Jemena Electricity Networks

Embedded Generation Guidelines

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Document History

Revision	Date	Amended by	Description of Changes
1.0	20/05/2013	Hung Nguyen	Initial Release
2.0	11/11/2021	Kevin Combe	Incorporates update to align with the latest AS/NZS 4777.2:2020
3.0	27/05/2024	Kevin Combe & Diptiman Yadav	Amended to include solar PV emergency backstop requirements

Authorisation

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1 ACRONYMS

In this guideline the following abbreviations have been adopted:

ACR	Automatic Circuit Recloser
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
CB	Circuit breaker
CSIP-AUS	Common Smart Inverter Profile Australia
CT	Current transformer
DLF	Distribution Loss Factor
DNSP	Distribution Network Service Provider (JEN)
DUoS	Distribution Use of System
DoE	Dynamic Operating Envelope
EDCoP	Electricity Distribution Code of Practice
ESC	Essential Services Commission
ESCODE	Electricity System Code
GMM	Generation Monitoring Meter
HV	High Voltage (above 1kV)
IEEE	Institute of Electrical and Electronics Engineers
IES	Inverter Energy System
ITPs	Inspection and Testing Plans
JEN	Jemena Electricity Network (Vic) Ltd
LPVT	Low Power Voltage Transformer
LV	Low Voltage (under 1kV)
MLF	Marginal Loss Factor
NECA	National Electricity Code Administrator
NEL	National Electricity Law
NEM	National Electricity Market
NER	National Electricity Rules
NMI	National Metering Identifier
NSP	Network Service Provider (either a TNSP or DNSP)
ROCOF	Rate of Change of Frequency
SIR	Service and Installation Rules
THD	Total harmonic distortion

TMS	Time multiplier setting
TNSP	Transmission Network Service Provider
TUoS	Transmission Use of System
VT	Voltage transformer

2 HOW TO USE THIS DOCUMENT

These Embedded Generation Guidelines have been prepared to assist proponents or their agents connect embedded generators to the JEN Network. This document is divided into a number of distinct chapters.

- Chapter 3 - Participation within the National Electricity Market (NEM)
- Chapter 4 - Connection Options and Opportunities
- Chapter 5 - Access Standards (Automatic and Minimum)
- Chapter 6 - Testing, Commissioning and Maintenance Requirements
- Chapter 7 - Operational Constraints and Standards

Chapter 3 contains background information on the NEM, the parties involved within the NEM and their role to assess embedded generator connections, the connection process, generator classifications and the available forms of access standards. Much of the information in Chapter 3 is a high level overview of that contained within other rules and codes related to embedded generation such as the NER and the EDCoP.

Chapter 4 contains background information on embedded generator connection options, opportunities and risk. When undertaking feasibility studies for the construction of an embedded generator this section briefly reviews what types of generator can be connected to the network, how it might connect and what costs and benefits might be involved.

Chapter 5 contains the embedded generator access standards that should be used as the underlying basis to design embedded generation systems that will satisfy DNSP standards. The standards are presented in a descriptive way with a focus on the automatic access standards. If these standards are satisfied, the generator proponent will not be denied network access on technical grounds. Minimum access standards are also tabled which provide the standards below which access to the network will be denied regardless of circumstance. Chapter 5 has a lot in common with chapter 5 of the NER, in some areas containing a direct summary of the standards within the NER, although in other areas it goes into specific detail for the DNSP distribution network. Where there is any conflict between these standards and the NER, the standards within the NER shall prevail.

Chapter 6 contains the testing, commissioning and maintenance requirements. These standards are generally high level but provide guidance on the level of detail required by the DNSP. It also provides guidelines on repair, asset replacement or other modifications following the commissioning of the generator and some of the obligations that will be included as part of the embedded generator connection agreement.

Chapter 7 contains operational constraints and standards including operator communications, the impact of planned and unplanned network and generator outages, operating standards, access rights and health and safety considerations.

By giving some consideration to the matters covered in chapters 6 and 7 at an early stage it may be possible to modify the design (such as provide inbuilt redundancy) to reduce the impact of network outage, repair, maintenance, etc. while operating the plant with health and safety considerations included as part of the design.

It is not expected that this document will be read from cover to cover but rather it shall be used as a reference during all stages of an embedded generation design and installation project. Nonetheless all embedded generators connected to the DNSP network are expected to fully comply with the standards covered in chapters 5, 6 and 7 and therefore these sections should be reviewed in detail as part of every design.

These Guidelines are not a substitute for, and should not be read in lieu of, the NEL, the NER or any other relevant laws, codes, rules procedures or polices, nor do they constitute legal or business advice. While the DNSP has used due care in the production of these Guidelines, to the extent permitted by law neither the DNSP, nor any of its employees make any representation or warranty as to the accuracy, reliability, completeness or suitability for particular purposes of the information in these Guidelines and shall not be liable for any errors, omissions or misrepresentations in the information contained in these Guidelines.

3 EMBEDDED GENERATOR PARTICIPATION WITHIN THE NATIONAL ELECTRICITY MARKET

3.1 Obligations

3.1.1 General

The term customer embraces both consumers and embedded generators. The various codes identify responsibilities of customers, who are expected to:

- Install and maintain protection equipment to clear faults within their installation and prevent sustained overload of their equipment.
- Install and maintain protection equipment to disconnect an embedded generator from the distribution network when certain faults occur on the distribution network.
- Control short circuit levels within their establishments or limit short circuit current originating from their generators.
- Balance load across the phases of their supply.
- Maintain the power factor of their load within certain limits.
- Ensure that transient or variable currents arising from switching or the operation of equipment (e.g. flicker) does not adversely affect other network users.
- Ensure that the harmonic current emissions from either load or generation do not exceed certain limits.

The obligations extend to the control of other negative effects originating within their installation to minimise adverse effects on other customers and the distribution system[1]. Customers can be seen to be in a position to pro-actively manage supply quality and safety.

Connection of an embedded generator with the DNSP network is acceptable for:

- parallel operation with the network, or
- exercising standby generating plant and using the network as an exercise load,

with any deficiency of energy being imported or any excess generation being exported across the network connection point.

Responsibilities defined under the ESCODE and NER require that the DNSP ensure the network connection of each network user does not adversely impact the quality of supply to other network users. Comprehensive but reasonable technical requirements are to be enforced. To this end the various DNSPs that operate throughout Victoria maintain a set of SIR that intend to ensure that an embedded generators installation comprises suitable equipment and a safe environment for operating personnel and the public and does not adversely affect the DNSP supply system[2].

By definition, distribution networks are an open and accessible public facility unlike the protected environment of a private generator. The DNSP network is exposed to a wide range of events that can result in:

- Full or partial loss of supply.
- Loss of individual phases.
- Imposition of solid or high impedance fault conditions.

[1] Ref. SIR 7.4
[2] Ref. SIR 9.1

- Transient interruption and re-establishment of supply.
- Transient over and under voltage conditions.
- Voltage waveform distortions.

An embedded generator that operates in parallel with the distribution network is required to acknowledge these risks and to take reasonable action to limit damage that could result from such events. Under some conditions disconnection is mandatory. The embedded generator must take whatever precautions are necessary to protect or disconnect the generating plant when any such adverse condition might place the generating plant or distribution network at risk.

Supply interruptions occasionally occur on distribution networks. While the DNSP will always move to restore supply as quickly as possible, there can be substantial benefit to loads by way of supply continuity, if embedded generation is established and controlled in a manner that it remains in service when the DNSP supply is lost. This security of supply requires careful engineering and selection of plant and control systems. The provision of embedded generation in connection with a load does not relieve a DNSP's responsibility to require provision, installation, operation and maintenance of load shedding systems for any loads in excess of 10MW. The occasions on which load shedding in this manner is exercised are rare and are always associated with events that are placing the wider integrated network at severe risk.

The generator should therefore anticipate such events in which the local load is either intentionally or unintentionally lost and network export rises to the maximum permitted level[3].

3.1.2 Regulatory codes and guidelines

3.1.2.1 Code relevance and threshold ratings

All relevant codes define generation connected at the distribution level as "embedded" generation regardless of capacity. Customer owned generators used for backup purposes that have make before break transition are classified as Stand-by Generators with the DNSP standards fully covered in the SIR.

The NER:

- Provide a framework and access arrangements for connecting loads or generators to a distribution network.
- Contains a fee structure aimed at recovering costs at a level adequate to support AEMO operations[4]. These fees and their recovery have little direct relevance to DNSPs. Connection charges for embedded generators are regulated by the jurisdictional regulator or the ESC in Victoria.
- Provides the authority to enable AEMO to prepare guidelines that allow a person or class of persons from <u>not</u> requiring to register as a Generator[5]. Such units would need to apply for a registration exemption with AEMO.
- Provide specific requirements for generating units over 30MW, power stations with multiple generating units totalling more than 30MW and generators requiring registration. The 30MW threshold introduces several important standards such as the following:
  - generators over 30MW will generally be scheduled unless they use a technology that results in intermittent power output, in which case they will classified as semi-scheduled,

[3] Ref. NER S5.1.10.2
[4] Ref. NER 2.11
[5] Ref. NER 2.2.1(c)

and therefore must have the systems required to enable the power output of the generator to be controlled in response to centralised dispatch instructions,

- generators over 30MW will generally be required to regulate voltage at a transmission node or provide reactive power under the direction of AEMO (although the DNSP may impose similar conditions for generators under 30MW on the distribution network),
- power output in response to frequency variations,
- stability performance and response to network disturbances,
- facilities to test control systems to establish dynamic operational characteristics,
- remote monitoring to AEMO control centres,

Therefore for generators under 30MW in size less detailed system planning data will generally be required than that indicated in the AEMO Generating System Model Guidelines, AEMO Generating System Design Data Sheet, and the AEMO Generating System Setting Data Sheet.[6] The NER make very limited reference to changes in technical requirements at any rating below the 30MW limit.

- Defines automatic, minimum and negotiated access standards (refer to section 3.4 of this report).

The EDCoP:

- Places no rating limitations on generator connections to distribution networks.
- Makes distinction based on rating at two thresholds:
  - Over 5MW synchronous generators must have an Excitation Control System, a voltage regulator and a frequency responsive governor. This condition is unlikely to be restrictive on unit selection.
  - Over 10MW synchronous generators must comply with the NER as if they were 30MW in rating in respect of response to disturbances, safe shutdown in an emergency, restart in emergency and frequency responsiveness and governor stability.
- In providing rulings on conditions related to servicing of load the EDCoP implies that embedded generators to not degrade those conditions. This is addressed under the sections titled Power frequency voltage excursions, Power factor, Load balance and Disturbing loads in addition to those required explicitly listed above.
- Wherever the EDCoP requirements conflict with any corresponding reference in the NER, the EDCoP takes precedence. But equally, wherever the EDCoP requirements do not address an issue addressed by the NER, the NER requirements must apply.

Electricity Industry Guideline no.15 – Connection of Embedded Generation:

- Regulates the negotiation of the commercial aspects of connection agreements. It provides no technical performance standards for embedded generators.
- States the principles that must be applied for determining the network connection fees that can be charged for the connection of embedded generators in Victoria.
- Regulates how DNSPs in Victoria pass through avoided TUoS fees to embedded generators.
- Provides guidance on how avoided DUoS costs should be shared with embedded generators.

[6] Ref NER S5.5.6

AEMO guidelines:

- Guidelines published by AEMO indicate that a unit will most likely be exempt from registration if:
  - it has a nameplate capacity under 5MW, or
  - it has no capability to export to a distribution system in excess of 5MW, or
  - it will not export more than 20GWh in any 12 month period, provided its nameplate rating is not greater than 30MW, or
  - it has no capability to synchronise or to operate electrically connected to a distribution system.

  Such units would need to apply for a registration exemption with AEMO. For embedded generation units that AEMO exempt from registration, the DNSP will be the only body responsible for granting access to the distribution network.
- For embedded generators in the 5MW to 30MW range, AEMO is also expected to set performance standards and AEMO may apply parts of the NER standards even though the EDCoP that apply in Victoria doesn't explicitly state that the NER standards apply for generators below 10MW.
- For embedded generators greater than 30MW AEMO is expected to apply the full technical NER standards and the DNSP will work with AEMO to provide one set of consistent network access standards to the embedded generator proponent.
- AEMO publish a number of guidelines and registration documents (available from its website) that apply to embedded generators in accordance with its own obligations under the NER. These documents supplement the NER.

The relationship between the codes:

The NER contained a jurisdictional derogation clause that designated the ESC as the overarching authority responsible for regulating the connection of generators to the distribution networks in Victoria. The derogation end date was 31 December 2010[7]. The ESC regulated the connection of embedded generators via several documents including the EDCoP, ESCODE and guideline no.15 which in turn make reference to the NER. The ESC regulations empowered DNSPs to establish their own reasonable technical requirements for the connection of embedded generators (the purpose of this document). To ensure consistency with national standards the DNSP developed its own standards using the NER as a framework with some additional detail where required. This is particularly important given the transition to national regulatory standards and the transfer of regulatory authority in Victoria from the ESC to the AER.

In addition to these DNSP standards, AEMO may also place technical standards on embedded generators in accordance with the NER although the DNSP is expected to provide any interface between an embedded generator proponent and AEMO so that the generator proponent is provided with a single set of consistent standards.

Unlike many other access standards in use (including the NER itself), the standards issued by the DNSP (within this document) are more descriptive and provide guidance on design philosophy. Yet at the same time wherever possible the DNSP standards draw upon existing standards such as the EDCoP that list strict limits and operating ranges on a range of measurable parameters. This approach provides consistency with other standards however it also providers the additional specific guidance

[7] Ref. NER 9.7.4(b)(2)

required for the designer in a number of areas such as protection, control, reliability, safety and network interface.

3.1.2.2 Other compliance requirements

The NER and EDCoP are focussed on the development and operation of an integrated supply network. Other Acts, regulatory codes, standards and guidelines are applicable, but in these the focus may be more peripheral but the intent is quite specific. Safety is a clear example.

The following Acts, regulatory codes, standards and guidelines are identified as relevant:

- Electricity Safety Act 1998 and associated Safety Regulations.
- Relevant Australian and International Standards.
- SAA Wiring Rules.
- Metrology procedure.
- Electricity customer metering code.
- SIR issued by the DNSPs.
- The Blue / Green Book.

Associated with this regulatory framework, the followings are further requirements that applicable with the embedded generator connection:

- A certificate of electrical safety is to be provided to confirm compliance with AS3000.
- A generator and all ancillary plant are required to be maintained in a safe condition.
- Operation and maintenance of the plant should comply with good industry practice.
- The plant is to be tested in accordance with the requirements of the Wiring Rules and all other relevant Australian Standards.
- The plant shall comply with planning and environmental laws.

3.2 Generator connection process

3.2.1 General

The Generator connection process shall follow chapter 5 of the NER as follows:

- Connection enquiry.
- Application to connect.
- An offer to connect in accordance with the DNSP’s licence as a distributor.
- Connection agreement.

In addition to the formal stages above it is common practice for the DNSP to receive a pre-Connection Enquiry as a first step that may consist of informal discussions or emails between the DNSP and the generator proponent regarding a range of matters such as:

- The connection process.
- Opportunities to provide network support.
- Project timing.
- Capacity of the network.
- General sharing of information such as network configuration in specific parts of the network.

- Any thresholds regarding generator size or fault level contribution over which a step change in connection cost may be expected.

All of these matters may assist with the exploration of opportunities, development of preliminary timelines and pre-feasibility studies without any commitments being made. In some cases, a generator proponent may even request that the DNSP undertake preliminary connections studies on their behalf for a fee to explore a range of connection options before even submitting a Connection Enquiry. Any such studies are undertaken outside of the regulated generator connection process described above.

An overview of the connection process is summarised in the flowchart in Figure 1.

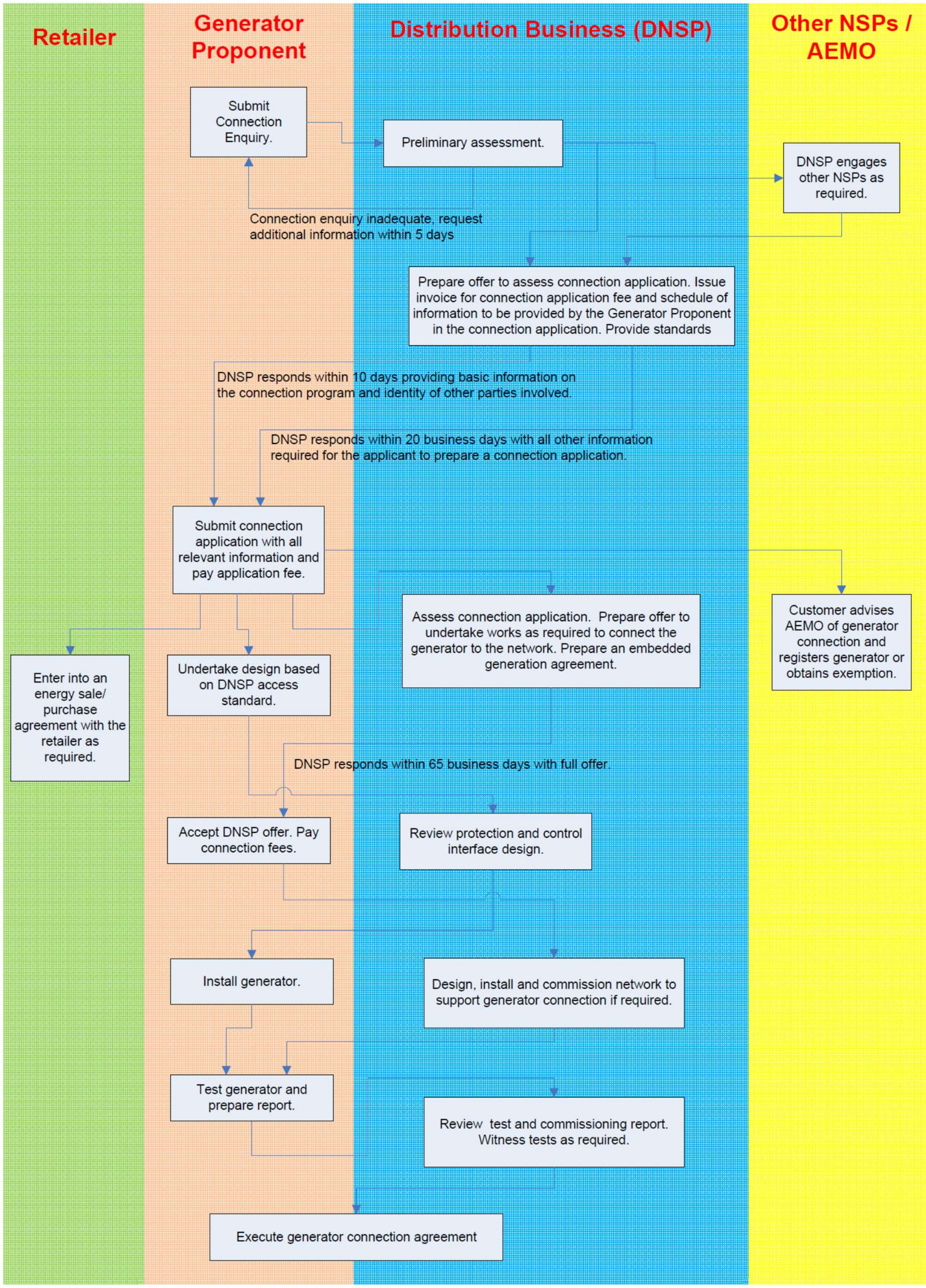


Figure 1: Simplified generator connection application process flowchart.

3.2.2 Connection enquiry

As part of the Connection Enquiry, which initiates the formal connection process, the Generator Proponent is required to provide the following information under Schedule 5.4 of the NER:

- Type of plant.
- Preferred site location.
- Maximum power generation or demand of whole plant.
- Expected energy production or consumption (MWh per month).
- Plant type and configuration – (e.g. number and type of generating units).
- Nature of any disturbing load (size of disturbing component MW/MVAr, duty cycle, nature of power electronic plant which may produce harmonic distortion).
- Technology of proposed generating unit (e.g. synchronous generating unit, induction generator, photovoltaic array, etc).
- When plant is to be in service – (e.g. estimated date for each generating unit).
- Name and address of enquirer, and, if relevant, of the party for whom the enquirer is acting.
- Major load data installed together with the generator, requirements for a construction supply and any auxiliary power requirements.

The Connection Enquiry should be a formal written submission.

The DNSP is required to respond to a Connection Enquiry with the following information[8]:

- Within 10 business days:
  - List of other NSPs that will need to be engaged in the processing of a connection application.
  - Whether any services the DNSP proposes to make are likely to be contestable.
  - Overview of the embedded generation connection process and preliminary program.
- Within 20 business days:
  - The automatic access standards, minimum access standards and applicable plant standards.
  - Where a proponent has indicated a preference to negotiate on any particular access standard(s) the DNSP must also advise if AEMO will need to be involved in such negotiations.
  - Preliminary information regarding the distribution network required for the generator proponent to conduct engineering development of the project and to allow assessment of the viability of their proposal.
  - The technical data that will need to be provided within a Connection Application so that the DNSP can process the Connection Application and prepare a connection offer.
  - The fees and charges that will apply to process a Connection Application.

The DNSPs aim to supply the information above within the target timeframes however this is only possible where the connection applicant provides sufficient information required in their Connection Enquiry. The DNSP may also need further time where consultation with other NSPs is required and these NSPs are not regulated to respond within timeframes that would enable the DNSP to meet its

[8] Ref. NER 5.3.3. Please refer to the NER for a comprehensive list of every requirement which has not been reproduced here.

obligation. In such circumstances the DNSP will negotiate with the connection applicant on a date by which the information can be provided.

3.2.3 Application to connect

The Embedded Generator Proponent must submit a Connection Application to the DNSP to obtain an offer to connect. The connection application must contain the following[9]:

- Detailed technical data for the facility to allow it to be assessed by the DNSP.
- The expected level and standard of service required.
- Any network support benefits the generator could provide and the commercial grounds upon which such services could be provided.
- Whether the generator shall be market or non-market and whether it shall be scheduled or non-scheduled.
- Where automatic access is not met, proposals for negotiated standards.

If the generator is registered, the scheduled data must be submitted in a form suitable for transmittal to AEMO and use of AEMO Generator design data and setting data schedules must be adopted as these contain more comprehensive content.

3.2.4 Offer to connect

In response to a Connection Application the DNSP is required to[10]:

- Apply consistent processes to determine the appropriate technical requirements to apply to the Connection Application[11].
- Conduct investigations to establish the impact of the proposal on all DNSP operations.
- Liaise with the TNSP and other DNSP's on a range of technical issues.
- Establish the range of capital works necessary to accommodate the proposal.
- Formulate a technical and commercial offer with full details sufficient to allow acceptance by the applicant.

As regulated by the DNSP's licence in Victoria, the DNSP must prepare an Offer to Connect within 65 working days or as otherwise agreed with the connection applicant. The time by which a DNSP must respond to a generator connection applicant with an offer does not commence until all the information required by the DNSP to prepare an offer is received. In addition, the DNSP may negotiate a longer time if the connection applicant requests that certain design and/or construction works go to tender.

The offer to connect will consist to two parts:

- An offer to provide connection services (i.e. undertake works on the distribution and/or transmission networks to allow the generator to connect).
- A connection agreement containing all technical, commercial and legal obligations for both parties for the ongoing connection and operation of the embedded generator.

[9] Ref. NER 5.3.4. Please refer to the NER for a comprehensive list of every requirement which has not been reproduced here.
[10] Ref. NER 5.3.5 and 5.3.6. Please refer to the NER for a comprehensive list of every requirement which has not been reproduced here.
[11] Ref. NER S5.1.1

The connection services Offer to Connect prepared by the DNSP shall be inclusive of all network connection fees including those that may be payable to other NSPs, however the offer will not include fees associated with registration and licensing imposed by the jurisdictional regulator the ESC, the AER or the AEMO not directly associated with the physical network connection. Once the Offer to Connect is formally accepted and payment is made by the proponent, the DNSP together with its subcontractors and other relevant NSPs will commence works.

3.2.5 Connection agreement

On acceptance of the offer and any final negotiation, the DNSP will prepare a Connection Agreement that will include all technical material, commercial provisions and terms and conditions.

The Connection Agreement will contain any ongoing fees to be paid by the embedded generator or any ongoing payments to be made by the DNSP to the embedded generator for services provided. The Connection Agreement must be signed prior to the final commissioning of the embedded generator.

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

3.3 *Generator classification*

3.3.1 Market and non-market classification

A Market Generator has an intention to sell all, or part, of the generated energy through the NEM. An embedded generator may be classified as a Non-market Generator if all of the electrical energy produced is consumed by a load connected to the same network connection point, or if the energy exported to the distribution network is purchased in its entirety by a licensed retailer.

3.3.2 Scheduled, semi-scheduled and non-scheduled classification

AEMO registered generators must be classified as either scheduled, semi-scheduled or non-scheduled to reflect the level of control that AEMO holds over the minute to minute real power output of the generating unit (dispatch). This level of dispatch control is driven by the imperative to maintain a supply and demand balance on the network at all times.

Scheduled

If a generator has a nett network power export over 30MW and the power output can be well controlled in response to dispatch instructions, it will generally be classified as scheduled. Scheduled generators must operate in accordance with the co-ordinated central dispatch process operated by AEMO, must notify AEMO of availability in each trading interval and must submit to AEMO a schedule of dispatch offers for each trading interval. A scheduled generator attracts more attention from AEMO because of the vital system security role they provide and their role in setting spot prices. Scheduled generators are required to advise of “energy constraints” together with special characteristics such as slow start, dispatch inflexibility or self-commitment and de-commitment requirements.

Semi-scheduled

If a generator has a power output over 30MW but is substantially intermittent, as may be the case for wind generation, the plant may be classified as a Semi-scheduled. The obligations to supply data to AEMO and establish telemetry facilities are no less stringent. In addition, operators of semi-scheduled plant are also required to submit energy conversion models developed in accordance with guidelines issued by AEMO.

Non-scheduled

A generator may be classified as non-scheduled if the generator has a rating under 30MW. It may also be classified as non-scheduled if 50% or more of the power or energy produced is consumed locally and the export does not exceed 30MW, or if the power generation is linked to the conditions of some other process that cannot be independently controlled, or if it is not practical to be centrally dispatched, or if the output cannot be well controlled in response to dispatch instructions.

3.3.3 Generator registration

A network user that intends to connect an electricity generator to the distribution network must register the generator with AEMO or obtain an exemption for registration from AEMO, and obtain a generating licence from the ESC. Exemptions to these requirements apply in some circumstances. An embedded generator that is classified as exempt from registration by AEMO is not required to pay participant fees, to have either energy output scheduled, or to have their energy generation commercially settled in the market.

Conditions where embedded generators may be exempt from obtaining a generator licence

In accordance with the Electricity Industry Act 2000 the Governor in Council issued an Order in Council on the 1 May 2002 which provides a general exemption for generators to hold a licence if they comply with all of the following[12]:

- The Generator capacity is less than 30MW.
- The total exported output of the Generator is supplied (or sold) to a licensed retailer.
- The Generator complies with all provisions of the EDCoP.
- The Generator is non-scheduled (i.e. not centrally dispatched).

To determine if a specific embedded generator is covered by the Order in Council, persons can apply to the ESC requesting the issue of a certificate in accordance with clause 5 of the Exemption Order, although the issuing of such a certificate by the ESC in no way grants the exemption. Guidance in regards to the need for a generator licence should be sought from the ESC.

Conditions where embedded generators may be exempt from obtaining AEMO registration

The conditions under which an embedded generator might avoid registration with AEMO are determined by AEMO and are addressed in guidelines issued by AEMO. At the time of publication of this document the relevant AEMO documents are "*Connecting New Generation – A Process Overview*" and "*Generator Registration Guide*". The following information is provided as a guide but any decision made must be based on AEMO documents. If any doubt exists assistance should be sought from AEMO.

An embedded generator may assume exemption if it meets any of the following criteria:

- Is rated less than 5MW and is a non-market and non-scheduled generator.
- Is not capable of exporting more than 5MW and is a non-market and non-scheduled generator.
- Cannot operate connected to the network (e.g. customer backup generator) and is a non-market and non-scheduled generator.

[12] Source: Table A.1 Schedule to the Order-in-Council.

An embedded generator rated greater than 5MW but less than 30MW that will export less than 20GWh in a year may apply for exemption from registration. Other extenuating circumstances may also be considered in response to an exemption by AEMO.

The NER provide guidance on "extenuating circumstances" that may permit exemption from registration. These circumstances cover generators over 30MW that effectively deliver less than 30MW and where all energy is sold locally. These cases are considered on a case by case basis. It is an exception for a generator or group of generators of 30MW capacity or more to be exempt from registration. AEMO guidelines identify the following categories of embedded generation as qualifying for standing exemption from registration:

- Emergency back-up generation.
- Small solar energy generating systems.
- Minor hydro power stations.
- Small generating facilities entirely contained within an owner's process.
- A 10MW wind farm with all generation sold to a local retailer.

3.3.4 Generator classification flow chart

A flow chart of the normal decision making process underlying generator classification is shown in Figure 2 and Figure 3. If a generator is a market generator, a scheduled generator or a semi scheduled generator it must be registered with AEMO. A non-market, non-scheduled generator may be exempt from registration. The flowcharts in Figure 2 and Figure 3 need to be used to determine if registration is likely to be required. AEMO is responsible for defining generator classifications and therefore the information provided below should be used as a guideline only.

