

Jemena Electricity Networks (Vic) Ltd

Connection Guidelines for Inverter Energy Systems 30 kVA - 200 kVA

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1	26/02/2016	Initial publication	E. Twining
2	12/01/2018	Recommended protection settings revised to align with AS4777.	E. Twining

Owning Functional Area

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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.
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

EDC	Victorian Electricity Distribution Code
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 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”.

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;
- Energy source may be solar PV, wind turbine or hydro turbine but not 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-4777 compliant and are on the list of approved inverters published by the Clean Energy Council¹.

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 website²;
- 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;
- Energy storage systems including batteries, fuel cells and uninterruptable power supplies (UPS);
- 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 <http://jemena.com.au/industry/electricity/embedded-generation>

³ [http://jemena.com.au/getattachment/25d5d563-1087-4619-ac93-ff2148c6e07a/Embedded-Generation-Guidelines-\(1\).aspx](http://jemena.com.au/getattachment/25d5d563-1087-4619-ac93-ff2148c6e07a/Embedded-Generation-Guidelines-(1).aspx)

2. CONNECTION PROCESS

The connection process is detailed in Jemena’s “Negotiated Connection Process (Embedded Generation)”⁴ and summarised Figure 2–1.

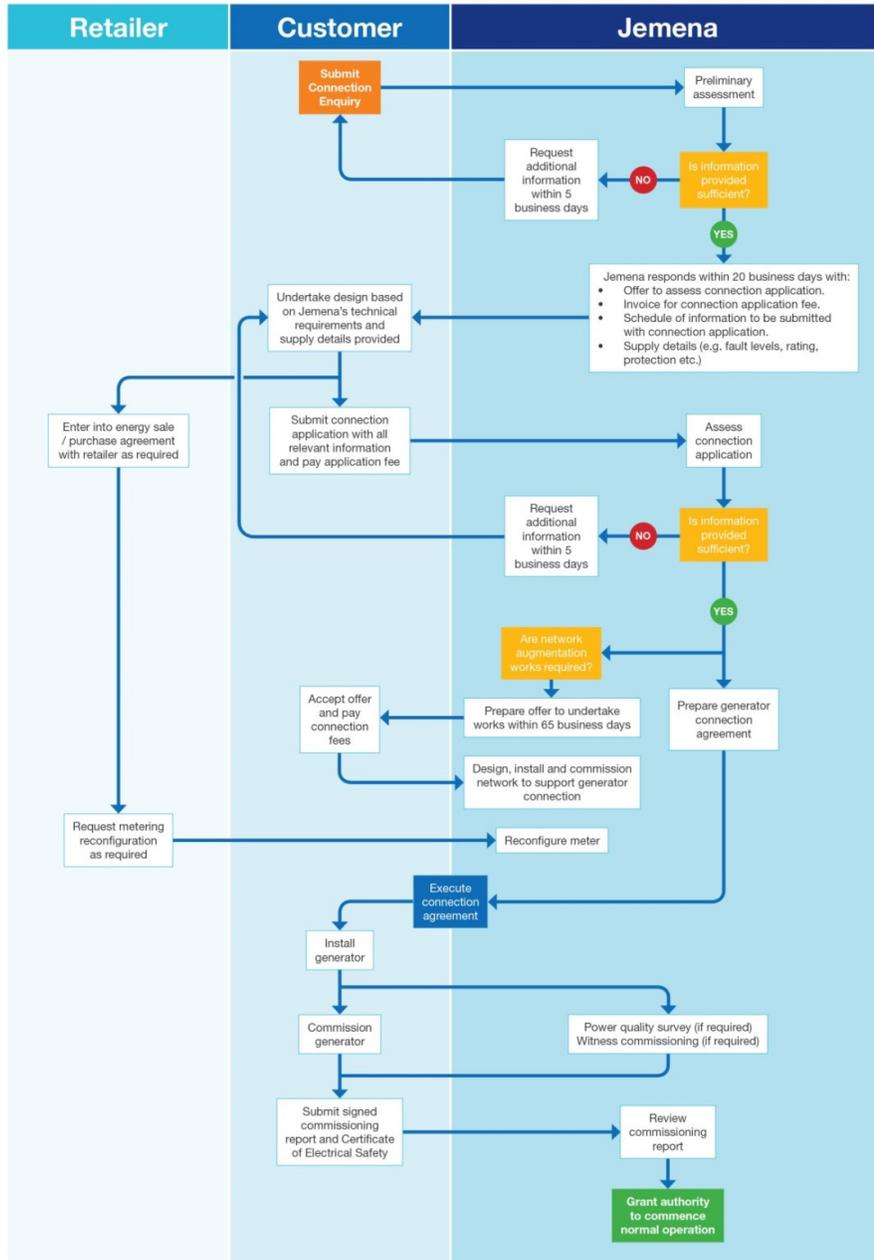


Figure 2–1: Simplified connection process for IES (30 kVA – 200 kVA)

⁴ <http://jemena.com.au/getattachment/54542f87-9e10-4006-a1e2-91dd6149a718/Jemena-Electricity-Networks-Embedded-Generation-Ne.aspx>

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, to 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)

3.2 QUALITY OF SUPPLY

Under the Electricity Distribution Code (EDC), 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 1%, although the level may rise to 2% for a total of 5 minutes in every 30 minute period.

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	+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% 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

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

Table 3–4: Voltage harmonic distortion limits

Voltage at point of common coupling	Total harmonic distortion	Individual voltage harmonics	
		Odd	Even
< 1 kV	5%	4%	2%
> 1 kV and \leq 66 kV	3%	2%	1%

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 (EDC)
	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)
Standards Australia	AS/NZS 4777.1: 2016 Grid connection of energy systems via inverters - Installation requirements
	AS/NZS 4777.2: 2015 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
