



Tasmanian Networks Pty Ltd

Guideline

Technical Requirements for the Connection of Embedded Generation

Revision

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Acronyms

AC	Alternating Current
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
CT	Current Transformer
DC	Direct Current
DFIG	Doubly Fed Induction Generator
DNSP	Distribution Network Service Provider
FCAS	Frequency Control Ancillary Services
NEM	National Electricity Market
NER	National Electricity Rules
OTTER	Office of the Tasmanian Economic Regulator
PV	Photovoltaic
PWM	Pulse Width Modulation
SCADA	Supervisory Control and Data Acquisition
TEC	Tasmanian Electricity Code
TNSP	Transmission Network Service Provider
VT	Voltage transformer

1 Overview

As the licensed Distribution Network Service Provider (DNSP) and Transmission Network Service Provider (TNSP) in Tasmania, Tasmanian Networks Pty Ltd (TasNetworks) must meet a number of legal and regulatory obligations in relation to the safety, reliability and quality of power supply made available to *Network Users*.

As part of its obligations, TasNetworks must ensure that the connection of embedded generation within the distribution network does not have an adverse impact on existing *Customers* or on operation of the network more generally.

To achieve this, TasNetworks requires that embedded *generating systems* proposing to connect to the distribution network, satisfy certain technical design and performance criteria. The technical requirements to be met by *generating systems* are called *access standards*. *Access standards* are provided for a range of technical issues that impact TasNetworks' obligations as a DNSP.

In a similar manner to that utilised within the National Electricity Rules (NER), the *access standards* applied by TasNetworks for the connection of embedded generation generally fall into one of three categories:

Automatic Access: A *generating system* that meets such a standard would not be unreasonably denied access to the distribution network.

Negotiated Access: A *generating system* that can be demonstrated to satisfy defined minimum access standards, but is unable (for whatever reason) capable of satisfying all *automatic access standards*, may still be granted a network connection subject to technical review and approval by TasNetworks.

It should be noted that the size and type of *generating system* to be connected will be taken into consideration to ensure that negotiated access standards are appropriate and relevant for the connection arrangements being proposed.

Minimum Access: Failure to meet a described minimum access standard will result in the *generation proponent* being refused access to the distribution network.

In all cases, TasNetworks will require the submission of suitable information from the *generation proponent* to enable technical assessments to be undertaken, including the need for any negotiated access arrangements, as well as evidence that all *minimum access standards* have been satisfied.

The objective of this document therefore, is to provide the necessary information such that the process for connecting embedded generation is simplified as much as is practical, without compromising TasNetworks' legal and regulatory obligations as the Tasmanian DNSP.

2 Scope

The scope of this document is to define the technical standards for the connection of non-registered embedded generation into the distribution network owned and operated by TasNetworks. *Generating systems* that are to be registered for operation in the National Electricity Market (NEM) will be assessed against the technical requirements specified by the NER.

A specific exclusion from the scope of this document is embedded generation which is interfaced through a single inverter deemed compliant with AS/NZS 4777 Parts 1, 2 and 3. TasNetworks has developed specific documentation pertaining to the connection requirements for such equipment, including the setting of under and over frequency and voltage protection that is consistent with the requirements of the Tasmanian power system.

3 Definitions

Defined terms used in this document are *italicised* and for the most part, are consistent with terminology used in other industry publications. Definitions that have been modified to suit the purposes of this document are provided below with the additional detail included:

<i>Access Standard</i>	Has the meaning given it by the NER.
<i>Connection point</i>	Has the meaning given it by the NER.
<i>Customer</i>	Has the meaning given it by the NER.
<i>Generation proponent</i>	A person who is proposing to engage in the activity of owning, controlling, or operating a <i>generating system</i> that is connected to, or otherwise supplies electricity to, a transmission or distribution system.
<i>Generator</i>	A person who engages in the activity of owning, controlling or operating a <i>generating system</i> that is connected to, or otherwise supplies electricity to, a transmission or distribution system. This includes <i>generating systems</i> that are registered with the Australian Energy Market Operator (AEMO) for operation within the National Electricity Market (NEM), as well as those which have sought and been granted exemption from registration, or are exempt under a standing offer.
<i>Generating system</i>	<p>A system comprising of one or more generating devices (including rotating equipment and/or static energy sources such as photovoltaic systems). A <i>generating system</i> includes auxiliary or reactive plant that is located on the <i>Generator's</i> side of the <i>connection point</i> which may be necessary for the <i>generating system</i> to meet its registered performance standards and/or any other technical requirements included in the <i>Generator's</i> Connection Agreement.</p> <p>The rating of a <i>generating system</i> is equal to the sum of the rated capacities of the generating devices that comprise it, irrespective of the load which may be supplied through the same <i>connection point</i>.</p> <p>An <i>embedded generating system</i> is one that is connected to the distribution network.</p>
<i>High Voltage (HV)</i>	Has the meaning given it by AS/NZS 3000.
<i>Low Voltage (LV)</i>	Has the meaning given it by AS/NZS 3000.
<i>Network User</i>	Has the meaning given it by the NER.

4 Reference Information

4.1 Rules and Standards

The following Rules and Standards are referenced throughout this document:

- (a) National Electricity Rules (NER) as published by Australian Energy Market Commission (AEMC).
- (b) Tasmanian Electricity Code (TEC) as published by the Office of the Tasmanian Economic Regulator (OTTER).
- (c) Frequency Operating Standards for Tasmania (18 Dec 2008) – as published by the Reliability Panel of the Australian Energy Market Commission (AEMC).
- (d) Australian and IEC Standards:
 - i. AS/NZS 3000 – Australian/New Zealand Wiring Rules).
 - ii. AS2067-2008 – Substations and high voltage installations exceeding 1 kV.
 - iii. AS 4777-1:2016 & AS 4777-2:2015 – Grid connection of energy systems via inverters.
 - iv. AS/NZS 61000.3.7:2001 – Assessment of emission limits for fluctuating loads in MV and HV power systems.
 - v. IEC Technical Report TR IEC 61000.3.7:2012 - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems.
 - vi. AS/NZS 61000.3.5:1998 - Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16 A.
 - vii. AS/NZS 61000.3.6:2001 – Assessment of emission limits for distorting loads in MV and HV power systems.
 - viii. IEC Technical Report TR IEC 61000.3.6:2012 - Assessment of emission limits for the connection of distorting loads to MV, HV and EHV power systems.

The above is not intended to be an exhaustive list of relevant standards, merely those which have been directly referenced in the body of the document. The need to apply “appropriate standards” as part of design processes has been stated throughout, with the relevance of specific standards being dependant on the type of *generating system* being proposed.

