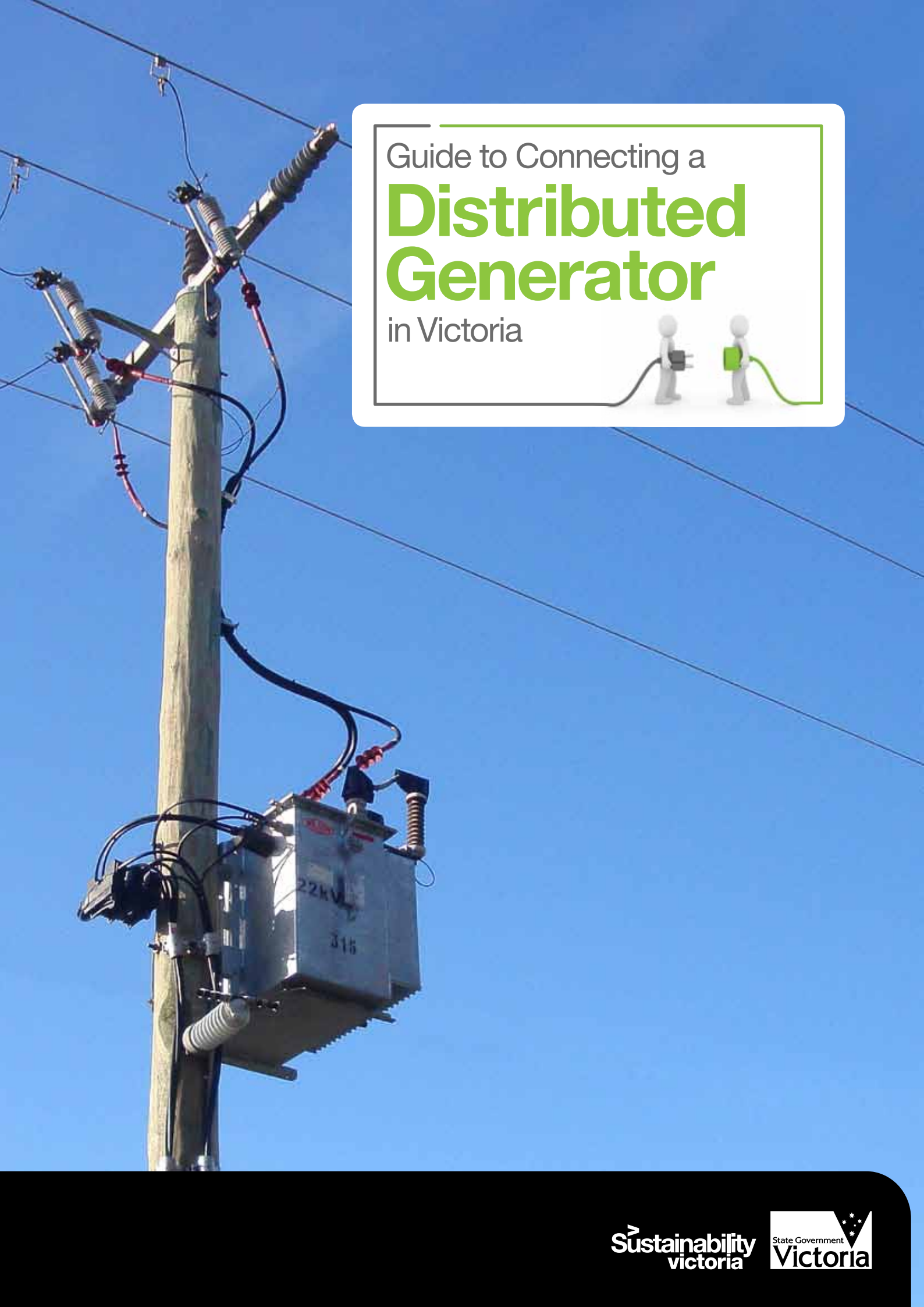


Guide to Connecting a

Distributed Generator

in Victoria



Acknowledgements

Sustainability Victoria wishes to acknowledge the following people and organisations for their support in the preparation of this Guide:

Bruce Thomson, Moreland Energy Foundation Limited
Faye Adams, City of Manningham
Mathew Dixon, City of Boroondara
Steven Peters, VicUrban
Karen Hucker, City of Yarra
Michelle Bennet, City of Darebin
Joe Thomas, CitiPower/Powercor
Peter Dobson, Department of Primary Industries

Disclaimer: The information in this guide is intended to be used as a resource to assist the application process towards obtaining an agreement to connect a generator to the electricity distribution network. Applicants should not rely solely on the information provided in this guide, as there may be issues outside of what has been mentioned that may influence the process.

ISBN 978-1-920825-22-5 (Paperback)

ISBN 978-1-920825-23-2 (PDF)

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1. Introduction



This guide aims to help prepare you for applying and connecting a generator to the electricity distribution network in Victoria. It outlines how to follow relevant rules and regulations and explains how to negotiate a connection or a network access arrangement with your distribution network service provider (DNSP).

In Victoria the majority of electricity is produced by large generators in the Latrobe Valley. The generated electricity is carried by the state-wide and national transmission network that operates at very high voltages over long distances.

The cost of generation, transmission and distribution of electricity has been increasing, prompting interest from Victorian businesses and consumers to invest in small to medium-scale generators. Examples include rooftop solar, cogeneration of heat and power and bioenergy plants.

These distributed generators usually connect to the local distribution grid that supplies power directly to residential and commercial premises.

In Victoria, distributed generation (DG) is formally known as embedded generation (EG) as these generators are embedded into the distribution network. The two terms are interchangeable and in this guide distributed generation is used.

This guide presents a five step process for connecting a small to medium-scale generator to the electricity distribution grid ('poles and wires'). It outlines your role, the DNSPs role and highlights issues and problems that may arise.

1.1 The scope of this guide

This guide covers generators with a supply capacity of between 10 kW and 10 MW suitable for connection to the distribution grid at voltages between 400 volts and 22,000 volts. The generators may be located at a business premises and connected on the customer side of the utility meter (e.g. gas cogeneration) or connected directly to the distribution grid (e.g. small wind farm).

The guide includes information about which companies and regulatory authorities oversee electricity grid connections.

This guide does not cover the connection of small solar photovoltaic (PV) systems 10 kW or less to the grid via an inverter. Small PV systems have a simpler agreed connection process, provided the inverter is covered under the Australian Standard AS 4777 - *Grid Connection of Energy Systems via Inverters*.

This is not a comprehensive technical guide.

You may need to refer to a detailed technical guide¹ or seek technical advice on electrical grid connections.

Note: Distribution network providers do not buy or sell electricity. If you anticipate exporting electricity you will need to negotiate a commercial power purchase agreement with a licenced energy retailer.



1. For example, *Guide for the Connection of Embedded Generation in the National Electricity Market*, Australian Business Council of Sustainable Energy 2003.

2. Who to deal with to successfully connect

Regulatory agencies, energy retailers and distributors have roles in granting you approval to connect a generator to the electricity distribution network.

Your local distribution network service provider or DNSP owns and operates the grid and is therefore your most important contact point.

Only your local DNSP can give you approval to connect your generator to the electricity distribution network. The terms of your approval will be outlined in a contract between you and your DNSP known as a Connection Agreement. You need to understand exactly what information the DNSP needs before you apply for a connection. It is strongly recommended that you begin discussions with your local DNSP as early as possible.

2.1 Who is my DNSP?

There are five DNSPs in Victoria, each responsible for a geographic area, so there is no need to choose your DNSP. You must deal with the network owner where your generator will connect to the grid.

The five Victorian DNSPs are:

- CitiPower — www.powercor.com.au
- Powercor — www.powercor.com.au
- Jemena — www.jemena.com.au
- United Energy — www.ue.com.au
- SP AusNet — www.sp-ausnet.com.au

The maps in Figure 1 provide an overview of DNSP operational boundaries. All five DNSPs have online resources on connecting a generator to the network, such as connection forms.²

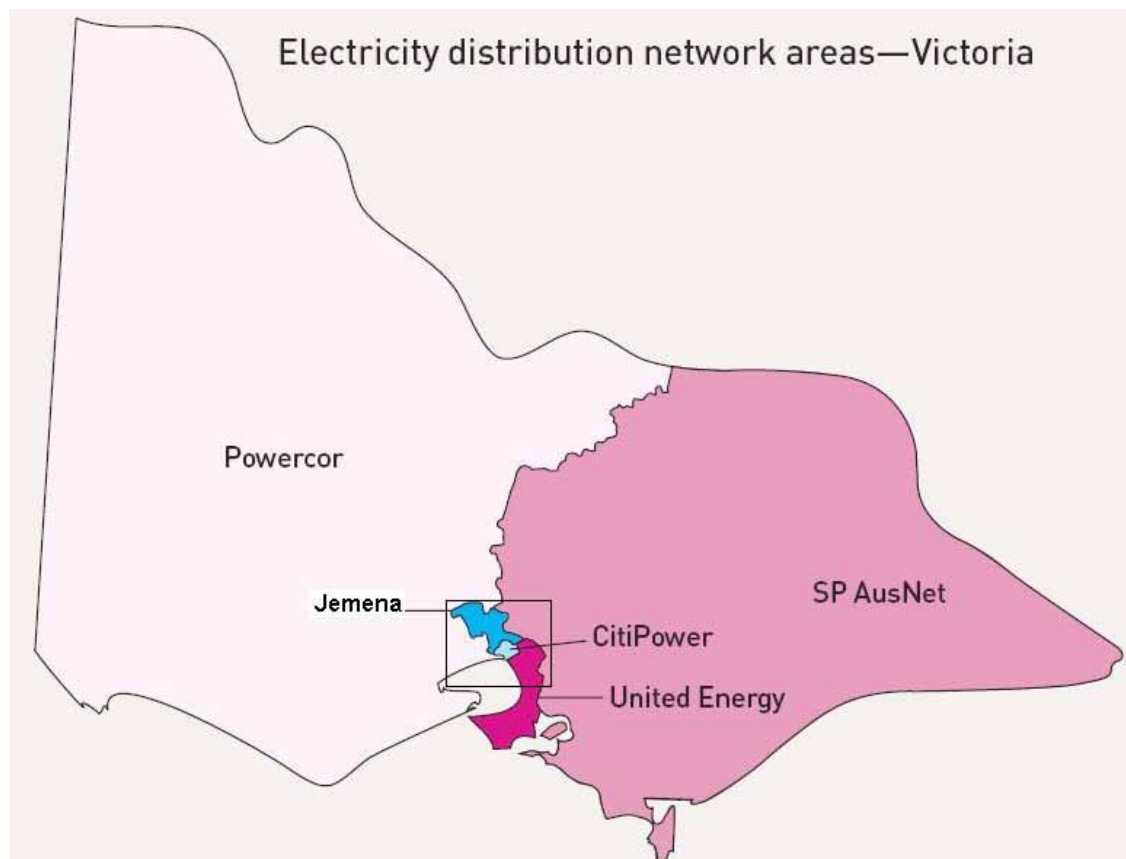


Figure 1: Victorian DNSP operational boundaries

2. Maps adapted from distribution and transmission connection planning reports published by Victorian distribution businesses and those published by the ESC.

