AusNet

AusNet Embedded Generator and Battery Performance & Study Guideline

For 1.5 to 4.99 MW generators and batteries connecting at 22 kV

Version 1.0

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Disclaimer

The information contained in this document is subject to review and AusNet may amend this document at any time. Amendments will be indicated in the Version History table, but AusNet Services does not undertake to keep this document up to date.

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1. Introduction

1.1. Purpose

This guideline is a comprehensive overview of the requirements for the connection of non-registered embedded generation (EG), including batteries, with name plate rating between 1.5 and 4.99 MW in the Victorian distribution networks operated by AusNet. The requirements assume the EG is connecting to the AusNet 22 kV network, which is typical for generators of this size. The connection process for a non-registered embedded generator is separate to and independent of the process required by the Australian Energy Market Operator (AEMO) for registered generators.

The generator performance access requirements outlined in this document (see sections 7, 8 and 9) are modelled on Schedule 5 of the National Electricity Rules (NER), the Victorian Electricity Distribution Code of Practice (EDCoP) and relevant Australian Standards, with some variations made where the rules outlined are not appropriate for sub-5MW EGs.

The requirements in this document will be periodically reviewed by AusNet in line with any changes to any relevant rules, regulations, standards and codes.

1.1.1. Requirement drivers

EGs have an important and welcome role to play in the rapid decarbonisation of the electricity sector and improved affordability, reliability and quality of supply for Low Voltage (LV) and Medium Voltage (MV) customers. It is worth noting that the 1.5 to 4.99 MW embedded generator connection space has several unique challenges compared to over-5 MW, transmission connections and very small connections. Most notably:

1) Limited applicability of well-known performance standards (e.g., NER Chapter 5 and AS4777 requirements may or may not be of relevance, depending on technology and context).
2) Victorian-specific technical requirements through the Victorian Electricity Distribution Code of Practice.
3) Limited standardisation of performance requirements between NSPs.
4) Potential for 22 kV-connected generator performance issues to directly impact on quality and reliability of supply for residential and commercial customers.
5) The need to coordinate output with high penetration of uncontrolled rooftop solar on the LV network.
6) Remote and high impedance 22 kV networks.
7) Poor availability and/or reliability of communications infrastructure.

The requirements in this document have hence been developed to balance the needs of AusNet's network and our need to support the rapid decarbonisation of the system. If there is confusion or a plant-specific problem with a requirement in this document, **AusNet strongly encourages applicants to discuss the requirement with AusNet as early as possible** in the connection process.

1.2. Scope

The following aspects of the grid connection process for EGs between 1.5 and 4.99 MW installed on the 22 kV network are considered in this document:

1) Relevant rules, regulations, standards and codes covered by AusNet.
2) Overview of EGs Frequency Control Ancillary Services (FCAS) registration.
3) The overall connection process.
4) Technical requirements for embedded generator device compliance, thermal loading, network isolation, earthing, protection, stand-by generators and plant, runback/curtailment, Distribution Feeder Automation (DFA), Rapid Earth Fault Current Limiter (REFCL), and communication systems.
5) Generator performance requirements based on Schedule 5.2 of the NER.
6) Documentation and generator modelling requirements – including those explicitly part of the connection application checklist.

Additional considerations outside the scope of the EG connection guideline will be considered on a case-by-case basis.

1.2.1. Document structure

This document has been developed to provide both AusNet's requirements for EG performance and additional guidance and suggestions on how to best assess the EG's impact to the network through simulation.

The document is set out as follows:

- Section 2 – 5 describe general requirements, rules and processes to be followed at a high level.
- Section 6 describes static technical requirements and evaluations to be completed in steady-state simulations.
- Section 7 describes dynamic technical requirements and evaluations to be completed in dynamic simulations.
- Section 8 describes protection requirements that will largely be evaluated through design choice approval, specialised protection studies and ongoing monitoring.
- Section 9 describes general technical requirements that will typically not require simulations by the proponent, but will either be evaluated through design choice approval, by AusNet internal teams or through ongoing monitoring.

1.3. Review

AusNet reserves the right to make updates to this guideline as required, to cater for changes to:

- The NER.
- AEMO's Power System Model Guideline.
- The Victorian EDCoP.
- Any other rules, regulations, standards and codes listed in Section 2.
- AusNet network planning requirements.

Additionally, to make minor corrections or to correct any oversights or ambiguous content.

Where any disagreements may exist between this guideline and the rules, regulations, standards and codes listed in section 2, the latter will take precedence.

1.4. Version History

Version	Date	Approved	Notes & Changes
1.0	03/04/2024	Suresh Damani	Initial version based on NEM-wide NSP review

Abbreviations and definitions

Abbreviation	Meaning
ADMS	Advanced Distribution Management System
AEMO	Australian Energy Market Operator
AST	AusNet
BESS	Battery Energy Storage System
CB	Circuit Breaker
DFA	Distribution Feeder Automation
DLL	Dynamic Link Library
DYR	PSS®E Dynamic Settings File
EDCoP	Electricity Distribution Code of Practice
EG	Embedded Generator
EHV	Extra High Voltage (>230 kV)
EMT	Electromagnetic Transient
FAT	Factory Acceptance Testing
FCAS	Frequency Control Ancillary Service
FRT	Fault Ride-Through
h	Harmonic order
HV	High Voltage (35 to 230 kV)
Hz	Hertz
IBR	Inverter Based Resource
ID	Identification
IEC	International Electrotechnical Commission
kA	kilo-Amp
kV	Kilovolt
LIB	Library file
LV	Low Voltage (<1kV)
MBD	PSS®SINCAL library file
MFRT	Multiple Fault Ride-Through
MV	Medium voltage (1 kV to 35 kV)
MVA	Mega Volt Ampere
MVAr	Mega Volt Ampere Reactive
MW	Mega Watt
NEM	National Electricity Market
NER	National Electricity Rules
OBJ	Object file
OEM	Original Equipment Manufacturer
PF	Power Factor
P_{lt}	Long-term flicker
PoC	Point of Connection
PPC	Power Plant Controller
P-Q	Active & Reactive Power
PSCAD™	Power System Computer Aided Design
PSS®E	Power System Simulator for Engineering
P_{st}	Short-term flicker
REFCL	Rapid Earth Fault Current Limiter
RMS	Root Mean Square
RoCoF	Rate of Change of Frequency
RUG	Releasable User Guide
SCADA	Supervisory control and data acquisition
SCR	Short Circuit Ratio
SINCAL	SIemens Network CALculation
SLD	Single Line Diagram
SMIB	Single Machine Infinite Bus
SOP	Standard Operating Procedure
TR	Technical Report
VRR	Voltage Regulation Relay
X/R	Ratio of reactance over resistance
ZSS	Zone Substation

2. Relevant rules, regulations, standards and codes

AusNet refers to the following documents in setting its requirements.

2.1. AusNet standards

1) REF 30-10 - REFCL Program HV Customer Policy Issue 2
2) SOP 11-16 V3 – Protection Requirements for Embedded Generators (referenced in Section 9)
3) SOP 33-09B – Embedded Generator Connection Application Form for 1.5 MW to 4.99 MW Connections
4) SOP 33-09C – Generator Performance, Protection Settings and Technical Data Form

2.2. Standards, codes and guidelines

1) AEMO Power System Model Guidelines
2) TR IEC 61000.3.6:2012[1]
3) TR IEC 61000.3.7:2012
4) Victorian Electricity Distribution Code of Practice (EDCoP)

2.3. Legislation and regulation

1) Electricity Supply Industry Act 1995
2) National Electricity Law
3) National Electricity Rules

[1] It is noted that the EDCoP refers to the NER, which itself refers to the 2001 version of these standards, however Standards Australia have deemed the 2001 standard superseded, and by NER Clause 1.7(i), the 2012 version is required to be used.

3. Registration

3.1. Generator registration

According to the AEMO Guide to Generator Exemptions and Classification of Generating Units[2], section 3.4 on Standing Exemptions, generating systems with a total nameplate rating of less than 5 MW will be automatically exempt from the requirement to register as a generator. As such, an application for exemption is also not required.

For sub-5 MW generating systems to qualify for the exemption, clause 3.4.1(b) must be true:

- "Where there is any potential for the generating system to export energy, either:
  - the sent-out generation is purchased in its entirety by a Market Participant who is financially responsible for all generated or consumed at the same connection point; or
  - each of the generating units comprising the generating system is classified as a market generating unit by a Market Small Generation Aggregator."

The automatic exemption also applies to generating systems connected to a distribution or transmission system via an embedded network at a parent connection point, having a combined total nameplate rating of less than 5 MW. This exemption is also subject to clause 3.4.1(b) being true for the EG system.

Maximum nameplate rating: MVA or MW?

AusNet will usually consider 22 kV-connected generators that output up to a maximum of 4.99 MW at 0.9 PF (i.e., a total nameplate rating of up to 5.54 MVA) as a sub-5 MW connection. Different requirements may be possible depending on connection location and connecting voltage level, but in all cases active power output must not exceed 4.99 MW during operation.

3.2. FCAS registration

Connection applicants wishing to register with AEMO to provide FCAS in the NEM can fill out the Application for Registration as a Market Ancillary Service Provider in the NEM[3]. Here the applicant can specify the type(s) of FCAS intended on being provided.

AEMO's FCAS Verification Tool (FCASVT)[4] can be used to determine the maximum ancillary service capacity of the proposed Battery Energy Storage system (BESS) and/or solar connection, per service being provided. Moreover, AEMO's Market ancillary service specification (MASS)[5] provides details about the types of FCAS, including the verification and testing procedures to be undertaken by FCAS providers.

Testing requirements for Contingency FCAS registration are provided in separate documents for wind and solar farms[6] and for BESS[7] respectively.

AusNet advises new proponents to consider the reliability and diversity of their communication and control systems in making a decision to participate in the regulation FCAS market. Similarly, new proponents should consider the requirements for high-speed metering, commissioning testing and modelling for participation in the contingency FCAS market. These participation requirements are outside the control of AusNet and should be reviewed by the proponent and discussed with AEMO and/or other relevant parties where required.

3.3. Network Support Agreements

Depending on the location and functionality of the EG being connected, AusNet may consider entering into an agreement with the proponent to provide network support during certain times of the day or year in return for financial compensation. Note that network support agreements are usually only considered for active power delivery or consumption. Please discuss this option with AusNet at the time of connection application submission.

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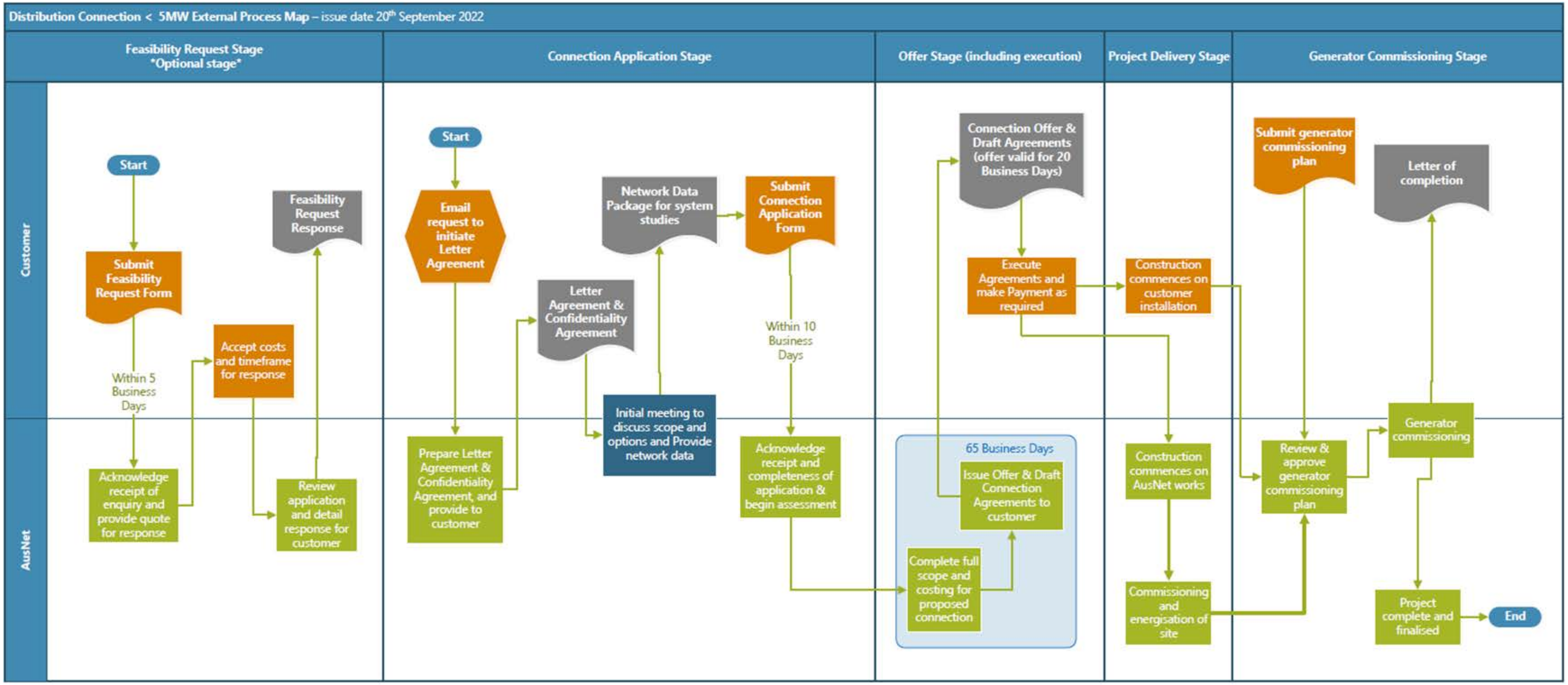
[2] Guide to Generator Exemptions and Classification of Generating Units
[3] Application for Registration NEM Market Ancillary Service Provider
[4] AEMO Market ancillary services specification and FCAS verification tool
[5] Market Ancillary Services Specification - v8.0 effective 9 Oct 2023
[6] Wind Farm and Solar Farm Guide to Contingency FCAS Registration
[7] Battery Energy Storage System guide to Contingency FCAS registration

4. Connection process overview

Also available on the AusNet 1.5 to 5 MW Connections website[8].



8 1.5MW to 5MW (ausnetservices.com.au)

5. Modelling requirements

EG plant modelling requirements are stipulated here in order to provide context for the static and dynamic study specific modelling requirements described in Section 6 and 7 of this technical guideline.

