PROCEDURE

Technical performance requirements for connection of large-scale embedded generators to the Evoenergy network

Key summary points

- This document outlines automatic, minimum and negotiable access standards for connection of registered proponents.

Disclaimer

Whilst this document contains material relevant to the electricity industry legislation, codes of practice and standards, it is not intended to provide legal advice on how electrical contractors can meet their own statutory obligations or comply with legislation, codes of practice or industry standards such as AS/NZS 3000 (Wiring Rules).

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Note

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1 Introduction

1.1 Purpose

The purpose of this document is to outline Evoenergy's technical requirements for the connection to, and parallel operation with, Evoenergy's high voltage (HV) and sub-transmission networks to the proponents of large scale embedded generation systems.

1.2 Scope

This document applies to any *Registered Generator* which operate in parallel with the Evoenergy network for more than 400 milliseconds (ms). It also covers any customer choosing to comply with Part A of National Electricity Rules (NER) Chapter 5 in developing a Generator Connection Agreement.

This document provides guidance on the interpretation of NER technical requirements in the context of Evoenergy's network. This document does not address connection process details. Proponents should refer to Evoenergy's embedded generation requirement documents available at the Evoenergy website for information on the connection process and Network Technical Study (NTS).

1.3 Background

Evoenergy has conducted a review of several key documents that describe the technical requirements for large scale embedded generator connections to a distribution network, and has formulated a grid code which outlines the requirements for connection of large scale embedded generators to Evoenergy's network. The following process was considered during the formation of the Grid Code.

1. Review, analysis and production of a summarised version of Chapter 5 of the NER[1] requirements;
2. Determination of the applicability of schedules S5.2.5.1 to S5.2.8 of the NER; fault ride through, frequency and voltage stabilisation, power quality and reactive power control aspects as required by Evoenergy;
3. Determination of other requirements of that may be applicable;
4. Determination of requirements of other applicable Australian and overseas standards;
5. Requirements for connection;
6. Determination of network support that can be provided by such installation and risks associated with providing this support; and
7. Determination of impact to the network and how these impacts can be managed.

1.4 Disclaimer

This document has been developed to assist Generators with understanding technical requirements. It is not possible to maintain and update this document each time the NER changes, it is therefore a guide only and must not be relied upon to be current at all times. This document cannot be controlled when printed and users should ensure they are using the most recent version from the Evoenergy website.

It is the document user's responsibility to satisfy themselves of compliance with the NER. If there is any inconsistency between this document and NER requirements, the NER will prevail. This document must not be used as a substitute to the NER.

Evoenergy does not make any representations as to the accuracy or currency of this document. Evoenergy will not accept liability for any loss or damage arising from reliance on this document. Proponents should seek their own professional and technical advice in respect of their compliance with the NER requirements and the otherwise in relation to the subject matter of this document.

[1] National Electricity Rules (NER) AEMO Guidelines for Assessment of Generator Proposed Performance Standards

2 Network Technical Study (NTS)

To facilitate Evoenergy's prime directives for the connection of large scale embedded generators to Evoenergy's network, the proponent is required to carry out a Network Technical Study (NTS), which addresses and shows compliance with the access standards as outlined in Chapter 5. In addition to complying with the access standards the proponent is also required to provide information as outlined in Evoenergy's Embedded Generation Requirements documents.

3 Applicability of National Electricity Rules (NER) – Chaper 5

3.1 Conditions for connection of embedded generators

Evoenergy's interpretation of the NER technical requirements as described in clause S5.2.5 and why they are required for a proponent to connect a large scale generator to Evoenergy's network is outlined in this chapter.

3.2 Technical requirements

Schedule S5.2.5 outlines the technical requirements for the connection of generators to a Network Service Provider's (NSP) network. The technical requirements are referred to as access standards, namely, automatic, minimum and negotiated access standards. The access standards define the acceptable level of performance which a Generator must achieve for connection to a NSPs' network.

Any proposed performance standard less than automatic must be reviewed and if appropriate, agreed by the NSP and by Australian Energy Market Operator (AEMO).

The Embedded Generation system must be operated and maintained to ensure compliance with the connection agreement, applicable legislation, codes and other regulatory instruments at all times. The generator must be responsible for developing and adhering to a maintenance plan and must provide operation and maintenance reports to Evoenergy on an annual basis. Evoenergy may inspect a system at any time to confirm compliance to the connection agreement.

3.3 Operating protocol

The Embedded Generator connection will require a joint operating protocol. This will be identified during the connection process by Evoenergy and communicated to the proponent. Evoenergy and the proponent must work together to produce an operating protocol that will be approved by both parties and contain the following information:

- Planned and unplanned outage procedures including notification periods
- Standard switching procedures
- Inter-tripping protection philosophy
- Interlocking procedures and philosophy
- Designated points of contact for Evoenergy and the generator
- System monitoring responsibilities
- Fault identification and rectification procedures
- Site access procedures

In addition to operating protocol, the proponent must adhere to the requirements of the Utilities Technical Regulation Team regarding operating certificates in accordance with the *Utilities (Technical Regulation) Act 2014* and *Utilities Act 2000*.

3.4 Maintenance

To ensure the electrical installation is maintained in a safe condition, the proponent must develop a maintenance plan that specifies the maintenance schedule for all equipment and details the frequency and types of maintenance. The generator must ensure the following maintenance requirements are met:

- Records of all maintenance activities are retained for all equipment.
- Changes to the electrical installation are performed by suitably qualified personnel and the generator holds a certificate of compliance issued in respect of any of the changes.
- Approval is obtained from Evoenergy prior to altering the connection for any addition, upgrade, extension, expansion, augmentation or any other kind of alteration, including changing inverter settings.
- Protection systems are to be tested by suitably qualified personnel at an interval no greater than five years after commissioning.

In the event a system is deemed to be non-compliant, Evoenergy will contact the generator to request that the system is rectified within a specified timeframe. If the generator fails to adequately address the non-compliance within the timeframe, Evoenergy will take steps to have the system disconnected from the network to ensure its obligations regarding the safe and reliable operation of the distribution network are met. This process may vary depending on the severity of the risk posed by the system.

4 Access standards

4.1 Automatic access standard

A plant that meets the automatic access standard will not be denied access to the network because of the technical requirement of this standard. A Generator that demonstrates this standard has shown sufficient capability for connection.

4.2 Minimum access standard

The minimum access standard is the minimum technical level of performance that the NSP will consider for connection to the NSP's network. A plant that does not meet the minimum access standard will be denied access to the network. All access standards as outlined in S5.2.5.1 to S5.2.8 have a minimum access standard.