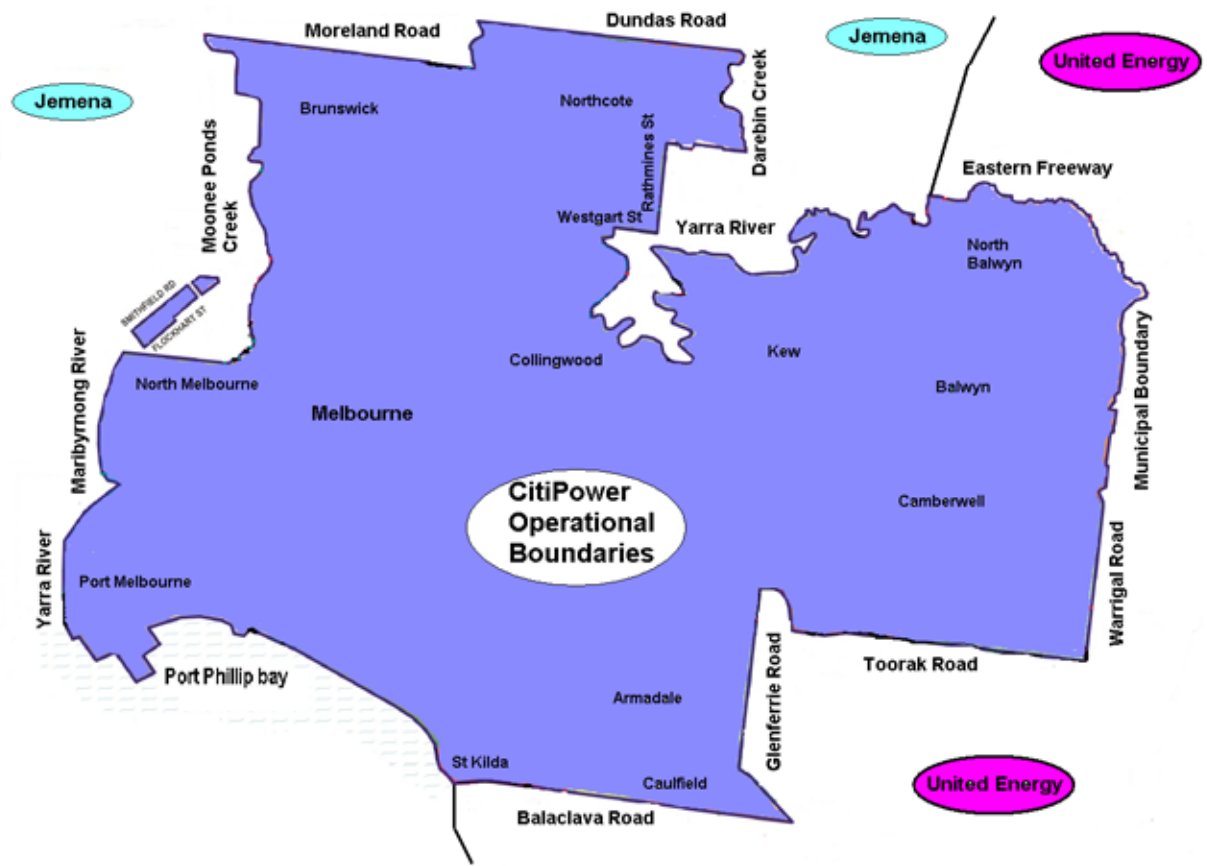
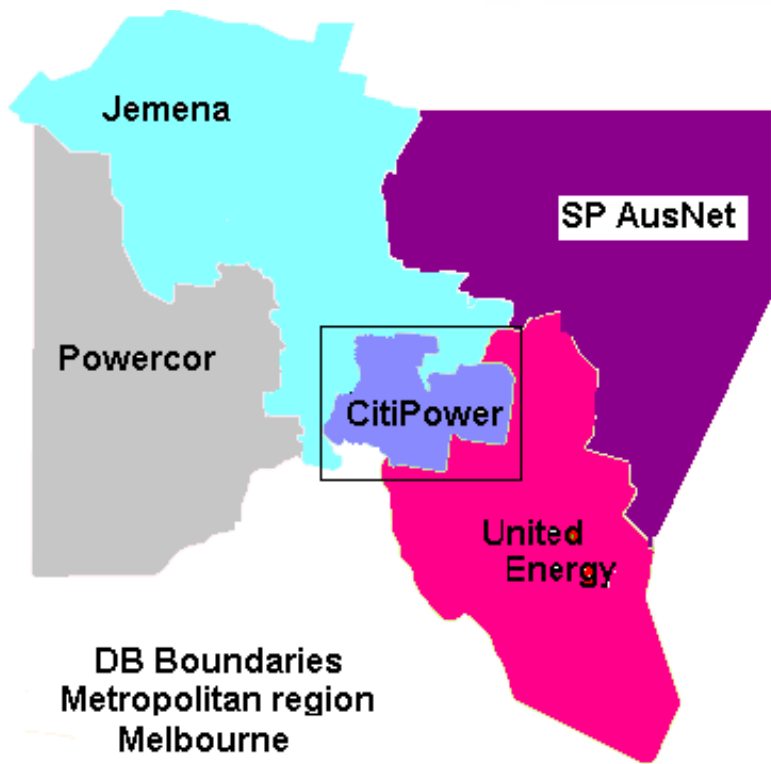


Figure 1: Victorian DNSP operational boundaries (continued)

2.2 Energy Safe Victoria

Energy Safe Victoria (ESV) is the safety regulator responsible for electrical and gas safety in Victoria. ESV oversees the design, construction and maintenance of electricity, gas and pipeline networks across the state and also licences and registers electricians.

ESV is required to issue a compliance certificate before you can switch on your connection after the installation and construction of your generator. In most instances, your site will be inspected to ensure all electrical works are safe and comply with Australian Standards. For more information visit www.esv.vic.gov.au

2.3 Essential Services Commission

The Essential Services Commission (ESC) is the independent regulator of the retail energy industry in Victoria. ESC manages licence arrangements for the distribution and sale of gas and electricity in Victoria. They ensure licensees comply with service standards or codes and have appropriate market arrangements and conduct.

For more information visit www.esv.vic.gov.au

2.4 Australian Energy Regulator

The Australian Energy Regulator (AER) is responsible for the regulation of the electricity distribution networks that deliver energy to Victorian households and businesses. For more information visit www.aer.gov.au

2.5 Energy retailers

Energy retailers are companies holding a Victorian Retail Electricity Licence, which permits them to buy and on-sell wholesale electricity to consumers. The ESC website lists Victorian energy retailers and their websites.³

Box 1: Compliance and regulatory issues

Connections to the electricity grid are governed by rules, regulations and codes that must be complied with to obtain a connection. These include:

1. National Electricity Rules (NER) govern the operation of the National Electricity Market (NEM), including mandatory requirements for protective controls and procedures for grid connected generators (Chapter 5). Chapter 7 covers metering arrangements. www.aemc.gov.au
2. National Electricity (Retail Connection) Amendment Rules 2010 specifically Chapter 5A 'Electricity connection for retail customers and distributed generators' once the National Electricity Customer Framework (NECF) comes into effect in Victoria. www.ret.gov.au
3. Victorian Electricity Distribution Code deals with all technical requirements that govern the operation of electricity distribution networks, specifically Section 7 on embedded or distributed generators. www.esc.vic.gov.au
4. Victorian Electricity Industry Guideline No. 15: Connection of Embedded Generation prepared by the Essential Services Commission of Victoria (to be replaced with the National Electricity Rules - Chapter 5A). www.esc.vic.gov.au
5. Victorian Electricity Supply Industry Service Installation and Rules. www.victoriansir.org.au
6. Electrical Safety Act 1998 (Victoria) and the associated Safety Regulations. www.austlii.edu.au/au
7. Electricity Industry Act 2000 (Victoria). www.austlii.edu.au

Further compliance and regulatory references are listed in Appendix 3, Section A.

3. Essential Services Commission 2011, 'Who are the gas and electricity retailers', www.esc.vic.gov.au/public/For+Consumers/Energy/

3. The connection agreement



A generator may be connected to the Victorian electricity grid only after permission has been granted by the local DNSP. This includes connection of an on-site generator at a customer's premises.

Whether the connection is new or a modification to an existing connection, it will require a formalised Connection Agreement between you and your DNSP. This agreement is your licence to operate the generator connected to the network. Before this agreement is made, however, all technical aspects of your application must be discussed with your DNSP and any associated issues must be resolved.

The National Electricity Rules Section 5.5 (b) state that:

"If requested by a Connection Applicant, whether as part of a connection enquiry, application to connect or the subsequent negotiation of a connection agreement, the Distribution Network Service Provider must negotiate in good faith with the Connection Applicant to reach agreement in respect of the distribution network user access arrangements sought by the Connection Applicant".

If the generator can export energy to the grid at any time, the connection agreement will include a second component called the Export Agreement.

Box 2: Connection Agreement and Export Agreement

Connection Agreement

In response to your application for network access and connection, your DNSP must offer you a Connection Agreement (formally titled Primary Connection (Augmentation) Agreement).

