared	Reviewed	Approved

Drawing No.	Date:	Rev.

EXAMPLE

APPENDIX B: REQUIREMENTS FOR APPLICATION DOCUMENTS

Protection Schematic

- Ensure it is site specific and aligns with single line diagram;
- Show current rating for the contactor or MCCB;
- Show protection schematic of master central protection relay and all slave contactors (if applicable);
  - Show communication cable between them and label its type (if applicable)
  - Show any communication devices (if applicable) which are used in protection and control schemes
- Show NMI and site address;
- Show customer's company name; and
- Show designer's company name and address.

Site Layout

- Ensure it is site specific and aligns with single line diagram;
- Show NMI and site address;
- Show customer's company name;
- Show symbols of the following at their physical location:
  - Transformer (if applicable), point of supply, MSB, MDB (if applicable), DB (if applicable), solar DB and all inverters (solar or battery inverters) at their physical location
- Show details of the circuit path between each of the symbol;
- Show roof area of solar panels;
- Clearly label what is new and what is existing;
- Show total solar panel capacity (kVA) and total inverter capacity (kVA); and
- Show designer's company name and address.