
# Customer Guidelines for Embedded Generation of Rating Up to 1 MW

September 2006

## Introduction and Purpose

These guidelines are intended to cover the installation of private generating sources of capacity up to one megawatt (1.0 MW) which customers wish to connect to the Powercor grid.

It is intended that such generating sources be allowed to be connected to the grid on the basis that:

- The customer, if they intend to export electricity into the Powercor grid, do so under a Network Connection Agreement with Powercor and a contractual arrangement with their Retailer.
- The customer still requires a supply of electricity from the Powercor grid for at least part of the time.

The guidelines have been prepared in order to:

- Promote customer installations which are safe for both the customer and for Powercor line maintenance personnel.
- Protect customer installations against damage under fault conditions.
- Ensure that other Powercor customers are not exposed to hazards or to disruptions of supply.

Sister documents provide guidelines for smaller plant, up to 20 kW in capacity, which incorporate sine wave dc/ac inverters for grid connection, and for generators above 1 MW which are intended to operate in parallel with the Powercor grid with significant export of power.

## Powercor Policy

Powercor is supportive of initiatives by electricity customers to install environmentally – friendly generating sources and will allow such installations to be interconnected with the grid provided that:

- Reliability and quality of the grid supply to other customers is not adversely affected.
- The safety of other customers and of Powercor employees and contractors is not put at risk.
- The customer's plant is of an approved design and capable of operating for extended periods.

Retailers have already introduced various programs through which customers may support the use of renewable resources on a larger scale for the generation of electricity.

600 kW generating plant fuelled by biogas

## Customer Equipment Types

The types of generating equipment covered by these guidelines include, but are not limited to the following:

- Photovoltaic arrays, fuel cells and other sources which are connected to the customer's loads and to the grid by dc/ac sine wave inverters.

- Wind generators which are connected to the mains by asynchronous generators or by static frequency converters.

- Synchronous generators driven by hydro turbines.

- Synchronous generators driven by gas engines, gas turbines or diesel engines.

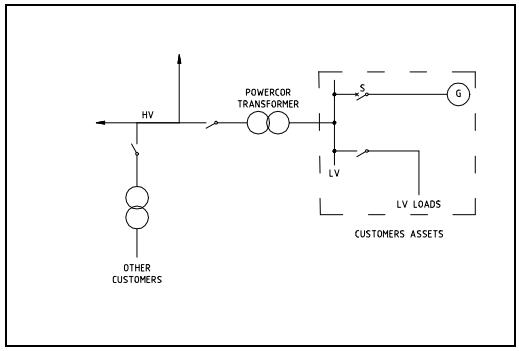
The last mentioned category includes commercial standby generating plant which is operated in parallel with the grid either by arrangement with Powercor for purposes of demand management or for routine on-load testing.

Rotating generators of rating greater than 50 KW should be of the synchronous type having an internal source of field excitation. Asynchronous (induction) generators above this rating may unduly load the grid and may not be connected to the grid without Powercor's specific agreement.

The details of the local network may require additional limitations.

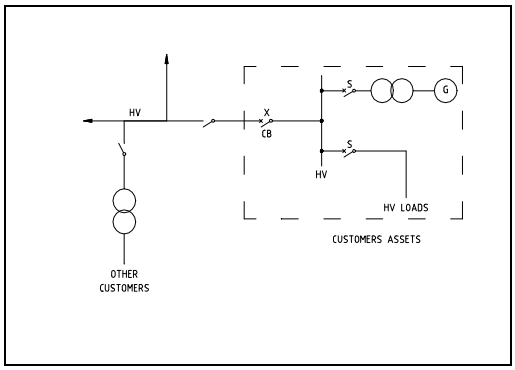
Typical generator examples are shown in the diagrams below:

**Arrangement A** represents a property supplied from a dedicated Powercor transformer. The embedded generator or inverter-connected source is connected to the customer's main switchboard and may export to the Powercor grid. An export limit of less than 1MW may apply, depending on the rating of Powercor's transformer.



