Jemena Electricity Networks (Vic) Ltd

Embedded Generation - Connection Principles and Guidelines

Embedded Generation - 5 MW or Greater

ELE GU 0004

Public

1 October 2014

An appropriate citation for this paper is:

Embedded Generation - Connection Principles and Guidelines

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Authorisation

Name	Job Title	Date	Signature
Reviewed by:			
Ashley Lloyd	Network Capacity Planning & Assessment Manager	17/09/2014	[signature]
Ken Lau	Secondary Plant Manager (Acting)	17/09/2014	[signature]
Approved by:			
Johan Esterhuizen	General Manager – Asset Strategy Electricity	18/09/2014	[signature]

History

Rev No	Date	Description of changes	Author
1	16/09/2014	Initial Release	Hung Nguyen Diptiman Yadav Bruce Woods Aditya Upadhye

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ABBREVIATIONS

ACR	Automatic Circuit Recloser
AEMO	Australian Energy Market Operator
CB	Circuit breaker
CT	Current transformer
DLF	Distribution Loss Factor
DNSP	Distribution Network Service Provider
EDC	Electricity Distribution Code
EG	Embedded Generator
ESC	Essential Services Commission
ESCODE	Electricity System Code
HV	High Voltage (above 1kV)
ITPs	Inspection and Testing Plans
JEN	Jemena Electricity Network
LV	Low Voltage (under 1kV)
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
VT	Voltage transformer

1. INTRODUCTION

The objective of this document is to provide the principles and technical requirements for the connection of embedded generation of greater than 5 MW to the Jemena Electricity Network. The document is intended to assist proponents or their agents connect embedded generators to understand the technical issues of concern for JEN and factor relevant considerations in the design of embedded generation systems.

Jemena recommends that this document be reviewed by the proponent in conjunction with the following:

1. Embedded Generation 5 MW or Greater - Connection Process Description (ELE PR 0007)
2. Embedded Generation 5 MW or Greater – Technical Access Standards (ELE SP 0003)

The document is structured as follows -

Chapter 2 explains the technical standards and JEN's requirements for the design of primary plant of embedded generation systems. Similarly, Chapter 3 explains the technical standards and JEN's requirements for the design of secondary systems. The proponent is expected to refer to the relevant sections of these chapters while preparing a design proposal for JEN's consideration. The connection principles and requirements on primary and secondary systems as laid out here will form the basis for negotiations on access standards between JEN and the proponent. Chapter 4 describes the remote monitoring, control and communications requirements. The requirements and relevant standards relating to revenue metering are depicted in Chapter 5.

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 requisite health and safety considerations.

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.

2. PRIMARY PLANT REQUIREMENTS

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 2-1.

Table 2-1: Primary plant standards

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	AS1243, AS60044.2, AS60044.3
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

Further information on major plant such as circuit breakers, current and voltage transformers, cables and power transformers are considered below.

2.1 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.

HV main switch[1]

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).

> Example
>
> 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.

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.

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[1] Ref. SIR 9.7.2 and figure 9.1.

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.[2] 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.

2.2 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 2-2.

2.3 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 AS1243

2.4 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:

- 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 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.

[2] Ref. NER S5.2.7

- Compliance with the following Australian Standards or equivalent international standards is required: AS2374.

2.5 CABLES

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

2.6 ULTIMATE FAULT LEVELS AND PLANT RATINGS[3]

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 EDC and network plant ratings (which may be less than the EDC limits). The EDC limits are shown in Table 2-2, together with deemed low voltage fault levels for residential connections[4].

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

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

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 2-2 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 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[5]

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.

[3] Ref. NER S5.2.8

[4] Ref. SIR 6.1.2

[5] Ref. NER S5.1a.8

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.[6]

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[7]

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 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 EDC 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:

Table 2-3: Generation plant short circuit ratings

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

The table above should be treated as a guide only. At some locations network fault levels operate above the EDC embedded generator limits. The automatic access standards will therefore be subject to site specific review.

2.7 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 limits in Table 2-4.

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.

[6] Ref. SIR 9.8

[7] Ref. NER S5.1.9

Table 2-4: Generation plant insulation level ratings

Nominal voltage	Short duration (60 sec) power frequency withstand voltage rating[8]	Lightning impulse withstand level (LIWL) voltage rating (1.2µsec / 50µsec) [9]
66kV	$140kV_{rms}$	$325kV_p$
22kV	$50kV_{rms}$	$150kV_p$ (outdoor plant) $125kV_p$ (indoor switchboard)[10]
11kV	$28kV_{rms}$	$95kV_p$ (indoor plant)
6.6kV	$20kV_{rms}$	$60kV_p$
230V/400V	$275V_{rms}$	$6.0kV_p$[11]

2.8 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.

2.9 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.

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.

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8 Voltage measured phase to ground.

9 Voltage measured phase to ground.

10 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.

11 Based on table 1 of clause 4.2.2 of the EDC. 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.

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.