The Connection Agreement sets out:

- The terms and conditions under which the DNSP will provide a connection to their system.
- The rights and obligations of each party concerning the installation, use and operation of the system.
- Details of the connection charges to be paid.

Export Agreement

If you anticipate exporting electricity to the network, you and your DNSP will need to agree to an Export Agreement. This agreement covers the technical and commercial conditions of exporting electricity to the network as a non-market generator (see Appendix 1: Glossary).

The DNSP can refuse to offer terms for connection if you fail to provide the necessary information with the application in accordance with the Victorian Electricity Distribution Code.

Obtaining approval to connect to the grid will require a technical assessment of both the generator technology and the distribution network at the proposed point of connection.

3.1 Fees and costs

Along with the cost to develop and install your generator, you will be responsible for all the fees and costs associated with connecting to the DNSP including:

- Application fees to your DNSP for access to network connection.
- Cost to conduct a connection feasibility study and, if required, a network stability study.
- Cost to connect.
- Network augmentation costs specific to each connection.
- Metering charges to be verified with the DNSP.

For more information about connection charges and principles see Appendix 3, Section D.

4. Technical information you need to know

A basic knowledge of the technical aspects for grid connection will assist you in discussing issues with your DNSP. Be clear in your own mind as to why you want to install a distributed generator and how you anticipate using it.

An understanding of the technical specifications and terminology will enable you to:

- Choose an appropriate generating technology that will be easy to connect.
- Provide timely and correct information to the DNSP.
- Understand the potential impact of the generator on the DNSP's network and the available operational options.

4.1 Understanding the distribution network

Not all parts of the electricity distribution network are the same and there are limitations. Information about the grid's characteristics at the proposed point of connection for your generation is required.

Historically, the network has been designed to accommodate power flow from transmission terminal stations through tiers of networks operating at progressively lower voltages to electricity consumers. The network was designed to supply power to customers rather than accept power from customers.

For your generator, a key technical requirement will be to not adversely impact other connected customers. The network must not operate outside the limits set in the rules and codes applying to the DNSP.

The DNSP has an obligation under license to own and maintain their network according to the Victorian Electricity Distribution Code (the Code). This is called quality of service and DNSPs can be heavily penalised by the regulator if they fail to meet these requirements.

4.2 DNSP quality of service

At the proposed point of connection, the network should be operating within the limits set in the Code, however it may be operating very close to the defined limits. The difference between the network's current operation and the defined limits, or the headroom, is the range that a generator has available to utilise. If more headroom is required upgrades will need to be made to the grid.

Below are some of the parameters that the DNSP aims to maintain within regulated limits.

Frequency

The power grid operates as an alternating current supply with a frequency of 50 Hz.

A distributed generator must be capable of continuous uninterrupted operation at the system frequency of 50 Hz.

Voltage

When power is drawn from the grid there is a fall in network voltage. Conversely, if a connected generator exports power into the network the voltage rises.

The operation of your generator must not cause the voltage anywhere on the circuit to go above or below the limits set in the Code. This can have an adverse effect on other customers connected to the same part of the network.

Nominal value	Limits (steady state)	Less than one minute
230 volts		
400 volts	- 6% to +10%	- 10% to +14%
460 volts		
6.6 kV	± 6%	± 10%
11 kV	± 10% (rural areas)	
22 kV		
66 kV	± 10%	± 15%

Table 1: Voltage limits



Power Factor

Power factor is a measure of how well the electrical voltage and the current are synchronised or 'in phase'. It is stated as a decimal fraction where 1.0 is in phase. At a number less than 1.0 the current shifts so that it flows ahead (leading) or behind the voltage (lagging). Many electrical machines and electronic devices can change the power factor of the grid supply. Your generator connection must be managed to maintain the power factor between ± 0.8 .

Supply voltage and maximum demand	Up to 100kVA	Between 100kVA - 2MVA	Over 2MVA
< 6.6kV	- 0.75 to +0.8	- 0.8 to +0.8	- 0.85 to +0.85
6.6kV			
11kV	- 0.8 to +0.8	- 0.85 to +0.85	- 0.9 to +0.9
22kV			
66kV	- 0.85 to +0.85	- 0.9 to +0.9	- 0.95 to +0.95

Table 2: Power Factor limits

Harmonics

The alternating current and voltage of the power system is intended to be a pure sine wave with a frequency of 50 Hz. This is similar to a pure musical tone that has a single frequency. Electronic equipment can add other frequencies to the power signal that causes harmonic distortion. The distortion results in the power signal being less pure. There are limits on the amount of harmonic distortion allowed in the distribution grid. This will be an issue if your generator is connecting to the grid using an inverter or another type of electronic power converter. Between 1000 volts and 66kV the total harmonic distortion of the voltage should be less than 3% with even harmonics being less than 1%.

Load balance

The power grid operates using a three wire or three phase system where power flows through each wire. Ideally, each of the three wires carries an equal share of the load and the supply is said to be balanced. Your generator must not cause the power network to be out of balance by more than 2% if the connection is above 1000 volts.

Fault levels

The fault level is one way of defining the strength of the electricity network at a particular point. Fault level is a measure of the current that will flow when there is a fault on a network. The fault level at the end of a long electricity power line is much lower than at the centre of an interconnected network. Your connection should not cause the fault level to exceed set limits. At a point where the available fault level is small the impact of a generator can be great enough to disturb other local consumers. For this reason, it is sometimes necessary to reinforce or augment the network to accommodate the generator connection which will increase the connection cost.

You will need to ensure that the design and operation of your generator does not cause fault levels in the distribution system exceeding those specified in Table 3.⁴

Voltage level kV	System fault level MVA	Short circuit level kA
66	2500	21.9
22	500	13.1
11	350	18.4
6.6	250	21.9
<1	36	50.0

Table 3: Distribution system fault levels⁴

4. Sourced from Section 7.8 of the Victorian Electricity Distribution Code.

The following sections (4.4 to 4.7) covers the preliminary information you will need to provide the DNSP at your first meeting.

4.3 Typical categories of connection

Connections to the grid are classified according to the:

- Type of generator
- Generator size or power output
- Mode of operation
- Connection voltage.

4.4 Types of generators

There are three types of generators, each with different technical challenges for your DNSP:

Synchronous generators	An alternating current (AC) device driven by a turbine or a motor rotating at a constant frequency synchronised with the grid frequency of 50Hz. These generators can also operate independently from the grid.
Asynchronous generators (also known as induction generators)	An AC device driven by a turbine or a motor rotating at constant frequency but slightly ahead of the grid frequency. The device draws energy from the grid to commence operation and cannot operate in isolation from the grid.
Inverters and power converters	An electronic device with no moving parts used to convert energy from solar panels and small wind turbines to AC power. There is an Australian Standard AS 4777 for inverters less than or equal to 10kW that DNSPs have agreed to accept as a standard connection not requiring detailed assessment.

Table 4: Types of generators

Appendix 4 contains further information on the main types of generators and associated control equipment.



image courtesy of Cogent Energy



4.5 Generator size or power output

The size of a generator is measured by its maximum power output, or capacity, in either kilowatts (kW) or megawatts (MW). Typical classifications are listed in Table 1.

Classification	Technical definition	Typical installations
Mini	<ul style="list-style-type: none"> > less than 10kW > connected to the LV distribution and generally installed within a customer installation 	<ul style="list-style-type: none"> > domestic roof top solar (PV) > natural gas-based micro-turbine systems > small wind turbines > micro hydro electric > fuel cell generators
Small	<ul style="list-style-type: none"> > 10kW single phase or between 30kW and 1MW three phase > connected to the LV network > not AS4777 compliant 	Generators for machines used in: <ul style="list-style-type: none"> > natural gas-based CHP > biomass and landfill > diesel-fuelled engines > fuel cell generators > small hydro-electric > individual wind turbines > storage/inverter
Medium	<ul style="list-style-type: none"> > 1MW to 10MW > connected to the LV/HV network 	Single or grouped generators for: <ul style="list-style-type: none"> > solar thermal (see small scale examples)
Large	<ul style="list-style-type: none"> > greater than 10MW > connected to the HV network 	Single or grouped generators/machines used in: <ul style="list-style-type: none"> > natural gas-based CHP > diesel-fuelled plant > wind farms > hydro-electric > solar thermal

Table 5: Typical categories of connection

4.6 Mode of operation

A generator can be designed to operate in three distinct modes:

Grid-parallel	Generator operates when connected to the grid.
Stand-by	Generator is manually switched on when normal grid supply is lost, for example, during a blackout or planned outage.
Island	Generator automatically disconnects from the grid when grid power is lost but continues to supply a site load.

Table 6: Mode of operation

Understanding the difference between each mode is important when evaluating the business case and cost of your proposed generator. Stand-by and island modes typically apply to on-site power generation systems. You will need to distinguish between them in your application to the DNSP.

4.6.1 Grid-parallel mode

Grid-parallel mode of operation enables the on-site generator to operate alongside the public supply network. This is the most common mode of operation. In this mode, the generator can either 'export' or 'not export' energy to the grid.

In grid-parallel mode, the generator must be capable of automatically shutting down during a grid supply disruption or blackout. However, generators also need to maintain operation during a very brief grid supply disturbance of one second or less. This is called 'ride-through capability'.

One of the main requirements of an on-site generator in grid-parallel mode is that it must remain stable at all times. This is termed synchronised or 'in phase' with the grid. The introduction of a generator into the grid may require the electricity distribution network and site network to be modified or reinforced. System design study should evaluate existing or proposed site loads including analysis of switchgear and transformers, operational sequences, load flows and fault levels.

4.6.2 Stand-by mode

Stand-by systems are generally designed for essential loads during a major supply disruption. In most cases, these generators are full or partial stand-by systems powered by a diesel or gas engine that is started manually when power is disrupted.

In stand-by mode, the generator can only be operated after your site is disconnected from the electricity network with a manual change-over switch. Where the stand-by generator is intended to supply the full load requirement of a site, then it must be of sufficient size to ensure security of supply and the expected demand for power.

Full stand-by generators do not need to synchronise with the grid and usually do not require a Connection Agreement. The DNSP will still need to be informed of the installation of a stand-by generator before it is commissioned.