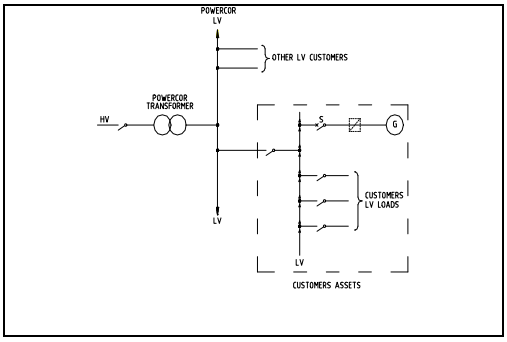

*Arrangement A- LV Customer*

**Arrangement B** represents a commercial or industrial premises having a high voltage distribution system. The embedded generator is connected to the customer's high voltage main switchboard and may export to the Powercor grid. Under these guidelines, a connected synchronous generator may be of rating up to 1MW.




*Arrangement B- HV Customer*

**Arrangement C** represents a commercial or industrial premises having a low voltage distribution system. The embedded generator or inverter-connected source is connected to the customer's low voltage main switchboard and may export to the Powercor grid both at low voltage, and at high voltage via Powercor's distribution transformer. In this case an export limit of less than 1MW may apply regardless of the generator type. This limit is determined by the local low voltage network and/or the rating of Powercor's transformer.




*Arrangement C- LV Customer*

In all cases the following safeguards are needed to prevent danger to life and damage to your equipment:

- Your generating plant, regardless of type, must be prevented from back-feeding the Powercor network if the mains supply is externally de-energised.

- Your generating plant, if of the synchronous type, must be prevented from connection out-of-phase onto the energised Powercor mains.

- Your equipment must include protective devices which will, in the event of a short circuit or other fault on your generator, disconnect your plant from the mains so that it will not be further damaged by large fault currents flowing from the external grid.

- Your equipment should be protected against incoming surges which may be caused by a lightning strike on overhead Powercor lines.

Your generating plant must also be equipped with controls which enable satisfactory operation over a variation in grid voltage. Under the Electricity Distribution Code, steady state grid voltage at the point of supply to the customer may vary by up to plus/minus 6% of nominal value.

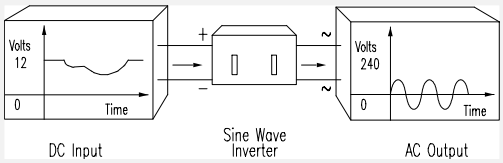
The Electricity Distribution Code also requires that the power factor of a customer's installation at the point of supply falls within the range 0.85 lagging to 0.85 leading when drawing more than 50% of maximum demand . For customers operating embedded synchronous generating plant, Powercor requires that the synchronous generator(s) send out electric power at a power factor in the range 0.85 to 0.95 leading, as measured at the generator's terminals.

**Inverters**

An inverter is an electronic device which converts DC (direct current) power to AC (alternating current) electrical power. The electrical distribution grid uses AC (50 Hz frequency) whilst most small generating equipment such as fuel cells and solar arrays generate DC power. An inverter has thyristors or other types of semiconducting devices to chop the DC source voltage to produce an AC output waveform (for example 24 V DC to 240 V AC, which is suitable for most electrical appliances).

As the output of the inverter usually is not perfectly sinusoidal, the output waveform will contain harmonics and high frequency noise. The harmonics and noise can create telephone interference and also interfere with sensitive equipment connected to the distribution grid near the inverter.

To connect to the Powercor network it must be of the grid interactive type and be approved by Powercor.