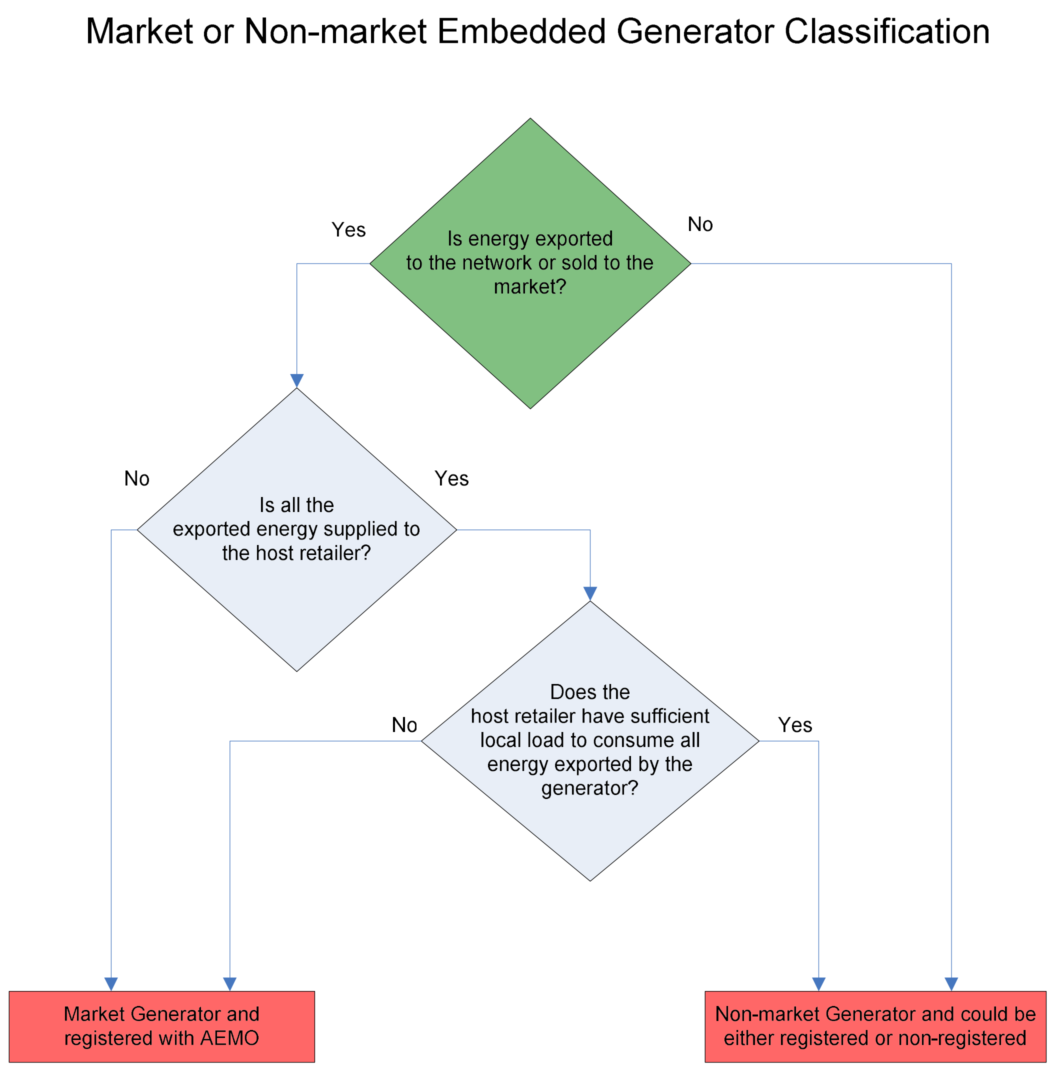


Figure 2: Generator classification flow chart – market or non-market

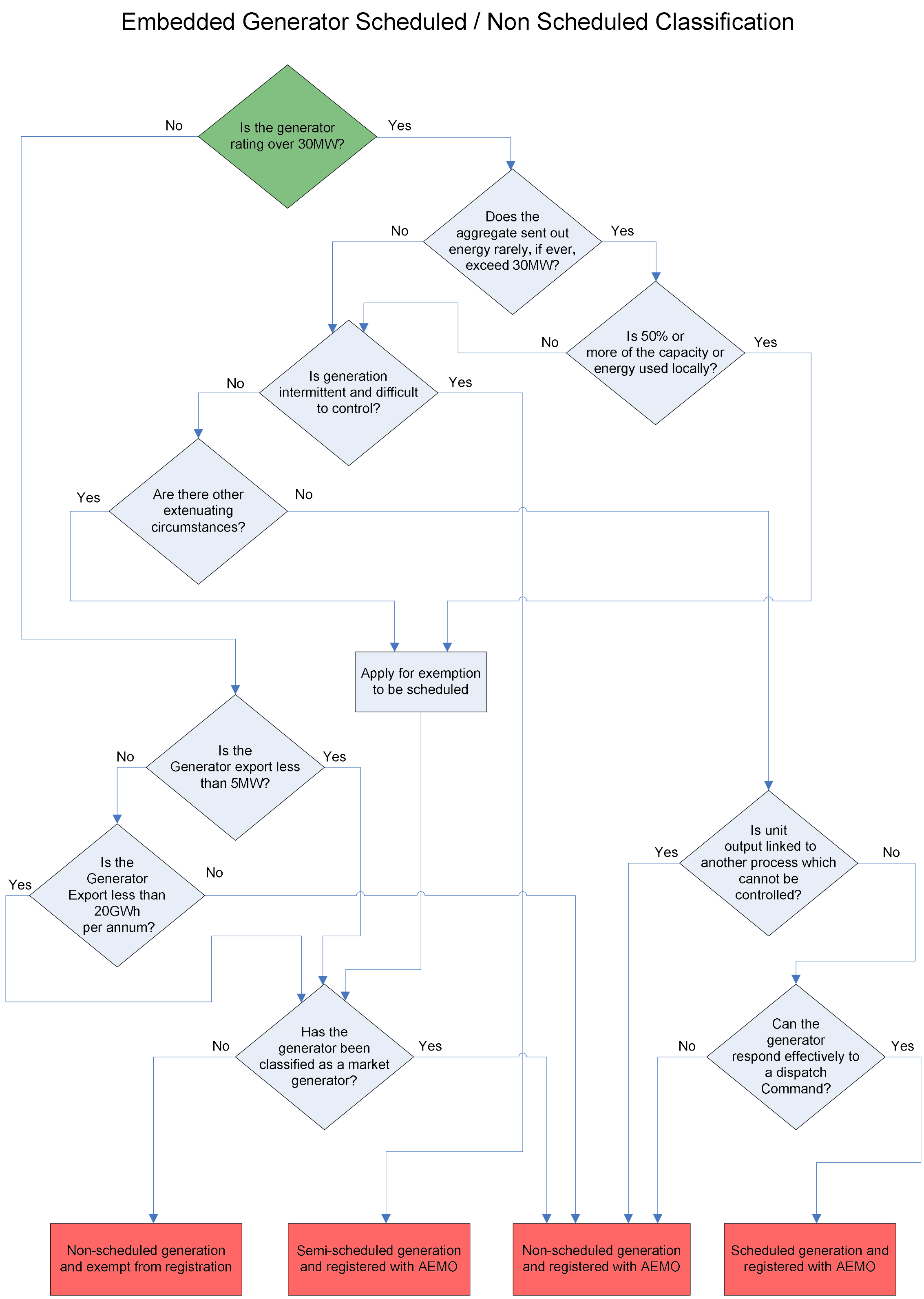


Figure 3: Generator classification flow chart – scheduled, semi-scheduled or non-scheduled

3.4 *Available generator connection (access) standards*

Access standards define the technical compliance specifications to be applied for a generator. Embedded Generator access standards usually apply at the generator connection point on the distribution network, however they could also apply at other locations specified by the NSP such as at the point of common coupling or even at various transmission connection points. Certain performance criteria are mandated under the NER providing the NSP with no flexibility while other standards can be negotiated with the NSP within certain bounds. The NSP must provide *automatic access standards*, *minimum access standards* and *plant standards* as described below.

3.4.1 Automatic access standards

If a proponent agrees to adopt all of the automatic access standards, the plant will not be denied access to the network on the basis of the access standards. All generator proponents should aim to satisfy the automatic access standards published by the NSP where it is economic to do so.

3.4.2 Minimum access standards

If a generator does not satisfy one or more minimum access standards it will be denied access to the network. The minimum access standards are considered a lower bound for negotiation. If particular aspects of the automatic access standards are difficult to satisfy then the generator proponent can propose a lower standard for the particular part identified but that lower standard cannot be less than that specified within the minimum access standards.

3.4.3 Negotiated access standards

Any access standard agreed to between the Generator Proponent and the NSP below the automatic access standard but above the minimum access standard is called a negotiated access standard.

Negotiations between an Embedded Generator Proponent and the DNSP will largely focus on establishing the negotiated access standard in each of the NER performance areas. In many areas the DNSP is obligated to take advice and endorsement from AEMO prior to any resolution, even though plant ratings are well below 30MW. Subject to satisfactory negotiated outcomes, the negotiated performance standards agreed between DNSP and the Embedded Generator will be an integral part of a final connection agreement.

3.4.4 Plant standards

A Plant Standard is an Australian or widely adopted international standard. A DNSP may apply a plant standard as the relevant standard to be used for a certain class of generator rather than the general automatic or minimum access standards. For example AS4777 may be used as the appropriate standard for inverter connected Embedded Generators under 200 kVA and is widely adopted by most DNSPs in Australia.

A generator proponent may also propose to adopt an Australian or international standard in preference to part of the automatic or minimum access standards. A generator seeking to make such a substitution is required to document the substitution proposed and to table the relevant standards. The NSP shall then approve the adoption of these plant standards if considered acceptable.

3.4.5 Relationship between technical standards

While the AEMO generator classification process is largely driven by commercial considerations, technical requirements are influenced by the type and size of the generator.

AEMO's technical compliance interest is primarily focused on network stability and voltage control. The risk to network stability reduces with unit capacity and therefore the need for compliance with strict stability standards should reduce with reducing generation capacity.

AEMO only requires the application of the NER on generators required to be registered. The NER acknowledges that with reducing rating there will be some relaxation of standards. The DNSP under its Distribution Licence is empowered to set reasonable technical standards in the absence of direct AEMO jurisdiction. The acceptable access standards for generation plant under these limits are left to the discretion of the DNSP after reasonable consideration of issues relevant to the distribution level.

The DNSP's approach aligns with the approach adopted by the NER and seeks advice from the generator of the highest reasonably available performance that can be delivered, in excess of the minimum performance standard, in those capacity ranges not embraced by the NER. The DNSP will seek to negotiate on these matters with an objective of agreeing on performance outcomes that will allow an acceptable set of negotiated access standards in all applications.

On some matters the achievable performance standard will not be clearly identifiable or quantifiable without some level of site test. In such instances, DNSP may agree to accept the suggested performance but subject to an acceptable demonstration during site commissioning. On successful conclusion of the site test, the generator and DNSP will negotiate and agree on an acceptable performance measure that will thereafter form part of the negotiated performance standard for that generating unit and be incorporated in the connection agreement.

In summary:

- Above 30MW there is no opportunity to shift from rigid compliance with the NER unless the generator is unregistered. Such a generator must apply to AEMO for an exemption from registration.
- Below 10MW, consistent with NER guidance, the DNSP can relax the requirements in a number of areas related to system security.
- In the range around 1MW there is recognition of the need to relax guidelines further to allow participation of standby plant on an intermittent basis.
- In the range very much below 1MW, minimum requirements that maintain appropriate safety measures are adopted, but there will be a focus on the need to establish acceptable disturbance to others across the 400V network.
- At the very lowest level inverter-based technologies take prominence and standards align with national guidelines for this type of plants.

It is against this framework that the DNSP has prepared this set of technical requirement guidelines that are aimed at maximising opportunity for network users to become network generators. Figure 4 illustrates in qualitative terms this progressive reduction of requirements intentionally introduced in these Guidelines.

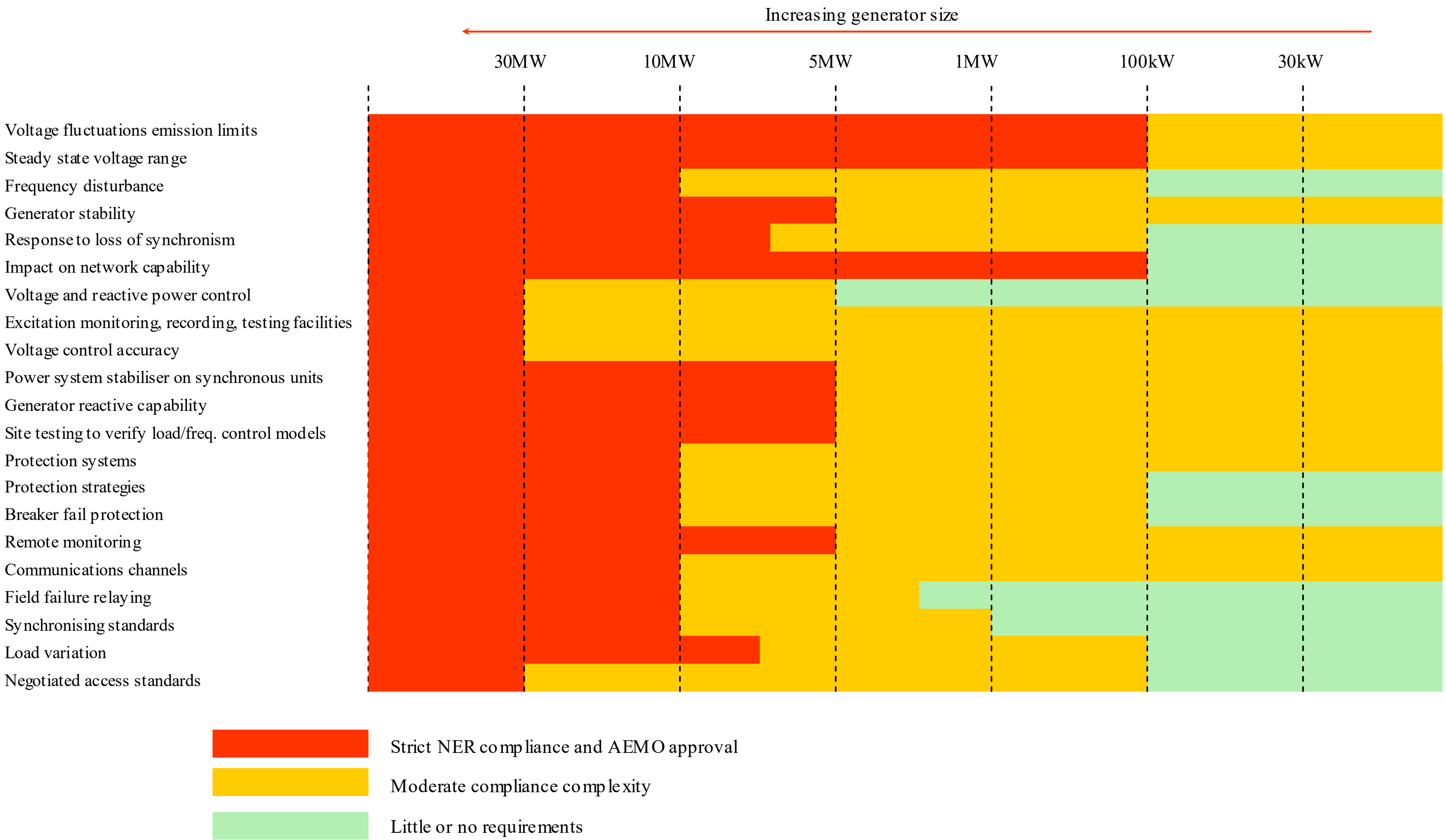


Figure 4: Progressive tightening of technical standards with generator capacity or classification

3.4.6 Reserved position on design standards or costs

The typical distribution network has hundreds of thousands of load connections and a steadily growing number of embedded generator connections. The DNSP has only limited control over the internal operation of these loads and generators. From time to time, conditions can therefore arise where the requirements of the relevant codes or rules are not satisfied on the network and while the DNSP will act to rectify the breach it may not always be within the capability of the DNSP to prevent such conditions from occurring. Under these circumstances the DNSP has and retains the right to require network users that are contributing to the compliance breach to:

- Improve the performance of their plant to meet their negotiated access standard, or
- Improve their connection standard from a negotiated access standard to the automatic access standard, or
- Continue contributing to the problem however enter into a new negotiated access standard and fund the reasonable costs of works necessary by the DNSP to mitigate their effect of connecting at a standard below the automatic access standard.

For the last two points above, such conditions will be included as part of the negotiated access standards of any embedded generator connection agreement. Without limiting the generality of the provision, conditions that would particularly fall into this classification include power frequency voltage fluctuation and voltage harmonic or voltage notching distortion[13]. Under any negotiated access standard agreed with a prospective embedded generator the agreement will not prevent the DNSP from taking whatever action may be required in future to ensure system standards or contracted obligations of other network users are satisfied. This could include revising a negotiated access standard to become an automatic access standard.

The NER specifically identifies an obligation on prospective generators to apply prudent design standards for the plant to be connected[14].

In assessing the robustness of any project, the DNSP will also seek guidance on the design life intended.

Where two or more generators connect at a point of common coupling with an overlapping interest and network capability constraints apply, the limited network capability will be shared between the generators based in proportion to their generating capacity. Examples could include constraints in respect of negative sequence voltage, harmonics, inductive interference, fault levels and thermal ratings. During assessment of any application and the setting of standards, this allocation may be relevant. In addition where works are required on the network to remove the constraint the cost of undertaking such works are expected to be allocated to each generator in proportion to their generating capacity. In any such cases the DNSP shall advise the applicant of the existence of other parties and the impact these other generators have on their proposal.

[13] NER clause S5.1.6(c)

[14] NER clause S5.3(e)(3)

4 EMBEDDED GENERATION CONNECTION OPTIONS AND OPPORTUNITIES

4.1 Plant type and connection

4.1.1 Acceptable generating plant

All forms of generating plant will be permitted to connect to the network if they can satisfy the access standards. In general, however, each type of generating plant has unique characteristics and this could limit its potential to satisfy these access standards in some circumstances. At some network locations, technical requirements may limit the type and/or capacity of a machine that may be connected. For example, multiple smaller capacity generator units may find it simpler to connect than a single large unit of the same aggregated capability.

4.1.1.1 Synchronous generators

For large high voltage generating plant synchronous machines have several advantages including their ability to smoothly control reactive power flows, power factor and voltage, to smoothly connect and disconnect from the network and to respond dynamically to voltage and frequency variations. This can provide benefit in the management of network stability and voltage profiles along distribution lines and feeders.

Although more flexible, synchronous generators also have some disadvantages. They require synchronising equipment and under certain conditions they can lose synchronism and will be required to disconnect from the network to avoid pole slipping and potential damage. They may also need interlocks with the distribution network protection to ensure that the synchronous generators cannot be connected to a network to which it is not satisfactorily synchronised. They also contribute to system fault levels and this will reduce available fault level margins on the system.

At times of network supply disruption, loads serviced from synchronous generators are more likely to see supply continuity through a more predictable ability to island with local site load. This is referred to as site islanding.

4.1.1.2 Asynchronous (Induction) generators

Asynchronous generators have the advantages of lower cost and maintenance through simpler design and construction which make them particularly well suited for smaller generator installations. Asynchronous generators typically contribute less to fault levels than synchronous generators as their fault level contribution is transitory.

Asynchronous generators may be of the mains-excited or self-excited form.

Mains-excited asynchronous generators

The mains-excited form draws reactive power from the DNSP network to power the field windings however may also require some capacitor banks to comply with the access standards for power factor. Mains-excited equipment has no requirement for special synchronising equipment for connection to the network and the generator protection and controls are simple and lower cost.

Mains-excited generators require a reactive energy supply from the electricity network to function thus there is an advantage that on loss of network supply the generator will usually not sustain operation and cannot form a local island with some network load. This is an advantage as local islanding with third party customers on the distribution network is currently prohibited. Nonetheless engineering studies and on-site tests may be required to ensure that self-excitation from power factor correction capacitors and/or capacitance of the electricity network will not inadvertently cause local islanding.

Self-excited asynchronous generators

Self-excited asynchronous generators usually use capacitor banks to provide the reactive power supply for the machine rather than the distribution network. The capacitance of the capacitor bank must be continuously adjusted to regulate the power factor (or voltage when islanded). The design has the advantages of reduced reactive demand from the network and may have the ability to form a site island if necessary. The control system though is more complex.

For small self-excited asynchronous generators (e.g. wind generator) grid connection via an inverter may be preferable (with AC to DC to AC conversion). Proposals need to address anti-islanding protection in a similar way to synchronous generators.

4.1.1.3 Inverter-connected generation

Static inverters are necessary when the electricity is produced from a direct current source such as a solar photovoltaic array or a wind generator with a DC alternator. Generation may also be from an AC source (such as a variable frequency source) not directly compatible with the DNSP network, with the source rectified to DC and then converted to a compatible AC supply. Inverters are the preferred form of connection for generators for the sub 100kW size. Inverters also have the following features:

- Generally, they contribute less to network fault levels. This provides a network benefit but can make it more difficult to detect and clear short circuit faults using conventional over-current protection.
- Large inverters may be mains-commutated using low switching speed thyristors however this type will typically require external filters to avoid harmonic voltage problems.
- Self-commutated (PWM) and high switching speed inverters (e.g. using MOSFET or IGBTs etc. as the switching devices) are preferred because of the lower harmonic levels they produce. These inverters typically have small inbuilt filters and have low harmonic emissions.
- The DC source may or may not incorporate energy storage such as a battery bank.
- Monitoring for technical compliance and safety can be demanding given that small inverter based generators are widely used and expected to increase in number.

In theory no size constraints are placed on inverter connected generation. Proponents should consider the relevance of alternative plant standards if the automatic and minimum access standards are considered to have deficiencies for some aspects that relate to the peculiarities of larger inverter based generation.

4.1.1.4 Portable generator parallel operation

Portable generators can be easily exchanged or modified making it difficult to verify that they comply with standards for protection, control and power quality and are often not designed for parallel operation with a distribution network. For this reason it is not recommended that portable generators be synchronised with the distribution network. In special cases the NSP will permit portable generators to be paralleled with the network however this is only following the rigorous process of connection application, negotiation and contract formation. It is likely to be necessary to have the critical protection and control systems as part of the permanent installation.

4.1.1.5 Generation under short-term parallel conditions

A load customer may request to briefly parallel their generator with the distribution network for the following reasons:

- If a generator is installed as backup against network supply loss then upon restoration back to the network the customer may prefer a seamless transfer without a further supply interruption (i.e. a make before break changeover).
- The customer may use the generator for demand management to reduce their load on the network assets at times of peak demand and again the customer will not want a supply interruption during the changeover.
- The generator may supply an embedded network and the generator owner would like to sell energy into the NEM however for some reason long term paralleling might be difficult or expensive because higher access standards are required.

The consequences of mal-operation are just as severe with short term parallel operation as with continuous operation therefore a DNSP is required to conduct an equally exhaustive analysis of the proposal as plant intended for continuous operation. Short term operations are therefore subject to the same access application procedure as for plant intended for continuous operation.

While noting that DNSPs will follow the same assessment process for short term parallel generators as those intending to operate continuously, it is expected that these generators will enter into a negotiated access standard and that some of the performance criteria will be relaxed. For example many of the power quality measures may be of little concern if the generator only parallels with the network for a few seconds per day. Likewise anti-islanding protection and backup redundant protection may be less rigorous.

4.1.2 Network connection options

There are various ways of connecting an embedded generator to the distribution network that are permitted within these standards. The option to be selected will depend upon both technical and commercial considerations. Each issue is given some consideration below.

Generator size versus connection voltage

To a large extent the generator connection voltage will depend upon the generator size and the availability of a network connection point. For each voltage level on the distribution network the thermal ratings of conductor, cables, transformers etc. limit the amount of power that can be practically injected into the network. The following chart provides a guide.

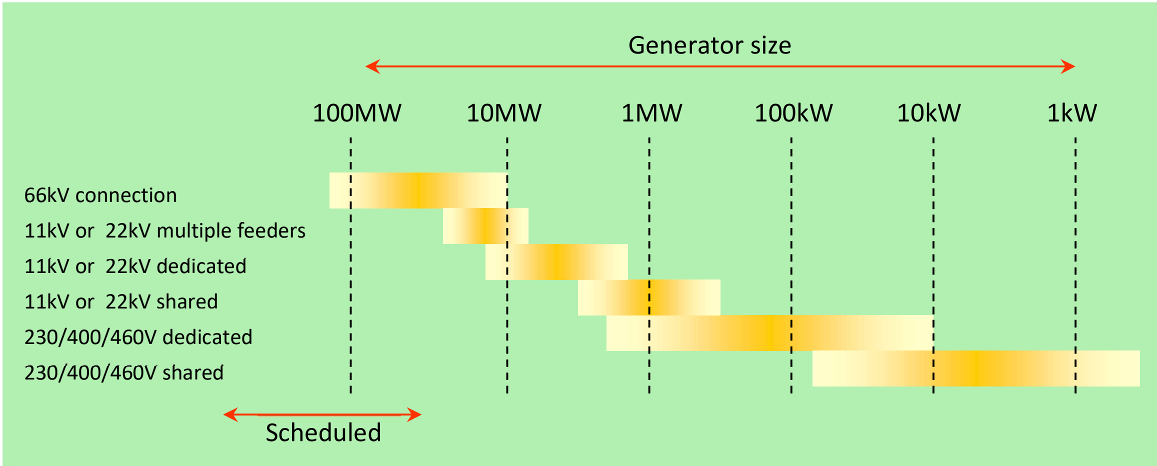


Figure 5: Typical generator size versus network connection voltage

Existing network configuration

The existing network configuration in the particular area the embedded generator is located will also affect the options available including connection voltage.

Examples For any given location generally only 11kV or 22kV distribution feeders will be available and it will not be possible to select either 11kV or 22kV. In a rural area distribution substations are typically small so a generator above 10kW may be forced to connect to a dedicated distribution substation and possibly fund the cost of installation.

Network fault levels

Where network fault levels will exceed the EDCoP limits or plant ratings it may be necessary to connect to another part of the network or at a higher voltage level.

Example A 1500kVA distribution substation is already installed on the distribution network and a generator proponent would like to connect a 500kVA generator. It is likely that the fault levels will exceed the distribution code limit of 50kA at low voltage thus the generator may need to connect at HV.

Power quality

DNSP or generator proponent modelling of the generator may reveal that connection to certain parts of the distribution network will degrade power quality such as voltage regulation, harmonics, flicker etc. It may be necessary to connect at a different part of the network such as a higher voltage level.

Security

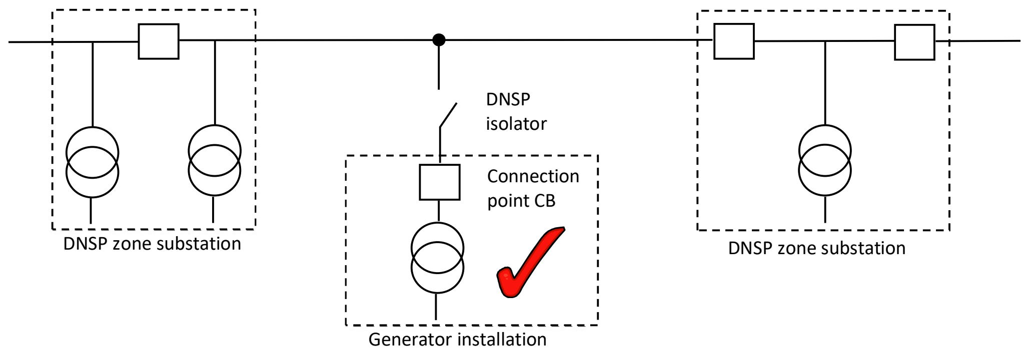
If it is necessary for the generator to continue operation even under certain fault conditions on the distribution network then multiple connections to the network may be required. Likewise, if the embedded generator provides network support, then the DNSP may impose a high security connection design.

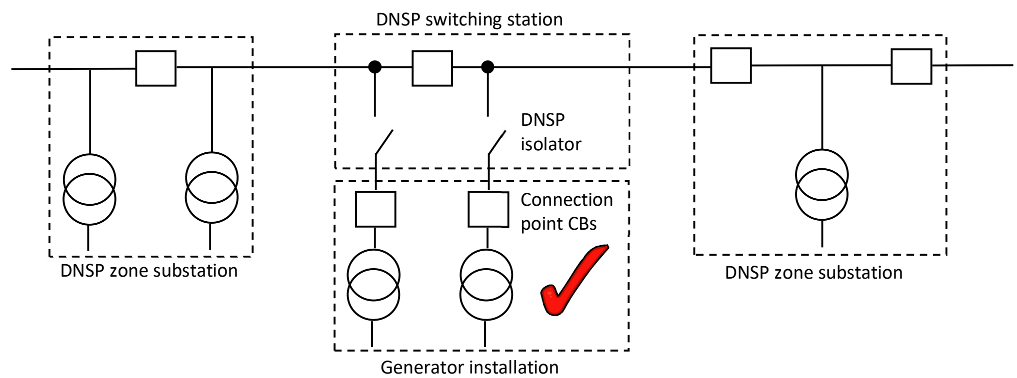
Connection point protection device

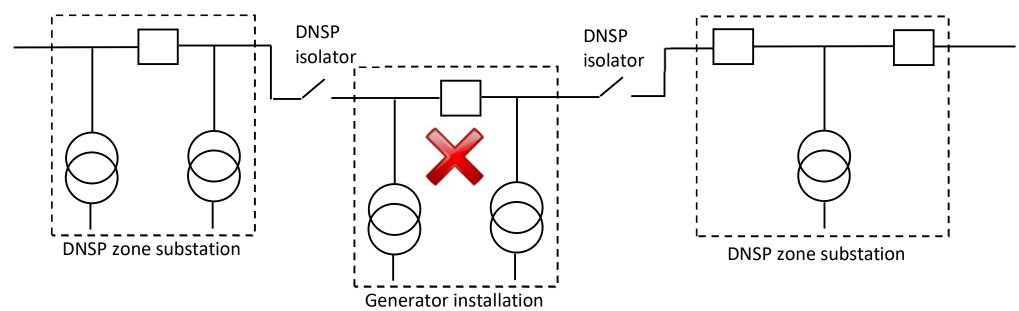
For all connection options the generator installation shall have a fault detection and interruption device at the connection point which disconnects all internal faults within an installation without impact on the distribution network. This also applies for large embedded generators connected at 66kV that connect into a shared sub transmission loop.

Examples

For a generator connected into a shared 66kV sub transmission loop the following single line diagrams show examples of designs that would, and would not be, accepted. In the last example a fault on one of the generator transformers would require tripping of one of the 66kV lines supplying one of the DNSP zone substations thus would not be permitted. It would also require electrical power to flow through a privately owned generator's assets to feed the shared distribution network which would also not be permitted.







11kV direct connected interface

Some parts of the DNSP network have distribution feeders operating at 11kV and to a lesser extent 6.6kV. Some generators operate directly at 6.6kV or 11kV without the need for step up transformers. While it is possible to directly connect these generators to the network in these areas it is not preferred.

The DNSP 11kV network is supplied through 66kV/11kV transformers with delta/star winding. The 11kV winding neutral is either solidly earthed or earthed via a four Ohm resistor. Changes in design policy may result in future alteration to the form of neutral earthing[15]. Current flowing in the neutral of the transformer to earth is used to detect phase to ground faults on the 11kV network.

If a generator connects directly at 11kV using a star connected winding with earthed star point then current will flow in the neutral because of network unbalance or during network short circuit faults and this will affect the operation of the network protection. Given that disabling this protection would compromise public safety, a generator connected directly at 11kV (or 6.6kV) shall have its generator winding connected in delta or as a floating star point. It is noted however that if the generator is required to service on site load in the absence of network connection (site islanding for backup) then the generator neutral will need to be earthed so that phase to ground faults within the installation can be detected. This could require the installation of an isolation transformer, automatic switching of the generator neutral depending upon the configuration or other solution.

Based on the issues above all embedded generators with a HV network connection shall connect via a transformer with a delta winding on the network side to comply with the automatic access standards. The inclusion of the transformer brings other benefits as well:

- Increased impedance with corresponding reduction in fault levels.
- Voltage adjustment through tap changing capability.
- Avoidance of future costs arising from network neutral earthing changes.
- Reduction of triplen harmonic exchange between generator and network.

Backup generation and short term paralleling

Backup generation is generally ‘break before make’ with mechanical or electrical interlocks that prevent the generator from connecting to the distribution network. For these arrangements the requirements are covered in the SIR and the DNSP is generally not concerned with the internal generator design. Some load customers however desire the ability to parallel their backup generation with the network for short periods of time during the changeover from generator to network to avoid a disruption to supply. If the generator can connect to the network, even if only for a matter of seconds, then the installation must comply with these standards.

The connection options for backup generation are basically the same as those that apply for a generator that is permanently connected. The main difference is that metering may not need to be altered if the parallel is limited to a matter of seconds and no energy is exported to the network. The generator would also be expected to enter into a negotiated connection agreement with less stringent technical requirements.

Net versus Gross metering

Many embedded generators are located together with a load and only the excess energy produced may be exported to the network. It is common to use a single bidirectional energy meter that only measures the Net energy import or export from the load/generator installation.

[15] An example of new technology is the Rapid Earth Fault Current Limiter.

Alternatively it may be desirable to use gross metering whereby all energy consumed by the load is obtained from the network and all energy produced by the embedded generator is exported to the network. This may provide a commercial advantage by selling energy at a higher rate than the cost to purchase energy from the network. There could be various reasons for the difference in rates such as premiums for clean renewable energy, hedging contracts, differences in tariffs offered by retailers, or the generator may wish to sell energy directly into the National Electricity Market as a market generator when energy prices peak.

The decision to use gross or Net metering will change the connection configuration. In general for gross metering the generator will need to be separately wired all the way to the metering point. In some circumstances however alternatives are possible where a generator meter is installed in series with the main connection point meter and energy metering summation is required to calculate the energy consumed by the load.

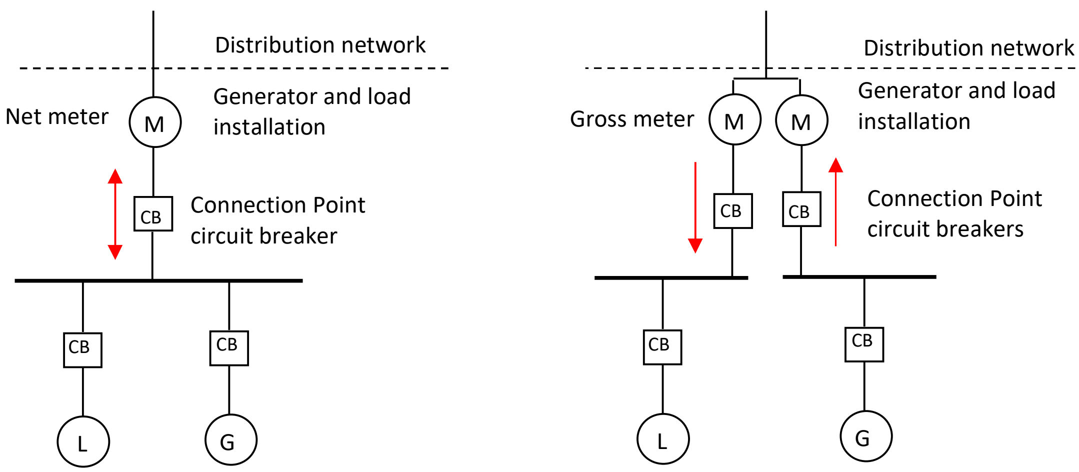


Figure 6: Examples of Net and Gross metering.

