Generator Performance Guideline

16 September 2019

Important Notice

Purpose

AEMO and Western Power has prepared this document to provide guidance about the standards for performance of generators in the Wholesale Electricity Market, as at the date of publication.

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1. Introduction

1.1 The *power system* is evolving

The South West Interconnected System (*SWIS*) is changing:

- *Generation* embedded in *customer* premises is becoming an increasingly significant source of electricity. The Australian Energy Market Operator (*AEMO*) has predicted that over the next ten years, on average, each year new roof-top photovoltaic (PV) systems will add 134 MW of *generation*[1];
- New large-scale grid connected renewable (solar and wind) *generation* projects are also being developed;
- Both the roof-top PV and grid connected renewable *generation* are inverter based, non-synchronous *generation*, meaning that over time the *power system* will have lower levels of synchronous *generators*.

The Technical Rules define the performance requirements that large-scale *generators* are required to meet. It is important that the generator performance standards are set appropriately and recognise the evolving characteristic of the *power system*.

1.2 Generator performance is critical for system security

A secure *power system* is one that is able to ride through unexpected contingencies without causing wide spread disruption in the *supply* of electricity to *customers*. To maintain system security *AEMO* as the system operator in collaboration with Western Power needs to identify the secure *power transfer* limits for the *SWIS* and to control the output from *generators* to keep power flows within the secure transfer limits.

Understanding how *generators* will perform during normal operation, in response to *contingency* events, and the support that *generators* can provide to help regulate *voltage* and *frequency* and maintain a stable *voltage* and *frequency* is crucial in accurately determining system security limits. When a new *generator* is proposed to connect to the *SWIS,* it is important that there is clarity regarding the level of performance that the *generator* is required to deliver to ensure that its connection does not degrade the security of the *power system*.

Various reviews have identified that maintaining appropriate *generation* performance requirements is critical. This is reflected in recommendation 2.1 from the Finkel review[2] which recommended that by mid-2018 the Australian Energy Market Commission (*AEMC*) should:

- Review and update the connection standards in their entirety.
- The updated connection standards should address system strength, *reactive power* and *voltage* control capabilities, the performance of *generators* during and subsequent to *contingency* events, and *active power* control capabilities.
- To be approved for connection, new *generators* must fully disclose any software or physical parameters that could affect security or *reliability*.
- Thereafter, a comprehensive review of the connection standards should be undertaken every three years.

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[1] https://www.aemo.com.au/Electricity/Wholesale-Electricity-Market-*WEM*/Planning-and-forecasting/*WEM*-Electricity-Statement-of-Opportunities 2018 Wholesale Electricity Market Electricity Statement of Opportunities

[2] https://www.energy.gov.au/government-priorities/energy-markets/independent-review-future-security-national-electricity-market

While the Finkel review primarily considered the National Electricity Market (*NEM*), the need for appropriate *generator* performance requirements is also relevant for the *SWIS*. It may well be argued that the isolated nature of the *SWIS* means that it is even more important to maintain accurate knowledge of *generator* performance.

In October 2018, the Australian Energy Market Commission (*AEMC*) completed a review of the *generator* performance standards in the National Electricity Rules (NER). This review recognised the changing characteristics of the *power system* and the need for refreshed *generator* performance standards to enhance *power system security* by implementing technical performance requirements that:

- reflect the range of new generating technologies that are expected to connect to the system in the future and the implications of those technologies for system security and the quality of *supply* to other users.
- better address the needs of the *power system*. In some cases, they need to be updated to efficiently manage *frequency* and *voltage* within acceptable limits, or to limit the risk of major *power system* collapse when those acceptable limits are breached. In other cases, they need to be updated to replace some of the valuable attributes being lost as synchronous *generation* retires, such as their inherent stabilising behaviour that assists the *power system* during certain disturbances.

This work provides a good foundation for reviewing the performance requirements that apply in the *SWIS*.

1.3 The requirements in the Technical Rules need revision

The Technical Rules define the performance requirements for the *network*, *generation* and *load* that in combination form the *SWIS*. The *generator* performance requirements in the Technical Rules are in need of review to address a variety of known limitations including:

- Performance requirements generally assume synchronous *generation* technology and its inherent ability to contribute to system strength and system stability
- There are gaps in the specified performance requirements, particularly when compared to the revised *generator* performance standards now implemented in the National Electricity Rules (NER)
- Some performance requirements are specified at a level inappropriate for a *power system* that incorporates a significant and growing level of variable non-synchronous *generation*
- Mandatory performance requirements provide little guidance regarding the circumstance that would support a negotiated level of performance
- The current requirements do not contemplate the role *AEMO* plays in agreeing *generator* performance requirements.

1.4 This guideline identifies proposed *generator* performance standards for the Wholesale Electricity Market

The introduction of the Generator Interim Access system will enable a number of *generator* connections to proceed that had previously been stalled because they were awaiting arrangements that would facilitate connection of new *generators* on a constrained basis, ensuring that *network* capability is not exceeded. There is a need for developers of new large-scale *generation* to understand technical performance requirements that would be sufficient to ensure connections that do not degrade the *SWIS power system security*. This guideline is intended to facilitate this understanding.

Western Power and *AEMO* have developed this guideline to help inform developers of the evolving technical requirements. The intention is that this guideline provides information that will help *generator* investors understand potential future obligations, should the technical performance requirements specified in this guideline be codified into the appropriate regulatory instruments such as the Technical Rules.

The guideline does not replace the existing regulatory requirements and compliance with this guideline is entirely voluntary. This guideline articulates a level of performance that Western Power and *AEMO* consider will be appropriate to maintain security of *supply* for the *SWIS*.

Western Power and *AEMO* intend to seek revisions to the relevant regulatory instruments to implement the technical performance requirements articulated in this guideline. This guideline will help *generators* and other interested stakeholders understand the proposed requirements. This guideline will also help *generators* and other interested stakeholders participate in future consultations undertaken as part of developing appropriate changes to the relevant regulatory instruments.

This guideline is also intended to provide information to *generation* developers that they may find helpful when specifying new *generation* equipment that will satisfy future *generator* performance requirements. *Generators* may also refer to this guideline where generating *plant* is modified to ensure their *generation* equipment will satisfy future *generator* performance requirements. This guideline indicates performance requirements expected for *generating systems* with a combined *nameplate rating* of the *generating units* exceeding 10 MW.

In this guideline document, defined terms appear in italics and have the meaning provided in section 4 which reflects the meaning in the Technical Rules or NER.

1.5 Exclusion of communications standards

This guideline does not include information on communications standards that *WEM* market participants must meet. That information can be found in other documents published by *AEMO*[3].

[3] https://www.aemo.com.au/Electricity/Wholesale-Electricity-Market-*WEM*/Procedures

2. Performance framework

It is recommended that the *generator* performance requirements for the *SWIS* adopt a structure and approach which is closely aligned with that followed in the NER. Within this new framework, the required performance for each *generator* will be defined by a set of *generator* performance standards (GPS). Each individual performance standard records the requirement to meet a specific technical characteristic. While the *SWIS* GPS cover the same set of technical characteristics as those defined in the NER, the required performance levels differ. The performance levels in the *SWIS* GPS reflect the particular requirements for maintaining *power system security* in the *SWIS*.

This approach offers benefits for *generation* investors by maintaining a level of consistency between the way technical performance requirements are specified in the *NEM* and in the *SWIS*. It also helps ensure that important technical performance criteria are captured and that the *AEMC*'s recently completed review is appropriately leveraged.

2.1 Required *generator* performance established via tripartite negotiation

It is envisaged that the negotiation of the GPS will involve a tripartite negotiation between the *generation* developer, Western Power and *AEMO*, with *AEMO* becoming involved in the negotiation of those *generator* performance standards that have a direct impact on *power system security*. These particular performance standards are identified as *AEMO advisory matters*. Western Power will be involved in the negotiation of all *generator* performance standards.

It is envisaged that each *generator* seeking to connect to the *SWIS* will negotiate set performance requirements and document the agreed set of performance criteria in its GPS. The GPS should be negotiated prior to the connection offer being made. Western Power will provide the agreed GPS to the connecting *generator* and *AEMO.*

The *generator* should maintain a close watch over its actual performance and flag to Western Power and *AEMO* immediately if it becomes aware of any inability to meet one of the performance standards specified in the GPS.

2.2 Agreed *generator* performance must lie within a specified range

The Technical Rules specify a set of required *generator* minimum performance characteristics. For each performance characteristic, a single performance target is specified.

A different approach is adopted in the *NER* where a performance band is specified for each technical performance criteria. The performance band represents a range of performance that may be acceptable at different *connection points*:

- The upper end of the range is referred as the automatic standard and represents a level of performance sufficient to ensure that connection of the *generator* would not be denied based on that particular performance characteristic.
- The lower end of the range is referred to as a minimum standard and represents the lowest level of performance that may, through negotiation, be acceptable. This level of performance is unlikely to be acceptable at all *connection points*. A *generator* not able to meet the minimum standard would not be allowed to connect at any *connection point*.
- The *generator* can propose a level of performance between the automatic and minimum standard and if the level of performance is lower than the automatic standard, the *generator* must demonstrate to the connecting *network service provider* and, where relevant *AEMO* that accepting the lower standard is appropriate. The *NER* includes specific details on criteria that must be demonstrated before any

standard lower than automatic is accepted which should encourage developers to target delivery of the automatic standard in most instances.

The specification of potential performance bands establishes a framework for arriving at a negotiated performance level that is appropriate for the *connection point* and allows *generators* to optimise their investment by avoiding investment in infrastructure to provide capability, unless it is required.

It is proposed that a similar approach be adopted for the *SWIS* GPS. Where appropriate, the required level of performance for a particular standard will be specified by a range identified by an upper, ideal level of performance and a lower, minimum performance level:

- The ideal level of performance is sufficient to ensure that connection of the *generator* would not be denied based on that particular performance characteristic.
- The minimum standard represents the lowest level of performance that may be acceptable. This level of performance is unlikely to be acceptable at all *connection points* and a *generator* not able to meet the minimum standard would not be allowed to connect.
- The *generator* can propose a level of performance between the ideal and minimum standard and if the proposed level of performance is lower than the ideal must demonstrate to Western Power and, where relevant, *AEMO* that accepting a lower standard is appropriate and will not degrade system security or the quality of *supply* for other *network customers*.

The performance band is illustrated inFigure 1 below.

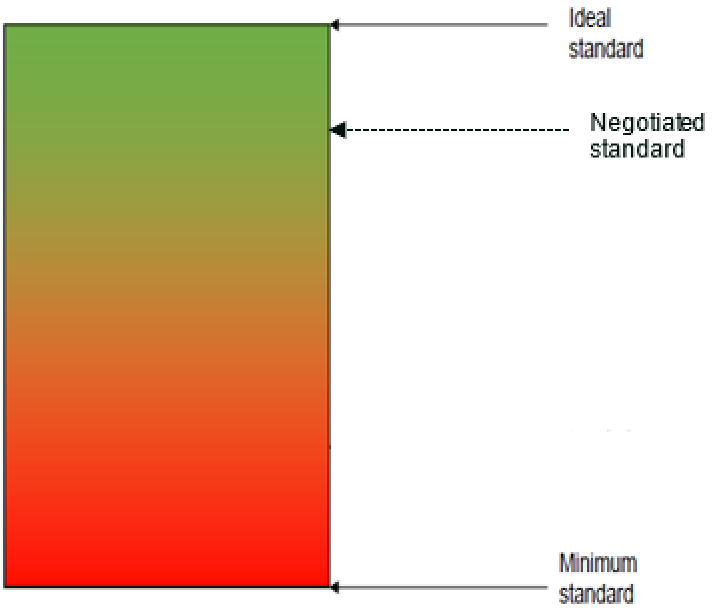

Figure 1 : Illustration of performance band

One advantage of defining a band that the negotiated performance standard must lie within is that it should remove any requirement for *generators* to negotiate derogations to the technical performance requirements in the Technical Rules. The negotiating band proposed in this guideline considers the range of relaxation of performance requirements that Western Power has, to date, been willing to accommodate via a derogation. In this way the negotiating band preserves the ability of *generators* to negotiate reduced performance obligations consistent with previously accepted derogations, noting that the ability to accept reduced performance will depend on a variety of factors including the location of the *connection point*.

3. Performance criteria

This section lists the individual performance areas that must be covered by each GPS. Each subsection describes a technical requirement and specifies the minimum and ideal standard for that requirement. Performance standards specify the performance, in relation to that standard, measured at the *connection point*.

The following common requirements apply when negotiating each individual performance standard (additional requirements specific to an individual standard are discussed in the relevant sub-section):

(a) A negotiated performance standard must:

(1) be no less onerous than the corresponding minimum performance standard;

(2) be set at a level that will not adversely affect *power system security*; and

(3) be set at a level that will not adversely affect the quality of *supply* for other *Network Users*;

(b) When submitting a proposal for a negotiated performance standard a *generator* must propose a standard that is as close as practicable to the corresponding ideal performance standard, having regard to:

(1) the need to protect the *plant* from damage;

(2) *power system* conditions at the location of the proposed connection; and

(3) the commercial and technical feasibility of complying with the ideal performance standard with respect to the relevant technical requirement.

(c) When proposing a negotiated performance standard, the *generator* must provide reasons and evidence as to why, in the reasonable opinion of the *generator*, the proposed negotiated performance standard is appropriate, including:

(1) how the *generator* has taken into account the matters outlined in subparagraphs (b); and

(2) how the proposed negotiated performance standard meets the requirements of paragraph (a).

Evidence should be provided to Western Power and Western Power will share it with *AEMO* as required.