4.3 Operating limits

Specific operating limits applicable to the Tasmanian power system that *generation proponents* should be aware of include the standard operating voltage ranges for HV and LV connections as shown in Table 1, and the Tasmanian Frequency Operating Standards as presented in Table 2 and Table 3. Please be aware that various access standards will make reference to these standard operating limits.

Table 1: Standard operating voltage ranges for Tasmania as defined by the TEC

Voltage level (kV)	Voltage range for time periods		
	Steady state (average over 10 minute period)	Less than 1 minute	Less than 10 seconds
< 1.0	Refer to: AS 61000.3.100 Section 5.1	± 10 %	Phase to earth 0 % - 150 % Phase to phase 0 % - 130 %
1-6.6 11 22	AS 61000.3.100 Section 5.2	± 10 %	Phase to earth 0 % - 180 % Phase to phase 0 % - 130 %
33 44 66	AS 61000.3.100 Section 5.2	± 15 %	Phase to earth 0 % - 150 % Phase to phase 0 % - 130 %

For the latest version please check the following link:

<<http://www.economicregulator.tas.gov.au/electricity/regulatory-framework/codes/tasmanian-electricity-code-downloads>>

Table 2: Tasmanian frequency operating standards - interconnected system

CONDITION	CONTAINMENT	STABILISATION	RECOVERY
Accumulated time error (other than multiple contingency events)	15 seconds		
Normal	49.75 to 50.25 Hz, 49.85 to 50.15 Hz 99% of the time	49.85 to 50.15 Hz within 5 minutes	
Load and generation event	48.0 to 52.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Network event	48.0 to 52.0 Hz	49.85 to 50.15 Hz within 10 minutes	
Separation event	47.0 to 55.0 Hz	48.0 to 52.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes
Multiple contingency event	47.0 to 55.0 Hz	48.0 to 52.0 Hz within 2 minutes	49.85 to 50.15 Hz within 10 minutes

Table 3: Tasmanian frequency operating standards - islanded system

CONDITION	CONTAINMENT	STABILISATION	RECOVERY
Normal	49.0 to 51.0 Hz		
Load and generation event	48.0 to 52.0 Hz	49.0 to 51.0 Hz within 10 minutes	
Network event	48.0 to 52.0 Hz	49.0 to 51.0 Hz within 10 minutes	
Separation event	47.0 to 55.0 Hz	48.0 to 52.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes
Multiple contingency event	47.0 to 55.0 Hz	48.0 to 52.0 Hz within 2 minutes	49.0 to 51.0 Hz within 10 minutes

Table 3 applies when an electrical island is formed within the Tasmanian power system and **should not** be interpreted as operation of the Tasmanian system operating as an island within the NEM, i.e. during periods of time when the Basslink interconnector is out of service.

5 Classification of Generation

5.1 Access standards for generators exempt from registration

The National Electricity Law (NEL) requires a person intending to participate in the NEM as a *generator* to register with AEMO. In order to obtain approval to physically connect to the power system, *generation proponents* must follow the connection process as detailed in Chapter 5 of the NER including satisfaction of all technical requirements outlined in Schedule 5.2. In this Schedule, *access standards* for the connection of generation into a distribution or transmission network are defined.

In accordance with Appendix 6 of AEMO's "NEM Generator Registration Guide", *generation proponents* may seek a registration exemption from AEMO. AEMO may grant an exemption when it believes that the *generating system* is not likely to have a material impact on the operation of the NEM, or on the activities of other *Market Participants*. AEMO offers standing exemptions to *generating systems* that meet the following criteria:

- (a) *Generating systems* that have a rated nameplate rating of less than 5 MW.
- (b) *Generating systems* that have a nameplate rating \geq 5 MW, but do not have the capability to export more than 5 MW to the network.

Generating systems that have a nameplate rating \geq 5 MW, but do not export more than 20 GWh per annum to the network, may also be granted exemption upon application.

For *generating systems* in excess of 5 MW that have sought and been granted exemption from registration, TasNetworks generally considers it appropriate to apply the *access standards* provided in Schedule 5.2.5 of the NER. Where the wording of *access standards* preclude their direct application to embedded generation, or are simply not appropriate, alternative descriptions have to be provided. As a result, variations to Schedule 5.2.5 are described in this document.

For *generating systems* that have a rated capacity of less than 5 MW, TasNetworks has defined its own technical standards which are described herein. In some cases, the *access standards* defined in NER Schedule 5.2.5 remain appropriate and continue to be referenced. Where possible, TasNetworks has sought to develop *access standards* that are aligned and compatible with existing policies published for *network users*, as well as various Australian Standards that are relevant for network connections of these types.

5.2 Generation technologies

The performance characteristics of different generation technologies vary widely. While there are a number of specific technologies now commercially available for use in embedded generation applications, they can all be broadly grouped as follows:

- (a) Network connected rotating synchronous machines.
- (b) Network connected rotating asynchronous machines.
- (c) Inverter interfaced generation.

TasNetworks will allow any of the above technologies to be connected to its distribution network noting that the performance characteristics of each demand different considerations (which may also be network dependant). TasNetworks will provide advice to *generation proponents* on the impacts of connecting a nominated generation type at the time a connection application is received and the proposed point of connection is nominated.

5.2.1 Synchronous machines

Synchronous generators are a traditional technology with well-established performance requirements. Examples of embedded generators typically using this type of machine include mini hydro applications, small frame size gas turbines (potentially producing steam or heat as a secondary output in co-gen operation), and reciprocating engine units fired on either diesel or gas.

Being a voltage source that is synchronously coupled to the power system, specific considerations for these types of machines include:

- (a) Provision of significant fault current with resulting network protection design and coordination requirements (to ensure safe and reliable operation of the machine and the connecting network).
- (b) Synchronisation requirements, including the management/modification of network controls such as auto reclose schemes.
- (c) Management of anti-islanding given the potential provision of both voltage and frequency control that may enable stable operation even once disconnected from the main network.

The correct specification of voltage control requirements can be particular important for synchronous machines especially at *weak connection points*. Utilising the inherent capability of a synchronous machine to control voltage can avoid issues in the network and enable the integration of embedded generation at locations that may otherwise be prohibitive.

5.2.2 Asynchronous (induction) machines

Asynchronous generators are also a very well understood and a relatively common technology. Typical examples for embedded generator applications include use in micro and mini hydro units and wind turbines applications where input power is variable or difficult to control. The ability to operate induction generators at variable speed (slip) makes them ideal for such circumstances, reducing control requirements quite considerably in some situations.