2.10 HIGH VOLTAGE GENERATOR INSTALLATIONS

Zero sequence impedance of generator installation observed from the network

The zero sequence impedance of the generator installation observed from the network must be infinite 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. (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:

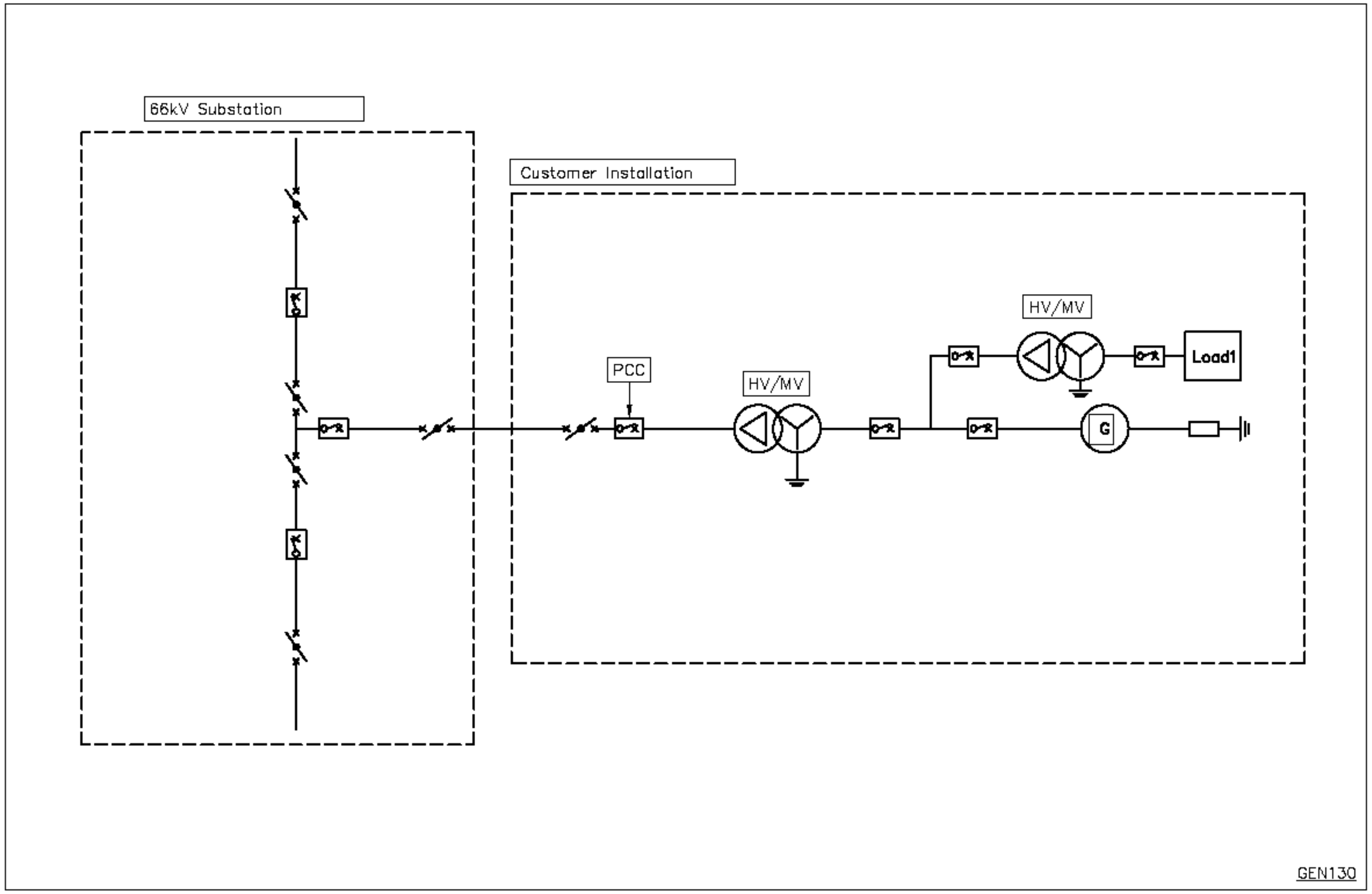
- An earthing transformer is provided on each bus section that is independently supplied or has generation connected.
- Each is equipped with a non-automatic circuit breaker or switch.
- Each is equipped with transformer protection directed at bus sectionalising and removing generation or supply sources 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.

2.11 EXAMPLE CONNECTION ARRANGEMENT OF PRIMARY PLANT FOR GENERATOR BETWEEN 5 MW AND 30 MW

Figure 2-1: Example EG Connection (5 – 30 MW) – Primary Plant Arrangement



3. PROTECTION AND CONTROL REQUIREMENTS

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.