(d) Western Power must, following the receipt of a proposed set of negotiated performance standards, consult with *AEMO* as soon as practicable in relation to *AEMO advisory matters*.

(e) *AEMO* must advise Western Power, in respect of *AEMO advisory matters*, whether the proposed negotiated performance standard should be accepted or rejected.

(f) When advising Western Power to reject a proposed negotiated performance standard, and subject to obligations in respect of confidential information, *AEMO* must:

(1) provide detailed reasons in writing for the rejection to Western Power, including where the basis of *AEMO*'s advice is lack of evidence from the *generator*, details of the additional evidence *AEMO* requires to continue assessing the proposed negotiated performance standard; and

(2) recommend a negotiated performance standard that *AEMO* considers to be appropriate.

(g) Western Power must, following the later of:

(1) receipt of a proposed negotiated performance standard; and

(2) receipt of all information required to allow assessment of the performance standard, including receipt of *AEMO*'s advice with respect to that performance standard

accept or reject a proposed negotiated access standard.

(h) Western Power must reject the proposed negotiated performance standard where:

(1) in Western Power's reasonable opinion, one or more of the requirements articulated in the previous paragraphs are not met; or

(2) *AEMO* has advised Western Power to reject the proposed negotiated performance standard.

(i) If Western Power rejects a proposed negotiated access standard, Western Power must, subject to obligations in respect of confidential information:

(1) provide detailed reasons in writing for the rejection, including details of advice provided by *AEMO* and details of the additional evidence required to continue assessing the proposed negotiated performance standard; and

(2) recommend a negotiated performance standard that Western Power and *AEMO* consider to be appropriate.

(j) The *generator* may in relation to the response received from Western Power:

(1) accept the negotiated performance standard proposed by Western Power;

(2) reject the negotiated performance standard proposed by Western Power, or

(3) propose an alternative negotiated performance standard to be further evaluated by Western Power and *AEMO* (as necessary).

3.1 *Reactive power* Capability

Reactive power provided by *generators* is essential to maintaining *voltage* stability and keeping the *voltage*s on the *network* within the limits defined in the Technical Rules.

3.1.1 Ideal performance standard

The ideal performance standard requires the *generating system* to have capability to *supply* or absorb *reactive power* consistent with the shaded area in Figure 2, which provides an illustration of the requirement for a *generating system* with a maximum *active power* of 100 MW.

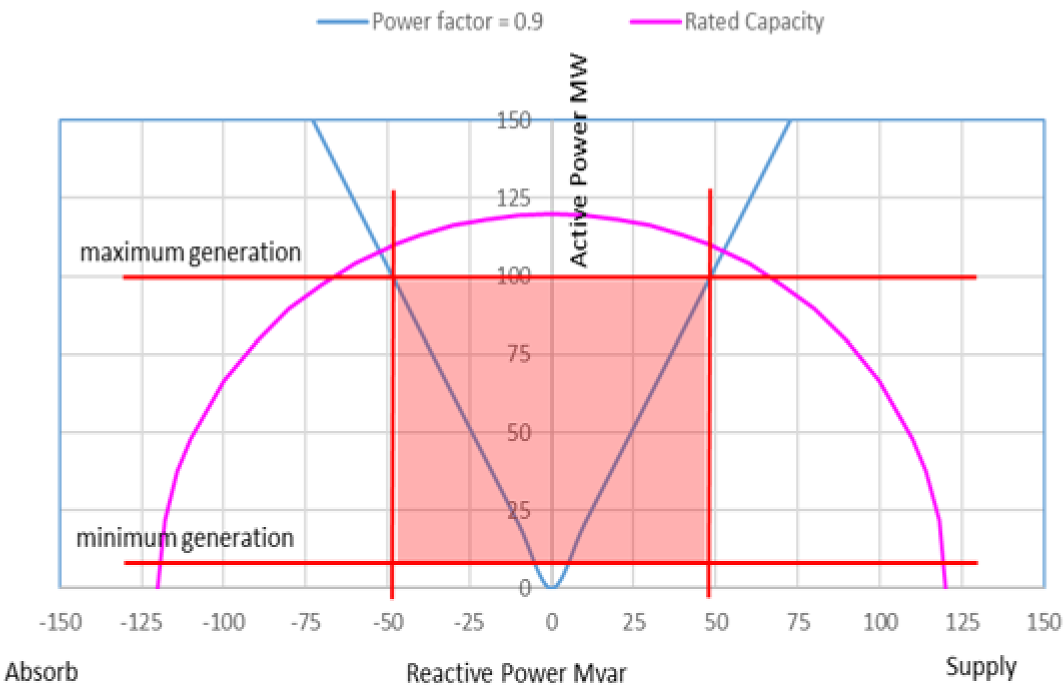

Figure 2 : *Reactive power* capability required to meet the ideal standard

To meet this standard, the *generating system*, while operating at any level of *active power* output between its registered[4] maximum and minimum *active power* output level, must be capable of *supply*ing or absorbing at its *connection point* an amount of *reactive power* of at least the amount equal to the product of the rated *active power* output of the *generating system* at nominal *voltage* and 0.484. This level of reactive capability should be able to be delivered continuously for *voltages* at the *connection point* within the range specified in clause 2.2.2 of the Technical Rules.

This requirement must be met for all operating conditions, including stated ambient temperature. Unless operating restrictions have been agreed in accordance with clause 3.1(b) of the Technical Rules, Western Power may assume the site specific maximum ambient temperature shown in the figure below when assessing compliance with the ideal performance standard.

[4] Registered data is specified in Attachment 3 of the Technical Rules

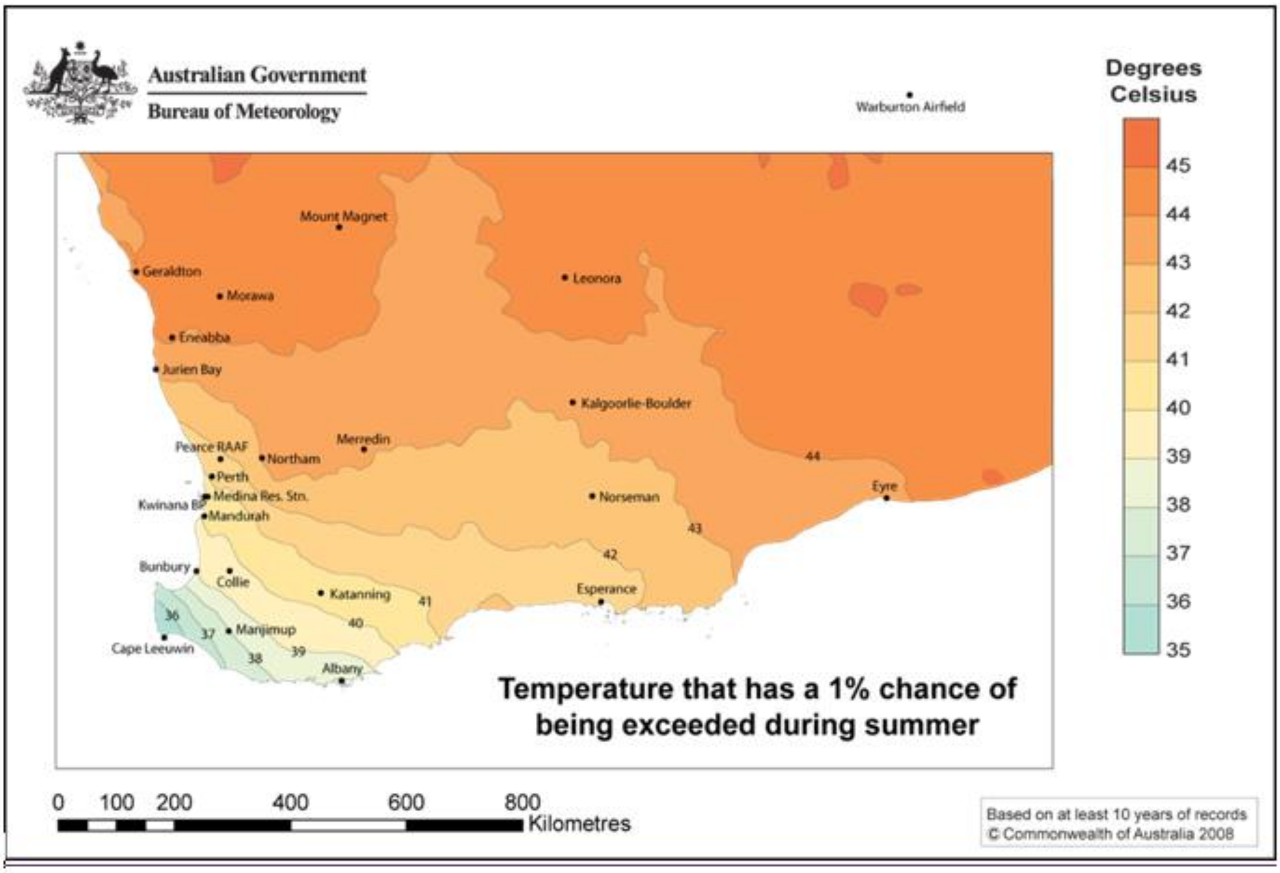

Figure 3 : Ambient temperatures for which ideal performance must be met

3.1.2 Minimum performance standard

The minimum performance standard requires the *generating system* to have capability to *supply* or absorb *reactive power* consistent with the shaded area in

Figure **4**, which provides an illustration of the requirement for a *generating system* with a maximum *active power* of 100 MW. This figure represents the required capability when the *voltage* at the *connection point* is 1.0 pu. For other *voltage* levels, it may be appropriate to relax the *reactive power* absorption or *supply* requirement depending on whether the *voltage* is lower or higher than 1.0pu. Figure 5 illustrates the level of relaxation allowed to meet the minimum performance standard.

To meet this standard, the *generating system*, while operating at any level of *active power* output between its registered maximum and minimum *active power* output level, must be capable of *supply*ing or absorbing at its *connection point* an amount of *reactive power* of at least the amount equal to the product of the rated *active power* output of the *generating system* and 0.329 for a *voltage* at the *connection point* of 1.0 pu.

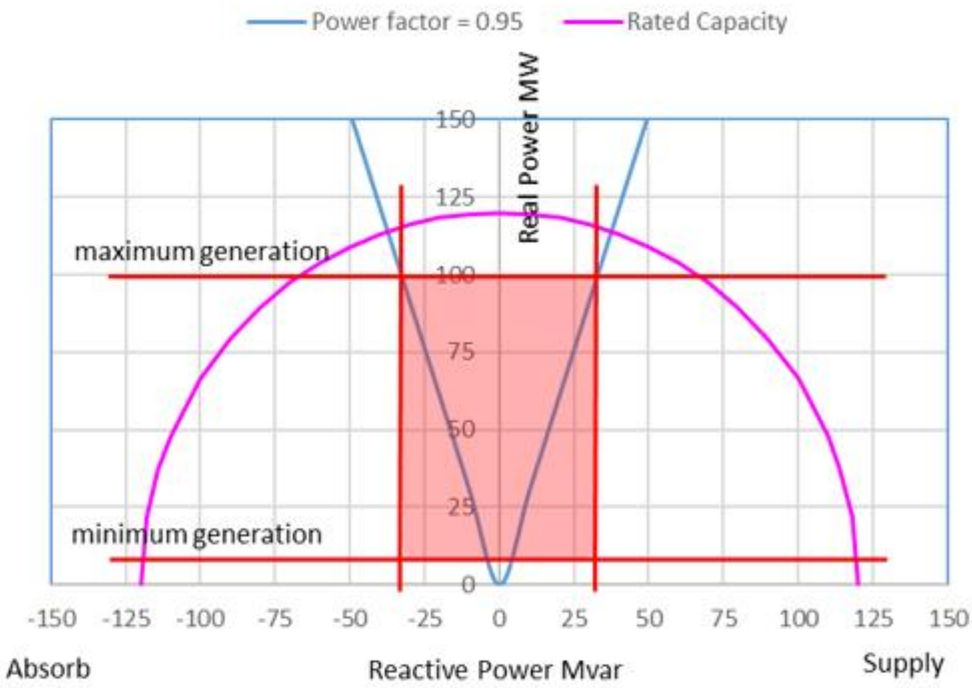

Figure 4 : *Reactive power* capability required to meet the minimum standard

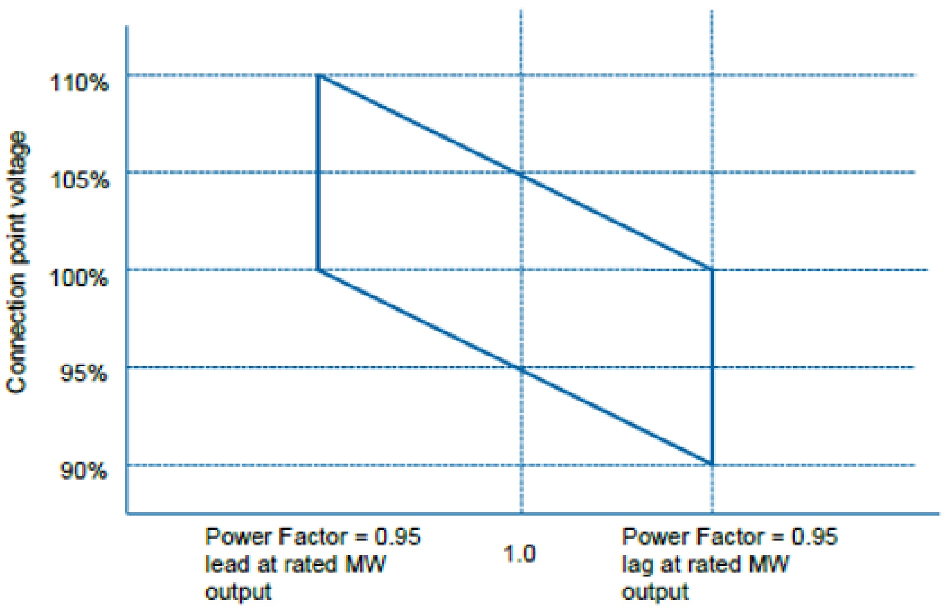

Figure 5 : Relaxation of *reactive power* requirement with *connection point voltage*

The *reactive power* capability in

Figure **4** can be varied as defined in Figure 5 when the *voltage* at the *connection point* varies between 0.9 per unit and 1.1 per unit.

