
Protection Requirements of Embedded Generators < 5 MVA (LV + HV up to 22KV)

Standard Operating Procedures

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Protection Requirements of Embedded Generators Policy

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5	22/01/2021	Update to summary of prot requirements	H. Al-Khalidi	P. Ascione

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Protection Requirements of Embedded Generators Policy

1 PURPOSE

This policy focuses on AusNet Services protection requirements for connection of embedded generator systems to AusNet Services distribution network to maintain the health and safety of personal and integrity and reliability of customers and network assets.

It has been noted lately that number of requests for new connections or upgrade of an existing connection has risen. Due to the network geographical nature and configuration, each connection will encounter different challenges and constrains based on generation capacity and arrangement. There may be additional protection requirements over and above those specified in this document to accommodate site specific requirements.

Normally, a zero export system will be requested when limited export is required, but other proposals (limited or reduced export) will be considered. Limited export systems will usually require additional cost to the proponent to undertake review of the proposed control mechanism and also to provide test reports to confirm performance of the control system. Refer to SOP 33-06 for systems to 200 kVA.

This policy does not preclude adherence to any other technical/Regulatory obligations such as the customer's compliance with other Standards, including the Victorian Service and Installation Rules (VSIR,s), AS/NZS3000, the Electricity Distribution Code including Clauses 4.8 and 7 , Good Industry Practice and any other relevant AusNet Services policies or requirements e.g. Communication Policy.

AusNet Services do not approve individual products and as a result no list of approved products is published. It is the customer's responsibility to maintain their system to perform in accordance with the agreed Connection Agreement. Variations from the agreed position could result in the System being "locked out" or other commercial penalty. It is expected that generators and generation ancillary equipment meets Australian Product or Equipment Standards when available or recognised International Standards which define acceptable performance.

2 SCOPE

The document addresses the minimum requirements based on each type and size of generation where it splits them into bands, and each will be addressed separately. This document is not intended to provide guidance on the design, protection or operation of embedded generators.

The following is the basis for AusNet Services protection requirements;

General Concept

- Protection transformers to be located at point of connection
- Maximum time for primary and back up protection to disconnect from grid <3 sec of network loss
- If protection is communication dependent, then must disconnect from grid in a maximum of 30 seconds of communication's failure
- For larger generators AusNet Services must have remote capability to disconnect generator
- A formal agreement with AusNet Services is required to permit operation of any generating system output in parallel with the electricity network, including zero export generating systems.

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The customer's electrician has other obligations which impact on network performance and safety, which are included in the installation obligations according to the Electricity Safety Act, the Service and Installation Rules and include compliance with AS/NZS 3000, AS/NZS 3010, AS/NZS 4777 and AS/NZS 5033.

Electricity Network requirements of the performance of a customer's installation and its impact on the electricity network need to focus on the obligations of each party at the Connection Point. This focus is clear for the impact of load connections, which is articulated by the Victorian Service and Installations Rules (VSIR). The VSIR's and the Victorian Distribution Code provide technical obligations for customers, Alternate Supplies and Embedded Generators, but do not cover all the issues now arising associated with higher levels of penetration of generating systems and two-way power flow. Additional technical requirements have been developed by individual DNSP's to enable certainty in the technical connection requirements.

3 ABBREVIATIONS AND DEFINITIONS

NOTE: National Electricity Rules definitions have been used when available. The common term Generator is equivalent to the defined term for an embedded generating unit or generating unit – generating unit and embedded generating unit are used interchangeably in this document and apply as required either for a generating system or embedded generating unit/s or micro EG connection.

Term	Definition
CEC	Clean Energy Council
CHP	Combined Heat and Power
Cogeneration	A generator which also operates with a CHP function
Connection Point	The agreed point of supply established between AusNet Services and the customer
embedded generating unit (EGU)	A generating unit connected within a distribution network and not having direct access to the transmission network. NOTE: Includes storage devices, synchronous condensers, generators with zero export, UPS connected to the electricity network via a line interactive reactor (choke).
embedded generator	Means a person that owns, controls or operates an embedded generating unit.
Installed Capacity	The combined Rating of one or more EGU installed within an electrical installation.
Inverter Energy System (IES)	An EGU system comprising one or more inverters together with one or more energy sources (which may include energy storage) and controls.
Energy Source	Any source of energy requiring conversion from one kind of energy to real or reactive A.C. electrical energy suitable for connection to the grid. NOTE: Examples include wind turbine, stored mechanical energy, hydro turbine, battery energy storage, fuel cell or solar photovoltaic.
LoM	Loss of Mains, protection also called anti-islanding protection
Islanding	Disconnection of section of network from the rest of the grid while power is supplied by an EGU connected to the section.
generating unit	The plant used in the production of electricity and all related equipment essential to its functioning as a single entity.
generating system	A system comprising one or more generating units and includes auxiliary or reactive plant that is located on the Generator's side of the connection point.

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Term	Definition
Generator	A person who engages in the activity of owning, controlling or operating a generating system that is connected to, or who otherwise supplies electricity to, a transmission or distribution system
micro EG connection	means a connection between an embedded generating unit and a distribution network of the kind contemplated by Australian Standard AS/NZS 4777 (Grid connection of energy systems via inverters).
NER	National Electricity Rules
Rating	The continuous or nominal rating of a generating unit in kVA
Trigeneration	Generation system which utilises waste heat from the generation process to be utilised for heating and to run an absorption chiller to provide cooling.
UPS	Uninterruptible Power Supply

4 PROTECTION REQUIREMENTS OF EMBEDDED GENERATORS

The following protection requirements have been written to provide the Generator with details that must be considered in the processing of a connection enquiry or an application to connect.

Regardless of the type of LoM installed, the Generator must accept that LoM may not be able to be set to discriminate with other protection systems on the AusNet Services network. Therefore, the Generator must accept that the generating units may trip for system disturbances and fault events both within and external to the local network that the generating system is connected to. This is particularly relevant for Vector Shift and Rate of Change of Frequency (RoCoF) protection where experience has shown setting of these schemes to be difficult to avoid nuisance tripping while providing adequate protection.

It is recommended that proponents design protection and control systems where the main and backup LoM protection trips circuit breakers/contactors which only control the generating system and do not control other loads within the customers' installation. Therefore, any nuisance tripping as described above will not cause a loss of supply to the customer, in particular to any critical loads.

AusNet Service will request the Generator to provide a protection study in cases where the proposal is for a large, complex generating system, or if AusNet Services perceive there could be difficulty in obtaining suitable co-ordination. A requested protection study is not a protection study to meet the Generator installation protection requirements. The study required, is to review AusNet Service's needs, which in this case is mainly the Interconnection Protection with a review of the installation protection to understand the performance of the integrated protection proposed. The Generator will also require an internal installation protection study to be undertaken.

4.1 ACCESS AND PERFORMANCE STANDARDS

The NER Schedules S5.2.5 and S5.2.6 refer to various performance standards that a Generator needs to consider for its detailed connection enquiry. During the preliminary response to the connection enquiry AusNet Services provides to the Connection Applicant written details of applicable standards and the normal voltage levels. These standards may be different depending on the various power system conditions at the proposed location of the connection.

For each standard, the NER defines an automatic, minimum and negotiated access standard (AAS, MAS and NAS). Please note all generators must meet the MAS. If a Generator meets the AAS, no further negotiation is required. If a generating system capability falls between the

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minimum and automatic standard, then a negotiated access standard must be agreed with AusNet Services. The NER describes the philosophy to underpin negotiations for these standards.

The Generator must be able to demonstrate compliance to the proposed standards by performing required studies and during commissioning tests.

4.2 GENERATOR PROTECTION

Generating unit and generating system/s protection is the responsibility of Generator.

All multi-phase embedded generating units must ensure that the A.C. output current shall be generated and injected into the multi-phase electrical installation as a multi-phase balanced current and should comply with;

- AS60034.1 Clause 7.2.2 or equivalent Standard
- AS/NZS 4777.1 Table 1
- AS/NZS 4777.2 Clause 10.5

Generally, AusNet Services does not specify what protection is required to protect the EGU; however in some special circumstances AusNet Services may require additional functions. The customer will be notified accordingly after an assessment is made.

On many occasions following a fault and associated disconnection of the AusNet Services electricity supply to a customer's installation an automatic reclose may be initiated following a delay period of up to 8 seconds. Failure of the customer's protection equipment to disconnect a generating unit prior to the automatic switching may result in damage not only to AusNet Services electricity network but also to the generating unit.

NOTE: The generating system control and synchronisation must occur at the generating system circuit breaker associated with the generating units' protection. Generating system reconnection can only occur once the distribution network has maintained stable supply conditions for more than 1 minute.

4.3 CUSTOMER INSTALLATION PROTECTION

This document does not cover the customer's protection obligations as required by;

- Electricity Safety Act, Electricity Safety (Installations) Regulations and other Australian Standards including AS/NZS3000, NOTE: Under AS/NZS 3000 the installation must incorporate protection against dangers and damage which take account of current flow directions and polarities.
- Distribution Code – In particular Section 7.
- Victorian Service and Installation Rules – Clause 6.8

4.4 INTERCONNECTION PROTECTION

Interconnection protection is a collective of protection relay's functions that operates the interface switch and blocks its closure. It's essentially required to permit a generating system to be connected to the electricity grid, to enable it to operate in a grid interactive mode. Interconnection protection must be located near the point of supply at the main switchboard and will control the operation of the main switch or generating system circuit breaker. In approved cases, the Interconnection Protection could initiate a trip of the generating system circuit breaker via a reliable system and secure communication path.