Induction generators require an external source of excitation and always absorb reactive power at their stator terminals (with the exception of doubly fed induction generators which are typically used in larger wind turbine applications). As such, the connection of this type of *generating system* requires consideration of issues which include:

- (a) Power factor operating range at the *connection point* and the impact on local distribution network voltage profile. The need for local reactive support to be

installed with the generator is one potential solution to this issue if not offered as standard. This arrangement is sometimes referred to as a “self-excited” induction generator.

- (b) Starting arrangements for the generator, i.e.: the use of direct online (DOL) starting as an induction motor may not be possible at weak *connection points* due to the high inrush currents involved. “Soft starting” arrangements may require consideration if not offered as standard.
- (c) The response of the *generating system* to islanding situations and the possibility of self-excitation. The issue to be managed is the risk of continued operation for a period of time even once disconnected from the main network.

Depending on the size of the generating unit, the provision of transient fault currents may also be a relevant consideration. An induction generator will feed current into a fault until such time that its internal magnetic field has collapsed causing de-excitation of the machine.

While induction generators are typically lower cost and have simpler control and protection arrangements, their connection to the distribution network still requires due consideration of potential issues so that network safety and performance can be managed.

5.2.3 Inverter based technologies

Inverter based generation systems use power electronics to convert electrical power from either direct current (DC), or a variable frequency alternating current (AC) waveform, to a 50 Hz AC supply which allows connection to the main network.

Inverter based generation systems may either be line commutated or self-commutated technologies. Line commutated inverter systems typically use power electronic devices such as thyristors and rely on the mains voltage signal as a reference for commutation. Self-commutated inverter systems use an internal high frequency reference signal for control of power electronics (IGBT, MOSFET etc.) typically implementing Pulse Width Modulation (PWM).

Static generating devices (such as PV panels), as well rotating plant, can be connected to the grid via an inverter. For the latter, this is generally preferable for small installations because of the additional control that is possible via the inverter, especially in relation to the management of *connection point* power factor and/or voltage.

In terms of *connection point* issues to be considered, the impact on network voltage control and anti-islanding protection is as per the other generation types already mentioned. In addition, inverter connected generating systems can potentially introduce power quality issues including harmonic distortion and flicker, depending on the *generating system's* size and inverter type being used.

6 Access Standards

6.1 General requirements

6.1.1 Compliance with standards

TasNetworks requires all *generation proponents* to comply with the relevant Australian or equivalent international standards.

6.1.2 Service protection device

TasNetworks requires a fuse or circuit breaker to be installed as close as practical to the *connection point* of the *generating system*. The service protection device may therefore be required to disconnect not only the generator, but also any additional primary equipment that may form part of the *generating system*, e.g. a step-up transformer.

The service protection device should be controlled by protection that is capable of disconnecting the *generating system* for internal and external faults (as appropriate).

6.1.3 Isolation device

For HV and LV connected *generating systems*, TasNetworks will install an isolation device upstream of the *connection point* to allow the *generating system* to be separated from the shared network without need to enter the *generators* premises.

For HV and LV connected *generating systems*, it is preferable that the *generator* also provide an isolation device capable of being locked in the 'open' position. The device must be made accessible by TasNetworks upon request.

6.1.4 Earthing

Earth faults in the distribution system result in earth potential rise and present a health and safety hazard for generator and distribution network employees, as well as members of the general public. To ensure that step and touch potentials are maintained within acceptable levels, the earthing system installed as part of a *generating system* development shall be compliant with the relevant standards.

For HV connected systems:

The *generating system* earthing shall be independent of the distribution system earthing and be compliant with AS 2067-2008.

TasNetworks requires that *generating system* provide no path for zero sequence currents, and therefore not contribute to an increase in the earth fault level at any point in the distribution network. TasNetworks acknowledges that under some specific circumstances, this requirement may not be achievable. In such cases, the *generation proponent* should negotiate with TasNetworks to determine an acceptable earthing arrangement.

Where a *generating system* can be operated within an electrical island separated from the distribution network, the *generating system* must be installed with an earthing system that can provide adequate earthing independent of that normally provided by the distribution

network. An example is an embedded generator that may operate in parallel with the distribution network under normal circumstances, but is capable of maintaining supply to a local load in the case of a separation event.

For LV connected systems:

The *generating system* earthing shall be independent of the distribution system earthing and be compliant with AS/NZS 3000. Appropriate studies must be undertaken to ensure step and touch potentials are maintained within acceptable levels.

To provide appropriate internal protection for LV earth faults, TasNetworks permits the *generating system* to provide a path for zero sequence currents. Depending on the size and type of *generating system*, this may require fault levels and earth grid designs in proximity to the proposed *connection point* to be reviewed as part of the connection process.

As for HV connected generators, where a *generating system* can be operated within an electrical island separated from the distribution network, the *generating system* must be installed with an earthing system that can provide adequate earthing independent of that normally provided by the distribution network.

6.2 Generating system capability

6.2.1 Reactive power capability and power factor requirements

TasNetworks requires that *generating systems* have sufficient reactive capability to maintain voltage at the *connection point* within prescribed limits.

For *generating systems* that are equal to or larger than 5 MW in capacity, TasNetworks considers the *access standards* defined in S5.2.5.1 of the NER to be appropriate. The *generating system* should ideally be capable of supplying and absorbing reactive power equal to the product of the rated active power and 0.395. This should be possible across the full range of active power outputs that the *generating system* may operate at.

For *generating systems* that are smaller than 5 MW, operation of the generator at a fixed power factor may be sufficient to maintain distribution network voltages within acceptable limits. For areas of the network where this is achievable, TasNetworks requires that the power factor at the *connection point* be maintained within the ranges provided in Table 3.

Table 4: Power Factor Operational Limits – Tasmanian Electricity Code (TEC), Table 1

Supply Voltage (kV)	Power factor range for customer maximum demand and voltage					
	Up to 100 kVA		Over 100 kVA – 2 MVA		Over 2 MVA	
	Minimum lagging	Minimum leading	Minimum lagging	Minimum leading	Minimum lagging	Minimum leading
<6.6	0.75	0.8	0.8	0.8	0.85	0.85
6.6 11 22	0.8	0.8	0.85	0.85	0.9	0.9
33 44 66	0.85	0.85	0.9	0.9	0.95	0.98

In weak areas of the network, managing *connection point* power factor as embedded generation output varies may not be sufficient to maintain acceptable distribution network voltages.

Under such circumstances, the requirement to regulate network voltages takes precedence. To meet its regulatory obligations, TasNetworks may require that the *generating system* operate at a power factor that is different to that permitted in Table 4, or alternatively, may require that the *generating system* operate in “voltage control mode” so as to provide dynamically controlled voltage support to the *connection point* and surrounding network.