4.2 Embedded generator network benefits and opportunities

4.2.1 Opportunity and risk

Networks provide benefits for generators such as allowing them to sell the energy that is not used locally to other load customers by transporting the energy via the network. The contrary is also true. Generators can provide network benefits by providing additional network supply capacity in a local region, reduce network losses, defer or even avoid network augmentation and provide ancillary services to regulate voltage and frequency.

NSPs are obligated to consider non-network solutions to alleviate capacity constraints on transmission and distribution networks. The most obvious non-network solution is an embedded generator however demand management could also potentially avoid or defer network augmentation. The purpose is to identify and implement the most cost effective way of overcoming each constraint. Opportunities for non-network solutions must be publicly released to promote and encourage embedded generation where it is viable.

Along with the benefits embedded generators may also face some risks. To defer network augmentation embedded generators may need to provide contracted network support. Failure to meet performance standards could result in financial penalty. Planned outages or faults on the distribution network could force the embedded generator out of service at certain times resulting in lost revenue. ESC guideline no.15 contemplates that connection agreements may include provision for financial compensations between either party. There is also provision in the NER that a generator may be required to compensate a DNSP in the event that dispatch of a generator's unit has an adverse commercial impact on the operations of another generator. The NER specifically refers to these compensations in the context of distribution connected generators.

4.2.2 Network ancillary services

AEMO is responsible for maintaining the network frequency close to 50Hz in accordance with the NEM frequency standards and for keeping the voltage within an acceptable range at particular nodes on the transmission network and for scheduling power flow between regions while maintaining power flows within the capability of plant. AEMO achieves these objectives by dispatching scheduled generators to match the load and via ancillary services.

Ancillary services can be one of the following:

- Frequency Control Ancillary Services (FCAS).
- Network Control Ancillary Services (NCAS).
- System Restart Ancillary Services (SRAS).

In practice FCAS and NCAS are offered by generators by providing either real power or reactive power reserves that may be required in response to a network fluctuation, disturbance or event or based on load flows to provide local network support. Any generator has the option to provide ancillary services.

A non-market generator that is not participating in the sale of real power through NEM, may be classified as a market generator for the purpose of delivering ancillary services but will be required to demonstrate communications or telemetry suited for receipt of dispatch instructions and auditing. Generators providing ancillary services have the following obligations:

- To submit offers for such ancillary services.
- To operate in accordance with the co-ordinated central dispatch process.
- Must only sell ancillary services through the ancillary service market.

An ancillary service generating unit must install and maintain monitoring equipment to monitor and record response to changes in the frequency of the power system. Standards to be met will be issued by AEMO[16]. AEMO may also request reports on the performance of any ancillary service generating unit to specific events and may direct that tests to confirm performance capability are undertaken. An ancillary services generating unit must at all times be capable of responding in the manner contemplated by the market ancillary service specification[17].

The DNSP must take care in assessing the impact of a prospective ancillary services generator as by definition the generator will impose rapid load changes with significant voltage impact on the local network.

4.2.3 Avoided Transmission Use of System charges

The TNSP (AEMO in Victoria) recover shared transmission network costs by charging DNSPs (and large customers directly connected to the transmission network). In turn the DNSP pass through these fees to its customers. These fees are known as TUoS charges.

[16] Ref. NER 3.11.7(a) and 3.11.7(b)
[17] Ref. NER 3.8.7A(k)

Generators connected to the distribution network reduce the demand on the transmission network and if sufficiently large, or in sufficient numbers, can ultimately defer or avoid the need for transmission network augmentation as distribution network demand increases. It is unlikely however that a single embedded generator would defer a major transmission upgrade on its own.

To recognise the value embedded generation could have in the long term, ESC guideline no.15 stipulates that a DNSP must pass through 100% of the avoided TUoS charges to the embedded generator.

4.2.4 Avoided Distribution Use of System charges

DNSPs recover the costs of building and maintaining the distribution network by charging DUoS tariffs to customers. In a similar way to the shared transmission network embedded generators may defer or avoid the need to augment the distribution network. Rather than pass through an average network avoided cost (as done for avoided TUoS), each embedded generator is evaluated independently to determine the benefits this generator may have. If it reduces network expenditure then the embedded generator will be entitled to a share of the benefits provided.

4.2.5 Network support

Most embedded generators are non-scheduled and are free to decide when and how much energy they will produce. If however a DNSP relies upon an embedded generator to supplement the energy supplied to its network customers at times when the distribution network is constrained, then it may be necessary for the embedded generator to provide contracted network support. This agreement gives the DNSP confidence that the embedded generator will be operating when required and may allow the DNSP to defer network augmentation. The financial benefits can then be shared with the embedded generator.

If the DNSP does not have this assurance that the embedded generator will operate when required then the DNSP will most likely conservatively assume that the generator does not operate at times of peak network demand (or may assign a probability that the embedded generator is not operating at times of peak network demand using probabilistic planning techniques). As a result the DNSP may proceed with plans to increase network capacity, no deferral gains will be obtained and the embedded generator may not be entitled to avoided DUoS payments.

To ensure that an embedded generator obtains avoided DUoS it may be necessary for the embedded generator to provide network support.

4.2.6 Reduction of network energy losses

Embedded generators have a major advantage in that they are located close to load centres. Thus the distance electrical power must travel from generator to load is significantly reduced if the entire generator output is used to supply local loads. By reducing the length the energy losses associated with transport can also be reduced.

On the transmission network energy losses are allocated to transmission connection points using MLFs while energy losses on the distribution network are allocated to customer distribution connection points using DLFs. To allocate the network energy losses to a particular distribution network customer, the customer’s metered energy consumption is multiplied by the MLF and DLF.

It is not practical to calculate DLF values uniquely for every distribution network connection point, there are simply too many. In Victoria network average DLFs are calculated for each major type of connection (small low voltage, large low voltage, high voltage, direct zone substation connection and sub transmission) for both short and long sub transmission giving a total of 10 average DLFs. For large customers (over 10MW or 40GWh/y) and large embedded generators (over 10MW) site specific DLFs are calculated for the particular location that customer/generator is connected. Embedded generators are also permitted to request a site specific DLF although conditions apply.

Example
Assume that a 12MW embedded generator produces 9,500MWh/y and has a MLF of 1.032 and a site specific DLF of 1.043. The embedded generator would be considered to have effectively produced 9,500 x 1.032 x 1.043 = 10,226MWh/y and this would be the energy settled in the NEM. (Note that this example has been simplified and does not consider the settlement of residue losses on the transmission network. This is required because unlike DLFs, MLFs are generally higher than the average network losses and will result in an over recovery of losses from load customers over the period of a year).

5 EMBEDDED GENERATION ACCESS (CONNECTION) STANDARDS

Unless stated otherwise all access standards in sections 5.1 to 5.4 are the automatic access standards. **Section 5.5 provides a summary of Section 5.1 to 5.4 giving both the automatic and minimum access standards**.

5.1 Primary plant standards

The design of the generator installation plant is the responsibility of the generator proponent. The DNSP will only seek to influence the design to the extent that the integrity of the design is seen to be inadequate and may undermine the reliability and quality of supply to other network users. These standards are therefore focused on primary plant design, earthing, fault levels and equipment specifications at the network interface and other internal parts of the installation that could impact the distribution network.

Relevant standards

Regulatory codes require the establishment of generating facilities in accordance with good industry practice. If the installation complies with Australian or International Standards the DNSP will consider the installation as meeting good industry practice. Common relevant standards are listed in Table 1.

Plant	**Standards**
Underground cables	AS1026, AS1429.1
Overhead lines	Energy Supply Association of Australia Ltd (ESAA) document D(b)5
High voltage circuit breakers	AS2006, AS2067, AS2068 and AS1824.
Current transformers	AS60044.1
Voltage transformers	AS60044.2
High voltage fuses	AS1033 or IEC282
Power transformers	AS2374
Motors	AS1329
Motors and generators	AS1359
Low voltage Circuit breakers	AS/NZS 3947.2 or AS/NZS 4898 or AS3111 and have instantaneous tripping characteristics of 10*In
Pole mounted low voltage circuit breakers	AS/NZS 3142 or recognised equivalent, or AS/NZS 4898 and the appropriate requirements of AS/NZS 3124
Low voltage fuses	AS/NZS 60269.2.1 or recognised equivalent
Low voltage miniature combined fuse switches	AS/NZS 60269.3.1
Low voltage fused disconnect switches	AS 3947.3
Earthing	AS2067

Table 1: Primary plant standards

For generators connected at low voltage refer to SIR clause 7.4.5. Further information on major plant such as circuit breakers, current and voltage transformers, cables and power transformers are considered below.

5.1.1 Network connection and isolation

The point of supply will be negotiated between the generator proponent and the DNSP but may be defined by an existing supply point for an existing load installation. It is preferred that the point of supply is as close to the property boundary as practical and has a direct and easily identifiable access for the DNSP and meter service provider.

LV service protection device[18]

Every distribution network LV connection (load or generator) must have a service protection device installed in accordance with the SIR.

For low voltage connections the service protection device shall be installed between the point of supply and the embedded generator energy meter. The service protection device can be either fuse or circuit breaker. The distributor must be provided with access to operate or work on the service protection devices at all times and must be able to lock the device in the open position. The embedded generator operator can only authorise a person to operate a circuit breaker used as a service protection device if it is not sealed or locked off by the distributor. LV service fuses can be removed and reinserted by electricians and 'L' and 'G' inspector licence holders.

HV main switch[19]

Unlike LV connections, HV connections do not require the customer to install a service protection device on the network side of the energy meter. A fault on the HV service cable or within the HV metering shall be detected and cleared by the distributor's protection. Nonetheless the embedded generator is required to install a main switch on the generator side of the energy meter consisting of a circuit breaker. The main switch must be accessible to authorised persons. The DNSP will install isolation switches or circuit breakers on the distribution network to isolate the embedded generator from the distribution network.

Generator isolation

All embedded generators (all sizes and voltages) must have a lockable generator isolating device owned and operated by the generator owner. While the isolating device should only be operated by the generator owner, the DNSP may insert their own padlock or similar locking device to lock the isolator in the open position when undertaking works on the distribution network or at the customer network connection or metering point. This device may isolate just the embedded generator or may isolate the whole installation (i.e. main switch).

Examples
For an LV photovoltaic inverter embedded generator the customer may install an isolating switch next to the inverter that allows the DNSP to install a padlock to lock the switch in the open position. For a large embedded generator power station connected at 22kV the generator owner may have a 22kV switchboard that allows each generator circuit breaker to be racked out and locked to prevent the circuit breakers from being re-inserted.

For HV connected generators the DNSP will also install an isolating device on the distribution network to allow the generator to be isolated from the shared network without operating generator owned assets. This could either be a manual operated isolating switch or a fully remote controlled circuit breaker. This device will only be controlled by the DNSP.

The generator installation shall not provide a means of earthing the network supply feed on the supply side of the main connection point circuit breaker or switch. If the supply cable or conductor needs to be isolated and earthed this will be undertaken independently by the DNSP.

[18] Ref. SIR 7.4.

[19] Ref. SIR 9.7.2 and figure 9.1.

Multiple supply points

Multiple points of supply to a single premise are generally avoided because it becomes difficult to identify isolation points leading to safety concerns, metering and billing becomes more complex and there is a risk that the two sources could be inadvertently paralleled together. Multiple points of supply will only be permitted if high security is required (e.g. reserve supply), if a single connection point will not provide sufficient capacity or if there is some other technical engineering reason. If the premise is a very large property then multiple network connections will be permitted on technical grounds such as voltage drop but the internal wiring must be well labelled or segregated to reduce the risk of mixing the supply points.

Power station auxiliary supply

It is preferable if the auxiliary electricity supply required for an embedded generator is taken from the distribution network using the same connection point as the main generator connection. When the generator is in operation some of the energy produced will be used to power the generator auxiliary equipment with the remainder supplying other local customer load or injected into the distribution network. This is consistent with the desire for a single connection point noted above.

There may be reasons where a generating system takes its auxiliary supplies via a connection point through which its generation output is not transferred to the network and the access standards which apply for this connection are the same as those applying for any load connection.[20] The reason for this independent auxiliary supply could be technical (e.g. the generator output is above 1kV and a 400V supply is required) or commercial (e.g. generator has a HV connection however LV tariffs for energy consumed may be lower). In such cases considerable care must be taken to clearly label the sources of supply and isolation points as required wherever multiple sources of supply exist.

5.1.2 Circuit breakers and switches

Compliance with the following Australian Standards or equivalent international standards is required: AS2006, AS2067, AS2068, AS1824, AS3947.2, AS4898 and AS3111.

CBs must be selected that can interrupt the expected fault current for faults on either side of the CB without re-strike with a rating dependent upon actual faults levels but as a minimum based on the fault levels listed in Table 2.

LV CBs used as a service protection device must have an instantaneous tripping characteristic in excess of 10xIn (‘D’ curve) so that inrush current during the starting of equipment does not cause the service protection device to nuisance trip.

5.1.3 Protection and metering current and voltage transformers

Compliance with the following Australian Standards or equivalent international standards is required:

- Current transformers AS60044.1
- Voltage transformers AS60044.2
- Requirements applicable to measuring relays and protection equipment IEC60255

5.1.4 Power transformers

Where a transformer is included in the design to step up the generator voltage to match the network feeder voltage the following requirements are to be met:

[20] Ref. NER S5.2.7

- The substation is required to be capable of operation under the range of system conditions defined by the access standards.
- Transformers connected to the DNSP network at 6.6kV, 11kV, 22kV and 66kV are required to have infinite zero sequence impedance as seen from the network side to comply with the automatic access standards. This can be achieved by using a delta winding on the network side or a star winding but with the star point floating.
- Earthing of the generator side transformer winding and the associated network must ensure adequate fault current for protection schemes on the network side to be effective, and will be required to meet the standards of redundant protection.
- Compliance with the following Australian Standards or equivalent international standards is required: AS2374.

5.1.5 Cables

Compliance with the following Australian Standards or equivalent international standards is required: AS1026 and AS1429.1.

5.1.6 Ultimate fault levels and plant ratings[21]

Maximum fault levels

The generator proponent is required to design and operate the generating plant such that the distribution and transmission network fault levels don't exceed the limits stated in the EDCoP and network plant ratings (which may be less than the EDCoP limits). The EDCoP limits are shown in Table 2, together with deemed low voltage fault levels for residential connections[22].

Voltage Level	System Fault Level	Short Circuit Level
220kV (TNSP)	15,000MVA	40.0kA
66kV (TNSP&DNSP)	2,500MVA	21.9kA
22kV	500MVA	13.1kA
11kV	350MVA	18.4kA
230V, 400V, 460V	36MVA	50kA
Residential 400V	7MVA	10kA (phase to phase)
Residential 230V, 460V	1.4MVA	6kA (phase to ground)

Table 2: Maximum fault levels established under distribution and transmission codes

It may be possible to increase the short circuit current ratings of network plant however any shallow network upgrades will require a funding contribution from the embedded generator proponent. The generator proponent may not be required to fund deep augmentation costs[23] however it could take considerable time for the DNSP to implement such upgrades.

For micro embedded generators connected to a residential installation such as a photovoltaic array it will generally be acceptable to use the deemed fault levels in Table 2 however if the installation is located close to a distribution substation the DNSP must be contacted to obtain the actual fault levels for the particular location.

The embedded generator proponent must assess fault levels together with the DNSP (and possibly the TNSP). If necessary, works will need to be undertaken to reduce fault levels below the limits in Table 2 or to replace constrained plant to allow the maximum fault levels to increase. To overcome a constraint it is common to use high impedance generators or transformers, install series reactors or

[21] Ref. NER S5.2.8

[22] Ref. SIR 6.1.2

[23] Ref. Electricity Industry Guideline No.15 3.3.2(b)(1)

earthing impedances, connect at an alternative connection point or higher voltage or split normally closed bus tie circuit breakers.

Generating plant installations that have a high aggregate capacity relative to the connected DNSP network capacity are expected to cause high X/R source impedance ratio. This will accentuate peak asymmetrical fault currents by introducing a large DC offset during the transient fault current. All primary plant, particularly CBs, need to be selected accordingly.

Fault clearance times[24]

In addition to the above fault current limits, the duration of the fault current must be limited via the action of protection devices to prevent through-current damaging plant, to prevent network instability, to reduce the chance of instability of another nearby generator, to limit step and touch potential hazards, to limit power quality impacts to other network users and to limit asset damage at the location of the fault. In general the slowest backup protection must also operate within the maximum fault clearance time limits. Refer to section 5.3 on Protection, control, monitoring and communications requirements to obtain further information on protection operating speed.

For embedded generators connected at LV (230V/400V), the fault clearance time for a solid phase to phase or phase to neutral short circuit at the network connection point must be less than 150ms.

For embedded generators connected at HV, the fault clearance time for a solid three phase short circuit at the network connection point must be less than 150ms at the maximum fault level advised by the DNSP to comply with the automatic access standards.[25]

Where these times cannot be achieved the embedded generator protection designer should consult with the DNSP to determine the maximum permissible fault clearance time to be adopted.

Generation plant short circuit specifications[26]

The short circuit ratings of generator installation plant will generally be acceptable if each item of plant is capable of safely carrying (withstanding) or interrupting the fault current that is expected to flow through that piece of plant for a duration equal to the fault clearance time of the backup protection. Where relevant, allowance must also be made for automatic reclose and future increases in fault levels up to the EDCoP limits.

The generator proponent must consult with the DNSP regarding the rating of plant that is proposed to be used however in general the following ratings will be regarded as acceptable:

Voltage	Fault current / time
66kV	21.9kA / 3s
22kV	13.1kA / 3s
11kV	18.4kA / 3s
6.6kV	21.9kA / 3s
Commercial/Industrial 230V/400V	50kA / 3s
Residential 400V	10kA / 0.1s or 0.04s if supplied from a cartridge service fuse
Residential 230V, 460V	6kA / 0.1s or 0.04s if supplied from a cartridge service fuse

Table 3: Generation plant short circuit ratings

The table above should be treated as a guide only. At some locations network fault levels operate above the EDCoP embedded generator limits. Likewise for micro embedded generators connected at 230V (such as a residential photovoltaic installation) the fault levels will generally be much lower and

[24] Ref. NER S5.1a.8
[25] Ref. SIR 9.8
[26] Ref. NER S5.1.9

it will not be necessary to satisfy a 50kA rating (e.g. 6kA[27] rating for single phase may be adequate in low fault current areas). The automatic access standards will therefore be subject to site specific review.

5.1.7 Insulation co-ordination

Insulation co-ordination is required to ensure safety clearances, separation of live parts and voltage impulse withstand levels are compliant with AS2067, AS4070 and AS1824.1.

Insulation co-ordination and impulse withstand capability is to be consistent with the design of insulation levels in the DNSP network and is to be implemented as agreed with DNSP. In general the temporary (short duration) and impulse voltage rating of each item of plant will match or exceed the following:

Nominal voltage	Short duration (60 sec) power frequency withstand voltage rating[28]	Lightning impulse withstand level (LIWL) voltage rating (1.2µsec / 50µsec) [29]
66kV	$140kV_{rms}$	$325kV_p$
22kV	$50kV_{rms}$	$150kV_p$ (outdoor plant) $125kV_p$ (indoor switchboard)[30]
11kV	$28kV_{rms}$	$95kV_p$ (indoor plant)
6.6kV	$20kV_{rms}$	$60kV_p$
230V/400V	$275V_{rms}$	$6.0kV_p$[31]

Table 4: Generation plant insulation level ratings

Where plant configuration results in any significant lightning exposure, particularly cases of aerial lines connected to the interface zone, surge arresters are to be installed that provide impulse protection for assets at the connection point including cable, switches, metering or CBs.

5.1.8 Surge arresters

Surge arresters must comply with AS1307. The short term and continuous voltage rating of surge arresters connected to the DNSP network at 11kV or 22kV must equal or exceed the network maximum phase to phase voltage as will be experienced during phase to ground faults where the distribution network uses an earthing system deploying either a neutral earthing resistor or ground fault neutraliser.

5.1.9 Earthing and control of step and touch potentials

Phase to ground faults give rise to step and touch potentials and therefore present a health and safety hazard. The design of the primary plant, associated structures and all accessible areas shall comply with AS2067 and ENA guideline EG1 – 2006 substation earthing guide to ensure step and touch potentials are within limits.

The earthing of the generating plant is to be established in compliance with the relevant codes. Earthing arrangements for loads that are to be serviced by the DNSP in the absence of the generating plant must be retained.

[27] SIR clause 7.4.5.1

[28] Voltage measured phase to ground.

[29] Voltage measured phase to ground.

[30] For all 22kV plant recommended LIWL is $150kV_p$ however $125kV_p$ may be permitted for indoor plant where the placement of over voltage limiting devices together with insulation coordination studies using an electromagnetic transient software package shows that $125kV_p$ is adequate.

[31] Based on table 2 of clause 20.4.2 of the EDCoP. This also corresponds with IEC664 category IV definition based on an 8/20µs wave shape at the entry point (connection point) to an installation. Other levels may be appropriate within an installation depending upon location and the sensitivity of equipment.

HV (6.6kV, 11kV, 22kV & 66kV) embedded generators

To comply with the automatic access standard the earthing system must provide satisfactory earthing independently of the DNSP network earthing system. (Bonding a DNSP earth grid with a generator installation earth grid may be permitted under negotiated access standards. In such circumstances if the generator can operate in island mode then when the generator operates in island mode the earthing system must be capable of operating independently and without connection to the DNSP network.)

Example A HV embedded generator installation is directly connected to a zone substation via a dedicated underground 22kV cable. The screen of the cable shall only be bonded to the generator installation earth grid to keep the zone substation and generator installation earth grids independent.

To comply with the automatic access standards all embedded generators connected at HV shall contribute no zero sequence current to the distribution network and therefore will not increase the phase to ground fault levels or step and touch potentials significantly. Again under a negotiated standard it may be possible to contribute to the phase to ground fault level however it will be necessary to undertake an earth grid design review for the areas impacted.

LV (230/400/460V) embedded generators

Generators connected at LV are permitted to contribute to phase to ground fault levels however an earth grid design review of the generator installation will be required together with the associated protection used to detect and clear the fault. (The permitted earth grid potential rise is a function of the duration of the voltage rise which depends upon the protection speed).

To comply with the automatic access standard the earthing system must provide satisfactory earthing independently of the DNSP network earthing system.

If a low voltage embedded generator is also designed to operate in island mode to supply local load at the same premise as the generator (i.e. a backup electrical supply in the event of a loss of supply from the distribution network) then it must have an earthing system that can provide satisfactory earthing independently of the DNSP network earthing system. This is a minimum access standard. (This is necessary because during a distribution network supply outage the neutral connection to the distribution network may be disconnected).

If the embedded generator can only operate in synchronism with the distribution network then in unusual circumstances the DNSP may permit the earthing system to rely upon the distribution network under a negotiated access standard however this would require very conservative assumptions regarding the performance of the distribution network.

If switching of neutrals is required as part of the LV generator system no part of the facility that is normally required to be earthed can become inadvertently unearthed.

5.1.9.1 High voltage generator installations

Zero sequence impedance of generator installation observed from the network

To meet the automatic access standards the zero sequence impedance of the generator installation observed from the network must be infinite. This is required to prevent zero sequence current flowing between the distribution network and the generator installation that will affect the operation of earth fault protection on the distribution network. In applications where the generator is directly connected to the DNSP network without a transformer, the generator neutral must be unearthed or connected in delta to satisfy the automatic access standards. (A zero sequence path between the generating plant and the distribution network may be permitted for HV installations under negotiated access standards if suitable protection schemes can be designed and implemented and the system does not compromise network safety standards.)

Earthing transformers

Interconnected star neutral (or a star delta) earthing transformers connected to the generation bus are an acceptable option of earthing provided:

- An earthing transformer is provided on each bus section that is independently supplied or has generation connected.
- Each is equipped with a non-automatic circuit breaker or switch.
- Each is equipped with transformer protection directed at bus sectionalising and removing generation or supply sources and not tripping of the circuit breaker or switch which would remove the earth.
- The earthing transformer does not provide a path for zero sequence current flowing between the distribution network and the generator installation. (As noted above a zero sequence path between the generating plant and the distribution network may be permitted for HV installations under negotiated access standards.)

Phase to ground fault current limiting devices

The generator installation may be earthed via an impedance such as a resistor or reactor to limit phase to ground fault current provided the protection is sufficiently sensitive to detect and clear the reduced fault current.

5.1.9.2 Low voltage generator installations

Low voltage generators shall be earthed in accordance with AS/NZS3000.

Where a generator neutral is available and shall be earthed (single phase or star connected three phase winding) the generator neutral(s) shall be bonded to earth at a single point, the main earth neutral point. Neither automatic nor manual switching of generator neutrals is permitted unless such switching simultaneously disconnects all phase conductors and neutral together.

For generators that only operate in parallel with the distribution network it is not mandatory that the generator neutrals be earthed. This could be desirable or necessary for several reasons, e.g. to limit phase to ground fault level or because a three phase asynchronous (induction) generator shall be used with a delta connected winding and no neutral point. For these generators the distribution network supply will be required to provide single phase fault current. For three phase asynchronous generators that are mains excited no special precautions are required because the generator voltage will quickly decay to zero following loss of the distribution network supply. For synchronous generators loss of mains protection will be required to quickly disconnect the generator from the network or any internal customer load when the distribution network supply is not available.

Where the generator can operate in local island mode to supply internal customer load in isolation to the distribution network it will be necessary to utilize an earthing system which will provide fault current for single phase to ground faults to enable protection to detect and clear the fault. In general it will also be necessary for the generator to provide a neutral so that single phase loads can be supplied within the installation.

Where multiple 400V generators are paralleled, third harmonic currents flowing between generators can create a problem. A static balancer may be used to avoid the need for parallel neutral connections however in such circumstances the static balancer must remain connected in service while the generators are in service to provide balanced phase to earth voltages and phase to ground fault current under fault conditions. This is required for the correct operation of protection schemes.

5.2 Embedded generator performance standards

System standards are established by the NER. System standards are intended to have application when addressed at any level of voltage throughout the integrated network. Within the Victorian jurisdiction, the EDCoP applies different standards in respect of variation in power frequency voltage and voltage unbalance. In all other respects the NER prevails.

5.2.1 Power frequency steady state voltage operating range

The standard nominal voltages accessible on the DNSP network are:

- 230V ph-n
- 400V ph-ph
- 460V ph-ph (only available in limited rural areas)
- 6.6kV ph-ph
- 11kV ph-ph
- 22kV ph-ph
- 66kV ph-ph

Variations from the standard nominal voltage may occur in accordance with Table 5.

Nominal Voltage	Minimum Voltage	Maximum Voltage
230V$_{ph-n}$ single phase	216V$_{ph-n}$	253V$_{ph-n}$
400V$_{ph-ph}$ three phase	376V$_{ph-ph}$	440V$_{ph-ph}$
460V$_{ph-ph}$ two phase	432V$_{ph-ph}$	506V$_{ph-ph}$
6.6kV$_{ph-ph}$ three phase	6.20kV$_{ph-ph}$	7.00kV$_{ph-ph}$
11kV$_{ph-ph}$ three phase	10.34kV$_{ph-ph}$	11.66kV$_{ph-ph}$
22kV$_{ph-ph}$ three phase	20.68kV$_{ph-ph}$	23.32kV$_{ph-ph}$
66kV$_{ph-ph}$ three phase	59.40kV$_{ph-ph}$	72.60kV$_{ph-ph}$

Table 5: Continuous acceptable voltage range[32]

The DNSP must use reasonable endeavours to include conditions in connection agreements to ensure all embedded generators operate their plant so that the power frequency voltage supplied to all network customers do not exceed the limits in Table 5.

The acceptable steady state voltage variation range is conditional upon reactive power flow and power factor at the connection point being limited to that defined in the connection agreement. Transient excursions (approaching 20% or higher) should not be experienced other than in conjunction with a credible contingency event. As a consequence of a contingency event the voltage at the connection point may fall to zero for any period in accordance with EDCoP clause 20.4.2.

The design of the generating plant should anticipate the likely time duration and magnitude of variation in the power frequency phase voltages which arise under network faults of varying nature and location.[33]

[32] Ref. EDCoP 20.4.2

[33] Ref. NER S5.1.4

The target level for supplied voltage at a generator connection point is assessed by the DNSP by taking account of the impact of all Network Users sharing the supply line. The target range may vary between conditions that represent a satisfactory operating state and those conditions arising after a credible contingency event.

Where independent control of voltage at the connection point is possible without adverse effect on other connection points, the DNSP is required to make reasonable endeavours to meet such a request.

The automatic access standards require:

- Generating plant to be capable of operating continuously with voltage variation within the range listed in Table 5.
- Generating plant to be operated so that under steady state conditions the power frequency voltage at the connection point shall not exceed the limits in Table 5 or shall not change by more than ±2%, before the action of any voltage regulation equipment on the electricity distribution network.

When assessing the impact an embedded generator has on voltage at the connection point it shall be assumed that the power consumed by loads and the power produced by all other generators shall remain constant on the feeder to which the generator is connected. It will however be necessary to model voltage regulation over the expected range of network conditions. The voltage control provided by on-load tap changing facilities at the zone substation can be included within any modelling to regulate the voltage at a zone substation 6.6kV, 11kV or 22kV bus but in general will not provide compensation for voltage drop along any downstream feeders.

460V systems

In some rural areas 3 wire 460V systems are installed where 2 phase (180 degree phase rotation) HV distribution is used. Small capacity generation can be connected to the 460V system. Feeder lengths are generally long and voltage drops associated with transient currents arising from rotating plant can be limiting. Consideration of the use of inverter-connected plant is advocated in these cases.

In these Guidelines the requirements set down for 400V plant are to be considered applicable to 460V applications. All reference to voltage fluctuations and limitations in respect to 400V applications can be assumed to be relevant to 460V applications.

5.2.2 Transient voltage fluctuation

Embedded generators shall be designed such that any sudden changes in current flow between the generator and the electricity distribution network do not cause voltage sags or swells that adversely impact other customers connected to the electricity distribution network. Embedded generators that create voltage disturbances shall have emission limits established by the DNSP in accordance with the provisions of part 3.5 and part 3.7 of IEC Electromagnetic Compatibility standards which are reproduced as Australian and New Zealand Standards AS/NZS 61000.3.5:1998 for low voltage equipment and AS/NZS 61000.3.7:2001 for medium and high voltage equipment.[34]

The level of voltage fluctuation in the supply experienced by all network users is required to be maintained at less than the "compatibility levels" set out in Table 1 of AS/NZS 61000.3.7:2001:

For connection at:	230V, 400V, 460V, 6.6kV, 11kV or 22kV
P_{st} =	1.0
P_{lt} =	0.8

Table 6 – Short term (P_{st}) and long term (P_{lt}) flicker compatibility limits

[34] Ref. EDCoP 20.10.1.

To keep flicker levels below the limits above the DNSP is required to provide emission limits for each load and generator connected to the network.

The DNSP shall provide the automatic access standards for flicker emission limits upon request for a particular point of common coupling on the distribution network. The DNSP is required to allocate emission limits no more onerous than specified in the relevant stages of analysis determined in accordance with the AS/NZS procedures. The DNSP must allocate emission limits no more onerous than the lesser of the acceptance levels determined in accordance with either the stage 1 or stage 2 of the evaluation procedure (refer to section 4 "General Principles" of AS/NZS 61000.3.7:2001).

While embedded generators can produce flicker by creating a disturbance when synchronising with the DNSP network or as a result of a sudden change in power output, most generators (particularly synchronous generators) will tend to reduce flicker caused by other loads connected to the network because they tend to reduce the source impedance at points of common coupling. For this reason, in general, the DNSP will not need to evaluate flicker levels when a generator connects unless the generator uses a technology which is likely to create a disturbance. If an assessment is required and flicker emission limits are to be allocated then the possible benefits the generator provides shall also be considered.

Example
A 2MW wind turbine generator is planned to connect to a 22kV feeder. The generator will create a voltage disturbance when it connects to the network and it will create some disturbance as power output changes in response to fluctuations in wind speed and turbulence. Despite the flicker caused by the generator, the generator shall also reduce the source impedance of the 22kV feeder and while operating it will reduce flicker caused by other loads supplied by the feeder. When allocating flicker emission limits the flicker reduction benefits shall also be considered. A 'net flicker emission limit' shall be allocated.

In addition to the flicker limits, LV generators should maintain the relative steady state voltage change (d_c) below 3% and the maximum relative voltage change (d_{max}) below 4% as defined in AS/NZS 61000.3.5:1998. The d_c and d_{max} limits for HV generators are to be established based on the guidelines given in AS/NZS 61000.3.7:2001.