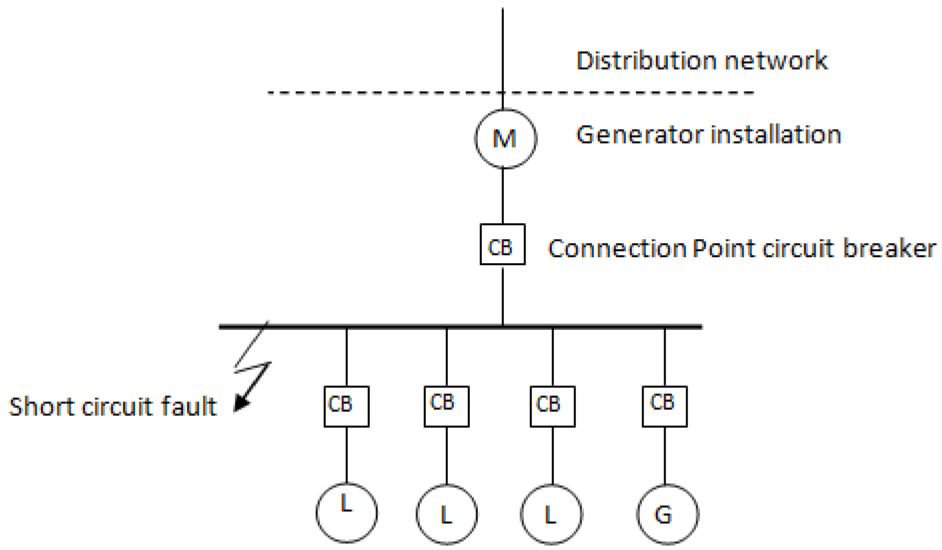
3.2 SHORT CIRCUIT FAULTS INTERNAL TO THE GENERATOR INSTALLATION

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 3-1 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 3-1: Typical generator installation with internal short circuit fault



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, protection zone overlap is required.

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.

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.
- Maximum and Minimum Fault conditions.

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 is preferred.

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 based over-current relays are used then the margin of at least 0.4 seconds must be maintained.

The DNSP will only consider slowing down the network protection to improve protection grading once the generator protection designer has demonstrated that despite using best industry practice the generator protection design is still inadequate to enable grading with the distribution network protection. Such changes 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.

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. 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.[12] Generator protection is not expected to be capable of operating if the zone substation uses resonant earthing, i.e. a ground fault neutraliser (GFN).

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 generators connected to the LV network the transmission network will maintain transient stability, voltage stability and oscillatory stability, regardless of fault duration. 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.

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

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.

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.

> 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 must be slowed down to allow time grading.

In such circumstances the DNSP will consider such requests however 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:

- 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 a blocking scheme will need to be implemented.

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.

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?

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.

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.

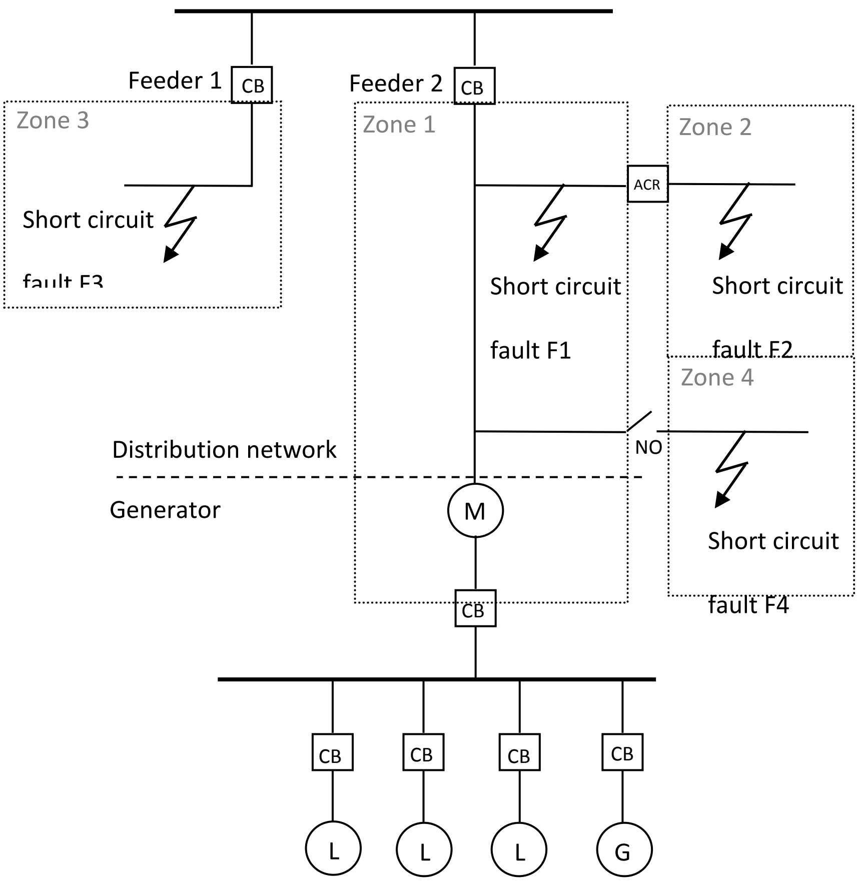
It is important that the generator installation protection is used to detect and clear the generator's contribution of short circuit faults within the DNSP network so that the generator installation protection acts to clear the fault with the distribution network protection. This reduces the risk of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

Example

A typical network is illustrated in Figure 3-2 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 3-2: Example of a typical generator installation with various distribution network short circuit faults



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.