The *generation proponent* must negotiate with TasNetworks to determine the minimum reactive capability of the *generating system* (that is available for use) and the control requirements necessary to support its operation at the proposed *connection point*.

6.2.2 Quality of supply

The introduction of voltage fluctuations, harmonics or voltage unbalance into the distribution network may result in the maloperation or damage to electrical equipment operated by other *network users*.

The impact of a particular development on the quality of supply is dependent on the current drawn or supplied by the *generating system* and the system impedances at the proposed *connection point*. To ensure that the quality of supply remains consistent with TasNetworks’ published planning limits¹, TasNetworks will allocate **emission limits** to a *generation proponent* at the time a connection application is processed.

Acceptable operation requires the *generating system* to comply with the allocated **emission limits**, which will typically be less than the published planning limits.

To determine these values, TasNetworks requires a *generation proponent* to specify the proposed *connection point* and the rating of the *generating system* at the connection enquiry stage.

6.2.2.1 Voltage fluctuations

The contribution of an embedded *generating system* to flicker and transient voltage deviations is dependent on the magnitude of change in the current supplied/drawn, and the equivalent impedance at that point in the network.

For HV connected *generating systems*, TasNetworks considers it appropriate to apply the *access standards* defined in S5.2.5.2 of the NER. This clause refers to emission limits that may be calculated using AS/NZS 61000.3.7:2001, noting however that this particular standard has been superseded by IEC Technical Report TR IEC 61000.3.7:2012.

Once a connection application is received, TasNetworks will determine which assessment stage (as defined in the standard) to apply based on the size of the *generating system* and the short circuit capacity at the proposed connection point.

For LV connected embedded *generating systems*, TasNetworks requires compliance with AS/NZS 61000.3.5:1998.

¹ Planning limits are published in TasNetworks Annual Planning Report (APR).

6.2.2.2 Harmonic injection limits

The impact of an embedded *generating system* on harmonic voltages in the network is dependent on the harmonic currents drawn or supplied through the *connection point* and the equivalent harmonic impedances at that point in the network.

For all *generating systems*, TasNetworks considers the *access standards* defined in S5.2.5.2 of the NER to be appropriate. The schedule refers to standard limits that may be calculated using AS/NZS 61000.3.6:2001, which has subsequently been superseded by IEC Technical Report TR IEC 61000.3.6:2012.

Once a connection application is received, TasNetworks will determine which assessment stage (as defined in the standard) to apply based on the size of the *generating system* and the short circuit capacity of the proposed connection point.

6.2.2.3 Voltage unbalance

To comply with the requirements of Schedule 5.1a.7 of the NER, TasNetworks must actively manage voltage unbalance in both the distribution and transmission networks.

At distribution level voltages relevant for the connection of embedded *generating systems*, TasNetworks considers performance to be adequate if the following conditions are satisfied when measured across a three phase connection point:

- (a) For HV connected *generating systems*, the current in any phase is not greater than 102 percent or less than 98 percent of the average of the currents in the three phases.
- (b) For LV connected *generating systems*, the current in any phase is not greater than 105 percent or less than 95 percent of the average of the currents in the three phases.

If the *generation proponent* cannot satisfy these requirements, TasNetworks considers it appropriate to determine unbalance requirements in accordance with IEC Technical Report TR IEC 61000.3.13.

6.2.2.4 Zero sequence generation

The introduction of zero sequence currents into the HV network may have adverse effects on the balancing of phase loadings and the operation of earth fault protection.

For single phase LV connected systems, the maximum size of single phase embedded *generating systems* will not exceed 10 kVA.

It is assumed that HV connected *generating systems* will be three phase.

6.2.3 Fault level requirements

In accordance with the requirements of Clause 8.7.8 of the Tasmanian Electricity Code, unless otherwise agreed in writing between the *generation proponent* and TasNetworks, the *generation proponent* must design and operate its *generating system* so that it does not cause fault levels in the distribution system to exceed the values specified in Table 5. In some areas of the network TasNetworks may require the fault level to be restricted to

values below those specified in Table 5. TasNetworks will advise the *generation proponent* of any requirements to limit and/or manage fault level contribution coming from the proposed *generating system*, at the time of connection application.

Table 5: Maximum allowable network fault levels at distribution system voltages as defined by the TEC.

Voltage level kV	System fault level MVA	Short circuit level kA
66	1500	13.1
44	1000	13.1
33	750	13.1
22	500	13.1
11	250	13.1
6.6	150	13.1
0.400	36	50.0

6.3 Response to system disturbances

6.3.1 Generating unit response to frequency disturbances

To prevent the cascading disconnection of embedded generation during and following a network frequency disturbance (with the resulting impacts that this would have on the broader power system), it is expected that *generating systems* will comply with the following performance requirements.

For *generating systems* that are equal to or larger than 5 MW, TasNetworks will apply the *access standards* as defined in Schedule 5.2.5.3 of the NER.

Generating systems that are smaller than 5 MW in capacity shall not disconnect from the network when frequency is within the range 48.0 Hz to 52.0 Hz unless one or more anti-islanding protection schemes has determined that the generator has become electrically separated from the main network supply. Anti-islanding protection is discussed in detail in Section 6.5.6.

In all cases, TasNetworks will review and negotiate the setting of under and over frequency protection so as to ensure coordination with other network protection and control schemes.

6.3.2 Generating unit response to voltage disturbances

When a voltage disturbance occurs in the power system, the recovery of voltage to the normal operating range is (generally) achieved through the clearance of the network fault that has caused the initial voltage disturbance. To ensure that the power system is robust to system events, it is therefore important that generators remain connected until at least primary protection has operated to clear the fault. Schedule Five of the NER specifies the maximum clearance time for transmission network fault events to be 120 ms.

Transmission fault events are a critical consideration given that wide areas of the network may suffer from a depressed voltage profile as a result, placing at risk significantly more embedded generating systems (as compared to a local distribution network fault event).

For *generating systems* that are equal to or larger than 5 MW, TasNetworks will apply the *access standards* defined in Schedule 5.2.5.4 of the NER.

For *generating systems* that are smaller than 5 MW, the *generating system* shall not disconnect from the network within 150 ms for any voltage disturbance. After 150 ms, the *generating system* may disconnect if the voltage remains outside of the operational voltage ranges for the corresponding time periods as defined in Section 8.6.4 of the TEC (refer Section 4.3, Table 1).

6.3.3 Generating response to disturbances following contingency events

When a network contingency event occurs, the recovery of the system to its pre-contingency operating state is (generally) achieved through the automatic control of generators (as well as other network devices) that remain connected to the power system. To ensure that the power system is robust to system events, it is therefore important that *generating systems* perform in a predictable manner in the post contingency period. Furthermore, *generating systems* should not unreasonably withdraw their available capacity for significant periods of time given the power imbalance that is then inflicted on the remainder of the power system.