4.3 Negotiated access standard

A negotiated access standard falls between the automatic and minimum access standards. It is an agreed[2] standard of performance for the relevant technical requirement that the NSP will accept for access to the network. This standard should be as close as possible to the automatic standard.

4.4 Performance access standard

A performance standard is an access standard that forms part of the terms and conditions of a Generator Connection Agreement. Where a Generator proposes a performance standard it will be referred to as a proposed performance standard until such time as both Evoenergy and AEMO have reviewed and accepted it, it will then become an agreed performance standard.

The agreed performance standards become part of the terms and conditions of a Generator Connection Agreement with the Generator and Evoenergy. If the Generator is applying to become a registered participant, a copy of the Generator Connection Agreement (with the commercial terms removed) can be submitted to AEMO.

5 Explanation of the NER and related technical requirements

In the context of Evoenergy's electricity network, Evoenergy has the following requirements which are an interpretation of the NER access standards:

5.1 Reactive power capability

Clause S5.2.5.1 of the NER describes the requirements of a Generator to provide reactive power at the point of connection over a range of power system conditions.

[2] Between the proponent and the NSP with advice from AEMO if it is an AEMO related matter

Automatic: The Generator must be capable of supplying and absorbing continuously at the connection point reactive power equal to 0.395 x rated active power of the plant at any level of active power and at any voltage range of 90 to 110%.

Minimum: No reactive power capability required.

Negotiated: Reactive power capability as close as possible to the automatic standard.

In order to determine the reactive power capability, the proponent needs to conduct steady state load flow studies at the connection point over a range of power system conditions. Typical operating voltage at the connection point and at the generation terminals and the tapping range of the transformers must be included in the studies.

The studies need to demonstrate that the Generator can provide the reactive power range over the range of the connection point voltage of 90 to 110% of nominal voltage. This could be demonstrated by a reactive power capability diagram which shows reactive capability from zero to 100% power output over a generation terminal voltage range of 90 to 110% of nominal voltage.

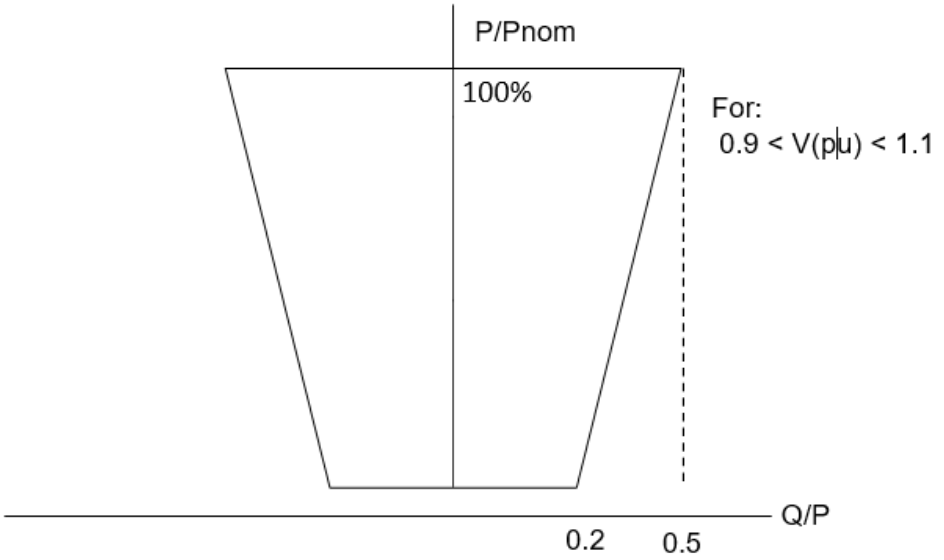

Figure 1. Reactive power capability Diagram (Example Only) – note that this is an example of a negotiated standard as IT'S not capable of Q= 0.395 x P for all levels of active power.

Evoenergy may consider a negotiated standard in cases where the connection point is in a lightly loaded area and compliance with voltage standards will be achieved; or where the active power output may improve reactive power margins on the network without additional reactive power capability. Any such negotiation is dependent on the network at the connection point.

If the generating system is used to provide support to the network Evoenergy may require the Generator to provide additional reactive power capability but this will depend on the circumstances of each connection.

The Generator, NSP and AEMO may negotiate a range of reactive power absorption and supply for the point of connection within which the plant must operate or a negotiate a limit which describes how the reactive power capability will vary depending on the active power output based on the plant's design characteristic.

In the case that the generating system is not able to perform at the level established, under reasonable circumstances the Generator must provide for the deficit of reactive power (supply and absorption) in one or more of the following ways:

- Pay the NSP a compensation to provide for the deficit;
- Install additional equipment connecting at the generating system's point of connection or at another location, such equipment is classified to be part of the generating system;
- Reach a commercial arrangement with a Registered Participant;
- If there are specific operating conditions under which the performance level cannot be met, the Generator may document this as a constituent of the negotiated access standard and agree to operational arrangements which allow the plant to meet the agreed performance levels in those specific conditions.

General – The agreed rated active power must be recorded in a performance standard and if deemed relevant also it's associated method of calculation. When the Generator is not supplying or absorbing reactive power, the

performance standard for consumption of energy under an ancillary services arrangement must be established under NER's clause S5.3.5 in which the Generator must be treated as a Market Customer.

5.2 Quality of electricity generated

Clause S5.2.5.2 of the NER requires the quality of the electricity generated by a Generator at the connection point to not have any detrimental effects on other customers. The Generator must not produce at the connection point voltage fluctuation, harmonic voltage distortion and voltage unbalance greater than the limits specified in the clause. The plant standards for harmonic voltage distribution are outlined in AS 1359.101 and IEC 60034-1 for a synchronous generating unit.

Automatic – Generating system does not produce amounts of voltage fluctuation and harmonics greater than the limits allocated to the Generator by the NSP. The voltage unbalance factor must not exceed the limits specified by the NSP.

Minimum – Generating system does not produce amounts of voltage fluctuation and harmonics greater than the limits (less onerous than for automatic access) allocated to the Generator by the NSP. The voltage unbalance factor must not exceed the limits specified in Table S5.1a.1 of the NER.

Negotiated – Limits to ensure the Evoenergy can meet its contractual obligations to existing users.

NER requires under a normal power system condition that the voltage at the connection point must not vary by more than ±10% of its normal voltage, provided that the reactive power flow and the power factor (pf) at the connection point is within the limits as specified in the Generator Connection Agreement.

However, as a result of a contingency event the voltage at the connection point must comply with Figure S5.1a.1. of the NER.