4.6.3 Island mode

In island mode, a grid-parallel generator can automatically disconnect from the grid in a power disruption or blackout and continue operating to fully or partially meet a consumers on-site power supply needs.

Generator controls or protection equipment separate the generator from the wider network by opening the main circuit breaker. In island mode, the generator stays cut off from the external grid. No transfer of electricity to or from the grid takes place but power supply to the site is maintained.

This arrangement is often used in hospitals and data centres where critical equipment necessitates a continuous power supply.

Each DNSP will have their preferred protective arrangements to manage islanding. You may require load-shedding capability that will add to the installation costs. Load-shedding is when some uses of electricity are cut off to ensure the generator is not overloaded.

Compared to stand-by mode, where a supply disruption can occur, the transition from grid-parallel to island mode is continuous and smooth, sometimes called 'bumpless transfer'.



4.7 Connection voltage

The generator's connection to the distribution network is usually dictated by the size and type of the generator. In general, smaller, lower capacity generators can connect to lower voltage distribution lines. Generators of 1MW to 10MW will usually require a high voltage connection (e.g. 22kV) direct to the zone substation.

Figure 2 below shows typical voltage levels for connection to the distribution network.

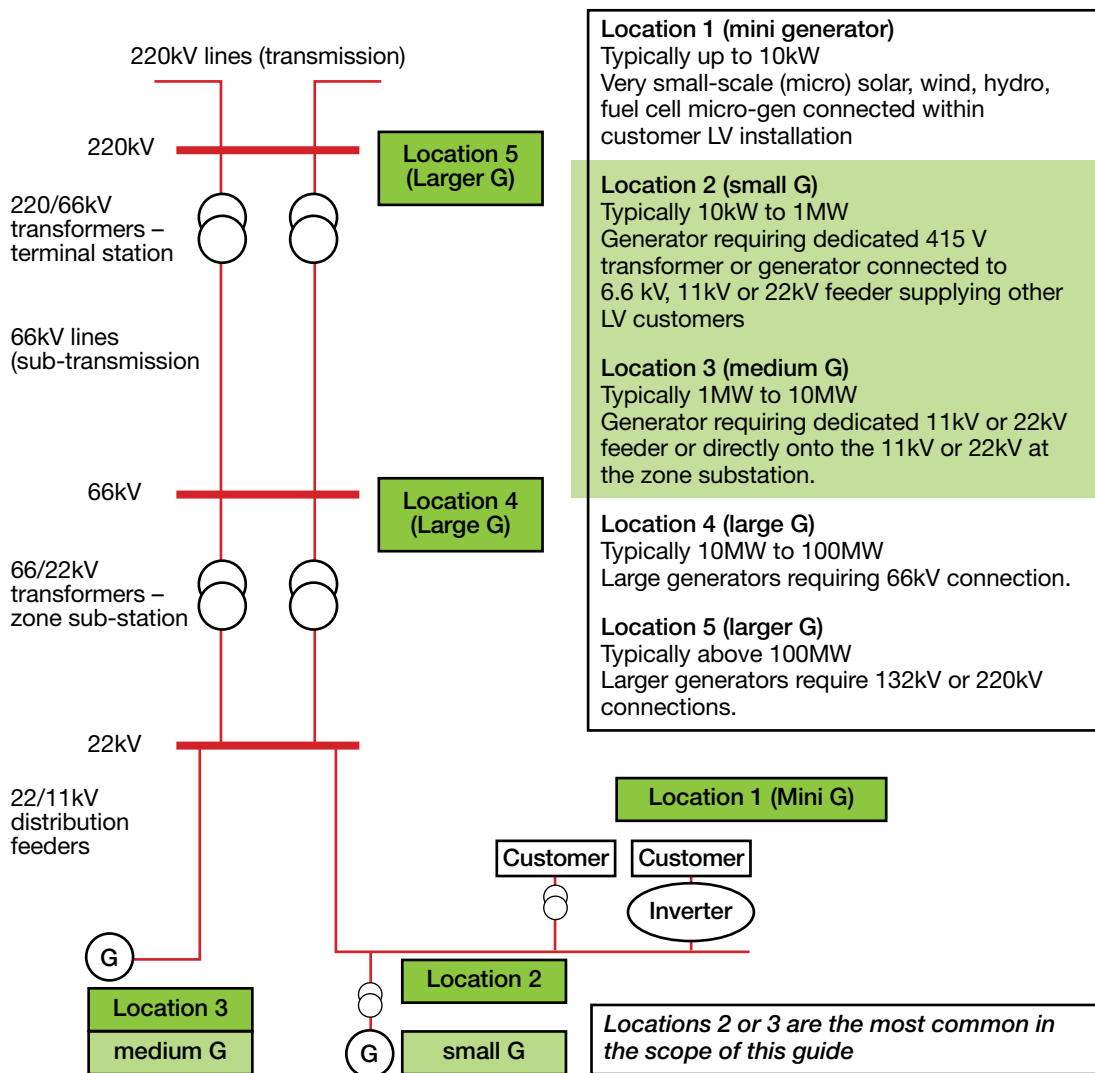


Figure 2: Schematic diagram of typical connection points to the grid.⁵

5. Diagram adapted from Citipower / Powercor.

5. Five steps to obtain a connection agreement

There are five steps to obtain a connection agreement. To achieve these steps will require time and negotiation.

Consider engaging an electrical engineering consultant with expertise in grid connections to manage much of what is outlined in this section.

The five steps to grid connection need to occur in parallel with the design and development of your generator and negotiation of construction contracts. You should integrate the timeline of these five steps with your project.

The success of a generator project is contingent on obtaining a connection agreement.

Contracts for the site development and installation of the generator should align with the connection process. Your goal is to reach a connection agreement with your DNSP, by which time you should be ready to finalise all other contracts.

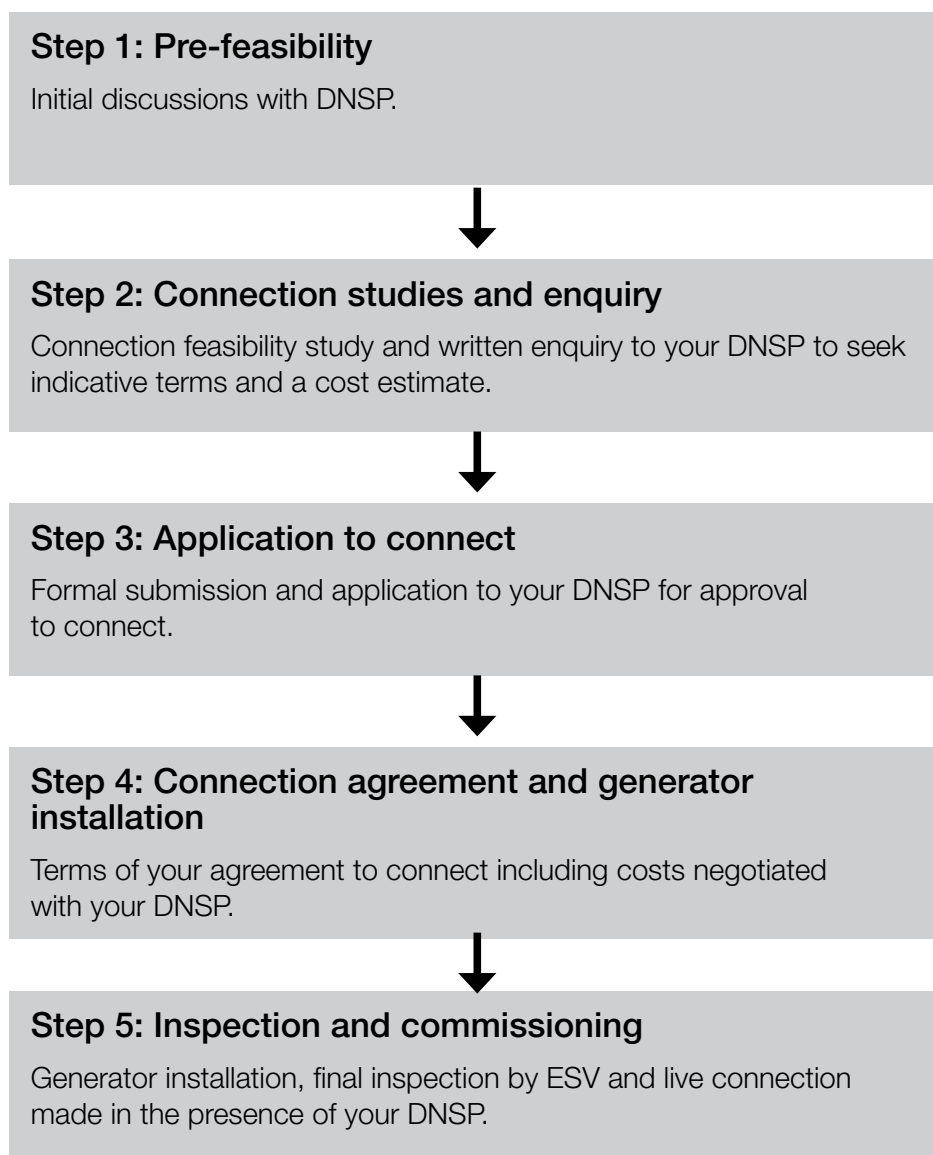


Figure 3: Five steps to grid connection



5.1 National Electricity Rules and your connection

Section 5 of the *National Electricity Rules* addresses new or modified electricity network connections. Schedule 5.2 of the Rules covers conditions for the connection of generators.

National Electricity (Retail Connection) Amendment Rules 2010 provides more detail including an outline of the expected process for a negotiated connection, once it comes into effect in Victoria.

The Rules expect both you and the DNSP to use all reasonable endeavours to agree upon relevant technical matters in respect of a new or altered connection of a generating system to the network including⁶:

- Design at the connection point
- Physical layout adjacent to the connection point
- Primary protection and backup protection
- Control characteristics
- Communications facilities
- Insulation co-ordination and lightning protection
- Fault levels and fault clearance
- Switching and isolation facilities
- Interlocking and synchronising arrangements
- Metering installations

The Rules also note that:

“A distributor must use its best endeavours to make a negotiated connection offer to the connection applicant within 65 business days after the date of the application for connection (but the time taken by the applicant to provide information reasonably sought by the distributor will not be counted)⁷.”