For *generating systems* that are equal to or larger than 5 MW, TasNetworks will apply the *access standards* defined in Schedule 5.2.5.5 of the NER.

For *generating systems* that are smaller than 5 MW, TasNetworks requires that a *generating system* be capable of supplying 95% of its pre-fault power within 500 ms of a fault being cleared by protection systems. If this requirement cannot be met, then the *generation proponent* must enter a process of negotiation with TasNetworks.

Where a *generating system* is capable of providing frequency control capability within this time frame, and does so in response to an over frequency condition, this characteristic shall take precedence over the active power recovery criteria discussed above.

6.4 Tolerance to steady state operating conditions

Generators should recognise that certain parameters within the power system are permitted to vary from ideal under normal system operating conditions. This includes voltage magnitude, frequency, flicker levels, harmonic distortion and voltage balance (across phases). *Generating systems* should be robust to variations within permissible limits.

For all *generating systems*, TasNetworks requires compliance with the *minimum access standard* defined in Schedule 5.2.5.6 of the NER.

6.5 Protection requirements

6.5.1 General

To ensure safe and reliable operation of the distribution network, appropriate protection must be fitted by embedded *generating systems*. In the design of protection schemes, consideration must be given to the requirements of the *generating system*, the network in the vicinity of the connection point, and the protection schemes that are already in place within the broader distribution network.

Communication and negotiation with TasNetworks will almost certainly be required to develop protection schemes that grade appropriately and provide adequate coverage (especially in the case of backup protection). It is important that the *generating system's* protection is able to identify and isolate all internal faults, and network faults beyond the *connection point*, as agreed with TasNetworks.

Although all embedded *generating systems* must meet certain minimum protection requirements, the level of protection required will depend on the specific nature of the embedded generation. This section aims to provide clarification on the specific protection requirements for *generating systems* of different technologies and sizes.

In general, for embedded *generating systems* that are equal to or larger than 5 MW in capacity, TasNetworks will apply the *access standards* defined in Schedule 5.2.5.9 of the NER. For all *generating systems*, the following issues and considerations will be assessed by TasNetworks as part of the connection application process.

6.5.2 Protection system design philosophy

TasNetworks requires embedded *generating systems* to implement duplicate protection systems to ensure that all faults are cleared, even with the failure or maloperation of a single protection element. It is recommended that the relays utilised for main and backup protection are sourced from different manufacturers, and where reasonable to do so, utilise separate CT cores and VT windings as their input signals.

Where the *generation proponent* does not believe it practical to install duplicate protection, the design of the protection system will take place through a collaborative process with TasNetworks. Negotiation will be required in regards to the provision of backup protection from network installed protection devices, either existing or new.

In all cases, the determination of protection zones and available protection overlap will need to be considered for forward and reverse power flow conditions to ensure that faults of all types can be identified and cleared. A specific consideration is the ability of the *generating system* to detect and respond to earth faults in an unearthed electrical island, as may occur following upstream protection and circuit breaker operations.

6.5.3 Protection operating speed

Failure to clear electrical faults in an appropriate time represents a potential safety risk to *network users* and the general public, can result in damage to equipment, and reduces the quality and reliability of power supply.

Generators should provide TasNetworks with expected protection operating times so that TasNetworks may:

- (a) Undertake protection coordination studies to assess what discrimination exists between overlapping protection devices. A review of proposed relay settings and expected circuit breaker operating times may be sufficient in many circumstances.
- (b) Confirm that protection operating times for faults within the *generating system* are consistent with existing network design philosophies.
- (c) Confirm that protection operating times do not result in a degradation of network reliability that would subsequently affect other *network users*.

As a general design rule, faults within the *generating system* should be cleared as quickly as possible, whereas faults remote from the *generating system* should be cleared in a manner that minimises disruption to other *network users*, i.e. occurs in a coordinated manner taking into account the operation of other network protection.

For faults external to the *generating system*, i.e. in the distribution network, installed protection devices must identify and isolate the fault from both the point of network supply as well as the *generating system* supply point. This applies to faults of any type.

To achieve discrimination between internal and external faults, it is recommended that the main incoming circuit breaker protection devices have directional protection capabilities. The *generation proponent* should consult with TasNetworks to determine the necessity for their particular installation.

Where the upstream protection device is a fast operating device such as a fuse, grading may not be appropriate or practical. In these instances, the *generation proponent* should demonstrate to TasNetworks that all practical steps have been made to grade the installed protection. TasNetworks may consider slowing the upstream protection if it believes it is necessary to prevent internal *generating system* faults from affecting other *network users*. However, if distribution protection must be slowed beyond threshold values that TasNetworks considers acceptable, it may be necessary to implement a blocking scheme to facilitate protection coordination.

6.5.4 Detection of internal generating system faults

TasNetworks requires that any fault internal to the embedded *generating system* is identified and isolated from the distribution network as fast as is practical. This is to ensure that distribution protection does not operate unnecessarily, resulting in loss of supply to other *network users*. To detect internal faults, any reliable techniques may be used. These may include, but are not limited to:

- (a) Differential protection.
- (b) Overcurrent protection.
- (c) Earth fault protection (including sensitive earth fault (SEF)).

The *generator* should attempt to grade the *generating system* protection with upstream protection with clearance margins of:

- (a) 250 ms for LV connected embedded generation.
- (b) 250 ms for HV connected embedded generation.

The generator must be capable of identifying and clearing high impedance phase to ground faults, internal to the *generating system*. Where the generator is connected to the network through a step-up transformer, protection of the generator side windings may be achieved through conventional earth fault protection methods and technologies. Discussion on protection of the network side of the transformer (or if the generator is connected directly to the distribution network) is discussed further in Section 6.5.5.

6.5.5 Detection of faults external to the generating system

For short circuit faults external to the *generating system*, the *generator's* protection must detect and isolate the fault as quickly as possible from the *generating system's* end. The protection should be capable of identifying faults beyond upstream distribution protection devices. That is, the protection zone of the *generator's* protection should overlap with the protection zone of the 2nd upstream distribution network protection device. To detect distribution network faults, including high impedance earth faults, any reliable technique may be used.

The sensitivity of the protection should be set such that all short circuit faults in the relevant protection zone, which are detectable by the distribution protection, are also detectable by the *generating system's* protection. For over current and distance protection schemes, sensitivity settings should include appropriate margins to be capable of detecting high impedance faults in the relevant protection zone. Increasing the sensitivity of the protection may result in the *generating system's* protection operating for faults that are outside the intended protection zone. If adequate discrimination cannot be achieved, TasNetworks will review the proposed protection schemes and provide advice on the suitability and acceptability of the scheme.