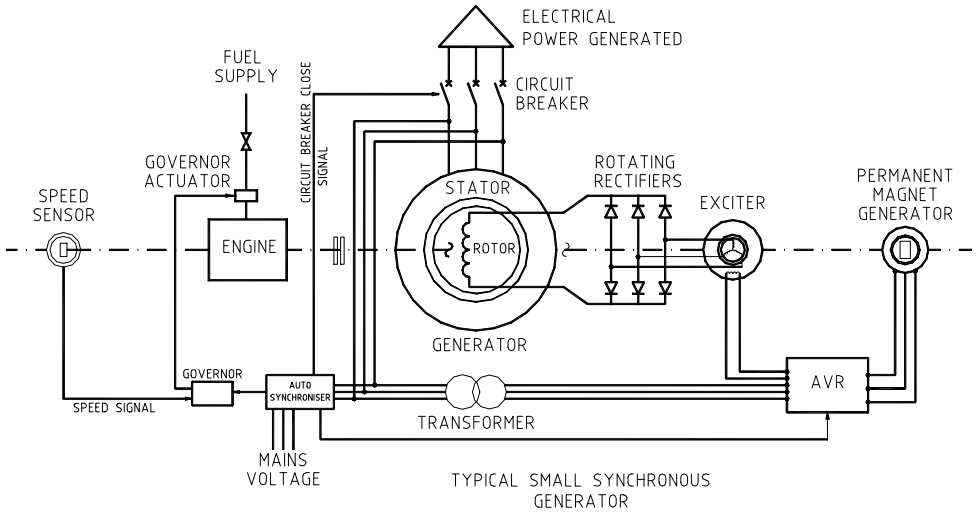


**Synchronous Generators**

A synchronous generator is an AC machine in which the rotor speed, and hence the frequency of the output voltage is constant. The magnetic field of the machine is produced by a dc current, the generation of which requires an auxiliary power supply to the generator.

Synchronous generators can operate connected to the grid or independent of it. To connect to the grid the following equipment is needed:

- Synchronising equipment (usually automatic).
- Automatic Voltage Regulator, which controls the field current.
- Governor, which automatically controls the fuel input to the engine/turbine to to keep speed and power output at the set levels.
- When connected to the grid, a synchronous generator is electrically locked in phase with the external grid.



TYPICAL SMALL SYNCHRONOUS GENERATOR

**Asynchronous Generators**

An asynchronous or induction generator is basically an induction motor driven above synchronous speed by the prime mover. Asynchronous generators usually maintain their magnetic fields by drawing magnetising current from the external grid, which can place additional demands on the grid.

They are not capable of operation isolated from the grid. When connected to long overhead lines safety problems due to over voltage may occur.

**Prime Mover**

Synchronous and asynchronous generators convert mechanical power to electrical power; the prime mover supplies the input mechanical power to the generator. The prime mover may be a turbine or a reciprocating engine. For generators less than 1 MW the prime mover is generally an engine.
Small turbines are usually driven either by the:

- expansion of steam
- combustion of gas
- flow of water (hydro)

Reciprocating engines used for power generation can be driven by:

- natural gas, LPG or biogas
- petrol
- diesel fuel/distillate

**Synchronising Equipment**

The grid voltage and the generator voltage are AC. In the case of synchronous generators, the generator voltage and the grid voltage must remain in phase (synchronised) at all times. If a generator is connected to the grid and a disturbance causes the generator to lose synchronism the generator voltage, current and power will fluctuate greatly.

Other customers connected to the grid will be disturbed; also the generator and the engine/ turbine may be damaged.

A synchronising relay is required to ensure that the generator is synchronised with the grid prior to connection. A pole slipping relay detects the loss of synchronisation and can be used to initiate the disconnection of a generator.

In the case of asynchronous generators, synchronising equipment is not needed.

**Protective Systems**

Protective devices are required to prevent damage to the generator if a fault occurs on the generator or close to it. The types of protection used depend on the size and the importance of the generator. Typical protection installed on generators smaller than 1 MW includes:

- Overcurrent
- Reverse power
- Under/over voltage
- Rotor earth fault
- Stator earth fault
- Under/over frequency
- Loss of synchronism (pole-slipping)
- Loss of mains

Where the generator is connected to the Powercor grid via a distribution feeder equipped with automatic reclosing, the loss of mains protection must disconnect the generator in a time which is safely less than the automatic reclose setting which is typically 3 seconds.