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Interconnection Protection function is to:

- Disconnect the generating system should the grid supply be interrupted for safety or operational needs. – Generally called anti-island protection.
- Protect the electricity network and other network customers from damage caused by connection of the generating system for legal and quality of supply needs (e.g. Machine Based generation, such as an induction generator, is capable of producing up to 2 times the rated voltage under certain fault conditions and is capable of producing up to several (6) times its rated current under certain fault conditions.) As a result, protection elements such as overcurrent and earth fault must be bidirectional to detect current flow from the grid and to the grid.
- For up to 22kV high voltage customer installations, the HV/LV interconnecting transformer must be delta/star with interconnection protection including Neutral Voltage displacement

All induction or synchronous generating units which are grid connected must incorporate the specified interconnection protection as a minimum. Loss of excitation from the grid is not sufficient to provide anti-island protection.

Any anti-island protection must disconnect the generating system in the dead time of the AusNet Services reclose function so as to protect the generating system from damage. Besides safety considerations this is a compelling reason why the Generators must provide interconnection protection within their installation which must conform to AusNet Services' requirements.

AusNet Services will require deadline blocking of the close function for all generating systems. A stable electricity supply from the grid must be present for all connected phases for a period of at least 1 minute before synchronising the generator is attempted. With many evolving network configurations such as independent minigrids and embedded networks this requirement is a very important consideration in the design of these alternatives.

The Designer needs to provide their proposed interconnection settings to AusNet Services for approval, comply with to the Victorian Service and Installation Rules or the settings provided by this document.

4.5 LOCATION OF MAIN SWITCHBOARD

AusNet Services must provide protection for the service line up to the Installation protective equipment as required by Electricity Safety (Installation) Regulations Clause 233,234 and 235. AusNet Services will not provide primary or backup protection beyond the installation's main switchboard. The main switchboard must be located as determined by the VSIR's and AS/NZS 3000 for low voltage installations and for HV installations within 15m of the point of supply.

4.6 AUSNET SERVICES DISCONNECTION

For generating systems with nameplate larger than 1.5 MVA, AusNet Services must have the ability to direct the disconnection of the generating system or the entire customer installation from the rest of the distribution network. This facility is provided by the Generator and controlled via normal control room to control room agreed operating procedures. In addition, AusNet Services must be able to independently disconnect the generating system under emergency conditions without reference. Due to the advent of remote-controlled enclosed switches, a remote controlled bi-directional a NOJA RC20 control box with ROCOF protection ACR with communication to customer MSB set to a single trip (no reclose) is required to be installed onto the electricity network adjacent to the connection point. The Generator needs to provide coordination for faults internal and external of site.

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The ACR structure provides:

- isolation point
- additional protection – Supply Capacity Control Device (in both directions) and a Supply Protective Device
- SCADA point for site communications with AusNet Services

4.7 INTERCONNECTION PROTECTION REQUIREMENTS

The following requirements define the minimum Interconnection Requirements only. Typical connection arrangements are shown in Appendix B.

Band	Classification Band	Technical Definition	Requirements	Typical Installations
Band 1	Micro	Installed Capacity less than or equal to 5kVA; usually AS/NZS 4777 compliant; installed within a (domestic) customer installation and connected to the LV network via the customer service connection. Exempt from holding a Generator licence	As required by Appendix A and compliance with AS/NZS 4777 Series as required.	Inverter connected plant; Domestic roof top PV, micro wind turbines, run of stream micro hydro.
Band 2	Mini	Installed capacity greater than 5kVA single phase up to 15kVA three phase; connected to the LV distribution and generally installed within a customer installation; not necessarily AS/NZS 4777 compliant. Exempt from holding a Generator licence	Unless limited export to SOP 33-06 must be connected to a multiple phase supply, Protection requirements Appendix A NOTE: Max single phase export limit for a 230/400v or 230/460v system is 5kVA per phase, max single phase export limit to a SWER system is 3.5kVA per phase where two phases are available 2 x 3.5 kVA	Larger PV systems, Fuel cells; combined heat and power systems (CHP); mini hydro; mini wind turbines
Band 3	Small	Installed capacity greater than 15kVA three phase up to 1.5 MVA and connected to the LV network; not necessarily AS4770 Compliant. Generally exempt from holding a Generator licence	3a - > 15kVA to 30kVA Must be connected to a three-phase supply, and includes systems of multiple AS/NZS 4777 compliant inverters which will require compliance with Appendix A Maximum out of balance of no more than 20A. If single phase inverters or micro inverters used the installation must comply with Table 1 of	Induction machines - biomass, landfill, small hydro, individual wind turbines, gas & diesel fuelled engine, small hydro; fuel cells; DC storage/inverter feeds. Multiple connections within an Embedded Network. 3a Customer to provide Single Line Diagram and generator technical details

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Band	Classification Band	Technical Definition	Requirements	Typical Installations
			<p>AS/NZS 4777.1. Non-IES generation must provide a balanced output across all phases. Phase balance protection may be required.</p> <p>3b - > 30kVA to 200kVA Must be connected to a three-phase supply only, protection requirements according to Appendix A. Non-IES generation must provide a balanced output across all phases. Phase balance protection may be required.</p> <p>3c - >200kVA to 1.5MVA Must be connected to a three-phase supply only, protection requirements according to Appendix A</p>	<p>3b Customer to provide Single Line Diagram and generator technical details. Small possibility of protection and system studies being required (generally required if the site is remote from the zone substation)</p> <p>3c Customer to provide Single Line Diagram and generator technical details. Generally protection and system studies will be required</p>
Band 4	Medium	<p>Installed capacity greater than 1.5MVA but no more than 5MVA, connected to either LV or HV network. This Band includes Embedded Generator connections within a HV customer installation.</p> <p>Generally exempt from holding a Generator licence</p>	<p>> 1.5MVA to 5MVA Must be connected to a three-phase supply, Protection must include a direct trip scheme (optional for IES but require Noja RC20 at POC).</p> <p>Protection requirements according to Appendix A and SCADA required in accordance with Appendix D.</p>	<p>Single or grouped large induction or smaller synchronous machines – biomass, landfill, hydro, solar or wind farm, solar thermal, gas & diesel fuelled engine drives; Large scale storage plus inverter feeds. Customer to provide Single Line Diagram and generator technical details. Protection and system studies will be required</p>
Band 5	Large	<p>Having a name plate rating greater than 5MVA. Market registered and required to meet NER requirements</p>	<p>Generally in accordance with Band 4 but each proposal will be reviewed and must comply with the NER and AusNet Services requirements including a direct trip scheme.</p>	<p>Single or grouped synchronous or power electronic controlled induction machines - windfarms, solar farm, hydro, solar thermal, gas & diesel fuelled plant</p>

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5 Protection

This section provides specific detail associated with the interconnection requirements of generating units on AusNet Services' distribution network.

5.1 LOCATION

Interconnection protection measurement (Protection Transformers) must be located on the main switchboard or adjacent to the main switchboard as agreed by AusNet Services and cannot be installed at a remote Generator Switchboard. An Interconnection Protection Distribution Board located within 5m of the Main Switch board will be considered.

A Staged/remote tripping of the Generator breaker rather than at the main switchboard circuit breaker will be considered provided a reliable communications path to trip the embedded generator/s is installed. Staged/remote tripping if proposed must incorporate a loss of communication trip of generation within maximum of 30 seconds.

If the customer's installation has multiple generators installed, interconnection protection operation must disconnect all generation installed at the customers installation.

5.2 RELAYS

Protection Relay manufacturer and model and proposed protection settings and schemes must be submitted for review by AusNet Services. However, AusNet Services will not assess or approve the actual protection relay but rather whether it provides the correct protection. The protection relays will be of Utility Grade, Generator class or subject to appropriate FAT testing of performance and accuracy.

'Utility Grade':

- Relays to IEC 60255 or ANSI/IEEE C37.90 etc.
- Installation to industry type practice
- Relays tested and maintained
- Relays set and configured correctly
- Relay manufacturer has dedicated technical support in Australia, preferably in Melbourne

5.3 PROTECTION TRANSFORMERS

Interconnection Protection must be capable of measuring

- Voltage to an accuracy of $\pm 1.5\%$ of the nominal value ($230\text{ V} \pm 3.45\text{V}$)
- Frequency to $\pm 0.2\%$ of the nominal value ($\pm 0.1\text{Hz}$) across its operating range of voltage, frequency and temperature.
- Current accuracy 1 percent.

Refer also to Section 6.1.

Protection Transformers shall comply with AS/NZS 60044 Series; Instrument Transformers.

Accuracy of current transformers is critical for effective co-ordination with AusNet Services protection; the design of protection systems must consider the consequence of incorrect co-ordination especially in schemes which incorporate zero export settings.