Voltage fluctuation (flicker, rapid voltage change) and harmonic voltage distortion limits are specified in AS 61000.3.7 (and AS 6100. 3.6). These are system compatibility and planning limits that the NSP uses to derive limits for a specific connection using calculation and allocation methodology recommended in these standards.

It should be acknowledged that the voltage flicker coefficients nominated by Evoenergy represent the minimum values emission limits that can be assigned by the NSP. Compliance is based on the procedure for assessing emission levels is in accordance with TR IEC 61000.3.7 2012 Section 4.2.2 "Assessment procedure for evaluation against planning levels".

Actual Flicker levels are compared to the following indices:

- The 95% probability weekly value of Pst; and
- The 95% probability weekly value of Plt.

Study results will need to assume power factor control of generation reactive dispatch; the facility will need to comply with voltage flicker thresholds assigned by Evoenergy.

If Evoenergy accepts a negotiated access standard the Generator may be required to upgrade to the automatic access standard where Evoenergy connects new customers to its network. This is required for Evoenergy to comply with the access standards defined in the NER.

5.3 Response to frequency disturbances

Clause S5.2.5.3 requires the generating system to ride through frequency disturbances at the connection point and remain connected for the range of frequencies as outlined in this clause.

For any conditions (incl. "island" conditions) in the frequency operating standards relevant to the generating unit's location:

- The widest range specified for the terms are referenced by the normal operating frequency band, operational frequency tolerance band, or extreme frequency excursion tolerance limits;
- The longest allowable time for power system's frequency to remain outside the operational frequency tolerance band and normal operating frequency band define the stabilisation time and recovery time respectively;
- Transient Frequency limit is 47.5 Hz and transient frequency time is 9 seconds, or such other value which may be determined by the Reliability Panel.

Automatic – The Generator must be capable of continuous uninterrupted operation within the given ranges as per Figure 2 below, unless the rate of change of frequency is outside the range of -4Hz to 4 Hz per second for more

than 0.25 seconds, -3Hz to 3Hz per second for more than one second, or such a range as determined time to time by the Reliability Panel.

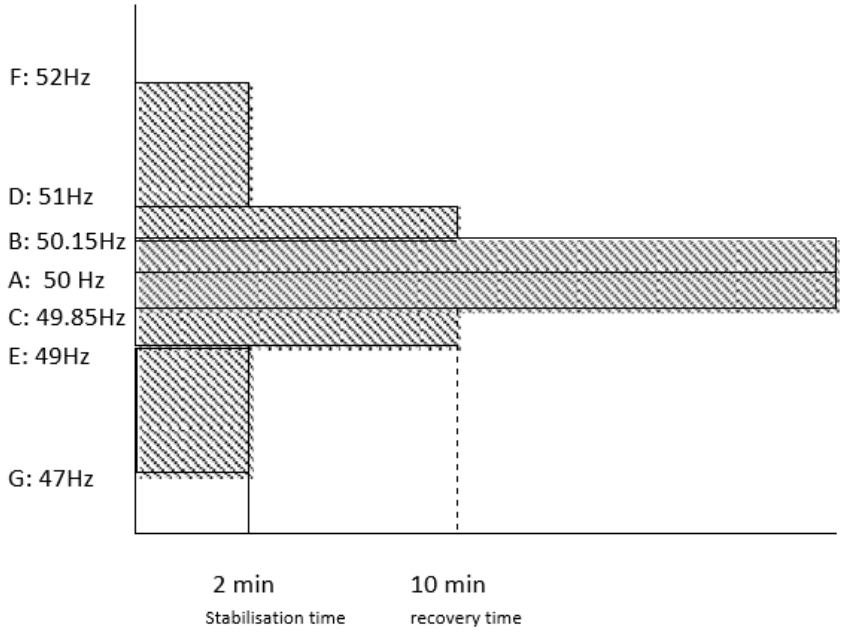

Figure 2. Frequency disturbance response automatic access standard

Minimum – Continuous uninterrupted operation within the given ranges with reduced timing and performance, as per Figure 3, unless the rate of change of frequency is outside the range of -2Hz to 2 Hz per second for more than 0.25 seconds, -1Hz to 1Hz per second for more than one second, or such a range as determined time to time by the Reliability Panel.

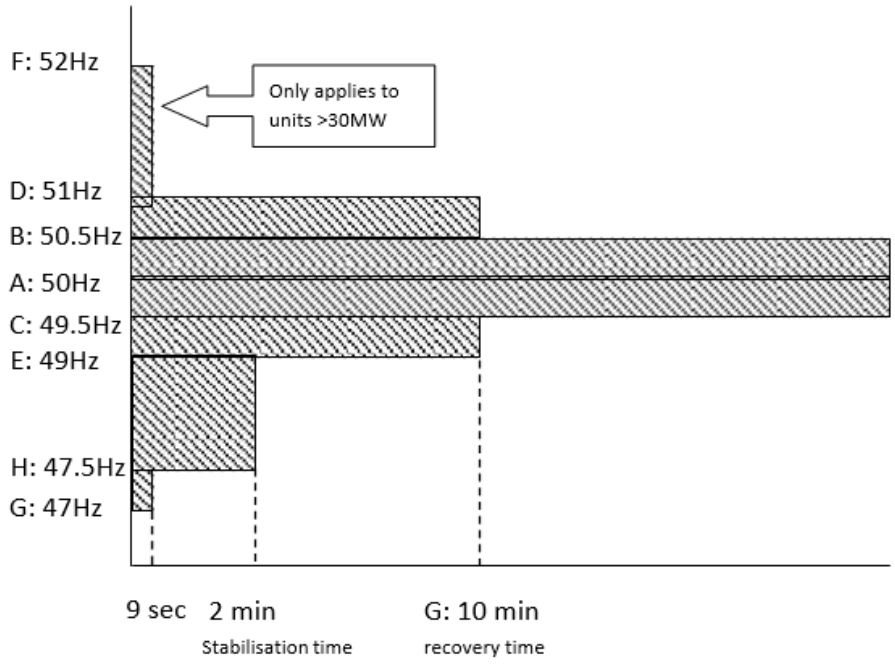

Figure 3. Frequency disturbance response Minimum access standards

Negotiated – Operation as close to the Automatic requirement without impacting on quality of supply.

The Generator must provide details of the over and under frequency protection, steady state frequency range operating capability and maximum rate of change of frequency operating capability.

5.4 Response to voltage distrubances

Clause S5.2.5.4 requires the Generator to ride through and remain connected for voltage disturbances at the connection point.

Automatic – Continuous uninterrupted operation within the given ranges as per Figures 4, 5.