	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% of network asset capacity i.e. when the total inverter capacity exceeds 30% of the network asset capacity, 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 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 or may isolate the whole installation (i.e. 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 failsafe features that disconnect the 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

The required inverter protection functionality and recommended settings are summarised in Table 4–2. These settings align with those recommended in AS/NZS 4777.2:2015.

Table 4–2: Inverter protection functionality⁵

Protection function	Recommended Settings	Trip delay time	Maximum disconnection time
Under voltage (V<)	180 V (ph-n)	1 sec	2 sec
Over voltage 1 (V>)	260 V (ph-n)	1 sec	2 sec
Over voltage 2 (V>>)	265 V (ph-n)	–	0.2 sec
Sustained overvoltage (based on average value over a 10 min period)	258 V (ph-n)	–	3 sec
Under-frequency (F<)	47 Hz	1 sec	2 sec
Over-frequency (F>)	52 Hz	1 sec	0.2 sec
Active anti-islanding (loss of mains)	–	–	2 sec
Reconnection delay	60 sec		

4.5.4 CENTRAL PROTECTION RELAY

The central protection relay must be installed as close to the main switch of the customer’s electrical installation as practicable. The protection provided by this relay, as detailed in Table 4–3, is in addition to and separate from the inverter protection.

⁵ Source: AS/NZS 4777.2:2015 Table 13 “Passive anti-islanding set-point values”.

Table 4–3: Central protection relay functionality⁶

Protection function	Recommended settings	Maximum disconnection time
Sustained over voltage (based on average value over a 10 min period)	255 V	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 ^{NOTE 1}	–	60 sec
Current unbalance ^{NOTE 2}	21.7 A	≤ 2 sec

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.

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).

⁶ 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”.

4.7 HARMONIC INJECTION LIMITS

In addition to the inverter harmonic current limits specified in AS4777.2:2015⁷, the customer must keep harmonic currents at the Point of Common Coupling below the limits defined in the EDC⁸, as reproduced in Table 4–4. 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 4–4: Harmonic current distortion limits

I _{sc} /I _L	Maximum harmonic current distortion in percent of I _L					Total Harmonic Distortion
	Individual harmonic order “h” (odd harmonics)					
	< 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%

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.

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

- The supply distribution substation or LV circuit already has a high level of solar PV penetration (typically greater than 30%);
- 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%.

⁷ AS/NZS 4777.2:2015 Clause 5.6.

⁸ Electricity Distribution Code Clause 4.4.3.

4 - TECHNICAL REQUIREMENTS

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 volt response mode⁹ – inverter varies either its real or reactive output in response to measured voltage;
- Enabling inverter power factor / reactive power mode¹⁰ – 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.