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5.4 PROTECTION CO-ORDINATION

Besides discrimination between protective devices as required by AS/NZS 3000, interconnection protection discrimination must also be considered. The proposed interconnection protection scheme, settings and co-ordination curves must comply with the Victorian Service and Installation Rules or the settings provided by this document or else are submitted to be reviewed by AusNet Services as part of the technical assessment before the customer proceeds with the installation. Low voltage connections will generally need to discriminate with the upstream substation lv fuse. All generating system larger than 200 kVA must be submit the proposed interconnection protection scheme, settings and co-ordination curves, to be reviewed by AusNet Services.

5.5 PHASE BALANCE PROTECTION

Phase balance current protection covering all generation at the customer’s installation must be provided for multi-phase installations having single phase generators which operate independently.

5.6 REVERSE POWER PROTECTION

Limited export systems less than 200 kVA are required to comply with SOP 33-06 and AS/NZS 4777.1 generator connections with export limitations, larger than 200 kVA must incorporate reverse power protection incorporating a hard trip setting. It is recommended that the design of the site limited export control system (Soft Limit) provide a suitable margin to permit the largest single load to be switched in a manner that will not impact on the reverse power protection.

Reverse Power protection will only monitor real power (kW), refer Figure 1 the setting must only operate on the x axis, and is not a form of anti-island protection.

Reverse Power settings must co-ordinate with any import or export Supply Capacity Control schemes for the installation, over current settings and installation power factor obligations.

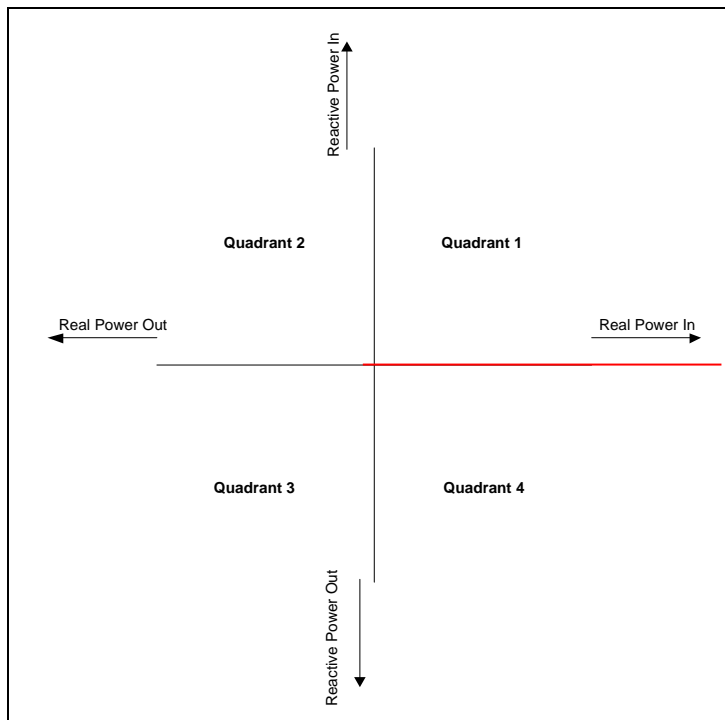


Figure 1

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5.7 REVERSE CURRENT PROTECTION

Reverse current protection generally will not operate within Quadrant 1 but can operate for a current flow setting in Quadrant 2, 3 or 4, dependent upon the torque angle setting. Reverse current protection may operate for a network fault. Reverse current protection will be taken into consideration in determining if an intertrip protection scheme is required.

It is very important to comply with either IEC or IEEE convention in relation to power factor in four quadrant operation.¹

6 OTHER CONNECTION REQUIREMENTS

6.1 RAPID EARTH FAULT CURRENT LIMITER (REFCL)

REFCLs can detect phase-to-earth faults. They then cancel the voltage on the fault within milliseconds of detecting it and limit the voltage of the fault to below the point where it can start a fire.² Many of AusNet Services rural 22 kV feeders have implemented this system which creates a situation whereby voltage conditions on the 22 kV electricity network are raised from 12.7 kV phase to earth Voltage to 24.2 kV phase to earth voltage. All customer impacted by REFCL must ensure that their high voltage equipment connected to the 22 kV electricity distribution network must be rated for a line to ground voltage of 24.2 kV.

For more information, refer to REF 30-10.

6.2 SINGLE LINE DIAGRAM

The customers Single Line Diagram (SLD) incorporating the protection scheme and initial settings must be submitted and reviewed as part of the technical assessment before the customer proceeds with the installation.

The agreed SLD will be included in one of the Connection Agreement Schedules.

Normal Drawing quality standards should be incorporated into any customer template including a Title Block with a minimum of the following;

- Drawing Title,
- Drawing Number,
- Designer,
- Approver,
- date of original,
- Sheet number and total number of sheets,
- Version control- including date, version number, brief description of amendment, etc.
- Refer to AS1100.101 Technical drawing Part 101: General principles, for examples.

6.3 STANDBY GENERATORS AND PLANT

The Generator protection requirements for switching standby plant are described below.

There is no additional interconnection protection requirement for a generator system which cannot parallel with the electricity distribution network. To maintain the safety of the electricity

¹ <http://www.schneider-electric.com/en/faqs/FA212521/>

² <https://www.energy.vic.gov.au/safety-and-emergencies/powerline-bushfire-safety-program/research-and-development/rapid-earth-fault-current-limiter>

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distribution network and the installation the designer and installer must comply with all relevant Standards including CT AS/NZS 3000, AS/NZS 3010, AS/NZS 3947.6.1 2001 and VSIR requirements. Particular attention to neutral wiring, earthing, active conductor isolation and interlocks is required to ensure the safety of the distribution network together with the installation safety. However there are additional requirements to meet the relevant Standards and Regulations e.g. operation of changeover devices, etc.

Note: A semiconductor (solid-state) device shall not be used for isolation purposes.

6.3.1 MAKE BEFORE BREAK

All line interactive UPS systems, including interactive systems incorporating line reactor (choke), are Embedded Generators as they are permanently connected to the electricity network.

All generators proposing a make before break generator system must consult with AusNet Services.

Generating systems must not connect to an un-energized distribution network and embedded generators must incorporate appropriate dead line blocking protection scheme.

6.3.1.1. AUTOMATIC TRANSFER SWITCH (ATS) SYSTEMS

Backup generating units with make before break transfer are classified as operating in parallel with the grid even though they may only be used as backup supplies and connect to the distribution network for short periods of time less than 1 second.

Any generator whose generating system operates in parallel with the grid must consult with AusNet Services of their proposal advising;

- Single Line Diagram of the proposal
- Transfer time and back up timer setting
- The protection settings of circuit breaker transfer switches and interlocking arrangements
- Earthing provisions, and
- Size of the generator

If a generating system is designed to synchronise and parallel with the distribution network via an ATS, its total combined rating per installation must be less than 1MVA otherwise formal Agreement with AusNet Services is required as the generating system is to be treated as an embedded generation.

Maximum parallel time permitted (Transfer time) is 100ms.

The transfer switch must be backed up with a 1 second delay backup timer which will operate to disconnect the generating system if the transfer has not been completed in this time.

Any generating system which connects to the grid for any duration must as a minimum install protection which incorporates u/o voltage and u/o frequency as a minimum by monitoring of voltage and frequency conditions at the ATS.

Other requirements for these embedded generation units, may also be relaxed (e.g. SCADA requirements) however this will depend upon the connection duration, generator size and other factors. Redundancy or fail-safe design is required to ensure the generator cannot parallel with the distribution network supply for more than the permitted time.

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6.4 DISTRIBUTION NETWORK FEEDER AUTOMATION (DFA)

AusNet Services has introduced rapid automatic fault restoration schemes which can transfer many customers electricity supply source from one feeder to another or even from one zone substation to another. This automatic switching to another source results in the removal of the generating system intertrip protection scheme and therefore the generating system must be removed from its connecting to the grid. Each generating system which has an intertrip protection scheme must incorporate logic to accommodate the network DFA scheme.

6.5 COMMUNICATIONS AND REMOTE MONITORING AND CONTROL

Refer also to Appendix D two different types of functions between the Embedded Generator and AusNet Services that require the communication services are:

1. Embedded Generator provided communications path from generator CB and Main Switch to the AusNet Services ACR so as to provide SCADA to AusNet Network Control Centre.

The following data points are generally required for any generator connected at 22kV or greater and embedded generation connected at low voltage of 1.5 MVA and above or incorporating a complex connection arrangement (dedicated or second methods of supply):

- MW (directional 3 phase)
- MVA_r (directional 3 phase)
- 3 x Phase Amps
- 3 x Phase to Phase Voltages and 3 x Phase to Ground Voltages
- Open/Close status of incomer feeder (site main switch)
- last trip Amp (R,W, B and N)
- generator c/b Open/Close status

Control scheme to facilitate,

- a) a remote trip of AusNet Services incomer ACR or
 - b) trip the embedded generator, subject to a suitable internal site failsafe tripping scheme and status.
2. If remote trip required (Intertrip), Embedded Generator to provide communication from Main Switch and (optional) generator CB, to all AusNet Services upstream protection device/s.

Note: If communications to incomer ACR - isolation of the two earthing systems is required either using a fibre optic path or intermediate relay to provide isolation.

6.6 CONTROL SYSTEMS REQUIRED

6.6.1 SYNCHRONISM CHECK

Synchronisation to the grid system can occur at the generator circuit breaker, at the Generator owned circuit breaker at the point of connection to the grid or, for AS/NZS 4777 compliant inverters at the disconnection device. Generator connection to the grid can only occur after the grid has been in a stable condition for more than 1 minute.