Embedded generators that produce an occasional voltage disturbance upon network connection

For embedded generators (such as some asynchronous plant) that produce a voltage disturbance each time they connect or disconnect from the network but otherwise do not create disturbances and where these disturbances only occur a few times a day it is generally more convenient to set emission limits based on Figure 7.

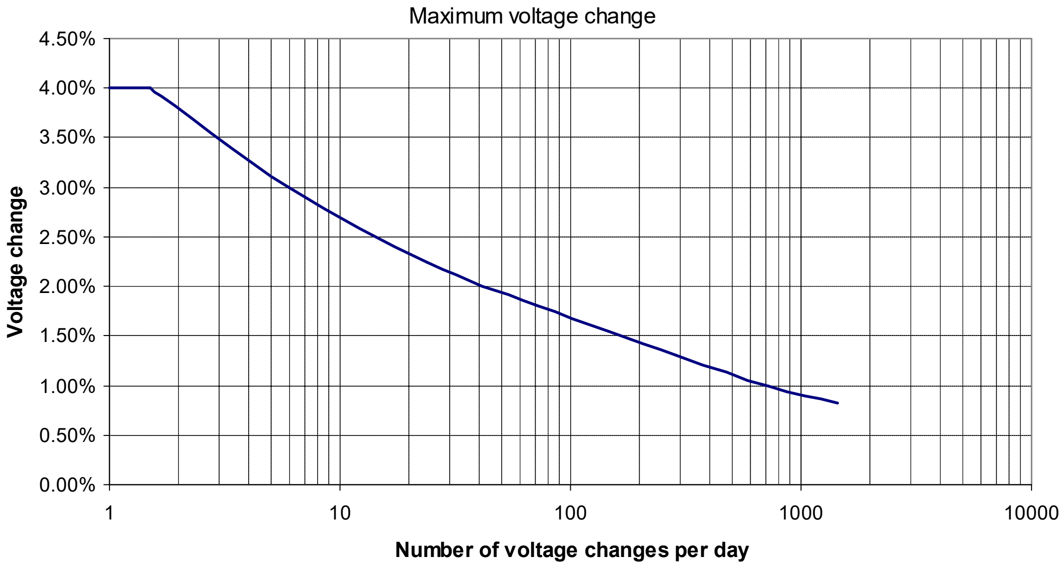


Figure 7: Maximum allowable transient voltage variations caused by an Embedded Generator[35]

Where an embedded generator causes less than one disturbance per hour, the maximum voltage disturbance at the point of common coupling shall be less than that stipulated in Figure 7 and the disturbance must not persist longer than 2 seconds. The maximum current transient will depend upon the network source impedance at the point of common coupling and the number of transients per day. The necessary source impedances shall be provided by the DNSP when requested so that the voltage transients can be calculated.

In addition, all rotating generating plant connected at low voltage (230V, 400V, 460V) shall be limited in capacity so that in the event of loss of synchronism, or pull out torque in the case of asynchronous plant, voltage fluctuation at the point of common coupling will not exceed 4% during the time it takes for the plant to disconnect or re-synchronise.

5.2.3 Operating frequency range

5.2.3.1 Steady state system frequency[36]

The responsibility for control of frequency remains with AEMO. The DNSP has no obligation in respect of frequency within the distribution network.

Frequency operating standards are as set down by AEMC. The normal operating frequency band is 49.85Hz to 50.15Hz and the frequency should be maintained within this band at least 99% of the time. Accumulated time error shall be contained within 5 seconds.[37]

5.2.3.2 Transient frequency disturbances[38]

During and following a power system disturbance (such as the trip of a large generator or load) the frequency of the network will fluctuate until it is stabilised and recovers back within the normal

[35] This chart has been reproduced based on figure 1 of AS2279.4-1991, “threshold of perceptibility”.

[36] Ref. NER clause S5.1a.2

[37] Ref. NECA Reliability Panel Frequency Operating Standards, Determination, September 2001. Section 9 – Determination, part A.

[38] Ref. NER clause S5.2.5.3

operating frequency band. Embedded generators should be able to operate within the expected frequency range for the duration of the disturbance without sustaining damage or disconnecting where such disconnection could exacerbate the initial problem or create a local distribution network disturbance.

To define the expected variation in frequency and duration of disturbances the EDCoP introduces the terms:

- normal operating frequency band
- normal operating frequency excursion band
- operational frequency tolerance band
- extreme frequency excursion tolerance limits

and in its determination the Reliability Panel established by the AEMC has defined these values for the NEM which have been reproduced in Figure 8 and Figure 9.

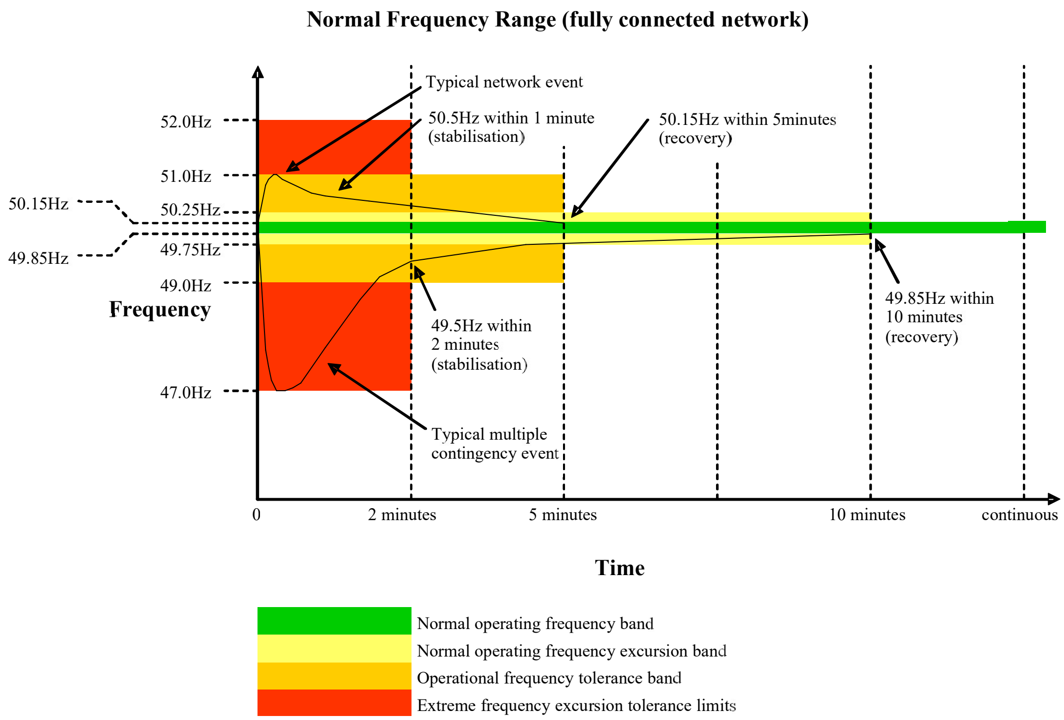


Figure 8: Maximum frequency disturbance magnitude and duration for a fully connected network

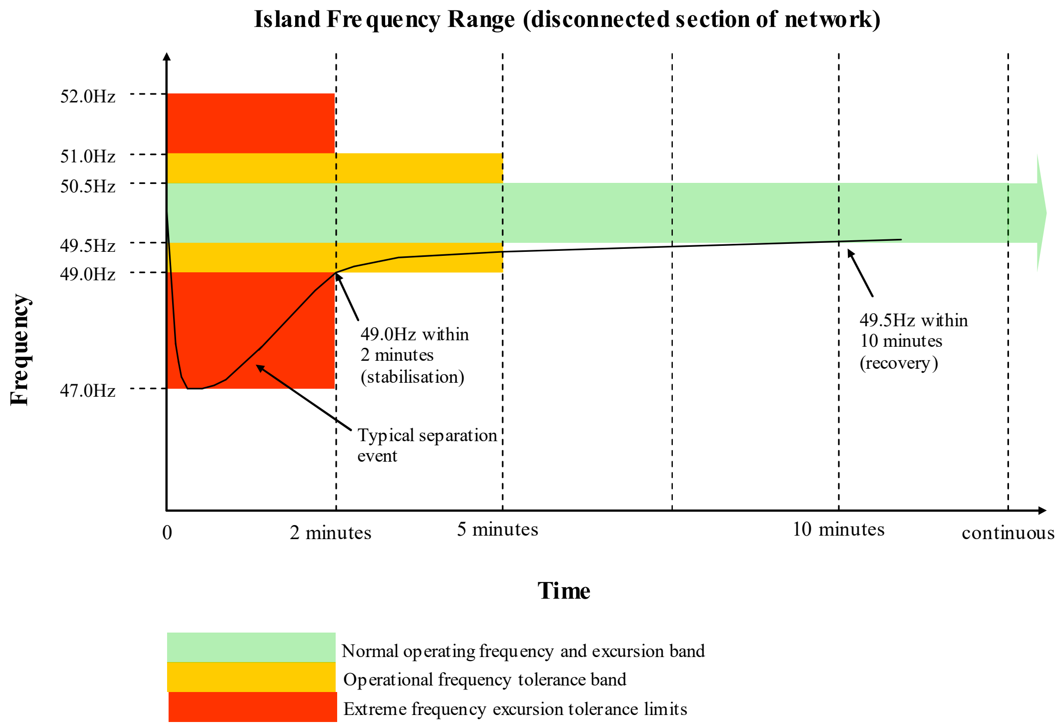


Figure 9: Maximum frequency disturbance magnitude and duration for an island network

Figure 8 shows the maximum frequency disturbance in magnitude and duration for any part of the network which is not an island while Figure 9 shows the corresponding maximum frequency variation for an islanded network if a separation event occurs. While scenarios have the same frequency extremes, the frequency regulation of an island network following recovery is not expected to be as tight. Typical disturbance events are plotted showing network frequency over time.

The automatic access standard requires that, following a system disturbance, the generator will continue to operate within the limits defined by the Reliability Panel established by the AEMC in its determination on frequency operating standards (and as reproduced in Figure 8 and Figure 9) and will only disconnect[39]:

- in response to a DNSP signal identifying that the generator has been islanded within the network and must trip in accordance with its connection agreement,
- in accordance with an ancillary services agreement,
- in accordance with a prior agreement with AEMO and the DNSP that the generator may island with load at the same connection point thereby effectively displaying under frequency load shedding,
- in response to a genuine fault on the prime mover or generator plant (not directly related to the frequency disturbance event) and following detection and operation of protection devices, or
- in accordance with any agreement with AEMO and the DNSP.

(The corresponding minimum access standard is provided in NER clause S5.2.5.3(c)).

[39] Ref. NER S5.1.3

Under the automatic access standard if the rate of change of frequency exceeds ±4Hz/s sustained for 0.25 seconds or more[40], or other such range determined by the Reliability Panel established by the AEMC then the generator has the discretion to disconnect. This may be necessary because this rate of change of frequency exceeds the capability of the generating plant. (Under the minimum access standard the corresponding limits are ±1Hz/s sustained for 1.0 seconds or more[41].)

The transient frequency disturbance ride through limits shall be negotiated between the embedded generator and the DNSP if:

- the embedded generator has a capacity under 30MW, and
- the embedded generator does not have a system in place to receive a remote trip signal from the DNSP network to avoid islanding, and
- the embedded generator uses loss of mains (anti-islanding) protection based on the rate of change of frequency operating principle.

In such circumstances priority shall be given to anti-islanding protection sensitivity although the protection must be designed such that the generator will not trip for common system disturbances to avoid nuisance tripping.

5.2.4 Generator stability[42]

During and following any power system disturbance it is desirable if all embedded generators remain connected to and synchronised with the distribution network and remain stable.

Power system disturbance

A disturbance could be a sudden change in frequency or a sudden change in power frequency voltage, a perturbation, triggered by any number of possible contingency events such as the loss of a large generator, loss of load, a transmission network separation event or a short circuit fault and trip of a transmission or distribution network element.

Stable operation

Following the disturbance in frequency or voltage, oscillations in rotor angle for synchronous generators, or more generally oscillations in real output power, should be damped and settle down to a steady state value within seconds. Likewise oscillations in generator reactive power output or voltage should also be damped and settle down to a steady state value quickly.

The generator stability performance standards that apply depend upon the size of the generator and the impact of unstable operation on other access standards.

Generators with capacity under 5MW

For generators under 5MW in capacity the automatic access standards do not mandate that stability studies be undertaken and therefore no stability standards apply however the generator must still satisfy the following requirements:

- Power quality standards (such as flicker, power factor etc.) must be satisfied, which are not expected to be met if a generator is regularly unstable.
- If the generator becomes unstable then generator protection shall detect and trip the unstable units.

[40] Ref. NER S5.2.5.3(b)
[41] Ref. NER S5.2.5.3(c)
[42] Ref. NER clause S5.1a.3

- If a generating unit regularly (more than once per month) becomes unstable (for any reason) then the generator operator must investigate the cause of the instability and consult with the DNSP on recommended solutions.
- In circumstances where a generator regularly becomes unstable the DNSP has the right to disconnect the generator, irrespective of the trigger or cause of the instability, until a solution is implemented thus it is recommended that embedded generator proponents undertake stability studies as considered prudent to reduce this risk.

Even if the generator is under 5MW in capacity if the generator provides network support services stability studies are required to ensure that the generator shall remain stable for all credible fault scenarios for which network support would be necessary.

Generators with capacity of 5MW or more but less than 30MW

For generators over 5MW stability studies are required to model the generator behaviour during and following credible network disturbances. For generators of this size instability is expected to have a serious detrimental effect on power quality and protection operation on the local DNSP network, in addition to generator damage. The following automatic access standards apply:

- All synchronous embedded generator units with a nameplate rating over 10MW shall comply with the standards applicable to generators with a capacity of 30MW or more (refer below).[43]
- The generator shall remain stable for all upstream 66kV sub transmission line short circuit faults if differential line protection is used to detect and clear the fault.
- The generator shall satisfy the standards applicable for generators over 30MW in capacity in relation to credible network disturbances on the transmission network (refer below). This includes transient frequency disturbances in the preceding section.
- For conditions under which the generator is not required to remain stable, and is not capable of stable operation, protection systems shall be implemented to detect the disturbance and actively and quickly disconnect the generator to minimise any adverse impact on quality of supply standards that a non-synchronised generator could cause.
- The generator shall remain stable for all power frequency voltage disturbances that fall within the stable zone of Figure 10.

[43] This is required to satisfy the EDCoP clause 21.5.3.

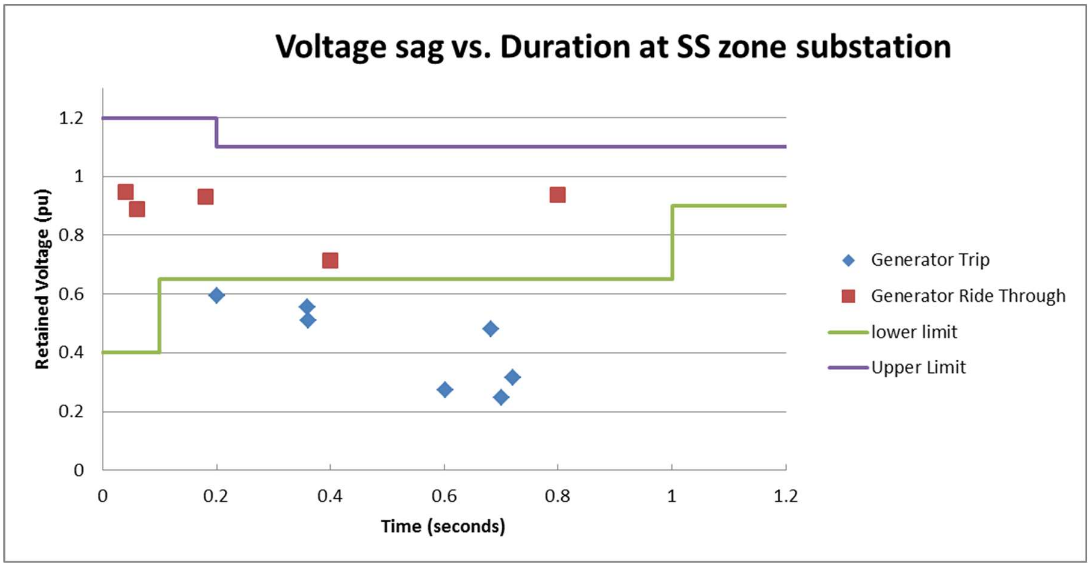


Figure 10: Embedded generator voltage disturbance ride through capability automatic access standard

The minimum access standard also requires stability studies to be undertaken however the ability for the generator to ride through each disturbance scenario is not specified and shall be negotiated with the DNSP depending upon the impact on the network.

Generators with capacity of 30MW or more

For generators of 30MW or more strict compliance with the NER is required. This includes (but does not limit) the following NER clauses:

- S5.2.5.4 Generating system response to voltage disturbances
- S5.2.5.5 Generating system response to disturbances following contingency events
- S5.2.5.6 Quality of electricity generated and continuous uninterrupted operation
- S5.2.5.7 Partial load rejection

This is necessary to ensure AEMO and DNSPs comply with NER clauses S5.1a.3 “System stability” and S5.1.8 “Stability”. Reference should be made directly with the NER however in summary the automatic access standards require adherence to the following:

- Each generating unit must be capable of continuous uninterrupted operation during and following a power frequency voltage disturbance at the connection point if the voltage falls within:
    - 70% to 80% of normal voltage for a duration of 2 seconds or less.
    - 80% to 90% of normal voltage for a duration of 10 seconds or less.
    - 90% to 110% of the normal voltage continuously.
    - The short term overvoltage limit contained within NER clause S5.1a.4 (Figure S5.1a.1) occurring as a consequence of a credible contingency event.
- Each generating unit must be capable of continuous uninterrupted operation during and following credible contingency events, except those contingency events that would directly disconnect the generator from the power system by removing network elements from service. These contingency events include:
    - A three phase fault on the transmission system cleared by the primary protection system.

  - Phase to phase, phase to ground or two phase to ground faults on the transmission system cleared by the operation of the CB fail protection (i.e. not the primary protection) if CB fail protection is installed. If CB fail protection is not installed then the clearance time shall be based on the longest of either the primary protection operating time, 80ms for faults on assets operating at ≥400kV, 100ms for assets operating ≥250kV but <400kV, 120ms for assets operating ≥100kV but <250kV, and 430ms for assets operating <100kV.
  - Three phase, phase to phase, phase to ground or two phase to ground faults on the distribution system cleared by the operation of the CB fail protection (i.e. not the primary protection) if CB fail protection is installed. If CB fail protection is not installed then the clearance time shall be based on the longest of either the primary protection operating time or 430ms.
- An internal Generator short circuit fault must be detected and cleared within a time that will not cause instability for other generating units.
- Each generating unit must be capable of continuous uninterrupted operation in the presence of voltage fluctuations, voltage unbalance and voltage harmonic distortion up to the levels specified in clauses S5.1a.5, S5.1a.6 and S5.1.a.7.
- Each synchronous generating unit must be capable of continuous uninterrupted operation during and following a sudden load reduction of 30% or an equivalent load reduction resulting from separation of the power system occurring within 10 seconds if following the load reduction the output from the generator remains above the minimum load required for continuous stable operation.

The minimum access standards within the NER have not been reproduced here, however in general they permit shorter protection operating times for short circuit faults down to the primary protection operating speed. In cases where the short circuit fault causes less than a 100MW reduction in generation and generator instability and subsequent disconnection do not adversely impact the quality of supply to other network users it may not be necessary for the generator to remain stable for certain types of short circuit fault at all. Non-compliance with the automatic access standard will require the approval of the AEMO.

Impact of automatic reclose

Stability studies shall include the impact of automatic reclose (both successful reclose and unsuccessful reclose) if oscillations persist longer than the reclose time.

5.2.5 Generator governor control system

All generators are expected to use a form of governor control system to regulate the input power to the generator which in turn will control the power output of the generator. This will be required for several purposes including the following:

- To ensure stable operation and constant power output. For generators with a variable uncontrollable input power (such as wind), the governor may still be required to ensure the output electrical power follows the available input power to maintain stable operation.
- To maximise generator efficiency and operate within a generator’s maximum power ratings.
- To remain stable for disturbances on the power system including short circuit faults and sudden changes in network load.
- To respond correctly to disturbances in system frequency by increasing or reducing power output.
- To ensure a generator with multiple units can evenly allocate and control the power output of each unit.

- To respond correctly to disturbances in power frequency voltage.
- To follow central dispatch instructions for scheduled generators. These instructions are normally issued electronically via an automatic generation control system at intervals not more than 5 minutes.[44]
- To provide ancillary services.

In general, embedded generators are not required to be capable of operating in island mode however where required the generator must have a governor control system that is able to regulate the generator frequency within certain limits and be capable of responding quickly to changes in load with a well damped response. If the generator is used as a backup alternative supply to the power system and only supplies local load on the same premises that would normally be supplied from the same network connection point as the embedded generator then the DNSP will not set any standard regarding the performance of the governor in island mode. Although unusual, if the embedded generator is used to provide black start ancillary services to AEMO then the DNSP will set governor performance standards for island operation in association with AEMO.

Commissioning tests are required to ensure the governor control system is stable under various conditions including various load outputs, the full power factor range, network faults and switching etc. The method of compliance with these load control criteria is to be approved by the DNSP.

5.2.5.1 Response to disturbances following a contingency event[45]

Following a short circuit fault on the power system for which the generator is expected to remain stable and connected, the automatic access standard requires each generating unit to maintain its active power output at a minimum of 95% of the immediate pre-fault power output within 100ms after the faulted element is disconnected. This requirement is subject to energy source availability.

5.2.5.2 Active power control[46]

Generators with capacity under 30MW

The automatic access standard requires generation output to ramp up or down smoothly at a rate of no more than 50kW/s to limit voltage fluctuations and allow transformer on load tap changers or capacitor banks to switch in response to changing network load flows and to regulate network voltages accordingly.

Generators with capacity of 30MW or more

The automatic access standard for scheduled generating units requires:

- Capability to maintain or change active power output in accordance with dispatch instructions.
- Ramping of its active power output from one level of dispatch to another.

The automatic access standard for semi-scheduled generating units, subject to energy source availability, requires capability to:

- Automatically reduce or increase active power output at a constant rate to or below the level specified in a dispatch instruction.

[44] Ref. NER 3.8.21

[45] NER clause S5.2.5.5

[46] NER clause S5.2.5.14

- Automatically limiting its active power output at or below the level specified in the dispatch instruction.
- Not change its active power output within 5 minutes by more than raise or lower amounts specified.
- Ramping its active power output linearly from one level of dispatch to another.
- Receive loading instructions issued electronically.

The automatic access standard for non-scheduled generating units, subject to energy source availability, requires capability to:

- Automatically reduce or increase active power output, within 5 minutes, at a constant rate to or below the level specified in an instruction.
- Automatically limit its active power output at or below the level specified in an instruction.
- Not change its active power output within 5 minutes by more than raise or lower amounts specified.
- Receive loading instructions issued electronically.

5.2.5.3 Frequency response[47]

All synchronous generator units over 5MW must have a governor system responsive to system frequency changes.[48] Likewise all generators that are not eligible to be exempt from registration with AEMO must ensure all generating units have a governor system that is responsive to power system frequency[49]. (A generator that is registered with AEMO but is eligible to be exempt from registration may not be required to have a governor system that is responsive to system frequency changes unless it is a synchronous unit over 5MW.)

The following section should be read in conjunction with section 5.2.3.2 of this document (page 51) on transient frequency disturbances. The automatic access standard requires that:

- Each generating unit's active power transfer to the power system must not increase in response to rising system frequency and must not decrease in response to a fall in system frequency.
- Generating units must be capable of automatically reducing active power transfer to the power system whenever the system frequency exceeds the upper limit of the normal operating band by at least the lesser of:
  - 20% of its maximum operating level for every 1Hz in frequency above the upper limit of the normal operating band,
  - 10% of the maximum operating level for the generator,
  - the difference between the generating unit's pre-disturbance power output level and unit's minimum operating level, but zero if the difference is negative.
- Generating units must be capable of automatically increasing active power transfer to the power system whenever the system frequency falls below the lower limit of the normal operating band by at least the lesser of:
  - 20% of its maximum operating level for every 1Hz in frequency below the lower limit of the normal operating band,

[47] Ref. NER S5.2.5.11
[48] Ref. EDCoP 21.5.2 (b)
[49] Ref. NER S5.2.1(b)

    - 5% of the maximum operating level for the generator,
    - One third of the difference between the generating unit's maximum operating level and the pre-disturbance power output level, but zero if the difference is negative.
- Generators contracting to provide market ancillary services are required to demonstrate rapid export change.
- Control systems directed at frequency control are to demonstrate adequate damping.

5.2.6 Generator reactive power control and power factor limits[50]

5.2.6.1 Steady state reactive power capability

Requirements for Generators eligible to be exempt from registration with AEMO

The automatic access standard requires an embedded generator to able to deliver sufficient reactive power[51] such that at peak real power transfer at the connection point the power factor at the network connection point is maintained within the limits contained in Table 7.[52] In addition whenever the real power transfer at the connection point is greater than 50% of the peak real power transfer the Generator shall use best endeavours to maintain the power factor within these limits.

Peak apparent power flow at the connection point	Up to 100kVA		Between 100kVA-2MVA		Over 2MVA	
	Minimum lagging	Minimum leading	Minimum lagging	Minimum leading	Minimum lagging	Minimum leading
Voltage = 230V/400V	0.80	0.80	0.80	0.80	0.85	0.85
Voltage = 6.6kV, 11kV or 22kV	0.80	0.80	0.85	0.85	0.90	0.90
Voltage = 66kV	0.85	0.85	0.90	0.90	0.95	0.98

Table 7: Power factor range for variation of maximum demand and voltage

Note: Lagging power factor is defined as reactive power flowing from the network into the connection point supplying the site regardless of whether it contains an embedded generator, load or both.

For large embedded generators or on weak parts of the distribution network an embedded generator may need to vary reactive power output of an embedded generator to regulate voltage at the connection point in accordance with voltage regulation requirements (refer to 5.2.1 on page 48). In such circumstances voltage regulation requirements take precedence over power factor limits however reactive power flows must be limited so that apparent power flows do not exceed network capability limits. Under such circumstances it will be necessary for the embedded generator to negotiate with the DNSP upon the minimum reactive power capability of the generator to regulate voltage, and if necessary, the power factor limits that will apply.

Requirements for Generators not eligible to be exempt from registration with AEMO[53]

The automatic access standards require all generators to be capable of supplying and absorbing continuously (measured at the connection point) an amount of reactive power of at least the product of the rated active power of the generating system and 0.395. This capability is required at any level

[50] Ref. NER S5.2.5.1

[51] The reactive power could be provided by the generators units themselves or by other components such as a switched shunt capacitor bank.

[52] Based on table 4, section 20.5, of the EDCoP.

[53] Ref. NER S5.2.5.1

of active power output and with any voltage at the connection point within the limits listed in Table 5 (on page 48).

The minimum access standards do not require the generator to have any capability to provide reactive power at the connection point. This means that the generator or the generating system should be able to maintain the operating power factor of unity at the connection point. Therefore, the generator or the generating system should be capable of compensating the reactive power demand and losses up to the connection point.

5.2.6.2 Generator excitation control system

The excitation and associated control systems must not adversely affect efforts by the DNSP to regulate power frequency voltage or maintain voltage stability on the distribution network.

Automatic access standards for Generators eligible to be exempt from registration with AEMO (under 30MW)

An embedded generator synchronous unit over 5MW must have an excitation control system including voltage regulator.[54] The excitation control system on a synchronous embedded generating unit with a nameplate rating over 10MW must comply with the NER requirements for generating units over 30MW in regard to response to disturbances, safe shutdown without external electricity supply, restart following loss of external electricity supply and voltage stability.[55] Where an embedded generator consists of multiple generating units the excitation control system on each unit shall ensure load sharing amongst each unit is well controlled and stable.

Voltages on the distribution network are largely controlled by the network thus in general when synchronous units operate on the distribution network the generator excitation control system will not be used to control voltage but shall be used to regulate power factor. The automatic access standard therefore requires the generator excitation control system to regulate reactive power output either:

- At a value that holds generator power factor reasonably constant.
- As a function of load on a specific part of the distribution network.

In special cases the DNSP may require the generator excitation control system to respond to the voltage at a node on the distribution network if the voltage exceeds certain limits while at other times the excitation control system will operate based on one of the modes above.

The modes of operation when isolated from the DNSP network are at the discretion of the Generator. When the Generator transitions from parallel to isolated island mode (or vice versa) the excitation system will be required to change operating mode and during this change the system must remain stable. This shall be demonstrated during commissioning tests. To comply with the automatic access standard the change in excitation system control mode must be automatic. (The minimum access standard permits manual change of excitation control mode only if manual control methods can be used without a detrimental impact on the distribution network. If manual controls are used pre-set timers must be provided to automatically disconnect the generator if the change in mode selection is not carried out in a pre-set time.)

Commissioning tests are required to establish stability in the reactive power control system under various generator load and power factor conditions and specifically in response to reactive control

[54] Ref. EDCoP 21.5.2

[55] Ref. EDCoP 21.5.3

switching operations in the network and the load facility of the generator. The method of compliance with these reactive power control criteria is to be approved by DNSP.

Requirements for Generators not eligible to be exempt from registration with AEMO (over 30MW)[56]

The automatic access standard requires that for generators that are not eligible to be exempt from AEMO registration, each generating unit must have an excitation capability and an associated excitation control systems that ensures:

- Power system oscillations arising between generators are damped.
- No degradation to damping of critical mode oscillations of the power system.
- No instability (including hunting of tap-changing transformers) that adversely affect other Registered Participants.
- Permanent facilities are included and operational that allow monitoring and recording of each input, output and key variable.
- Facilities are available for testing that would establish dynamic operational characteristics.

Synchronous generating units complying with the automatic access standards are to have excitation capabilities and associated excitation control systems able to:

- Regulate voltage at an agreed location to within 0.5% of the set-point.
- Regulate voltage in a manner that helps support network voltages during network faults.
- Incorporate limiting devices that act in response to a voltage disturbance to ensure the generating unit will not trip at the limits of its operating capability. These limiting devices must not detract from the operation of any power system stabiliser and must be co-ordinated with all protection schemes.
- Regulate voltage such that voltage may be set and held at the connection point, or other agreed location, in at least the range 95%-105% of normal voltage and without use of a tap-changing transformer.
- Operate the stator at a voltage of 105% of the nominal voltage continuously at rated power output.
- Static excitation systems must be able to increase the field winding voltage from the rated field voltage (the voltage required to deliver rated active power at rated power factor, rated speed and nominal generator output voltage) up to the excitation ceiling voltage in under 0.05 seconds. The static excitation system ceiling voltage shall be at least 2.3 times greater than the generator rated field voltage.
- Non-static excitation systems must be able to increase the field winding voltage from the rated field voltage (the voltage required to deliver rated active power at rated power factor, rated speed and nominal generator output voltage) up to the excitation ceiling voltage in under 0.5 seconds. The non-static excitation system ceiling voltage shall be at least 1.5 times greater than the generator rated field voltage.
- Increase or reduce excitation voltage (and therefore reactive power output) in response to generator output voltage (compensation settable for either boost or droop).
- Achieve settling times in response to a step change of voltage set-point at the connection point (or voltage at the agreed location) as shown in Table 8.

[56] Ref. NER S5.2.5.13

Generator type	Connection condition	Initiating disturbance	Measured parameter	Acceptance criteria
Synchronous generators	Unsynchronised and at speed	5% voltage set-point change	Voltage settling time	<2.5 seconds
	Connected and synchronised	5% voltage disturbance that does not cause limiter action	Voltage settling time	<5 seconds
			Active power settling time	<5 seconds
			Reactive power settling time	<5 seconds
Synchronous generators – For each limiter action individually tested	Connected and synchronised	5% voltage disturbance but causing limiter action (refer note below on disturbance start condition)	Voltage settling time	<7.5 seconds
			Active power settling time	<7.5 seconds
			Reactive power settling time	<7.5 seconds
Asynchronous generators	Connected	5% voltage disturbance but not causing limiter action	Voltage settling time	<5 seconds
			Active power settling time	<5 seconds
			Reactive power settling time	<5 seconds
Asynchronous generators – For each limiter action individually tested	Connected	5% voltage disturbance but causing limiter action (refer note below on disturbance start condition)	Voltage settling time	<7.5 seconds
			Active power settling time	<7.5 seconds
			Reactive power settling time	<7.5 seconds
			Reactive power rise time	<2 seconds

Table 8: Excitation control system performance under test

Notes:

- Tests intentionally causing limiter action are to be initiated from an excitation level from which a voltage disturbance of 2.5% would just cause limiter action.
- Settling time means in relation to a step response test or simulation of a control system, the time measured from initiation of a step change in an input quality to the time when the magnitude of error between the output quality and its final settling value remains less than 10% of:
  (1) if the sustained change in the quantity is less than half of the maximum change in that output quantity, the maximum change induced in that output quantity; or
  (2) the sustained change induced in that output quantity.