**Surge Protection**

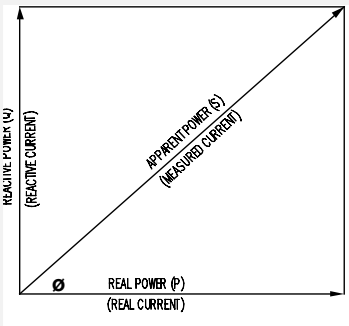
If lightning strikes overhead power lines near a generating plant, the generator insulation is liable to be damaged and requires protective devices to divert the surge away from the generator. Overvoltages may also occur when switching occurs in the power network.

Surge arresters are used to protect equipment from such overvoltages. They are installed in parallel with the equipment they are protecting. They are designed to conduct away surge currents only when a large overvoltage occurs.

**Power Factor**

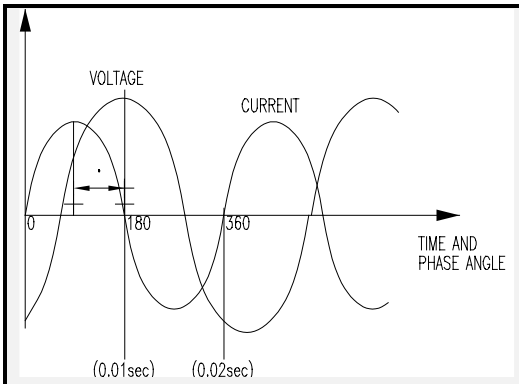
Generators can produce both active and reactive power. Active power carries out useful work whilst reactive power serves only to maintain magnetic and electric fields in the external network. Power factor is determined by the ratio between active power (P) and reactive power (Q). Power factor = cosine [arctan (P/Q)].

Reactive power produced by the generator and exported into the grid can cause additional losses in the distribution system but can also assist in controlling local network voltage. Generators are usually designed to operate over a power factor range of 1.0 to 0.8 leading.




POWER FACTOR DIAGRAM

MEASURED CURRENT IS THE VECTOR SUM OF THE CURRENT WHICH CARRIES REAL POWER (REAL CURRENT) AND THE CURRENT WHICH IS REQUIRED TO MAINTAIN MAGNETIC FIELDS (REACTIVE CURRENT)




**Automatic Voltage Regulators (AVR)**

An AVR controls the output voltage of a generator. The AVR senses the generator terminal voltage and adjusts the generator field current accordingly. The AVR must be able to respond quickly to disturbances to help the generator remain stable and to ensure that the voltage remains within acceptable limits.

**Governors**

Governors monitor the speed and power output of the engine or turbine and adjust the fuel flow via valves to keep the synchronous generator at the correct speed. The generator must operate at 50 Hz or otherwise it would lose synchronism with the grid.

Governors also control the power output of the generator.

**Planning and Selection**

Powercor is not able to offer assistance in the planning and selection of your proposed generating equipment other than the advice relating to the interface with the Powercor grid.

The Sustainable Energy Authority Victoria(SEAV) has details of Accredited Consultants and

Suppliers who are experienced in this area.

You are strongly advised to carefully estimate your equipment costs and continuing running costs to ensure that your installation is financially viable if you intend to export electricity into the grid.

Be careful to purchase generating equipment having a suitable technical specification and which is equipped for interconnection with the grid (see technical boxes below).
The following equipment selections are subject to Powercor's approval:

- Sine wave inverters.
- Anti-backfeed protection.
- Governing, excitation and synchronising equipment (synchronous generators)
- Interconnecting switchgear and associated protection relays.

**Installation and Connection to Grid**

The installation of generating sources should always be carried out strictly in accordance with the manufacturer's recommendations, and must meet the requirements of your local council's planning and building departments.