5.1. Generally

AusNet requires models to be up to date, accurate and consistent with the documentation submitted as part of the proponent's connection application. During the course of AusNet's review of the proponent's submission, if an issue is found with models or data that prevents the adequate assessment of the proposed plant's performance, **AusNet will halt further application assessment until the modelling or data issue is resolved to AusNet's satisfaction**.

Moreover, the contracts to be signed as part of the connection agreement will require models to be maintained throughout the life of the plant, whereby if there are changes made to the plant, or if there are software version changes within the industry, an updated/compatible model must be provided.

5.2. Modelling Software

Table 1 Modelling Requirements high-level summary

	PSS®SINCAL	PSS®E	PSCAD™
Also known as	SINCAL	PSSE	PSCAD
Purpose	Load-flow	Load-flow & dynamics	Dynamics
Topology	Wide-network (22 kV)	SMIB	SMIB
Required	Yes	Yes	Yes
Version	18.5	34.7[9]	5.0.2
Bitness	64 bit	32 & 64 bit	32 & 64 bit
Libraries	.MBD	.OBJ and .DLL	.DLL only
Dependencies	N/A	None[10]	Redistributable only
Plant representation	Aggregated by technology type, site-specific, reticulation and PoC transformer, includes PPC[11]		
Documentation	Steady state studies report (Refer to *Steady State Study Report Template Sub 5MW – AusNet*)	Releasable User Guide	Releasable User Guide

5.2.1. PSS®SINCAL Modelling

A static PSS®SINCAL model of the plant is required. It must:

1) Be modelled up to its connection point.
2) Have appropriate aggregated representations (inverters, transformers, loads etc.).
3) Include OEM- and site-specific steady state parameters.

AusNet Services will provide the 22 kV network data in PSS®SINCAL format version 18.5. The PSS®SINCAL model of the plant up to its connection point will need to be connected with the AusNet 22 kV network to facilitate the steady state studies.

5.2.1.1. PSS®SINCAL Version

AusNet currently requires PSS®SINCAL models submitted to be compatible with version 18.5. Please note that it is an obligation that an appropriate model is available throughout the life of the plant, including accommodations to changing simulation software versions, bitness, FORTRAN versions, and operating system requirements.

[9] Version 35.4+ likely to be required for all new connection in 2024 onwards, pending AEMO direction.
[10] This includes dependencies on external configuration files, such as .cfg, .ini or .txt files, which are not acceptable.
[11] Steady state modelling in SINCAL does not require PPC

5.2.2. PSS®E modelling

A static and dynamic PSS®E model of the plant is required. It must:

1) Be modelled up to its connection point.
2) Have appropriate aggregated representations (inverters, transformers, loads etc.).
3) Include OEM- and site-specific steady state and dynamic parameters.
4) (If used) Include a correct representation of the central plant controller / park controller including site-specific settings. If a central plant controller is not used, individual generator (inverter) units and the reticulation system need to be modelled.
5) Have relevant protection functions adequately modelled.
6) Have a corresponding Releasable User Guide[12] that documents the salient steady-state information and dynamic parameters (e.g., STATE, ICON, CONS, VARS).

Dynamic studies using a Single Machine Infinite Bus (SMIB) representation of the PSS®E model will be required for all sub-5 MW generator connections, based on the network impedance at the connection point to demonstrate fault ride through capability, voltage and frequency disturbance responses. The network impedance at the connection point needs to be calculated from PSS®SINCAL network model at N-1 contingency (minimum fault level).

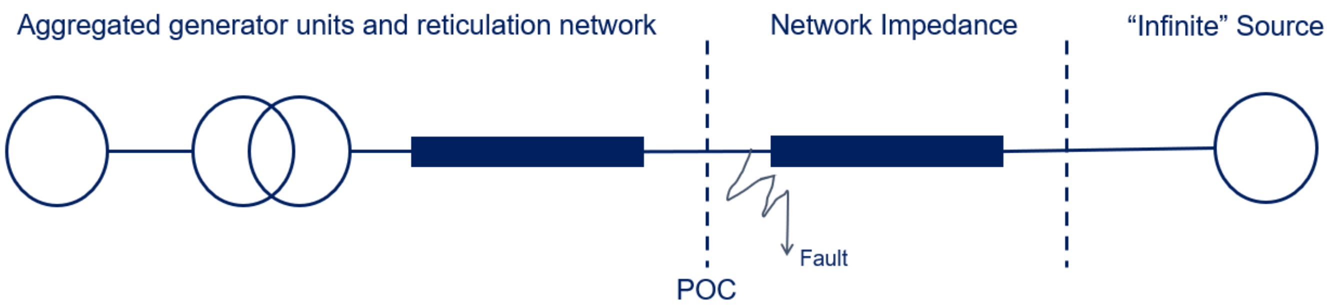


Figure 1 A SMIB representation of a generator plant

Before submitting, the applicant must ensure that the model is robust and set up correctly and can have its dynamics successfully initialised (without suspect initial conditions) for a full range of operating points and grid conditions. Applicants are strongly advised to review the AEMO Power System Model Guidelines for an indication of the quality of the model AusNet will be expecting.

5.2.2.1. PSS®E version

AusNet currently requires PSS®E models submitted to be compatible with PSS®E v34.7. Please note that it is an obligation that an appropriate model is available throughout the life of the plant, including accommodations to changing simulation software versions, bitness, FORTRAN versions, and operating system requirements.

Although not currently confirmed, it is highly likely that the industry will move to a later version of PSS®E in the near future (version 35 or 36). It will be a requirement that an appropriate model be made available by the applicant to accommodate this change, noting that **these later versions will require 64-bit compatible dynamic models**.

Both DLL and OBJ files for the dynamic model will be required. Submission of model source code to AusNet is not required.

Please see the AEMO Power System Model Guidelines[13] for a more detailed discussion on typical RMS modelling requirements.

5.2.3. PSCAD™ modelling

A PSCAD™ model of the plant is required. It must:

1) Be modelled up to its connection point.
2) Have appropriate aggregated representations (inverters, transformers, loads etc.).
3) Include OEM- and site-specific steady state and dynamic parameters.

[12] AEMO guideline and template for preparation of Releasable User Guide for guidance.
[13] AEMO Power System Model Guidelines.

4) (If used) Include a correct representation of the central plant controller / park controller including site-specific settings. If a central plant controller is not used, individual generator (inverter) units and the reticulation system need to be modelled.

5) Have relevant protection functions adequately modelled.

6) Have a corresponding Releasable User Guide[14] that documents the salient steady-state information and dynamic parameters.

Although the PSCAD™ model is required, it is usually only required for posterity[15], and PSCAD™ dynamic studies are only required when system strength limitations (i.e., minimum short-circuit ratio ≤ 5) are identified at connection point. If PSCAD™ studies are required the fault ride through capability, voltage and frequency disturbance responses need to be demonstrated with PSCAD™ simulation studies.

5.2.3.1. PSCAD version

AusNet currently requires PSCAD models submitted to be compatible with version 5.0.2 and later.

Please note:

1) Both 32-bit and 64-bit models are required.

2) There must not be dependencies on external software packages or libraries that are not common redistributable libraries (e.g., a dependency on Microsoft Visual C++ or E-TRAN redistributable libraries is acceptable, a dependency on a commercial version of Visual Studio's libraries is not acceptable).

3) In line with the most recent AEMO Power System Model Guidelines, external libraries must be provided in pre-compiled .DLL format, rather than .OBJ or .LIB files which require runtime compilation.

Please note that it is an obligation that an appropriate model is available throughout the life of the plant, including accommodations to changing simulation software versions, bitness, FORTRAN versions, and operating system requirements.

Please see the AEMO Power System Model Guidelines for a more detailed discussion on typical EMT modelling requirements.

[14] AEMO guideline and template for preparation of Releasable User Guide for guidance.

[15] Inverter-based sub-5 MW connections in the AusNet network are predicted to reach a such a large amount in the upcoming years that despite the rigor this guideline intends to create in analyzing EGs, future potential for control system interactions is a possibility that AusNet must be prepared to investigate, and EMT models are the most expedient way to do so.

6. Static performance & study requirements

6.1. Steady state modelling

The 22 kV network data will be provided in PSS®SINCAL format (version 18.5) to facilitate the steady state studies. AusNet advises that the steady state modelling and studies are to be performed and the plant's steady state performance to be approved by AusNet **before** proceeding to dynamic studies. Once the steady state performance is approved, the proponent can use the approved control settings in the dynamic studies.

The steady state study report is to note the relevant data considered for the studies, such as feeder loading levels (Amps/MW/MVAr), voltages at the zone substation bus, status of capacitor banks, line voltage regulator settings, details and parameters of each element of the proposed system (i.e., inverter parameters, transformers, reticulation system etc.).

6.1.1. Input data

AusNet will provide an information data pack so that the proponent can perform the steady state studies. The information pack typically contains the items below:

- PSS®SINCAL model of the 22kV network;
- Low capacitance cable specifications (if EG/battery connects to REFCL feeder) (see section 9.3);
- Steady State Study Report Template Sub 5 MW – AusNet;
- Information data pack (typically includes the information below):
    - Network configurations;
    - Sensitivity analysis requirements;
    - Maximum and minimum fault level at 22kV ZSS bus;
    - Equipment (station Voltage Regulation Relay (VRR), line voltage regulator, capacitor bank etc.) settings;
    - List of other committed and existing projects in the area;
    - Maximum and minimum demand forecast of the feeder & Zone Substation (ZSS);
    - Maximum and minimum historic demand of the feeder & ZSS;
    - Load demand across the feeders (maximum and minimum);
    - Switch status data;
    - Conductor details; and
    - Modelling notes etc.
- A voltage harmonic allocation

6.1.2. Network Configurations

6.1.2.1. System Normal

AusNet 22 kV feeders are operated radially from the ZSS. The system normal network configuration will be considered to be where the EG/ Battery is connected to a usual nearby feeder and no Distribution Feeder Automation is under operation.

6.1.2.2. Distribution Feeder Automation (DFA)

AusNet uses rapid automatic fault restoration schemes which can transfer many MV and LV customers' electricity supply source from one 22 kV feeder to another or even from one zone substation to another.

For many IBR-based plant, such transfers may result in unsustainably low system strength for the EG to remain in stable operation. Hence, the EG is expected to trip and remain offline upon DFA activation. The EG must only reconnect once the normal network configuration has been restored.

In some circumstances, the proponent may wish to remain connected for DFA scenarios. While AusNet will consider this arrangement, it is important for the proponent to note that all studies outlined in this guideline will need to be repeated for the secondary network configurations (DFA configuration 1, DFA configuration 2 etc) in addition to the system normal configuration, as electrically it is an entirely new connection point to the broader network. AusNet encourages proponents to weigh the cost of the additional work versus the likelihood of a DFA failover occurring. This likelihood can be assessed from historical ‘Switch status data’ listed in section 6.1.1.

6.2. Load flow studies

The plant is to be modelled with an appropriate aggregated representation of the inverters, any relevant loads, reticulation system and transformers up to the PoC.

The load flow studies are to be performed for:

- Maximum and minimum network loading scenarios.
- Each of the required network configurations (system normal, DFA configurations if used, etc.).
- Forecast scenarios.

The load flow studies are to assess the following characteristics for each loading scenario in each required network configuration with and without the proposed system in service.

6.2.1. Thermal loading impact

This study assesses the impact of the proposed EG/battery on the applicable feeders' thermal capacity to accommodate the proposed exports and imports (if applicable, e.g., BESS).

This must list and describe the highest loaded branches of the relevant feeders to which the plant is connected:

- For each network configuration.
- For both maximum and minimum load cases.
- With and without the plant in service.

Note that loading levels and ratings of line voltage regulators must be included, where applicable. An example of the data to be produced from this study is shown in Table 2.

Table 2 Highly loaded feeder sections to be listed for each network configuration in both maximum and minimum load cases

Feeder Name	Node 1	Node 2	Element Type	Rating	Thermal loading (% rating)	
					With the proposed plant	Without the proposed plant
Feeder 1	*e.g., A*	*e.g., D*	*e.g., 3/12 Steel*	*e.g., 28 A*	*e.g., 115*	*e.g., 85*
Feeder 2	*e.g., X*	*e.g., Y*	*e.g., 19/3.25*	*e.g., 230 A*	*e.g., 80*	*e.g., 75*
...						

Note that the thermal loading impact of the EG in the distribution network should be kept to a minimum, ideally below 90% of rating. Network equipment overloads and loading levels greater than 90% of thermal rating, if any, must be highlighted in the report. AusNet will study the mitigation measures with the proponent.

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.2. Voltage profile

The voltage profile along the feeder must be generated, from the ZSS to feeder extremities. This must be studied:

- For each network configuration; and
- For both maximum and minimum load cases; and
- With and without the plant in service.

The applicant may consider more than one voltage profile for each network configuration considering multiple feeder extremities where applicable. This includes:

1) Snapshot of the feeder layout highlighting the route considered for the voltage profile.
2) Voltage profile plots with nodes (along with node distances) on the horizontal axis from the zone substation to a feeder extremity (identifying relevant nodes such as the zone Substation 22 kV bus, connection point of the proposed system, nodes on either side of voltage regulators, capacitor banks etc.) and voltage levels on the vertical axis as % of nominal phase to phase voltage (i.e. 22 kV).

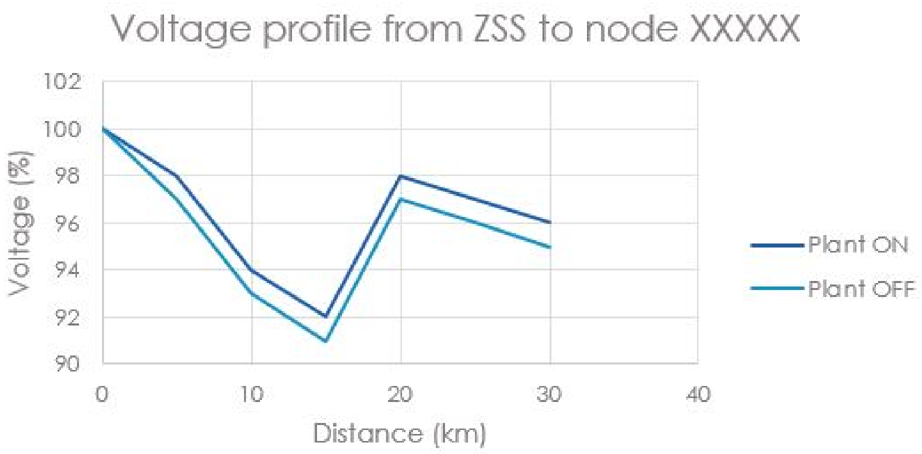


Figure 2 Voltage profile needs to be illustrated for different network configurations in maximum and minimum load conditions

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.3. Voltage variation considering the proposed plant connection

The steady state voltage variations are to be assessed at several key locations within the applicable feeders. This analysis is carried out with the automatic tap operation of transformers where applicable. It includes:

1) Tables showing the voltage levels (% of nominal phase to phase voltage) and % voltage variation with and without the proposed system, nodes capturing the zone substation 22 kV bus, connection point, feeder T-off points, nodes on either side of line voltage regulators, capacitor banks, major customers, feeder extremity nodes and any other relevant nodes.
2) For line voltage regulators, include the loading levels (MW, MVAr, Amps) and voltages on nodes on either side of the line voltage regulators and tap position headroom.