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6.6.2 COMMUNICATION LINKS REQUIRED AT POWER STATIONS

If the protection and control requirements call for an X & Y or duplicated requirement, two separate and independent optical fibre cables with diverse routes should be installed between the Embedded Generation Units and the zone sub or switching station. Sufficient cores should be provided in each optical cable for protection, control and communication functions.

6.7 RELAY AND TRIPPING SUPPLIES

Relay power supplies, tripping and circuitry associated with the interconnection and LoM protection systems must be fail safe. That is any failure of any part of the system must result in the generator being disconnected and unable to be re-connected to the electricity network.

Therefore, circuit breakers with shunt trips will not be acceptable. Where ac (or dc) supplies are proposed to be used, normally open contactors held in by healthy ac (or dc) volts or undervoltage release of circuit breakers on loss of ac (or dc) supply, relay fail and system fail will be required.

6.8 EARTHING REQUIREMENTS

The earthing system shall ensure the safety of personnel and the public, protect electrical installations, ensure correct system operations, and minimise interferences on other infrastructure. At a minimum the earthing system shall comply with all relevant Australian Standards, codes, and best industry practices. Potential earthing hazards shall be eliminated or adequately mitigated.

As embedded generation connections become an integral part of the distribution network once connected, they need to be designed such that any neutral earthing arrangements for the generators and any interconnection transformers suit the requirements of both the distribution network and the Connection Applicant's generation system.

Where these requirements are unable to be met, the Connection Applicant shall consult AusNet Services.

6.8.1 HV GENERATOR EARTHING REQUIREMENTS

To meet the automatic access standards the zero-sequence impedance of the generator observed from the network must be infinite. This is required to prevent earth fault current flowing between the network and the generator that can affect earth fault protection on the network.

Generator and transformer earthing will be reviewed and designed on a case-by-case basis by AusNet Services and the Connection Applicant.

6.8.2 LV GENERATOR EARTHING REQUIREMENTS

To comply with the automatic access standards the earthing system of an LV generator must provide satisfactory earthing independently of the AusNet Services network earthing system to prevent the generator from being a source for earth fault, limit any contribution to a network earth fault and inhibit the flow of harmonic currents through the neutral.

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6.9 COMMISSIONING AND TESTING REQUIREMENTS

6.9.1 PRINCIPLES

It is expected that the commissioning process will be directly managed by the Embedded Generator and witnessed by AusNet Services. It should be noted that AEMO may have requirements over and above the requirements of AusNet Services.

At the first stage of the commissioning process, the Embedded Generator must develop a commissioning plan and submit the plan to AusNet Services.

The Commissioning Plan requirements and requirements below must be developed commensurate with;

- the size (Band) of the generator
- Market Registration if applicable
- the VSIR's permissions and requirements
- Electricity Safety Acts and application of AS/NZS 3000 and other applicable Standards including AS/NZS 4777.1

The Embedded Generator is required to cooperate with AusNet Services to ensure that commissioning is undertaken in a manner that:

- does not adversely affect other customers connected to the network
- does not affect quality of supply, particularly to customers connected to the same part of the network; and
- minimises the risk of damage to the equipment of the network or other customer connected to the network

The Embedded Generator is responsible for specifying and undertaking commissioning tests and providing evidence to AusNet Services that demonstrates the performance of the plant. The commissioning tests of interest to AusNet Services are considered a part of the overall commissioning activities, with AusNet Services expecting that the Embedded Generator would have additional commissioning requirements.

General principles applied for the commissioning of generating systems connected to the AusNet Services network are:

- Commissioning tests are undertaken on site, FAT are not acceptable for Commissioning test
- Evidence of FAT may be requested for individual items of equipment
- Commissioning test usually require direct injection of primary current or voltage as required although secondary injection which incorporates additional performance tests might be required to meet particular circumstances such as high current central protection
- Commissioning tests are intended to provide evidence to AusNet Services at the time of commissioning that a generating system may remain safely connected to the power system, and if required the generating system meets the Registered Performance Standards and any other technical requirements specified in the connection agreement.
- AusNet Services requires the applicant to compare the actual recorded results with the results expected from design or modelling. Once a model is verified under one set of conditions, it is assumed to be verified for other sets of conditions in the model
- The Embedded Generator shall provide an opportunity for AusNet Services to witness any tests if requested. As a result the AusNet Services must be advised of the date of the proposed Commissioning date (min 5 working days' notice) to enable AusNet Services to witness the tests if we choose

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- AusNet Services may request any tests to be repeated if the test results do not demonstrate compliance with the agreed performance
- Independent equipment is to be installed to collect commissioning results separate from the device under test; and the resolution and accuracy of the test instruments, for both time and recorded value, are suitable to measure the response

6.9.2 DEMONSTRATION OF PERFORMANCE STANDARDS

During commissioning, the applicant must demonstrate that its generating system meets or exceeds the Registered Performance Standards. Wherever practicable, the performance of the generating system must be demonstrated by test. Particular performance standards and the associated testing will be discussed on a case-by-case basis.

To robustly demonstrate the performance of the generating system against all performance standards, AusNet Services requires that commissioning tests demonstrate that the actual plant performance meets the expected plant performance within predefined and agreed tolerances. The requirements for how the test will be assessed will be agreed on a case-by-case basis.

Commissioning tests are undertaken under power system conditions at the time of commissioning; however, the comparison of actual results against the design or modelled results provides reasonable evidence that the generator may remain in service for the full range of power system conditions according to its design.

The generator must advise AusNet Services that the generating system is able to comply with each of the Registered Performance Standards.

If the results show a failure to meet a generating system's Registered Performance Standard or model, AusNet Services may halt or modify the commissioning process of the generator if there is a risk of damage to the power system or other safety concerns. Where the generating system is connected and acts inconsistently with its Registered Performance Standards at commissioning, AusNet Services may also constrain the output of the generating system to any output (including zero), or otherwise disconnect the plant.

6.9.3 HOLD POINTS

AusNet Services will nominate specific points in the commissioning plan on a case-by-case basis, at which the generator must submit results for AusNet Services to review prior to progressing further with commissioning. Broadly, AusNet Services may require the applicant to submit commissioning test results prior to energisation or synchronisation occurring and through a staged release of capacity. This process allows the demonstration of Registered Performance Standards through testing at various pre-agreed output levels. Typically, hold points will be established at minimum load, and 50% and 75% of maximum output of the generating system or generating unit.

6.9.4 DEVELOPING A COMMISSIONING PLAN

As the first stage of the commissioning process, the applicant must develop a commissioning plan and submit the plan to AusNet Services. The commissioning plan including the proposed commissioning program dates, must be submitted at least three months prior to when commissioning is expected to take place for a transmission connected generating system and a minimum of one month prior to when commissioning is expected to take place for a

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distribution connected generating system. Generally smaller IES systems to 200 kVA would generally require a minimum of 5 working days.

The plan is then reviewed by AusNet Services. AusNet Services may also request further information in relation to the proposed plan, including test procedures or data capture and storage methods.

If AusNet Services identifies any concerns, the parties will negotiate changes to the commissioning plan until a final plan is agreed.

AusNet Services must notify the registered participant that they agree with the proposed commissioning plan or require changes to it in the interest of maintaining power system security, safety of operation, and quality of supply.

6.9.5 COMMISSIONING TEST PLAN REQUIREMENTS

The NER do not detail any specific commissioning tests that must be undertaken by a registered participant. Instead, as technologies, types and the specific installation (either in installed equipment or settings) may vary from site to site, it is expected that the tests will be tailored to the requirements of the installed equipment and settings.

The commissioning plan must include a list of commissioning tests to be undertaken, providing:

- a description of the purpose of the test, outlining
- the equipment under test
- which performance standard will be assessed
- what comparison against the expected result
- the proposed dates for test
- the proposed duration of test
- measurement equipment; and
- any specific network conditions

The plan must allow for hold points and include a proposal for evidence to be provided at each hold point.

The commissioning plan may include other commissioning tests; however, it must show clearly which tests are intended to demonstrate the performance of the generating system against the Registered Performance Standards.

AusNet Services may request a specific commissioning test procedure for further clarity regarding a particular test.

6.9.6 UNDERTAKING COMMISSIONING

Preconditions to Online Commissioning

Prior to commencing online commissioning of a generating system, the following must be completed:

- approval of commissioning plan for the generating system
- registration of the generating system; and
- commissioning of SCADA systems relating to the generating system

Protection Requirements of Embedded Generators Policy

Provision of Commissioning Status Advice

As commissioning activities may be subject to rescheduling due to on-site works and issues, AusNet Services may request that the applicant provide regular updates regarding commissioning. These updates may be requested on a weekly or daily basis depending on the impact of the generating system on the local network. This status advice may also provide an opportunity to review and update the commissioning plan.

6.9.7 UNDERTAKING A COMMISSIONING TEST

As commissioning activities may impact on the network, specific actions may be required prior to undertaking online commissioning tests. For these tests, AusNet Services requires that the applicant:

- advise appropriate contact details in advance of commissioning
- contact the AusNet Services commissioning engineer prior to commencing a commissioning test that
 - a. may impact the MW, MVA_r, voltage or frequency of the generating system; or
 - b. has the potential to impact the performance of the generating system as outlined in the Registered Performance Standards or any other network configuration and
- follows all appropriate operational and market protocols – including reflecting its commissioning activities in its interaction with electricity market systems

The AusNet Services control room may, at its sole discretion and to manage quality of supply to customers, require the delay or cancellation of a commissioning test due to system conditions at the time.