The use of inflammable fuels is subject to state government regulation, as are the emission of exhaust gases and noise.

The electrical controls, cabling and connection to the Powercor grid must be carried out by a registered electrical contractor.

Your new installation must be checked by a licenced electrical inspector prior to connection to the Powercor grid.

Where it is wished to export more than 20 KW into the Powercor grid, your plant must generate three phase ac power. For connection to the grid, you must confirm with Powercor that a three phase line is available to your premises.

Your new installation may not be connected to the Powercor grid prior to the successful completion of tests at your premises which must be witnessed by a Powercor officer.

**Generating Plant Fuelled by Gases or Inflammable Liquids**

If your installation uses an engine, gas turbine, fuel cell or other equipment which is fuelled by natural gas, LPG, biogas, petrol, diesel fuel, distillate or other inflammable source, you are obliged to comply with the following regulations (where applicable):

- Gas installation code (AG601)
- Code for industrial and commercial gas-fired appliances (AG501)
- EPA policy on noise emissions
- EPA policy on atmospheric emissions
- MFB and CFA requirements
- Local municipal planning and building regulations

Where electrical equipment (including generators) are located at or close to sources of inflammable gas or vapour, it is also necessary to follow the Hazardous Area Standards (see Standards Association Of Australia HB13) in order to mitigate risks of explosion. For generating plant it is common to provide protection ventilation (AS1482) and to exclude as many electrical accessories as possible from the hazardous area.

***Notes to your Electrical Contractor***

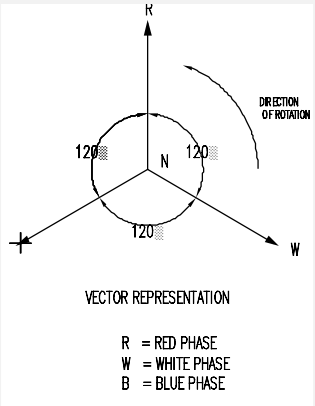
1. *Electrical installation work for generating plant fuelled by gases or inflammable liquids should not be commenced without a documented design which takes into account the requirements of the above codes and standards.*

2. *You are advised to confirm that the proposed grid interface equipment (switchgear,protective systems,sine wave inverters, synchronous generator ancillary equipment, etc) are of types approved by Powercor.*

**Three phase and Single phase power**

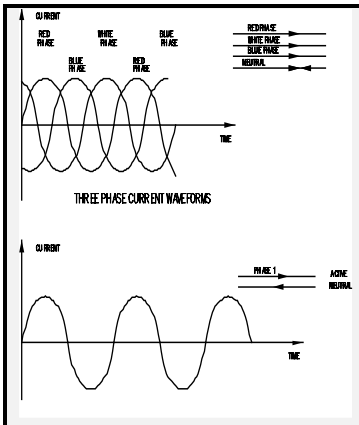
Generally all power is distributed in three phases. A vector representation of the three phases is shown below. Each phase voltage is of equal magnitude but separated by 120° from the other phases. For a low voltage (LV) system the line to line voltage is 415 V. An industrial site generally has a 3 phase connection.

The power supply connected to most houses is single phase. That is, only one of the 3 phases and the neutral is connected to the house distribution board. The phase to neutral voltage is 240 V, which is 415 V divided by the square root of 3.




VECTOR REPRESENTATION

R = RED PHASE
W = WHITE PHASE
B = BLUE PHASE




**Site Test Requirements**

Prior to the installation being connected to the grid electrical, tests will be required to be performed by a registered electrical contractor or licensed electrical inspector. The number and type of tests required depends on the whether the installation is high or low voltage. Typical tests performed are:

- Earthing system resistance
- Insulation resistance
- High voltage test
- Performance test of AVR and governing systems
- Functional test of all protective relays
- Functional test of all safety circuits and interlocks

**Powercor Responsibilities**

- Powercor is responsible for the safe and reliable transport of electricity to your premises and to the premises of all its other customers.