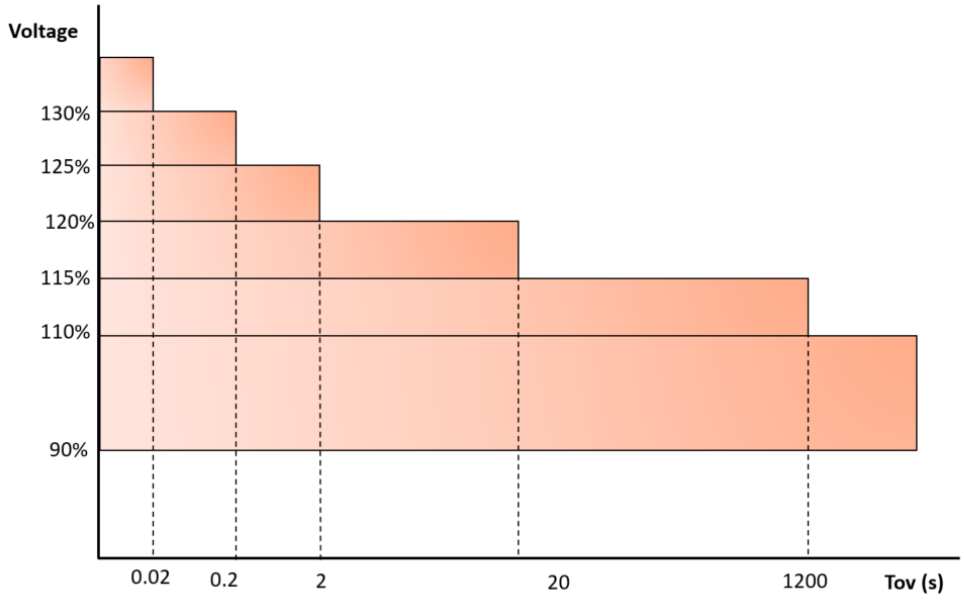

Figure 4. Response to voltage disturbances over 110 percent, automatic access standard

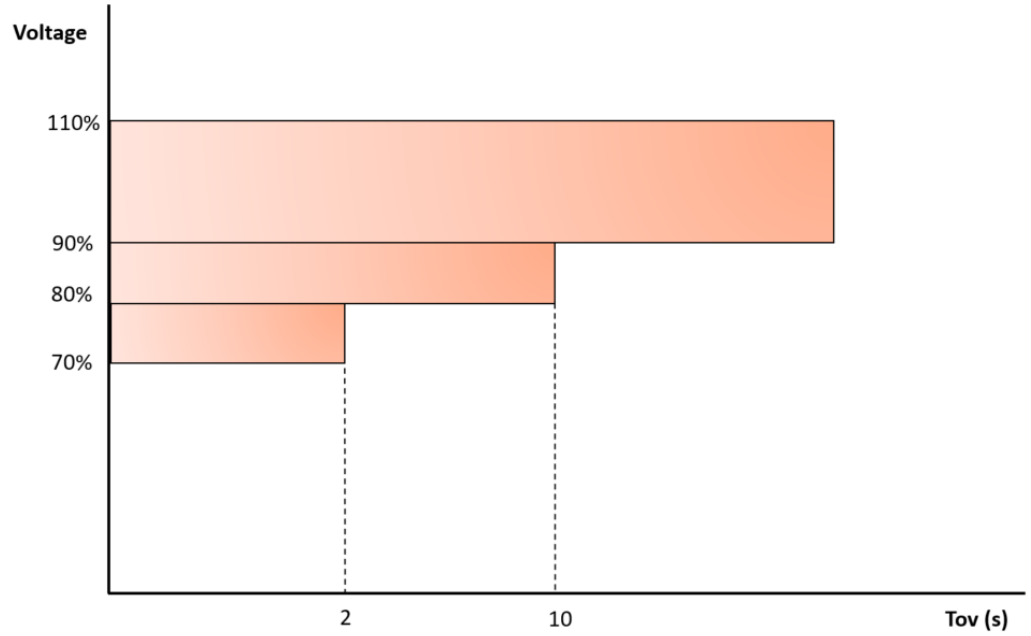

Figure 5. Response to voltage disturbances Under 110 percent, Automatic access standard

The ranges detailed above are also subject to the requirement that the Generator does not cause nearby LV networks to be outside the range of ±6%.

Minimum – Continuous uninterrupted operation within a range of ±10% of normal voltage provided the voltage to frequency ratio is above specified limits.

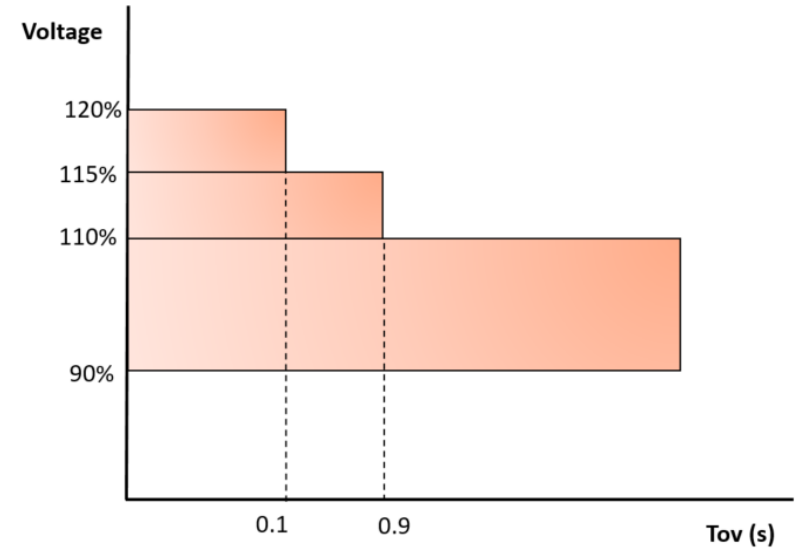

Figure 6. Response to voltage disturbances over 110 percent, minimum access standard