See section 6.4 for further details. An example table is shown in Table 3.

Table 3 Voltage variations to be reported for each network configuration in maximum and minimum load cases

Node ID	**% of nominal voltage**			**Line to line voltage in kV**		
	With the proposed plant	Without the proposed plant	Voltage variation	With the proposed plant	Without the proposed plant	Voltage variation
e.g., cn_7567964	*e.g., 101.70*	*e.g., 101.26*	*e.g., 0.44*	*e.g., 22.374*	*e.g., 22.277*	*e.g., 0.097*
…						

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.4. Power flow at feeder head

Possibilities of reverse power flow/total demand at the feeder maximum and minimum loads are to be identified. This should detail the power flow at the feeder heads for different network configurations at maximum and minimum loads. This may include a reverse power flow at the feeder head. Table 4 provides an example as to how this data should be recorded.

Table 4 Power flow at feeder head for maximum and minimum load scenarios

Network	**Feeder ID**	**With the proposed plant**			**Without the proposed plant**		
		P (MW)	Q (MVAr)	S (MVA)	P (MW)	Q (MVAr)	S (MVA)
System normal	Feeder 1	*e.g., 1.8*	*e.g., 2.8*	*e.g., 3.33*	*e.g., 6.43*	*e.g., 2.3*	*e.g., 6.83*
DFA configuration 1	Feeder 1						
	Feeder 2						

...	...						

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.5. Power factor at point of connection

The power factor at connection point is to be listed in a table for each of the network configurations in both maximum load and minimum load scenarios. Table 5 provides an example as to how this data should be recorded.

Table 5 Power factor at Point of connection

Configuration	High load	Low load
System normal	*e.g., 0.98*	*e.g., 0.98*
DFA configuration 1		
...		

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.6. Voltage variation considering trip of the proposed plant

The voltage variation for the loss of proponent's installation (i.e., EG trip) is to be determined as follows:

1) Identify voltage variations due to an EG trip from 100% output to disconnection of the plant, with all transformer taps locked.
2) Develop tables showing the voltage levels (% of nominal voltage) and % voltage variations for nodes capturing the zone substation 22 kV bus, connection point, feeder T-off points, nodes on either side of line voltage regulators, capacitor banks, major customers, feeder extremity nodes and any other relevant nodes.
3) For line voltage regulators, include the loading levels (MW, MVAr, Amps) and voltages on nodes on either side of the line voltage regulators and tap position headroom.

An example of the table to be developed is shown in Table 6.

Table 6 Voltage variation due to generator trip for each network configurations in maximum and minimum load cases

Node ID	**% of nominal voltage**			**Line to line voltage in kV**		
	With the proposed plant/ before trip	Without the proposed plant/ after trip	Voltage variation	With the proposed plant/ before trip	Without the proposed plant/ after trip	Voltage variation
e.g., bd16142	*e.g., 99.42*	*e.g., 98.95*	*e.g., 0.47*	*e.g., 21.87*	*e.g., 21.76*	*e.g., 0.1*
...						

Note that Table 6 of IEC TR 61000.3.7:2012 requires infrequent voltage variations, such as those induced by tripping of an EG, to be limited 5-6% of nominal voltage. AusNet abides by this standard and will check for compliance.

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.7. Voltage variation due to generation output variations

The voltage variation due to generation output variations (e.g., from maximum export to maximum import for a BESS, from maximum export to minimum export for a wind farm) must be reported, as follows:

1) Identify voltage variations due to generation output variations considered from 100% export to 100% import (BESS) or 100% to minimum export (for other EGs) of the plant with all transformer taps enabled.
2) Tables showing the voltage levels (% of nominal voltage) and % voltage variations for nodes capturing the zone substation 22 kV bus, connection point, feeder T-off points, nodes on either side of line voltage regulators, capacitor banks, major customers, feeder extremity nodes and any other relevant nodes.
3) For line voltage regulators, include the loading levels (MW, MVAr, Amps) and voltages on nodes on either side of the line voltage regulators and tap position headroom.

An example of the table to be developed is shown in Table 7.

Table 7 Voltage variation due to generation output variations for each network configurations in maximum and minimum load cases

Node ID	% of nominal voltage			Line to line voltage in kV		
	Maximum export	Maximum import	Voltage variation	Maximum export	Maximum import	Voltage variation
e.g., cn_8269709	*e.g., 99.42*	*e.g., 98.95*	*e.g., 0.47*	*e.g., 21.87*	*e.g., 21.76*	*e.g., 0.1*
…						

Additional studies for forecast load profiles will also be required for this item (see Section 6.2.8).

6.2.8. Sensitivity analysis

Additional steady state studies will be required based on forecasts for feeder maximum and minimum load demand for **system normal network configuration only**.

The following information is provided in the information data pack (see Section 6.1.1) to facilitate these studies:

- The forecast years to consider.
- The forecast years' feeder demand.
- The forecast years' ZSS demand.

6.3. Reactive power capability

6.3.1. Requirement

AusNet requires that an EG operating at:

1) any level of active power output; and
2) any voltage at the connection point within the limits described in Section 7.3.1 without a contingency event,

must be capable of supplying and absorbing continuously at its connection point an amount of reactive power of at least the amount equal to the product of the rated active power of the generating system and the multiplication factor shown in Figure 3, for a given normal PoC voltage.

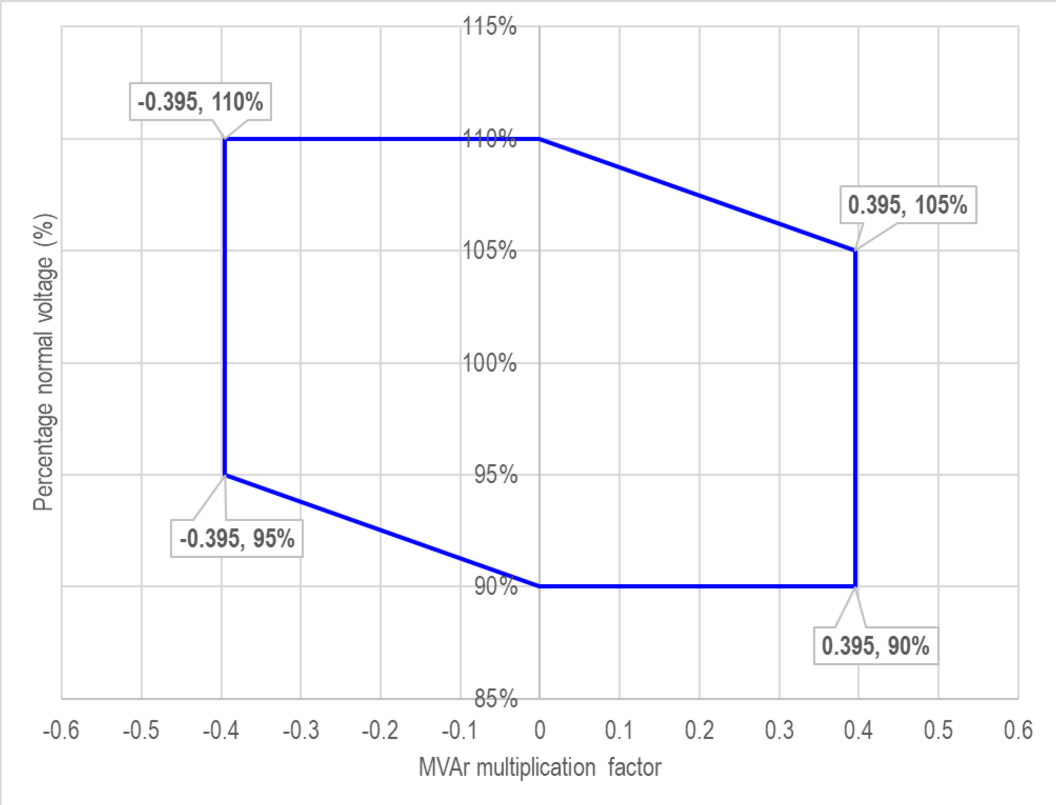


Figure 3 Reactive power vs. PoC voltage profile

If a generating system can meet this standard, no further negotiation is required. Otherwise, further negotiation with AusNet is required in determining whether the reactive power capability is suitable to meet the power system stability and security standards of the distribution network, or whether additional reactive support is needed at the connecting plant.

6.3.1.1. Power factor control

AusNet may allow EG systems to operate at a fixed PF and specify an allowable PF operational limit provided the network voltage level is maintained within the specified range and voltage variation before and after connection is maintained within the specified limit (refer section 6.4).

If PF control is not capable of maintaining the required network voltage profile, then AusNet recommends voltage control with sufficient reactive power capability over an encompassing range of connection point voltages (refer Section 6.4).

6.3.2. Compliance

The proponent must clearly indicate the raw reactive power capability of the EG – accounting for any operating voltage limitations the EG or its reticulation network may have or impose – and the proposed capability for which a PPC (if any) will limit P-Q output.

The proponent should present the following information and figures as part of the steady state studies and documentation:

1) The reactive power capability curves showing the reactive power range for any level of active power output from 0% to 100% (four quadrant reactive power capability curves for energy storage systems where applicable):

   a) For each distinctive generating unit for EG **terminal voltages** from 0.9 pu, 1.0 pu and 1.1 pu of nominal voltages (usually part of the data provided by the OEM);

   b) For the generating system for **connection point** voltages of 0.9 pu, 1.0 pu and 1.1 pu of nominal voltages, including an overlay of the proposed operating envelope or power factor line (see example in Figure 3);

   c) Reactive and active power capability curves for (i) and (ii) above clearly indicating descriptions of the applicable temperatures for the curve, if hot or cold weather can change the system's operation capability. (Typically, two curves are to be submitted, one for 25°C, and another for 50°C).

2) A description of any expected limitations, reductions, or other changes to reactive power capability for voltages outside the ±10% nominal voltage range.

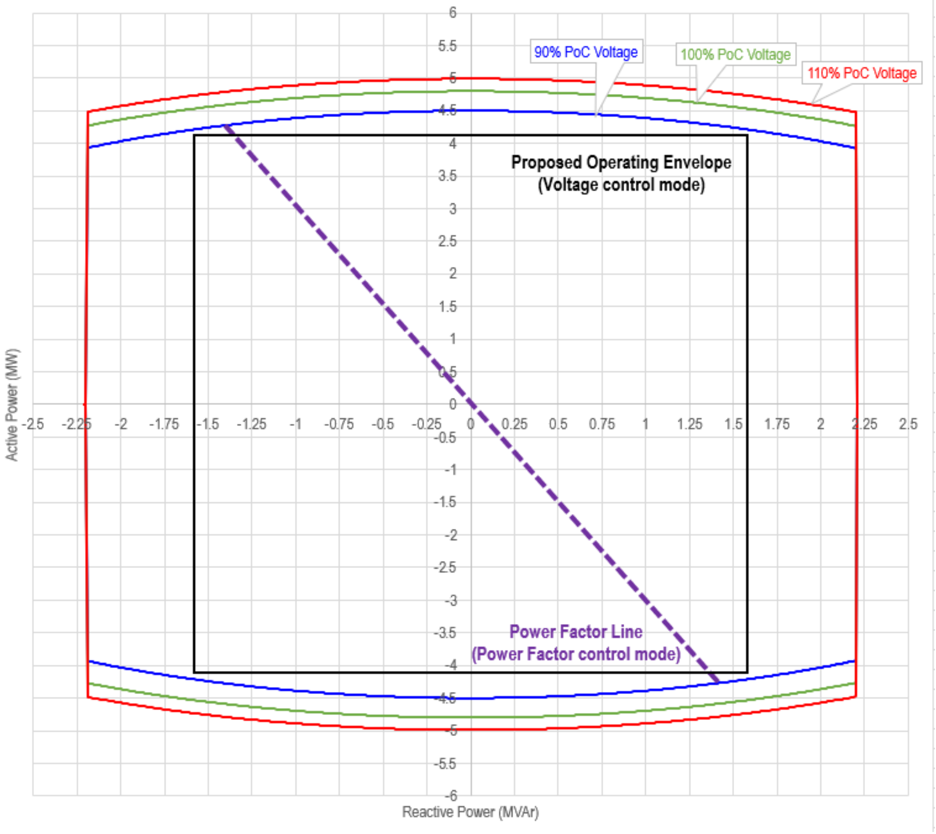


Figure 4 Example connection point capability curve for a BESS at a given operating temperature. Voltage control envelope and power factor line overlays added as example.

Note, compliance with this curve will also be checked as part of dynamic studies.

6.4. Voltage regulation

Impacts to voltage on the 22 kV network directly affect lower voltage customers (including residential customers) as there is no voltage regulation between the 22 kV and 415 V network. With embedded generation and changing load profiles, LV customers sensitivity to overvoltages and undervoltages is a major concern for AusNet, and consequently AusNet is obliged to strongly uphold tight voltage compliance standards. Additionally, it is important to note that voltage sensitivity challenges are magnified towards the end of long 22 kV feeders, or feeders that have low X/R ratios.

6.4.1. Requirement

Voltages pre-and post-connection of EGs between 1.5 and 4.99 MW should be maintained within an acceptable range detailed below. EG systems of this size are typically connected into the 22 kV network, for which the acceptable voltage range is specified by AusNet to be 90-103% of the nominal voltage.

For the connection of new EGs between 1.5 and 4.99 MW, the connecting proponent must:

1) Not cause voltage across the feeder outside the acceptable range of 90-103%;
2) Restrict voltage increases to 0.5%[16] across the feeder during light load conditions (compared to pre-connection conditions); and
3) Restrict voltage decreases to 0.5% across the feeder during peak load conditions (compared to pre-connection conditions).

The above must consider the action of any existing line regulators present on the feeder and the action of zone-substation voltage regulation relays, and result in compliant voltage control behaviour across the feeder and its voltage regulation components.