Non-scheduled *generating systems* may, with Western Power's agreement, achieve the *reactive power* capability specified in

Figure **4** by reducing the *active power* output when the ambient temperature exceeds 25°C.

3.1.3 Basis for negotiation

In addition to the general provisions for negotiating any performance standard, when negotiating the appropriate *reactive power* capability performance standard, the *generator*, Western Power and *AEMO*:

- must ensure that the *reactive power* capability of the *generating system* is consistent with maintaining *power system security* and is sufficient to ensure that all relevant system standards are met before and after credible *contingency* events under normal and planned outage operating conditions of the *power system*, taking into account existing *power system* conditions and any other relevant projects in relation to the connection of other *Network Users*; and
- may negotiate a limit that describes how the *reactive power* capability varies as a function of *active power* output due to a design characteristic of the *plant*.

The GPS will record the *reactive power* capability of the *generating system* under each of the following conditions:

- 50°C ambient temperature and 0.9 per unit *voltage* at the *connection point*
- 50°C ambient temperature and 1.0 per unit *voltage* at the *connection point*
- 50°C ambient temperature and 1.1 per unit *voltage* at the *connection point*
- 25°C ambient temperature and 0.9 per unit *voltage* at the *connection point*
- 25°C ambient temperature and 1.0 per unit *voltage* at the *connection point*
- 25°C ambient temperature and 1.1 per unit *voltage* at the *connection point*

3.1.4 Comparison with the current Technical Rules

The proposed ideal standard has been developed by considering the performance requirement specified in clause 3.3.3.1 of the Technical Rules with some adjustments made to adopt a performance requirement that is appropriate for all *generation* technologies. The proposed standards specify requirements at the *connection point* and the definition of *generating system* allows for requirements to be delivered taking into account shunt equipment and tap changer controls that form part of the *generating system*.

The proposed minimum standard allows a reduced level of performance consistent with that which has been allowed at some *connection points* and recognised in derogations granted previously by Western Power.

The minimum standard also recognises that delivering the range of *reactive power* capability required by the ideal standard under the high ambient conditions that can occur during summer is difficult for some *generation* technologies connected to the *power system* via inverters. The ideal standard may add significant additional costs by requiring additional inverter capacity to cope with derating under high ambient temperatures. In some areas of the *network* the need for *reactive power* absorption on these high temperature days is diminished due the significant proportion of air conditioning *load*. The minimum standard provides an opportunity to allow a relaxed requirement while still providing sufficient *reactive power* to *control system voltages*.

3.2 *Voltage* and *Reactive power* Control

The specific *control systems* implemented in *generating systems* to control *voltage* and/or *reactive power* output have a critical impact on controlling *voltage* on the *power system*. The performance requirements are set to assist in delivering stable control of *voltage* within the range of nominal *voltage* specified clause 2.2.2 of the Technical Rules.

The *control systems* and techniques used to control *voltage* and *reactive power* differ appreciably for *synchronous* and other forms of *generation*. The performance standards are therefore separated into requirements common to all forms of *generation* and specific requirements for *synchronous* and other forms of *generation*. The *synchronous generation* requirements would also apply to synchronous condensers, which may be required in some areas of the *SWIS* to address system strength issues.

3.2.1 Ideal performance standard

To meet the ideal performance standard a *generating system* must meet the requirements outlined in this section 3.2.1. In summary the ideal performance standard requires the *generating system* to have the ability to regulate *voltage*, *reactive power* and *power factor*. The active control modes will be nominated by Western Power, after liaising with *AEMO*, but the *generating system* will be able to switch between control modes if required.

3.2.1.1 Common requirements

A *generating system* must have *plant* capabilities and *control systems* sufficient to ensure that:

- *power system* oscillations, for the *frequencies* of oscillation of the *generating unit* against any other *generating unit*, are *adequately damped*;
- operation of the *generating system* does not degrade the damping of any critical mode of oscillation of the *power system*; and
- operation of the *generating system* does not cause instability (including hunting of *tap-changing transformer control systems*) that would adversely impact other *Network Users*;

Control systems on *generating systems* that control *voltage* and *reactive power* must include permanently installed and operational monitoring and recording facilities for key variables, including each input and output and facilities for testing whether the *control system* is sufficient to establish its dynamic operational characteristics.

A *generating system* must have *control systems* able to regulate *voltage*, *reactive power* and *power factor*, with the ability to:

- operate in any control mode; and
- switch between control modes,

as shown in the manufacturer's and/or design specifications of the relevant equipment and demonstrated to the reasonable satisfaction of Western Power and *AEMO*. Western Power and *AEMO* will nominate one or more control modes to be implemented when the *generating system* is commissioned and may require additional control modes to be commissioned after connection if they reasonably consider such additional modes to be necessary to ensure *power system security* or quality of *supply*. Where a *generating system* has been commissioned for more than one control mode, the *generator*, Western Power and *AEMO* must agree on a procedure for switching between control modes. The initial operating mode, other available modes and the procedure for switching between modes must be recorded as part of the performance standard.

A *generating system* must have a *voltage control system* that:

- regulates *voltage* at the *connection point* or another agreed location in the *power system* (including within the *generating system*) to within 0.5% of the setpoint, where that setpoint may be adjusted to incorporate any *voltage* droop or reactive current compensation agreed with *AEMO* and Western Power;
- regulates *voltage* in a manner that helps to support *network voltages* during faults and does not prevent Western Power from achieving the requirements for *voltage* performance and stability specified in clauses 2.2.2, and 2.2.7 to 2.2.11 of the Technical Rules;
- allows the *voltage* setpoint to be continuously controllable in the range of at least 95% to 105% of the target *voltage* (as determined by Western Power) at the *connection point* or agreed location on the *power system*, without reliance on a *tap-changing transformer* and subject to the performance standards for *reactive power* capability agreed with *AEMO* and Western Power; and
- has limiting devices to ensure that a *voltage* disturbance does not cause a *generating unit* to trip at the limits of its operating capability. The *generating system* must be capable of stable operation for indefinite periods while under the control of any limiter. Limiters must not detract from the performance of any stabilising circuits and must have settings applied that are coordinated with all *protection systems*.

Where provided, a *power system* stabiliser must have:

- for a *synchronous generating unit*, measurements of rotor speed and *active power* output of the *generating unit* as inputs, and otherwise, measurements of *power system frequency* and *active power* output of the *generating unit* as inputs;
- two washout filters for each input, with ability to bypass one of them if necessary;
- sufficient (and not less than two) lead-lag transfer function blocks (or equivalent number of complex poles and zeros) with adjustable gain and time-constants, to compensate fully for the phase lags due to the generating *plant*;
- an output limiter, which for a *synchronous generating unit* is continually adjustable over the range of –10% to +10% of stator *voltage*;
- monitoring and recording facilities for key variables including inputs, output and the inputs to the lead-lag transfer function blocks; and
- facilities to permit testing of the *power system* stabiliser in isolation from the *power system* by injection of test signals, sufficient to establish the transfer function of the *power system* stabiliser.

Where provided, a *reactive power* or *power factor control system* must:

- regulate *reactive power* or *power factor* (as applicable) at the *connection point* or another agreed location in the *power system* (including within the *generating system*), to within:
  - (i) for a *generating system* operating in *reactive power* mode, 2% of the rating (in MVA) of the *generating system* (expressed in MVAr); or
  - (ii) for a *generating system* operating in *power factor* mode, a *power factor* equivalent to 2% of the rating (in MVA) of the *generating system* (expressed in MVAr);
- allow the *reactive power* or *power factor* setpoint to be continuously controllable across the *reactive power* capability range specified in the relevant performance standard; and
- for the *generating system* connected to the *power system*, and for a step change in setpoint of at least 50% of the *reactive power* capability documented in the relevant performance standard, or a 5% disturbance in the regulated *voltage* setpoint:

(i) have *settling times* for *active power*, *reactive power* and *voltage* of less than 5.0 seconds from an operating point where the *voltage* disturbance would not cause any limiting device to operate; and

(ii) have *settling times* for *active power, reactive power* and *voltage* of less than 7.5 seconds when operating into any limiting device from an operating point where a *voltage* disturbance of 2.5% would just cause the limiting device to operate.

Western Power may determine whether to use a setpoint step test or a 5% *voltage* disturbance test for the purposes of this subparagraph.

The structure and parameter settings of all components of the *control system*, including the *voltage* regulator, *reactive power* regulator, *power system* stabiliser, power amplifiers and all associated limiters, must be approved by Western Power and *AEMO*.

The structure and settings of the *voltage / reactive power control system* must not be changed, corrected or adjusted in any manner without the prior written approval of both Western Power and *AEMO*.

Control system settings may require alteration from time to time as advised by Western Power. A *Generator* must cooperate with Western Power by applying the new settings and participating in tests to demonstrate their effectiveness. Where necessary, revised settings will be documented in an amended performance standard.

3.2.1.2 Synchronous *generator*

A synchronous *generating system* must have an *excitation control system* that:

- can operate the stator continuously at 105% of nominal *voltage* with rated *active power* output;
- has an excitation ceiling *voltage* of at least:

  (A) for a *static excitation system*, 2.3 times; or

  (B) for other *excitation control systems*, 1.5 times,

  the excitation required to achieve *generation* at the *nameplate rating* for rated *power factor*, rated speed and nominal *voltage*;
- has a *power system* stabiliser with sufficient flexibility to enable damping performance to be maximised, with the stabilising circuit responsive and adjustable over a *frequency* range from 0.1 Hz to 2.5 Hz.

The performance characteristics required for AC exciter, rotating rectifier and *static excitation systems* are specified in Table 1.

Table 1 : Synchronous *generator excitation control system* performance requirements

Performance Item	Units	Static Excitation	AC Exciter or Rotating Rectifier	Notes
Sensitivity: A sustained 0.5% error between the *voltage* reference and the sensed *voltage* must produce an excitation *voltage* change of not less than 1.0 per unit.	Gain (ratio)	200 minimum	200 minimum	1
Field *voltage rise time*: Time for field *voltage* to rise from rated *voltage* to excitation ceiling *voltage* following the application of a short duration impulse to the *voltage* reference.	second	0.05 maximum	0.5 maximum	2,4
Settling time with the *generating unit* unsynchronised following a disturbance equivalent to a 5% step change in the sensed *generating unit* terminal *voltage*.	second	1.5 maximum	2.5 maximum	3
Settling time with the *generating unit* synchronised following a disturbance equivalent to a 5% step change in the sensed *generating unit* terminal *voltage*. Must be met at all operating points within the *generating unit* capability.	second	2.5 maximum	5 maximum	3
Settling time following any disturbance which causes an excitation limiter to operate. Disturbance applied from an operating point where a *voltage* disturbance of 2.5% would just cause the limiting device to operate.	second	5 maximum	5 maximum	3

Notes:

1. One per unit excitation *voltage* is that field *voltage* required to produce nominal *voltage* on the air gap line of the *generating unit* open circuit characteristic (Refer IEEE Standard 115-1983 - Test Procedures for Synchronous Machines). *Excitation control system* with both proportional and integral actions must achieve a minimum equivalent gain of 200.
2. Rated field *voltage* is that *voltage* required to give nominal *generating unit* terminal *voltage* when the *generating unit* is operating at its maximum continuous rating. *Rise time* is defined as the time taken for the field *voltage* to rise from 10% to 90% of the increment value.
3. *Settling time* is defined as the time taken for the *generating unit* terminal *voltage* to settle and stay within an error band of ±10% of its increment value.
4. Field *voltage* means *generating unit* field *voltage*.

3.2.1.3 *Generating systems* that are not comprised of *synchronous generating units*

A *generating system*, other than one comprised of *synchronous generating units*, must have a *voltage control system* that has a power oscillation damping capability with sufficient flexibility to enable damping performance to be maximised, with the stabilising circuit responsive and adjustable over a *frequency* range from 0.1 Hz to 2.5 Hz.

The performance characteristics required for the *voltage* and *reactive power control systems* of all non-*synchronous generating units* are specified in Table 2.

Table 2 : Non-synchronous *generator control system* performance requirements

Performance Item	Units	Limiting Value	Notes
Sensitivity: A sustained 0.5% error between the reference *voltage* and the sensed *voltage* must produce an output change of not less than 100% of the *reactive power generation* capability of the *generating unit*, measured at the point of control.	Gain (ratio)	200 minimum	1
Rise time: Time for the controlled parameter (*voltage* or *reactive power* output) to rise from the initial value to 90% of the change between the initial value and the final value following the application of a 5% step change to the *control system* reference.	second	1.5 maximum	2
Small disturbance *settling time*: *Settling time* of the controlled parameter with the *generating unit connected* to the *transmission or distribution network* following a step change in the *control system* reference that is not large enough to cause saturation of the controlled output parameter. Must be met at all operating points within the *generating unit's* capability.	second	2.5 maximum	3
Large disturbance *settling time* *Settling time* of the controlled parameter following a large disturbance, including a *transmission or distribution network* fault, which would cause the maximum value of the controlled output parameter to be just exceeded and a limiter to operate.	second	5 maximum	3
Notes: 1. A *control system* with both proportional and integral actions must be capable of achieving a minimum equivalent gain of 200. 2. The controlled parameter and the point where the parameter is to be measured must be agreed and included in the relevant connection agreement. 3. *Settling time* is defined as the time taken for the controlled parameter to settle and stay within an error band of ±10% of its increment value.			