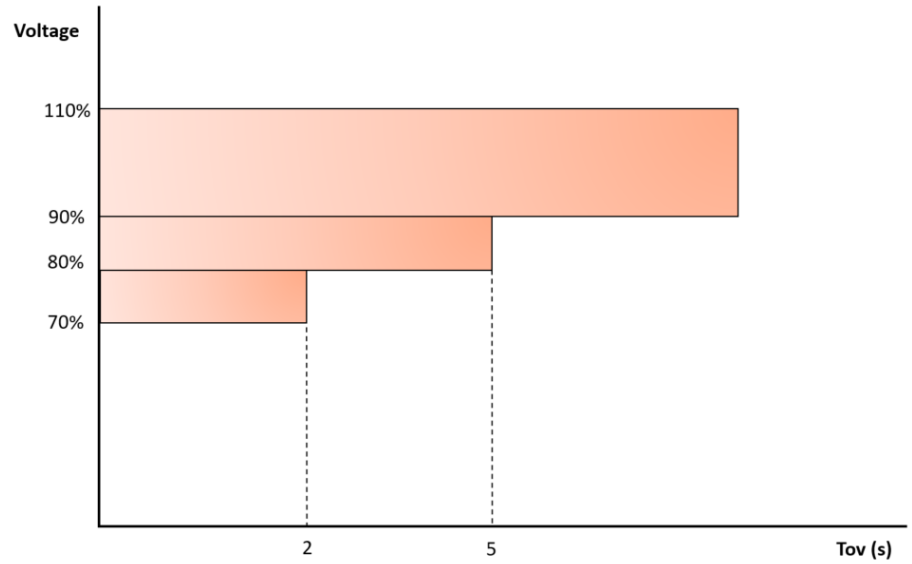

Figure 7. Response to voltage disturbances under 110 percent, minimum access standard

Negotiated – Operation as close to the Automatic requirement without impacting on plant safety, loss of generated power not greater than 100 MW if the automatic access standard were applied, and no adverse impact on the quality of supply or power system security.

The Generator must provide:

- Details of over and under voltage protection and their settings/limits; a curve (similar to Figure S5.1a.1 of the NER) which shows the range of voltages the Generator can ride through and remain connected for that range; and
- Details of the Generator's voltage operating capability. The generating units must be capable of continuous uninterrupted operation for the range of voltages specified in the automatic access standard, except where AEMO and the Network Service Provider agree that the total reduction of generation in the power system as a result of any voltage excursion within levels specified by the automatic access standard would not exceed 100 MW, or a greater limit based on what AEMO and the Network Service Provider both consider to be reasonable in the circumstances.

Evoenergy may require protection in place to trip the generating system where all three line to line voltages are below 0.85 pu and the plant is absorbing inductive reactive power. This is to prevent the Generator from acting as a load and impeding network voltage recovery after a fault.

5.5 Response to disturbances following contingency events

Clause S5.2.5.5 of NER requires the Generator to remain in continuous uninterrupted operation through credible contingency events and network faults described below.

In this clause S5.2.5.5 a fault includes:

- A fault of the relevant type having a metallic conducting path; and
- A fault of the relevant type resulting from re-closure onto a fault by the operation of automatic reclose equipment.

Each generating unit must remain in continuous uninterrupted operation for the disturbance caused by an event that is:

I. A credible contingency event

II. A three phase fault in a transmission system cleared by all relevant primary protection systems

III. A two phase to ground, phase to phase or phase to ground fault in a transmission system cleared in:

   a) The longest time expected to be taken for all relevant primary protection systems to clear the fault; or

   b) If a protection system referred to above in (a) is not installed, the greater of the time specified in column 4 of Table S5.1a.2 (or if none is specified, 430 milliseconds) and the longest time expected to be taken for all relevant primary protection systems to clear the fault

IV. A three phase, two phase to ground, phase to phase or phase to ground fault in a distribution network cleared in:

a) The longest time expected to be taken for all relevant primary protection systems to clear the fault; or

b) If a protection system referred to in subparagraph (a) is not installed, the greater of the time specified in column 4 of Table S5.1a.2 (or if none is specified, 430 milliseconds) and 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.

Subject to any changed power system conditions or energy source availability beyond the Generator's reasonable control, a generating system and each of its generating units, in respect of the types of fault described above will supply to or absorb from the network:

- To assist the maintenance of power system voltages during the application of the fault, capacitive reactive current of at least the greater of its pre-disturbance reactive;
- After disconnection of the faulted element, reactive power sufficient to ensure that the connection point voltage is within the range for continuous uninterrupted operation under clause S5.2.5.4; and
- From 430 milliseconds after disconnection of the faulted element, active power of at least 95% of the level existing just prior to the fault.

Automatic – For faults on a transmission network, three phase fault cleared by primary protection, phase to phase, two and single phase to ground faults as per the limits. For faults on a distribution network all faults cleared as per the limits. However, the event itself may disconnect the Generator from the network by removing the connection elements from service, otherwise the generating system must stay connected. The Generator is also required to provide a specified level of reactive power support during the fault and sufficient reactive power to maintain connection point voltage within a specified range with no significant reduction in active power after the fault.

Minimum – For a transmission or distribution network phase to phase, two and single phase to ground faults cleared by the longest relevant primary protection (ensuring there is no adverse impact on network security and generation loss limited to 100MW are not exceeded). However, the event itself may disconnect the Generator from the network by removing other network elements from service. The Generator is also required to provide sufficient reactive power to maintain connection point voltage within a specified range with no significant reduction in active power after the fault.

Negotiated – As agreed with NSP and AEMO in consideration of existing network constraints. The plant must not trip other connected loads and Generators as a result of an event for which they would otherwise not have tripped.

The proponent must conduct time domain dynamic studies showing the Generator's capability to remain connected for the range of faults described in this clause. The studies should cover a range of operating conditions such as but not limited to the following:

- Maximum power generation at various levels of operating power factor conditions;
- Light, medium and high regional demands; and
- High and low level of interconnector transfer conditions.

Fault simulation studies should also demonstrate the following:

- For each drop of 1% of the voltage at the connection point the Generator should supply a reactive current equal to 4% of the maximum continuous current; and
- 95% of the pre-fault active output is achieved within 100 ms of fault clearance.

Operational arrangements such as control settings for the generating system's terminal voltage or transformer tap changers must meet the agreed level of performance.

5.6 Quality of electricity generated and continuous uninterrupted operation

Clause S5.2.5.6 of the NER requires the Generator to remain connected for the specified values of voltage fluctuation, harmonic voltage distortion and voltage unbalance at the connection point.

Minimum - Plant must not disconnect from the network due to voltage fluctuation, harmonic voltage distortion and voltage unbalance conditions within their specified limits defined by the Access Standards set out in the clauses S5.1a.5, S5.1a.6 and S5.1a.7 of the NER. The proponent must provide documentary evidence to support this requirement.

5.7 Partial load rejection

Clause S5.2.5.7 only applies to synchronous generating systems and requires the Generator to remain connected during and following a power system load reduction.

Automatic - The Generator must remain connected during and following a load reduction of 30% 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 load.

Minimum - The Generator must remain connected during and following a load reduction of 5% 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 load.

General – Agreed partial load rejection performance has to be recorded in the Performance Standards.