6.4.2. Compliance

The applicant must demonstrate how the chosen control strategy to regulate voltage or power factor achieves these targets and meets AusNet's requirements through simulations at maximum and minimum load scenarios for a range of reasonable dispatch conditions and system configurations.

Note that generally, it is expected electrically distant connections to ZSS will likely need more complex voltage control schemes (e.g., voltage droop control) while PF control may be acceptable for stronger connections closer to the ZSS. This may change depending on project specifics. See Table 8 for high-level, non-exhaustive pros and cons.

Table 8 Examples of different reactive control strategy characteristics

Reactive Control Type	Pros	Cons
Power Factor	Simple to implement. Reduced set of studies. Reduced set of commissioning tests. Reduced interaction with network voltage control schemes.	Very limited network locations where appropriate. Less likely to meet network voltage control requirements. May cause ZSS transformers to hit tap limits.
Voltage droop control	More likely to meet the network's voltage control needs. May be suitable in locations deeper into the network / further from the ZSS.	May require reduction in MW output to preserve headroom for MVAr. May interact with existing voltage control schemes. Additional studies and coordination strategies required.
Voltage control	More likely to meet the network's voltage control needs. Default mode for many synchronous machine AVRs.	May interact with existing voltage control schemes. Oscillatory behaviour possibility increased. Additional studies and coordination strategies required.

6.4.2.1. Voltage breaches

If there are high voltage or low voltage breaches due to the new connection, AusNet will consider the mitigation measures in discussions with the proponent. The proponent may arrange workshops with AusNet to show their voltage variation results before submitting the full connection study report.

[16] Please note, this requirement may be stricter (e.g., 0.0%) depending on where in the network the connection will be, particularly towards the end of long 22 kV feeders and on feeders with very low X/R ratios.

Moreover, AusNet may suggest a voltage setpoint at the PoC to be adhered to for a new EG connection, depending on the location and general voltage profile in the network. Otherwise, the connection applicant will be asked to determine a suitable setpoint and voltage control methodology (e.g., direct voltage control, voltage droop control, or PF control) to implement as part of the connection study that would minimise the voltage variation post-connection of the proposed plant.

6.4.2.2. Voltage Droop Control

If voltage droop control is to be implemented, a voltage droop profile (example shown in Figure 4) must be developed that meets the above requirements and provides suitable reactive margins for the scenarios considered.

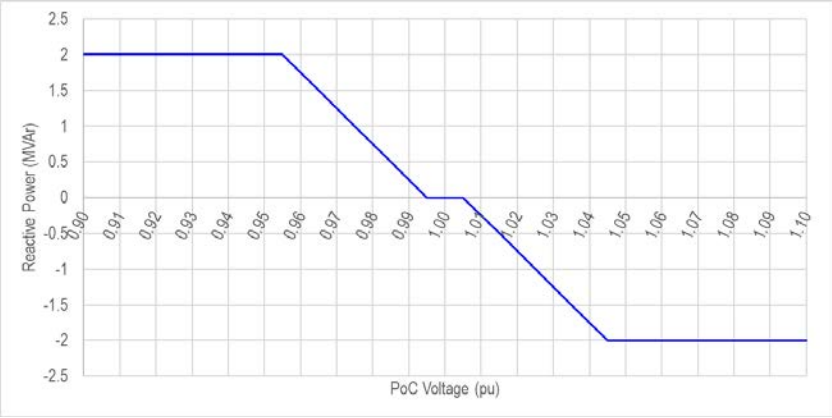


Figure 5 Example voltage droop curve (positive Q is injecting)

Note, compliance with this curve will also be checked as part of dynamic studies. See Section 7.7.

6.5. Fault level requirements

6.5.1. Requirement

The maximum short circuit fault levels in AusNet's distribution network must not exceed the fault levels specified in Table 6 of the Victorian EDCoP (reproduced in Table 9 below) as a result of the connection of an EG unit.

Table 9 EDC Maximum Distribution System Fault Levels

DISTRIBUTION SYSTEM FAULT LEVELS		
Voltage Level (kV)	**System Fault Level (kVA)**	**Short Circuit Level (kA)**
66	2500	21.9
22	500	13.1
11	350	18.4
6.6	250	21.9
<1	36	50.0

6.5.2. Compliance

The proponent must provide fault level studies to assess the 3 phase, phase to phase to ground and phase to ground fault levels (in kA and MVA) and the fault current contribution (in kA) at the connection point. This is to be conducted with and without the proposed plant, considering each network configuration and incorporating maximum and minimum fault level at the ZSS.

Table 10 Fault levels and fault current contribution from the proposed plant incorporating maximum and minimum fault level at ZSS

Scenario	**Fault type**	**With the proposed plant**				**Without the proposed plant**				**Fault current contribution from the proposed plant at the connection point**
		Fault level at the ZSS		Fault level at the connection point		Fault level at the ZSS		Fault level at the connection point		
		MVA	Amps	MVA	Amps	MVA	Amps	MVA	Amps	Amps
System normal	3Ph	*e.g., 402.90*	*e.g., 10586*	*e.g., 50.51*	*e.g.,1327*	*e.g.,399.44*	*e.g.,10495*	*e.g.,47.84*	*e.g.,1257*	*e.g.,70*
	Ph-Ph-G									
	Ph-G									
DFA configuration 1	3Ph									
	Ph-Ph-G									
	Ph-G									
DFA configuration 2	3Ph									
	Ph-Ph-G									
	Ph-G									

6.6. Quality of electricity generated

6.6.1. Requirement

The 22 kV connection point, with or without the EG in service, must not have:

1) Voltage fluctuation greater than the limits described in Section 6.6.1.1;
2) Harmonic voltage distortion greater than the emission limits described in Section 6.6.1.2; and
3) Voltage unbalance greater than the limits described in Section 6.6.1.3.

These limits are inclusive of the effect of the existing network and its connections and customer loads prior to EG connection, i.e., **these are not *allocations* to the new connecting EG**.

Additionally, the EG must not:

4) Inject current harmonics greater than the limits described in Section 6.6.1.4; and
5) Inject unbalanced currents greater than the limits described in Section 6.6.1.5.

6.6.1.1. Voltage fluctuations (flicker)

AusNet refers to the planning levels from TR IEC 61000.3.7:2012 for MV power systems as to the flicker limit that must not be exceeded at the connection point. This is described in Table 11.

Table 11 Indicative values of planning levels for flicker in MV power systems

Planning levels	1 kV – 35 kV
P_{st}	0.9
P_{lt}	0.7

6.6.1.2. Voltage harmonic levels

AusNet refers to the planning levels from TR IEC 61000.3.6:2012 for MV power systems as to the harmonic voltage level that must not be exceeded at the connection point. This is described in Table 12.

Table 12 Indicative planning levels for harmonic voltages (in percent of the fundamental voltage) in MV (1 – 35 kV) power systems

Odd harmonics, non-triplen		Odd harmonics, triplen		Even harmonics	
Order h	**Harmonic Voltage %**	**Order h**	**Harmonic Voltage %**	**Order h**	**Harmonic Voltage %**
5	5.00	3	4.00	2	1.80
7	4.00	9	1.20	4	1.00
11	3.00	15	0.30	6	0.50
13	2.50	21	0.20	8	0.50
17	1.70	27	0.20	10	0.47
19	1.50	33	0.20	12	0.43
23	1.20	39	0.20	14	0.40
25	1.09	45	0.20	16	0.38
29	0.91			18	0.36
31	0.84			20	0.35
35	0.72			22	0.33
37	0.67			24	0.32
41	0.59			26	0.32
43	0.55			28	0.31
47	0.49			30	0.30
49	0.46			32	0.30
				34	0.29
				36	0.29
				38	0.29
				40	0.28
				42	0.28
				44	0.28
				46	0.27
				48	0.27
				50	0.27
Note that Total Harmonic Distortion must not exceed 6.5 %.					

6.6.1.3. Voltage unbalance

AusNet refers to the Victorian EDCoP requirements, which itself refers to NER clause S5.1a.7 as to the unbalanced voltage level that must not be exceeded at the connection point. This is described in Table 13 with the 22 kV level requirements highlighted.

Table 13 Voltage unbalance limits

Nominal supply voltage (kV)	Maximum negative sequence voltage (% of nominal voltage)			
	No contingency event	Credible contingency event or protected event	General	Once per hour
	30-minute average	30-minute average	10-minute average	1-minute average
More than 100	0.5	0.7	1.0	2.0
More than 10 but not more than 100	1.3	1.3	2.0	2.5
10 or less	2.0	2.0	2.5	3.0

6.6.1.4. Current harmonic limits

AusNet refers to the Victorian EDCoP requirements as to the maximum harmonic current injection level. This is described in Table 14.

Table 14 Harmonic Current Distortion Limits in Percent of Maximum Current (%)

Harmonic Type	h<11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	THD
Odd	4.0	2.0	1.5	0.6	0.3	5.0
Even	1.0	0.5	0.38	0.15	0.08	

6.6.1.5. Unbalanced currents limits

AusNet refers to the Victorian EDCoP requirements as to the maximum unbalanced current injection level. This is described in Table 15.

Table 15 Unbalanced current injection limits

Nominal supply voltage	Maximum acceptable deviation from the average of the three phase currents	
	Continuous	Up to 2 minutes
>1 kV	2%	4%

6.6.1.5.1. Zero sequence currents

The presence of zero sequence currents in the MV network can potentially disrupt the balance of phase loadings and impact the functioning of earth fault protection systems (e.g., REFCL). It is a requirement that the physical connection of three-phase equipment take this into consideration.

6.6.2. Compliance

AusNet will provide:

1) A voltage harmonic allocation limit to the connecting customer at the nearest 22 kV zone substation busbar and an emission assessment method.

2) Allocation limits for the flicker emissions (Minimum Emission Limits at MV as specified in Table 4 of TR IEC 61000.3.7:2012)

For harmonics emissions, using the provided limit, the SINCAL model of the 22 kV feeder, emission assessment method and the harmonic model of the EG, the customer is to perform power quality studies to yield the following results:

1) The harmonic current profile of the generating units for each harmonic order.

2) The harmonics voltage emissions for the generating system for each harmonic order.

3) Provision of details of any known sensitivity of the plant to grid harmonics.

6.6.2.1. Deferred work

Flicker assessment and negative sequence voltage compliance assessments through modelling are not expected at the connection application stage. However, the proponent is required to submit the compliance certifications from the OEM for the generating units.

During the commissioning phase, applicant must demonstrate the plant compliance for the flicker, voltage and current harmonics, voltage unbalance as per the measurement/assessment process agreed in the commissioning test plan.

Moreover, the connection applicant will agree with AusNet contractually that, throughout the life of the plant, should harmonic issues be found in the area that the plant is connected, the plant will aid in the investigation in good faith and respond to reasonable requests of AusNet to track down the issue. Part of the ongoing compliance will be the need to install a designated power quality meter for the proposed connecting plant (see Section 9.5).

6.7. Deliverables

After completion of the steady-state studies, the following needs to be submitted by the proponent to AusNet:

1) The PSS®SINCAL model of each case and network configurations used in the studies with proposed plant included.
2) Steady-state study report demonstrating the performance of the proposed plant, including:
    a) Reactive capability curves as outlined in Section 6.3.2.
    b) Proposed reactive control strategies and how they meet voltage regulation requirements of Section 6.4.1.
    c) Details of any other salient control strategies of the plant.
3) Power quality report (including certifications from the OEM for aspects not studied)
4) Cable schedule (see section 9.3 if the proposed plant connects to REFCL feeder)
5) Single line diagram (SLD)
6) Geographical layout diagram, including:
    a) Location of PoC to the grid.
    b) Location of mains switch board with the central protection relay.
    c) Site access arrangements.
7) Details of site load without generation (where applicable).
8) Manufacturer information of the EG equipment
    a) OEM datasheets and manuals.
    b) Details of the relevant Australian or equivalent standards to which the EG complies.
    c) General control system overview (details of what controllers are present and active in the EG).
    d) Confirmation as to what minimum SCR and X/R levels the plant can reliably operate (low system strength scenarios).
9) Any compliance certificates for power quality standards met.
10) Drawings reflecting communication facilities for remote tripping and monitoring.
11) Any other information request as identified by AusNet during the course of application evaluation.

7. Dynamic performance & study requirements

7.1. Dynamic modelling

The proponent will be required to perform a variety of dynamic simulations in PSS®E to demonstrate their EG's ability to meet the minimum dynamic performance requirements set out in this section. Currently, AusNet only requires these studies to be performed in a SMIB environment. However, AusNet reserves the right to expand the extent of the network to be modelled, particularly if a proposed EG will be electrically close to another existing EG or dynamic network component.

The plant is to be modelled with an appropriate aggregated representation of the inverters, any relevant loads, reticulation system and transformers up to the PoC. If there are multiple technology types, or if a central plant controller is not used, it may be necessary to model individual units and the reticulation network. Please discuss with AusNet before commencing studies[17].

The impedance to be presented to the EG at its PoC is expected to reflect the impedances determined through the steady state studies in PSS®SINCAL at an N-1 contingency (minimum fault level)[18].

Please note, for all studies in Section 7:

- AusNet reserves the right to request additional studies for different network configurations, disturbances, operating points or other scenarios as needed.
- Where an inverter based EG proposes to connect at a location and size that would see its PoC SCR to be less than or equal to five[19], matching PSCAD™ studies will be also be required[20].
- The energy source availability requirement of Section 7.9 will require a single PSCAD™ study to be completed, as RMS models (i.e., PSS®E) are not capable of appropriately modelling DC-side dynamics.

7.1.1. Input data

The following items should be agreed upon between AusNet and the proponent before dynamic studies commence:

Table 16 Dynamic studies agreed inputs

Section	Item
7.1	Appropriate aggregation methodology for the plant.
7.3.2.2	Any alternate power factors to be considered.
7.4.1.4 & 7.4.2.3	The MFRT profile (residual voltage depth, length, etc.).
7.4.2 & 8.3.1	Confirmation of fault clearance times.
7.5.1	The need for partial load rejection tests.
7.6.1	An agreed active power response to frequency deviations.
7.7.1.1	An agreed target normal voltage.
7.7.1.1	An agreed reactive power capability (see Section 6.3.1)
7.8.1.2	Speed of EG response to a network-initiated control scheme.