3.2.2 Minimum performance standard

To meet the minimum performance standard a *generating system* must meet the requirements outlined in this section 3.2.2. In summary the minimum performance standard requires the *generating system* to have the ability to regulate *voltage* or either *reactive power* or *power factor*. A single control mode will be implemented as agreed with Western Power and *AEMO*.

3.2.2.1 Common requirements

A *generating system* must have *plant* capabilities and *control systems*, including, if appropriate, a *power system* stabiliser, sufficient to ensure that:

- *power system* oscillations, for the *frequencies* of oscillation of the *generating unit* against any other *generating unit*, are *adequately damped*;
- operation of the *generating unit* does not degrade:
  - (A) any mode of oscillation that is within 0.3 nepers per second of being unstable, by more than 0.01 nepers per second; and
  - (B) any other mode of oscillation to within 0.29 nepers per second of being unstable; and
- operation of the *generating unit* does not cause instability (including hunting of *tap-changing transformer control systems*) that would adversely impact other *Network Users*;
- a *generating system* comprised of *generating units* must have facilities for testing its *control systems* sufficient to establish their dynamic operational characteristics;
- a *generating system* must have facilities with a *control system* to regulate:
  - (i) *voltage*; or
  - (ii) either *reactive power* or *power factor* with the agreement of *AEMO* and Western Power;
- a *voltage control system* for a *generating system* must:
  - (i) regulate *voltage* at the *connection point* or another agreed location in the *power system* (including within the *generating system*), to within 2% of the setpoint, where that setpoint may be adjusted to incorporate any *voltage* droop or reactive current compensation agreed with *AEMO* and Western Power; and
  - (ii) allow the *voltage* setpoint to be controllable in the range of at least 98% to 102% of the target *voltage* (as determined by Western Power) at the *connection point* or the agreed location, subject to the *reactive power* capability agreed with *AEMO* and Western Power and documented in the relevant performance standards;
- a *generating system's reactive power* or *power factor control system* must:
  - (i) regulate *reactive power* or *power factor* (as applicable) at the *connection point* or another agreed location in the *power system* (including within the *generating system*), to within:
    - (A) for a *generating system* operating in *reactive power* mode, 5% of the nameplate rating (in MVA) of the *generating system* (expressed in MVAr); or
    - (B) for a *generating system* operating in *power factor* mode, a *power factor* equivalent to 5% of the nameplate rating (in MVA) of the *generating system* (expressed in MVAr); and
  - (ii) allow the *reactive power* or *power factor* setpoint to be continuously controllable across the *reactive power* capability defined in the relevant performance standard;
- has limiting devices to ensure that a *voltage* disturbance does not cause a *generating unit* to trip at the limits of its operating capability. The *generating system* must be capable of stable operation for indefinite periods while under the control of any limiter. Limiters must not detract from the performance of any stabilising circuits and must have settings applied that are coordinated with all *protection systems*.

3.2.2.2 Synchronous *generator*

A *synchronous generating unit*, with an *excitation control system* required to regulate *voltage* must:

- have excitation ceiling *voltage* of at least 1.5 times the excitation required to achieve *generation* at the *nameplate rating* for rated *power factor*, rated speed and nominal *voltage*;

- subject to the ceiling *voltage* requirement, have a *settling time* of less than 7.5 seconds for a 5% *voltage* disturbance with the *generating unit* synchronised from an operating point where such a *voltage* disturbance would not cause any limiting device to operate

3.2.2.3 *Generating systems* that are not comprised of *synchronous generating units*

A *generating system*, other than one comprised of *synchronous generating units*, with a *voltage control system* must have a *settling time* less than 7.5 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.

3.2.3 Basis for negotiation

The negotiated access standard proposed by the *generator* must be the highest level that the *generating system* can reasonably achieve, including by installation of additional dynamic *reactive power* equipment, and through optimising its *control systems*.

3.2.4 Comparison with the current Technical Rules

The ideal standard reflects the level of performance of a voltage *control system* in the current version of the Technical Rules (clause 3.3.4.5), but defines an expanded set of control modes that may be required.

3.3 *Active Power* Control

Maintaining system security requires the power flows on the *network* to be controlled within secure operating limits. This is achieved by controlling the *active power* produced from *generators*.

3.3.1 Ideal performance standard

To meet the ideal standard a *generating system* must have an *active power control system* capable of:

- for a scheduled *generating unit* or a scheduled *generating system*:
  - (i) maintaining and changing its *active power* output in accordance with its *dispatch* instructions;
  - (ii) ramping its *active power* output linearly from one level of *dispatch* to another;
  - (iii) receiving and automatically responding to signals delivered from the automatic *generation control system*, as updated at a rate of once every four seconds (or such other period specified by *AEMO*) and
  - (iv) in a thermally stable state, of changing *active power generation* in response to a *dispatch* instruction at a rate not less than 5% of the *generating unit's or generating system's nameplate rating* per minute.
- subject to energy source availability, for a non-scheduled *generating unit* or non-scheduled *generating system*:
  - (i) automatically reducing or increasing its *active power* output within 5 minutes, at a constant rate, to or below the level specified in an instruction electronically issued by a control centre, subject to subparagraph (iii);
  - (ii) automatically limiting its *active power* output, to below the level specified in subparagraph (i);
  - (iii) not changing its *active power* output within five minutes by more than the raise and lower amounts specified in an instruction electronically issued by a control centre; and

(iv) must not change its *active power generation* at a rate greater than 10 MW per minute or 15% of the power station's aggregate *nameplate rating* per minute, whichever is the lower or as agreed with Western Power and *AEMO*.

- Each *control system* used to satisfy the ideal *active power* standard must be *adequately damped*.

3.3.2 Minimum performance standard

To meet the minimum performance standard, a *generating system* must have an *active power control system* capable of:

- for a scheduled *generating unit* or a scheduled *generating system*:

  (i) maintaining and changing its *active power* output in accordance with its *dispatch* instructions; and

  (ii) receiving and automatically responding to signals delivered from the automatic *generation control system,* as updated at a rate of once every four seconds (or such other period specified by *AEMO*).

- for a non-scheduled *generating system*:

  (i) reducing its *active power* output, within five minutes, to or below the level required to manage *network* flows that is specified in a verbal instruction issued by the control centre;

  (ii) limiting its *active power* output, to or below the level specified in subparagraph (i); and

  (iii) subject to energy source availability, ensuring that the change of *active power* output in a five minute period does not exceed a value agreed with *AEMO* and Western Power;

- Each *control system* used to satisfy the minimum *active power* standard must be *adequately damped*.

3.3.3 Basis for negotiation

The negotiated access standard must document to *AEMO's* satisfaction any operational arrangements necessary to manage *network* flows that may include a requirement for the *generating system* to be operated in a manner that prevents its output changing within 5 minutes by more than an amount specified by a control centre.

3.3.4 Comparison with the current Technical Rules

The proposed approach retains the ramp rate provisions, specified in clause 3.3.3.5 of the Technical Rules while better defining performance requirements that support a move towards security constrained *dispatch* and implementing the *generation dispatch* constraints required by the *generator* interim access system.

3.4 System Strength

As the number of inverter connected *generators* increases, it is likely that the system strength measured, as the short circuit ratio (SCR), being the ratio of short circuit current to rated *load* current, will decline across the *SWIS*. The relative *distribution* of *synchronous generating units* and inverter connected *generation* across the *SWIS* is likely to result in the system strength varying between *connection points*.

At very low levels of system strength, interactions between an inverter connected *generator* and the rest of the *power system* can make it difficult to maintain *voltage* stability and maintain stable operation of those *generators*.

While no specific *generator* performance standard addressing system strength is proposed, it is recommended that *generators* seeking connection to the *SWIS* provide, as part of the technical details, in their connection application, a statement of the lowest short circuit ratio that will allow stable operation of their equipment. This requirement could be achieved by amending schedule 3 of the Technical Rules, which specifies the technical details required in support of connection applications. Specifically, the following additional data shown in Table 3 should be provided.

Table 3 : Data to confirm lowest stable short circuit ratio

Data Description	Units	Data Category
Short Circuit Ratio The lowest short circuit ratio at the *connection point* for which the *generating system*, including its *control systems*: (i) will be commissioned to maintain stable operation; and (ii) has the design capability to maintain stable operation. For the purposes of the above, "short circuit ratio" is the synchronous three phase fault level (expressed in MVA) at the *connection point* divided by the rated output of the *generating system* (expressed in MW or MVA) at Western Power's discretion.	Numeric ratio	S, D, R

In addition, all *generators* should undertake a preliminary assessment of system strength[5] at their proposed *connection point* and if that assessment, performed using the Minimum Short Circuit Ratio (MSCR) method described in the *AEMO* guideline, indicates there is insufficient Available Fault Level (AFL) to accommodate the new *generator* connection then this would trigger the need for a detailed assessment using a functioning PSCAD or equivalent Electromagnetic Transient (EMT) model of the *generator*. This model will need to be provided to Western Power and used to demonstrate that the *generator* will operate stably when connected.

3.4.1 Comparison with the current Technical Rules

The Technical Rules are silent on the requirement to operate stably for expected levels of system strength. The proposed revision discussed in section 1.3 of this document addresses that limitation.

3.5 Inertia and *Frequency* Control

Maintaining adequate control of *frequency* is necessary to ensure *power system security*. Having sufficient *generation* capacity that can automatically adjust its output to correct changes in *frequency* helps ensure sufficient *frequency* response is available. Adequate *frequency* control is very important for an islanded *power system* such as the *SWIS,* as there is no ability to draw on support from neighbouring *power systems*.

3.5.1 Ideal performance standard

To meet the ideal performance level a *generating system* must:

[5] *AEMO* has published a system strength assessment guideline that describes the assessment method https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/System-Strength-Impact-Assessment-Guidelines

- have inertia or an equivalent fast *frequency* response capability, sufficient to not cause:
  - (i) any reduction of rotor angle stability, *frequency* stability or *voltage* stability related *power transfer* capability relative to the level that would apply if the *generating system* was not connected, and
  - (ii) an increased need for *load shedding* to manage rate of change of *frequency* (RoCoF) following the trip of a *generating unit*.
- have an automatic variable *load* control characteristic. *Generating units* with turbine *control systems* must include facilities for both speed and *load* control.
- have *generating units* capable of operation in a mode in which they will automatically and accurately alter *active power* output to allow for *changes* in the relevant *dispatch* level and for changes in *frequency* of the *transmission and distribution system* and in a manner to sustain its initial response. All *generating units* must operate in this mode unless instructed otherwise by *AEMO* or Western Power.
- have a dead band on each *generating system* (the sum of increase and decrease in *power system frequency* before a measurable change in the *generating unit*'s *active power* output occurs) which is less than 0.05 Hz. When defining the dead band, it needs to be symmetrical around 50 Hz.
- Provide control ranges and response times for *generating units* such that:
  - (A) the overall response of each *generating unit* for *power system frequency* excursions must be settable and be capable of achieving an increase in the *generating unit's active power* output of not less than 5% for a 0.1 Hz reduction in *power system frequency* (4% droop) for any initial output up to 85% of registered maximum active power output.
  - (B) each *generating unit* must also be capable of achieving a reduction in the *generating unit's active power* output of not less than 5% for a 0.1 Hz increase in system *frequency* provided this does not require operation below the *technical minimum*.
  - (C) for initial outputs above 85% of rated *active power* output, each *generating unit's* response capability must be included in the relevant performance standard.
  - (D) *thermal generating units* must be able to sustain *load* changes of at least 10% for a *frequency* decrease and 30% for a *frequency* increase if changes occur within the above limits of output.
  - (E) scheduled *generating units* achieve a rate of response for any *frequency* disturbance, of at least 90% of the maximum response expected according to the droop characteristic within 6 seconds for *thermal generating units* and the new output must be sustained for not less than a further 10 seconds.
  - (F) non-scheduled *generating units* achieve a rate of response for any *frequency* disturbance, of at least 90% of the maximum response expected within 2 seconds and the new output must be sustained for not less than a further 10 seconds.

All *control systems* relied on to satisfy this performance standard must be *adequately damped*.

3.5.2 Minimum performance standard

To meet the minimum performance level a *generating system* must achieve the performance requirements for the ideal standard except that for non-scheduled *generation* performance is subject to energy source availability.

3.5.3 Basis for negotiation

The negotiated performance standard should recognise that there is no requirement for a *generating system* to operate below its *technical minimum* in response to a rise in the *frequency* of the *power system* as measured at the *connection point*, or above its rated *active power* output in response to a fall in the *frequency* of the *power system* as measured at the *connection point*.

3.5.4 Comparison with the current Technical Rules

The ideal standard reflects the current requirements in the Technical Rules for scheduled *generation* and applies that level of performance for all *generating units*. The minimum standard recognises that performance requirements for non-scheduled *generating systems* are subject to energy source availability.

3.6 Disturbance ride-through (*continuous uninterrupted operation*)

The ability of *generating systems* to ride through *power system* disturbances is crucial for maintaining *power system security*. *Contingency* events such as faults on the *network* and unexpected trips of *loads* and *generators,* all disturb the *power system* resulting in temporary deviations in *voltages* and *frequency* from normal operating levels. If *generating units* fail to ride through such events, they can create further disturbances increasing *voltage* and *frequency* deviations and the impact of the original *contingency* and in the worst case, lead to a cascading failure of the *power system*.