- Powercor reserves the right to inspect your installation by prior arrangement.

- Powercor may be obliged to disconnect your generating plant if it is causing nuisance to other customers connected to the grid.

**Customer Responsibilities**

- The customer is responsible for the safe installation, operation and maintenance of his generating source. The installation must conform to Australian Standards, AS/NZ 3000:2000, and the Service & Installation Rules and should be regularly inspected and maintained in accordance with the manufacturer's instruction manuals.

- The customer is responsible for the safety of any person operating or maintaining generating equipment and accessories which are on his premises.

- The customer is responsible for fitting adequate protective devices to prevent damage to his generating equipment under conditions of short circuit, voltage surges or other faults.

- The customer is responsible for meeting all current codes and regulations dealing with the storage and use of inflammable fuels, with levels of noise and atmospheric emissions, and with personnel safety and health.

***Victorian Electricity Distribution Code***

*The Electricity Distribution Code, which is administered by the Essential Services Commission, further defines the responsibilities of Distributors and their Customers. The Code, which considers embedded generators in Chapter 7, is available at website http//www.esc.vic.gov.au/*

**Energy Pricing and Metering**

Subject to approval of your proposed installation, Powercor will enter into a Network Connection Agreement. You will need to enter into an agreement with a Retailer to purchase electricity which is exported into the grid. The agreement would typically cover the price paid by the Retailer, hours of operation, and total annual amount of electricity.

The form of the Network Connection Agreement may be obtained from your local Powercor customer connection adviser.

When your generator is in operation, you will experience: reduction in your imported electricity, which may approach zero export of surplus electricity into the grid.

Exported electricity must be separately metered so that the correct payments may be made.

A project fee and Network extension works costs will be applied for interconnection of generating sources to the Powercor grid.

Metering arrangements must be made with your relevant Retailer.

The Retailer will arrange to have electronic metering installed at your premises which will separately meter energy (kilowatt hours) which is drawn from the grid and energy which is exported into the grid.

The provision of this metering will typically incur a metering fee. Contact your Retailer for Metering Fees.

**Forms of Agreement**

1. All generating customers located within Powercor's boundaries must enter into a Network Connection Agreement with Powercor for connection to the Powercor grid. Where modifications to the local grid are needed to accommodate your generating plant, you must also enter into an Extension Works contract


2. You also need an Agreement with your relevant Retailer for the sale and purchase of electricity.

   Your local customer connection adviser will discuss these forms with you.

**Installation Approvals**

The embedded generation installation will need to be inspected by a licensed electrical inspector and Powercor Engineer. The Office of the Chief Electrical Inspector maintains a listing of licensed electrical inspectors.

**Communications and Attendance**

Powercor operations and maintenance personnel may need to contact you at short notice prior to carrying out any urgent maintenance work on the nearby network.

Safety considerations may require a visit to your premises by Powercor operations personnel to check the status of your generator installation. On application, you will be asked to provide contact details for these purposes.

**Insurance**

Most building insurance policies will not cover risks associated with generating plant.

You are advised to contact your own insurance company to check coverage and make additional arrangements.

**Operation and Maintenance**

Your equipment should be regularly inspected and maintained in accordance with the manufacturer's guidelines.

**Maintenance and Operation of Gas-fuelled Prime Movers**

For safety reasons, the maintenance of gas-fuelled generating plant should only be carried out by specialist maintenance engineers who are experienced and qualified in the field.

**Application Form**

Customers seeking to install electrical generating plant must fill out the application form to be obtained from your local Powercor customer connection adviser.

Please provide all details requested on the form in order to avoid delays in approval.

The customer connection adviser will ask that details of your equipment (see the listing P 17) be attached to your application. He will also ask for a sketch of the electrical wiring proposed by your electrical contractor (see the examples included). For most generator installations, the customer connection adviser will wish to convene a meeting with a Powercor engineer present.