[17] Decided on a case-by-case basis. Ideally no more than 4 models for the entire plant grouped by technology.
[18] Note, this N-1 contingency event is from upstream network and this minimum fault level at 22kV ZSS bus will be advised by AusNet in 'Information data pack' (see section 6.1.1).
[19] By any means whereby the plant intends to remain in operation, including DFA scenarios.
[20] As described in Section 5.2.3, a matching PSCAD™ model will need to be submitted for all connections, but PSCAD™ studies are only currently required for such low system strength scenarios.

7.2. Generating unit response to frequency disturbances

This section refers to the plant's ability to withstand frequency disturbances. Active power response to frequency disturbances is discussed in Section 7.6.

7.2.1. Requirement

AusNet requires that EG units should not disconnect (or cause other generating units to disconnect) during and following a network frequency disturbance, consistent with the minimum standards in the NEM.

EG systems with a capacity ranging from 1.5 to 4.99 MW are not to disconnect from the network when the frequency fluctuates within the range of 47.0 Hz to 52.0 Hz with the profile shown in Figure 5, unless:

1) The rate of change of frequency (RoCoF) is outside the range of -2 Hz to 2 Hz per second for more than 0.25 seconds, -1 Hz to 1 Hz per second for more than one second; or
2) One or more anti-islanding protection schemes detect that the generator has become electrically isolated from the primary network supply.

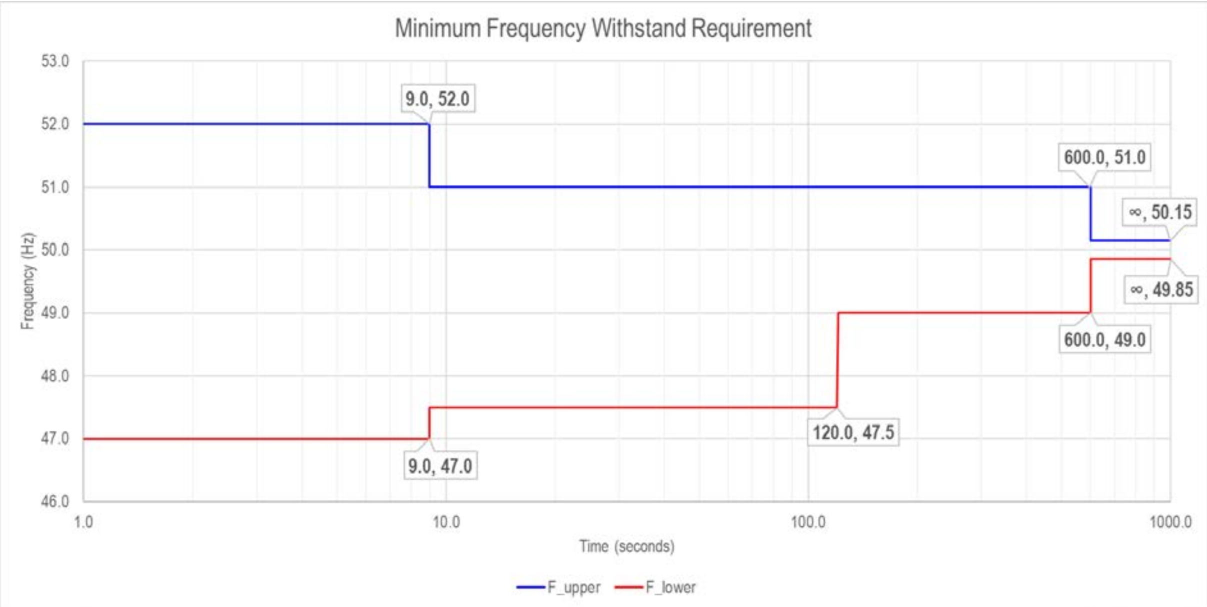


Figure 6 Minimum Frequency Withstand Requirement

AusNet will conduct an assessment and negotiation process to establish appropriate under and over frequency protection settings, ensuring harmonization with other network protection and control mechanisms.

N.B., When choosing protection settings, AusNet recommends adding a margin to both sensitivity and time delay settings to ensure that simulations can be completed at exactly the limits above without causing the modelled plant to trip because of very high precision calculations or relay features such as hysteresis and reset ratios.

7.2.2. Compliance

Dynamic simulations must be completed to assess the connecting plant's ability to withstand at least the above RoCoF withstand requirements and the upper and lower bounds of the frequency profile shown in Figure 5.

Within the dynamic PSS®E SMIB environment, the infinite machine frequency should be ramped away from nominal (50 Hz) to impose a frequency disturbance on the EG model which tests the above limits. The list of test conditions is shown in Table 17. The built-in PLBVFU1 model may be of use here.

Batteries are to conduct the studies for both MW import and export scenarios.

Table 17 Frequency withstand tests

Test #	SCR & X/R	Active Power	Target Frequency	RoCoF	Hold for at least
722-1-A	Min case PoC	100%	47 Hz		9 s
722-1-B			47.5 Hz		120 s

Test #	SCR & X/R	Active Power	Target Frequency	RoCoF	Hold for at least
722-1-C			49 Hz	Maximum plant withstand capability	600 s
722-1-D			51 Hz		600 s
722-1-E			52 Hz		9 s
722-2-A	Min case PoC	Minimum P	47 Hz	Maximum plant withstand capability	9 s
722-2-B			47.5 Hz		120 s
722-2-C			49 Hz		600 s
722-2-D			51 Hz		600 s
722-2-E			52 Hz		9 s

Note that the RoCoF withstand capability of the plant will determine the ramp profile applied to reach these limits, noting it must meet or exceed the minimum requirements described in Section 7.2.1. Figure 6 shows an example of a underfrequency profile that adheres to the minimum RoCoF requirements.

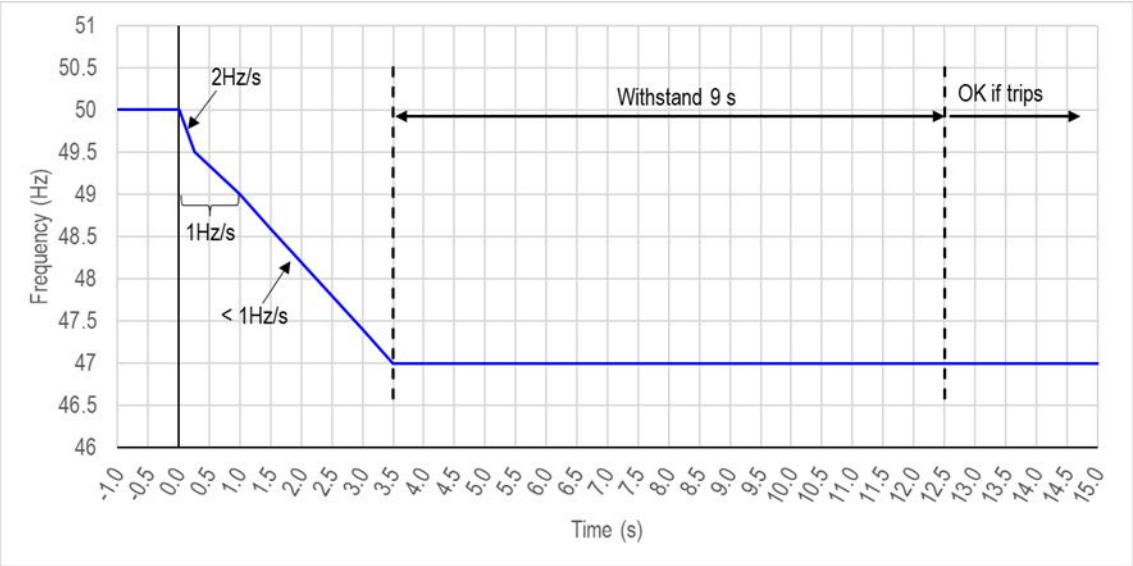


Figure 7 Example of a frequency profile for the 50 Hz to 47 Hz withstand test, adhering to minimum RoCoF limits

For these studies, please note that as shown in Figure 6, the withstand time only begins after the target frequency has been reached.

Note: PSCAD™ dynamic studies are required for this clause (same studies as PSS®E) when system strength limitations (i.e., minimum short-circuit ratio ≤ 5) are identified at connection point**.**

7.3. Generating unit response to voltage disturbances

This section refers to the plant's ability to withstand voltage disturbances and remain in continuous uninterrupted operation (CUO). More aspects related to contingency events and reactive power response are discussed in Section 7.4 and Section 7.7.

7.3.1. Requirement

For EG systems that are between 1.5 and 4.99 MW, the generating system will maintain CUO[21] when a power system disturbance causes the voltage at the connection point to vary within the following ranges:

1) 110-120% range of normal voltage for up to 10 seconds
2) 90-110% range of normal voltage continuously
3) 80-90% range of normal voltage for up to 5 seconds
4) 70-80% range of normal voltage for up to 2 seconds

Note that the use of PoC transformer tap changers to maintain CUO is only acceptable for variations *greater* than 10% within the range of 90% to 110% of nominal voltage.

When choosing protection settings, AusNet recommends adding a margin to both sensitivity and time delay settings to ensure that simulations can be completed at exactly the limits above without causing the modelled plant to trip due to high precision calculations or relay features such as hysteresis and reset ratios.

7.3.2. Compliance

7.3.2.1. For EGs in voltage or voltage droop control

The connecting plant must be able to demonstrate through dynamic simulations its ability to maintain CUO for different plant operating conditions and for a variety of voltage disturbances as shown in Table 18.

Batteries are to conduct the studies for both MW import and export scenarios.

Table 18 Voltage withstand test list for EGs in voltage control

Test #	SCR & X/R	Initial Active Power	Initial Reactive Power	Withstand Voltage	Withstand time
732-1-A	Min case PoC	100%	Maximum Injection	120%	10 s
732-1-B				110%	600 s*
732-1-C				90%	600 s*
732-1-D				80 %	5 s
732-1-E				70 %	2 s
732-2-A	Min case PoC	100%	Maximum Absorption	120%	10 s
732-2-B				110%	600 s*
732-2-C				90%	600 s*
732-2-D				80 %	5 s
732-2-E				70 %	2 s
732-3-A	Min case PoC	Minimum	Maximum Injection	120%	10 s
732-3-B				110%	600 s*
732-3-C				90%	600 s*
732-3-D				80 %	5 s
732-3-E				70 %	2 s
732-4-A	Min case PoC	Minimum	Maximum Absorption	120%	10 s
732-4-B				110%	600 s*
732-4-C				90%	600 s*
732-4-D				80 %	5 s

[21] For the purposes of this dynamic assessment, continuous uninterrupted operation (CUO) refers to the ability to withstand the disturbance without disconnecting, and for PoC voltages between 0.9 pu and 1.1 pu of the nominal voltage level during the disturbance, there being no reduction in active power at the connection point, compared to the pre-disturbance active power levels. If there is a slight reduction in active power output due to losses associated with increased current during the disturbance, this is considered acceptable for CUO. (Also refer to the NER chapter 10 definition of continuous uninterrupted operation.)

Test #	SCR & X/R	Initial Active Power	Initial Reactive Power	Withstand Voltage	Withstand time
732-4-E				70 %	2 s
* this is a continuous withstand requirement, limited to a 10 minute interval for the sake of modelling practicality.					

7.3.2.2. For EGs in power factor control

The connecting plant must be able to demonstrate through dynamic simulations its ability to maintain CUO for different plant operating conditions and for a variety of voltage disturbances as shown in Table 19.

Batteries are to conduct the studies for both MW import and export scenarios.

Table 19 Voltage withstand test list for EGs in droop control

Test #	SCR & X/R	Initial Active Power	Initial Reactive Power	Withstand Voltage	Withstand time
732-5-A	Min case PoC	100%	As dictated by power factor	120%	10 s
732-5-B				110%	600 s*
732-5-C				90%	600 s*
732-5-D				80 %	5 s
732-5-E				70 %	2 s
732-6-A	Min case PoC	Minimum	As dictated by power factor	120%	10 s
732-6-B				110%	600 s*
732-6-C				90%	600 s*
732-6-D				80 %	5 s
732-6-E				70 %	2 s
* this is a continuous withstand requirement, limited to a 10-minute interval for the sake of modelling practicality.					

If the PF setpoint may be required to change during the lifetime of the plant, the proponent is to test for voltage disturbances at a variety of PF setpoints, as directed by AusNet.

7.3.2.3. PPC coordination & entrapment avoidance

If a PPC is present in the EG, correct coordination between the PPC and the generating units must be clearly demonstrated for each of the MW and MVAr dispatch conditions listed above. In particular, it must be demonstrated that:

- The PPC does not continue to attempt to regulate the generating unit outputs when the generating units have entered a FRT state (i.e., the PPC refrains from winding-up).
- The FRT detection thresholds in the PPC and the generating units have been selected appropriately for the given plant and its reticulation network impedance for all dispatch scenarios listed above (i.e., chosen thresholds and hysteresis margins do not result in cycling behaviour or incorrect FRT coordination between PPC and generating units)

Given the various ways OEMs implement equipment, AusNet cannot provide specific advice in this guideline on how best to demonstrate this, however it is noted that presenting outputs of FRT flags available in models is often used.

Note: PSCAD™ dynamic studies are required for this clause (same studies as PSS®E) when system strength limitations (i.e., minimum short-circuit ratio ≤ 5) are identified at connection point.

7.4. Generating response to disturbances following contingency events

7.4.1. Requirement

The EG must remain in continuous uninterrupted operation (CUO) for any disturbance caused by a single-phase-to-ground, phase-to-phase, two-phase-to-ground, or three-phase fault in the distribution network cleared in the longest time expected to be taken for all relevant primary protection systems to clear the fault, provided that the event is not one that would disconnect the generating unit from the power system by removing network elements from service.

Please note that AusNet attempts reclose for all line faults on both the 22 kV distribution network (usually 8 seconds) and 66 kV sub-transmission network (usually 3 seconds). While primary clearance times for the 66 kV network may be several hundred milliseconds, it is not uncommon for 22 kV faults to persist for several seconds.

7.4.1.1. Fault Current Injection for Asynchronous Plant

Generally, for all fault-types, EGs comprised of IBR plant must provide:

1) Capacitive reactive current in addition to its pre-disturbance level of a percentage greater than 0% of the maximum continuous current of the generating system for each 1% reduction of voltage at the connection point below the fault ride-through threshold and the generating system must commence a response when the connection point voltage is in the range of 80 to 90%.
2) Inductive reactive current in addition to its pre-disturbance level of a percentage greater than 0% of the maximum continuous current of the generating system for each 1% increase of voltage at the connection point above the fault ride-through threshold and the generating system must commence a response when the connection point voltage is in the range of 110 to 120%.

The reactive current response must be adequately controlled throughout the disturbance and must commence as soon as practicable following the initiating conditions being met.