A set of GPS are proposed that collectively specify the requirement for *generators* to ride through *power systems* disturbances and maintain *continuous uninterrupted operation*. A separate performance standard specifies the requirement to ride through:

- *frequency* disturbances
- *voltage* disturbances
- multiple *contingencies*
- partial *load* rejection
- quality of *supply* issues

3.7 Disturbance ride-through (*frequency*)

3.7.1 Ideal performance standard

To meet the ideal performance standard, a *generating system* must maintain *continuous uninterrupted operation* for *frequencies* within the range identified in Figure 6 and for a RoCoF within the range shown in Figure 7.

A *generator* must maintain *continuous uninterrupted operation* provided, following an over *frequency contingency* event:

- *Frequency* does not exceed 52.5 Hz;
- *Frequency* returns below 52 Hz within 6 seconds;
- *Frequency* returns below 51 Hz within 2 minutes; and
- *Frequency* returns below 50.2 Hz within 15 minutes

A *generator* must maintain *continuous uninterrupted operation* provided, following an under *frequency contingency* event:

- *Frequency* is does not fall below 47 Hz;
- *Frequency* returns above 48.75 Hz within 2 minutes; and
- *Frequency* returns above 49.8 Hz within 15 minutes

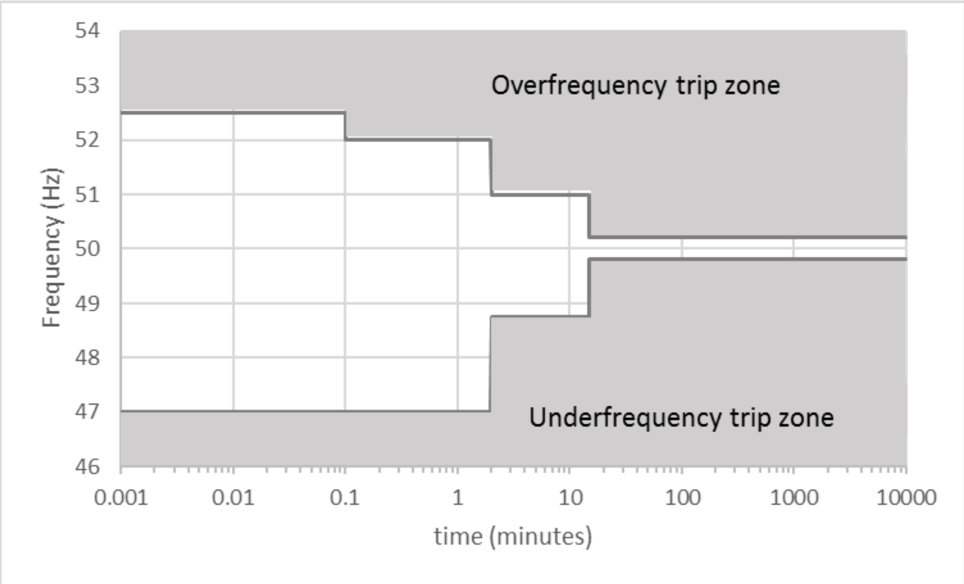

Figure 6 : *Frequency* variations that a *generating system* must ride through to meet the ideal standard

A *generator* must maintain *continuous uninterrupted operation* provided following an over or under *frequency contingency* event:

- The absolute value of the RoCoF does not exceed 4 Hz/s for the first 250 ms, and
- The absolute value of the RoCoF does not exceed 3 Hz/s for the first second.

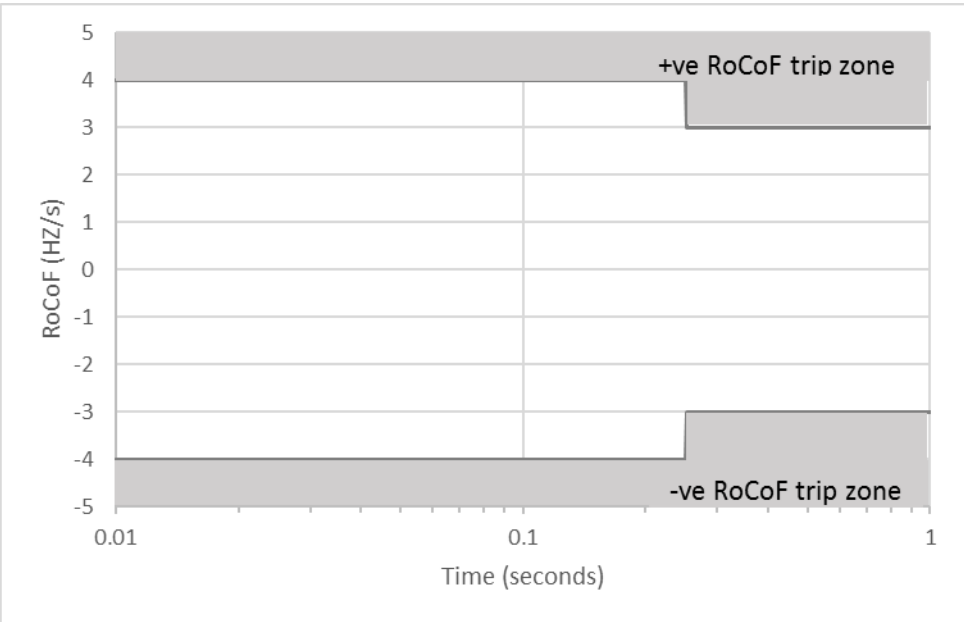

Figure 7 : RoCoF that a *generating system* must ride through to meet the ideal standard

3.7.2 Minimum performance standard

To meet the minimum performance standard, a *generating system* must maintain *continuous uninterrupted operation* for *frequencies* within the range identified in Figure 8 and for a RoCoF within the range shown in Figure 9.

A *generator* must maintain *continuous uninterrupted operation* provided, following an over *frequency contingency* event:

- *Frequency* does not exceed 52 Hz;
- *Frequency* returns below 51 Hz within 10 seconds; and
- *Frequency* returns below 50.2 Hz within 15 minutes

A *generator* must maintain *continuous uninterrupted operation* provided, following an under *frequency contingency* event:

- *Frequency* does not fall below 47 Hz;
- *Frequency* returns above 47.5 Hz within 10 seconds;
- *Frequency* returns above 48.75 Hz within 2 minutes; and
- *Frequency* returns above 49.8 Hz within 15 minutes

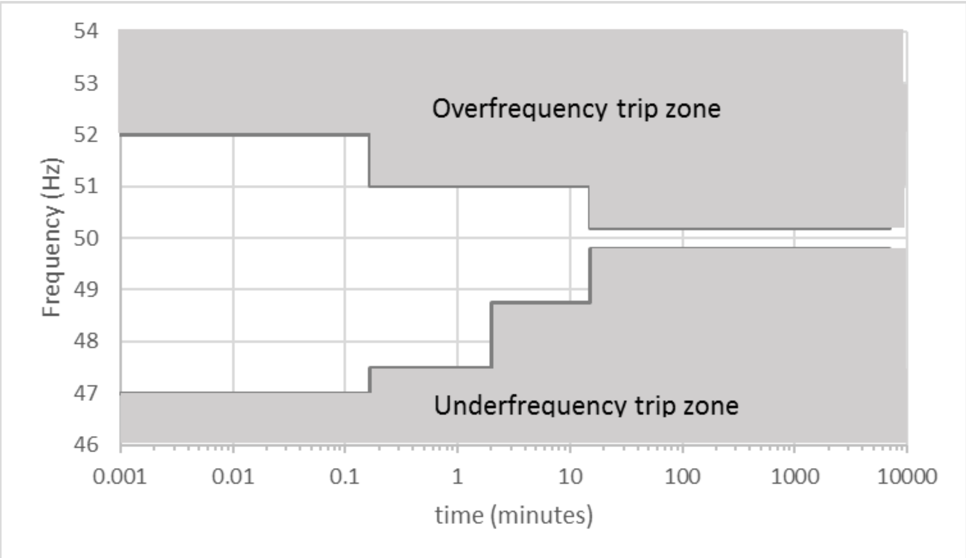

Figure 8 : *Frequency* variations that a *generating system* must ride through to meet the minimum standard

A *generator* must maintain *continuous uninterrupted operation* provided, following an over or under *frequency contingency* event:

- The absolute value of the RoCoF does not exceed 2 Hz/s for the first 250 ms, and
- The absolute value of the RoCoF does not exceed 1 Hz/s for the first second.

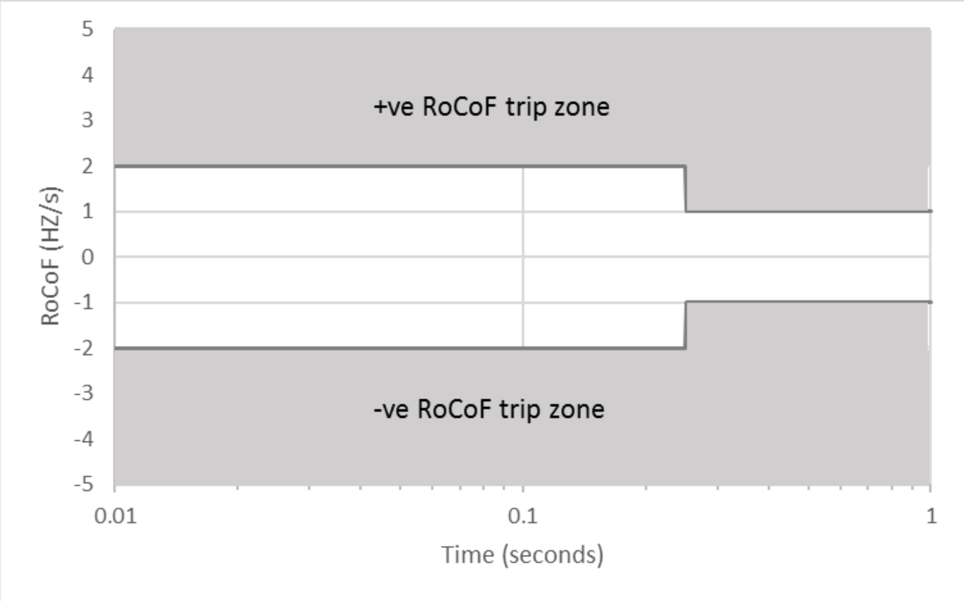

Figure 9 : RoCoF that a *generating system* must ride through to meet the minimum standard

3.7.3 Basis for negotiation

A negotiated performance standard could be accepted provided Western Power and *AEMO* agree that the *frequency* would be unlikely to fall below the lower bound of the single *contingency* event band, specified in table 2.1 in the Technical Rules, as a result of over *frequency* tripping of *generating units* with a negotiated performance standard.

3.7.4 Comparison with the current Technical Rules

The over and under *frequency* ride through in the ideal standard reflects the approach adopted in the *NER* with the *frequency* threshold aligned to the *frequency* operating standards for the *SWIS* as specified in table 2.1 of the Technical Rules.

The withstand times for over and under-*frequency* events specified in the minimum standard reflect those specified in clause 3.3.3.3(b) of the Technical Rules.

The RoCoF requirements reflect those in the *NER* which have been developed by the *AEMC* considering international practice. The RoCoF requirements are more relaxed than those specified in clause 3.3.3.3(d) of the Technical Rules, but better reflect expected capabilities of *thermal generating units* as identified through the *AEMC* review.

3.8 Disturbance ride through (*voltage*)

3.8.1 Ideal performance standard

To meet the ideal performance standard, a *generating system* must maintain *continuous uninterrupted operation* where a *power system* disturbance causes *voltage* at the *connection point* to vary within the range identified in Figure 10**.** The *voltage* ride through requirement is defined by durations expressed with reference to two points in time T(ov) and T(uv). The *voltage* ride through requirements are also set with reference to the normal *voltage* at the connection, which is the operating *voltage* level agreed between Western Power and *AEMO*.

T(ov) means a point in time when the *voltage* at the *connection point* first varied above 110% of normal *voltage* before returning to between 90% and 110% of normal *voltage*, and T(uv) means a point in time when the *voltage* at the *connection point* first varied below 90% of normal *voltage* before returning to between 90% and 110% of normal *voltage*.

A *generator* must maintain *continuous uninterrupted operation* provided, following an over *voltage* event:

- *Voltage* does not exceed 130% of normal *voltage* for more than 0.02 s after T(ov);
- *Voltage* returns below 125% of normal *voltage* within 0.2 s after T(ov)
- *Voltage* returns below 120% of normal *voltage* within 2.0 s after T(ov)
- *Voltage* returns below 115% of normal *voltage* within 20.0 s after T(ov)
- *Voltage* returns below 110% of normal *voltage* within 20.0 minutes after T(ov)

A *generator* must maintain *continuous uninterrupted operation* provided, following an under *voltage* event:

- *Voltage* remains at 0% of normal *voltage* for no more than 450 ms after T(uv)
- *Voltage* returns above 70% of normal *voltage* within 450 ms after T(uv);
- *Voltage* returns above 80% of normal *voltage* within 2.0 s after T(uv)
- *Voltage* returns above 90% of normal *voltage* within 10.0 s after T(uv)

The *generating unit* is required to remain in *continuous uninterrupted operation* while the *voltage* remains within 90% to 110% of normal *voltage*.