5.2 Steps to connection

Step 1: Pre-feasibility

The first step is to identify your DNSP and gather information from their website about their requirements for new connections. You should know the type, size and mode of operation of the proposed generator, your preferred connection point on the network and the timeframe for the installation.

Arrange a face-to-face meeting with the DNSP to discuss their technical requirements and the information needed for a connection feasibility study. The study will support your written connection enquiry. At this meeting ask questions on all the issues or concerns you have connecting your generator to the network.

Use this meeting to clearly identify what information is required by the DNSP in the written connection enquiry (Step 2).

You will need to provide the following information to the DNSP:

- Type of generator proposed (e.g. synchronous / asynchronous, see Appendix 4)
- Size of generator proposed, in kilowatts (kW) or megawatts (MW)
- Connection mode (grid-parallel, island or stand-by)
- Geographical location of the proposed generator
- Proposed connection point to the electricity distribution network, preferably the nearest zone substation

6. National Electricity Rules, Schedule 5.1, Section 5.2.3

7. National Electricity (Retail Connection) Amendment Rules 2010, Section 5A.F.4

You should obtain information about the available capacity, fault levels and other characteristics of the electrical network at your proposed point of connection.

Be aware that other parties may be applying to connect to the same local network, which may impact on the available network capacity and fault levels. You will need to explore all these variables with your DNSP before lodging a formal enquiry to connect to the grid. If the available capacity of the substation or other components is limited, network upgrade and augmentation options will need to be considered.

The nature, degree and costs of any augmentation will vary depending on the location and status of the zone substation. The location will determine the capability of the network to accommodate the generator and its likely impact on existing customers. The augmentation must meet Code compliance and Australian Standards.

Past experience has shown that network connection and augmentation costs can be very significant and in many cases will influence the financial viability of proposals to connect a generator to the network.

What you can expect the DNSP to cover at the meeting

At your meeting, the DNSP should be able to provide some verbal advice as to how they would prefer to progress your enquiry. This might include:

- Operating conditions at the proposed point of connection
- Suggestions as to alternative connection points
- The type of access standard to apply: automatic, minimum or negotiated

At this meeting, make sure you confirm who will be your prime contact at the DNSP to manage your connection application.

CHECKLIST - Step 1: Pre-feasibility

After Step 1 you should have:

- Identified the relevant DNSP and reviewed what information is available online, remembering that you may need to request some information from them directly.
- Prepared preliminary information for the DNSP on the proposed generator, including the location and connection point, connection mode, proposed system size and type (to be finalised during Step 2) and project timeframes.
- Held a meeting with the DNSP to obtain advice and build understanding of the information required to prepare an official connection enquiry.
- Established a clear plan for communications between you and your DNSP, including the identification of a key point of contact.
- An initial understanding of the connection services, timeframes and costs between:
 - Basic and standard connection (usually called automatic access)
 - Negotiated connection or access (usually for generators)
- Collated the issues and potential resolutions, tasks to be undertaken (including potential costs and timeframes) and decided what will inform your decision to proceed to the next phase.



Step 2: Connection studies and enquiry

Step 2 involves two tasks:

1. Conducting a network connection feasibility study which may include a network stability study.
2. Submitting a written connection enquiry to the DNSP.

The connection feasibility study determines requirements for technical specifications, the network code and the DNSP. The connection feasibility study is submitted to the DNSP with the written connection enquiry.

A connection feasibility study can be done in-house but is usually prepared by an experienced grid connection consultant who understands your generator and DNSP requirements. Good communication with your DNSP and any consultants you engage is critical. Ultimately, you are aiming for a solution to network connection that meets the codes and rules but is not 'gold plated' or unduly expensive.

The connection feasibility study will:

- Clarify information required for the connection application (see Box 3 below).
- Assess the technical status of the generator and the electricity distribution network it will connect to.
- Explore and clarify any arrangements to import / export to and from the network.
- Provide estimates of costs and timeframes to undertake the work.
- Provide the DNSP with the required level of detail to assess your application.

The degree of detail required will depend on the generator type, its impact on the network and its potential impact on future generator connections. The DNSP may help you select a generator for system studies but it will be your responsibility to fund the connection feasibility study.

Box 3: Information from the DNSP

You should request the DNSP provide the information below to enable the connection feasibility study (Step 2):

- The highest expected single phase and three phase fault levels at the connection point with the generating system not connected.
- The clearing times of the existing protection systems that would clear a fault at the location that the new connection would join the existing transmission system or distribution system.
- The expected limits of voltage fluctuation, harmonic voltage distortion and voltage unbalance at the connection point with the generating system not connected.
- Technical information relevant to the connection point with the generating system not synchronised including equivalent source impedance information (sufficient to estimate fault levels), voltage fluctuations, harmonic voltage distortion (for harmonics relevant to the generating system) and voltage unbalance.
- Information relating to the performance of the national grid that is reasonably necessary for the connection applicant to prepare an application to connect. This would include:
A model of the power system (including relevant considered projects and the range of expected operating conditions) sufficient to carry out load flow and dynamic simulations.

The connection feasibility study (Box 4) will enable you to understand your connection requirements and the status and capability of the existing network. It will investigate load flows, system and network protection settings, detailed generator data and costs of network connection. This information may vary between sites.

Box 4: Key outcomes of a connection feasibility study

The key outcomes of the connection feasibility study are identifying:

- The electrical characteristics of the generator that influence the connection.
- The current fault level status at the point of connection on the network. The general rule for access to connection is that available fault level headroom (safety margin usually given in kilo-Amperes or kA) at the connection point is larger than the maximum fault currents that the generator could introduce during its operation.

As a minimum, the feasibility study must address the:

- Design and physical layout at and adjacent to the connection point
- Primary protection and backup protection (DNSP feedback can help)
- Operational control characteristics
- Communications and alarms
- Insulation coordination and lightning protection
- Switching and isolation facilities, interlocking arrangements
- Metering installations

The feasibility study should also emphasise the:

- Impact on existing customer supply quality
- Impact on existing network infrastructure
- Fault level issues, including fault clearance times
- Stability of the on-site generator
- Long-term viability of the generator and operation
- Connection to electrically weak networks, if generator in remote location
- Transfer of customer load between network and generator

The study will identify network limitations and inform the development of options for upgrades including voltage control, switchboards, relays, circuit breakers, isolators and fault protection. It should also assist you develop options for your generator's mode of operation. An island mode of operation, for example, may require additional protection equipment.

For systems typically over 1MW capacity, an additional investigation called a network stability study may be required as part of, or as an extension to, the feasibility study. This may incur additional costs. Check whether this will be required at your initial meeting with the DNSP.

Allow for the cost of these studies in your project budget.

Box 5: Key points you can expect your DNSP to consider

That the:

- Installation of your proposed generator operates as part of the electrical distribution network
- Nature and cost of any extension or augmentation of the existing network deemed necessary and how those costs will be met
- Reliability and quality of the grid supply to other customers is not adversely affected by the proposed generator
- Safety of other customers, company employees and contractors is not put at risk
- Generator is not operated above the agreed megawatt rating
- Generator meets approved design and operates reliably.



CHECKLIST - Step 2: Connection enquiry

After Step 2 you should have:

- Established that the proposed generator can be supported by you and your DNSP, subject to resolving a grid connection.
- Completed a connection feasibility study.
- Completed a network stability study, if required.
- Confirmed with your DNSP the possibility of a connection to the electricity distribution network through a formal letter briefly explaining the key aspects of your generator and the location (with a copy of the connection feasibility study).
- Received detailed feedback from your DNSP on the technical requirements, timeframes and costs for connection.

Step 3: Application to connect

The DNSP must make reasonable endeavours to make a connection offer that complies with the applicants reasonable requirements.

A DNSP and a connection applicant for a negotiated connection contract must negotiate in accordance with the negotiation framework set out in clause 5A.C.3. National Electricity (Retail Connection) Amendment Rules 2010, once the NECF comes into effect in Victoria.

Key elements of the negotiation framework are that the DNSP should provide information the connection applicant reasonably requires in order to negotiate on an informed basis including:

- An estimate of the amount to be charged for assessment of the application and the making of a connection offer for a negotiated connection contract.
- An estimate of connection charges.
- A statement of the basis on which connection charges are calculated.
- An estimate of any applicable charges for supply services and a statement of the basis of their calculation, if the connection applicant has elected to extend the negotiations to supply services.

Step 3 is the formal submission of your Application to Connect to the DNSP including negotiated terms and conditions. This includes:

- Submitting detailed technical and commercial information about your generator.
- Payment of application fees – to be ascertained from your DNSP.
- Finalising augmentation requirements and the associated cost.
- Negotiating contractual terms and conditions.
- Considering any EPA and planning issues and seeking approval (see Appendix 3).

The intended outcome of Step 3 is to obtain an Offer to Connect from your DNSP. This is a critical milestone on the path to establishing a connection between your generator and the electricity distribution network. Your connection is most likely to be subject to a negotiated connection contract.

Once again, communications between you and your DNSP is important as you negotiate a range of technical and commercial terms for your connection.

An important factor in gaining connection approval from your DNSP will be your selection of an appropriate generator. The DNSP can refuse to offer terms for connection if you fail to provide the application information in accordance with the Victorian Distribution Code as indicated in Table 7.

Information	Description
Name and address of applicant	Include the name of the business on behalf of whom you act, if relevant
Preferred generator site location	List any alternatives in order of preference
Generator configuration	Number, type and mode of operation of generators
Type of generator	Gas engine or turbine generating unit: wind turbine, solar plant, hydro turbine etc
Technology of proposed generator	Synchronous generating unit, asynchronous or induction generator, photovoltaic array, etc
Maximum power generation capacity of the generator	Power demand of whole plant (MW and / or MVA), averaged over 15 minutes or specified period
Expected energy production or consumption	MWh per month or annum
Nature of generation (expected generation pattern)	<ul style="list-style-type: none"> • Variations over day / week / season / year • Size of disturbing component MW / MVA, duty cycle and nature of power electronic plant which may produce harmonic distortion
When plant is to be in service	Estimated date of service for each generator
Other information	<ul style="list-style-type: none"> • Site layout plan, including intended location for point of connection to network • Electrical single line diagram with proposed protection (primary and back up) and control equipment • Amount and timing of power required during construction or any auxiliary power requirements

Table 7: Information required by the Victorian Distribution Code for your application to connect.