To provide effective earth fault protection, TasNetworks operates its HV distribution network with single point earth connections at zone or terminal substations (see Figure 1). Where two step-down transformers operate in parallel, the secondary star side of both transformers is solidly earthed.

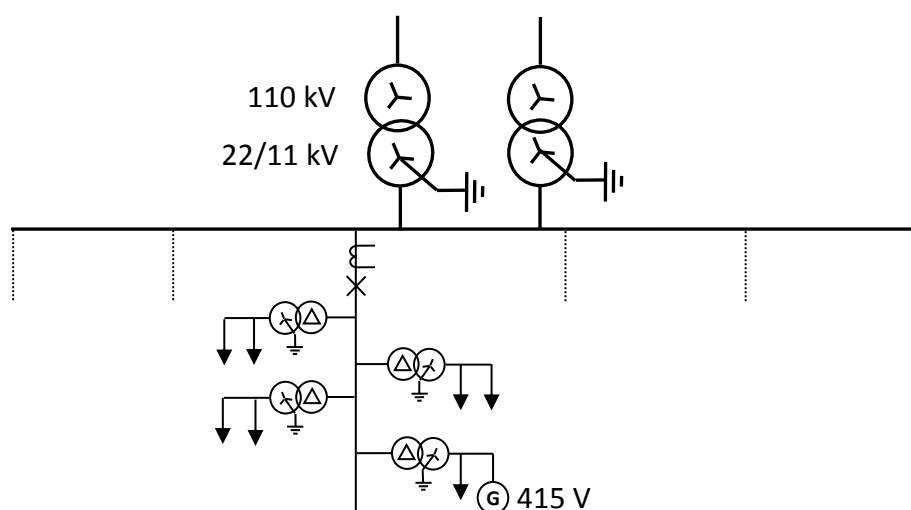


Figure 1: Typical winding configuration for terminal and distribution substations

Earth fault protection is applied to each outgoing feeder to allow identification and isolation of downstream faults. It is for this reason that all connections to the HV network are required to have an infinite (very high) zero sequence impedance.

This makes the detection of earth faults within the distribution network by embedded *generating systems* challenging. Without a means of detecting earth faults on the HV network, the embedded *generating system* may feasibly continue to energise the faulted network. While it is acknowledged that earth fault currents will be low under such circumstances, it is an operating condition that TasNetworks considers unacceptable.

For *generating systems* smaller than 200 kW, TasNetworks considers it acceptable for earth faults to be detected and cleared by distribution network protection, at which time the *generating system* must disconnect via anti-islanding protection. The anti-islanding protection should be fast acting and not include any unnecessary delays.

For HV connected embedded *generating systems* larger than 200 kW in capacity, TasNetworks considers it unacceptable to rely on the operation of anti-islanding protection as a method for clearing earth faults. Examples of protection technologies that TasNetworks would accept in these circumstances include:

- (a) Inter-trip signal from distribution network earth fault protection.
- (b) Suitably located neutral voltage displacement protection.

TasNetworks acknowledges that these technologies may be expensive for the *generator* to implement, and may not be necessary in some network circumstances. The *generation proponent* should consult with TasNetworks to determine the necessity of such protection at the time of application.

For LV connected *generating systems* larger than 200 kW, TasNetworks may consider it unacceptable for the *generating system* to rely on the operation of anti-islanding protection as a method for clearing earth faults. Where TasNetworks identifies it to be credible for the *generating system* to form a viable island with local load, TasNetworks will install voltage transformers for neutral voltage displacement protection on the HV side of the customer's distribution transformer. The customer will contribute some or all of the cost of installing this protection depending on the circumstances.

Ownership of this protection equipment will be dependent on the nature of the connection, and will be negotiated at the time of the connection application. As a general rule, it is **not** preferred that *generators* own and are responsible for equipment beyond the asset boundary of the *generating system* itself.

6.5.6 Anti-islanding protection

Electrical islanding (in the distribution network) is the process where a sub-section of the network is disconnected from other sources of generation (through fault or other network switching events), but remains energised via embedded *generating system(s)* connected in the local area.

Two fundamental conditions must exist if a viable electrical island is to form:

1. The embedded *generating system(s)* can continue to operate as a voltage source without the normal network supply being present.
2. The load and generation in the islanded section of the network can achieve equilibrium such that load demand is balanced by generation capability.

The development of electrical islands in the distribution network represents a significant risk to TasNetworks, from both a safety and compliance perspective. A key consideration is that TasNetworks has no remote visibility or control of the *generating systems* or significant sections of the distribution network itself.

Under the provisions contained in Schedule 5.2.5.8(c) of the NER, TasNetworks requires that *generating systems* be automatically disconnected by remote control schemes or agreed local protection whenever the part of the network to which the *generating system* is connected becomes disconnected from the Tasmanian grid, forming an island that supplies another *network user*.

The specific requirements for anti-islanding protection are dependent on the technical characteristics of the proposed *generating system* and the location of the *connection point* in the distribution network. The most significant factors are:

- The size and type of the *generating system* in question.
- The location and number of upstream disconnection points (including re-closers).
- The minimum and maximum load demand that could be islanded with the *generating system*.
- The presence of network capacitance, either in the form of charging effects (especially supplied by AC cables) or dedicated shunt capacitors (as may be used for voltage control). Due to this, the potential operation of induction generating units in an islanded network should not be immediately discounted.

To mitigate the risks associated with islanding, TasNetworks requires the installation of suitable protection to prevent sustained operation of the *generating system* once islanded. TasNetworks preferred method is:

The installation of a communication based inter-trip scheme where the statuses of remote circuit breakers/re-closers are signalled to the *generating system*. Options to use synchro-phasor systems based on the comparison of local and remote voltage angles to determine the synchronicity of two points in the network are also possible.

TasNetworks will accept the reliability of a single high quality fibre optic communication scheme for this function. TasNetworks will also accept other communication methods (e.g. radio or microwave) if the method incorporates “heartbeat” signals for fail-safe operation. To facilitate this requirement up-to five seconds delay is permitted for detection of an island condition.

TasNetworks could also accept combinations of the following protections under certain circumstances:

- (a) Rate of change of frequency (ROCOF).
- (b) Voltage vector shift.

- (c) Under / over voltage.
- (d) Under / over frequency including frequency bias schemes as implemented in some inverters.
- (e) Reverse power flow detection, either active or reactive or both (only acceptable in some circumstances).