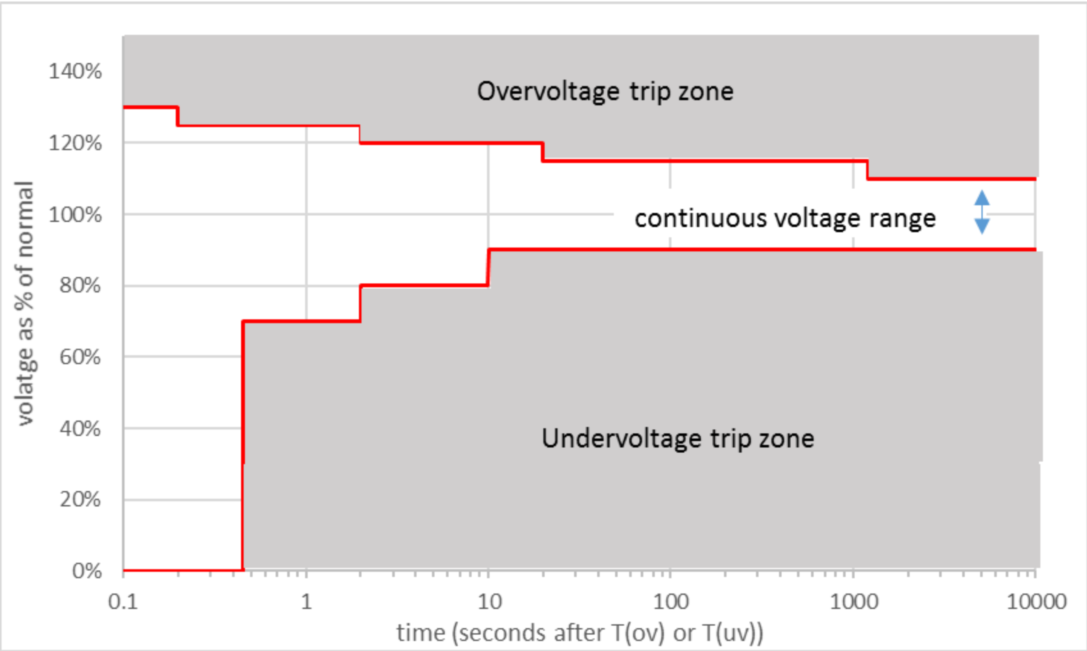

Figure 10 : *Voltage* variations that a *generating system* must ride through to meet the ideal standard

3.8.2 Minimum performance standard

To meet the minimum performance standard a *generating system* must maintain *continuous uninterrupted operation* for *voltages* within the range identified in Figure 11. The *voltage* ride through requirement is defined by durations expressed with reference to two points in time T(ov) and T(uv).

T(ov) means a point in time when the *voltage* at the *connection point* first varied above 110% of normal *voltage* before returning to between 90% and 110% of normal *voltage*, and T(uv) means a point in time when the *voltage* at the *connection point* first varied below 90% of normal *voltage* before returning to between 90% and 110% of normal *voltage*.

A *generator* must maintain *continuous uninterrupted operation* provided, following an over *voltage* event:

- *Voltage* does not exceed 120% of normal *voltage* after T(ov);
- *Voltage* returns below 115% of normal *voltage* within 0.1 s after T(ov)
- *Voltage* returns below 110% of normal *voltage* within 0.9 s after T(ov)

A *generator* must maintain *continuous uninterrupted operation* provided, following an under *voltage* event:

- *Voltage* remains at 0% of normal *voltage* for no more than 450 ms after T(uv)
- *Voltage* returns above 70% of normal *voltage* within 450 ms after T(uv);
- *Voltage* returns above 80% of normal *voltage* within 2.0 s after T(uv)
- *Voltage* returns above 90% of normal *voltage* within 5.0 s after T(uv)

The *generating system* is required to remain in *continuous uninterrupted operation* while the *voltage* remains within 90% to 110% of normal *voltage,* provided the ratio of *voltage* to *frequency* (as measured at the *connection point* and expressed as a percentage of normal *voltage* and a percentage of 50 Hz) does not exceed:

- a value of 1.15 for more than two minutes; or
- a value of 1.10 for more than 10 minutes.

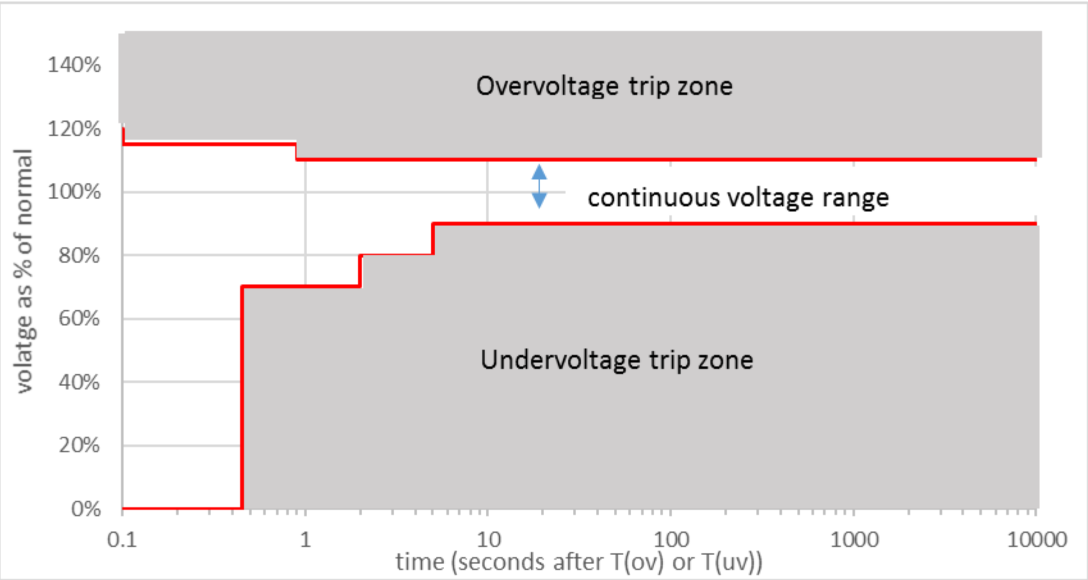

Figure 11 : *Voltage* variations that a *generating system* must ride through to meet the minimum standard

The duration of the zero *voltage* level may be relaxed through agreement between Western Power and the generator from that shown in Figure 11 to align with the timing achieved by breaker fail protection in the relevant region of the *power system*.

3.8.3 Basis for negotiation

The negotiated performance standard should reflect that a *generating system* and each of its operating *generating units* must be capable of *continuous uninterrupted operation* for the range of *voltages* specified in the ideal performance standard, except where *AEMO* and Western Power agree that:

- the total reduction of *generation* in the *power system* as a result of any *voltage* excursion within levels specified by the ideal performance standard, would not exceed 30 MW[6].

The performance standard must include any operational arrangements necessary to ensure the *generating system* and each of its *generating units* will meet its agreed performance levels.

3.8.4 Comparison with the current Technical Rules

The proposed performance standards expand on the requirements in the Technical Rules, which focus more on the requirement to ride through low *voltages* immediately following faults. Collectively the performance standard for *voltage* ride through and that proposed for riding through multiple *contingency* events provide a more detailed specification of required performance than is contained in the Technical Rules.

3.9 Disturbance ride through (multiple contingencies)

The importance of defining the ability of *generating systems* to ride through multiple *contingency* events was highlighted through the analysis of the 2016 South Australia blackout, performed by *AEMO*. Analysis of that event identified that repeated *contingencies* in close succession had triggered protection operations on a number of wind farms resulting in significantly reduced *generation* from wind turbine *generators*.

This mode of protection operation had not been identified prior to the South Australia blackout and there was nothing in the GPS at the time that provided guidance regarding an acceptable level of performance in relation to riding through multiple *contingency* events.

The specification of multiple *contingency* ride performance is also not well defined in the Technical Rules.

General requirement

This set of performance standards uses the term 'fault' to include a fault of the relevant type having a metallic conducting path. The following general requirements must be met to satisfy any negotiated performance standard.

All *generating systems*

The performance standard must include any operational arrangements to ensure the *generating system,* including all operating *generating units* will meet their agreed performance levels under abnormal *network* or *generating system* conditions.

When assessing multiple disturbances, a fault that is re-established following operation of automatic reclose equipment shall be counted as a separate disturbance.

[6] The threshold value of 30 MW is 30% of the 100 MW threshold specified in the NER, the lower threshold reflects the relative sizes of the *SWIS* and the *NEM*

Synchronous *generating systems* and units

For a *generating system* comprised solely of *synchronous generating units*, the reactive current contribution, as measured at the *connection point* may be limited to 250% of the *maximum continuous current* of the *generating system*. For a *synchronous generating unit* in any other *generating system*, the reactive current contribution may be limited to 250% of the *maximum continuous current* of that *synchronous generating unit*.

Asynchronous *generating systems*

For a *generating system* comprised of *asynchronous generating units*:

- the reactive current contribution may be limited to the *maximum continuous current* of a *generating system*, including its operating *asynchronous generating units*;
- the reactive current contribution and *voltage* deviation described may be measured at a location other than the *connection point* (including within the relevant *generating system*), where agreed with *AEMO* and Western Power, in which case the level of injection and absorption will be assessed at that agreed location;
- the reactive current contribution required may be calculated using phase to phase, phase to ground or sequence components of *voltages*. The ratio of the negative sequence to positive sequence components of the reactive current contribution must be agreed with *AEMO* and Western Power for the types of disturbances specified in this performance standard; and
- the performance standard must record all conditions (which may include temperature) considered relevant by both *AEMO* and Western Power under which the reactive current response is required.

3.9.1 Ideal performance standard

The ideal performance standard is specified by requirements expressed as:

- requirements to be met by all *generating systems*
- additional requirements to be met by *generating systems* that:
  - (i) include *synchronous generating units*; or
  - (ii) include *asynchronous generating units*.

Common requirements for all *generating systems*

A *generating system* and each of its *generating units* must remain in *continuous uninterrupted operation* for any disturbance caused by:

- a credible *contingency* event;
- a three phase fault in a *transmission system* cleared by all relevant primary *protection systems*;
- a two phase to ground, phase to phase or phase to ground fault in a *transmission or distribution system* or a three phase fault in a *distribution system* cleared in:
  - (i) the longest time expected to be taken for a relevant breaker fail *protection system* to clear the fault; or
  - (ii) if a *protection system* referred to in subparagraph (i) is not installed, the greater of 450 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 or as a result of the operation of an inter-trip or runback scheme approved by both Western Power and *AEMO*.

A *generating system* and each of its *generating units* must remain in *continuous uninterrupted operation* for a series of up to 15 disturbances within any five minute period caused by any combination of the events described in the previous paragraph where:

- up to six of the disturbances cause the *voltage* at the *connection point* to drop below 50% of normal *voltage*;
- in parts of the *network* where three-phase automatic reclosure is permitted, up to two of the disturbances are three-phase faults, and otherwise, up to one three-phase fault where *voltage* at the *connection point* drops below 50% of normal *voltage*;
- up to one disturbance is cleared by a breaker fail *protection system* or similar back-up *protection system;*
- up to one disturbance causes the *voltage* at the *connection point* to vary within the ranges measured from the T(uv) point, as specified in the ideal performance standard for *voltage* ride through;
- the minimum clearance from the end of one disturbance and commencement of the next disturbance may be zero milliseconds; and
- all remaining disturbances are caused by faults, other than three-phase faults,

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;
- the cumulative time that *voltage* at the *connection point* is lower than 90% of normal *voltage* exceeding 1,800 milliseconds within any five minute period; or
- the time integral, within any five minute period, of the difference between 90% of normal *voltage* and the *voltage* at the *connection point* when the *voltage* at the *connection point* is lower than 90% of normal *voltage* exceeding 1 pu second.

To achieve the ideal performance standard, one of these disturbances should result in the *voltage* profile in Figure 12, which illustrates the low *voltage* ride-through requirement during an auto reclose operation.

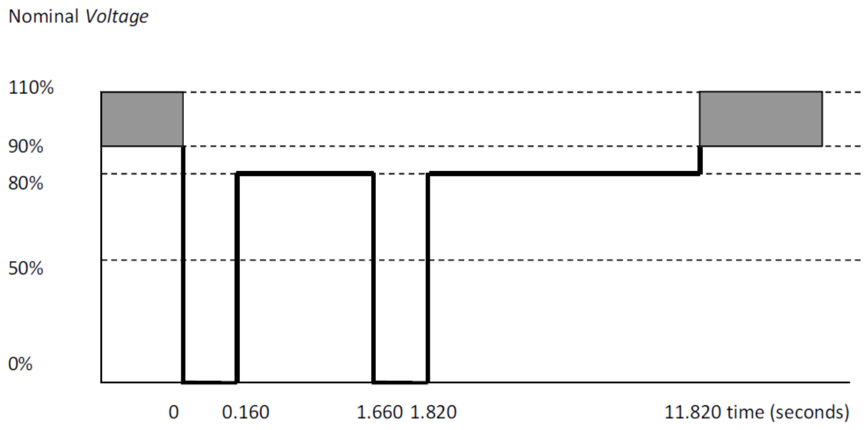

Figure 12 : *Connection point voltage* during auto reclose operation

Additional requirements for *synchronous generating units*

Subject to any changed *power system* conditions or energy source availability beyond a *generator's* reasonable control, a *generating system* comprised of *synchronous generating units*, in respect of the following faults:

- a three-phase fault in a *transmission system* cleared by all relevant primary *protection systems*, or
- a two-phase to ground, phase to phase or phase to ground fault in a *transmission or distribution system* or a three-phase fault in a *distribution system* cleared in:
  - (i) the longest time expected to be taken for a relevant breaker fail *protection system* to clear the fault; or
  - (ii) if a *protection system* referred to in subparagraph (i) is not installed, the greater of 450 milliseconds and the longest time expected to be taken for all relevant primary *protection systems* to clear the fault.

must *supply* to or absorb from the *network*:

- to assist the maintenance of *power system voltages* during the fault, capacitive reactive current of at least the greater of its pre-disturbance reactive current and 4% of the *maximum continuous current* of the *generating system* including all operating *synchronous generating units* (in the absence of a disturbance) for each 1% reduction (from the level existing just prior to the fault) of *connection point voltage* during the fault;
- after clearance of the fault, *reactive power* sufficient to ensure that the *connection point voltage* is within the range for *continuous uninterrupted operation*; and
- from 100 milliseconds after clearance of the fault, *active power* of at least 95% of the level existing just prior to the fault.