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.

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 3-2. 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.

The protection systems 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. 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 permitted under a negotiated access standard if the impact of generator nuisance tripping can be tolerated.)

3.3.4 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.

A generator connected at HV cannot supply zero sequence current to the distribution network. 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 is expected to 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:

1. Distribution network earth fault protection with remote trip to the generator; or
2. Sensitive differential line protection scheme or neutral displacement protection at the generator site. The neutral displacement requires HV voltage transformers 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. The generator must be able to reliably trip within 0.2 seconds after the operation of the network earth fault protection.

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. The proponent is required to design protection 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. 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 schemes to obtain:

- 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 the generator must trip within 0.2 seconds following the operation of the network protection.

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. 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. 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.

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 accommodate 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).
- 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.

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.

3.5 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.

3.6 ANTI-ISLANDING PROTECTION

Under no circumstance shall an embedded generator be permitted to island any part of the electricity distribution network. Islanding[13] 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 EDC 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 other regulatory 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 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

[13] 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.

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 below.

- Synchronous Generator
  - If the generator rating is less than 80% of the minimum demand on the feeder protection zone then ROCOF and voltage vector shift protection are adequate.
  - If the generator rating is more than 80% of the minimum demand on the feeder protection zone then a dedicated inter-trip scheme between the feeder circuit breaker (or ACR) and the embedded generator's controlling circuit breaker is required. The integrity of the inter-trip scheme shall be continuously monitored and shall trip the controlling circuit breaker upon failure.
- Asynchronous Generator
  - 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 must be installed regardless of the outcome of such studies to ensure the generator trips quickly.
- Static Inverter
  - Passive and Active anti-islanding protection in accordance with AS4777-2002 Part 3 'Grid Connection of Energy Systems Via Inverters – Grid Protection Requirements'.

3.7 BACKUP PROTECTION PHILOSOPHY

The protection system is required 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.

3.7.1 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).

3.7.2 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.

3.7.3 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.

3.7.4 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).

3.7.5 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. 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.

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.

3.7.6 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.

3.8 EXAMPLE CONNECTION ARRANGEMENT OF SECONDARY PLANT FOR GENERATOR BETWEEN 5 MW AND 30 MW

Figure 3-3 below provides an example of secondary system arrangement for an embedded generator connected to JEN. The size of the embedded generator is between 5 MW and 30 MW.

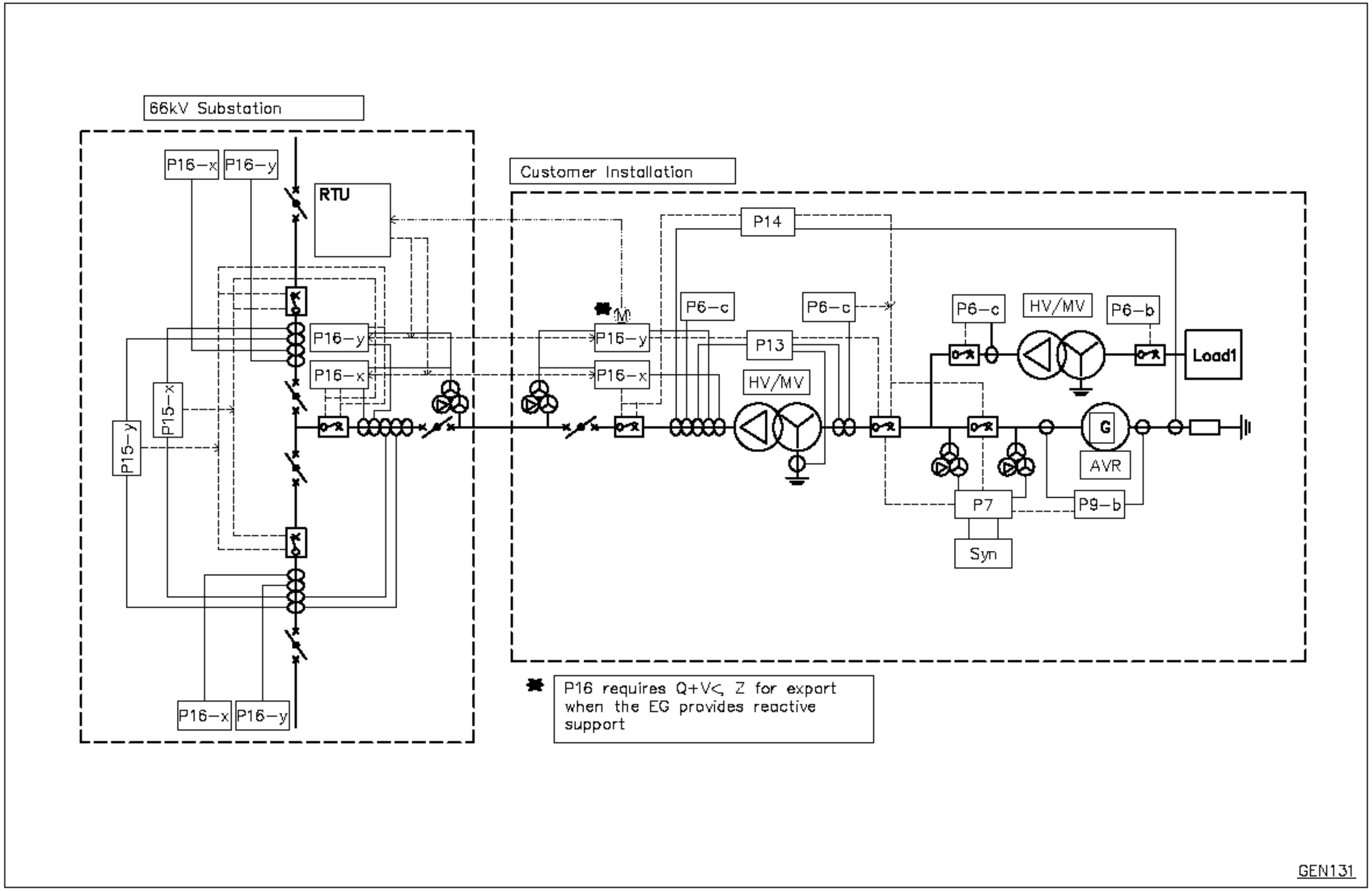
Table 3-1 provides a legend for the abbreviations used in the single line diagram.