For customers residing within Powercor's boundaries the name of the retailer must be stated. Powercor will forward a copy of its Notice of Approval to the nominated retailer.

**Information and Queries**

Refer Information Sheet.

**Disclaimer**

While Powercor makes efforts to ensure that this information and material is current and accurate, the information and material is provided to you on the understanding that:

- Powercor makes no warranty, guarantee or promise, express or implied, in relation to the content or accuracy of this information and material.
- You will seek verification and/or professional advice from an independent source before relying on or acting upon any of this information and material.
- Powercor is not liable or responsible in any way for the results of any actions taken on the basis of this information and material.

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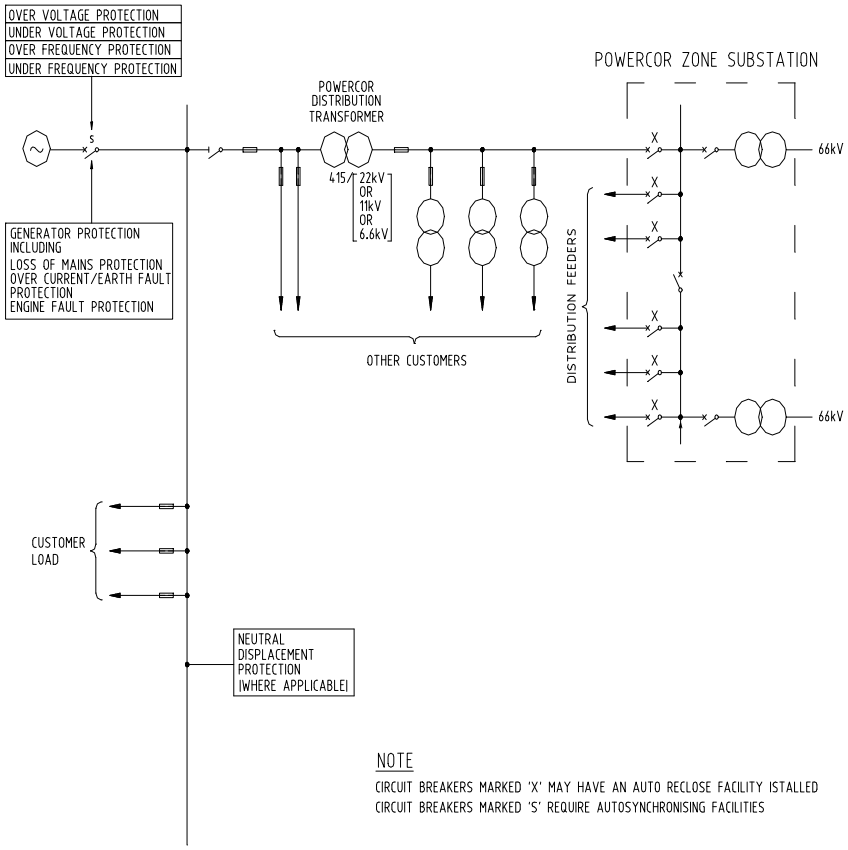


**Example:- LV Grid Connection**

# Information Sheet

For general advice and information on Accredited Consultants and Suppliers please contact the Sustainable Energy Authority(SEAV) on **1300 363 744**.

**To Contact Powercor**
(For Grid Connection)

| | |
|---|---|
| **Customer Enquiries:** | **132 206** |
| Service Difficulties & Faults: | 132 412 |
| Business Customer Enquiries: | 132 334 |
| New Connections: | 1300 360 410 |
| Interpreter Service: | 131 450 |

**Head Office**

Powercor Australia Ltd
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Fax: +61 3 9683 4499