6.9.8 COMMISSIONING RESULTS

During the preparation of the commissioning plan AusNet Services will nominate any tests that need to be reviewed prior to undertaking further testing and any other test results that need to be submitted as they become available.

The output of the generating system will be restricted, and testing will not be permitted at higher output levels until a review of the commissioning test results is completed. Once AusNet Services has reviewed the commissioning test results for each hold point, AusNet Services will allow the generating system to progress beyond that hold point.

6.9.9 COMMISSIONING REPORT

A draft commissioning report must be submitted to AusNet Services no more than two weeks after the completion of commissioning. This commissioning report must:

- outline the commissioning tests undertaken on-site
- compare expected performance (modelled) with on-site performance; and
- outline the conclusions drawn regarding compliance with the NER, compliance with the design and consistency with the model

For more information, refer to SOP 33-07.

Protection Requirements of Embedded Generators Policy

6.10 NETWORK AUGMENTATION

As a guide, a generating plant of capacity below 1 MVA is generally not connected to the high voltage distribution system. This limit is indicative only as it depends on many factors including the location, generators size, network short circuit rating, the nature of other loads and local factors. It is sometimes necessary to augment the network to accommodate the proposed generation to comply with the required quality of supply to other customers.

The connection process will identify the extent of network extension and augmentation that is required to facilitate a generation connection. The shared network augmentation will be undertaken according to AusNet Services' standards.

Connection costs undertaken to enable the connection of the generation system will be funded by the customer in accordance with Regulatory requirements.

6.11 MAINTENANCE

A routine maintenance plan of primary and secondary protection equipment incorporating verification of overall system performance must be developed and implemented as required by AS/NZ3000 and AS/NZS 4777.1 and the manufacturer's requirements. Any unique maintenance requirements should be incorporated into the Connection Agreement.

6.12 RESOURCE REFERENCES

Document ID	Document Title
30-4161-05	Distribution Design Manual, Commercial/Industrial
<u>AS/NZS 3000</u>	Wiring Rules
<u>AS/NZS 3010</u>	Electrical installations—Generating sets
<u>AS/NZS 4777</u>	Grid connection of energy systems via inverters
<u>AS60034.1</u>	Rotating electrical machines: Part 1: Rating and performance
<u>ENA DOC_030-2011</u>	ENA Guideline for the preparation of documentation for connection of Embedded Generation within Distribution Networks
<u>SOP 33-05A</u>	Embedded Generator Connection Enquiry Form
<u>SOP 33-05</u>	Guidelines for the Connection of Embedded Generators Greater than 5MW
<u>SOP 33-06</u>	Export limits for Embedded Generators up to 200 kVA connected at Low Voltage
<u>SOP 33-07</u>	30kW to 200 kW: Central Protection Commissioning Test Report
<u>SOP 33-08</u>	Solar PV Generator - Power Quality Compliance Requirements
VSIR	Victorian Service and Installation Rules

Protection Requirements of Embedded Generators Policy

6.13 APPENDICES

APPENDIX A: SUMMARY OF EMBEDDED GENERATORS INTERCONNECTION MINIMAL PROTECTION REQUIREMENTS

APPENDIX B: PROTECTION SCHEME EXAMPLES

APPENDIX C: TYPICAL INTERCONNECTION PROTECTION SETTINGS

APPENDIX D: COMMUNICATIONS FOR SCADA AND PROTECTION (INTERTRIP)

APPENDIX E: SUPPLY PROTECTION DEVICE

The preferred SCADA path is via the AusNet Services ACR located on the network adjacent to the connection point as described in Clause 6.5

SCADA remote monitoring does require reliable communication links that not necessarily of a high security (i.e. redundancy) to comply with the automatic access standards. Licensed or unlicensed radio, microwave link, internet based communications or other methods may be considered however it will need to be demonstrated that the method used is reliable.

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APPENDIX

E:

SUPPLY

PROTECTION

DEVICE

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APPENDIX A: SUMMARY OF EMBEDDED GENERATORS INTERCONNECTION MINIMAL PROTECTION REQUIREMENTS

Protection Requirements	Generator Rated Name plate						
	LV			HV		HV Non-Export	
	< 30kVA	30kVA to < 200kVA	200kVA to 1.5MVA	>1.5MVA to 5MVA	> 5MVA	1.5MVA to 5MVA	
50/51 P Phase Overcurrent		M ¹	M ¹	M ¹		M ¹	
50/51 N Neutral Overcurrent		O	O	M	In addition to NER, AusNet Services requirements are to be negotiated on a case by case basis	M	
27/59 Under/Over Voltage	To AS/NZS 4777 or compliant with 30 kVA to 200 kVA of this Table	M	M	M		M	
59N Neutral Voltage Displacement		O	O	M		M	
81U/81O Under/Over Frequency		M	M	M		M	
81R RoCoF		M	M	M		M	
78 Vector Shift		M ²	M ²	M			
46 Phase Balance Current		M ³	M ³	M ³			
32 Reverse Power				AR		O	M
67 Reverse Current				AR		O	AR
94 Intertrip						M ⁴	M
50M Communication Failure					M		M
Dead Network Line Block Gen C/B Close	M	M	M	M		M	
M Mandatory O Optional AR As Required				³ As Required if not generator integrated See Clause 5.5		⁵ Alternate schemes may be considered	
		¹ To meet AS/NZS 3000		² Not Required for IES		⁴ Required if non IES and ≥1.5MVA	

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APPENDIX B: PROTECTION SCHEME EXAMPLES

The following are examples of typical connections which meet the requirements of this standard. These are examples only. The specific design will be a function of the customer network and may require different arrangements.

If the installation has any Safety Services Circuits no grid connected generation including IES can be connected to these circuits

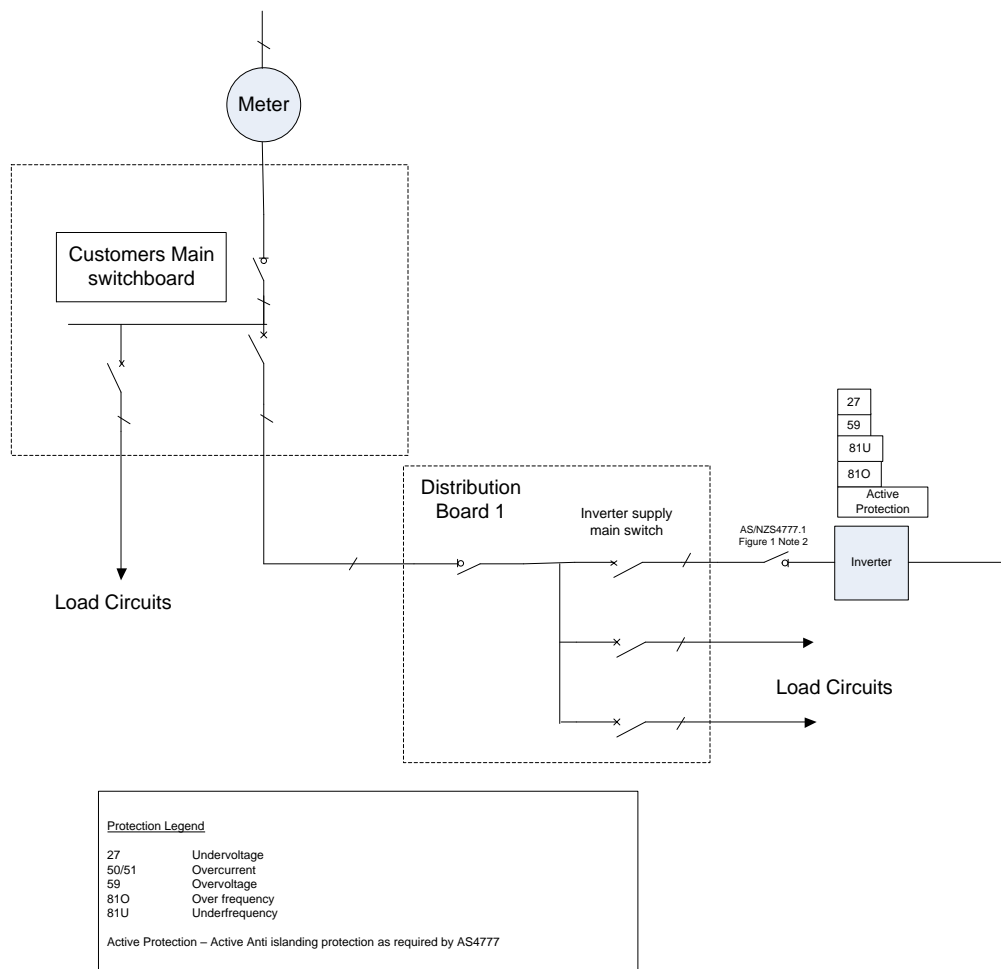
Inverter Energy Systems

The following provides the typical requirements. The customer is responsible for the protection of their installation including the IES system and other equipment within their installation

In addition to the IES being compliant with AS/NZS 4777 any IES equal or greater than 30kVA to less than 200kVA will require additional protection at the customer’s main switch position.