For *generating systems* that are smaller than 200 kW, TasNetworks considers it unlikely that stable electrical islands will be sustainable. Therefore, anti-islanding protection requirements are generally less onerous. TasNetworks would typically expect that embedded *generating systems* of this size would install a combination of the standard options listed from (a) to (e) above.

For *generating systems* that are equal to or larger than 200 kW, especially those involving synchronous machines, TasNetworks considers the formation of a load/generation island to be a credible possibility. TasNetworks will conduct studies to determine the specific requirements for anti-islanding protection and provide these to the *generation proponent* at the time of connection application. Note: If a credible island condition can exist with a synchronous *generating system* TasNetworks will only accept its preferred communications based anti-islanding protection scheme.

6.5.7 Generator connection and disconnection

The connection and disconnection process for embedded *generating systems* should be performed, as far as practicable, in a way that minimises the impact on other *network users*. The exact requirements for connection and disconnection of a *generating system* to the distribution network will depend on the machine type and size.

For example, a large synchronous machine connected to a weak part of the distribution network may be required to reduce power output below a specified value prior to normal disconnection from the network.

The requirements for the connection of induction generators to the distribution network shall be determined after the impact of the *generating system* on power quality has been considered. As previously mentioned, the initial starting of induction generators direct-online (DOL) may not be allowed due to the impact on other *network users*.

Where rotating machines lose their supply of mechanical power, they will naturally transition into motoring mode and begin drawing active power from the network. It is recommended that rotating machines be installed with reverse power flow protection to disconnect under such conditions.

6.5.8 Automatic reclose

TasNetworks utilises automatic circuit re-closers (ACR) as network protection devices to identify and clear transient faults and to prevent the unnecessary operation of permanent protection devices such as fuses. Re-closers will typically attempt three auto close sequences before locking out. Where possible and deemed necessary, ACRs will be configured with live-load-blocking to prevent out-of-sync closing onto downstream network elements that may have remained energised from an alternate source.

After a re-closer opens for the first time, embedded *generating systems* should disconnect from the network via anti-islanding protection before the first reclose attempt. The minimum operating time for TasNetworks' re-closers is 5 seconds. TasNetworks requires embedded *generating systems* to disconnect from the network within 2 seconds of the island being formed.

Embedded generating systems shall only reconnect to the network when the network has been re-energised and has remained within the normal operational voltage and frequency limits for a period of at least one minute. This is to ensure that any reclose event has been successful and to maximise the probability that the embedded *generating system* will maintain operation after reconnecting to the network.

6.6 Power system protection requirements

6.6.1 Protection of generating systems from power system disturbances

To maintain network security and reliability, it is important that *generating systems* do not disconnect from the network for operating conditions that remain within their stated capability. All *generating systems* are expected to maintain continuous, uninterrupted operation except when exposed to abnormal power systems conditions that have been accepted to by TasNetworks.

For embedded *generating systems* that are equal to or larger than 5 MW, TasNetworks requires compliance with the *minimum access standard* and general requirements defined in Schedule 5.2.5.8 of the NER.

6.6.2 Protection to trip plant for unstable operation

To prevent sustained, unstable behaviour of a *generating system* impacting other *network users*, suitable protection must be installed to disconnect the *generating system* when its operation becomes abnormal.

TasNetworks considers the *access standards* defined in Schedule 5.2.5.10 of the NER to be appropriate for *generating systems* of all sizes.

6.7 General control requirements

6.7.1 Frequency control

While AEMO is directly responsible for managing power system frequency, which it does via purchase of Frequency Control Ancillary Services (FCAS) from the eight spot markets which exist in the NEM, embedded *generating systems* also have a role to play.

This is especially true in a small power system such as Tasmania, where frequency control has traditionally been more challenging.

For *generating systems* that are equal to or larger than 5 MW in capacity, TasNetworks will apply the *access standards* defined in Schedule 5.2.5.11 of the NER.

For *generating system* small than 5 MW, the expectations of TasNetworks are as follows:

- (a) Where practical to do so, all *generating systems* should provide frequency control capabilities and be responsive to network frequency disturbances. A speed droop characteristic equivalent to 4% (as would be defined for governor control systems installed on synchronous machines) is considered typical and adequate.

The impact that frequency control capabilities may have on anti-islanding protection arrangements will be considered during the connection application assessment process.

- (b) Where normal operation of the *generating system* naturally inhibits any increase in active power output to support the system recovery from under frequency events, consideration should still be given to the control of over frequency conditions. For such circumstances, a controlled reduction in active power output proportional to frequency deviation is beneficial.
- (c) All *generating systems* should comply with the *minimum access standard* defined by Schedule 5.2.5.11 of the NER, taking into account the active power recovery characteristics immediately post fault as defined in Section 6.3.3 of this guideline.

All frequency control systems installed as part of a *generating system* should be adequately damped as defined by the NER, i.e. the controller's response to a frequency deviation should be tuned to prevent oscillatory behaviours and/or excessive overshoot that may be counterproductive to the stable recovery of system frequency.

6.7.2 Voltage and reactive power control

To ensure that network voltages can be effectively managed, all *generating systems* comprised of synchronous machines, doubly fed induction generators or inverter interfaced energy sources should be fitted with appropriate control systems that allow voltage, reactive power and power factor at the *generating systems* terminals to be dynamically controlled.

For induction generators, the requirement for independent control of switched capacitor banks or other forms of reactive compensation will be determined as part of the connection application assessment process.

The selection of an appropriate control arrangement will be dependent on the size of the *generating system* and the proposed connection point to the distribution network. The specification of control requirements will occur in conjunction with TasNetworks.

In relation to dynamic response requirements, for *generating systems* greater than or equal to 5 MW, TasNetworks will apply the *access standards* defined in Schedule 5.2.5.13 of the NER.

For *generating systems* less than 5 MW, TasNetworks will apply the performance requirements stipulated in Schedule S5.2.5.13 (b)(3) and (4) of the NER as the appropriate *automatic access standard*. Schedule S5.2.5.13 (d)(3) and (4) of the NER will be referenced as the corresponding *minimum access standard*.

The specified sections of the NER are consistent with the general expectations described above and have the intent of providing sufficient control capability such that TasNetworks

can continue to manage its regulatory obligations once the *generating system* is connected to the distribution network.

6.8 Network capability

To facilitate efficient operation of the energy market in the Tasmanian region, TasNetworks requires that inter-regional and intra-regional power transfer capabilities are not adversely affected by the connection of embedded generation into the distribution network.

For *generating systems* equal to or larger than 5 MW, TasNetworks will apply the *access standards* defined in Schedule 5.2.5.12 of the NER. This will in most cases require a basic review of perceived risk based on the size of the *generating system* and the connection point to the network. Detailed studies would only be undertaken if deemed necessary based on the initial assessment.