Table 3-1: Legend for Single Line Diagram

Abreviation / ID	Description	Protection Scheme
G	Embedded Generator	
P6-a	Distribution Sub Station LV Protection	Distribution Substation LV Protection Phase Overcurrent - 50/51P Earth Fault - 50/51N, G
P6-b	LV Protection	Phase Overcurrent - 50/51P Earth Fault - 50/51N, G
P6-c	HV Protection	Phase Overcurrent - 50/51P Earth Fault - 50/51N, G
P7	CB Close Interlocks	
P9-A	Generator Protection Scheme	Main or Generator Circuit Breaker Synch Check Interlock - 48 Phase angle difference -78 Voltage difference -47 Phase sequence - 47 Negative sequence -46 Slip frequency -81
P9-B	Full Generator Protection Scheme	Full Gen Prot scheme Current diff - 87 OC - 50/51P Negative sequence - 46 Voltage balance - 47 U/Volt -27 O/Volts -27 U/Frequency -81

		O/Frequency -81
Syn	Automatic Synchroniser	
M	Metering	
P13	Transformer Diff Prot scheme	HV and LV OC 50/51P Current Diff - 87 Transformer REF applied if NER is used Inter trip - 85
P14	Overall Unit Gen/Transformer Current Diff Protection	Current Diff - 87
INV	Inverter protection scheme	25-Synchro check 27-U/Volts 59-O/Volts 81U-U/Frequency 81O-O/Frequency 81R-Freq shift Anti-Islanding (LOM) Vector shift and RoCoF
P15	Bus Protection X and Y	High Impedance X and Y schemes
P16	Line Protection X and Y	Current Differential - 87 Over current back up – 50/51P Distance back up - 21
RTU	Remote Terminal Unit	Measurement and control
GC	Generator Control Scheme	AVR and Governor controls

Figure 3-3: Example EG Connection (5 – 30 MW) – Secondary Plant Arrangement



3.9 GENERATOR CONNECTION OR SYNCHRONISATION AND DISCONNECTION

3.9.1 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 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.

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. Test results at commissioning can be used to demonstrate such compliance.

3.9.2 ASYNCHRONOUS GENERATORS

Mains excited generators

The generator start up method shall be determined after due consideration of the impact on network voltage disturbance.

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. .

3.9.3 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.

3.9.4 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.

3.10 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.[14] 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.

[14] 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.

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. Remote blocking is required 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.

4. REMOTE MONITORING AND COMMUNICATIONS REQUIREMENTS

All local generator monitoring and controls shall be the full responsibility of the embedded generator operator and the DNSP shall not monitor local alarms or operate local controls.

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.

4.1 DNSP REMOTE MONITORING

All generators must have the following remote monitoring back to the DNSP control centre:

- 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.

4.2 DNSP REMOTE CONTROLS

The DNSP shall not directly remotely control any generator assets. This removes the risk associated with multiple operators controlling the same plant which could result in operator error. The only exception is the indirect control that is possible when an embedded generator has remote inter-tripping.

Embedded generator with remote tripping

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.

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. 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 on site load from the network if the network supply comes from an alternative feeder. Various options are possible to obtain the desired operational requirement.

4.3 DNSP PREFERRED COMMUNICATION METHODS AND PROTOCOLS

Communications links may be required for protection (such as remote trips or differential protection) or for SCADA 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 may continue operation for up to 24 hours following loss of one of the communication links.

SCADA remote monitoring does not require high security (i.e. redundancy) however reliable communication links are required. Radio, microwave link etc. may be considered however it will need to be demonstrated that the method used is reliable.

Communications protocol

The communication protocol for remote monitoring shall be in a suitable format to allow integration into the DNSP's prevailing SCADA communication protocol (currently DNP3.0 level 2).