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.

⁹ AS4777.2 Clause 6.3.2

¹⁰ AS4777.2 Clause 6.3.3

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 factored into the connection application fee and the customer will be notified of the requirement at the connection enquiry 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 4777.2:2015 compliant inverters. However where the default inverter settings have changed to align with AS/NZS 4777.2:2015, evidence should be provided to confirm settings have been set as agreed with Jemena (an attached configuration file or screen shots are acceptable).

5.1.3 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;
- 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 (if enabled); and
- Voltage response / power factor profile (if response mode is enabled).

Note that bench testing of central protection relay is acceptable providing end-to-end functionality is confirmed on site with a loss of mains test.

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.

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 3 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.

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 form¹¹ 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 form¹²;
- Detailed Single Line Diagram (SLD) including inverters, central protection relay and connection to Jemena network. The SLD should clearly label the lockable generator isolating device. (Refer to Appendix B for sample SLD).
- Site layout diagram highlighting location of panels, inverters and lockable generator isolating device.
- Design report including:
 - Inverter and central protection relay manufacturer and model details;
 - Proposed inverter and central protection relay protection settings including settings calculations and operate times;
 - Maximum export to JEN network;
- Voltage rise / drop calculations between inverters, main switchboard, and point of supply; and

¹¹ <http://jemena.com.au/getattachment/a2b4e6ab-521e-458a-8dc0-e525b6eb8dc8/Embedded-Generation-Connection-Preliminary-Enquiry.aspx>

¹² <http://jemena.com.au/getattachment/b83a24de-3720-4fdb-a1d1-70063b304ccf/Application-for-Embedded-Generation-Connection.aspx>

- Commissioning program.

6.3 COMMISSIONING

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

- Signed and dated commissioning report; and
- Certificate of Electrical Safety to demonstrate that the generator installation has been inspected by a licensed electrical inspector.

APPENDIX A: SAMPLE SINGLE LINE DIAGRAM

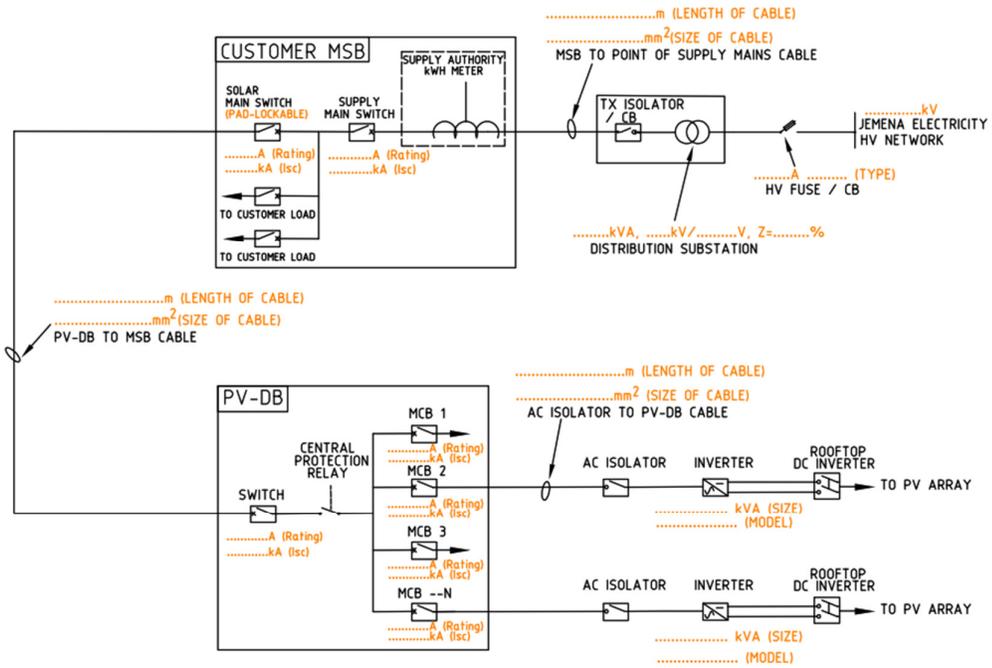


Fig: SAMPLE SINGLE LINE DIAGRAM FOR SOLAR PV CONNECTION (30 kVA TO 200 kVA)