The power system stabiliser characteristics are to include:

- Monitoring and recording facilities for key variables including inputs, outputs and the inputs to the lead-lag transfer function controller blocks.
- For synchronous generating units recorded input variables shall include rotor speed and active power output while for other generating types input variable shall include power system frequency and active power output.
- Two wash-out filters for each input with ability to bypass one.
- Sufficient, but not less than two, lead-lag transfer blocks (or equivalent number of complex poles and zeros) with adjustable gain and time-constants, to compensate fully for the phase lags due to the generating plant.
- An output limiter, which for a synchronous generating unit is continually adjustable over the range -10% to +10% of stator voltage.
- Facilities that permit injection of test signals into the power system stabiliser, while in isolation of the power system, and sufficient to establish the transfer function of the power system stabiliser.

The automatic access requirements for asynchronous generating units are contained within NER clause S5.2.5.13(b)(4). In general asynchronous generating units must have associated plant that enables the embedded generator to achieve reactive power control and stability with equivalent levels of performance as an embedded generator utilising synchronous units.

5.2.7 Harmonic tolerance

Harmonic current produced by load on the distribution network causes voltage harmonic distortion throughout the distribution and transmission network. Embedded generators connected to the distribution network may represent a low impedance path for certain harmonics. Embedded generators must be tolerant to the level of voltage harmonic distortion up to the limits listed in Table 9 and must be suitably designed and where necessary de-rated to allow for the presence of these harmonics.

The distributor shall keep the voltage harmonic distortion within the following limits[57]:

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

Table 9: Voltage harmonic distortion limits

The Generator shall ensure that connection of the generating units to the distribution network do not create any network resonances that amplify harmonic distortion levels on the network.

5.2.8 Harmonic injection limits

Harmonic currents can flow into an embedded generating unit because:

- The generator acts as a sink for harmonic currents produced by load on the network.
- The generator creates a resonance condition on the network that amplifies background harmonics.
- The generator acts as a source of harmonic current due to the non-linear behaviour of the generator itself.

If the generator acts as a source of harmonic current then limits apply regarding the amount of harmonic current that can be produced by the generator and injected into the distribution network. These limits shall be determined based on the generator classification.

Automatic access standards for Generators eligible to be exempt from registration with AEMO (under 30MW)

For small embedded generators the limits contained within the EDCoP apply and are reproduced in Table 10. The limits for even harmonics are limited to 25% of those for the odd harmonics and the limits vary according to the ratio of the short current level (I_{SC}) and the load or embedded generator current (I_L).

[57] Ref. EDCoP clause 20.6.1 and NER schedule 5.1a clause S5.1a.6.

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

Table 10: Current harmonic distortion limits

The DNPS must also comply with IEEE Standard 519-2014 'Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems'.

Requirements for Generators not eligible to be exempt from registration with AEMO (over 30MW)

In addition to the obligations contained within the EDCoP, for larger embedded generators over 30MW embedded generators shall also be required to comply with NER clause S5.2.5.2.

The level of harmonic voltage distortion in the DNSP supply to any network user is required to be maintained at less than the "compatibility levels" set out in Table 1 of AS/NZS 61000.3.6:2001.

The DNSP must allocate emission limits no more onerous than specified in the relevant stages of analysis determined in accordance with the AS/NZS procedures. The DNSP will thereby identify the share of harmonic distortion that may be attributed to any generator.

Site specific parameters will be advised in response to a Connection Enquiry. For the purpose of setting automatic access standards, the DNSP must allocate emission limits no more onerous than the lesser of the acceptance levels determined in accordance with either stage 1 or stage 2 of the evaluation procedure. The minimum access standard requires that DNSP must allocate emission limits no more onerous than the acceptance levels determined in accordance with the stage 3 evaluation procedure.

5.2.9 Negative and zero sequence injection limits

Voltage and current negative sequence unbalance[58]

The DNSP is required to maintain the negative sequence voltage at the point of common coupling for three phase installations within the EDCoP limits. These limits restrict the negative sequence voltage to 1%, although the level may rise to 2% for a total of 5 minutes in every 30 minute period.

An embedded generator must ensure that the generator contribution to the negative sequence voltage at the point of common coupling does not cause the distributor to exceed the EDCoP limits. This shall be achieved if the Generator is able to keep the output current magnitude and power factor of the embedded generator balanced on each phase. If the total current at the connection point for an embedded generator is balanced in accordance with Table 11, then the Generator will be considered to comply with the automatic access standards for negative sequence injection. If the Generator does not comply with these limits then it will be necessary for the Generator to demonstrate that the negative sequence currents it injects at the network connection point will not cause the DNSP to exceed the EDCoP voltage negative sequence limits on any part of the distribution network.

[58] Ref. EDCoP clause 20.8

Generator connection voltage	Current in each phase must not deviate from the average of the three phase currents by more than:	
	For periods greater than 2 minutes	For periods less than 2 minutes
<1kV	5.0%	10.0%
≥1kV	2.0%	4.0%

Table 11: Load balance for an embedded generator

For the generating units having nameplate rating over 10MW, must comply with the clause S5.2.5.2 of the NER.

Zero sequence current

For generators connected to the distribution network connected at LV (230/400V) the maximum single phase generator size permitted under the automatic access standards is 10kVA. LV embedded generators over this size must be three phase and have zero sequence current under 5% of the positive sequence current.

For generators connected at HV (6.6kV, 11kV, 22kV or 66kV) the automatic access standard requires the zero sequence current to be zero.

5.2.10 Inductive Interference[59]

A generating unit must not cause inductive interference above the limits specified in AS/NZ 2344:2016.

5.2.11 Network signalling[60]

The DNSP and TNSP may use the network power conductors for the purpose of control signalling. In accordance with provisions of AS/NZS 61000.2.2:2003 signals of the following form may be present:

- Ripple control systems.
- Medium frequency power line carrier systems.
- Radio frequency power line carrier systems.

Equipment supplied by the generator and exposed to these signals shall be designed so they are not adversely affected by these signals and DNSP is not to be considered liable for any adverse impact.

If installation of shunt capacitors is a feature of the generation facility, the generator is to ensure the capacitor installation does not severely attenuate any audio frequency signals used for network load control or operations or adversely impact harmonic voltage levels at the connection point.

5.2.12 Generator impact on network capability[61]

The DNSP must consider the impact that any generator might have on any inter-regional or intra-regional power transfer capability and AEMO must be consulted on this matter. Any adverse impact must reflect as limitations in a negotiated access standard and will be pursued by DNSP.

Where power transfer capabilities of the network could be enhanced by inclusion of additional control system facilities such as power system stabilisers, the DNSP may be required to negotiate with the generator for such facilities.

[59] Ref. EDCoP clause 21.8
[60] Ref. EDCoP clause 20.4.6
[61] NER clause S5.2.5.12

The automatic access standard requires that the generator will have no adverse impacts on any inter-regional or intra-regional power transfer capability and in most cases generators connected to the distribution network will be too small to create such adverse impacts.

5.2.13 Generator fault current contribution

The fault contribution of the generator or the generating system to the fault current on the connecting network through its connection point must not exceed the contribution level that will ensure that the total fault current will not exceed the ultimate fault levels given in Table 2 as specified in the EDCoP and can be safely interrupted by the circuit breakers of the connecting network. Given the fault ratings of the existing circuit breakers in the network can be below the ultimate fault current for the relevant voltage level, this requirement is subject to a site specific review.

5.3 Protection, control, monitoring and communications requirements

5.3.1 General principles for the detection and clearance of all faults

Electrical protection shall be provided to ensure the safety and integrity of the electricity distribution network is not in any way compromised by the connection and operation of the embedded generator. These standards only relate to the protection and performance of the distribution network however the generator protection designer must also consider the protection that will be necessary to protect the generating plant.

All electrical faults within the generator installation shall be automatically detected and rapidly isolated from the electricity distribution network. All plausible electrical faults on the electricity distribution network (external to the generator installation) shall also be automatically detected and the generator contribution is to be rapidly interrupted. In this regard, the generator installation protection devices shall be configured to trip either the connection point circuit breaker or the generator circuit breaker.

5.3.2 Short circuit faults internal to the generator installation

Any short circuit fault within a generator installation must be detected and disconnected from the distribution network as quickly as possible. This includes three phase, phase to phase and phase to ground faults.

Example A typical fault is illustrated in Figure 11. In this example the connection point circuit breaker would be expected to trip and isolate the fault from the distribution network however the generator circuit breaker would also need to trip to clear the fault altogether.

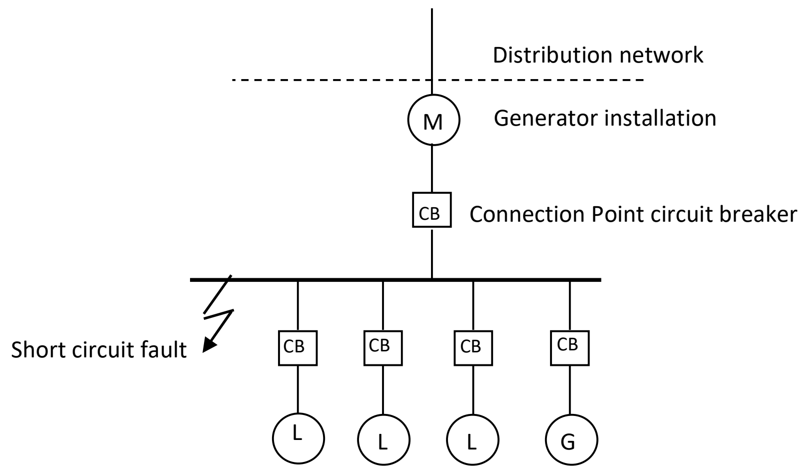


Figure 11: Typical generator installation with internal short circuit fault

5.3.2.1 Overlapping protection zones

Short circuit faults at any location within the generator installation must be detectable. This requires particular consideration where directional and differential protection is used and faults on one side of a current transformer cannot be detected. To ensure non-detection zones don't occur, the automatic access standards require protection zone overlap.

In accordance with SIR clause 9.8 it is recommended that the current transformers used for internal installation fault detection are located on the network side of the connection point circuit breaker to avoid a non-detection zone. It is noted however that for the detection of faults on the distribution network it may be preferable for the current transformer to be located on the generator installation side. If the primary protection cannot detect a small region (such as between a current transformer and circuit breaker) then the backup protection must be able to detect this region as a minimum.

5.3.2.2 Protection grading

It is important that the protection used to detect and clear short circuit faults within the generator installation grades with the protection on the distribution network so that the generator installation protection clears the fault before the distribution network protection acts. This limits the impact of the fault on other network users.

The grading margin in all cases must make reasonable aggregate allowance for:

- Tolerances on relay detection and operating speed.
- Reset and overshoot characteristics.
- CB clearance times.
- Communication times (if relevant).
- A margin of safety.

LV connected generators

For generators connected at LV that are not supplied from a service fuse it is necessary to undertake a grading study and to grade with the upstream network protection where possible. If the immediate upstream protection uses a circuit breaker then grading is necessary to comply with the automatic access standards with a margin of at least 0.25 seconds. If the upstream protection is a high speed fuse then it is noted that grading may not be possible at high fault currents unless a fuse is used which may not be desirable.

Therefore while it is not necessary to achieve adequate grading at all fault currents, it is necessary to undertake a grading study to demonstrate that all practical steps have been taken to make the protection grade.

HV connected generators

For generators connected at HV the generator protection must grade with the distribution network protection with a margin of at least 0.4 seconds to satisfy the automatic access standards. (The minimum access standard requires a grading study to be undertaken and reasonable attempts to grade with upstream protection must be demonstrated however non-coordination at high fault currents may be permitted in certain circumstances.).

If the generator installation protection is interlocked with the protection on the distribution network with communications between relays then the time based protection grading constraints don't exist. In this case the operating time difference between distribution network protection and the generator installation protection could be zero. When conventional inverse time or definite time based over-current / earth fault relays are used then the margin of 0.4 seconds must be maintained to achieve the automatic access standard.

Any changes to above stated grading margins will need to be approved by the DNSP.

Situations where protection grading is not practical

If a generator connects to the distribution network and the primary upstream protection is a high speed fuse then grading may not be possible over the full prospective fault current range unless the generator installation also uses fuses for protection which may not be desirable.

Examples HV generator connected to a distribution feeder spur which is protected by a line fuse. An LV generator connected directly to a distribution substation which is protected by a HV fuse.

For such designs protection grading is not necessary to comply with the minimum access standards at very high fault levels however every attempt must be made to make the generator protection as fast as practical and consultation with the DNSP protection engineer will be necessary. In accordance with the definition of minimum access standards the DNSP has no obligation to accept a proposed design that does not provide protection coordination.

If the generator connects at LV and is supplied via a service fuse then it is not necessary for any protection grading studies to be undertaken. Nonetheless it is recommended that some consideration be given to grading to avoid unnecessary service fuse operation for an internal generator installation fault.

5.3.2.3 High impedance phase to ground short circuit faults

For HV installations the generator installation must also be able to detect and clear high impedance phase to ground faults and this protection must grade with the protection on the distribution network to comply with the automatic access standards. Typical protection will include inverse time earth fault protection and definite time sensitive earth fault (SEF) protection. In practice SEF protection that can be set down to 4A shall be adequate for HV connected generators.[62] Generator protection is not expected to be capable of operating if the zone substation uses resonant earthing, i.e. Rapid Earth Fault Current Limiter.

For LV installations the DNSP does not impose any special requirements however the generator must comply with relevant industry standards for earth fault protection including Australian Standards AS/NZS3000.

5.3.2.4 Protection operating speed

Protection speed should be set as fast as practical for obvious reasons such as health and safety, equipment and property damage and power quality. All protection must operate within the critical fault clearing times to maintain stability on the main transmission network. Protection speed should also be set as fast as possible to reduce the chance of creating instability for another nearby embedded generator.

Given the need to discriminate between internal generator installation faults (where the protection must be extremely fast) and external network faults (where the protection may need to be slower to allow adequate grading and to prevent nuisance tripping) it may be necessary to use directional protection, particularly for larger HV generators.

Where generator protection can be set to grade with existing network protection it will generally be regarded as acceptable from a network perspective.

Critical fault clearance time

For most generators connected to a 6.6kV, 11kV or 22kV distribution feeder it is unlikely that a short circuit fault will cause transmission network instability. 66kV sub transmission faults are likely to cause network instability unless the fault current is interrupted quickly.

For sub transmission network protection that incorporates inverse time overcurrent protection the existing protection must already comply with the critical fault clearing times. Therefore if the generator protection grades with the sub transmission network protection then it will automatically comply with the transmission network stability requirements. For sub transmission lines only protected by differential protection additional consideration shall be given to both critical fault clearance time and grading with bus overcurrent protection at the terminal station.

Instability for other network generators

It may be possible for a fault within one embedded generator installation to potentially cause instability for another embedded generator even though the transmission network remains stable. This can result in a cascade of tripping. Local instability must be evaluated where multiple generators are able to influence one another during a network disturbance. Where practical steps can be taken to mitigate the risk they must be implemented. This issue will be given high importance if embedded generators are used to provide network support or if the loss of multiple generators creates power quality problems for the network.

Maximum fault clearance times

Wherever possible the generator protection designer shall attempt to grade the internal installation protection with the existing network protection. In some situations however it may be necessary to consider slowing down the network protection.

[62] For distribution feeder protection at the zone substation, SEF minop is typically set at 9A. Automatic circuit reclosers (ACRs) typically have the SEF minop set at 5A.

Example
A HV generator is located close to the start of a long distribution feeder. It is not possible to grade using current because the fault current within the generator installation is almost the same as the fault current at the start of the feeder. To grade with the feeder protection, the feeder protection may need to be slowed down to allow time grading.

In such circumstances the DNSP will consider such requests however to comply with the automatic access standards the electricity distribution network protection shall not be reduced any slower than the following times for all solid three phase, phase to phase and phase to ground short circuit faults:

- LV protection maximum operating time = 0.9 seconds.
- HV distribution feeder protection operating time = 0.9 seconds.
- 66kV sub transmission protection operating time = 0.4 seconds.

If the generator protection does not grade and the network protection cannot be made any slower, then alternative schemes such as a blocking scheme will need to be implemented to meet the automatic access standards.

Network protection operating times slower than those listed above or inadequate grading margins would require the approval of the DNSP and would require a negotiated connection agreement.

5.3.2.5 Backup protection

If the primary protection equipment fails to detect or interrupt fault current within the generator installation it is necessary for a backup protection scheme to detect and clear the fault.

For a short circuit on the main switchboard within the generator installation it may be acceptable to rely upon the distribution network protection however the generator protection designer is responsible for checking that the network protection will be adequate to provide this backup function and in addition the generator is required to align their protection settings for any future DNSP setting changes. If the distribution feeder protection is inadequate (e.g. fault current is very low and over current protection may not detect fault condition) then the generator protection designer must design their own backup or failsafe protection. For faults on sub switchboards within the generator installation the distribution network protection must not be relied upon for backup.

If blocking schemes are implemented and protection systems fail then special consideration must be given to determine what type of backup protection will operate.

Example
Consider a generator connected to a HV feeder with protection blocking scheme that blocks the distribution network feeder protection for a fault within the generator internal installation. If the generator protection fails to clear the fault and the distribution network feeder protection is blocked what protection will detect and clear the fault?

Refer to section 5.3.6 for further information.

5.3.3 Distribution network short circuit faults external to an installation

For any short circuit faults within the distribution network where the generator is connected to, the generator protection must detect the fault and disconnect the generator from the distribution network as quickly as possible. This includes three phase, phase to phase and phase to ground faults.

5.3.3.1 Distribution network protection zones

For each generator installation it is necessary to identify the various protection zones on the distribution network and to determine the primary protection and backup protection that shall detect and clear the fault within each zone. Both the network and generator protection will be required to detect and clear the fault. The analysis must be undertaken in conjunction with the DNSP.

It is important that the generator installation protection is used to detect and clear the generator's contribution of short circuit faults within the DNSP network so that the generator installation protection acts to clear the fault with the distribution network protection. This reduces the risk of islanding.

Example A typical network is illustrated in Figure 12 however various network topologies are possible. In this example the generator protection must detect and quickly clear all faults in zone 1 however the distribution network is dynamic with switching occurring daily. If zone 1 is extended by transferring load from zone 4 to zone 1 then the protection must also detect and clear faults within zone 4. The generator protection will be required as backup protection for zone 2, while for zone 3 the generator protection will not be required to act at all. In this example the connection point circuit breaker could be expected to trip and isolate the generator from the distribution network when certain short circuit faults occur on the distribution network. The generator circuit breaker could also be used to trip the generator to clear the fault.

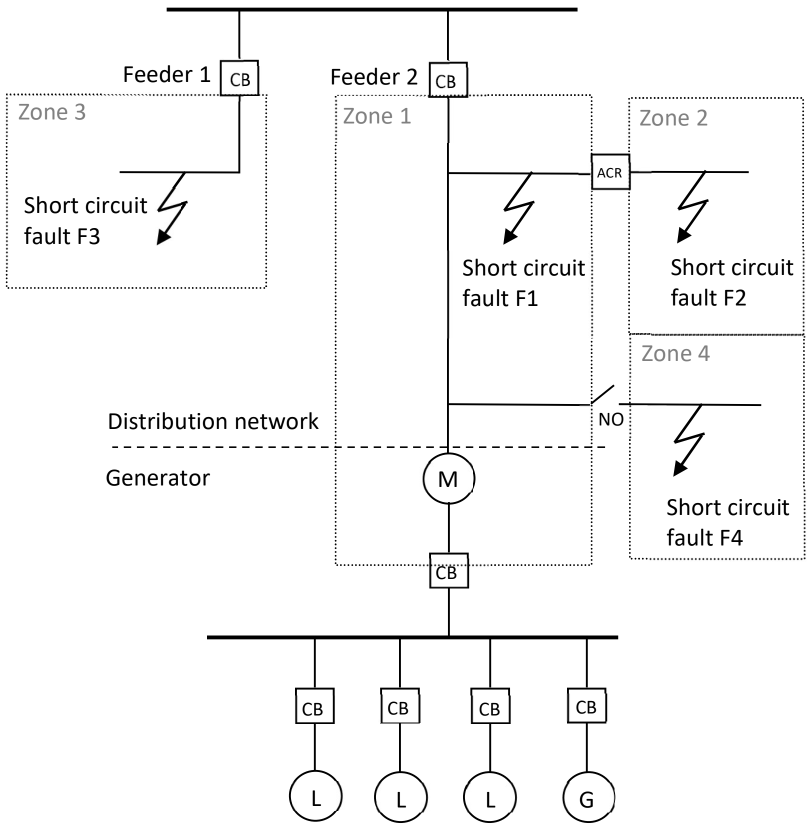


Figure 12: An example of a typical generator installation with various distribution network short circuit faults

5.3.3.2 Protection techniques and setting guidelines

The generator protection designer is free to use any available reliable technique to detect network short circuit faults in the various zones however conventional over-current, directional over-current, distance protection or anti-islanding protection is likely to be utilised. Earth fault over-current and sensitive earth fault protection may also be used in certain circumstances. For embedded generators connected to the sub transmission network, differential line protection schemes are the preferred primary protection. While the DNSP shall not be responsible for approving generator installation designs the DNSP has the right to refuse proposed designs that are not considered adequate.

The protection must be sufficiently sensitive to detect all short circuit faults on the distribution network that would be detectable by DNSP protection schemes and must include a safety margin.

Example

Consider an over-current protection scheme designed to detect and clear three phase, phase to phase and phase to ground short circuit faults on the distribution network. When selecting what minimum operating current (MinOp) setting to use the following safety margin may be applied:

Generator Protection	Network condition	Maximum permitted MinOp setting
Primary over-current protection	System normal	70% lower than the lowest solid short circuit fault current within the normal protection zone.
	System abnormal	50% lower than the lowest solid short circuit fault current within the extended abnormal protection zone.
Backup over-current protection	System normal	50% lower than the lowest solid short circuit fault current within the normal protection zone.
	System abnormal	Backup protection not expected to operate over the extended abnormal protection zone.

System normal referred to above means that all network switches are in their normal state and the protection zone is easily defined. When the network is abnormal the protection zone could be extended in size. The DNSP will define the normal and abnormal protection zones for a particular embedded generator when requested or in response to a Connection Application. The above is only an example; in all circumstances, quickest practicable fault clearance times shall be designed

Similar methods to that used in the example above must be applied to distance protection to ensure the protection will operate reliably and for all other forms of protection. This is required to provide some safety margin allowing for some uncertainty in the short circuit fault impedance, modelling error, fault impedance measurement etc.

5.3.3.3 Protection grading and discrimination against faults beyond the protection zone

The detection and clearance of faults on the distribution network can be complex because the protection may need to discriminate between faults at various locations. To illustrate refer back to Figure 12. Fault F1 within protection zone 1 must be cleared in the fastest time possible. Fault F2 within protection zone 2 would normally be cleared by the ACR and therefore the generator protection should not operate unless the ACR fails to clear the fault in which case the generator protection must operate. For fault F3 within zone 3 the generator protection should never operate (although if feeder 1 CB failed to operate the bus would trip together with feeder 2 CB and the generator anti-islanding protection must operate). Fault F4 within zone 4 must be cleared if the network is abnormal.

To satisfy the automatic access standards the protection must discriminate against faults within other protection zones otherwise the generator could trip unnecessarily when other protection should act to detect and clear the fault. If a satisfactory design using inverse time over-current or distance protection cannot be achieved then differential protection and/or protection blocking schemes shall be used as part of the automatic access standards. These more costly protection schemes are likely to be necessary for large embedded generators. (Full discrimination is not required for the minimum access standards. A lack of discrimination may be reviewed by DNSP under a negotiated access standard if the impact of generator nuisance tripping can be tolerated.)

5.3.3.4 Phase to ground faults

LV phase to ground faults

For generators connected at LV the generator protection must detect and clear all LV phase to ground faults within the defined protection zone on the distribution network to comply with the automatic access standards. The protection must also comply with the requirements of AS/NZS3000.

HV phase to ground faults

For any HV phase to ground faults within the defined protection zone for which the generator protection must act, the embedded generator protection must disconnect the generator from the network. This applies for generators connected to the network at either HV or LV.

To comply with the automatic access standards a generator connected at HV cannot supply zero sequence current. This can be achieved using various means such as connecting the generator via a transformer with delta winding on the network side or using a delta connected generator winding, or using star connected transformer or generator with the star point floating etc.

Connection of an embedded generator that can provide zero sequence current will be considered if the generator proponent submits a suitable design however special protection schemes are likely to be required to ensure that the network protection will operate satisfactorily. Step and touch potentials associated with increased earth grid potential rise will also need to be reviewed. If any such proposal is acceptable it will only be under the terms of a negotiated connection agreement.

HV phase to ground faults need special consideration because if a HV connected generator complies with the automatic access standards they will not provide any zero sequence current. LV generators without generator transformers will connect to the LV network which in turn is connected to the HV network via a transformer with a Dyn11 vector group. In either case the generator will not provide phase to ground fault current on the HV network making phase to ground short circuit detection difficult for the generator. Nonetheless it is necessary for all embedded generators to reliably trip whenever phase to ground faults occur on the HV network within the defined protection zone for which it must act.

The preferred techniques to be used for the detection of phase to ground faults on the HV network are either:

(i) Distribution network earth fault protection with remote trip to the generator.

(ii) Sensitive differential line protection scheme or neutral displacement protection at the generator site. The neutral displacement requires HV voltage transformers, or low power voltage transformers known as LPVTs, and the differential and remote trip options require a reliable communications link so these protection schemes can be expensive.

Given that the distribution network earth fault protection will detect the fault and will trip the network supply to the fault it is possible for the generator protection to rely upon anti-islanding protection to be used to trip the generator for phase to ground faults on the HV network. To comply with the automatic access standards the generator must be able to reliably trip within 0.2 seconds after the operation of the network earth fault protection.

5.3.3.5 Protection operating speed

In the same way as internal generator installation faults, protection used to clear faults on the distribution network should be set as fast as practical for the same obvious reasons such as health and safety and equipment and property damage. Where generator protection can be designed with a fault clearance time equal to or less than the network protection it will be regarded as acceptable.

While it is desirable for the generator installation protection to clear network faults within the detection zone quickly, it is also desirable for the protection to discriminate for faults outside the protection zone otherwise the generator will trip unnecessarily. Depending upon the type of protection used, operating speed for faults external to the generator installation may be cleared more slowly than internal installation faults. It is acknowledged that it may be a challenge to obtain a good balance of fast operating time within the protection zone while also achieving good discrimination against faults outside the protection zone in all circumstances.

If necessary network protection can be slowed down depending on case by case basis to ensure protection will grade. To comply with the automatic access standards the electricity distribution network protection shall not be reduced any slower than the following times for all solid three phase, phase to phase and phase to ground short circuit faults:

- LV protection maximum operating time = 0.9 seconds.
- HV distribution feeder protection operating time = 0.9 seconds.
- 66kV sub transmission protection operating time = 0.4 seconds.

Slower operating times would require the approval of the DNSP protection engineer and would require a negotiated connection agreement.

For phase to ground short circuit faults the generator may rely upon the operation of the network protection followed by anti-islanding protection to trip the generator. If using this method the generator protection will be slower than the network protection however to comply with the automatic access standards the generator must trip within 0.2 seconds following the operation of the network protection.

5.3.3.6 Backup and duplicate protection

At least two independent protection relays must be designed to detect all fault types although each relay is not required to operate on the same principle and indeed different relay types and methods of operation are preferred to prevent common mode failure. This system is sometime called “dual visibility” of faults. If both protection schemes operate in parallel with similar speed of operation the two protection relays shall be termed “X” and “Y”. If one protection device is considered the main protection relay that operates in the fastest possible time it will normally be referred to as the “primary” protection and the second device may be called “backup” protection. Backup protection may trip more than just the faulted zone and may be slower to act.

If the generator primary protection equipment fails to detect or clear a short circuit fault on the distribution network it is necessary for a backup protection scheme to detect and clear the fault. To satisfy the automatic access standards the backup scheme must operate no slower than either: (i) the network backup protection, or (ii) 0.5 seconds longer than the expected operating time of the primary generator installation protection if it had operated.

Example
A connection point circuit breaker may fail to trip for a fault on the network. A suitable solution could be to implement over-current protection on the generator which trips the generator circuit breaker independently from the connection point circuit breaker.

Refer to section 5.3.6 for further information.

5.3.3.7 Modification of existing distribution network protection

The DNSP will undertake a review of the adequacy of the existing distribution network protection to support the connection of an embedded generator in conjunction with the generator protection designer. To ensure compliance with protection standards it may be necessary to do any of the following:

- Review and revise protection settings, particularly distance protection schemes which will measure different fault impedances with the generator in service.
- At the request of the generator protection designer the DNSP may slow down distribution network protection (such as ACR or feeder) so that the generator HV installation protection grades with the network protection. (This will only be considered if the maximum fault clearance time remains acceptable and subject to compliance to DNSP's design standards).
- Replace non directional protection with directional over-current protection to avoid sympathetic tripping for faults not within the protection zone (such as faults on other feeders).
- Install differential line protection, remote inter-trips or blocking schemes all necessary to provide over-current or earth fault protection.

5.3.4 Power quality protection

Generator protection shall be installed to detect abnormal network conditions and to trip the generator once certain limits are exceeded. These abnormalities could be high or low voltage, high or low frequency, or current or voltage unbalance (negative sequence). The abnormality could be the result of a network fault, a generator fault, island condition or other cause. In each case it is necessary to trip the generator to protect other network users, to protect the distribution network, to protect the generator and to protect life.

Duplication of these protection schemes is not necessary. The failure of this type of protection does not result in high or immediate risk. Some of these schemes may be used to protect against islanding however they will always be used in conjunction with other independent techniques which are more reliable at detecting islanding.

5.3.4.1 Under and over voltage protection

Under and over voltage protection can be used to detect abnormalities caused by an array of possible network or generator faults and is required to protect the generation plant, and network plant, and other network users. To protect the generation plant from damage the protection designer must select settings based on the plant ratings. The following requirements only relate to protection of the network plant and to protect other network users in the event a fault within the generator installation causes unacceptable voltage fluctuations on the distribution network, particularly under island conditions.

The automatic access standards require that under steady state conditions the generator shall not increase or reduce the power frequency voltage at the connection point either:

- Outside the range listed in Table 5 (refer to page 48), or
- By more than ±2%, before the action of any voltage regulation equipment on the electricity distribution network.

The automatic access standards require under/over voltage protection to trip the generator within the following times if the voltage at the connection point exceeds the range in Table 5:

- If the voltage is within the range 0% to 5% over the upper limit then the protection must operate within 3 minutes.
- If the voltage is within the range 0% to -5% below the lower limit then the protection must operate within 3 minutes.
- If the voltage is more than +5% above the upper limit then the protection must operate within 2 seconds.
- If the voltage is more than -5% below the lower limit then the protection must operate within 2 seconds.

The 3 minute limits provide time for the voltage to return to an acceptable level before tripping the generator for short voltage excursions. The protection settings may be set tighter if desired to protect equipment and for the purposes of anti-islanding protection. An inverse time characteristic can also be used reducing the tripping time if the voltage is well outside the limits.

If the voltage exceeds the limits above the generator must trip regardless of the cause of the voltage excursion even if tripping the generator makes the voltage excursion on the distribution network larger. Under a negotiated connection agreement or in cases where a generator provides network support a generator may be required to provide local voltage regulation and the above tripping limits could be altered to suit the particular circumstances.

5.3.4.2 Under and over frequency protection

Independent embedded generators are too small to have a measurable influence on network frequency on their own therefore a faulty generator will not cause frequency fluctuations when synchronised with the network. Nonetheless under and over frequency protection may be necessary to protect the generator against frequency variations caused by external events and will be necessary to ensure an islanded condition with uncontrolled frequency is not sustained[63]. Under and over frequency protection cannot be set such that the generator does not comply with NER obligations related to the way large generating plant must respond to network frequency variations.

To comply with the automatic access standards the generator must trip if the frequency moves outside the range 48Hz to 51Hz for more than 2 seconds unless the generator has remote inter-trips with the distribution network protection that prevent islanding. An inverse time characteristic can also be used reducing the tripping time if the frequency is well outside the limits.