Protection communication protocols will use the native protocol of the matching protection relays 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. 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 may be bidirectional is load is also connected at the same connection point 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.

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.

5.1 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.

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.

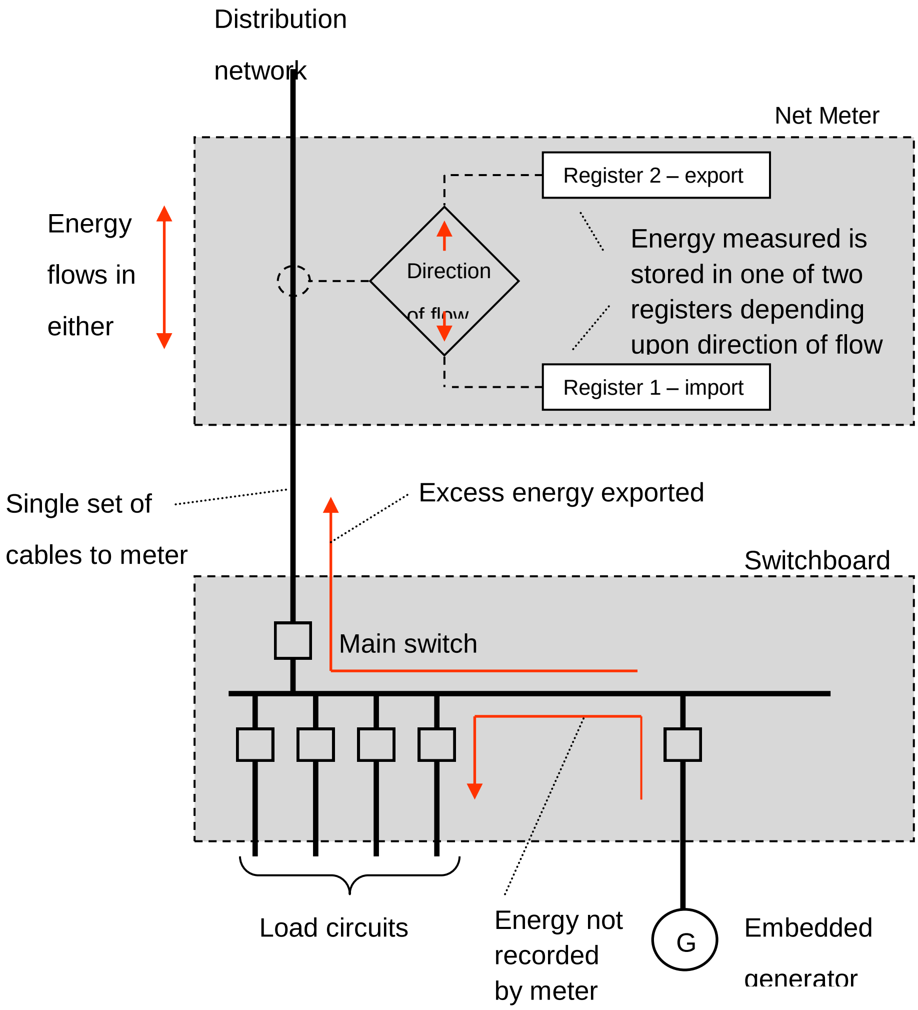
5.1.1 NET AND GROSS METERING

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.

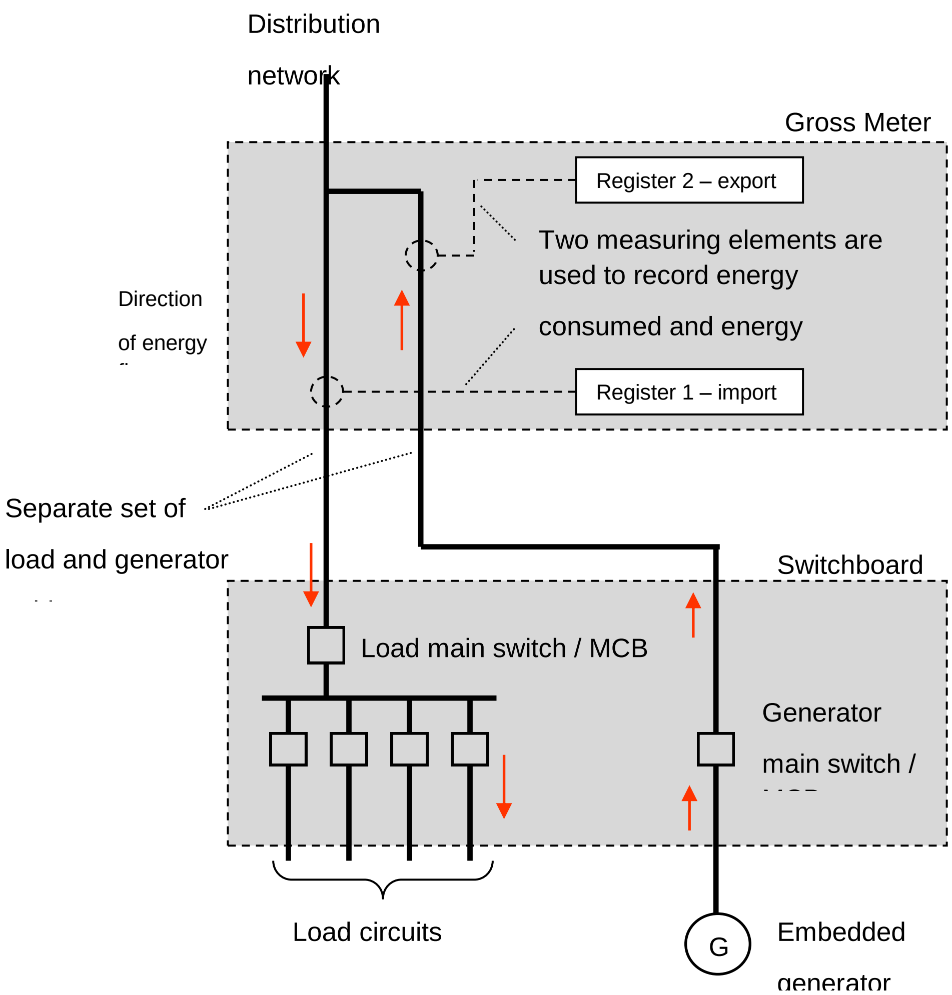
Figure 5-1: Example of a net metering configuration