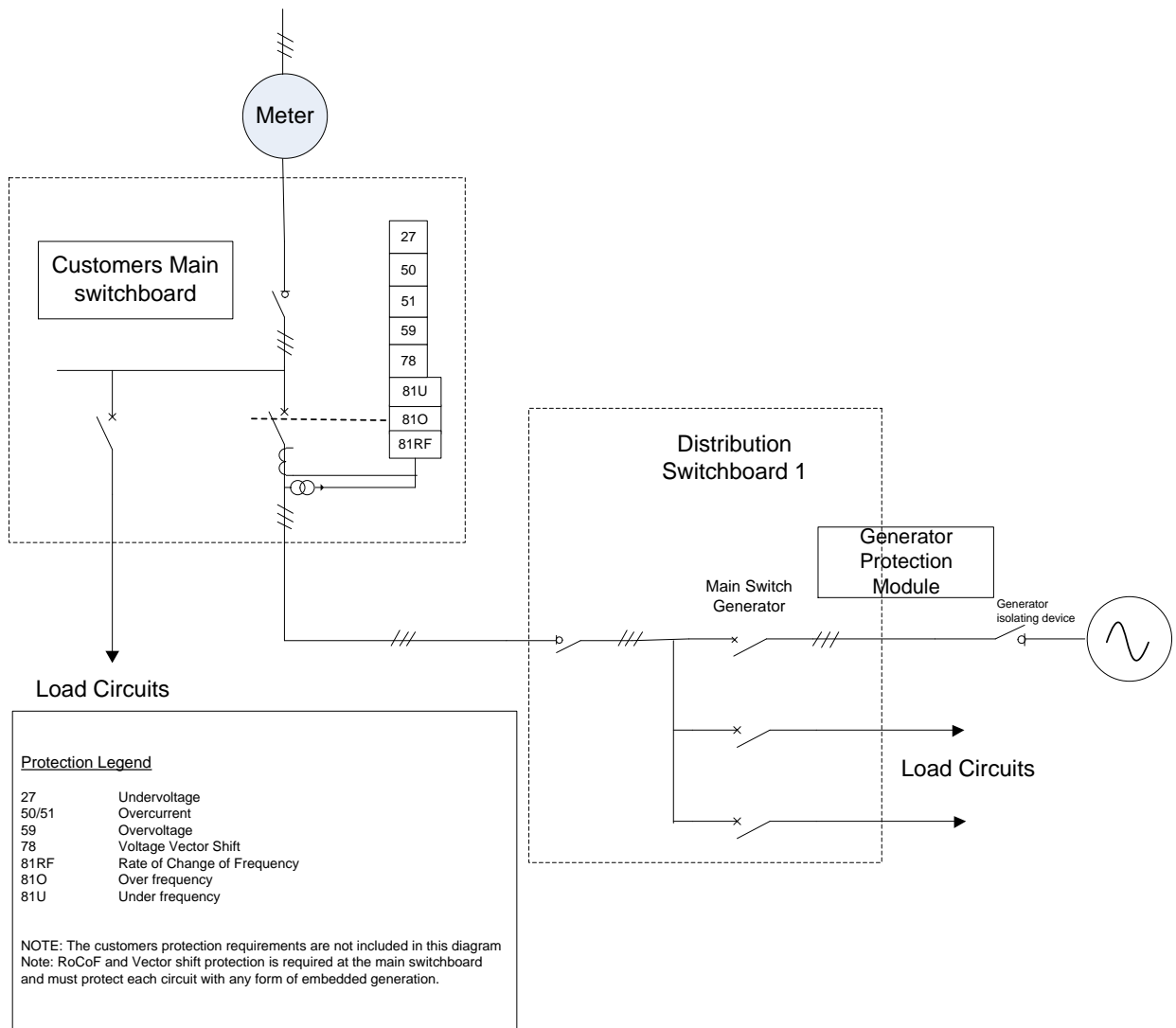
1. If an energy source including energy storage systems is grid connected via an inverter, the inverter must comply with AS/NZS 4777. If not on the CEC list Inverters must be Type tested by a NATA accredited Laboratory to comply with AS/NZS 4777 test certificate and full test report is to be provided which will be verified by a suitably qualified person.
2. AusNet Services has provided relief from the general policy for Interconnection Protection to be located at the main switchboard, for small scale AS/NZS 4777 compliant inverters to < 30kVA. For these systems AusNet Services will permit the interconnection protection to be located within the generator protection scheme as described below. Any variations to the installation will require a new Agreement.

B.1 BAND 1 AND 2 (0 kVA to 15 kVA), IES CONNECTION



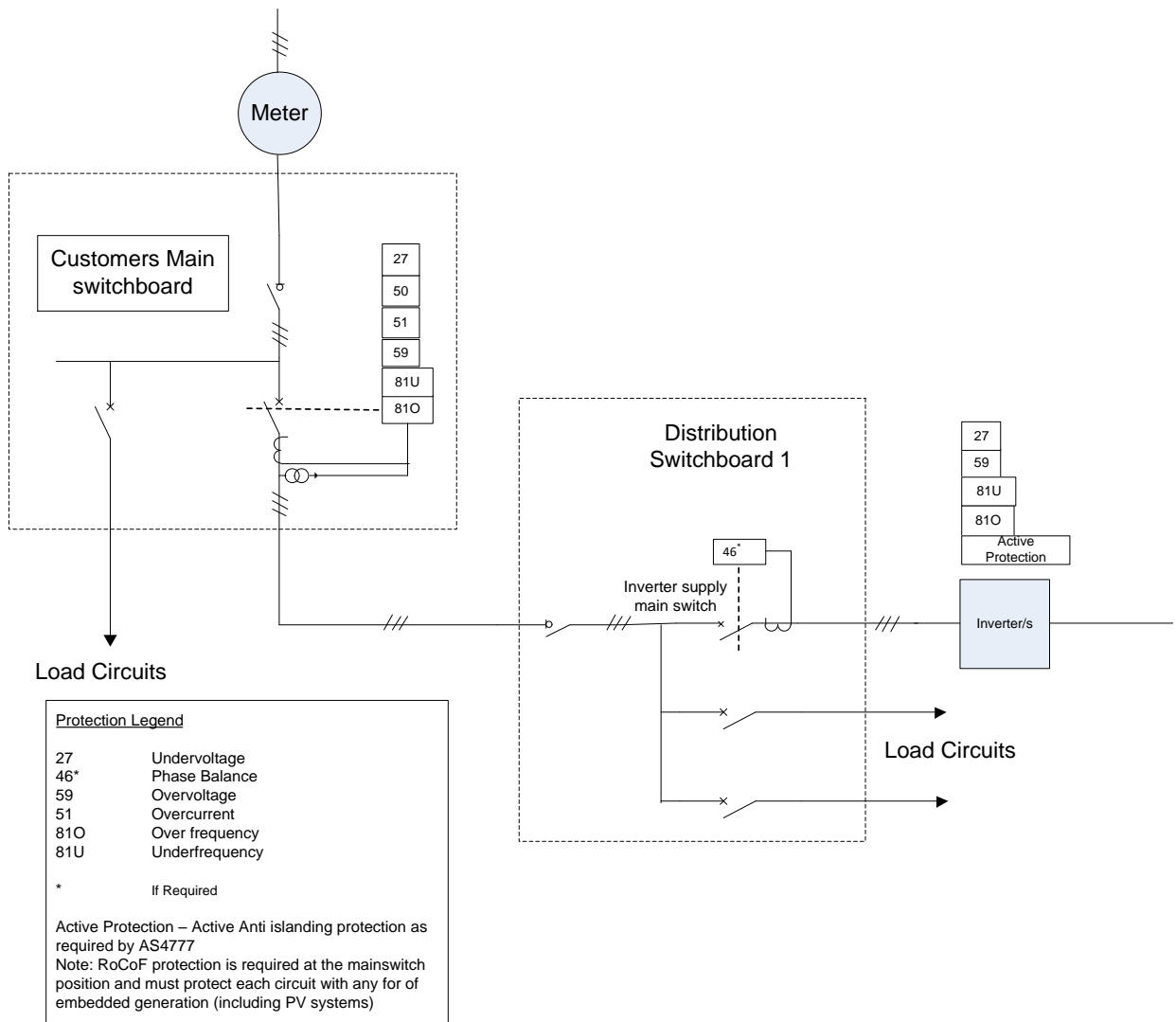
Protection Requirements of Embedded Generators Policy