Postal Address:
Locked Bag 14090 MCMC
Melbourne Victoria 8001

**Other Powercor offices are located at:**

| | |
|---|---|
| Ballarat | Norman Street, Ballarat |
| Bendigo | 601-611 Napier Street, Bendigo |
| Geelong | Roseneath Street, North Geelong |
| Horsham | 17 McLachlan Street, Horsham |
| Mildura | Eleventh Street, Mildura |
| Shepparton | 8–10 Wheeler Street, Shepparton |
| Sunshine | 20 Hertford Road, Sunshine |
| Warrnambool | 7 Strong Street, Warrnambool |

**Electrical Measurement Units**

| *Quantity* | *Unit* | *Unit Symbol* |
|---|---|---|
| *Current* | *ampere* | *A* |
| *Potential Difference* | *volt* | *V* |
| *Power* | *Kilowatt* | *kW* |
| *Reactive Power* | *Kilovar* | *kVAr* |
| *Apparent Power* | *kilovoltampere* | *kVA* |
| *Frequency* | *hertz* | *Hz* |
| *Energy* | *kilowatthour* | *kWh* |

***Glossary of Terms***

| | |
|---|---|
| *grid* | *the electrical distribution network* |
| *DC* | *Direct current. The direction of current flow does not change.* |
| *AC* | *Alternating current. The direction and magnitude of current oscillate to a sine wave function.The Australian grid operates at 50 Hz (50 oscillations per second); USA and some other countries operate at 60 Hz.* |
| *Inverter* | *An electronic device that converts DC power to AC power. A sine wave inverter produces a sine wave output with very low harmonic distortion* |
| *Renewable electricity* | *Power that comes from a renewable source such as solar, hydro and wind.* |
| *Voltage Regulation* | *The drop in voltage between no load and full load.* |
| *Voltage Regulator* | *(for a synchronous generator) The ancillary device which controls the dc field current of the machine in order to regulate the output ac voltage of the machine to a set value regardless of the load current.* |
| *Governor* | *A control device on a reciprocating engine or turbine which regulates the flow of fuel to produce a set power output at a given speed.* |
| *Retailer* | *The supplier of electrical energy (as a market commodity) to a customer in any location.* |

| | |
|---|---|
| *Distributor* | *The owner and operator of the electricity distribution network (grid) to which the customer is connected. The retailer's energy must be delivered to the customer via the distributor's poles and wires (network); the distributor charges for this service.* |
| *Embedded Generator* | *An entity which owns and operates generating plant which is connected to the distribution network and not to the transmission network. Embedded Generators do not trade on the National Electricity Market but sell their export electricity to retailers.* |
| *Efficiency* | *Output power divided by input power.* |
| *Harmonics* | *Whole numbered multiples of the fundamental frequency. For example, the fifth harmonic = 5 x 50 Hz = 250 Hz.* |
| *Total Harmonic Distortion* | *The square root of the sum of all the harmonic components, divided by the fundamental component.* |

* Powercor Australia Ltd ABN 89 064 651 109

**Application Information:- Grid Connection**
(Embedded Generation Up to 1 MW)

Name: Telephone No:

Address:

Account No: Electricity Retailer:

National Metering Identifier No.(NMI)

**Energy Generation Source:**
(Eg Biomass, Wind, etc)

**Supplier(s) of Generating Equipment:**

. Electrical Consultant - Telephone No:

. Electrician - Telephone No:

**Equipment Details**

For Rotating generator

- Driving machine:
- Fuel:
- Generator manufacturer:
- Model no:
- Continuous rating (kVA):
- Voltage:
- No. of phases:
- Type of excitation:
- AVR Model No:
- Type of engine governor:
- Governor Model No:
- Protective devices (list)
- Autosynchroniser Model No:

For Grid Connection via Inverter

- Type of Inverter:
- Manufacturer: Rating(W):
- Inverter Model Name: Model No:
- Compliance Number:

**Proposed Point of Connection:**

**Proposed Protective Device at Point of Connection:**

**Other Installation Details:** ( Additional Sheets if necessary)

**Circuit Diagram**(Refer Examples)