At the end of Step 3, variations to the original application to connect may be needed. For example, contracts and cost estimates, affected by EPA and planning issues for extensions or augmentations. Early consultations with your DNSP about EPA processes may help to avoid delays at Step 3.

CHECKLIST - Step 3: Application to connect

At Step 3 you should have:

- Selected an appropriate generator and model.
- Applied for connection with your DNSP.
- Negotiated any augmentations (including the cost) with your DNSP.
- Negotiated technical and commercial terms and conditions.
- Received an offer to connect from your DNSP.



Step 4: Connection agreement and generator installation

At Step 4 you will form a legally binding connection agreement. You will need to accept the offer to connect from the DNSP, along with the negotiated terms and conditions of the connection agreement.

It is advisable to finalise the connection agreement before commencing the construction and installation of the generator.

CHECKLIST - Step 4: Connection agreement and generator installation

After Step 4 you should have:

- Accepted your DNSP's offer
- Signed off the connection agreement between you and your DNSP
- Completed installation of your generator and network extensions / augmentation

Step 5: Inspection and commissioning

Once the generator has been installed, the site and all works will need to be inspected and tested before live connection to the network.

ESV will conduct the inspection and may request alterations if required. They will issue a Certificate of Electrical Safety.

Following the inspection, a range of connection tests will be performed in the presence of a DNSP representative. Live connection to the network will then take place.

After connection, the generating plant will be tested and commissioned by the installation engineer to ensure the plant is ready for regular service.

CHECKLIST - Step 5: Inspection and commissioning

After Step 5 you should have:

- Arranged and completed an inspection of the electrical works by ESV
- Successfully tested the system connection in the presence of your DNSP
- Achieved live connection
- Undertaken and completed commissioning

5.3 Connection process flowchart and checklist

The connection process and interactions with a DNSP are illustrated in the connection process flowchart and checklist (Figure 4). The DNSP processes used have been adapted from CitiPower / Powercor Guidelines (Appendix 5). These guidelines may not be applicable to all Victorian DNSPs.

Steps 1 to 5 are presented in a single connection checklist template (Figure 5) so you can track your progress. Adapt the template to suit your DNSP processes.

You are strongly advised to document every step of the project and negotiations with your DNSP. This should include generation issues, connection arrangements and protection settings.

Connection process flow chart

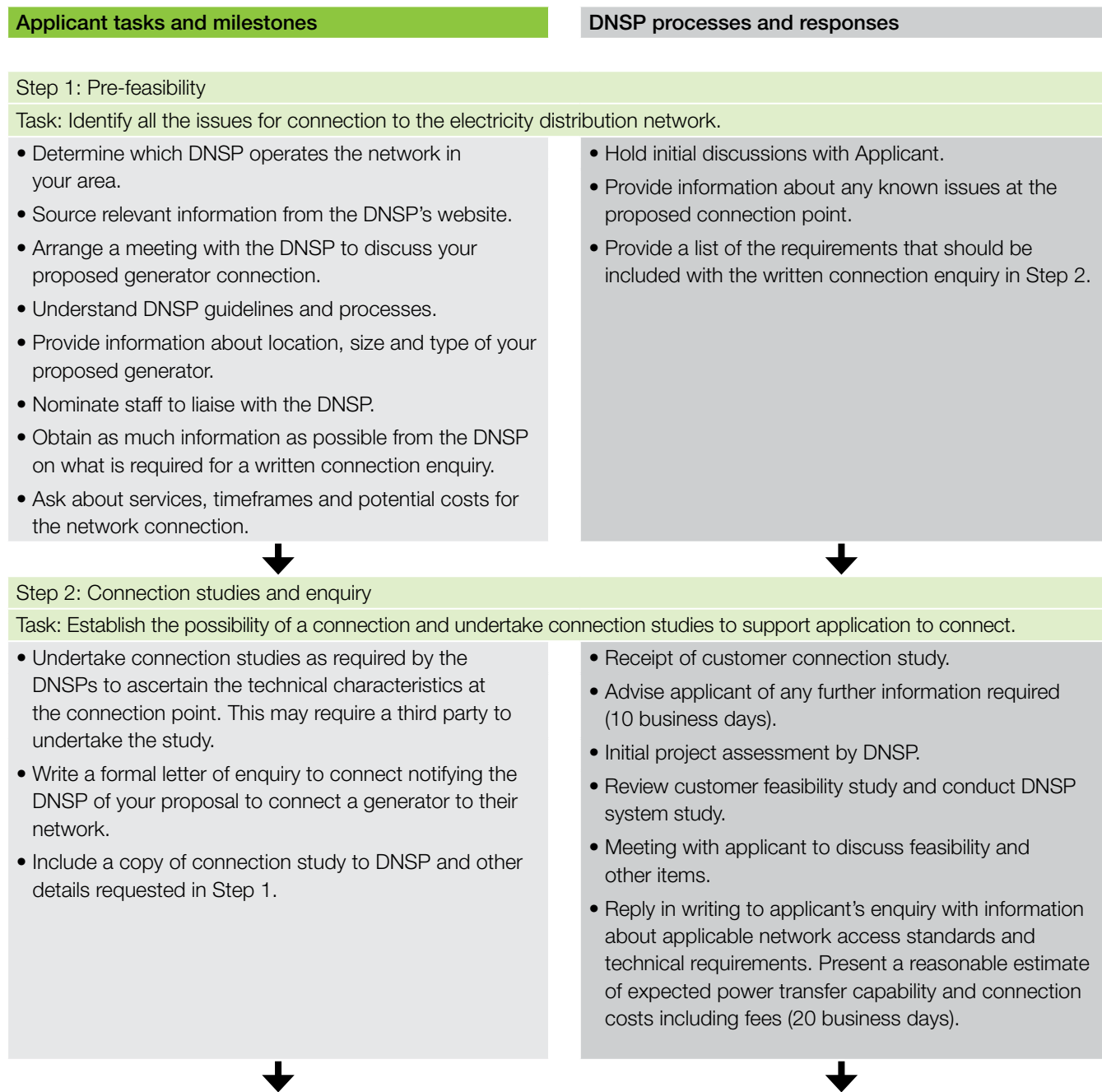


Figure 4. Connection process flowchart

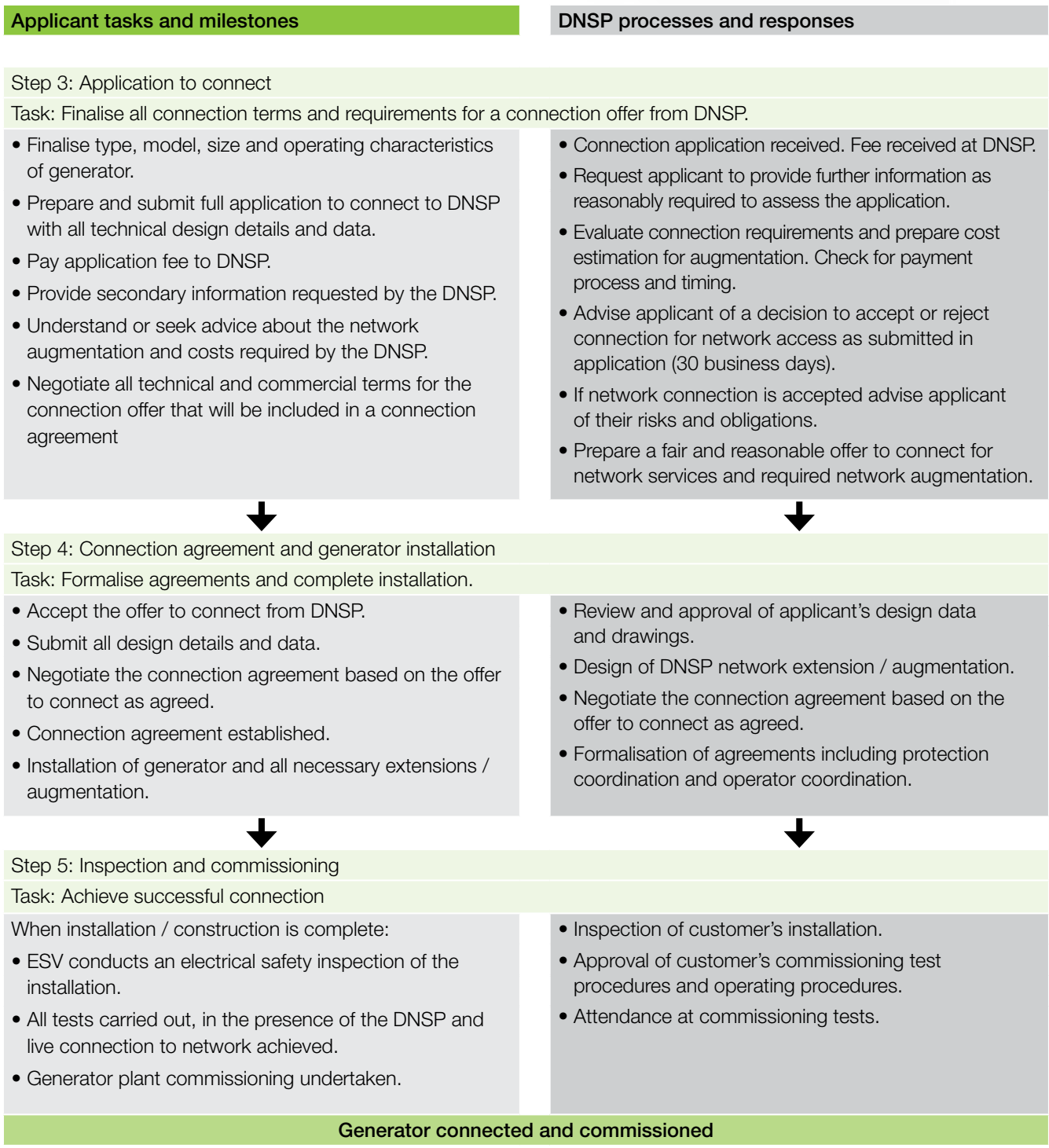


Figure 4. Connection process flowchart (continued)