B.2 BAND 1 AND 2 (0 kVA to 15 kVA), NON-IES CONNECTION



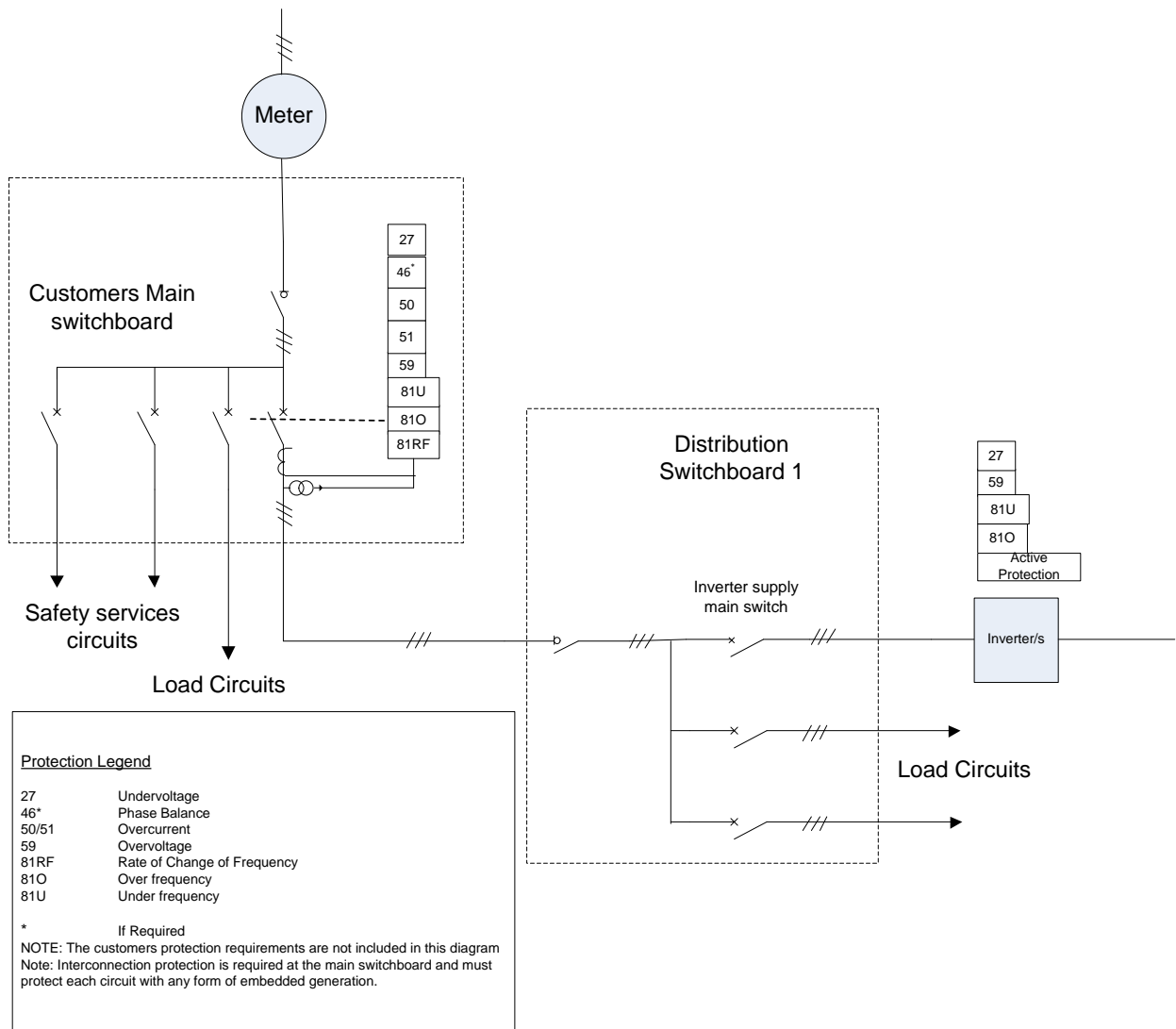
Protection Requirements of Embedded Generators Policy

B.3 BAND 3a (>15 kVA to 30 kVA) IES CONNECTION



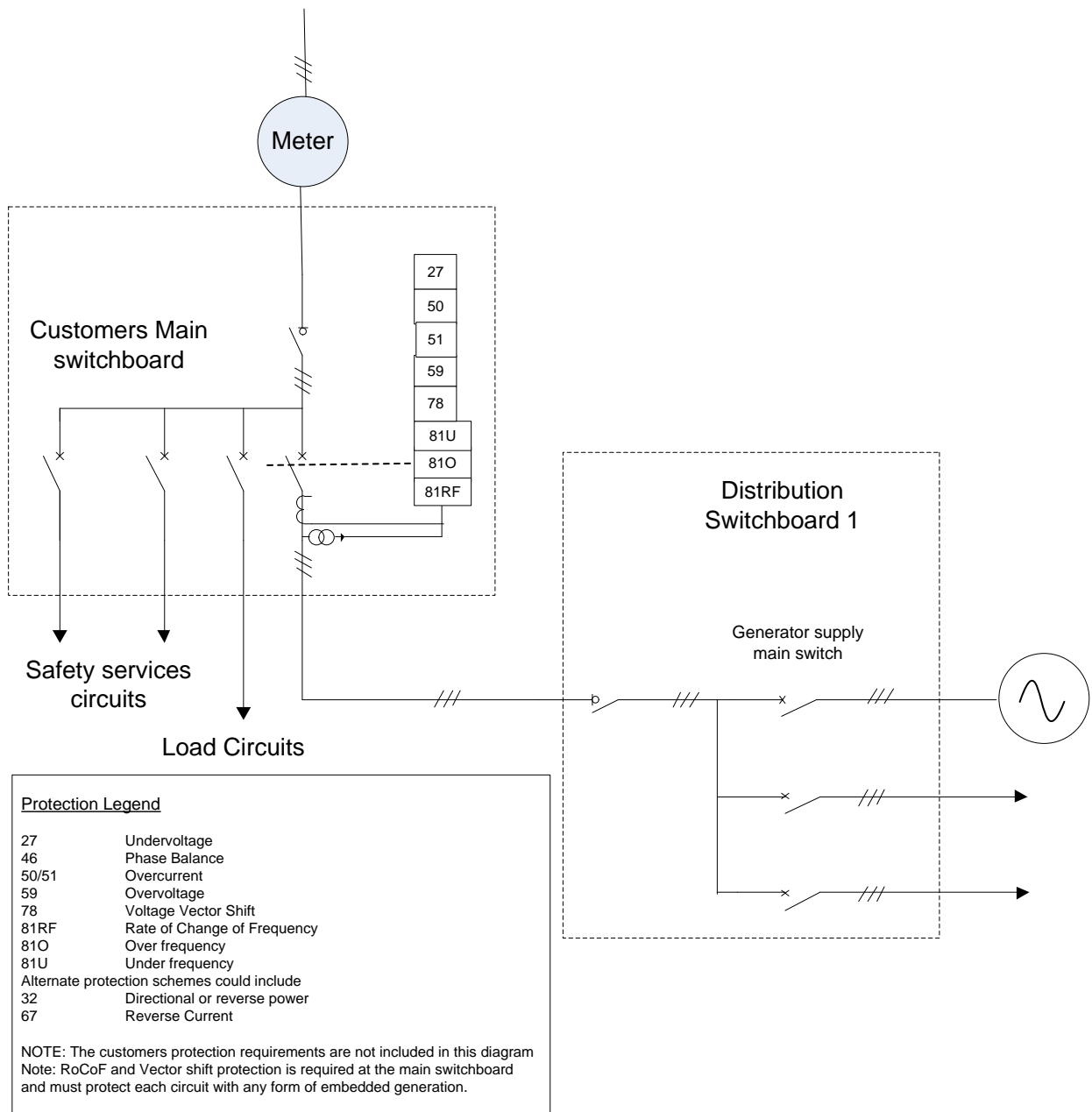
Protection Requirements of Embedded Generators Policy

B.4 BAND 3b (>30 kVA to 200kVA) IES CONNECTION



Protection Requirements of Embedded Generators Policy

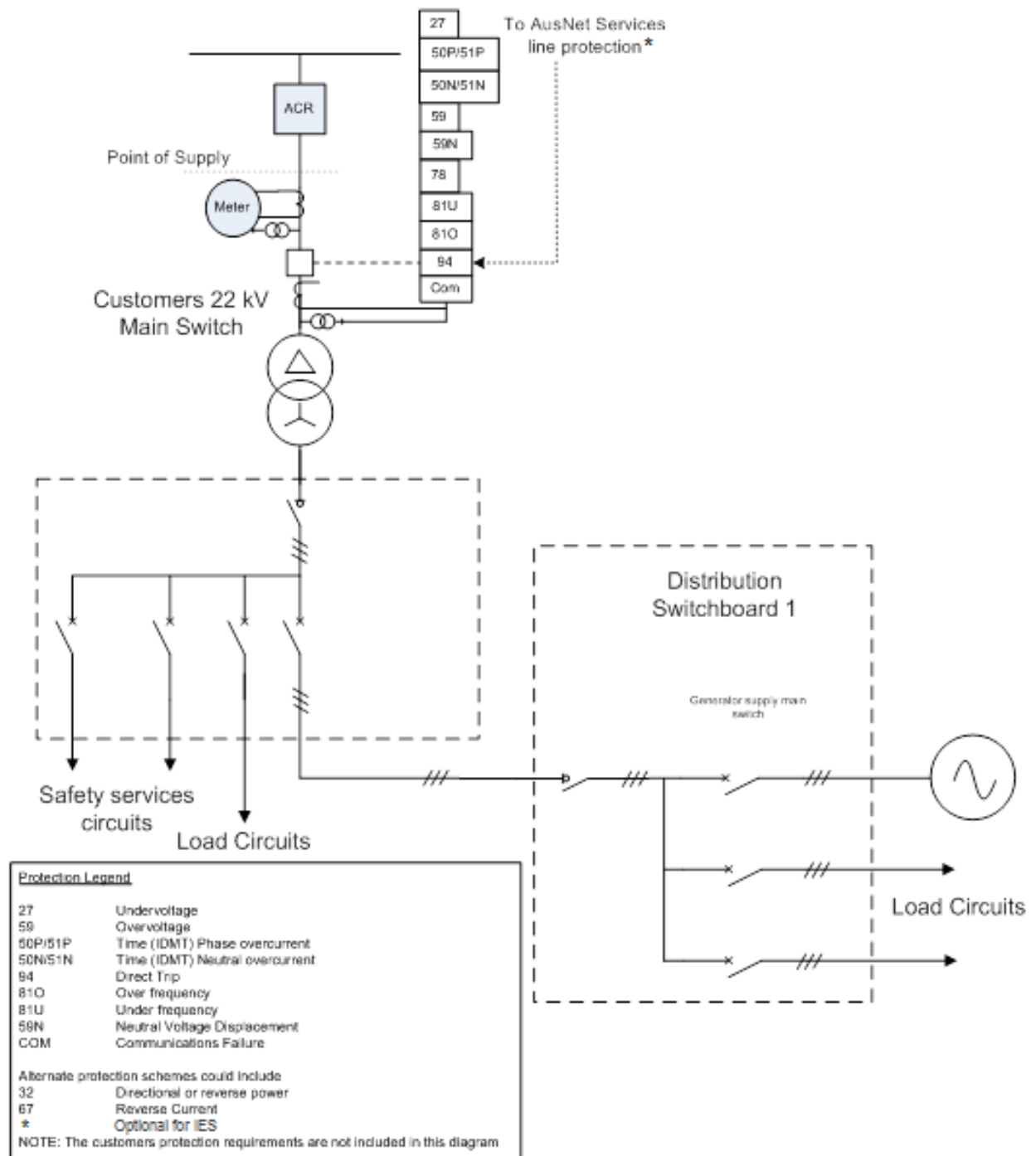
B.5 BAND 3c (30 kVA to 1.5 MVA) NON-IES CONNECTION