Generator must not trip for small frequency perturbations

Network frequency drops when total network load exceeds generator output thus to maintain stability it is desirable to keep generators connected under such conditions. Undesired tripping of generators under high network frequency is less of a problem for stability however it is nonetheless preferable to keep the generator in service and to reduce generator output in response to higher than target frequency.

[63] If the generator is not connected to the network but is used to supply load internal to an installation, for example as a backup generator, then under and over frequency protection may be used to protect the internal load however such requirements are not of interest to the DNSP.

For embedded generators with an aggregate output over 10MW the generator plant must comply with the NER obligations in regards to response to network frequency variations, stability and governing requirements. Refer to section 5.2.3 (page 51) of this report.

For embedded generators with an aggregate output less than 10MW to comply with the automatic access standards it is also necessary that the generator does not trip within the range 49.5Hz to 50.2Hz under steady state conditions. For generators with remote inter tripping that are unlikely to island with the DNSP network it is recommended that this range be extended even wider to provide improved network stability in response to large fluctuations in frequency associated with major contingency events.

5.3.4.3 Negative sequence protection

All three phase generators must detect the loss of a phase from the distribution network and trip all three phases of the connection circuit breaker within 2 seconds. It may be possible to use several techniques to detect the loss of a phase however a simple under voltage protection relay for each phase may be inadequate if the generator keeps the voltage within the normal range on each phase.

It may be necessary to use negative sequence protection for both generator voltage and current. Anti-islanding protection may also be used if it can be demonstrated to reliably detect the loss of a single phase for small generators.

Where multiple single phase generators are combined and effectively operate as a large three phase generator (e.g. photovoltaic embedded generators using multiple single phase inverters balanced across three phases) it is only necessary to trip all three phases for a fault on a single phase generator if it causes unacceptable negative sequence voltage and tripping generators across all three phases will reduce the voltage unbalance.

5.3.5 Anti-islanding protection

Under no circumstance shall an embedded generator be permitted to island any part of the electricity distribution network that supplies third party customers based on the automatic access standards. Islanding[64] refers to the situation whereby the embedded generator remains connected to a section of the electricity distribution network which has been isolated from the normal source of supply e.g. as a result of a network fault condition or during network maintenance work.

Islanding shall be avoided for the following reasons:

- It creates a serious health and safety risk to operational personnel, contractors and the general public.
- Quality of electricity supply to customers connected to the islanded electricity distribution network will be determined solely by the generator’s own control systems and may breach the operating limits imposed on DNSPs by the EDCoP and other standards.
- It could cause severe damage to assets on the electricity distribution network and/or other connected customer’s equipment.

While islanding may have possible benefits by allowing parts of a network to continue operation during network faults it would be necessary to address the issues above and possible other regulatory

[64] Islanding within this context refers to a situation where the embedded generator supplies load while still connected to a part of the distribution network that is not connected and supplied from the main transmission network. Site islanding whereby a generator supplies customer load, the generator is connected to the load side of the energy settlement meter (i.e. is unmetered), and the generator is not electrical connected to the distribution network can be undertaken without consultation with the DNSP.

matters before islanding would be considered. If islanding were considered then it would be under a negotiated connection agreement framework acknowledging the special standards this would require.

Where the generator output is small relative to the local load islanding is unlikely because the generator output will be insufficient to allow sustained islanding. In such cases it is acceptable to use simple low cost techniques such as rate of change of frequency (ROCOF) or vector shift to detect islanding and to trip the generator. Where it is likely that the generator output could sustain the local load anti-islanding must include remote inter-trips from the distribution network protection.

Export limit or reverse power protection is not considered adequate for the purpose of anti-islanding protection for primary protection because the distribution network may not have sufficient load for such protection to operate. Minimum import limit protection avoids the risk associated with insufficient network load however does not address the risk that an embedded generator may islanded together with other embedded generators on the network. Over-load protection is not considered adequate for the purpose of anti-islanding protection either because it is not a reliable method of detecting islanding. While these methods may help to avoid islanding as an additional technique or as a form of backup, they do not diminish the need to use more robust techniques.

As a guide acceptable forms of anti-islanding protection are listed in Table 12.

Type of Generator	Anti-Islanding Protection	
	Connection Voltage	
	Low Voltage (<1000V)	**High Voltage (>1000V)**
Synchronous	If the combined aggregated generator(s) rating is less than 1 MVA, then rate of change of frequency (ROCOF), voltage vector shift, over and under voltage, over and under frequency protection are adequate.	If the combined aggregated generator(s) rating is less than 1 MVA, then ROCOF, voltage vector shift, over and under voltage, over and under frequency protection are adequate.
	If the combined aggregated generator(s) rating is more than 80% of the minimum load on the distribution substation the generator shall either have a dedicated distribution substation or connect at HV under automatic access standards.	If the combined aggregated generator(s) rating is 1 MVA or greater, a dedicated inter-trip scheme between the feeder circuit breaker (and / or ACR) and the embedded generator's controlling circuit breaker is required.
	If the combined aggregated generator(s) rating is 1 MVA or greater, a dedicated inter-trip scheme between the feeder circuit breaker (and / or ACR) and the embedded generator's controlling circuit breaker is required.	
Asynchronous	An induction machine draws reactive energy for excitation from the electricity network and therefore cannot sustain operation and island. It is noted however that asynchronous generators may self-excite from power factor correction capacitors and/or adjacent capacitance within the electricity network. For large generators studies will need to be undertaken to confirm that the output from such a generator will decay rapidly when network connection is lost. Anti-islanding protection in the form of ROCOF, voltage vector shift, over and under voltage, over and under frequency must be installed regardless of the outcome of such studies to ensure the generator trips quickly. If the combined aggregated generator(s) rating is 1 MVA or greater, a dedicated inter-trip scheme between the feeder circuit breaker (and / or ACR) and the embedded generator's controlling circuit breaker is required if the asynchronous generators is capable of self-excitation.	
Static Inverter / IES	Passive and Active anti-islanding protection in accordance with JEN Guideline "Connection Guidelines for Inverter Energy Systems 30 kVA – 200 kVA (ELE GU 0014)". If the combined aggregated generation rating is 1 MVA or greater, the requirement for a dedicated inter-trip scheme between the feeder circuit breaker (and / or ACR) and the embedded generator's controlling circuit breaker will be determined during assessment.	

Table 12: Guidelines for anti-islanding protection

Anti-islanding protection must detect and trip the generator within 0.2 seconds to satisfy the automatic access standards except inverter-connected generators that must be compliant with the latest AS4777 standards where the generator must trip within 2.0 seconds. The protection must function for both three phase and single phase electrical islands. The minimum access standards require the anti-islanding protection to operate at least 0.5 seconds faster than the feeder automatic reclose time and a maximum time of 2.5 seconds.

5.3.6 Backup protection philosophy

The automatic access standards require the protection system to operate satisfactorily to detect and clear faults even when any single non failsafe component of the protection system fails. These faults could be within the generator installation or on the electricity distribution network. To achieve this objective in most cases it will be necessary to install both primary and backup protection schemes that trip independent circuit breakers.

5.3.6.1 Failsafe components

Virtually all single components are not considered failsafe. One exception is a conventional fuse which is always considered to operate and go open circuit under short circuit conditions. But alone even a fuse may not provide adequate protection for a multiphase generator. For a single phase to ground fault on a three phase generator all phases must be isolated and independent fuses on each phase may not satisfy this requirement.

Example Non failsafe components that could fail include circuit breakers, current transformers, voltage transformers, protection relays, cables in a common duct or trench, AC power supply, DC power supply (including a battery) etc.

It may be possible to make a system fail in a controlled way that is considered safe making a protection scheme failsafe even if the individual components are not failsafe.

Example To protect against a DC power supply failure it may be possible to hold open a circuit breaker using a DC solenoid operated from the DC power supply. If the DC power supply fails then the circuit breaker will instantly open and the system fails but remains in a safe state with the circuit breaker open.

Given that most components or systems are not failsafe, it is necessary to install suitable backup protection schemes. The backup device could be an identical duplicated component or it could be a different type of device altogether working on a different principle of operation.

Example Backup for a circuit breaker could be another circuit breaker of the same model (identical duplicated component) because circuit breakers are not considered likely to suffer from common mode failure. For a Rate of Change of Frequency (ROCOF) anti-islanding protection relay backup could be a relay from another manufacturer using Vector Shift (different device with different mode of operation).

Care should be taken to avoid common mode failure where possible.

5.3.6.2 Common mode failure

Certain types of equipment are prone to common mode failure. In other words if two identical pieces of equipment are installed at the same installation and operated in the same way there is a moderate risk that both devices will fail at the same time due to a common fault. This is particularly true for microprocessor based equipment that uses the same software that could contain a programming bug.

Backup protection devices should use equipment from a different manufacturer or use equipment that operates using a different design principle if from the same manufacturer. If equipment is correctly maintained and is not prone to common mode failure, such as circuit breakers or batteries, then duplication of identical equipment will be acceptable.

The automatic connected standards require duplicated protection relays from independent manufacturers or the use of protection relays that operate using a different principle of operation if from the same manufacturer.

5.3.6.3 Protection review required by the embedded generator protection designer

The embedded generator protection system designer shall list every component of the protection system and shall consider the impact failure of any component would have on the operation of the protection system if failure of that component in any way impacts the distribution network. The designer shall ensure that the system will either fail in a failsafe way or backup redundant protection components will operate and provide adequate performance.

5.3.6.4 Monitoring of equipment health

The probability of multiple failures at the same time is low so by duplicating protection components a very reliable protection system can be designed. This concept is only effective if faulty components are detected and repaired rapidly when they fail.

If any duplicated protection component fails then the component shall be repaired within 24 hours or the generator shall be disconnected from the distribution network. Sufficient monitoring of protection and control equipment health is required to meet this requirement. Acceptable methods of achieving this requirement include:

- Remote monitoring of alarms and equipment health back to a central control centre.
- Regular monitoring of local alarms and equipment health by an operator on site.

If remote monitoring is not available and local monitoring is insufficient to detect a fault and repair it or disconnect the generator within 24 hours of the fault occurring then the local alarm shall be configured to automatically shut down or trip the generator so that the system fails in a failsafe way.

Communication links for remote monitoring to control centres must ping the generator site daily to ensure communication links are functional.

Communication links for protection remote tripping or differential protection schemes must also fail in a failsafe way and initiate protection tripping upon failure unless duplicated. If such links are duplicated then the faulty communication link must be repaired within 24 hours otherwise the embedded generator must be disconnected from the network (or again instantaneously trip the generator upon communications failure).

5.3.6.5 Backup protection can use equipment on the electricity distribution network

For a short circuit fault on the main switchboard of a generator (or customer) installation it is acceptable to develop a solution that uses protection on the distribution network as the backup under the automatic access standards. This backup protection on the network could be a fuse, ACR or circuit breaker.

If the backup protection uses the distribution network protection, then it is unacceptable for the primary protection to be out of service for any period of time with the generator in service. Any alarms or monitoring which indicate a possible primary protection fault must immediately trip the generator and preferably automatically.

The distribution network operator permits the network protection equipment to be used as backup for certain faults to reduce generator connection costs however the generator proponent must minimise the risk of initiating distribution network protection tripping which in most cases will interrupt supply to other network users.

5.3.6.6 Examples of common backup schemes

Circuit Breaker fail protection

CB fail protection is a good way of detecting failure of a CB to clear a fault when initiated by a protection relay and can be configured to trip an upstream CB. For example if a 22kV network connection CB (mains incomer CB) fails to operate then the CB fail protection should trip the generator CB and the distribution feeder CB as a backup. If a communication link to the zone substation is not available then it may be acceptable to rely upon the feeder over-current protection however proper protection studies would need to be undertaken to ensure that the zone substation protection would be adequate to detect such generator installation faults.

Anti-islanding ROCOF protection

Where a generator does not have a hard wired remote inter-trip to prevent a generator from islanding with distribution network load ROCOF protection is commonly used to trip the network connection CB (mains incomer CB). Backup protection could be implemented using an independent relay using the vector shift principle that trips the generator CB. If either the protection relay or CB fail to operate a completely independent scheme will operate.

Over current protection

To detect short circuit faults, protection schemes such as inverse time over current, definite time over current or differential protection schemes may be used. If the primary protection relay fails to operate correctly then backup could consist of duplicated 'X' and 'Y' protection relays. These relays can be from different manufacturers or upstream protection that has been graded with the primary protection to act as a backup if the primary protection fails. The secondary backup protection may however rely upon a completely different principle. For example if a short circuit fault causes a large drop in the supply voltage then under voltage protection could be used to detect and clear a short circuit fault. Alternatively distance protection may be used which calculates the impedance of the load on the generator by measuring both current and voltage. Indeed for generators that act as a current source (such as many inverter based generators) over current protection may be ineffective at detecting short circuit faults and load impedance based short circuit detection schemes may be the only effective method of detecting short circuit faults for primary protection.

5.3.7 Recommended protection schemes for each type of generating plant

Table 13 shows the recommended protection schemes for each type of generating plant used to protect the distribution network. It may not include all protection required to protect the generator installation, including transformers, internal switchboards and sub circuits etc. This table should only be treated as a guideline. Many of the protection schemes are not mandated and the table should not be considered as a comprehensive list either.

Type of Generator	Connection Voltage	Suggested Protection Requirements
Static Inverter	Low Voltage	For IES under 200 kVA, protection in accordance with JEN Guideline “Connection Guidelines for Inverter Energy Systems 30 kVA – 200 kVA (ELE GU 0014)”. For IES over 200 kVA, “Connection Guidelines for Inverter Energy Systems 30 kVA – 200 kVA (ELE GU 0014)” will also be used as the primary design reference however compliance with AS4777 standards will not be automatically considered adequate.
Asynchronous / Synchronous	Low Voltage	Under & Over Frequency. Under & Over Voltage. Current negative sequence (loss of phase) for three phase generators. Overcurrent[1]. Sensitive Earth Fault[1]. Anti-Islanding.
Asynchronous / Synchronous	High Voltage 6.6kV, 11kV or 22kV Shared feeder	Under & Over Frequency. Under & Over Voltage. Current negative sequence (loss of phase). Overcurrent[1]. Earthfault[2]. Definite Time Sensitive Earthfault[2]. Neutral Displacement[3]. Anti-Islanding. Remote inter-trips depending upon size.
Synchronous	High Voltage 6.6kV, 11kV or 22kV dedicated feeder	Under & Over Frequency. Under & Over Voltage. Current negative sequence (loss of phase). Overcurrent[1]. Earthfault[2]. Definite Time Sensitive Earthfault[2]. Neutral Displacement[3]. Anti-Islanding. Remote inter-trips. Additional protection on the high voltage feeder may be required e.g. line current differential (unit) protection.
Synchronous	Sub transmission 66kV	Under & Over Frequency. Under & Over Voltage. Current negative sequence (loss of phase). Overcurrent[1]. Earthfault[2]. Definite Time Sensitive Earthfault[2]. Neutral Displacement[3]. Pole Slipping. Reverse power flow. Line current differential (unit) protection. Remote inter-trips.
All generators.	All	Where DNSP imposes an export limit at the point of connection, reverse power protection shall be implemented.

Table 13: Recommended protection schemes

Notes:

1. To detect phase faults on the electricity distribution network and within the generator installation (directional control may be required).
2. To detect earth faults within the generator installation.
3. To detect earth faults on the electricity distribution network.

Where studies reveal that a generator may have an adverse impact on the distribution network under abnormal or fault conditions additional protection will be recommended. For example if exceeding an active or reactive power export or import limit under certain conditions creates a problem on the network (such as exceeding plant thermal ratings or causing excessive voltage fluctuations) then protection may be required to limit the import or export and to trip the generator if normal control systems fail. Detection of such abnormalities may also forewarn of pending generator instability.

The generator access standards provide functional performance requirements that are generally non prescriptive regarding the type of protection devices to be used however Table 13 may assist some generator protection designers.

5.3.8 Generator connection or synchronisation and disconnection

5.3.8.1 Synchronous generators

Synchronous generators shall be synchronised to the distribution network supply using automatic synchronisation controllers to remove the risk of human error inadvertently closing a generator circuit breaker when the generator is not correctly synchronised with the distribution network supply.

Synchronisation check relays are required to meet the automatic access standards to block an operator from closing the generator circuit breaker if the generator is unsynchronised. The synchronisation check relay can be designed based on measuring the voltage across the open contacts of the generator circuit breaker or other suitable methods as proposed by the designer.

The voltage and phase angle difference between the generator output and the distribution network supply must be sufficiently low such that synchronisation of the generator does not cause a voltage disturbance that is noticeable by other network users. For large generators modelling will be necessary to calculate this impact and the phase angle and voltage limits will be set accordingly. For large machines with low impedance the disturbance will be greater and lower limits may apply. As a guide for generators connected at HV synchronisation error should be less than 10 electrical degrees before closing the generator circuit breaker. For generators connected at LV synchronisation error should be less than 15 electrical degrees before closing the generator circuit breaker.

Manual synchronisation may be permitted under negotiated standards however this will normally only be accepted in unusual situations such as testing laboratories where generators are tested under controlled conditions and will not be permitted for permanent installations.

Before disconnecting a synchronous generator under normal controlled conditions (not fault conditions) the real and reactive power must be gradually ramped down to below 10% of the generator rating before opening the generator circuit breaker to minimise any risk of network disturbance to comply with the automatic access standards. Reverse power flow is permitted before disconnecting a generator however again the power flow into the generator should be under 10% of the generator rating. For small LV connected generators this requirement may be relaxed under negotiated standards if it can be demonstrated that the generator is too small to have any material impact on supply voltage that could affect other network users. Test results at commissioning can be used to demonstrate such compliance.

5.3.8.2 Asynchronous generators

Mains excited generators

The generator start up method shall be determined after due consideration of the impact on network voltage disturbance (refer to 5.2.2 on page 49 of this report).

To minimise any network disturbance it is recommended that mains excited asynchronous generators should be driven up close to synchronous speed before closing the generator circuit breaker. This will also minimise short term over current on the generator stator and rotor windings. As a guide a speed within ±10% of the synchronous speed is recommended (depending on the size of the generator) before closing the generator circuit breaker (and an electric motor may be necessary to do this). For some designs it may be possible to use the generator to motor up to synchronous speed, particularly for small LV machines and the impact on the network will be similar to starting of an induction motor however even in these circumstances consideration to star-delta starters and soft starters is recommended. Again the starting method used will be heavily dependent upon the size of the voltage disturbance created during generator start up.

Self-excited generators

For self-excited asynchronous generators it may be possible to regulate frequency and voltage by dynamically controlling shaft speed and reactive load. It may be necessary to connect a charged capacitor to provide initial flux to get the generator started. If the frequency and voltage can be sufficiently well controlled then these generators can be synchronised like a synchronous generator. Alternatively they can be started similar to a mains excited generator. The starting method to be used can be freely determined by the designer as long as the method selected does not cause a voltage disturbance which exceeds the limits in section 5.2.2 on page 49 of this report.

5.3.8.3 Inverter generators

Inverter based generators naturally synchronise if mains commutated. Self-commutated or high speed switching designs must use suitable control techniques to synchronise and will typically need to generate an internal reference sinusoidal waveform that will need to be shifted in frequency, phase and voltage to match the network supply. Inverter based generators will typically connect using power electronic switching devices rather than circuit breakers. The circuit breakers may only be used for protection. Inverter based generators offer excellent control and power should be gradually ramped up during connection and ramped down during disconnection. When used with variable energy sources such as solar or wind the output from these generators could vary continually.

5.3.8.4 Disconnection based on reverse power flow

For both synchronous and asynchronous generators a loss of driving power from the prime mover (such as mechanical fault, loss of fuel, loss of wind etc.) may result in the generator attempting to hold synchronous speed by shifting to motoring operation. Simple measurement of reverse power flow is generally sufficient to detect this condition and trip the unit if necessary.

It may even be possible to use this technique to disconnect a generator under controlled conditions. Reducing prime mover power to zero avoids the risk of prime mover over-speed and the reverse power detection can be used to disconnect the generator smoothly as the output power passes through zero.

5.3.9 Automatic reclose

With the exception of fuses, most parts of the distribution network protection include automatic reclose by closing the feeder circuit breaker or line recloser after a pre-defined time delay (typically 3 to 8 seconds). This is intended to restore supply following transient network faults as quickly as practicable. The reclosing of feeders is an important facet of distribution network operation in achieving the target availability levels set by the regulator. Multi shot reclose may also be used in some cases.

Whenever network supply is lost the generator must disconnect as quickly as possible to avoid islanding and shall not reclose (i.e. a generator shall not attempt to reconnect to the distribution network if the voltage on the network is not within the normal operating range under any circumstances). If the embedded generator is permitted to reconnect following supply restoration or a successful reclose then it can only reconnect or synchronise back with the network once the network connection is restored for a minimum of 1 minute. This allows time for multiple recloses and ensures that the reclose was successful and has stabilised before attempting to reconnect the generator.[65] If the network voltage is outside the normal operating range following a network fault it is also recommended that the generator not connect until the voltage returns to normal which may take longer than 1 minute.

If a generator does not disconnect prior to the distribution network feeder reclose or recloses itself before the feeder reclose the generator would be suddenly connected to the network unsynchronised and generator damage would be likely.

Under some conditions a generator will not be permitted to reconnect following supply restoration such as automatic reclose. If a generator has remote inter-trips it may not be possible for the generator to reconnect unless the generator is supplied from the circuit with the special protection inter-trip. In some cases the reclose could transfer supply to another network feeder that does not have the necessary remote protection inter-trips. The automatic access standards will include remote blocking to prevent the generator reconnecting in these circumstances even though the supply voltage has returned to normal.

The responsibility for the correct operation of the connection CB and the provision of any reclose interlock signals remains with the generator. The connection agreement will require the generator to indemnify the DNSP against any damage or injury that might arise as a consequence of a legitimate reclose carried out in a manner consistent with the provisions of the connection agreement.

5.3.10 DNSP generator monitoring and control

5.3.10.1 DNSP local generator monitoring and controls

All local generator monitoring and controls shall be the full responsibility of the embedded generator operator and the DNSP shall monitor alarms or operate controls remotely.

The DNSP will install some form of embedded generator isolation on the distribution network to be able to disconnect the generator during maintenance or faults. This device could be a fuse, switch, ACR or CB and will be owned and operated by the DNSP. It may be controlled locally or remotely. The generator operator will not have authority to control this device.

[65] In some circumstances where an embedded generator is also used as a backup generator in the event of a network supply outage some sensitive customers may decide to wait for longer than 1 minute before re-synchronising their generator with the distribution network supply. This is because immediately following a momentary network outage there is a significantly higher risk that another outage will follow unless the source of the fault has been completely removed and no secondary damage to the network assets has occurred. The customer load can be supplied by the generator with minimal impact on the customer's operations.

5.3.10.2 DNSP remote monitoring

All generators require remote monitoring with the communication connection type needing to be defined and evaluated.

For each authorised communication type and specific requirements refer to:

- Embedded Generation Emergency Backstop Requirements
- JEN ELE-999-GL-EL-007 Jemena Embedded Generation Backstop Guideline

For generators connected at sub transmission (66kV), or above 1MVA, or with remote inter-trip protection schemes must have the following remote monitoring back to the DNSP control centre to satisfy the automatic access standards:

- Generator and Mains Incomer circuit breaker status.
- Analogue measurement of generator real power output (kW or MW). Measurement accuracy must be within ±2%.
- Analogue measurement of generator reactive power output (kVAr or MVAr). Measurement accuracy must be within ±2%.
- Analogue measurement of current on each of the three phases (A). Measurement must be true RMS with an accuracy of ±1%.

In some circumstances measurement of other parameters may also be necessary such as voltage or power quality parameters such as harmonics, flicker and dips and swells. These additional requirements may only be necessary where there is some doubt if the automatic access standards for power quality can be satisfied, or if they will not be satisfied (i.e. a negotiated access standard), and regular monitoring is therefore necessary.

5.3.10.3 DNSP remote controls

All generators require remote control with the communication connection type needing to be defined and evaluated.

For each authorised communication type and specific requirements refer to:

- Embedded Generation Emergency Backstop Requirements
- JEN ELE-999-GL-EL-007 Jemena Embedded Generation Backstop Guideline

Depending on the connection type the DNSP may remotely control generator assets, some of the commands may include setting export/import limits, tripping/restoring systems, etc. The risk associated with multiple operators controlling the same plant which could result in operator error is evaluated and implemented differently depending on the communication type and configuration.

Embedded generator with inter-tripping protection

Where an embedded generator receives a remote inter-trip protection signal from the distribution network it will be possible for a DNSP operator to remotely trip a generator from the distribution network. Refer to section 7.2.1.1 on page 118 of this report for further information on operational aspects.

A signal from the distribution network to remotely trip a generator can trip either the connection point circuit breaker (to disconnect the whole installation from the distribution network) or just the generator circuit breaker or some other circuit breaker that disconnects the generator from the distribution network. This decision will depend upon the generator proponent preference. It is noted that if the generator circuit breaker is tripped then it may not be possible to supply the local on-site load from the generator while network is abnormal. On the other hand, if the connection point circuit breaker is tripped it may not be possible to supply the local onsite load from the network if the network supply comes from an alternative feeder. Various options are possible to obtain the desired operational requirement.

5.3.11 DNSP preferred communication methods and protocols

Communications links may be required for protection (such as remote trips or differential protection) or for SCADA[66] monitoring and control. The preferred communications medium is point to point single mode fibre optic cable for all protection, control and remote monitoring. Where existing infrastructure using copper communications cables is available this can also be utilised however copper cables shall not be used where new communication links are to be installed.

Reliability and security of communication

Communications links used for protection must be reliable and have high availability (i.e. a low failure rate). Reliable services include dedicated fibre optic cable, dedicated copper line, or leased service from a licensed communications carrier. Even a reliable communications link may not be considered secure if it can fail during a single contingency. Therefore, any protection reliant upon a single non secure communications link must continuously monitor the integrity of the communications and trip the embedded generator in the event of a communications failure. If reliable independent duplicated communication links are used then the generator can continue operation for up to 24 hours following loss of one of the communication links.

SCADA remote monitoring does not require redundancy to comply with the automatic access standards, however reliable communication links are required. Licensed or unlicensed radio, microwave link, internet based communications or other methods may be considered however it will need to be demonstrated that the method used is reliable.

For specific embedded generation backstop requirements regarding reliable and secure communication methods, refer to JEN ELE-999-GL-EL-007 Jemena Embedded Generation Backstop Guideline.

Communications protocol

The communication protocol for remote monitoring shall be in a suitable format to allow integration into the prevailing SCADA communication protocol (currently DNP3.0 or IEEE 2030.5).

Protection communication protocols will use the native protocol of the matching protection relays or IEDs at either end where available. Status and control circuits may also be provided using suitable hard-wired contacts via an interface terminal strip to be converted to a digital form for communication transmission by the DNSP. In this case the DNSP may own communications infrastructure at the generator installation site.

5.4 Revenue metering requirements

The metering standards that apply for load connections to the DNSP network also apply for generators connected to the DNSP network however active power can be bidirectional and this requires metering that can accurately measure energy flow in both directions. The energy that flows in each direction must be stored in separate registers. The actual metering required will also depend upon the network and retail tariff selected by the Generator or if the Generator is registered with the AEMO then the energy shall be directly settled on the market and AEMO metering requirements prevail.

[66] For small generators of up to 200kVA, CSIP-AUS over public internet is used for monitoring and control.

5.4.1 Metering options

There are many possible ways of metering the energy produced by an embedded generator and it is beyond the scope of this document to list them all and to advise under what circumstances certain metering arrangements will be permitted. In special cases it will be necessary to consult with the DNSP and the AEMO. The following list of metering types may provide some guidance.

5.4.1.1 Bidirectional metering

In general embedded generation metering requires an electronic meter with separate import and export registers (bidirectional metering) that will accept periods of reverse power flow, i.e. when power is flowing into the network from a customer's premise. Bidirectional metering may not be required in special circumstances where reverse power flow is not possible as described below, however this will require the approval of the DNSP under negotiated access standards.

Where an embedded generator is not capable of exporting energy to the distribution network it may not be necessary to install bi-directional energy metering. All other obligations remain. To ensure the generator cannot export energy to the distribution network it is necessary to either:

- install reverse power flow protection that will trip the generator (or disconnect the whole installation from the distribution network) when energy follows in the reverse direction (from a customer installation into the distribution network), or
- demonstrate that the minimum load within an installation will always exceed the maximum generator output by a significant safety margin.

In both cases it is necessary to obtain the approval of the DNSP to avoid the need to install bi-directional energy metering.

5.4.1.2 Net and gross metering

Two forms of bidirectional metering are possible, Net or Gross, however depending upon electricity tariffs offered by the DNSP and Retailer only one form of metering may be offered. Where a Generator is registered with AEMO the output of the generator must be measured independently of any load.

Net metering

These meters contain at least two registers, with one register used to record energy flow into the installation, and one register used to record energy flow out of an installation. Net metering will not record the energy consumed within an installation that was simultaneously produced by the embedded generator within the installation. Likewise net metering will not record the energy produced by the embedded generator within an installation that was simultaneously consumed by the load within the installation.

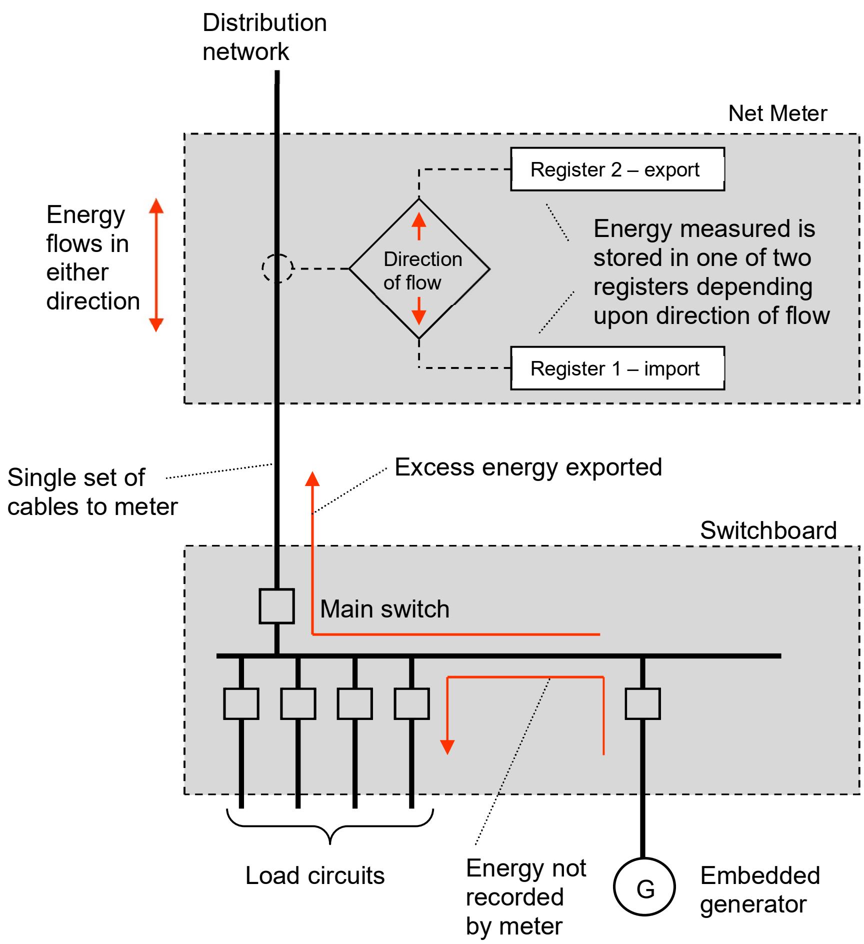


Figure 13: Example of a net metering configuration

Gross metering

These meters contain at least two registers with one register used to record energy consumed by the load within the installation and one register used to record the energy produced by the embedded generator within the installation. Gross metering will record the energy consumed within an installation that was simultaneously produced by the embedded generator within the installation. Likewise gross metering will record the energy produced by the embedded generator within an installation that was simultaneously consumed by the load within the installation.