Connection checklist

Milestone task	Date of completion
Step 1: Pre-feasibility	
<input type="checkbox"/> Meeting with DNSP	_____
<input type="checkbox"/> DNSP requirements and timeframes noted	_____
<input type="checkbox"/> Nominate key staff contacts	_____
Step 2: Connection studies and enquiry	
<input type="checkbox"/> Connection feasibility study completed	_____
<input type="checkbox"/> Enquiry letter with feasibility report sent to DNSP	_____
<input type="checkbox"/> DNSP reply with requirements for connection received	_____
<input type="checkbox"/> Decision made to proceed to the application stage	_____
Step 3: Application to connect	
<input type="checkbox"/> Selection of appropriate generator type and model	_____
<input type="checkbox"/> Complete all detailed design and technical specifications	_____
<input type="checkbox"/> Application for connection submitted to DNSP	_____
<input type="checkbox"/> Negotiations with DNSP on augmentations completed	_____
<input type="checkbox"/> Offer to connect from DNSP received	_____
Step 4: Connection agreement and generator installation	
<input type="checkbox"/> Acceptance of offer to connect	_____
<input type="checkbox"/> Terms and conditions for connection agreed	_____
<input type="checkbox"/> Connection agreement signed by both parties	_____
<input type="checkbox"/> Generator installation complete	_____
<input type="checkbox"/> Network extensions and augmentations completed	_____
Step 5: Inspection and commissioning	
<input type="checkbox"/> ESV inspection of generator installation	_____
<input type="checkbox"/> Connection works inspected	_____
<input type="checkbox"/> Generator successfully connected to the grid	_____

Figure 5: Connection Checklist

Appendix 1: Glossary



Technical terms and definitions

Distribution feeder: An electric line and associated equipment at a normal voltage level at 6.6kV, 11kV or 22kV which a DNSP uses to distribute electricity. Sub-transmission lines connect to the terminal stations and supply zone substations. Zone substations transform the sub-transmission line voltages (e.g. 66kV) to distribution voltages (e.g. 22kV, 11kV and 6.6kV) and supply the distribution substations via distribution feeders (See Figure 2).

Distributed generation: Any generator that makes its grid connection to a local electricity distribution network and not the state-wide or national transmission network. Also called embedded generator - a term sometimes used to cover any generator connected to the distribution grid or 'embedded' within the grid. In Victoria currently this is connections at 66,000V down to 230V. Hence distributed generation can vary from several MW size (such as wind farms) to small kW size units (such as solar panels on homes).

The usual technical definition includes generators up to 30MW electrical capacities connected to the distribution network. In Victoria examples include: smaller wind farms, biomass generators, solar photovoltaic systems and natural gas-fuelled cogeneration and trigeneration systems. While most of the energy sources for these systems are renewable, natural gas is not renewable; however, it provides a low greenhouse gas emission source of electricity when used in a cogeneration or tri-generation system together with other energy services (heating and cooling).

Distribution network: Local domestic to high voltage (< 66kV) network of wires and equipment that bring electricity to a consumer's premises.

DNSP: Distribution Network Service Provider. Also referred to as Distribution Network Businesses. In Victoria each distribution network business has responsibility for managing and planning the augmentation of their distribution network.

Fault levels: The maximum current that can flow under a three phase short circuit condition. It can vary depending on the point at which the fault occurs. The magnitude of the fault level will have a significant influence on the choice and design of the protection equipment used for the connection.

Generator capacity: Maximum power production of a generator measured in kW or MW.

Grid: Generic term that refers to the interconnected system of wires and other equipment that moves electricity from generators to consumers. Also called the network or 'poles and wires'.

Harmonic distortion: Current and voltage waveform distortions are commonly produced through motor drives and electronically driven devices, including power supply systems. These distortions can affect loads, harm distribution equipments and transformers mainly through overheating.

Non-market generators: Smaller generators, below a name plate rating of less than 5MW or generators between 5MW and 30MW that exports less than 20GWh in any 12-month period. They are exempt from registration with the Australian Energy Market Operator (AEMO) and do not have direct access to the wholesale electricity market. Also they do not receive income from the National Electricity Market pool for the electricity that is exported to the network. For non-market generators the sale of sent-out energy is a private bilateral transaction between the relevant parties that occurs outside of the National Electricity Market framework. The entirety of a non-market generator's sent-out generation must be purchased by either the local retailer or a customer located at the same connection point at a price agreed upon between the local retailer / customer and the non-market generator.

On-site generator: An electricity generator located at a customer's premises and connected on the customer side of the utility meter.

Transmission network: Very high voltage (> 66kV) network of power lines that link generators to the distribution network.

Units and abbreviations

A, kA: Amperes or kilo-Amperes (1000 Amperes) – unit of measuring electrical current.

BTU: British Thermal Unit

kW, MW: Kilo or Megawatt is a measure of real electrical power or energy rate of production or demand, e.g. capacity of a power generating unit. kW_e is the electrical capacity and kW_{th} is the thermal capacity: 1MW = 1000kW = 1 million watts

kWh, MWh, GWh: A common unit to measure energy consumption or use that is read through a meter.
1MWh = 1000kWh; 1GWh = 1000MWh

MJ, GJ: Mega or Giga Joules. This is a common unit to measure heat energy content, e.g. energy content of reticulated natural gas (Vic) is 38.8MJ/m³

1GJ = 1000MJ; 1GJ = 277.8kWh; 1kWh = 3.6MJ

1 million BTU = 0.2928MWh = 1054MJ

MVA, MVAR: Mega-Volt-Ampere. These terms of electrical power dispatch that refer to Apparent power and Reactive power respectively.

V, kV: Volts or kilo-volts (1000V). The voltage level of an electrical supply system.

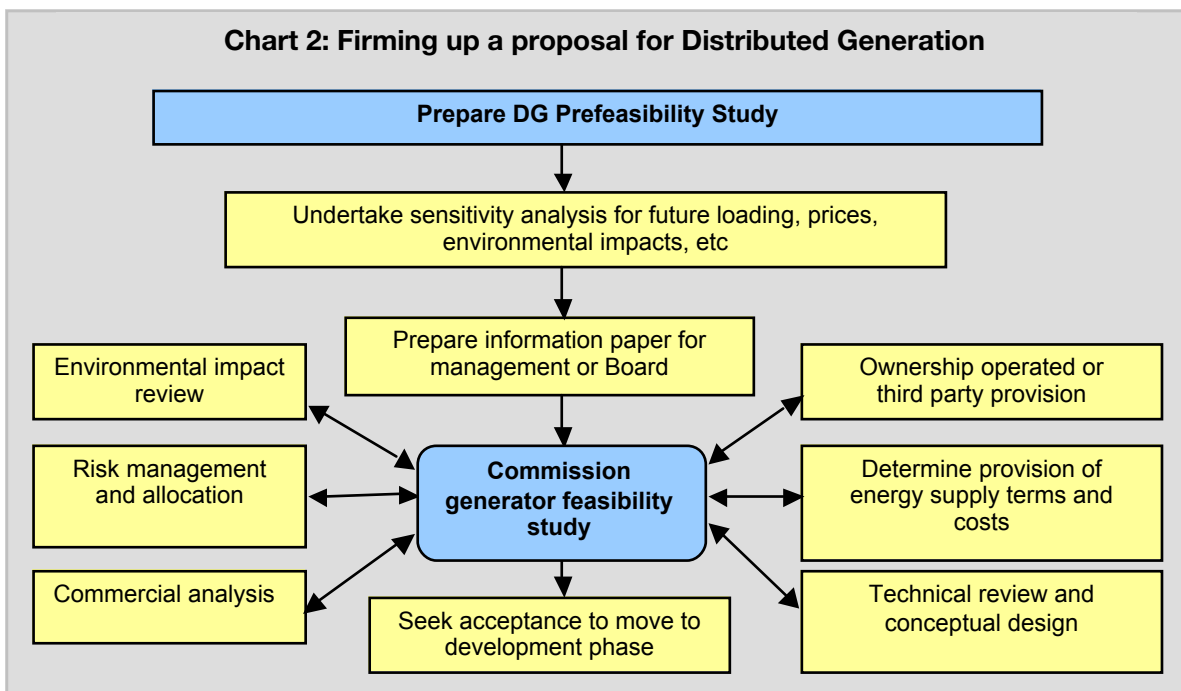
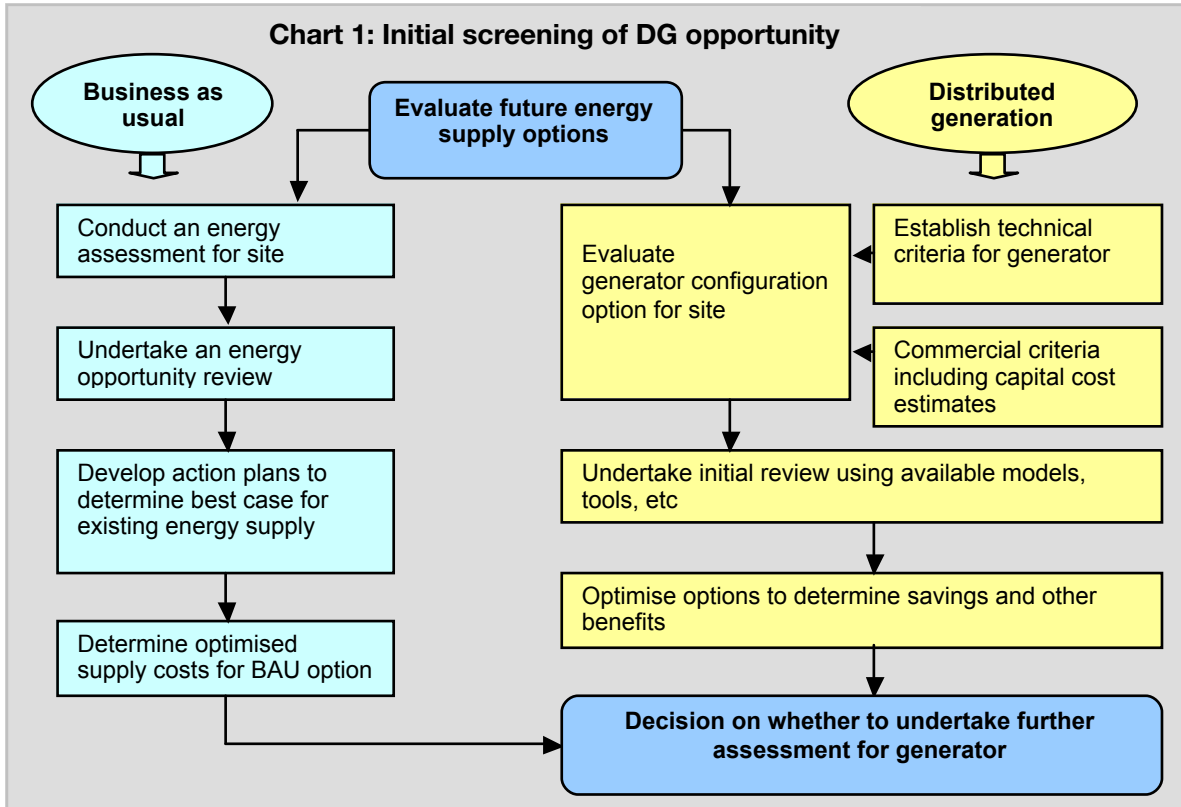
Acronyms