Additional requirements for a*synchronous generating units*

Subject to any changed *power system* conditions or energy source availability beyond the *Generator's* reasonable control, a *generating system* comprised of *asynchronous generating units*, for the following faults:

- a three-phase fault in a *transmission system* cleared by all relevant primary *protection systems*, or
- a two-phase to ground, phase to phase or phase to ground fault in a *transmission or distribution system* or a three-phase fault in a *distribution system* cleared in:
  - (i) the longest time expected to be taken for a relevant breaker fail *protection system* to clear the fault; or
  - (ii) if a *protection system* referred to in subparagraph (i) is not installed, the greater 450 milliseconds and the longest time expected to be taken for all relevant primary *protection systems* to clear the fault,

must have facilities capable of *supply*ing to or absorbing from the *network*:

- to assist the maintenance of *power system voltages* during the fault:
  - (i) capacitive reactive current in addition to its pre-disturbance level of at least 4% of the *maximum continuous current* of the *generating system,* including all operating *asynchronous generating units* (in the absence of a disturbance) for each 1% reduction of *voltage* at the *connection point* below the under-*voltage* range of 85% to 90% of normal *voltage, except* where a *generating system* is directly connected to the *power system* with no step-up or connection *transformer* and *voltage* at the *connection point* is 5%, or lower, of normal *voltage*; and
  - (ii) inductive reactive current in addition to its pre-disturbance level of at least 6% of the *maximum continuous current* of the *generating system,* including all operating *asynchronous generating units* (in the absence of a disturbance) for each 1% increase of *voltage* at the *connection point* above the over-*voltage* range of 110% to 115% of normal *voltage,*

during the disturbance and maintained until *connection point voltage* recovers to between 90% and 110% of normal *voltage*, or such other range agreed with Western Power and *AEMO*.

; and

- from 100 milliseconds after clearance of the fault, *active power* of at least 95% of the level existing just prior to the fault.

The under-*voltage* and over-*voltage* range referenced in paragraph (i) and (ii), immediately above, may be varied with the agreement of Western Power and *AEMO* (provided the magnitude of the range between the upper and lower bounds remains at 5%).

The reactive current response referenced in paragraph (i) and (ii), immediately above, must have a *rise time* of no greater than 40 milliseconds and a *settling time* of no greater than 70 milliseconds and must be *adequately damped*

Despite the amount of reactive current injected or absorbed during *voltage* disturbances, and subject to thermal limitations and energy source availability, a *generating system* must make available at all times:

- sufficient current to maintain rated *apparent power* of the *generating system,* including all operating *generating units* (in the absence of a disturbance), for all *connection point voltages* above 115% (or otherwise, above the agreed over-*voltage* range); and
- the *maximum continuous current* of the *generating system,* including all operating *generating units* (in the absence of a disturbance) for all *connection point voltages* below 85% (or otherwise, below the agreed under-*voltage* range),

except that *AEMO* and Western Power may agree limits on active current injection where required to maintain *power system security* and/or the quality of *supply* to other *Network Users*.

3.9.2 Minimum performance standard

The ideal performance standard is specified by requirements expressed as:

- requirements to be met by all *generating systems*
- additional requirements to be met by *generating systems* that:
  - (i) include *synchronous generating units*; or
  - (ii) include *asynchronous generating units*.

Common requirements for all *generating systems*

A *generating system* and each of its *generating units* must remain in *continuous uninterrupted operation* for any disturbance caused by an event that is:

- a credible *contingency* event; or
- a single phase to ground, phase to phase or two phase to ground fault or three-phase fault in a *transmission system* or *distribution network* cleared in the longest time expected to be taken for all relevant primary *protection systems* to clear the fault, unless *AEMO* and Western Power agree that the total reduction of *generation* in the *power system* due to that fault would not exceed 30 MW,

provided that the event is not one that would disconnect the *generating unit* from the *power system* by removing *network* elements from service.

A *generating system* and each of its *generating units* must remain in *continuous uninterrupted operation* for a series of up to six disturbances within any five-minute period caused by any combination of the events described in the previous paragraph where:

- up to three of the disturbances causes the *voltage* at the *connection point* to drop below 50% of normal *voltage*;
- up to one disturbance causes the *voltage* at the *connection point* to vary within the ranges measured from the T(uv) in the performance standard for *voltage* ride through agreed with *AEMO* and Western Power;
- the time difference between the clearance of one disturbance and commencement of the next disturbance exceeds 200 milliseconds;
- no more than three of the disturbances occur within 30 seconds; and
- all disturbances are caused by faults,

provided that none of the events would result in:

- the islanding of the *generating system* or a material reduction in *power transfer* capability by removing *network* elements from service;
- the cumulative time that *voltage* at the *connection point* is lower than 90% of normal *voltage* exceeding 1,000 milliseconds within any five-minute period; or
- the time integral, within any five-minute period, of the difference between 90% of normal *voltage* and the *voltage* at the *connection point* when the *voltage* at the *connection point* is lower than 90% of normal *voltage* exceeding 0.5 pu second,

and there is a minimum of 30 minutes where no disturbances occur following a five-minute period of multiple disturbances.

Additional requirements for *synchronous generating units*

Subject to any changed *power system* conditions or energy source availability beyond the *generator's* reasonable control after clearance of the fault, a *generating system* comprised of *synchronous generating units*, in respect of the types of fault described in the previous sub section must:

- deliver *active power* to the *network*, and *supply* or absorb leading or lagging *reactive power*, sufficient to ensure that the *connection point voltage* is within the range for *continuous uninterrupted operation* agreed under relevant performance standard; and
- return to at least 95% of the pre-fault *active power* output, after clearance of the fault, within a period of time agreed by the *generator*, *AEMO* and Western Power.

Additional requirements for a*synchronous generating units*

Subject to any changed *power system* conditions or energy source availability beyond the *generator's* reasonable control, a *generating system* comprised of *asynchronous generating units*, for the following types of faults:

- a single phase to ground, phase to phase or two phase to ground fault or three-phase fault in a *transmission system* or *distribution network* cleared in the longest time expected to be taken for all relevant primary *protection system*s to clear the fault, unless *AEMO* and Western Power agree that the total reduction of *generation* in the *power system* due to that fault would not exceed 30 MW

must have facilities capable of *supply*ing to or absorbing from the *network*,

- to assist the maintenance of *power system voltages* during the fault:
  - (i) capacitive reactive current in addition to its pre-disturbance level of at least 2% of the *maximum continuous current* of the *generating system* including all operating *asynchronous generating units* (in the absence of a disturbance) for each 1% reduction of *voltage* at the *connection point* below the under-*voltage* range of 80% to 90% of normal *voltage,* except where:
    - *voltage* at the *connection point* is 15% or lower of normal *voltage*; or
    - *where the generating system* is directly connected to the *power system with no step-up or connection transformer and voltage at the connection point is 20% or lower of normal voltage;*
  - (ii) inductive reactive current in addition to its pre-disturbance level of at least 2% of *the maximum continuous current* of the *generating system* including all operating *asynchronous generating units* (in the absence of a disturbance) for each 1% increase of *voltage* at the *connection point* above the over-*voltage* range of 110% to 120% of the normal *voltage* range;

  during the disturbance and maintained until the *connection point voltage* recovers to between 90% and 110% of normal *voltage*, or such other range agreed with Western Power and *AEMO, and*
- return to at least 95% of the pre-fault *active power* output, after clearance of the fault, within a period of time agreed by the connection applicant, *AEMO* and Western Power.

The under-*voltage* and over-*voltage* range referenced in paragraph (i) and (ii) may be varied with the agreement of Western Power and *AEMO* (provided the magnitude of the range between the upper and lower bounds remains at 10%).

Where *AEMO* and Western Power require the *generating system* to sustain a response duration of two seconds or less, the reactive current response referenced in paragraphs (i) and (ii), immediately above, must have a *rise time* of no greater than 40 milliseconds and a *settling time* of no greater than 70 milliseconds and must be *adequately damped*; and where *AEMO* and Western Power require the *generating system* to sustain a response duration of greater than two seconds, the reactive current *rise time* and *settling time* must be as soon as practicable and must be *adequately damped.*

3.9.3 Basis for negotiation

A proposed negotiated performance standard may be accepted if the connection of the *plant* at the proposed performance level would not cause other generating *plant* or *loads* to trip as a result of an event, when they would otherwise not have tripped for the same event.

3.9.4 Comparison with the current Technical Rules

The Technical Rules do not specify a requirement to ride through multiple *contingency* events. The proposed standards reflect those recently introduced into the NER.

3.10 Disturbance ride through (partial *load* rejection)

This performance standard specifies the requirement for a *generator* to ride-through a sudden reduction in the required amount of *active power* it is required to generate (ie a partial *load* rejection). Meeting this requirement enhances system security as *generation* is less likely to trip following a partial *load* reduction.

3.10.1 Ideal performance standard

To meet the ideal standard a *generating unit* must be capable of *continuous uninterrupted operation* as during and following a sudden reduction in required *active power generation* imposed from the *power system*, provided that the reduction is less than 30% of the *generating units nameplate rating* and the required *active power generation* remains above the *generating unit's* registered minimum *active power generation* capability.

3.10.2 Minimum performance standard

To meet the ideal standard a *generating unit* must be capable of *continuous uninterrupted operation* during and following a sudden reduction in required *active power generation* imposed from the *power system*, provided that the reduction is less than 5% of the *generating unit's nameplate rating* and the required *active power generation* remains above the *generating unit's* registered minimum *active power generation* capability.

3.10.3 Basis for negotiation

There are no additional requirements beyond those specified at the start of section 3 that need to be considered in negotiating this performance standard.

3.10.4 Comparison with the current Technical Rules

The ideal standard reflects the requirement currently contained in the Technical Rules, while the minimum standard is based on the minimum requirement specified in the NER.

3.11 Disturbance ride through (quality of *supply*)

This performance standard specifies the requirement to ride-through *voltage* fluctuations, harmonic *voltage* distortion and *voltage* unbalance. For this performance standard, the ideal and minimum standards are identical, which reflects the approach adopted in the NER.

The performance standard requires that a *generating system* 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 in clauses 2.2.3, 2.2.4 and 2.2.5 of the Technical Rules.

3.11.1 Comparison with the current Technical Rules

This performance requirement is not reflected in the Technical Rules. Adopting the proposed standards aligns with the *NER* and addresses this gap in the Technical Rules.

3.12 *Generator protection systems*

To maintain system security, it is important that *generators* have sufficient *protection systems* that will reliably and promptly disconnect faulty equipment, disconnect islanded *generators* and disconnect *generators* that are becoming unstable. This performance standard reflects the requirements *generator* protection equipment must satisfy to achieve these objectives.

In the *NER* the *generator* protection equipment requirements are separated into requirements that impact system security and requirements than disconnect *generators* as a result of instability. The two sets of requirements are combined into a consolidated set of *generator* protection requirements in the Technical Rules.

This guideline has adopted an approach consistent with the Technical Rules and defines a single performance standard for *generator* protection.

3.12.1 Ideal performance standard

To meet the ideal standard, a *generating system* must meet the protection requirements as specified in clause 3.3.3.8, 3.5.2 and 2.9 of the Technical Rules which require faults to be cleared within minimum times specified in tables 2.10 and 2.11 or where not defined, a critical fault clearance time developed by Western Power.

This will require installing protection schemes that have the level of redundancy specified in the Technical Rules and operate to clear faults within the prescribed time.

In addition, *transmission* connected *generating systems* must install anti-islanding protection to ensure the *generating unit* is prevented from *supply*ing an isolated portion of the *network*. The details regarding the performance requirements for anti-islanding systems for *transmission* connected *generators* are documented in the fact sheet produced by Western Power [7], while for *distribution* connected *generators,* the requirements are specified in clause 3.6.10.3 of the Technical Rules.

Generators must provide protection necessary to disconnect the *generator* during abnormal conditions, as specified in clause 3.3.3.8 of the Technical Rules, in the *power system* that would threaten the stability of the *generator* or risk damage to the *generator.* The setting of such protections schemes should be chosen to deliver the performance specified by the ideal standards for disturbance ride-through.

3.12.2 Minimum performance standard

In most respects the minimum performance standard is the same as the ideal standard with the exception that:

[7] Western Power Fact Sheet, "Anti –islanding protection requirements

- Fault clearing times may be relaxed to meet the actual clearing times implemented in the relevant portion of the *transmission network* and *distribution network,* where those times are longer than those specified in tables 2.10 and 2.11 of the Technical Rules
- *Generators* must provide protection necessary to disconnect the *generator* during abnormal conditions as specified in clause 3.3.3.8 of the Technical Rules, in the *power system* that would threaten the stability of the *generator* or risk damage to the *generator*. The setting of such protections schemes should be chosen to deliver the performance specified by the minimum standards for disturbance ride-through.