For *generating systems* smaller than 5 MW, it is considered unlikely that there will be material impacts on power transfer capabilities at the transmission system level. A cursory examination of any potential issues will be undertaken as part of the connection application assessment process if deemed necessary.

6.9 Monitoring and control requirements

6.9.1 TasNetworks local monitoring and control

Local monitoring and control of the *generating system* is the responsibility of the *generator*.

As outlined in Section 6.1.3, TasNetworks will install an isolation device on the distribution network that is capable of disconnecting the *generating system* during periods of planned maintenance (on the network), or for abnormal network configurations that may follow faults or emergencies (bush fires, storm events, road accidents etc.). This device may be operated locally or remotely and will not be accessible by the *generator*.

6.9.2 TasNetworks remote monitoring

For *generating systems* equal to or larger than 5 MW in capacity, or *generating systems* with remote inter-trip protection implemented back to an established terminal or zone substation, TasNetworks requires that the following information be provided via a communication interface:

- (a) Generator and mains incomer circuit breaker status.
- (b) Analogue measurement of generator real and reactive power output with a measurement accuracy of at least $\pm 2\%$.
- (c) Analogue measurement of generator and connection point line to line voltage with a measurement accuracy of at least $\pm 0.5\%$.
- (d) Analogue measurement of current (amps) on each of the three phases at the connection point. Measurement must be true RMS with an accuracy of $\pm 1\%$.

Depending on the size and type of *generating system*, what other equipment may be installed as part of the *generating system* development, and the proposed connection point

in the distribution network, TasNetworks may advise the customer of additional requirements after the connection application has been assessed.

6.9.3 TasNetworks remote control

With the exception of remote inter-trip functions, TasNetworks will not have direct remote control of any *generating system* functions. The generator will be responsible for following the operational directives as communicated from time to time from TasNetworks Control Centre.

For *generating systems* with a remote inter-trip scheme implemented, it is acceptable for the remotely initiated trip signal to operate the main incoming breaker and/or the breaker(s) of the individual generating device(s).

Some work performed by TasNetworks on its electrical assets is conducted under live-line operating conditions, which for safety reasons, requires the configuration of specific protection settings in certain network devices, e.g. sensitive earth fault protection.

TasNetworks requires the *generator* to have the capability to modify the setting of protection devices to facilitate live-line access. Where this functionality is not available or is impractical, the *generating system* will be isolated (disconnected) during such works.

6.9.4 Preferred communication methods and protocols

To ensure the safe and reliable operation of the *generating system* and distribution network, communication links installed for the purposes of protection and control must have high reliability and availability. Protection and control schemes must be designed and implemented in such a way that the loss of any single communication device will not compromise its functionality or reliability.

Protection schemes that rely on communication links must provide continuous monitoring (of the communication link integrity) and trip the *generating system* in the event of a communications failure.

TasNetworks' preferred communications medium is point-to-point fibre optic for all protection, control and remote monitoring. Where the implementation of fibre is excessively expensive or impractical, it may be appropriate for another communications medium to be used.

Where the communications link is being utilised for primary protection and control functions, the *generation proponent* must demonstrate to TasNetworks that the proposed solution has a sufficiently high level of reliability and availability, and that mitigating control actions can be implemented in the case of a communication link failure.

The communication protocol for remote monitoring will be of a suitable format to allow integration with TasNetworks' existing SCADA system which is based on DNP 3.0.

6.10 Metering requirements

As a licensed meter service provider, TasNetworks offers metering services to load and embedded generation customers and will install an appropriate meter with bi-directional capabilities as requested by retailers.

The meters that TasNetworks currently use for embedded *generating system* installations allow customers to connect embedded generation to one tariff connection in a “net” metering arrangement. Any power that is generated by the *generating system* will offset the load that is being consumed simultaneously. If the net generation exceeds the net load, any excess power will be imported to the grid at the specified feed-in tariff.

The meters that are currently used for embedded *generating systems* do not allow generated power to be netted off against more than one load tariff. *Customers* must therefore select which load tariff that they wish the generated electricity to be connected to.

For information on feed-in tariffs and tariff structures, *generation proponents* should contact their retailer. For details on any of the following, please refer to TasNetworks website:

- (a) “Network Tariff Application and Price Guide”.
- (b) “Metering Services Application and Price Guide”
- (c) For installation requirements, refer to “Service and Installation Rules”.

For general metering requirements and NEM specific requirements, please refer to Chapter 7 of the NER.

7 Other relevant information

In addition to the information provided in this guideline, TasNetworks has prepared separate documentation pertaining to specific issues.

It is recommended that *generation proponents* refer to the TasNetworks website for further details. The following documents are provided in TasNetworks “Information Pack” for embedded generators and are recommended reading in conjunction with this guideline:

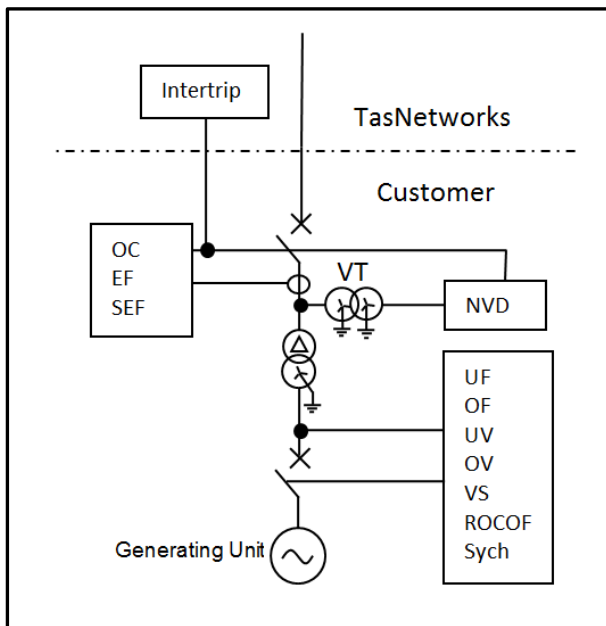
- (a) Description of application process.
- (b) Process for negotiating access standards.
- (c) Large Embedded Generator Connection – Typical Connection Arrangements.
- (d) Typical protection and control systems.

Appendix A – Sample Protection and Control Schematics

The following diagrams are provided for general reference only. The specific earthing, switchgear and protection arrangements will be determined by the type of *generating system* to be connected.

The diagrams are intended to indicate the type of information that TasNetworks would expect to be provided to assess the suitability of a proposed connection to its distribution network.

A.1 HV Connected System



A.2 LV Connected System