Exceptions and restrictions to the provision of fault current may be considered or even necessary depending on the requirements of the local network and its protection systems.

7.4.1.2. Fault Current Injection for Synchronous Plant

An EG comprised of synchronous generating units must:

1) Deliver active power to the network, and supply or absorb reactive power in a manner that aids in restoring network voltages to the pre-disturbance level; but
2) Disconnect from the power system should a pole-slip condition be detected, in line with Section 8.4.

7.4.1.3. Post Fault Clearance Behaviour (Synchronous and Asynchronous)

EGs must:

1) Promptly cease reactive fault current injection upon system voltage returning to its normal range, and not impose an unreasonable voltage overshoot on the network PoC due to delayed controller action or otherwise.
2) Exhibit the ability to restore 95% of their pre-fault active power supply within 500 milliseconds following the clearance of a fault by protection systems.
    a) When an EG has the capability to provide frequency control within the specified timeframe and does so in response to an over-frequency condition, this characteristic shall take precedence over the above requirement for active power recovery.
3) Any oscillations present on fault clearance must be damped and generally consistent with the technology type comprising the EG, and returning to steady state within 20 seconds.

Inability to meet these requirements necessitates engagement in a negotiation process with AusNet.

7.4.1.4. Multiple Fault Ride-Through (MFRT)

Although faults on the same feeder as the plant in question will result in the plant being tripped offline through its anti-islanding function, it is possible for faults on adjacent 22 kV feeders, zone substations and the upstream 66 kV network to result in multiple disturbances that would not see the plant removed from service.

As AusNet generally attempts recloses for all line faults (including 3-phase faults) on both the 22 and 66 kV network, the requirement for MFRT is as follows:

1) Up to six disturbances in a five-minute period, causing the voltage at the connection point to vary within the ranges set by AusNet;
2) Up to three of the disturbances cause the voltage at the connection point to drop below 50% of normal voltage;
3) The time difference between the clearance of one disturbance and commencement of the next disturbance exceeds 200 milliseconds; and
4) No more than three of the disturbances occur within 30 seconds

provided that none of the events would result in the islanding of the generating system or cause a material reduction in power transfer capability by removing network elements from service.

7.4.2. Compliance

Provide dynamic simulations to capture and assess the EG's ability to withstand the following contingency events and to assess the EG's ability to maintain CUO:

1) Bolted three-phase fault for fault duration of 1 second.
2) Phase-Phase-Ground fault for 2 seconds.
3) Phase-Ground fault for 3 seconds.

For each of the simulations above, compare the plant's modelled performance to each of the requirements listed in Section 7.4.1, and confirm if they have been satisfactorily met.

Confirm that no instabilities or unexpected/unexplained behaviour is present in the result, and that any discrete control systems in both individual generating units and the PPC correctly entered and exited their FRT routine. Synchronous machines will be expected to trip within their critical clearance time.

Fault types and clearance times discussed above may be decreased or extended depending on the nature of the network to which the EG connects, and historical fault events in the area. Please consult AusNet before commencing studies.

7.4.2.1. For EGs in voltage or voltage droop control

The connecting plant must be able to demonstrate through dynamic simulations its ability to meet the above requirements for different operating conditions and for a variety of voltage disturbances as shown in Table 20.

Batteries are to conduct the studies for both import and export scenarios.

Table 20 Default fault assessment tests for V or Vdroop control

Test #	SCR & X/R	Initial Active Power	Initial Reactive Power	Disturbance	Clearance
742-1-A	Min case PoC	100%	Maximum Injection	3ph fault	1 s
742-1-B				2ph fault	2 s
742-1-C				1ph fault	3 s
742-2-A	Min case PoC	100%	Maximum Absorption	3ph fault	1 s
742-2-B				2ph fault	2 s
742-2-C				1ph fault	3 s
742-3-A	Min case PoC	Minimum P	Maximum Injection	3ph fault	1 s
742-3-B				2ph fault	2 s
742-3-C				1ph fault	3 s
742-4-A	Min case PoC	Minimum P	Maximum Absorption	3ph fault	1 s
742-4-B				2ph fault	2 s
742-4-C				1ph fault	3 s

7.4.2.2. For EGs in power factor control

The connecting plant must be able to demonstrate through dynamic simulations its ability to meet the above requirements for different operating conditions and for a variety of voltage disturbances as shown in Table 21.

Batteries are to conduct the studies for both import and export scenarios.

Table 21 Default fault assessment tests for PF control

Test #	SCR & X/R	Initial Active Power	Initial Reactive Setpoint	Disturbance	Clearance
742-5-A	Min case PoC	100%	As agreed from steady state studies	3ph fault	1 s
742-5-B				2ph fault	2 s
742-5-C				1ph fault	3 s
742-6-A	Min case PoC	Minimum P	As agreed from steady state studies	3ph fault	1 s
742-6-B				2ph fault	2 s
742-6-C				1ph fault	3 s

7.4.2.3. Multiple Fault Ride-Through

For all EG types, confirm the fault sequence to be assessed in consultation with AusNet, and then apply six faults of varying residual voltage over the space of 180 seconds and confirm the EG's ability to meet the requirements set out in 7.4.1.

Based on generation type and availability of historical point of connection disturbance information, AusNet may elect to apply a custom profile for assessment or use the default profile. The default test sequences are presented in Table 22 and the profile shown in Figure 7.

Batteries are to conduct the studies for both import and export scenarios.

Table 22 Default MFRT test assessments for all generators

Test #	SCR & X/R	Initial Active Power	Reactive Setpoint	Disturbance begins (s)	Residual Voltage (pu)	Disturbance ends (s)
742-7	Min case PoC	100%	As agreed from steady state studies	5	0.33	7
				27	0.72	30
				70	0.05	71
				108	0.85	111
				159	0.6	161
				162	0.01	163
742-8	Min case PoC	Minimum P	As agreed from steady state studies	5	0.33	7
				27	0.72	30
				70	0.05	71
				108	0.85	111
				159	0.6	161
				162	0.01	163

Note that PSCAD studies (if required) should explore the appropriate fault type (e.g., 2LG, LG, etc.) with similar residual voltages, rather than the simple positive sequence residual voltage used in PSS®E.

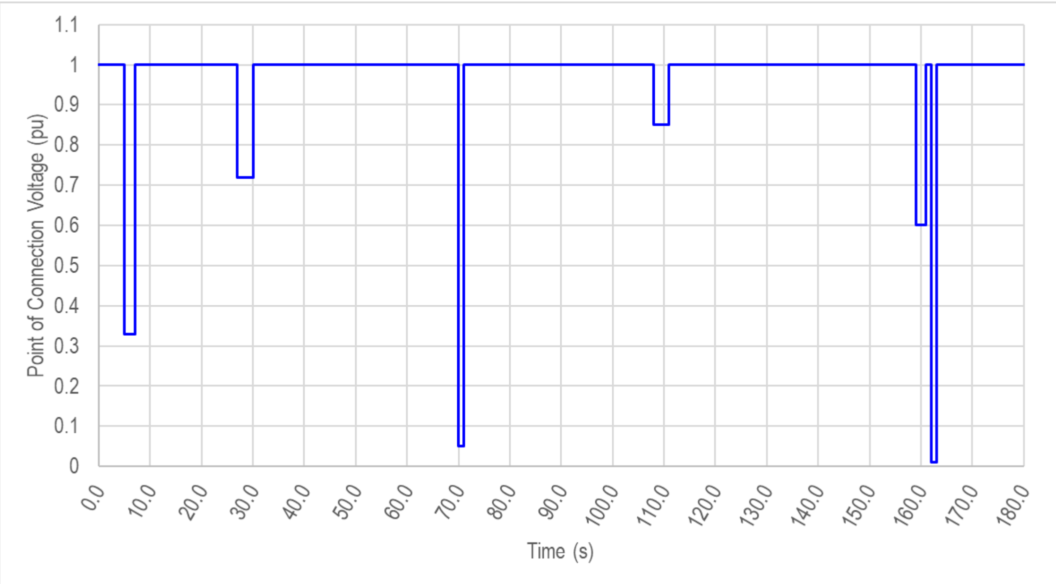


Figure 8 Default MFRT profile

Note: PSCAD™ dynamic studies are required for this clause (same studies as PSS®E) when system strength limitations (i.e., minimum short-circuit ratio ≤ 5) are identified at connection point.

7.5. Partial load rejection

7.5.1. Requirement

On a case-by-case basis (for synchronous machine connections), AusNet may require the EG must be capable of continuous uninterrupted operation during and following a power system load reduction of between 5% (minimum) to 30% (automatic) from its pre-disturbance level, or equivalent impact from separation of part of the power system in less than 10 seconds, provided that the loading level remains above minimum generation.

7.5.2. Compliance

The proponent may be asked to provide dynamic studies demonstrating the generating system's ability to remain in continuous uninterrupted operation for the load reductions specified above.

7.6. Frequency control

7.6.1. Requirement

All EGs between 1.5 and 4.99 MW must show the following characteristics in response to power system frequency changes.

For an EG system under relatively stable input energy, power transfer to the power system must not:

1) Increase in response to a rise in the frequency of the power system as measured at the connection point; and
2) Decrease more than 2% per Hz in response to a fall in the frequency of the power system as measured at the connection point.

An EG must be capable of operating in frequency response mode such that, subject to energy source availability, it automatically provides:

1) A decrease in power transfer to the power system in response to a rise in the frequency of the power system as measured at the connection point; or
2) An increase in power transfer to the power system in response to a fall in the frequency of the power system as measured at the connection point.

where the change in active power is either proportional or otherwise as agreed with AusNet, and when the network frequency exceeds a deadband of ±0.15 Hz from nominal.

As part of the EG's frequency response for scenarios that do not also include a voltage disturbance, its agreed reactive power control strategy must not be compromised or otherwise altered to the detriment of network voltage control.

7.6.2. Compliance

The connecting plant must be able to demonstrate through dynamic simulations its ability to meet the above requirements for different operating conditions and for a variety of frequency disturbances as shown in Table 23. All ramps are linear.

Batteries are to conduct the studies for both import and export scenarios.

Table 23 Frequency Control Tests

Test #	SCR & X/R	Initial Active Power	Frequency Deviation	RoCoF
762-1	Min case PoC	100%	+1 Hz (51 Hz)	+1 Hz/s
762-2			-1 Hz (49 Hz)	-1 Hz/s
762-3		Minimum P	+1 Hz (51 Hz)	+1 Hz/s
762-4			-1 Hz (49 Hz)	-1 Hz/s

Examples of the expected frequency deviation profile applied to the infinite machine are shown in Figure 8 and Figure 9.

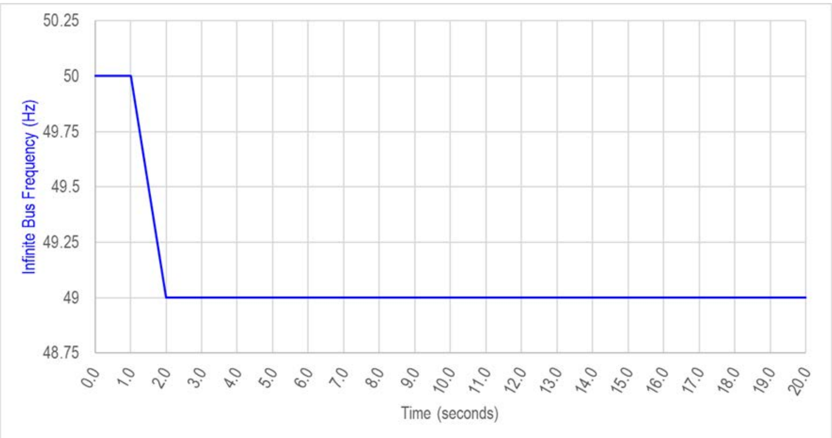


Figure 9 Frequency Decrease Test

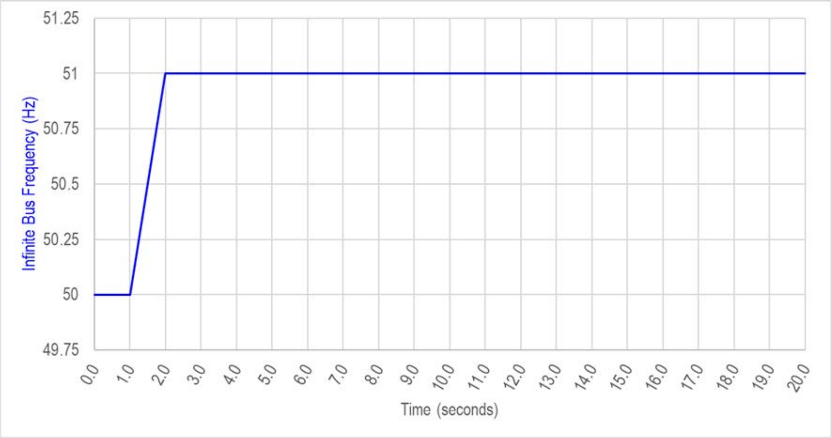


Figure 10 Frequency Increase Test

7.7. Voltage and reactive power control

7.7.1. Requirement

All EG systems must have appropriate systems in place to dynamically control voltage or power factor at the connection point. As described in Section 6.2 and Section 6.4, the appropriate control arrangement to meet requirements specified by AusNet will depend on the specifics of the connection, its location, and the needs of the surrounding network.

7.7.1.1. EGs under voltage or voltage droop control

A voltage control system for an EG must:

1) Regulate voltage at the connection point to within 0.5% of the setpoint, where that setpoint may be adjusted to incorporate any voltage droop or reactive current compensation agreed with AusNet;
2) Allow the voltage setpoint to be controllable in the range of at least ±0.05 pu of normal target voltage (as approved by AusNet from steady state studies) at the connection point, subject to the reactive power capability agreed with AusNet;
3) Have a settling time less than 10 seconds for a 5% voltage disturbance with the generating unit electrically connected to the power system from an operating point where such a voltage disturbance would not cause any limiting device to operate; and
4) Have limiting devices to ensure that a voltage disturbance would not cause the generating unit to trip at the limits of its operating capability.

7.7.1.2. EGs under power factor control

A power factor control system for an EG must:

1) Regulate power factor at the connection point to within 100 kVAr that the power factor requires; and
2) Allow the power factor setpoint to be continuously controllable across the reactive power capability range.