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 5-2: 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.

5.2 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.

5.3 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:

1. 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[15] may be required to align with the market trading interval period for generators registered with AEMO in accordance with AEMO market settlement requirements.
2. The metering shall be installed and maintained according to the requirements of the applicable electricity law.
3. The meter shall be compliant with AEMO regulations.
4. The metering panel shall be compliant with the SIR.
5. The energy level shall be based on the generator output.
6. An AEMO registered Meter Provider and Meter Data Agent shall be engaged to provide metering and metering data collection and processing.
7. 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.
8. 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 METERING STANDARDS

Metering provisions

Metering provisions are to be consistent with the requirements of[16]:

- The National Electricity Rules, particularly chapter 7.
- Metrology Procedure: Part A – National Electricity Market.[17]
- Metrology Procedure: Part B – Metering Data Validation, Substitution and Estimation Procedure for Metering Types 1 – 7.

15 Ref. NER clause 7.9.3 and 9.9.9.

16 Ref. SIR clause 9.13

17 As of the 1/1/2007 the AEMO national metrology procedures superseded the Victorian Electricity Supply Industry Metrology Procedures that previously applied in Victoria.

- 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.
- 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 >1MW 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 net 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[18]:

- 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[19]:

[18] Ref. SIR clause 9.13.3.

- 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.

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

6. TESTING, COMMISSIONING AND MAINTENANCE REQUIREMENTS

6.1 TESTING

The generator is required to undertake suitable tests during commissioning to confirm compliance with the generator access standards as documented in the connection agreement including 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. Other testing may also be necessary to ensure the generator operates with the performance expected (such as energy efficiency).

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.[20]

Post commissioning tests may also be necessary, in respect of power quality issues, 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:

- Australian Standards.[21]
- Connection agreement.[22]

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.[23]

[20] Ref. NER clause 5.8.5(c)

[21] Ref. NER clause 5.7.3(a) and clause 5.8.1(a)

[22] Ref. NER clause 5.7.3(a) and clause 5.8.1(a)

[23] 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[24]:

- 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.[25]

6.1.1 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 current threshold levels.
- 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.

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[24] Ref. ESCODE clause 150.4.1, 2, 10 and 12

[25] Ref. ESCODE clause 170.2.1

6.1.2 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. However, prior 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.

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

6.3.1 MAINTENANCE PLAN

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.

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 3 years of record.

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.[26]

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.[27]

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.[28]

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.

[26] ESCODE clause 160, ESCODE clause 180.1, 2, 3 and 4

[27] Ref. NER clause 5.7.4(a)(2)

[28] Ref. NER clause 5.7.5(a)

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.[29]

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.[30]

[29] ESCODE clause 150.6

[30] 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 as part of the network planning processes. The generator is required to 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 generating system with 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[31]:

- 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.

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.

[31] ESCODE clause 220.1, 270.1 and 290.2

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 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 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 on-site 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 set point.

- 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 as applicable to the embedded generator.

On non-scheduled 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.[32]

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 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.[33]

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.

[32] Ref. NER clause 4.8.12(d)

[33] SIR clause 9.15.1

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[34]

Operations staff is 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:

- 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

[34] SIR clause 9.15.3

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 may be 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. SUMMARY OF GENERATOR TECHNICAL ACCESS STANDARDS

JEN Document ELE SP 0003 (Technical Access Standards for Embedded Generators greater than 5 MW) provides description of the automatic access and minimum access standards applicable for the connection of embedded generators greater than 5 MW in size to the Jemena distribution network.