Consideration may be given to alternate interconnection protection schemes which take account of the site load and reverse power or reverse current elements.

Protection Requirements of Embedded Generators Policy

B.6 BAND 4 (1.5 MVA to 5 MVA) CONNECTION

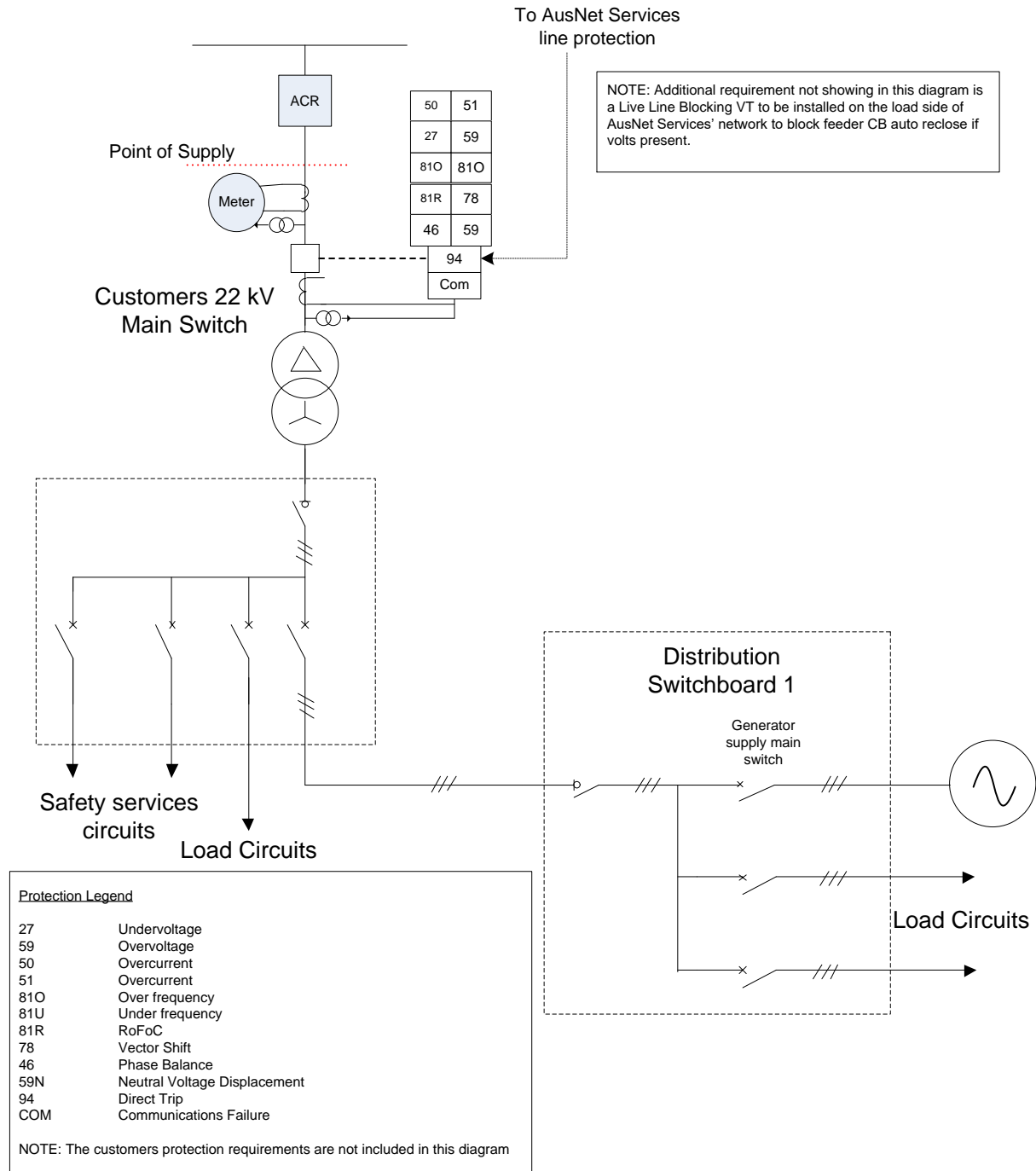


For HV installations to 22 kV the HV/LV interconnecting transformer must be delta/star with interconnection protection including Neutral Voltage displacement.

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B.7 BAND 5 (>5 MVA) CONNECTION

As the majority of these proposals involve market registration, compliance with the technical requirements of the National Electricity Rules and the generator impact of system performance is required. The interconnection protection requirements for safety of the network must be co-ordinated with registration requirements and the connection process must be undertaken in accordance with SOP 33-05.



Protection Requirements of Embedded Generators Policy

APPENDIX C: TYPICAL INTERCONNECTION PROTECTION SETTINGS

The designer needs to provide their proposed initial settings. The following Interconnection protection settings (incorporating Central Protection requirements of AS/NZ4777.1) provide typical settings. Refer to the Victorian Service and Installation Rules or AS477.2 for the inverter settings.

Reconnection of the generator to the electricity network can occur following the maintenance of voltage levels from the electricity network being established and within acceptable limits of AS60038 for a minimum of 60 seconds.

	Disconnection Time	Setting
Overvoltage (V>>)	2 Sec	260V
Undervoltage (V<)	2 Sec	180V
Over Frequency (F>)	2 Sec	52 Hz
Under Frequency (F<)	2 Sec	47.5 Hz
RoCoF	1 Sec	0.5 to 4 Hz/Sec
Vector Shift	1 Sec	8 Deg
Phase balance protection*	2 Sec	21.7 A

* For Band 1 to Band 3b inclusive, phase balance protection for an IES if required must comply with AS/NZS 4777.1 and is not required for generators compliant with AS 60034.1,

Protection Requirements of Embedded Generators Policy

APPENDIX D: COMMUNICATIONS FOR SCADA AND PROTECTION (INTERTRIP)

From IEC/TS 62786:2017

It is the Embedded Generators responsibility to provide all required communications path to meet the following performance requirements.

1. Intertrip

A secure communications path between all AusNet Services upstream protection devices and the proposed embedded generator units is required. Generally this will require point to point single mode fibre optic cable for all protection but also incorporating control and remote monitoring.

In all cases loss of communications will initiate an appropriate protection response as required by this Policy.

The communication system should be compatible with the IEC 61850 series although other legacy communication systems are still in operation.

Point to Point Radio is acceptable

When public communication is used physical security and cyber security measures must be considered.

2. SCADA

The preferred SCADA path is via the AusNet Services ACR located on the network adjacent to the connection point as described in Clause 6.5

SCADA remote monitoring does require reliable communication links that not necessarily of a high security (i.e. redundancy) to comply with the automatic access standards. Licensed or unlicensed radio, microwave link, internet based communications or other methods may be considered however it will need to be demonstrated that the method used is reliable.

Protection Requirements of Embedded Generators Policy

APPENDIX E: SUPPLY PROTECTION DEVICE

The VSIR's define the additional Supply Protection Device requirements for lv connections. The Interconnection protection must not interfere with the correct operation of this device.

The VSIR's references the following;

Note: In some cases Distributors may utilise their HV protection equipment for supply protection. It will be necessary to confirm the supply protection arrangement with the relevant distributor at the design stage of the electrical installation.

This Note refers to AusNet Services Document 30-4161-05 Distribution Design Manual, Commercial /Industrial

It must be noted that upstream protection devices are generally not directional.