7.7.1.3. Generally

A EG must have plant capabilities and control systems sufficient to ensure that:

1) EG oscillations that result from both setpoint changes and network disturbances are adequately damped; and
2) The EG does not cause instability (including hunting of tap-changing transformer control systems, line regulators or ZSS transformers) that would adversely impact the network or other EGs;
3) Any limiting present must not detract from the performance of any power oscillation damping capability and be co-ordinated with all protection systems.
4) The model dynamic performance must conform to the given reactive capability curve discussed in Section 6.3. A satisfactory explanation or model revision must be given if:
   a) The plant P-Q response is not able to meet the agreed capability curve for a given connection point voltage and temperature, or
   b) The plant P-Q response exceeds the agreed capability curve for a given connection point voltage and temperature.

7.7.2. Compliance

Dynamic simulations in PSS®E and PSCAD™ (if applicable) must be produced which can demonstrate the plant's ability to meet the requirements set out in Section 7.7.1 for its given reactive control mode, as well as demonstrating that the P-Q profile and voltage droop profile (if applicable) are dynamically met.

Dynamic simulations must demonstrate the following:

1) The EG responds to the disturbance in the manner that the chosen reactive power control scheme (and its settings) dictates;
2) The EG remains stable in response to a reactive power setpoint change, with minimal oscillatory behaviour and settling times met;
3) Ability to regulate its output within the tolerances set out in Section 7.7.1;

4) Ability to maintain its active power output to the pre-disturbance level when the PoC voltage is within the 90% to 110% range.

7.7.2.1. For EGs in voltage or voltage droop control

The connecting EG must be able to demonstrate through dynamic simulations its ability to meet the above requirements for different operating conditions and for voltage setpoint changes as shown in Table 24.

Batteries are to conduct the studies for both import and export scenarios.

Table 24 Voltage control reference step tests

Test #	SCR & X/R	Initial Active Power	Initial Voltage Setpoint	Setpoint change
772-1-A	Min case PoC	100%	As agreed from steady state studies	+0.05 pu
772-1-B				-0.05 pu
772-2-A	Min case PoC	Minimum	As agreed from steady state studies	+0.05 pu
772-2-B				-0.05 pu
772-3-A	Min case PoC	100%	As agreed from steady state studies	Positive step sufficient to activate a limiting device
772-3-B	Min case PoC	100%	As agreed from steady state studies	Negative step sufficient to activate a limiting device

7.7.2.2. For EGs in power factor control

The connecting EG must be able to demonstrate through dynamic simulations its ability to meet the above requirements for different operating conditions and for reactive setpoint changes as shown in Table 25.

Batteries are to conduct the studies for both import and export scenarios.

Table 25 Power factor control reference step tests

Test #	SCR & X/R	Initial Active Power	Initial Power Factor Setpoint	Setpoint change
772-4-A	Min case PoC	100%	As agreed from steady state studies	+ 50% of the PoC reactive power capability
772-4-B				- 50% of the PoC reactive power capability
772-5-A	Min case PoC	Minimum	As agreed from steady state studies	+ 50% of the PoC reactive power capability
772-5-B				- 50% of the PoC reactive power capability
772-6-A	Min case PoC	100%	As agreed from steady state studies	Positive step sufficient to activate a limiting device
772-6-B	Min case PoC	100%	As agreed from steady state studies	Negative step sufficient to activate a limiting device

7.8. Active power control

7.8.1. Requirement

EGs are expected to be able to have active power control systems capable of responding to two categories of active power control signals:

1) Responses to changes requested from the plant owner's bidding system.
2) Responses to network-initiated control schemes.

7.8.1.1. Bidding system response

The plants response from its bidding system must have the following characteristics:

1) Respond to setpoint changes with a symmetrical linear ramp rate of no faster than 1 MW/minute (up and down); and
2) Subject to energy source availability, maintain its output in accordance with its bidding system command.

7.8.1.2. Network-initiated control schemes

The plants response to network-initiated control schemes must have the following characteristics:

1) Respond to setpoint changes with a linear ramp rate of at least 100% in 20 seconds (up and down) or another rate as agreed with AusNet;
2) For curtailment (runback) schemes, limit its active power output to or below the level commanded until the network-initiated command is rescinded; and
3) For network support schemes, maintain its output in accordance with the network support agreement profile until the network-initiated command is rescinded.

7.8.2. Compliance

The connecting EG must be able to demonstrate through dynamic simulations its ability to meet the above requirements for different operating conditions and for active power reference changes as shown in Table 26.

The studies must demonstrate that:

1) The generating system can linearly adjust its active output at a ramp rate of 1 MW/min during system normal operation.
2) The generating system can linearly adjust its active output at the rate agreed with AusNet for the relevant network-initiated control scheme.
3) The EG's reactive power output changes (or does not change) consistent with the chosen reactive control scheme.

Batteries are to conduct the studies for both import and export scenarios.

Table 26 Active power control reference tests

Test #	MW setpoint mechanism	SCR & X/R	Initial Reactive Setpoint	Sequence	
				Time	Active Power Reference
782-1	Bidding system	Min case PoC	As agreed from steady state studies	0 s	100%
				1 s	50%
				180 s*	100%
				350 s*	0% (or Minimum P)
				670 s*	100%
782-2	Network control scheme	Min case PoC	As agreed from steady state studies	0 s	100%
				10 s	0%
*The timing assumes a nameplate of approximately 4.99 MW, which would take 5 minutes to ramp at ±1 MW/min. Smaller installations will be able to reduce timing accordingly.					

Example of the reference profiles and expected responses described in Table 26 are shown in Figure 10 and Figure 11.

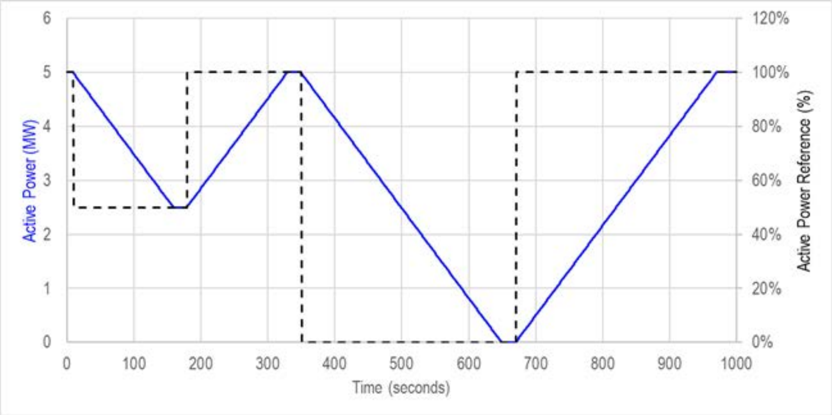


Figure 11 Example demonstrating expected 1MW/s ramp response to bidding control

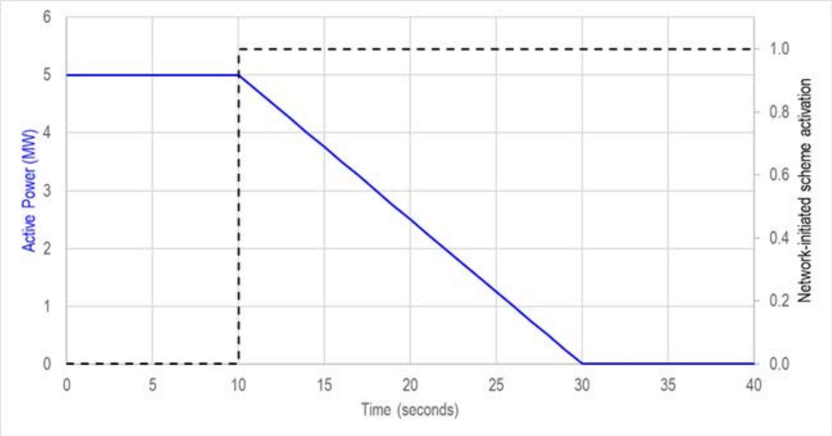


Figure 12 Example demonstrating expected rapid response to network-initiated control scheme

7.9. Energy source availability

This requirement is based on contemporary experience with IBR plant showing poor performance in the field when DC-side sources cannot provide the necessary energy to support the commanded active power output.

It is applicable to IBR EGs only, including any hybrid combinations.

7.9.1. Requirement

EGs must demonstrate stable performance when a variable input energy source (e.g., photovoltaic solar, chemical energy storage) is incapable of providing the necessary energy that the commanded active power output of the EG requires (on an instantaneous basis).

EGs must demonstrate strong coordination between their DC-side controllers and their AC-side inverters to cater for this scenario.

Responses must be stable when the energy source availability is both static and ramping to a new value.

7.9.2. Compliance

The EG must perform a study in PSCAD™ to confirm that coordination between the DC-side energy source and the AC-side inverter output has been considered in the control system coordination and design.

Note: A PSCAD™ study is required as although some PSS®E models contain dynamic fields purporting to represent the input energy source availability, AusNet experience has found that such RMS models typically simplify the DC-side controller mechanisms to an extent whereby their outputs cannot be relied upon.

Batteries are to conduct the studies for both import and export scenarios, however the proponent may suggest altered profiles to better suit equipment behaviour.

Test #	SCR & X/R	Reactive Setpoint	Sequence		
			Time	AC-side active power setpoint	DC-side energy source output*
792-1	Min case PoC	As agreed from steady state studies	0 s	100%	100 %
			5 s		100 %
			30 s		5 %
			40 s		5 %
			65 s		100 %
			70 s		100 %
* Source availability should be linearly ramped between targets, not stepped.					

An example profile of the above test is shown in Figure 12 below.

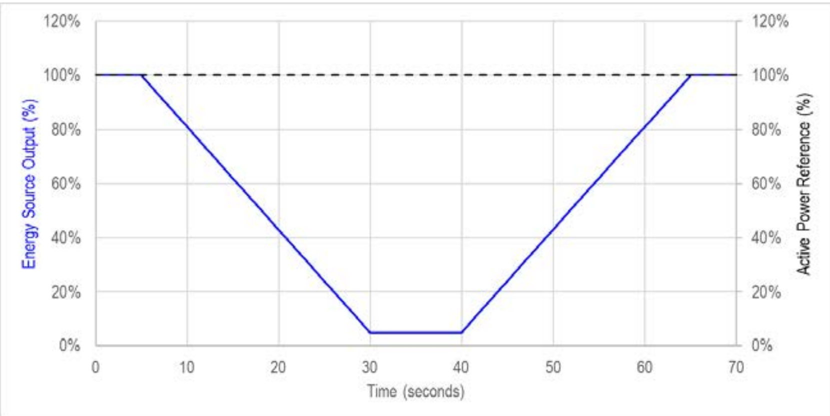


Figure 13 Energy source ramping test (solar farm, BESS export)

If the EG comprises wind turbines, please discuss an appropriate wind speed profile with AusNet before commencing studies.

7.10. Deliverables

After completion of the above dynamic studies, the following needs to be submitted by the proponent to AusNet:

1) A Releasable User Guide (RUG) for the PSS®E model consistent with the requirements of the AEMO RUG Template[22].
2) A Releasable User Guide (RUG) for the PSCAD™ model consistent with the requirements of the AEMO RUG Template[23].
3) A copy of the PSS®E and PSCAD™ models of the plant consistent with the requirements of Section 5.
4) PSS®E to PSCAD™ parameter mapping sheet (if applicable).
5) Evidence demonstrating that the supplied PSS®E and PSCAD™ models are indeed representative of the EG to be installed[24].
6) Any additional modelling documentation required to effectively use, alter and understand the PSS®E or PSCAD™ models[25].
7) A PSS®E dynamic study report, covering all tests outlined from Section 7.2 to Section 7.8, including:
    a) The proponent's self-assessment on whether each test demonstrates compliance with the requirements set out in each subsection.
        i) Where a test shows non-compliance, commentary on the cause and proposed rectification methods to be investigated.
    b) Plots for all tests performed that contain the appropriate quantities of interest, are clearly discernible, at an appropriate scale, and use contrasting colours where appropriate (ideally using vector images rather than screenshots).
    c) In an appendix, a clear table of all DYR settings used in the model that generated the results (to be updated if there are multiple iterations of the report).
8) A PSCAD™ study for Section 7.9.
9) If required, a PSCAD™ dynamic study report, covering all tests outlined from Section 7.2 to Section 7.8, including:
    a) The proponent's self-assessment on whether each test demonstrates compliance with the requirements set out in each subsection.
        i) Where a test shows non-compliance, commentary on the cause and proposed rectification methods to be investigated.
    b) Plots for all tests performed that contain the appropriate quantities of interest, are clearly discernible, at an appropriate scale, and use contrasting colours where appropriate (ideally using vector images rather than screenshots).
10) Upon request, a copy of the raw output data from simulations in .CSV or .XLSX form.
11) Completed generator performance, protection settings and technical data form.

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[22] https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/guideline-and-template-for-preparation-of-a-releasable-user-guide.pdf

[23] https://aemo.com.au/-/media/files/electricity/nem/network_connections/transmission-and-distribution/guideline-and-template-for-preparation-of-a-releasable-user-guide.pdf

[24] This may be achieved by requesting existing type testing or FAT results from the OEM of the inverter/generator overlaid with modelling results. Note this is simply to confirm that the models are representative of the equipment to be installed and need not be tuned to the specific plant.

[25] If these documents are deemed confidential, they must be marked as such and AusNet must be informed so that they are retained in secure databases.

8. Protection

As this Guideline is predominantly focused on the performance and studies requirements of 22 kV-connected 1.5 to 4.99 MW generators, this section is only a high-level summary of the typical protection mechanisms expected by AusNet for EGs. Please consult SOP 11-16 for more information.

8.1. Protection relay types

Protection requirements of EGs are described in detail in sections SOP 11-16**.** Applicants must conform to the protection requirements in SOP 11-16[26]. Additionally, please **consult with the protection engineer assigned to assess your connection** for further information.

Table 27 shows minimum requirements for 22 kV-connected 1.5 - 4.99 MW EG connections:

Table 27 Minimum Protection Requirements

No.	Description	Notes
50/51 P	Phase Overcurrent	
50/51 N	Neutral Overcurrent	
27/59	Under/Over Voltage	
59N	Neutral Voltage Displacement	
81U/81O	Under/Over Frequency	
81R	RoCoF	
78	Vector Shift	
46	Phase Balance Current	
32	Reverse Power	If applicable for plant type
67	Reverse Current	If applicable for plant type
94	Intertrip	
50M	Communication Failure	
	Dead Network Line Block Gen CB Close	

8.1.1. Further considerations

Please note, there are additional requirements in SOP 11-16 around:

- Automatic Transfer Schemes;
- Distribution Feeder Automation;
- Network Isolation;
- Standby Generators & Plant;
    - Inc. Make-Before-Break Schemes;
- Earthing requirements; and
- Compatibility with REFCL feeders.