For generating systems greater than 30 MW, refer to Schedule S5.2.5.5 within Chapter 5 (Network Connection, Planning and Expansion) of the National Electricity Rules found on the AEMC website - http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/Current-Rules

The table below provides a summary description of the standards for generating systems between 5 MW and 30 MW. Note that the summary description here is for information only. The detailed automatic and minimum standards are available in JEN Document ELE SP 0003.

Table 8-1: Summary Description of Technical Access Standards

Clause	Summary Description	Reference in Technical Access Standards Document (ELE SP 0003)	Reference in current document
Reactive Power Capability	This clause states the requirement on generating systems to supply and / or absorb reactive power so as to maintain an adequate steady-state voltage profile at the point of connection. The size and technology of the generating system along with site-specific requirements will dictate an acceptable negotiated access standard.	Section 2.2.1	n/a
Quality of Electricity Generated	This clause stipulates the requirement on the generating system to have an adequate quality for the electricity it generates. This includes power quality considerations such as voltage flicker, voltage step, harmonic emissions and negative and zero sequence current injections at the connection point. While negotiating the specific standard, JEN will consider the size and technology of the generating system, and the impact on neighbouring network equipment and customer installations.	Section 2.2.2	n/a
Generating unit response to	This clause requires that a generating system and each of its generating	Section 2.2.3	n/a

frequency disturbances	units must be capable of continuous uninterrupted operation for frequencies in the ranges for a given duration as prescribed by the *Reliability Panel*. There are separate requirements for the automatic and the minimum standard. This clause is an AEMO advisory matter.		
Generating unit response to voltage disturbances	This generating system and each of its generating units is capable of continuous uninterrupted operation within certain range of voltages for the given duration at its connection point. Depending on the size and location of the embedded generation, JEN may enforce a standard that is as close to the automatic standard as possible. This clause is an AEMO advisory matter.	Section 2.2.4	n/a
Generating System Response to Disturbances following Contingency Events	The clause requires that the generation system and each of its generating units remains in continuous uninterrupted operation for a disturbance caused by an event that is a three phase fault, two phase to ground, phase to phase or phase to ground fault (certain exceptions apply). This clause is an AEMO advisory matter.	Section 2.2.5	n/a
Quality of Electricity Generated and Continuous Uninterrupted Operation	This clause stipulates that the generating system including each of its operating generating units and reactive plant, will maintain continuous uninterrupted operation for voltage fluctuation, harmonic voltage distortion and voltage unbalance at the connection point up to set-defined levels (usually based on power quality standards AS / NZS 61000)	Section 2.2.6	n/a
Partial load rejection	This clause requires that each generating unit must be capable of continuous uninterrupted operation during and following a power system load reduction for certain duration. This clause is an AEMO advisory matter.	Section 2.2.7	n/a
Protection of generating systems from power system disturbances	This clause stipulates the protection systems to be designed and installed by the embedded generator in order to protection itself from abnormal system conditions. This includes protection for over / under voltage, over / under frequency and islanding conditions. This clause is an AEMO advisory matter.	Section 2.2.8	Section 3.6
Protection systems that impact on	This clause prescribes the design of primary, backup and breaker fail	Section 2.2.9	Sections 3.2, 3.3, 3.7

power system security	protection systems that help maintain power system security in the event of faults within the distribution network, transmission network as well as within the generating system. This clause is an AEMO advisory matter.		
Protection to trip plant for unstable operation	The generating system is required to install protection systems to prevent its unstable operation from impacting the wider distribution and transmission system. This clause is an AEMO advisory matter.	Section 2.2.10	Sections 3.4, 3.5
Frequency Control	This clause stipulates the response of the embedded generator's governing system to changes in system frequency. This clause is an AEMO advisory matter.	Section 2.2.11	n/a
Impact on Network Capability	A generating system must have plant capabilities and control systems that are sufficient so that it does not reduce any inter-regional or intra-regional power transfer capability and it does not adversely impact the quality of supply and performance of any of customers connected to the distribution system. This clause is an AEMO advisory matter.	Section 2.2.12	n/a
Voltage and Reactive Power Control	This clause requires embedded generators to have excitation systems to regulate voltage, power factor or reactive power at their connection point. The excitation system should be designed and tuned such that it operates in a stable manner and has adequate response characteristics. This clause is an AEMO advisory matter.	Section 2.2.13	n/a
Active Power Control	The generating system must have an active power control system that controls the rate of change of active power. This clause is an AEMO advisory matter.	Section 2.2.14	n/a
Remote Monitoring	This clause stipulates the requirement to have adequate remote monitoring equipment and monitoring from the control room (JEN and / or AEMO) of power system quantities such as voltage, current, active power, reactive power etc. This clause is an AEMO advisory matter.	Section 2.2.15	Sections 4.1, 4.2
Communications Equipment	This clause states the communication facilities and their reliability, required for communications between the control room (JEN and / or	Section 2.2.16	Sections 4.3

	AEMO) and the embedded generator. This clause is an AEMO advisory matter.		
Fault Current	The contribution of 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 within the connecting network does not exceed the limits as set in the Distribution Code	Section 2.2.17	Section 2.6