5.8 Protection of generating systems from power system disturbances

Clause S5.2.5.8 of the NER states the generating system must have sufficient operational protection systems that disconnect and prevent damage to the Generator or Evoenergy's network from a power system disturbance. More information can be found in Evoenergy's Embedded Generation Guidelines.

Minimum - Plant protection and control system must keep the generating system connected under abnormal conditions as required by the relevant clauses of NER unless it is required to trip to (i) disconnect any faulted element in its system (S5.2.5.9) or (ii) to prevent a condition that would lead to unstable operation (S5.2.5.10). For a generating system of 30MW or greater connected to a transmission system, facilities are required to reduce its output or disconnect automatically under certain over frequency conditions nominated by AEMO.

Any generating units are required by a Generator or Network Service Provider to be automatically disconnected from the power system in response to abnormal conditions arising from the power system, the relevant protection system or control system will not disconnect the generating system for:

(i.) conditions for which it will remain in continuous uninterrupted operation; or
(ii.) conditions it will withstand under the Rules; and General requirements:

a. AEMO or the Network Service Provider may require that an access standard include a requirement for the generating system to be automatically disconnected by a local or remote control scheme whenever the part of the network to which it is connected has been disconnected from the national grid, forming an island that supplies a Customer.
b. The access standard will include specification of conditions for which the generating unit or generating system will trip and will not trip.
c. Notwithstanding clauses S52.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.7, a generating system may be automatically disconnected from the power system under any of the following conditions:
d. The Network Service Provider is not liable for any loss or damage incurred by the Generator or any other person as a consequence of a fault on either the power system, or within the Generator's facility.
    1. in accordance with an ancillary services agreement between the Generator and AEMO;
    2. where a load that is not part of the generating system has the same connection point as the generating system and AEMO and the Network Service Provider agree that the disconnection would in effect be under-frequency load shedding;
    3. where the generating system is automatically disconnected under paragraph (a) or clause S5.2.5.9;
    4. where the generating system is automatically disconnected under clause S5.2.5.10 due to a failure of the generating plant; or
    5. in accordance with an agreement between the Generator and a Network Service Provider (including an agreement in relation to an emergency control scheme under clause S5.1.8) to provide a service that AEMO agrees is necessary to maintain or restore power system security in the event of a specified contingency event.
e. The Network Service Provider is not liable for any loss or damage incurred by the Generator or any other person as a consequence of a fault on either the power system, or within the Generator's facility.

Negotiated - A negotiated access standard may only be accepted to the extent that physical plant limitations prevent compliance with the automatic access standard. Generators may reduce output by less than 50% for 3 seconds, or over a longer reasonable period when responding proportionally to frequency deviations. Or, generators may cut active power, by a reasonable amount within a reasonable period set by AEMO when frequency rises above the normal operating band, holding that reduced output until frequency returns to normal.

When determining what is “reasonable,” Evoenergy and AEMO will consider the plant’s maximum rate of change of frequency and its physical limitations. In general, any required reduction in active power should be achieved through fast ramping rather than disconnecting generating units.

General - Anti-islanding protection may also be specified as an additional requirement by the NSP. Conditions of trip and other performance conditions must be specified in the Generator Connection Agreement. The NSP is not liable for loss or damage incurred by the Generator as a result of the fault on either the power system or the Generator’s facility.

The minimum protection and SCADA requirements are outlined in Evoenergy’s Guidelines for embedded Generator connection to Evoenergy’s low voltage (LV) network (see link below). Although the guidelines refer to low voltage connections, protection and SCADA requirements as contained in the guidelines can also be applied to connection to the high voltage (HV) network. If additional protection and SCADA schemes are required, Evoenergy will notify the proponent after conducting the review of the NTS.

The proponent must provide the following:

- Protection single line diagram showing all the protection schemes including AC and DC circuits and circuit breaker tripping logic; and
- A report showing proper interface and coordination between the Generator and Evoenergy’s network and confirmation that fault clearance times are as specified in Table S5.1a.2 of NER.

5.9 Protection systems that impact on power system security

Clause S5.2.5.9 of the NER requires adequate levels of protection that prevent a fault in the Generator from compromising Evoenergy’s power system security. More information can be found in Evoenergy’s Embedded Generation Guidelines.

Automatic – Generating system must have primary protection systems to disconnect the faulted element from the power system within the applicable fault clearance times given in the NER for any fault in the generating system and in protection zones that include the connection point. The protection systems must also have sufficient redundancy to make sure faulted elements within the protection zone are disconnected. When circuit breakers cannot clear faults, breaker fail protection systems must be controlled by the primary protection system to clear the fault within the applicable fault clearance time.

Minimum – Must have sufficient protection to give fault clearance times to prevent unstable operation under normal power flow conditions. Where the fault clearance time is less than 10 seconds then breaker fail protection must be provided clear any faults within the applicable fault clearance time as per the NER.

General – Interfacing and coordination required between the Generator and the NSP.

Under the NER the Generator must provide primary, backup and breaker fail protection for Automatic Access at the connection point. This is to ensure the protection system is robust and reliable with as little impact on the rest of the power system as possible. The generator must also coordinate on use of current and voltage transformer secondary circuits, including tripping one party’s circuit breakers by protection systems of other party. Inter-operation between protection system settings must be coordinated.

5.10 Protection to trip plant for unstable operation

Clause S5.2.5.10 of the NER requires disconnection of the Generator for unstable conditions such as active power, reactive power or voltage instability at the connection point. More information can be found in Evoenergy’s Embedded Generation Guidelines.

Automatic – The protection must trip when active power, reactive power or voltage at the connection point becomes unstable as specified.

For synchronous generating units the protection system must include disconnection under pole slipping conditions. Both synchronous and asynchronous generating units must provide a protection system which includes disconnection under conditions including active power, reactive power or those in which generating unit causes voltage at connection point to become unstable.

Minimum – Generating system must not cause a voltage disturbance at the connection point due to sustained unstable behaviour of the network of more than the maximum level per Table 6 of AS6100.3.7:2012.

Negotiated – Unstable plant must be tripped where NSP and or AEMO considers it necessary.

The type of protection required is covered in the preceding section. The proponent must provide information as detailed in the preceding section.

5.11 Frequency control

Subject to the generating system output definition, in regards to scheduled, semi-scheduled or non-scheduled, clause S5.2.5.11 of NER reviews the power response of the generating system to an increase or decrease in network frequency.

Automatic – The generating system must not increase or decrease its power transfer for a rise or fall in the system frequency respectively. The generating system must be able to reduce or increase its power output for the specified system frequencies levels.