SOP 11-16 also provides information regarding the standards and tolerances of equipment used in the EG's protection schemes.

[26] Should a contradiction arise between this guideline and SOP 11-16 on protection matters, the content in SOP 11-16 prevails.

8.2. Protection of generating systems from power system disturbances

8.2.1. Requirement

1) An EG's relevant protection system or control system must not disconnect the generating system for:
   a) Conditions for which it must remain in continuous uninterrupted operation; or
   b) Conditions it must withstand as described in Section 7.
2) The EG may disconnect for scenarios where withstand requirements in Section 7 have been met or exceeded.
3) The EG must disconnect for scenarios where:
   a) The disturbance results in the potential for the EG to form an island with the remaining network (i.e., anti-islanding protection is required);
   b) The fault is within the generation protection zone as described in Section 8.3;
   c) It is in response to unstable operation as described in Section 8.4; or
   d) It is in response to an agreed protection or control scheme with AusNet.

8.2.2. Compliance

Where practicable, compliance will automatically be assessed from the studies performed within Section 7. Otherwise, it will be assessed on a case-by-case basis through ongoing monitoring.

8.3. Protection systems that impact on power system security

8.3.1. Requirement

Protection systems must be provided to disconnect from the power system any faulted element within an EG and in protection zones that include the connection point within the applicable fault clearance time.

Depending on the installation, a breaker fail protection system may be necessary to clear from the power system any fault within that protection zone that is not cleared by the circuit breakers controlled by the primary protection system within the applicable fault clearance time as advised by AusNet.

8.3.2. Compliance

Compliance will be evaluated through a protection study in cases where the proposal is for a complex generating system, or if AusNet perceives there could be difficulty in obtaining suitable coordination.

Please note, such a requested protection study is not the standard protection study to meet the generator installation protection requirements. It is an additional study for complex plant to satisfy AusNet that the internal protection coordination is satisfactory.

8.4. Protection to trip plant for unstable operation

8.4.1. Requirement

8.4.1.1. For synchronous machines

For synchronous EGs, AusNet requires a protection system to disconnect it promptly when a condition that would lead to pole slipping is detected, to prevent pole slipping or other conditions where a generating unit causes active power, reactive power or voltage at the connection point to become unstable as assessed in accordance with the AEMO power system stability guidelines[27].

8.4.1.2. For inverter-based resources

For inverter-based EGs, AusNet requires a protection system to disconnect it promptly for conditions where the active power, reactive power or voltage at the connection point becomes unstable as assessed in accordance with the AEMO power system stability guidelines[28].

8.4.1.3. Generally

An EG must not cause a voltage disturbance at the connection point due to sustained unstable behaviour of more than the levels shown in Table 28.

Table 28 Voltage Disturbance Limits

r (hour^{-1})	Dynamic Voltage Change / Nominal Voltage (%)
r ≤ 1	4
1 < r ≤ 10	3
10 < r ≤ 100	2
100 < r ≤ 1000	1.25

8.4.2. Compliance

Where practicable, compliance will automatically be assessed from the studies performed within Section 7. Otherwise, it will be assessed through ongoing monitoring.

8.5. Deliverables

The following needs to be submitted by the proponent to AusNet:

1) A protection study showing compliance with the requirements of the above section and SOP 11-16 (deliverable at the time of detailed design). The proponent must ensure that hardware is selected with the protection functions as per SOP 11-16.

2) If requested by AusNet (for complex plant), an internal protection coordination study as described in Section 8.3.2.

[27] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/power-system-stability-guidelines.pdf
[28] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/power-system-stability-guidelines.pdf

9. Other technical requirements

The following technical requirements stand for 1.5 to 4.99 MW connections but are generally evaluated by means other than pre-connection simulations.

9.1. Quality of electricity generated and continuous uninterrupted operation

9.1.1. Requirement

AusNet requires that an EG, including each of its operating generating units and reactive plant, must not disconnect from the power system as a result of voltage fluctuation, harmonic voltage distortion and voltage unbalance conditions at the connection point within the levels specified Section 6.6.1.

9.1.2. Compliance

This requirement will be evaluated through ongoing monitoring.

9.2. Impact on network capability

9.2.1. Requirement

Any new generating system must not reduce any inter-regional or intra-regional power transfer capability as a result of its connection to the network.

9.2.2. Compliance

For EG systems with a capacity of 1.5 to 4.99 MW, it is unlikely that significant effects on power transfer capacities at the transmission system level will occur. An initial assessment of any possible concerns will be conducted by AusNet as a routine part of the connection application process.

9.3. Rapid Earth Fault Current Limiter

9.3.1. Requirement

If the proposed connection point is on a Rapid Earth Fault Current Limiter (REFCL) feeder, the proponent's design must meet the AusNet REFCL requirements (see REF 30-10, provided in info pack if connecting to a REFCL feeder). Additionally:

1) The proponent must provide conductor details (manufacturer data sheets are preferred) and a schedule of conductors that are not zero sequence isolated from the 22 kV network. Cables that are not zero sequence isolated from the 22 kV network are required to be low capacitance cables.

2) To assist with its ongoing REFCL obligations, AusNet requires that:

   a) 22 kV cable length is minimised where practical (there may be limitations in 22 kV cable length that can be installed without an isolation transformer); and

   b) Circuits do not run in parallel with HV or EHV transmission lines.

3) The AusNet MV customer policy specifies that the connection must be able to withstand *at least* 3 continuous minutes with the 22 kV phase to earth voltage elevated to 24.2 kV. Typically, it is expected that up to 10 minutes withstand is required.

4) Harmonic contributions will garner additional scrutiny, and the proponent must provide estimates on the harmonic contributions the new EG will inject earlier in the connection process.

9.4. Remote Monitoring and Control

9.4.1. Requirement

See Section 7.5 of SOP 11-16 for further information. Please note, the requirements of SOP 11-16 do not consider additional communication needs for FCAS or runback schemes, which must be factored in separately and in agreement with AusNet and AEMO (the latter for FCAS matters).

9.4.2. ADMS Interface (Optional)

The influx of new EG connections is seeing portions of the network constrained, resulting in some EGs being subjected to heavy curtailments. To counter this issue (amongst other matters), AusNet is currently rolling out an upgrade to its energy management system that will see advanced functionality in dynamically controlling plant to both meet network needs and maximise local generation output (known as Advanced Distribution Management Systems or ADMS).

Although not currently a requirement, EG proponents are strongly encouraged to make provision within their plant to receive and act upon control signals from the AusNet ADMS system so that the EG can participate in dynamic network management controls. It is important to note that participation in ADMS control does not increase the likelihood of EG output being curtailed, but rather when a curtailment is necessary, it increases the chance of it being a **non-zero** curtailment (counter to the current arrangement whereby a curtailment to 0 MW is required).

At the time of writing, full technical interface details are not available, but it is expected to require:

- Use of the DNP3 SCADA protocol.
- Fast and robust network communications with AusNet.
- The ability to adhere to active power export limits (and import limits for BESS).
- The ability to respond to reactive power setpoint and mode changes.

AusNet encourages interested parties to discuss the requirements with AusNet at the time of application.

9.5. Ongoing performance monitoring

The EG has a requirement to continuously monitor its performance for the life of the plant, as measured at the connection point to the AusNet network.

Although there is currently no formal compliance monitoring scheme to be established as is the case in over-5 MW connections, AusNet works on the principle of good faith and expects the proponent to self-report any non-compliances to its agreed performance standard and will promptly respond to AusNet requests for data from their point of connection high speed monitor[29].

Reporting of non-compliance matters should be made via email to: GPS.Compliance@ausnetservices.com.au

9.5.1. High-speed monitoring requirements

The precise requirements for high-speed monitoring will be discussed with the proponent at the time of application and depending on the specifics of the installation. However, as a minimum, AusNet expects:

- A permanent high-speed monitor to be installed at the point of connection at the 22 kV voltage level;
- RMS measurements of all voltage and current phases, active and reactive power, frequency and phase angle;
- RMS quantities to be calculated and stored no slower than 20 ms, with deep storage (at least 1 year);
- The device to be capable of continuous (10-minute average) measuring and recording of:
  - Voltage and current harmonics to at least the 40th order;
  - Voltage and current Total Harmonic Distortion;
  - Long- and short-term flicker;
  - Voltage and current unbalance;

[29] **Note**: AusNet will work with the proponent to resolve any performance issues in a manner that causes least impact to our customers, our network and the EG's operation. However, AusNet retains the right to curtail or disconnect an EG from its network for performance standard violations or system security matters. See contract for further details.

- The device to be compliant with IEC 61000-4-30 Class A;
- Capable of automatic triggering and recording of both RMS and waveforms for fault events; and
- Recording of appropriate control scheme inputs (e.g., network control scheme runback enable/disable signals).

9.6. Runback requirements

This section should be considered alongside the commentary provided in Section 9.4.2.

Increasing connection volumes across both the 22 and 66 kV network means it is now expected that most EGs will need to respond to network-initiated runback commands during periods of network constraint.

9.6.1. Requirement

EGs are expected to have the capability to respond to runback commands by:

- Having an appropriate interface device to receive runback commands from the AusNet SCADA system or an in-field protection relay (as appropriate).
- Have reliable communications to be able to respond to runback commands quickly and reliably.
  - The use of the external 4G/5G communication networks may or may not be acceptable, depending on the circumstances of the connection.
  - Depending on the operating arrangements of the EG, redundant communications links may be required.
  - The general principle of communication loss is that if AusNet cannot communicate with the EG, the EG must be tripped at its PoC breaker until communication is restored. This typically necessitates the use of ‘heartbeat’ signals.
- In some circumstances, hardware-based runback schemes may be required. AusNet attempts to limit the usage of such schemes due to the additional costs to the proponent, however in some cases it will be necessary.

9.6.2. Compliance

Section 7.8 already includes a simulation to evaluate the plant’s response to a network control scheme activation signal. Actual EG performance will be confirmed through commissioning testing and through ongoing monitoring.

10. Submission checklists

10.1. Initial project requirements

Table 29 Initial project requirements

✓	Item
	Letter Agreement[30] with AusNet.
	Confidentiality Agreement with AusNet.
	Information relating to land issues, environmental issues, cultural heritage, stakeholder engagement and status of proponent's progress on these activities.

10.2. Steady state

Table 30 Steady State Studies Checklist

✓	Item
	The PSS®SINCAL model of each case and network configurations used in the studies with proposed plant included.
	Steady-state study report demonstrating the performance of the proposed plant.
	Reactive capability curves as outlined in Section 6.3.2.
	Proposed reactive control strategies and how they meet voltage regulation requirements of Section 6.4.1.
	Details of any other salient control strategies of the plant, including fault ride-through strategies.
	Power quality report.
	Cable schedule (see section 9.3 if the proposed plant connects to REFCL feeder).
	Geographical layout of the proposed plant.
	Single line diagram of proposed plant.
	Layout diagram.
	Details of site load without generation (where applicable).
	Manufacturer information of the EG equipment.
	OEM datasheets and manuals.
	Details of the relevant Australian or equivalent standards to which the EG complies.
	General control system overview (details of what controllers are present and active in the EG).
	Confirmation as to what minimum SCR and X/R levels the plant can reliably operate (low system strength scenarios).
	Any other information request as identified by AusNet during the course of application evaluation.

10.3. Dynamics

Table 31 Dynamic Studies Checklist

✓	Item
	A Releasable User Guide (RUG) for the PSS®E model consistent with the requirements of the AEMO RUG Template.
	A Releasable User Guide (RUG) for the PSCAD™ model consistent with the requirements of the AEMO RUG Template.
	A copy of the PSS®E and PSCAD™ models of the plant consistent with the requirements of Section 5.
	PSS®E to PSCAD™ parameter mapping sheet (if applicable).
	Evidence demonstrating that the supplied PSS®E and PSCAD™ models are indeed representative of the EG to be installed.
	Any additional modelling documentation required to effectively use, alter and understand the PSS®E or PSCAD™ models.
	A PSS®E dynamic study report, covering all tests outlined from Section 7.2 to Section 7.8, inclusive.
	A PSCAD™ study for Section 7.9.
	If required, a PSCAD™ dynamic study report, covering all tests outlined from Section 7.2 to Section 7.8, inclusive.

[30] Draft templates provided upon request. Note the Letter Agreement will require an upfront initial payment.

	Upon request, a copy of the raw output data from simulations in .CSV or .XLSX form.
	Completed generator performance, protection settings and technical data form.

11. Frequently Asked Questions

1) Does the proponent need to perform load flow studies for DFA network configurations?

The proponent needs to perform load flow studies for DFA network configurations only when they decide to stay connected and online during the occurrence of a DFA. If the proponent decides to stay disconnected when a DFA occurs, no load flow study is required for such network configurations (most common approach).

2) How to calculate the minimum network fault impedance at PoC for the purpose of SMIB dynamic studies?

The minimum fault impedance (at N-1 contingency) at the 22 kV ZSS bus is provided in information data pack (section 6.1.1). This fault impedance is needed to be input at the infeeder of the feeder in PSS®SINCAL model. Then, the fault impedance at the PoC can be calculated by a short circuit analysis in PSS®SINCAL.

3) What is the key comparison AusNet looks for in the steady state study?

AusNet wants to understand the impact of the proposed EG connection on AusNet network. Therefore, AusNet will look for comparison between 'before connection' and 'after connection' for each network configuration for maximum and minimum demand separately for each aspect described in section 6.2.

4) What is the difference between a "modelling spike" and an overshoot?

A "modelling spike" is a numerical spike which may occur with some dynamic models encountering a non-linearity with improper filtering applied. Typically, the profile very sharply increases, lasts for one or two timesteps and then very sharply returns to the previous or similar value prior to the spike. Whilst undesirable and attempts to rectify such model performance must be made, it is usually not considered a genuine performance issue of the plant, but an artefact of the model.

An overshoot response is a far more plausible response from a plant's model in response to a changed condition, often lasting much longer than one or two timesteps and with a ramp up and down consistent with plant dynamics. This is often a genuine issue with the plant performance to be rectified by the proponent before acceptance of the studies.

5) Which voltage control strategy and setpoint need to be used in the dynamic studies?

Unless otherwise specified, the voltage control strategy and setpoint that comply with the requirements described in section 6.4 in steady state studies and has been approved by AusNet.

6) What if my minimum active power is zero? Do I need to do the study at 0 MW export (or import)

Yes, but if the EG is a BESS, you only need to perform the 0 MW tests once.

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