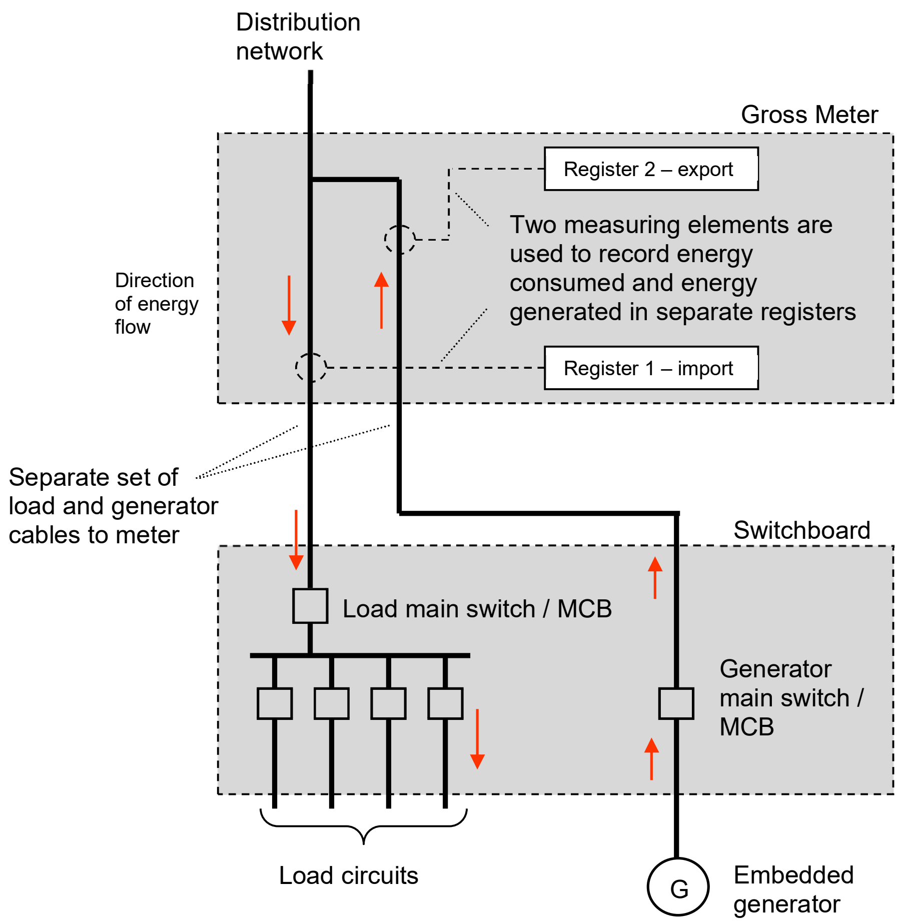


Figure 14: Example of a gross metering configuration

Single register accumulation meters, such as induction meters with rotating disc, that 'turn backwards' when exporting energy to the distribution network are not permitted.

5.4.1.3 Embedded network metering

In some circumstances an embedded generator may connect to an embedded network. An embedded network is essentially a privately owned micro distribution network that is supplied from a distribution network on a single title of land. Individual customers within the embedded network receive a reticulated supply from the owner of the embedded network. Examples include shopping centres, retirement villages and commercial business parks. The revenue energy meters at the interface between the distribution network and the embedded network are deemed "parent meters" and the meters at the interface between the individual customers and the embedded network are deemed "child meters". If an embedded generator connects to the embedded network, it will require a child meter. The DNSP shall issue an NMI for both parent and child meters when requested but is not responsible for registering the embedded network itself.

When an embedded generator is connected to an embedded network the parent meter must be a bidirectional net meter. DNSP tariffs will be applied based on the energy flow through the parent meter.

The DNSP has no direct relationship with the load customers or embedded generators connected to the embedded network. The DNSP shall form a connection agreement with the embedded network owner and this agreement shall include standards that apply for any embedded generation connected within the embedded network.

5.4.2 General metering principles

The provision of revenue metering including current and voltage transformers shall be the responsibility of the generator proponent or nominated meter provider and shall conform to the following requirements:

(i) Metering shall be a four quadrant interval type, capable of measuring net Wh and VArh for both import and export energy flows. Each interval shall be at least 30 minutes although shorter periods such as a 15 minute interval[67] may be required to align with the market trading interval period for generators registered with AEMO in accordance with AEMO market settlement requirements.

(ii) The metering shall be installed and maintained according to the requirements of the applicable electricity law.

(iii) The meter shall be compliant with AEMO regulations.

(iv) The metering panel shall be compliant with the SIR.

(v) The energy level shall be based on the generator output.

(vi) An AEMO registered Meter Provider and Meter Data Agent shall be engaged to provide metering and metering data collection and processing.

(vii) The Responsible Person shall supply interval data from the metering installation, to the DNSP. If check metering is installed, the DNSP will have the right to access the check metering data.

(viii) The metering shall be error corrected by the generator proponent to the satisfaction of the DNSP to ensure accurate recording of energy flows at levels expected to be exported or imported. This is of particular importance where the level of energy consumed by the generation site is significantly less than the design generation export.

5.4.3 Metering standards

Metering provisions

Metering provisions are to be consistent with the requirements of[68]:

- The National Electricity Rules, particularly chapter 7.
- Metrology Procedure: Part A – National Electricity Market.[69]
- Metrology Procedure: Part B – Metering Data Validation, Substitution and Estimation Procedure for Metering Types 1 – 7.
- Electricity Customer Metering Code that applies to all residential customers and all small business customers that consume less than 40MWh per annum in Victoria.

A registered participant may accept responsibility as the Responsible Person or may engage the DNSP for that responsibility.

A Responsible person is required to:

- Engage a registered metering provider.
- Ensure a metering installation is provided, installed and maintained.

[67] Ref. NER clause 7.9.3 and 9.9.9.
[68] Ref. SIR clause 9.13
[69] As of the 1/1/2007 the AEMO national metrology procedures superseded the Victorian Electricity Supply Industry Metrology Procedures that previously applied in Victoria.

- Ensure the components, accuracy and testing complies with the relevant procedures for the type of installation.
- Ensures security of the metering installation.
- Ensures that the type of installation remains appropriate for the level and direction of energy transfer.
- Provides and maintains the telecommunications links and access thereto, including a modem and isolation facilities as required by telecommunications regulations.
- Apply for the NMI for the facility.
- Permit access at any time for the metering provider.
- Ensure compliance with the ESCODE and Electricity Customer Metering Code.

The selected metering type is to reflect the level of annual energy transfer and other required features. The accuracy requirements for an installation are to be provided in accordance with the NER. For generating units >1MVA facilities generally require enhanced accuracy provisions. The revenue metering point is to be as close as possible to the connection point with no "loss" between.

Use of data or signals from the metering installation may be negotiated with the DNSP. In general, metering CT and VT are to be used solely for metering and not for customer protection or load monitoring. If the generator seeks to monitor energy use and control energy management equipment, energy and time impulses are generally available as an output from the metering equipment by agreement with the meter provider.

Summary of standards

The following list of standards are provided as a guide but must not be treated as the primary source. Please refer to the applicable metering codes listed above.

The metering system is expected to include the following:

- VTs and CTs, unless a small LV generator is connected in which case direct metering shall be used.
- Secure and protected signal input wiring.
- An appropriate panel provision either stand alone or potentially integral to other equipment.
- Metering and data logger features.
- A communications interface.
- A telecommunications link such as telephone service, radio transmitter or other data link service.
- Auxiliary power supply.
- Alarm circuit.
- Security enclosure.
- Test links and fusing.
- Summation equipment as required.

The metering equipment is required to conform to the following:

- Metering shall be a four quadrant interval type, capable of measuring nett Wh and VArh independently for import and export energy flows. Generators registered with AEMO will be required to record energy flows in each 15 minute trading interval. All other generators shall record energy flows over 30 minute intervals.

- The meter range is to be approved by DNSP shall be capable of achieving the required accuracy in accordance with the NER, based on the expected range of import/export. Particular consideration will be directed to achievement of accuracy if there is disparity in the expected levels of import and export.
- The facility is to be capable of recording both active and reactive interval energy data as required under the contract agreements.

The nominated Responsible Party is required to supply interval data from the metering installation to the DNSP. If check metering is installed the DNSP retains the right of access to the check metering data.

The metering data is to be error corrected by the generator to the satisfaction of DNSP, to ensure accurate recording of energy flows throughout the metering period.

Accommodation requirements for metering facilities include:

- Paved, level, access space of at least 1.0m depth in front of the metering enclosure.
- Free access routes to authorised personnel.
- Not being subject to industrial contamination, extreme temperatures or vandalism.
- By agreement metering transformers may be installed within HV switchgear providing that:
  - Transformers must be supplied by the Meter Provider.
  - Transformers must be located in a dedicated HV compartment maintained under Meter Providers seal.
  - Have clear polarity identification and access to secondary terminals.
  - Have secondary circuit fusing and wiring in accordance with the SIR.

Performance requirements of the metering transformers are to comply with Table 9.1 of SIR and specifically[70]:

- VTs – 110V secondary, class 0.5M, 50VA, impulse withstand 1.5/30s.
- CTs – 5A secondary, class 0.5M, 15VA, rated burden 0.6 ohm, short time rating 2 seconds.
- Metering test facilities are to provide for burden testing of the CTs.

Meter mounting facilities are to be provided in a metering panel or enclosure that complies with the following[71]:

- Relevant Australian or IEC standards.
- Ambient conditions between -5 and 45 deg C and a daily average of 35 deg C.
- Internal ambient exceeding external ambient by 15 deg C.
- Atmospheric conditions as per AS 2005 Part 10 (Clause 3.5).
- Meter panel size, fixing and wiring as specified in the SIR and other metering codes.
- Location and level of protection against physical damage as specified with particular note of the prohibition of location behind closed and locked doors and gates.

[70] Ref. SIR clause 9.13.3.

[71] Ref. SIR clause 8.4, 8.5 & 8.6.

5.5 Summary of embedded generator automatic and minimum access standards

Tabled below is a summary of the automatic access standards covered in detail in sections 5.1 to 5.4 together with the minimum access standards. All embedded generator proponents are encouraged to comply with the automatic access standards however in certain circumstances a lower standard may be negotiated. Under no circumstances will a standard less than the minimum access standard be permitted.

5.5.1 Primary plant standards

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Generating plant Compliance with standards.	Table 1 (Page 40)	All generators.	Compliance with all relevant Australian or recognised equivalent international standards.	Compliance with all relevant Australian or recognised equivalent international standard for all critical primary plant. Non critical plant may be negotiated on a case by case basis.
Service protection device.	5.1.1 (Page 40)	LV generator.	Fuse or CB between the point of supply and the revenue meter.	
		HV generator.	CB on the customer or generator side of the revenue meter.	
Generator isolation.	5.1.1 (Page 40)	All generators.	Isolation device to be installed by the Generator to enable the DNSP to insert a padlock to lock the generator isolator in the open position.	
Fault clearance times for solid short circuit fault.	5.1.6 (Page 43)	LV generator.	150ms	
		HV generator.	150ms	
Plant short circuit specifications.	5.1.6 (Page 43)	All generators.	All plant must comply with Table 3 (page 44) as a minimum however in special circumstances higher ratings may be deemed necessary by the DNSP.	All plant short circuit specifications must exceed all existing and forecast ultimate fault levels within the Generator installation.
Insulation co-ordination.	5.1.7 (Page 45)	All generators.	All plant must comply with Table 4 (page 45).	As determined adequate following analysis using an electromagnetic transient software package after evaluating the performance of suitable surge protection devices.

Compliance requirement	**Reference**	**Generator Classification**	**Automatic Access Standard**	**Minimum Access Standard**
Earthing	5.1.9 (Page 45)	All generators.	Earthing system to provide adequate earthing to limit step and touch potentials to an acceptable level independent from the DNSP network earthing system.	Earthing system to provide adequate earthing to limit step and touch potentials to an acceptable level.
Network signalling	5.2.11 (Page 66)	All generators	The generator and the associated equipment should be immune to the presence of ripple control, medium frequency PLC and radio frequency PLC systems in the network that are used for DNSP's communication purposes.	

5.5.2 Embedded generator performance standards

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Power frequency steady state voltage operating range.	5.2.1 (Page 48)	All generators.	All generating plant must be capable of continuous operation over the range provided in Table 5 on page 48 of this document.	All generating plant must be capable of continuous operation over the expected voltage range at the network connection point. If the generating plant cannot operate over the full range in Table 5 (page 48) then suitable protection must be provided that shall trip the generator to prevent generator damage.
Transient voltage fluctuation.	5.2.2 (Page 49)	LV generators.	Generating plant shall comply with the relative steady state voltage change, maximum relative voltage change, short term flicker limit and long term flicker limit determined in accordance with AS61000.3.5:1998.	
		HV generators.	Generating plant shall comply with the relative steady state voltage change, maximum relative voltage change, short term flicker limit and long term flicker limit determined in accordance with AS61000.3.7:2001.	
Transient frequency disturbance.	5.2.3.2 (Page 51)	All generators.	All generators must be able to operate over the frequency range illustrated in Figure 8 and Figure 9 on page 53 of this document.	Compliance with NER clause S5.2.5.3(c).
Rate of change of frequency.	5.2.3.2 (Page 51)	Generators over 30MW or with remote inter trip.	Generating plant shall not trip if the rate of change of frequency is less than ±4Hz/s for less than 0.25 seconds.	Generating plant shall not trip if the rate of change of frequency is less than ±1Hz/s for less than 1.0 seconds.
		Generators <30MW using ROCOF protection to detect islanding.	Generator shall not trip due to rate of change of frequency commonly experienced on the network on a monthly basis to minimise nuisance tripping to an acceptable level.	To be negotiated with the DNSP.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Generator stability	5.2.4 (Page 54)	Generators <5MW	All generating plant must generally remain stable becoming unstable less than once per month and must trip from the network at the onset of instability. Stability studies are not mandated.	All generating plant must generally remain stable and must trip from the network at the onset of instability. Power quality standards cannot be compromised when the generator becomes unstable.
		Generators >=5MW and <30MW	Stability studies required. Synchronous generators >10MW to be treated as though >30MW. Generator to be stable for all upstream 66kV network faults cleared by differential protection and all credible transmission network disturbances. The generator shall remain stable for all disturbances of magnitude and duration illustrated in Figure 10.	Stability studies required however the ability of the generator to remain synchronised for each disturbance scenario is to be negotiated with the DNSP.
		Generators >30MW	Strict compliance with the NER. Refer to section 5.2.4 of this report on page 54 of this document.	
Generator governor control.	5.2.5 (Page 57)	All generators.	All generators require a governor control system to provide stable and controlled power output.	
Response to disturbances following a contingency event.	5.2.5.1 (Page 58)	All generators.	Following a short circuit fault active power output to remain at a minimum of 95% of pre-fault power output.	Following a network contingency event, the generator must provide sufficient active and reactive power to maintain the connection point voltage over the range provided in Table 5 on page 48 of this document provided that the fault would not cause the generator being isolated from the rest of the system or tripped off.
Active power control.	5.2.5.1 (Page 58)	Generators <30MW.	The rate of change of active power shall be controlled below 50kW/second.	The maximum rate of change of active power shall be negotiated with the DNSP.
		Generators >=30MW.	Compliance with NER clause S5.2.5.5 with standards that vary between scheduled, semi-scheduled and non-scheduled generators.	Compliance with NER clause S5.2.5.5 with standards that vary between scheduled, semi-scheduled and non-scheduled generators.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Frequency response.	5.2.5.3 (Page 59)	All generators.	Active power output must not increase in response to increasing frequency and decrease in response to decreasing frequency.	
		Generators >1MW.	Must have a governor system that is responsive to system frequency and increases power output as frequency drops and reduces power output as frequency increases.	To be negotiated with the DNSP depending upon the generator technology and practical capabilities.
Steady state reactive power capability.	5.2.6.1 (Page 60)	Generators eligible to be exempt from registration with AEMO.	Provide sufficient reactive power to regulate power factor in accordance with Table 7 on page 60 of this document. In special circumstances additional capability may be required to regulate voltage at the connection point.	No capability required.
		Generators not eligible to be exempt from registration with AEMO <30MW.	Minimum of the product of 0.395 and the rated active power capability of the generator.	Maintain the operating power factor of unity at the connection point.
Generator excitation control system.	5.2.6.2 (Page 61)	Generators eligible to be exempt from registration with AEMO and <=10MW if synchronous or <=30MW if not synchronous.	Synchronous generators over 1MW must have an automatic excitation control system. The excitation control system shall either regulate generator power factor within designated limits or respond as a function of load on a specific part of the distribution network as advised by the DNSP.	Must implement systems as required to comply with power factor, voltage disturbance and stability standards.
		Synchronous Generators eligible to be exempt from registration with AEMO >10MW.	As above but must also comply with NER requirements for generators above 30MW in regards to response to disturbances, safe shutdown without external electricity supply, restart following loss of electricity supply and voltage stability.	To be negotiated with the DNSP however standards will be based upon the NER.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
		Generators not eligible to be exempt from registration with AEMO >=30MW.	*Too detailed to list here. Please refer to section 5.2.6.2 on page 61 of this document.* *Compliance with the NER clauses S5.2.5.5 and S5.2.5.13*	To be negotiated with the DNSP however standards will be based upon the NER.
Harmonic tolerance.	5.2.7 (Page 64)	All generators.	Generators shall be designed to operate in the presence of harmonic voltage distortion up to the limits in Table 9 on page 64 of this document.	To be negotiated with the DNSP however if a lower capability is accepted the Generator may be required to fund works to reduce voltage harmonic distortion levels on the distribution network.
Harmonic injection limits.	5.2.8 (Page 64)	Generators eligible to be exempt from registration with AEMO <30MW.	Source of harmonic current produced by an embedded generator must be less than listed in Table 10 on page 65 of the document.	
		Generators not eligible to be exempt from registration with AEMO >=30MW.	In addition to above, compliance with emission limits calculated in accordance with AS/NZS610003.6:2001.	
Negative sequence injection limits.	5.2.9 (Page 65)	Generators < 10MW.	Compliance with Table 11 on page 66 of this document.	Demonstration that the generator will not cause the DNSP to exceed the EDCoP negative sequence voltage limits on any part of the network. Injection limits can for example exceed those listed in Table 11 on page 66 if this lowers negative sequence voltage on the DNSP network.
		Generators ≥ 10MW	Compliance with the NER clause S5.2.5.6	
Zero sequence injection limits.	5.2.9 (Page 65)	LV generator.	Maximum size of single phase generator is 10kVA. For three phase generators zero sequence current must be less than 5% of positive sequence.	To be negotiated with the DNSP. In regions where three phase power is unavailable, larger single phase generators will be considered.
		HV generator.	Zero sequence current shall be zero under all conditions.	To be negotiated with the DNSP.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Inductive interference	5.2.10 (page 66)	All generators	The generator or the generating system must not cause inductive interference above the limits specified in AS/NZ 2344-1997	
Network signalling	5.2.11 (Page 66)	All generators	The generator or the generating system must not interfere or impair the DNSP's ability to use the network for communication purposes to monitor, operate and control of the network.	
Impact on network capability	5.2.12 (Page 66)	All generators	The generator or the generating system must not reduce any inter-regional or intra-regional power transfer capabilities that exist prior connecting the generator or the generating system.	The generator of the generating system must not impair the DNSP's ability to supply the customer load and must not reduce the power transfer capabilities into the region by more than the combined sent out generation.
Fault current contribution	5.2.13 (Page 67)	All generators	The DNSP will specify the maximum allowable fault contribution from the generator based on the fault level limits given in Table 2 of this report and the fault ratings of the existing equipment installed in the DNSP's network.	Fault current levels on the DNSP's network shall not be permitted to exceed the limits given in Table 2 of this report as a result of the connection of the generator. Work may be required to reduce fault level contribution from the distribution network to achieve this requirement.

5.5.3 Protection, control, monitoring and communications requirements

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Internal short circuit faults.	5.3.2 (Page 67)	All generators.	All short circuit faults within the installation must be disconnected from the distribution network as quickly as practically possible.	
Protection grading of internal faults.	5.3.2.2 (Page 68)	LV generator protected by a service fuse.	No grading study required.	
		LV generator protected by CB or HV fuse.	Grading study showing at least 0.25 second margin.	Grading study required and must take reasonable attempt to grade with upstream protection however non coordination at high fault currents may be permitted if approved by the DNSP.
		HV generator.	Grading study showing at least 0.4 second.	Grading study required and must take reasonable attempt to grade with upstream protection however non coordination at high fault currents may be permitted if approved by the DNSP.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Internal high impedance phase to ground faults.	5.3.2.3 (Page 69)	LV generator.	No special requirements or need for sensitive earth fault protection but installation must comply with relevant Australian Standards including AS/NZS3000.	
		HV generator.	Must be able to detect and disconnect all high impedance faults with sensitivity that is as good as or better than the existing distribution network protection and have adequate grading. If the distribution network protection sensitivity is improved in future then the generator protection shall also be capable of improving sensitivity using a setting change only. In practice SEF protection that can be set down to 4A shall be adequate. Generator protection is not expected to be capable of operating if the zone substation uses resonant earthing (GFN).	Must be able to detect and disconnect all high impedance faults with sensitivity that is as good as the existing distribution network protection. (Except in the case of GFN earthing at the zone substation).
Protection operating speed for internal short circuit faults.	5.3.2.4 (Page 70)	All generators.	All protection must operate with sufficient speed to grade adequately for all possible short circuit levels with the distribution network protection with the margin listed above.	All protection must operate with sufficient speed to grade adequately for the most probable short circuit levels with the distribution network protection with the margin listed above. In some situations where the distribution network protection uses high speed fuses adequate grading may not be necessary for all fault currents and therefore slower generator protection may be accepted.

Compliance requirement	**Reference**	**Generator Classification**	**Automatic Access Standard**	**Minimum Access Standard**
Backup protection for internal generator installation faults.	5.3.2.5 (Page 71)	All generators.	Backup protection shall be implemented to operate in the event that the primary protection fails to detect or clear a fault. Fault types covered include short circuit faults and anti-islanding protection. Power quality type protection does not require backup. Backup protection principles apply to both primary plant and secondary control systems. For short circuit faults on the main switchboard distribution network protection can be used as backup. Fail safe devices such as fuses do not require backup.	A risk assessment is required to justify not installing backup protection systems to detect and clear internal generator installation faults. Reduced levels of redundancy or backup will only be permitted by the DNSP if the generator only synchronises with the distribution network for short periods of time and the risk assessment shows that the cost of additional protection schemes is not economic.
External short circuit faults (on the distribution network).	5.3.3 (Page 71)	All generators.	For all short circuit faults within the declared protection zone the generator protection must detect the fault and disconnect the generator from the distribution network as quickly as practically possible and no slower than the distribution network protection.	For all short circuit faults within the declared protection zone the generator protection must detect the fault and disconnect the generator from the distribution network as quickly as practically possible.
Protection grading of external faults (on the distribution network).	5.3.3.3 (Page 74)	All generators.	Coordinates with the DNSP protection for all fault types and locations based on a normal network configuration.	Does not coordinate with DNSP protection, i.e. the generator may trip unnecessarily. This is only acceptable if tripping of the generator can be tolerated.
Detection and interruption of phase to ground fault current on the distribution network.	5.3.3.4 (Page 75)	LV generators.	The generator must detect and clear all phase to ground faults within the protection zone.	No fault detection methods required however the generator must trip following the operation of distribution network protection to avoid an electrical island in accordance with anti-islanding protection standards.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
		HV generators.	The generator must not contribute to phase to ground fault current on the distribution network. The generator must be isolated from the network within 0.2 seconds of the distribution network earth fault protection clearing the fault.	The generator must trip within 0.2 seconds of the distribution network earth fault protection. If the generator contributes to distribution network phase to ground fault current then the protection design will include necessary modifications to the existing distribution network protection to ensure it continues to operate with adequate performance.
Protection operating speed for external network short circuit faults.	5.3.3.5 (Page 76)	All generators.	All protection must operate with sufficient speed to clear the fault within the same time as the network protection for phase to phase and three phase faults. For phase to ground faults the protection must operate within 0.2 seconds of the distribution network protection for all faults within the designated protection zones. The absolute maximum fault clearance times shall be: LV&HV: 0.9 seconds. 66kV sub transmission: 0.4 seconds.	All protection must operate with sufficient speed to clear the fault within 0.5 seconds of the distribution network protection for all solid short circuit faults within the designated protection zones.
Backup protection for external network short circuit faults.	5.3.3.6 (Page 76)	All generators.	Backup or redundant protection shall operate to clear external network short circuit faults within the time taken for the primary network protection or within 0.5 seconds longer than the time expected if the primary generator protection had operated.	No capability required. (Although the DNSP shall only waive the requirement for backup protection in special cases.)
Modification of existing distribution network protection.	5.3.3.7 (Page 77)	All generators.	Undertake a review of the impact the embedded generator has on the operation of the distribution network protection and fund necessary works. This assessment will be undertaken by the DNSP on behalf of the generator proponent.	
Under and over voltage protection.	5.3.4.1 (Page 77)	All generators.	The generator shall trip within 2 seconds if the voltage exceeds the limits in Table 5 (page 48) by more than 5%. The generator shall trip within 3 minutes if the voltage exceeds the limits in Table 5 (page 48) by 0-5%.	To be negotiated with the DNSP however standards will be based upon the NER.

Compliance requirement	**Reference**	**Generator Classification**	**Automatic Access Standard**	**Minimum Access Standard**
Under and over frequency protection.	5.3.4.2 (Page 78)	Generators without remote inter-trip using frequency measurement for anti-islanding protection.	The generator must trip if the frequency moves outside the range 48Hz – 51Hz for more than 2 seconds.	
		Generators <10MW.	The generator must not trip if the steady state frequency remains within the range 49.5Hz – 50.2Hz.	
		Generators >=10MW.	Must comply with the NER obligations for response to network frequency variations, stability and governing requirements. Refer to section 5.2.3 (page 51).	
Negative sequence protection.	5.3.4.3 (page 79)	Three-phase generators.	The generator protection must be able to detect the loss of a single phase on the distribution network or within the generator installation and trip all three phases of the generator within 2 seconds.	The generator protection must be able to detect the loss of a single phase on the distribution network or within the generator installation and trip all three phases of the generator within 2 seconds. For a LV generator connected to a dedicated distribution substation this protection is not mandatory although recommended to prevent generator damage.
		Single-phase generators.	Not required unless individual single-phase generators are installed on each phase of a three phase installation and tripping of one generator creates unacceptable negative sequence voltage.	No capability required.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Anti-islanding protection.	5.3.5 (Page 79)	LV inverter based generators.	Passive and Active anti-islanding methods must disconnect the generator from the distribution network within 2.0 seconds of an electrical island forming.	Anti-islanding methods must disconnect the generator from the distribution network within 2.0 seconds of an electrical island forming.
		Generators without remote inter-trip protection.	Anti-islanding methods must disconnect the generator from the distribution network within 0.2 seconds of an electrical island forming.	Anti-islanding methods must disconnect the generator from the distribution network within the lower of the automatic reclose time for the distribution network protection less 0.5 seconds or 2.5 seconds following an electrical island forming.
		Generators with remote inter-trip protection.	The generator shall trip when it receives a trip signal from the DNSP.	
Protection security.	5.3.6.3 (Page 83)	All generators.	Protection review and documented report listing all protection components, impact of individual component failure and redundant or backup components that will act to provide adequate protection security.	
Monitoring of equipment health.	5.3.6.4 (Page 83)	LV inverter based generators.	Follow equipment suppliers and manufacturers maintenance recommendations.	
		All other generators.	Sufficient monitoring of alarms is necessary either locally or remotely to ensure the generator will not operate for longer than 24 hours using a single (non-duplicated or redundant) protection system. If sufficient monitoring cannot be provided then all relay failure alarms shall result in immediate generator shutdown or tripping.	
Reverse power protection	5.3.7 (Page 84)	All generators.	Where DNSP imposes an export limit at the point of connection, reverse power protection shall be implemented.	

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Generator synchronisation.	5.3.8 (Page 86)	Inverter connected generators.	Synchronisation using power electronic (solid state) switching devices with smooth seamless generator connection and ramp up of power output.	
		Asynchronous generators.	It is recommended that the generator be driven up to synchronisation speed prior to closing the generator CB however methods required will depend upon generator size and source impedance. Synchronisation methods must not create a voltage disturbance that breaches power quality standards. Refer to section 5.2.2 on page 49.	Synchronisation methods must not create a voltage disturbance that breaches power quality standards. Refer to section 5.2.2 on page 49.
		Synchronous generators.	Automatic synchronisation controllers and synchronisation check relays must be utilised. Synchronisation setting shall be based on system studies to ensure supply quality standards are maintained during synchronisation. As a guide, HV generators should have synchronisation error under 10 electrical degrees and LV generators should have synchronisation error below 15 electrical degrees.	Synchronisation setting shall be based on system studies to ensure supply quality standards are maintained during synchronisation.
Automatic reclose.	5.3.9 (Page 87)	All generators.	Embedded generators are not permitted to reclose (attempt to reconnect to the distribution network) following a loss of network supply until the voltage on the distribution network returns and stays within the normal operating range for a duration of minimum 1 minute.	
DNSP remote monitoring of generators.	5.3.10.2 (Page 89)	All generators.	Require communications established via approved and supported communication type (I.e CSIP-AUS, GMM or DOE over SCADA.)	
		Generators >=1MVA or with 66kV connection voltage or with remote inter-trip.	Generator CB status, real power with accuracy of ±2% or better, reactive power with accuracy of ±2% or better and true RMS current on each phase with accuracy ±1% or better.	To be negotiated with the DNSP however standards will be based upon the NER.

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Reliability and security of communications	5.3.11 (Page 90)	All generators with communications required for protection.	If a single communications link is utilised, failure of the communications link shall cause immediate generator tripping. If duplicated communication links are utilised, the generator can operate for up to 24 hours using a single communications link.	

5.5.4 Revenue metering requirements

Compliance requirement	Reference	Generator Classification	Automatic Access Standard	Minimum Access Standard
Bi-directional metering.	5.4.1.1 (Page 91)	LV inverter based generators <10kVA per phase.	A two quadrant electronic interval meter that records active energy flow in both directions over every 30 minute period is required.	If active power is not able to flow from an embedded generator installation into the distribution network, then bi-directional metering may not be necessary.
		LV inverter based generators >=10kVA per phase or generators not registered with AEMO.	A four quadrant electronic interval meter that records active and reactive energy flow in both directions over every 30 minute period is required.	
		Generators registered with AEMO.	A four quadrant electronic interval meter that records active and reactive energy flow in both directions over every 15 minute period is required.	
Metering standards	5.4.3 (Page 94)	All generators.	Too detailed to reproduce here. Refer to section 5.4.3 on page 94.	Too detailed to reproduce here. Refer to section 5.4.3 on page 94.

6 EMBEDDED GENERATION TESTING, COMMISSIONING AND MAINTENANCE REQUIREMENTS

6.1 Testing

The generator is required to undertake suitable tests during commissioning to confirm compliance with the intended design of all safety, protection, control, metering, quality of supply and monitoring systems associated with the generator installation, together with the electrical integrity of all primary circuit equipment. If the generator is contracted to provide network support, then additional testing and continuous monitoring may be necessary to ensure that the generator meets specified performance for generating capacity (for active and reactive power), start-up time and generator stability. While other testing will also be necessary to ensure the generator operates with the performance expected (such as energy efficiency) these tests are of lesser concern to the DNSP.

The actual tests undertaken will depend upon the type of generator plant and secondary circuit equipment installed. The content, sequence and timing of the tests are to be proposed by the generator. The tests shall only be performed by competent testing personnel with appropriately calibrated test equipment.

A detailed test and commissioning program shall be submitted to the DNSP for review. The DNSP will identify requirements for, or request adjustment on proposals from the generator, for testing at the interface with the DNSP network. The generator shall provide an opportunity for the DNSP to witness any tests and to request any tests to be repeated if the test results do not demonstrate compliance with the agreed access standard.

Upon completion of all tests, a copy of all test results in the form of a comprehensive test report shall be submitted to the DNSP, with certification by a qualified engineer or tradesperson.[72]

Post commissioning tests may also be necessary, in respect of power quality issues or embedded generation backstop verification[73], to ensure operation of the generator complies with specified requirements. Ongoing performance monitoring for larger plant will also be necessary to monitor performance in response to network fluctuations in frequency or voltage and to ensure stable operation during network disturbances. These requirements may be directly imposed by AEMO for registered generators, particular those over 30MW in capacity or providing ancillary services. Any evidence of the failure of a generator to meet any specified operational requirement will be sufficient grounds for a DNSP to seek tests and improvements.