AC	Alternating Current
AEMC	Australian Energy Markets Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
CFA	Country Fire Authority
DG	Distributed Generation (or Embedded Generation)
EPA	Environment Protection Agency
ESC	Essential Services Commission (of Victoria)
ESV	Energy Safe Victoria
HV	High Voltage (11kV and 22kV)
LV	Low voltage (230V and 400V)
MCE	Ministerial Council for Energy
MFB	Metropolitan Fire and Emergency Services Board
NEM	National Electricity Market
NER	National Electricity Rules

Appendix 2: Setting the context



The charts below give an overview of the process used to screen opportunities for distributed generation. These flow charts are guide only individual projects have their own context. The connection processes described in this guide will form a major component of the generator installation and implementation process.



Appendix 3: Additional matters to coordinate

Regulation of generating plant fuelled by gases or inflammable liquids⁸

Where applicable, applicants are obliged to comply with the following regulations, among related requirements, if the 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:

- Gas installation code (AG601)
- Code for industrial and commercial gas-fired appliances (AG501) (www.blis.tas.gov.au)
- EPA policy on noise emissions (www.epa.vic.gov.au)
- EPA policy on atmospheric emissions (www.epa.vic.gov.au)
- MFB and CFA requirements
- Local municipal planning and building regulations

Where electrical equipment (including generators) is 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. It is common to provide protection ventilation (AS1482) and to exclude as many electrical accessories as possible from the hazardous area.

Metering arrangements

The applicant is responsible for appointing a metering provider to install and maintain metering equipment at the location agreed with their DNSP. The type of metering installation required and its accuracy requirements should be in accordance with the National Electricity Rules (Chapter 7) unless otherwise agreed with the electricity retailer or metering provider. Proponents should ensure that they understand their responsibilities with regard to these functions.

Minimum standards for new metering equipment⁹ (for a non-market generator)

- Metering equipment for medium DG operating as a non-market generator must comply with the minimum standards for metering installations as prescribed in the Rules for market generators.
- Metering equipment for small DG operating as non-market generators must comply with the minimum standards of accuracy for new metering equipment for electrical installations with consumption of less than 100 GWh per annum, in accordance with the Victorian Electricity Customer Metering Code.
- Metering equipment for medium DG non-market generators must be able to measure active energy and reactive energy.
- A distributor may require the metering equipment for small DG or micro DG operating as non-market generators to measure active energy and reactive energy taking into account the size of the generator, its proposed role and its location in the network.
- Metering equipment for non-market generators must be able to measure positive and negative flows separately and for the avoidance of doubt this metering requirement allows the customer load and the non-market generator to be connected together on the customer's side of the meter so that any exports are 'net metered'.
- Where avoided cost payments or tariffs for the purchase of electricity from the non-market generator are based on different rates according to the time of day, interval metering equipment must be installed.

It is in the best interests of the applicant to refer to the Electricity Customer Metering Code published by the ESC.

8. Extract from the Customer Guidelines for embedded generation of rating up to 1MW, Powercor Australia.

9. Extract from Draft National Code of Practice for Embedded Generation, DRET 2006.



Environmental considerations

Connection by the DNSP may be subject to EPA Victoria¹⁰ and planning approvals for any necessary network augmentations or extension works. Early consultations, possibly during Step 3 or even earlier with the DNSP on these issues can help avoid delays at the connection stage. Potential issues include:

- Footprint of distributed generation, especially wind and solar
- Community expectations and objections
- Construction of electrical grid infrastructure to integrate into existing grid
- Overhead versus underground causing capital cost escalation
- Heritage areas
- Native flora and fauna
- Noise impact
- Aesthetic impact.

Connection charges and provisions

Connection charge means a charge made by a DNSP for a connection service. In Victoria, the connection charging principles are set according to the distributed or embedded generator unit size classification. The principle is that any customer pays for the costs it causes to be incurred (less any incremental revenue). Where there are multiple beneficiaries (such as plans to augment the network in future to accommodate load growth) the DG pays only a share, such as the cost to bring forward planned works.

A limit has been placed on charging for deep augmentation costs, with the limit set at the cost of works up to and including the first transformation in the distribution system.

The Draft National Code of Practice for Embedded Generation notes that: “The Distributor (DNSP) shall be entitled to levy a fair and reasonable charge on the generator for connection and integration to the distribution system”.

Also:

The Distributor must provide in the connection offer a disaggregation of the proposed charges. As a minimum this disaggregation must, where applicable and where this information is available to the distributor, indicate the contribution to total cost of the following items:

- Dedicated connection assets
- Extension assets
- Augmentation (reinforcement) of the existing network (including any protection).
- Metering and data collection costs
- Any provision for operation, repair and maintenance of relevant network assets (including any allowance for ongoing requirements).

In the context, network augmentation costs are called the shallow connection costs as they impact on the distribution side of the network or the first transformation in the distribution system. The nature and cost of augmentation will vary depending on the site and this will be part of the negotiation that the applicant will need to undertake with their DNSP. The augmentations generally include voltage controls, switchboards, circuit breakers, relays and isolators.

For more information on the connection charge principles and guidelines refer to Part E of the National Electricity (Retail Connection) Amendment Rules 2010 and the Draft National Code of Practice for Embedded Generation (MCE, Feb 2006).

10. Under Victoria's EPA, no emission license is required for generator capacity below 20MVA, but a Works Permit is required for generator capacity more than 1MVA.

Appendix 4: Types of generators and equipment

The following definitions and descriptions in this section have been sourced from Customer Guidelines for Embedded Generation of rating up to 1MW, prepared by Powercor Australia, September 2006.

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. When connected to the grid, a synchronous generator is electrically locked in phase with the external grid.

To connect to the grid the following equipment is needed:

- synchronising equipment (usually automatic)
- automatic Voltage Regulator which controls the field current
- a governor which automatically controls the fuel input to the engine/turbine to keep speed and power output at the set levels.

Synchronising equipment

In the case of synchronous generators, the generator voltage and the grid voltage (both AC) 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 and 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.

Asynchronous generators

An asynchronous or induction generator is an induction motor driven above synchronous speed. 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 operating in isolation of the grid, i.e. as islanded or stand-by systems. When connected to long overhead lines, safety problems due to over voltage may occur.

Inverters and power converters

Power converters and inverters are being used increasingly with distributed generation typically involving technologies that use micro turbines, photovoltaic systems and wind generators. Micro turbines in the range of a few kW to a MW are now available in the market. Most micro turbines generate AC frequencies in the range of 1000Hz to 3000Hz that needs to be converted to line frequency (50Hz) before the generated power becomes usable. In many cases high frequency power from the generator must be converted to DC using power converters before the inverter provides voltage supply at lower frequency required for grid connection. Inverters are commonly used in applications where energy storage like batteries or ultra capacitors is involved. Power converters can also provide valuable ancillary services including voltage support and static volt-amp-reactive (VAR) compensation.



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. The feasibility study will identify the type of protection equipment needed for the DG connection. While protection equipment and fault limiting plant is used to protect the network in general, the following issues need to be covered for the generator and the local electrical services (typically up to 1MW). Check with DNSPs on larger sized systems for any additional requirements.

- Over current
- 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 grid via a distribution feeder equipped with automatic reclosing, the generator must disconnect in a time less than that taken by the reclosers to repower the line (typically three seconds).



Appendix 5: Useful links and references

The information and material used to prepare this document has been sourced from a variety of published documents, reports and articles prepared and published by DNSPs, DG proponents, regulatory bodies and various government agencies from the list below. All links were current as of November 2011.

Clean Energy Council 2004, Technical Guide for Connection of Renewable Generators to the Local Electricity Network, www.cleanenergycouncil.org.au

DRET 2006, A Draft National Code of Practice for Embedded Generation, www.ret.gov.au

Sustainability Victoria 2011, Cogeneration - frequently asked questions (FAQs) www.resourcesmart.vic.gov.au/for_businesses/energy_4513.html

CitiPower / Powercor 2010, Customer Guidelines for Sub Transmission Embedded Generation,

Powercor Australia 2006, Customer Guidelines for Embedded Generation of rating up to 1MW, www.powercor.com.au

DNSP websites

CitiPower / Powercor
www.powercor.com.au

SP AusNet
www.sp-ausnet.com.au

Jemena
www.jemena.com.au

United Energy
www.ue.com.au

Regulators and relevant government agencies

Essential Services Commission - Victoria
www.esc.vic.gov.au/public

Australian Energy Regulator
www.aer.gov.au

Australian Energy Market Commission
www.aemc.gov.au

Australian Energy Market Operator
www.aemo.com.au

Department of Resources, Energy and Tourism
www.ret.gov.au

International agencies of interest

UK Department of Transport and Industry. The Contribution to Distribution Network Fault Levels from the connection of Distributed Generation.
www.webarchive.nationalarchives.gov.uk/

US Department of Energy – Industrial DE information
www1.eere.energy.gov/industry/distributedenergy

World Alliance for Decentralized Energy (WADE)
www.localpower.org/