Minimum – The generating system power transfer must not increase due to a rise in system frequency, nor decrease by the specified value (2% per Hertz [Hz]) for a fall in the system frequency.

General – Control system must be adequately damped. The proponent must provide the following:

- Details of the control system to be supplied such as operating modes, topology, control system time constants, droop settings and operating dead bands; and
- Time domain dynamic studies showing the active power response to an increase or decrease in network frequency.

5.12 Impact of network capability

Clause S5.2.5.12 discusses the impact on inter-regional and intra-regional power transfer.

Automatic – No reduction in inter-regional and intra-regional transfer capability.

Minimum – No reduction in the ability of the network to supply a customer or any power transfer capability into a region by more than the generating system.

Negotiated – As agreed with AEMO and Evoenergy where the generating system minimises any reduction in power transfer and the minimum standard is maintained.

General – As agreed with Evoenergy for the inclusion of more control system facilities.

The impact on the network capability is ascertained by what happens to the local network when the generating system is connected. This is defined in a number of ways.

Generator stability: The proponent needs to carry out a time domain dynamic study on the generating system's response to a frequency or voltage disturbance on the network. The study will include the response of the generating system to various network faults or conditions.

Network stability: The study needs to show the dynamic response of the network to a Generator trip (fault). For a prescribed trip (say instantaneous trip of the generating system) the network voltages must not exceed voltage change limits and absolute limits. If they do then remediation measures need to be provided by the Generator as the generating system will cause the network to operate outside its prescribed boundaries, or a limitation on generation operation may be applied.

Network rating: The thermal response of the network feeders and equipment is included in the studies. Under worst case scenarios such as Summer-High and Summer-Low the thermal loading of transformers, circuit breakers and feeders need to be shown with and without the connection of the Generator. This will show if the Generator will have any impact on the network.

Inter-regional flow: The inter-regional feeders are assessed by comparing their transient stability responses prior to the Generator connection and after the connection. For both cases the network has the same fault applied and the transient response waveforms are overlayed to show the impact. If they are identical then this will show no significant change/impact.

5.13 Voltage and reactive power control

Clause S5.2.5.13 of the NER refers to the control of the voltage at the connection point. It considers the performance of the voltage control system and the ability of the Generator to increase or decrease its reactive power output due to a power system incident.

The NER has a number of detailed clauses surrounding the capability of the control system on the level of settling times, rise times and various other responses to control signals received or the control strategy employed. While proponents must address these, they have not been reproduced in this guide.

Reasonable approaches for voltage and reactive power control

For Generator connections less than 100 kV and less than 30 MW, the following sections offer the basis for a reasonable approach to addressing some of the requirements of S5.2.5.13.

Evoenergy does not guarantee these sections are exhaustive, nor does Evoenergy guarantee it will accept this level for all locations in the Evoenergy network, it is provided as a guide only. Additional to Evoenergy's requirements, any proposed negotiated or minimum standard, including standards based off this template, requires input from AEMO.

Voltage control strategy

Every generator connected to the Evoenergy network must have a voltage control system. This must be in the form of constant power factor, constant reactive power or constant voltage (similar to an AVR). Evoenergy generally considers the following voltage control strategies to be reasonable:

- Q = constant
- V = constant
- Cos ϕ = constant
- Cos ϕ = f(P)
- Q = f(V)
- Cos ϕ = f(V)

Note that the proposed voltage control strategy must not prevent Evoenergy as the NSP from achieving the requirements of clauses S5.1a.3 and S5.1a.4, this must be determined through the NTS.

Proponents should seek a control strategy with a dynamic response as close as possible to the automatic access standard in the NER.

Control system

NER S5.2.5.13 (b) (2) (i) (ii) requires facilities for both monitoring of key variables and for testing its operational characteristics. The key variables that Evoenergy requires are listed in Appendix A.

A fault recorder which logs events such as voltage disturbances, changes in set point, etc. to log and report on the control system's dynamic response to operational events is considered mandatory.

Evoenergy requires proponents to provide details of how their testing facilities will prove its dynamic operating characteristics.

Control system damping

The generating system must have a voltage control system that ensures any oscillations are adequately damped with no degradation of critical oscillatory modes and with no instabilities such as hunting.

Control system testing

The control system must include a way, means or method to test its performance. Facilities for testing and their needs are to be agreed with Evoenergy on the specified limits and requirements. One or more of the following methods may form the basis of a reasonable approach to control system testing.

- Simulating inputs with software
- Test links
- Primary injection points

The above list is not intended to be exhaustive: other methods may be proposed by the proponent.

Power system stabiliser

Control system must not detract from the performance of any power system stabilizer and will be co-ordinated and as agreed by Evoenergy.

Evoenergy NTS requirements

The NTS will include dynamic modelling which includes a model of the control system of the machine. These are often available from the manufacturer. This modelling needs to address all of the dynamic responses of the proposed access standard.

The time domain dynamic studies need to capture factors such as network constraints and performance, along with the Generator's performance ability. It should also demonstrate the adequacy of the voltage and reactive control system and be consistent with typical commissioning tests and frequency domain (small-signal) studies.

Automatic – The generator will have plant capabilities and control systems sufficient to ensure that:

(i) Adequately damps oscillations and does not worsen existing system oscillatory modes.
(ii) Does not introduce instability (including interactions like tap changer hunting or control instability) that could impact other Evoenergy customers.
(iii) Includes permanently installed monitoring and recording of key control variables and enables testing of dynamic performance to verify behaviour.
(iv) Can control voltage, reactive power, or power factor, and switch between modes.

1. Capability must align with OEM design and be demonstrably acceptable to the NSP and AEMO given control settings.

(v) Actively regulates voltage at the connection point:

1. Maintains voltage within ±0.5% of setpoint
2. Allows continuous setpoint adjustment of at least +/- 5%
3. Supports network voltage during disturbances and does not hinder NSP obligations (e.g. broader voltage control requirements)
4. does not rely on a tap-changing transformer as the means of voltage regulation.

(vi) Operates in a system-supportive manner at limits, includes controls/limiters to avoid tripping or adverse behaviour at capability limits and ensures behaviour during disturbances supports overall network performance.
Minimum – The generator will have plant capabilities and control systems sufficient to ensure that:
(i) Power system oscillations, for the frequencies of oscillation of the generating unit against any other generating unit, are adequately damped;
(ii) Operation of the generating system does not degrade:

1. any mode of oscillation that is within 0.3 nepers per second of being unstable, by more than 0.01 neper per second; and
2. Any other mode of oscillation to within 0.29 nepers per second of being unstable

(iii) Operation of the generating system does not cause instability (including hunting of tap-changing transformer control systems) that would adversely impact other Registered Participants.