Each generator must provide evidence that its generating system complies with:

- Technical requirements of the NER clause S5.2.5 or EDCoP requirements.[74]
- Australian Standards.[75]
- Connection agreement.[76]

Both new or replacement equipment that has been connected must be proved to comply with standards by appropriate tests. The DNSP has the right to witness such tests. The generator is required to advise the DNSP of the results of such tests and is required to produce test certificates as evidence of compliance.[77]

[72] Ref. NER clause 5.8.5(c)
[73] Ref. Embedded Generator Emergency Backstop Procedures
[74] Ref. NER clause 5.7.3(a) and clause 5.8.1(a)
[75] Ref. NER clause 5.7.3(a) and clause 5.8.1(a)
[76] Ref. NER clause 5.7.3(a) and clause 5.8.1(a)
[77] Ref. NER clause 5.8.1(b)

A generator operating a unit larger than 30MW or a station capacity of 60MW or more must conduct tests to demonstrate that compliance with the ESCODE requirements has been achieved as follows[78]:

- Reactive power capability.
- Quality of electricity generated.
- Unit response to frequency disturbances.
- Partial load rejection.
- Protection to detect internal generator installation faults and external distribution network faults and to disconnect the generator under such conditions.
- Protection of generating systems from power system disturbances.
- Protection system that impinge on power system security.
- Protection to trip plant for unstable operation.
- Frequency control.
- Voltage and reactive power control.
- The capability of a multiple unit power station to comply with the requirements for responses to frequency disturbances.
- Proof that each of the duplicate protection systems applied to the units and related to power system security operates within the parameters specified in the connection agreement.[79]

6.1.1.1 Specific tests for inverter-connected generation

Prior to testing, the installation is to be the subject of inspection by an independent electrical inspector whose accreditation has been approved by the DNSP in advance. On approval by the inspector of suitability to be energised, conduct of site tests is required in line with the following.

Electrical integrity tests

Initial tests as follows are required to prove suitability for connection to the network:

- HV test with data logging and communication circuits connected to earth.
- Secondary Injection Testing of the central (or back up) protection relay shall be completed as per JEN Guideline “Connection Guidelines for Inverter Energy Systems 30 kVA – 200 kVA (ELE GU 0014)”.
- Fail-safe operation of the protective device shall be tested as per JEN Guideline “Connection Guidelines for Inverter Energy Systems 30 kVA – 200 kVA (ELE GU 0014)”.
- Anti-islanding and reconnection tests shall be performed as per JEN Guideline “Connection Guidelines for Inverter Energy Systems 30 kVA – 200 kVA (ELE GU 0014)”.
- Test that for earth faults on either side of the main switch the inverter is disconnected from the fault by a means independent of the primary grid protection device.
- Test that for phase to phase faults on either side of the main switch the inverter is disconnected from the fault by a means independent of the primary grid protection device.
- Any additional tests of the grid protection feature recommended by the supplier.

Functional performance tests

The following tests are required to prove suitability for sustained operation under variable loading conditions:

[78] Ref. ESCODE clause 150.4.1, 2, 10 and 12
[79] Ref. ESCODE clause 170.2.1

- Test for THD to the 50th harmonic in the output current under operation of the energy source at +/-5% of full load and at +/-5% of 25% load. If the THD is measured to be within 1% of the limit under either test, the test is to be continued to measure individual harmonics for compliance under similar operating conditions.
- Test for transients in current or voltage waveform on connection to the DNSP network and record resulting profile.
- Verification of voltage and frequency stability over the intended range of operation.
- Verification of power factor compliance over the intended range of operation.
- Evidence of the intended performance:
  - Stability in response to change in the level of any capacitive support.
  - Rapid voltage decay on loss of mains on a line-commutated unit.
  - Stable operation on loss of mains on a self-commutated unit.
  - Synchronising a self-commutated unit including measurement of any voltage fluctuation on connection.

6.1.2 Protection and control testing requirements

Tests are to include:

- Internal diagnostic testing is to be successfully run before any other testing.
- Secondary injection testing of all relays is recommended in order to:
  - Retain a reference on relay performance for future calibration checks.
  - Identify any relay malfunction before more critical periods of unit commissioning.
- Secondary injection testing is to be carried out:
  - At a minimum of three points to verify any time current relationship, including a point at or near setting.
  - As required to prove time and pick-up threshold levels of the parameters.
- Pick-up and reset accuracy is to be verified against manufacturers guarantee at TMS of 1 and at the setting point.
- Each relay function is to be proven capable of tripping the respective circuit breaker from a secondary injection initiation.

6.1.3 DNSP remote monitoring and control testing requirements

Automatic control system and monitoring system tests are to include:

- Any internal diagnostic testing of control or communications systems is to be successfully run before any other testing.
- All activation signals are to be proven from the DNSP side of the communication interface at the site to the activated device under the generators control.
- All activation signals are to be proven from the generator side of the communication interface at the site to the (remote) activated device under the DNSP control.
- All initiating signals are to be proven from the DNSP initiating device to the generator side of the communication interface at the site.
- All initiating signals are to be proven from the generator initiating device to the DNSP side of the communication interface at the site.
- All initiating signals are to be proven from the DNSP initiating device to the activated device under the generators control under as close to operational conditions as can be simulated. Where appropriate, timing tests are to be included.

- All initiating signals are to be proven from the generator initiating device to the activated device under the DNSP control. Where appropriate, timing tests are to be included.
- Proximity to operating conditions is sought in order to maximise the opportunity that multifunctional circuits, that may suffer from excessive burden, will malfunction under test.
- Any final measured quantity remote metering for the interconnection zone will be verified under generator export test.

6.2 Commissioning

The DNSP will not take an active part in commissioning of the generator and the associated equipment, but a side role in any requirements on their part to assist (i.e. the sending and receiving of remote controls). Prior to commissioning, the proponent must submit the DNSP their ITPs and commissioning plans for comments if any. It should be noted that the DNSP will not approve or validate the proposed ITPs and commissioning plans but might request additional tests or improvements to the plans if the DNSP perceives necessary.

A copy of the test and commissioning report must be submitted to the DNSP to demonstrate compliance with the network access standards. The report shall list order codes, make & model and firmware versions of all protection and control devices including inverters, and shall document and demonstrate that the each of the designed protection & control settings and fail-safe features is functioning as expected. All settings and configurations shall be proven to be secured.

If the DNSP deems necessary, a representative of the DNSP might participate in witnessing the commissioning tests. The DNSP will work with the proponent to arrange mutually convenient times for witnessing the tests.

6.3 Maintenance& Ongoing operation

Unreliable generator performance can impact DNSP operations and reduce supply quality to other network users. The generator is required to ensure all generating plant including the protection, control, metering and monitoring systems associated with the generator installation are maintained in accordance with good industry practice.

6.3.1 Maintenance plan

The generator proponent is to prepare and keep active a 5 year forward maintenance program. The DNSP may request access to the maintenance program and maintenance and test reports for the purpose of review and to establish generator compliance with the program.

In respect of the excitation and governing control systems, any maintenance that could reasonably be expected have an adverse impact on dynamic performance, must be notified to the DNSP and AEMO.

6.3.2 Maintenance records

Generators who would otherwise be required to be registered by AEMO are required to be supported by full operations and maintenance records of the previous 7 years of operation. All other unregistered HV generators are required to be supported by full operations and maintenance records of the previous 5 years of operation. LV and inverter-connected generators are to be supported by at least previous 3 years of record.

6.3.3 Operational Verification Requirements

Where a generator has ongoing operational verification requirements, i.e testing of remote emergency backstop functionality or otherwise, the generator will be tested and verified regularly to ensure it operates correctly when needed. Compliance with Jemena's verification processes is mandatory.

6.4 Asset replacement, modifications or upgrade

No modification that might reasonably be considered to have an adverse effect on the compliance of a generating unit on system security may be carried out without prior approval of DNSP/AEMO. DNSP/AEMO may require the generator to conduct a test to demonstrate that the unit has been modified in accordance with the proposal and remains compliant with the technical requirements.[80]

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

The connection agreement is required to nominate a period after which DNSP and the generator are to co-operate in the testing of protection systems.[81]

Where any tests on equipment require a change to the normal operation of the unit, the nature of the tests is to be made known to DNSP in advance.[82]

6.5 Design Information and audits

Within 3 months of entering service or within 3 months of any subsequent testing, the generator must update the information provided on the functional block representation of relevant control systems. The documentation is to be held at the generating unit in compliance with relevant codes and is to be readily accessible by DNSP representatives. The documentation is to include:

- A single line diagram showing all electrical metering points, protection functions and zone of coverage.
- A record of all approved protection settings.
- A copy of the approved operating procedures.

At intervals of not less than 6 months, AEMO or the DNSP may, with appropriate notice, audit the records of the generator with a view to establishing compliance of units with technical requirements.[83]

Each registered generator must maintain records for 7 years setting out details of all technical performance tests and monitoring conducted and is make this available to AEMO or the DNSP on request.[84]

[80] ESCODE clause 160, ESCODE clause 180.1, 2, 3 and 4
[81] Ref. NER clause 5.7.4(a)(2)
[82] Ref. NER clause 5.7.5(a)
[83] ESCODE clause 150.6
[84] Ref. NER clause 5.7.3(g)

7 OPERATIONAL CONSTRAINTS AND STANDARDS

7.1 Operational communication

7.1.1 Communication with the DNSP

DNSP has a responsibility to report to AEMO routinely on embedded generator performance, including generation backstop enablement, as part of the network planning processes. The automatic access standard requires that the generator report on the operation of the plant on a month by month basis, reporting at no more than 3 monthly intervals.

For this purpose, the generating plant is to equip with:

- Non-resettable operation counters that separately record:
  - Each connection of the plant to the network.
  - Each trip event that causes disconnection of the unit.
  - Each significant fault alarm, significance being agreed with DNSP but is expected to relate to defects that could put reliable continuous operation of the plant at risk.
- Hours of connected operation counter.

7.1.2 Communication with AEMO

A generator operating a unit of 30MW or more, or a combined capacity of 30MW or more must report to AEMO annually detailing compliance against the NER requirements for protection systems impacting power system security and tripping of plant for unstable operation. The generator must supply AEMO with such additional information as might be requested.

A generator must report annually in respect of such units[85]:

- Details on forced and scheduled outages and reduction in capacity.
- A maintenance program for the next year and indications for a further 5 years.
- Reliability expectations for use in modelling studies and generated energy projections for the 6 years.

The generator is required to annually report to AEMO on the performance of all embedded generators. Information required form the generator includes load and generation data:

- Existing loads/generation units, load/generation profiles and changes to load/generation scheduling.
- Forecasts of load/generation growth, anticipated new or redundant loads/generation.
- Planned outages.

7.2 Network operating conditions

7.2.1 Planned and unplanned outages

7.2.1.1 Remote tripping of an embedded generator by the DNSP

Where an embedded generator receives a remote inter-trip protection signal from the distribution network it will be possible for a DNSP operator to remotely trip a generator from the distribution network. To do so will require the distribution network circuit breaker to be opened which in turn will isolate a section of the distribution network and may result in customer loss of supply. Such switching is only used in emergencies and therefore will be rare. For all planned works the DNSP operator will

[85] ESCODE clause 220.1, 270.1 and 290.2

contact the generator operator to organise an orderly shutdown and isolation of the embedded generator.

Once an embedded generator is disconnected the DNSP may enable an interlock to prevent the generator from being re-connected. This may be necessary to prevent a generator from synchronising to the wrong feeder when the distribution network is switched abnormally.

The circuit breaker used to isolate the generator from the distribution network can be either the connection point circuit breaker (to disconnect the whole installation from the distribution network) or just the generator circuit breaker or some other circuit breaker that disconnects the generator from the distribution network. This decision will depend upon the generator proponent preference. It is noted that if the generator circuit breaker is tripped then it may not be possible to supply the local onsite load from the generator while network is abnormal. On the other hand if the connection point circuit breaker is tripped it may not be possible to supply the local onsite load from the network if the network supply comes from an alternative feeder. Various options are possible to obtain the desired operational requirement.

7.2.2 Live line sequence

When works are undertaken near or on live distribution feeders the DNSP enables live line sequence which disables automatic reclose and enables low set instantaneous over-current protection. During live line sequence grading will not be achieved with downstream protection (including the protection within an embedded generation installation). The generator protection will also need to act much more quickly to disconnect from the network for short circuit feeder faults while live line sequence is enabled. It may be possible for the embedded generator to utilise its anti-islanding protection to trip within 0.1 seconds of the distribution network protection however if this cannot be achieve then it may be necessary for the DNSP to enable an instantaneous over-current protection element at the embedded generator site together with instantaneous neutral displacement protection for phase to ground faults.

7.3 Operating standards

7.3.1 Standard work procedures

Scheduled units on offer to the NEM are to have available appropriate personnel to receive and carry out AEMO direction at any time. The nominees for receipt of operational communications in the generating facility must be advised to AEMO and must be personnel responsible for the operation of the relevant equipment.

AEMO may issue directions to registered generators connected at the distribution level that are within the performance standards of the unit and covering:

- Transformer tap position.
- Voltage control setpoint.
- Reactive power transfer level at the point of connection.

Non- scheduled units do not necessarily require personnel to be in continuous attendance of the generator and electrical systems, providing the level of automation has been proven. Attendance to prime mover or energy supply systems must comply with statutory codes. A responsible party is required to be accessible by agreed communication channels at all times. The nominees for receipt of operational communications relating to the generating facility must be advised to the DNSP together with evidence of qualification for the duties.

Operating routines

AEMO maintains a set of standards for key operating parameters of the network:

- Voltage.
- Frequency.
- Quality of supply.
- Stability margins.
- Protection clearance times.

A generator cannot presume that the network operates within these standards at all times, but they should expect to be reasonably informed of circumstances when the standard of supply at the connection point will not conform. Divergence ranges are nominated to assist in the selection of plant and equipment with adequate ratings. For plant connected at the distribution level, the DNSP will interpret these standards.

On non-dispatched plant, routine generation operations are expected to be carried out in accordance with operating schedules pre-agreed with the DNSP and based on pre-service analysis by the DNSP. These schedules would include pre-agreement on voltage control parameters. A network abnormality or emergency would normally be a precursor for DNSP operations staff to make contact and request a change in operating parameters.

At the distribution level there are limitations on the level of flexibility for transfer of export power to an alternate substation feeder. While line capacity may be available under alternate feeder configurations, alternate feeders may not be equipped with the necessary protection equipment and appropriate protection/control settings. Reactive power support measures may also not be appropriate. The DNSP is only required to continue to allow the transfer of power from a generating facility with certain network facilities or plant out of service ("credible contingency events") if specified in the connection agreement.

The DNSP has the option to require the generator to cease operations for safety reasons or if operations are divergent from agreed procedures. A generator must comply with a request from the DNSP to disconnect. Disconnection by DNSP is an option for failure to comply.

In line with the AEMO responsibility for system security, DNSP is obligated to provide all reasonable assistance to AEMO for the purpose of disconnection of a generating unit, in the event that AEMO determines that it has the authority or responsibility to require such disconnection.

The generator may be required to respond to direction from either the DNSP or AEMO as relevant in the event of a major system disruption, and as provided in the connection agreement.

The operating procedures to be established by the generator and that relate to:

- any interaction with the DNSP,
- operation of interfacing plant, and
- the routine start-up, shutdown or loading changes on the generator;

are to be developed in consultation with the DNSP and a written version submitted for approval. The procedures are to be held by both parties and are not to be altered without mutual agreement. In the interests of safety of all parties, operations activity is not to diverge from the written procedures. Reasonable operating logs are to be kept that enable traceability of operations and identification of the occurrence of adverse events.

Each generator and the Network Service Provider must develop local black system procedures in accordance with guidelines developed and published by AEMO.[86]

[86] Ref. NER clause 4.8.12(d)

Agreements with the DNSP will also address operations immediately after a network shutdown. A generator must comply with DNSP advice or with the requirements of the local black system procedures as quickly as is practicable.

Work Procedures

For a generator that seeks to interface to a distribution utility, a substantial understanding of the implications of Blue and Green Book principles is essential.

In hierarchy electrical safety documentation is developed:

- Acts and Regulations.
- Codes (Blue Book and LV Code).
- Organisational procedures.
- Work Instructions.

If the organisational procedures set down are to be varied, within the electricity distribution businesses it is mandatory to:

- Complete a hazard identification and risk assessment.
- Document the process.
- Advise the relevant Electrical Safety Committee.

A generator is required by regulation to put in place operating procedures that are directed toward safety of personnel. The DNSP advocates the Blue Book framework as the most appropriate upon which to base those procedures. This is reinforced by the SIR that require that the minimum operating procedures for customers HV installations are as set out in the Blue Book.[87]

In all operational interaction with the generator, the DNSP will not co-operate with procedures that fall short of the principles identified in the Blue Book. Particular attention is drawn to the use of a SCAP – Statement of Condition of Apparatus/Plant – a statement used between operating authorities to confirm plant conditions and isolations to support an access authority or other operational requirements. The SCAP will become a critical operational communication between DNSP and generator.

The responsibility for establishing and maintaining safe work procedures lies with the generator and is enforced through the various work safety Acts and Regulations. Prior to participating in the commissioning of the plant and to accepting entry of the plant to commercial service, DNSP will seek to sight and provide comment on the adequacy of the proposed operational and maintenance safety procedures.

Personnel[88]

Operations staff are to be fully prepared by:

- Receiving training in safe operation.
- Familiarity with electrical work procedures that are safe and in accordance with statutory requirements.
- Familiarity with permit to work procedures for HV plant.
- Being knowledgeable on safety interlocking systems.

All generating installations are required to comply with the relevant codes in respect of design and safety in operation. Operators are required:

[87] SIR clause 9.15.1

[88] SIR clause 9.15.3

- To have appropriate certification from relevant safety authorities or evidence of any specific exemption.
- To have relevant training, knowledge and preferably experience in the operation of generating plant.
- To have adequate knowledge to recognise changes in DNSP network conditions.
- To be competent in terms of exercise of judgement in emergency.
- To have received training in safe operation.
- To have familiarity with electrical work procedures that are safe and in accordance with statutory requirements.
- To have familiarity with permit to work procedures for HV plant.
- To be knowledgeable on safety interlocking systems.

HV switching is only to be carried out by operators accredited for that specific purpose. The generator is to establish and maintain in place a procedure that allows access on a 24hr/7 day basis, to an accredited operator in the event that unexpected access is required for activities such as:

- Inspection of the HV metering transformers.
- Load shedding.
- Routine maintenance.
- HV supply cable repair or testing.

7.3.2 Health and safety (blue/green book)

The Blue Book – Code Of Practice Of Electrical Safety For Work On Or Near High Voltage Electrical Apparatus – addresses the principles applied and electrical safety procedures, appropriate to instances involving any approach to HV apparatus of any form.
The Blue Book:

- Has general application throughout the electricity power supply industry.
- Sets minimum standards that may be enhanced by organisational procedures.

The Blue Book is supplemented by the Green Book, a variation that interprets Blue Book guidance in the context of the electricity distribution industry and seeks to embrace the implications for contractors to that industry.

Blue Book principles address issues such as:

- Hazard identification.
- Permissible approach to equipment and exclusion zones – personnel and mobile plant.
- Authorisations to operate electrical equipment and management of earthing devices.
- First aid competency.
- Clarity of communication.
- Use of standardised documentation.
- Approved equipment and routine testing of this - such as PPE, insulated platforms and insulated operating sticks.
- Labelling, barriers and signs.
- Use of safety observers.
- Fitness of personnel for work.
- Acceptable electric and magnetic fields.

- Training standards.
- Access permit procedures and authorisations.
- Sanctions for testing.
- Declared out of commission plant.
- Live work.
- Procedures for operating on insulated power or supervisory cables.

The Blue Book also gives guidance on procedures related to approach to low voltage assets.

7.3.3 Access rights

DNSP representatives and relevant AEMO representatives, are to have right of access at all times for the purpose of operations or to assess compliance in the event that there are reasonable grounds to suspect non-compliant performance or operations.

The DNSP reserves the right of access to any service protection device or supply connection device at any time in order to ensure safety of access to operations or maintenance personnel required to work on the DNSP network.

Routine access will be required to the following equipment:

- The connection point CB, connection point isolator and associated earth switches
- The metering enclosure and measuring transformers
- The RME and associated communications gear
- The relaying associated with feeder intertrip, reclosure blocking, network fault and interfacing plant protection.

Access for the purpose of inspection of other plant is to be by mutual agreement.

7.3.4 Generator operation in the presence of defects

Generator defects shall be identified during routine maintenance inspections and testing, from alarms, from generator trips or other forms of abnormality. The actions to be taken and the time to repair will depend upon the nature of the defect and associated risk. Where a defect could impact the operation of a protection scheme or critical control scheme it will generally be necessary to take the generator out of service until the defect is repaired.

Where an embedded generator has duplicated protection or backup protection (i.e. it has redundant protection) the generator is permitted to operate for a maximum of 24 hours on a single protection scheme. During this time at least one protection scheme must be fully operational to detect and clear every fault type within the generator installation or on the distribution network that must be cleared. If the failed component cannot be repaired or replaced within 24 hours then the generator shall be disconnected from the distribution network until such repairs are made.

To reduce the risk associated with extended outages it is recommended that critical spares be kept and service and maintenance contracts be maintained.

8 Data to be submitted by the Generator Proponent

Upon request the DNSP shall provide a list of information to be provided so that the DNSP can assess the connection enquiry and the connection application and can prepare a connection offer and generator connection agreement suitable for execution. The following sections provide some guidance however this will be tailed by the DNSP depending upon the generator technology, size and connection point on the network.

8.1 Connection enquiry

The DNSP will typically require the following information from the generator proponent to assess the connection enquiry:

Preliminary Enquiry Information	**To be provided as part of connection enquiry**
Embedded Generator Applicant / Proponent / Owner	
Business name	
ABN	
Contact name	
Address	
Telephone number	
Fax number	
E-mail address	
Connection Enquiry Applicant acting on behalf of the Proponent above	
Business name	
ABN	
Contact name	
Address	
Telephone number	
Fax number	
E-mail address	
Generating Plant	
Address of generator installation	
Proposed connection point and voltage	
Energy source / fuel (e.g. natural gas, wind etc)	
Type of plant or technology (e.g. synchronous turbine, inverter)	
Number of generating units	
Rating of each unit (MW or MVA)	
Maximum total power generation (MW or MVA)	
Expected energy production per annum (MWh)	
Expected hours of operation (base load or peaking plant etc)	
Date of service envisaged (or dates in the case of multiple units)	
Initial concept single line diagram	
Nature of any disturbing load/generator likely to disturb the voltage waveform	
Estimated load to be serviced after commissioning (MW)	
Proposed communication connection type (i.e CSIP-AUS, GMM, DNP3)	

Preliminary Enquiry Information	To be provided as part of connection enquiry
Requirements for an electricity supply during construction or any auxiliary power requirements if known	
AEMO Classification	
Exempt or registered generator	
Market or non-market generator	
Scheduled or semi-scheduled dispatch	
Commercial	
Desire to provide network support or offer to alleviate published network constraint	

8.2 Connection application

Information provided in the connection enquiry shall be updated if any changes to the proposed generator have been made.

The DNSP will typically require the following information from the generator proponent to assess the connection application. The following is suitable for a large generator however small generators will only be required to provide a subset of this information.

In accordance with NER clause S5.5.2 the following list of required data is coded into categories allowing information to be provided in stages as it becomes available during the design and connection application process.

Preliminary or Standard (S) system planning data should be provided with the application to connect and provides the initial information required to access the application, to review the connection options, to develop a connection offer and to provide the necessary site specific connection standards. Detailed (D) planning data is additional information that will be developed during the design of the generator. Together the Standard and Detailed data form the Registered (R) system planning data that will be included within the connection agreement to be signed by both parties.

The Registered data can be further subdivided into data that is available prior to generator connection (R1) such as protection settings and data that will not be available until after commissioning (R2) such as results from on load tests. Where it is possible that some parameters may change during the design and commissioning that parameter may be given more than one category signifying that it is necessary for the generator proponent to confirm the values more than once.

Schedule AC 2
Additional General Information

Additional general material	**S**	**D**	**R1**	**R2**
Provide evidence that a generator licence has been issued by the Essential Services Commission (or provide a suitable exemption)		•		
Provide evidence that the generator is registered with AEMO (or provide a suitable exemption)		•		
Drawings and maps showing generator installation site		•		•
Load schedule with calculations showing derivation of diversified maximum demand if the load is not currently serviced by the network and demand during construction (table)		•		
Maximum Net export with consideration of above load over a 15 minute metering interval based on calculation and measurement (MW and MVA)		•		•
Maximum real and reactive power transfer capability required at the point of connection for real power flow in either direction		•		

Schedule AC 3

Network and plant technical data of equipment at or near the connection point

	S	D	R1	R2
Voltage Rating				
Nominal voltage (kV)	•	•		
Highest voltage (kV)		•		
Insulation Co-ordination				
Rated lightning impulse withstand voltage (kVp)		•		
Rated short duration power frequency withstand voltage (kV)		•		
Surge arrestor type and specifications (text)		•		
Rated Currents for Each Component				
Circuit maximum continuous current rating(A)	•	•		
Circuit maximum cyclic current rating (A)		•	•	
Rated short time withstand current (kA)		•		
Rated short time withstand current maximum time (sec)		•		
Ambient conditions under which above ratings apply	•	•		
Earthing				
Generator installation earthing method and impact on network earthing system (text description)	•	•		
Earth grid rated current (kA)		•		
Earth grid rated current maximum time (sec)		•		
Insulation Pollution Performance				
Minimum total creepage (mm)		•		
Pollution level (level of IEC 815)		•		
Controls				
Communication Connection Type with all supporting docs and/justifications (CEC listing of inverter & gateway pair)	•	•	•	•
If CSIP-AUS connection model and supporting docs (Standalone, Aggregator, Cloud onshore, cloud offshore, etc)	•	•	•	•
Remote controls and data transmission arrangements (text)		•		
Metering provided by customer				
Metering service provider (text)		•		

	S	D	R1	R2
Meter class / classification		•		
Current transformer winding ratios (A/A)		•		
Voltage transformer winding ratios (V/kV)		•		
Measurement transformer test certification details (text)			•	
Network Configuration				
Operation Diagrams showing the electrical circuits of the existing and proposed main Facilities within the Registered Participant's ownership including busbar, phasing and earthing arrangements, switching facilities and operating voltages (single line diagrams).	•	•	•	
Impedance of all plant				
Synchronous, transient and sub transient positive, negative and zero sequence resistance and reactance for synchronous generators (% on 100MVA base)	•	•	•	
Positive, negative and zero sequence series resistance and reactance for all other plant including transformers, cables, reactors etc (% on 100MVA base)		•	•	
Shunt susceptance for each item of plant including cables (% on 100MVA base)		•	•	
Mutual coupling between physically adjacent elements if significant (% on 100MVA base)		•	•	
Short circuit current Infeed to the Network				
Maximum generator 3-phase short circuit infeed current including infeeds from generating units connected to the Registered Participant's system, calculated by method of AS3851-1991 (kA)	•	•	•	
Site total induction and synchronous motor 3 phase contribution at fault clearance (kA sym)		•		
Site total induction and synchronous motor asymmetrical peak contribution (kAp)		•		
Total infeed current at the instant of fault including contribution of induction motors (kA)		•	•	
Minimum zero sequence impedance of the Registered Participant's network at the connection point (% on 100MVA base)		•	•	
Minimum negative sequence impedance of the Registered Participant's network at the connection point (% on 100MVA base)		•	•	
Technical details of the generating units				
Provision of information in accordance with the Generating System Design Data Sheets, Generating System Setting Data Sheets and the Generating System Model Guidelines where such details are not confidential information.	•	•	•	•

	S	D	R1	R2
Power transformer				
Nominal voltage ratio (kV : kV)	•	•		
Tapping range (buck % - boost %)		•		
Vector group (text)	•	•		
Natural cooling nameplate rating (MVA)	•	•		
Forced cooling nameplate rating (MVA)	•	•		
Saturation curve (diagram)			•	
Switchgear				
Manufacturer and model numbers for circuit breakers, switches and isolators (text)		•		
Reactive compensation				
Single line diagram of shunt capacitor bank (diagram)	•	•		
Location and rating of individual shunt capacitors (MVAr)	•	•		
Capacitor bank capacitance (µF)		•		
Size of capacitor bank series reactor (mH)		•		
Equivalent series resistance of capacitor bank (Ω)		•		
Single line diagram of shunt reactors (diagram)	•	•		
Location and rating of individual shunt reactors (MVAr)	•	•		
Inductance of shunt reactor (mH)		•		
Details of special controls such as point on wave switching		•		

Schedule AC 4
Network Plant, Secondary Design and Apparatus Setting Data

	S	D	R1	R2
Protection Data for Protection relevant to the Connection Point				
Protection and control design report (detailed report including control and protection settings)	•	•	•	
Anti-islanding protection	•	•	•	
Protection block diagram (diagram)	•	•	•	
Control and communications block diagram (diagram)	•	•	•	
Interface hardware and communication protocols between the DNSP network and the Generator for all protection, control and monitoring.	•	•	•	
Data transmission arrangements for AEMO		•	•	
Inspection & Test Plan (ITP) report with results from all commissioning tests			•	•
On Load Tap changer (OLTC)				
Regulated bus (text)		•		
Method of control such as independent, master/follower… (text)		•		
Time delay settings for definite time or inverse time		•	•	
Shunt reactor and capacitor bank control				
Method of switching (text)	•			
Details of automatic control logic such that operating characteristics can be determined (text)		•	•	

Schedule AC 5
Generator Design Data Sheet

	Unit	Synchronous generators	Asynchronous generators
Rated terminal voltage - Vt	kV		
Nameplate rating	MW		
Rated power factor at Vt			
Rated capability	MVA		
Ambient temperature basis for ratings	degC		
If site conditions require any limits			
Site maximum continuous output - Pmax	MW		
Site minimum continuous output - Pmin	MW		
Maximum export reactive power at Pmax	MVAr		Not applicable
Maximum export reactive power at Pmin	MVAr		Not applicable
Maximum import reactive power at Pmax	MVAr		
Maximum import reactive power at Pmin	MVAr		
Inertia constant – Generator	MWs		
Inertia constant – Prime mover/Gearbox	MWs		
Number of poles			
Rated slip	%	Not applicable	
Short circuit ratio			Not applicable
Rated stator current at Vt	A		
Rated rotor current at Vt - Ir	A		Not applicable
Rotor voltage for Ir	V		Not applicable
Base for following impedances	MVA		
Stator resistance	%		
Stator leakage reactance	%		Not applicable
Stator leakage reactance unsaturated	%	Not applicable	
Stator leakage reactance at Vt	%	Not applicable	
Negative sequence resistance	%	Not applicable	
Negative sequence reactance	%	Not applicable	
Negative sequence impedance	%		Not applicable
Zero sequence resistance	%	Not applicable	
Zero sequence reactance	%	Not applicable	
Zero sequence impedance	%		Not applicable
Direct axis unsaturated synchronous reactance	%		Not applicable
Direct axis unsaturated transient reactance	%		Not applicable

	Unit	Synchronous generators	Asynchronous generators
Direct axis unsaturated sub-transient reactance	%		Not applicable
Quadrature axis unsaturated synchronous reactance	%		Not applicable
Quadrature axis unsaturated transient reactance	%		Not applicable
Quadrature axis unsaturated sub-transient reactance	%		Not applicable
Iron loss resistance (referred to stator)	%	Not applicable	
Magnetizing reactance unsaturated (referred to stator)	%	Not applicable	
Magnetizing reactance at Vt (referred to stator)	%	Not applicable	
Rotor resistance at rated slip (referred to stator)	%	Not applicable	
Rotor leakage reactance unsaturated (referred to stator)	%	Not applicable	
Rotor leakage reactance at Vt (referred to stator)	%	Not applicable	
Direct axis open circuit transient time constant	S		Not applicable
Direct axis open circuit sub-transient time constant	S		Not applicable
Quadrature axis open circuit transient time constant	S		Not applicable
Quadrature axis open circuit sub-transient time constant	S		Not applicable
Generator 3 phase short circuit (calculated AS3851) – At fault clearance	kA sym		
Generator 3 phase short circuit (calculated AS3851) – After decrement	kA sym		
Decrement period for reduced 3 phase fault	secs		
Generator asymmetrical peak contribution	kAp		
Generator winding pitch			
References to diagrams providing the following data			
Capability chart			
Open circuit characteristic			Not applicable
Short circuit characteristic			Not applicable
Zero power factor curve			Not applicable
Magnetising curve (voltage versus current)		Not applicable	
Speed (slip) versus torque (power) curves		Not applicable	
Equivalent circuit diagram		Not applicable	

8.3 Additional information

The DNSP will also require the following:

- A copy of the certificate of electrical safety to demonstrate that the generator installation has been inspected by a licensed electrical inspector.
- A copy of the maintenance policy to ensure all electrical components will be appropriately maintained to provide reliable operation into the future.
- Contact name, telephone, E-mail and address of operational staff as required during generator operation for coordination of works between the Generator's operators and JEN network operators.