The generating unit or generating system will have facilities to regulate voltage or reactive power or power factor in a manner that does not prevent the Network Service Provider from achieving the requirements of clause S5.1a.3 and S5.1a.4; and sufficient to achieve the performance of agreed in respect of clauses S5.2.51, S5.2.5.2, S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.6 and S5.2.5.12.

5.14 Active power control

Clause S5.2.5.14 of the NER deals with the control of the output active power and the ability of the Generator to increase or decrease its active power transfer when required by AEMO.

Automatic – A scheduled generating system must be able to maintain and change its active power output as specified including dispatch instructions, able to ramp its active power linearly from one level of dispatch to another, and able to receive and automatically respond to signals from automatic generation control system as updated at a rate of once every 4 seconds (or such a period as per AEMO).

A non-scheduled generating system must be able to automatically change its active power output within 5 minutes as specified including dispatch instructions, and able to automatically limit its active power output.

A semi-scheduled generating system must be able to automatically change its active power output within 5 minutes as specified including dispatch instructions, able to automatically limit its active power output, able to ramp its active power output linearly from one dispatch level to another and able to receive and automatically respond to signals delivered from automatic generation control system as updated at a rate of once every 4 seconds (or such a period as per AEMO).

Minimum – Scheduled and semi-scheduled Generators maintaining active power output in accordance with the dispatch instructions which may be as short as 4s. For non-scheduled Generators, managing its active power output as specified within 5 minutes.

Negotiated – AEMO to agree and advice on the requirements of negotiated standard and any information and upgrades required.

General – Systems must be adequately damped.

Information supplied by the proponent must include details of the active power control system via drawings and a description detailing how the Generator will respond to AEMO's dispatch targets.

The generating system active power output must be reduced or disconnected in response to control request signals as agreed with Evoenergy. This includes events where danger, overload, islanding, network stability, safety and management are critical. The active power output needs to be capable of being reduced in 10% steps and the target output must be realised with one minute of receipt of the signal from Evoenergy.

5.15 Short circuit radio

Clause S5.2.5.15 relates to the plant's capability to operate in certain connection conditions as it relates to the network short circuit ratio. This clause is only applicable to asynchronous generators.

The system must be capable of stable operation and remain connected at the connection point at or above the agreed short circuit ratio (SCR) determined under the System Strength Impact Assessment Guidelines. The agreed SCR and the associated active power capability (or maximum demand) must be recorded in the performance standards and notified in accordance with NER 5.3.4C(b1).

Minimum – the generator must have plant capability sufficient for its asynchronous production units to operate stably and remain connected at a short circuit ratio of 3.0.

Where capability shortfalls are identified, the proponent may address them by system strength connection works, an agreed system strength remediation scheme, or by electing to pay the system strength charge per NER 5.3.4B. The agreed SCR and any operational arrangements must be reflected in the performance standards.

5.16 Remote monitoring and control

Clause S5.2.6.1 of the NER deals with remote monitoring of generating system by AEMO and Evoenergy control centres to monitor the performance of the Generator.

Automatic – Subject to scheduling and size (as per the NER), the generating system must have remote monitoring equipment to transmit to AEMO the specified quantities required for AEMO to discharge its duties.

Minimum – Subject to scheduling and size (as per the NER), the generating system must have remote monitoring equipment to provide AEMO with the following quantities. Active power output and reactive power output (if connected to a transmission system).

Negotiated – As agreed with AEMO and documented in the agreed performance standard.

Evoenergy will also require SCADA as detailed in the preceding sections.

5.17 Communication equipment

Clause S5.2.6.2 of the NER deals with the basic communications required between AEMO and Evoenergy control centres and the electrical supply to the remote monitoring and control equipment.

Automatic – Two separate telephone facilities to be provided. Back-up power supply for remote communication and control facilities for three hours following on from a loss of supply.

Minimum – Provision of a telephone facility and one hour back up supply.

Negotiated – Agreed communication facilities between AEMO, Evoenergy and the Generator subject to the specified limits.

5.18 Power station auxiliary supplies

Clause S5.2.7 of the NER requires auxiliary supply from a different connection point. In this case the auxiliary supply will be treated as a new customer load.

5.19 Fault current

Clause S5.2.8 of the NER deals with fault current contribution to Evoenergy's network and the fault current withstand of the Generator and associated circuit breakers required to isolate it from the network.

Automatic – The generating system does not produce fault currents in which the contribution exceeds the operational limits of the existing network lines and equipment. The generating systems connecting equipment must be rated to the levels specified by the NSP and could be the ultimate fault level of the network.

Minimum – The generating system does not need to limit fault contribution. The generating systems connecting equipment is rated and can operate as specified by Evoenergy.

Negotiated – As agreed with Evoenergy and documented in the Generator Connection Agreement.

The proponent must carry out fault level studies that include:

- Maximum fault levels at both the point of connection and in the wider network;
- Equipment sufficiently rated to withstand the fault levels required; and
- The fault level contribution will not result in the fault withstand capability of the surrounding network equipment.

For Generators with inverters the fault current contribution must not exceed the rated current of the inverter(s). If this occurs, then the use of short circuit current limiters must be used in agreement with the Network Operator.

6 Terms and abbreviations

Term	Definition
AEMO	The Australian Energy Market Operator.
DNSP	The Distribution Network Service Provider.
Generator	The person or legal entity seeking to connect, own or operate a generating system. The terms Proponent and Generator are used interchangeably in this document.
Registered Generator	A person or legal entity registered with the AEMO as a Registered Participant as per Chapter 5 of the NER.
Generating system	The plant and equipment used for generating electricity.
NER	The National Electricity Rules.
NSP	See DNSP.
NTS	Network Technical Study. The connection of an embedded generator installation to a distribution network will inevitably result in some local changes to the characteristics of the network. To evaluate the possible consequences of these changes Evoenergy will carry out a network study with the installation included in the network model. This involves the use of detailed databases describing the electrical characteristics of the network and can be used to analyse how the network will behave under different loading conditions or in the event of particular faults.
Proponent	The person or legal entity seeking to connect, own or operate a generating system. The terms Proponent and Generator are used interchangeably in this document.

Table 1. Glossary of terms

Other Capitalised words used in this document have the same meaning as given to them in the NER.

7 Version control

Version	Details	Updated
0.1	Initial Draft	Ravi Anegondy
0.2	Initial Feedback and edit to Section 5.2, 5.4	Richard Pozza

0.3	Minor Adjustments	Gavin Morrison
0.4	Template Change	Alison Davis
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8 Document control

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