3.12.3 Basis for negotiation

There are no additional requirements beyond those specified at the start of section 3 that need to be considered in negotiating this performance standard.

3.12.4 Comparison with the current Technical Rules

The performance standard reflects the requirements in the Technical Rules.

3.13 Quality of electricity generated

This performance standard specifies the requirement for *generators* to produce a *voltage* waveform that is free of distortion. This is necessary to ensure that the quality of *supply* requirements specified in the Technical Rules can be delivered.

3.13.1 Ideal performance standard

To meet the ideal performance standard a *generating system* when generating and when not generating, must not produce at any of its connection points for *generation*:

- *voltage* fluctuation greater than the limits allocated by Western Power, that are no more onerous than the lesser of the acceptance levels determined in accordance with either of the stage 1 or the stage 2 evaluation procedures defined in AS/NZS 61000.3.7:2001;
- harmonic *voltage* distortion greater than the emission limits specified in AS 1359.101 and IEC 60034-1 or emission limits allocated by Western Power, that are no more onerous than the lesser of the acceptance levels determined in accordance with either of the stage 1 or the stage 2 evaluation procedures defined in AS/NZS 61000.3.6:2001; and
- *voltage* imbalance greater than the limits determined by Western Power, as necessary to achieve the negative phase *voltage* at the *connection point* as specified in clause 2.2.5 of the Technical Rules.

3.13.2 Minimum performance standard

To meet the minimum access standard a *generating system* when generating and when not generating must not produce at any of its *connection points* for *generation*:

- *voltage* fluctuations greater than limits determined by Western Power in consultation with the *generator* using the stage 3 evaluation procedure defined in AS/NZS61000.3.7:2001, with the *generator* agreeing to fund any works necessary to mitigate adverse effects from accepting this emission level;
- harmonic *voltage* distortion greater than the emission limits specified in AS 1359.101 and IEC 60034-1 or emission limits determined by Western Power in consultation with *generator* using the Stage 3

evaluation procedure defined in AS/NZS 61000.3.6:2001 with the *generator* agreeing to fund any works necessary to mitigate adverse effects from accepting this emission level; and

- *voltage* imbalance more than limits determined by Western Power as necessary to achieve the negative phase *voltage* at the *connection point* as specified in clause 2.2.5 of the Technical Rules.

3.13.3 Basis for negotiation

A negotiated performance standard must not prevent Western Power meeting the system performance standards specified in the Technical Rules or contractual obligations to existing *Network Users*.

3.13.4 Comparison with the current Technical Rules

The level of harmonic performance specified for the ideal standard reflects the current requirements in the Technical Rules. The inclusion of requirements for *voltage* unbalance and *voltage* fluctuations fills a gap that exists in the Technical Rules.

3.14 Impact on *network* transfer capability

If the connection of a new *generator* significantly reduces existing *network* transfer capability, this can impact the ability to *supply* existing *customers*. In the *NER,* there is a specific performance standard that describes the level of adverse reduction in transfer capability that may be allowed.

The approach adopted in the Technical Rules is that a new *generator* is not permitted to cause a reduction in *power transfer* capability (see clause 3.3.1(d)). It is recommended that this requirement in the Technical Rules be retained. This will mean that the minimum and ideal standard are the same.

3.15 Model provision

Many aspects of *power system* behaviour require careful study using computer models that collectively simulate the combined performance of the integrated *power system*. *Generators* are required to provide sufficiently accurate models of generating *plant* to facilitate these studies.

In 2016, Western Power published *generator* and *load* model guidelines[8], which specify the requirements for the computer models *generators* must *supply* to enable the study of the dynamic and steady state performance. Since that time, there has been continued growth in the level of inverter connected *generation* and this has created concerns regarding declining system strength in some areas of the *SWIS*.

At low levels of system strength and during *contingency* events, inverter connected *generators* may adversely interact with each other and may exhibit unstable operation. In order to accurately study this issue, *network service provider*s and *AEMO* in the *NEM* now require *generators* to provide an Electromagnetic Transient (EMT) model implemented on an approved software platform such as PSCAD. Details of the EMT modelling requirements in the *NEM* are articulated in the *power system* model guidelines published by *AEMO* in July 2018 [9].

AEMO also has a need to be able to model the *power system* and as such has an interest in receiving *generator* models at an appropriate stage in the connection process to review the model and assess whether it is fit-for-purpose.

[8] https://westernpower.com.au/connections/planning-your-project/*transmission*-loads-and-large-generators/
[9] http://www.*aemo*.com.au/Electricity/National-Electricity-Market-NEM/Network-connections/Modelling-requirements

3.15.1 Ideal performance standard

To meet the ideal performance standard, a *generator* must provide a computer simulation model that meets the requirement specified in the Western Power guidelines and an EMT model meeting the requirement specified in the *AEMO* guideline.

3.15.2 Minimum performance standard

To meet the minimum performance standard, a *generator* must provide a computer simulation model that meets the requirement specified in the Western Power guidelines and where Western Power advises that a detailed assessment of system strength is required, an EMT model meeting the requirement specified in the *AEMO* guideline.

3.15.3 Basis for negotiation

A negotiated performance standard must not prevent Western Power meeting the system performance standards specified in the Technical Rules or contractual obligations to existing *Network Users*.

3.15.4 Comparison with the current Technical Rules

The modelling requirement builds on that in the Technical Rules leveraging the recently revised *NEM* system model guideline to specify the requirement for EMT models.

4. Definitions

Most of the definitions in the table below have been extracted from the Technical Rules or the *NER*. These terms appear in *italics* throughout the guideline.

Word	Definition
Active energy	A measure of electrical energy flow, being the time integral of the product of *voltage* and the in-phase component of current flow across a *connection point*, expressed in watthours (Wh).
Active power	The rate at which *active energy* is transferred.
Adequately damped	In relation to a *control system*, when tested with a step change of a feedback input or corresponding reference, or otherwise observed, any oscillatory response at a *frequency* of: (a) 0.05 Hz or less, has a damping ratio of at least 0.4; (b) between 0.05 Hz and 0.6 Hz, has a halving time of 5 seconds or less (equivalent to a damping coefficient –0.14 nepers per second or less); and (c) 0.6 Hz or more, has a damping ratio of at least 0.05 in relation to a minimum access standard and a damping ratio of at least 0.1 otherwise. System oscillations originating from system electro-mechanical characteristics, electro-magnetic effect or non-linearity of system components, and triggered by any small disturbance or large disturbance in the *power system*, must remain within the small disturbance rotor angle stability criteria and the *power system* must return to a stable operating state following the disturbance. The small disturbance rotor angle stability criteria are: (a) The damping ratio of electromechanical oscillations must be at least 0.1. (b) For electro-mechanical oscillations as a result of a small disturbance, the damping ratio of the oscillation must be at least 0.5. (c) In addition to the requirements of clauses 2.2.8(a) and 2.2.8(b), the halving time of any electro-mechanical oscillations must not exceed 5 seconds.
AEMC	The Australian Energy Market Commission, which is established under section 5 of the Australian Energy Market Commission Establishment Act 2004 (SA).
AEMO	The Australian Energy Market Operator
AEMO advisory matter	Advice on the acceptability of the negotiated performance standards for all areas of technical performance except the quality of electricity generated, is known as *AEMO advisory matters*

Word	Definition
Apparent power	The square root of the sum of the squares of the *active power* and the *reactive power*.
Asynchronous generating unit	A *generating unit* that is not a *synchronous generating unit*.
Connect, Connected, Connection	To form a physical link to or through a *transmission network* (including to a *network* connection asset or a dedicated connection asset that is physically linked to that *transmission network*) or *distribution network*.
Connection point	A point on the *network* where the *Network Service Provider*'s primary equipment (excluding metering assets) is connected to primary equipment owned by a User.
Contingency	An event affecting the *power system* which Western Power expects would be likely to involve the failure or removal from operational service of a *generating unit* or *transmission/distribution* element.
Continuous uninterrupted operation	In respect of a *generating system* or operating *generating unit* operating immediately prior to a *power system* disturbance: (a) not disconnecting from the *power system* except in accordance with its performance standards, (b) during the disturbance, contributing active and reactive current as required by its performance standards; (c) after clearance of any electrical fault that caused the disturbance, only substantially varying its *active power* and *reactive power,* as required or permitted by its performance standards; and (d) not exacerbating or prolonging the disturbance or causing a subsequent disturbance for other connected *plant*, except as required or permitted by its performance standards. with all essential auxiliary and reactive *plant* remaining in service
Control system	Means of monitoring and controlling the operation of the *power system* or equipment, including *generating units* connected to a *transmission* or *distribution network*.
Customer	A person who: engages in the activity of purchasing electricity supplied through a *transmission* or *distribution system* to a *connection point*
Dispatch	The act of in committing to service all or part of the *generation* available from a *generating unit*.
Distribution	Activities pertaining to a *distribution system* including the conveyance of electricity through that *distribution system*.

Word	Definition
Distribution network	A *network* which is not a *transmission network*.
Distribution system	A *distribution network*, together with the connection assets associated with the *distribution network*, which is connected to another *transmission* or *distribution system*.
Excitation control system	In relation to a *generating unit*, the automatic *control system* that provides the field excitation for the *generator* of the *generating unit* (including excitation limiting devices and any *power system* stabiliser).
Frequency	For alternating current electricity, the number of cycles occurring in each second.
Generating unit	The *plant* used in the production of electricity and all related equipment essential to its functioning as a single entity.
Generating system	A system comprising one or more *generating unit*s and includes auxiliary or reactive *plant* that is located on the *Generator*'s side of the *connection point* and is necessary for the *generating system* to meet its performance standards.
Generator	Any person who owns, controls or operates a *generating system* that supplies electricity to, or who otherwise supplies electricity to, the *transmission system* or *distribution system*.
Generation	The production of electrical power by converting another form of energy in a *generating unit*.
Load	A *connection point* or defined set of *connection points* at which electrical power is delivered to a person or to another *network* or the amount of electrical power delivered at a defined instant at a *connection point* or aggregated over a defined set of *connection points*.
Load shedding	Reducing or disconnecting *load* from the *power system*.
Nameplate rating	The maximum continuous output or consumption in MW of an item of equipment as specified by the manufacturer, or as subsequently modified.
NEM	The National Electricity Market.
NER	The National Electricity Rules

Word	Definition
Network	The apparatus, equipment, *plant* and buildings used to convey, and control the conveyance of, electricity to *customers*. When referring to Western Power, means a *network* owned, operated or controlled by Western Power.
Network Service Provider	In the *SWIS*, Western Power is the *Network Service Provider*. In the *NEM* a *Network Service Provider* is a person who engages in the activity of owning, controlling or operating a *transmission* or *distribution system* and who is registered by *AEMO* as a *Network Service Provider* under Chapter 2 of the NER.
Network User	A *Generator*, a *Transmission network Customer*, or a *Distribution Network Customer*.
Maximum continuous current	Maximum current injected at the *connection point* when the *generating system* is delivering registered maximum *apparent power* and the *connection point voltage* is within the normal range.
Plant	In relation to a *connection point*, includes all equipment involved in generating, utilising or transmitting electrical energy.
Power factor	The ratio of the *active power* to the *apparent power* at a metering point.
Power system	The electric *power system* constituted by the South West interconnected system *Network* and its connected *generation* and *load*s, operated as an integrated system.
Power system security	The safe scheduling, operation and control of the *power system* on a continuous basis in accordance with the principles set out in clause 5 of the Technical Rules and the operating procedures of Western Power and *AEMO*.
Power transfer	The instantaneous rate at which *active energy* is transferred between *connection points*.
Protection system	A system, which includes equipment, used to protect a Registered Participant's facilities from damage due to an electrical or mechanical fault or due to certain conditions of the *power system*.

Word	Definition
Reactive power	The rate at which reactive energy is transferred. *Reactive power* is a necessary component of alternating current electricity that is separate from *active power* and is predominantly consumed in the creation of magnetic fields in motors and *transformer*s and produced by *plant* such as: (a) alternating current *generators*; (b) capacitors, including the capacitive effect of parallel *transmission* wires; and (c) synchronous condensers.
Reliability	The probability of a system, device, *plant* or equipment performing its function adequately for the period of time intended, under the operating conditions encountered.
Rise time	In relation to a *control system*, the time taken for an output quantity to rise from 10% to 90% of the maximum change induced in that quantity by a step change of an input quantity.
Settling time	In relation to a *control system*, the time measured from initiation of a step change in an input quantity to the time when the magnitude of error between the output quantity and its final settling value remains less than 10% of: (a) if the sustained change in the quantity is less than half of the maximum change in that output quantity, the maximum change induced in that output quantity; or (b) the sustained change induced in that output quantity.
South West interconnected system or *SWIS*	The *transmission system* and *distribution system* in south west area of the state of Western Australia, extending from Geraldton to Albany areas and across to the Eastern Goldfields region.
Static excitation system	An *excitation control system* in which the power to the rotor of a *synchronous generating unit* is transmitted through high power solid-state electronic devices.
Supply	The delivery of electricity.
Synchronous generating unit	The alternating current *generating unit*s which operate at the equivalent speed of the *frequency* of the *power system* in its normal operating state.

Word	Definition
Tap-changing transformer	A *transformer* with the capability to allow internal adjustment of output *voltages* which can be automatically or manually initiated, and which is used as a major component in the control of the *voltage* of *transmission network* and *distribution network* in conjunction with the operation of reactive *plant*. The *connection point* of a *generating unit* may have an associated *tap-changing transformer*, usually provided by the *Generator*.
Technical minimum	The minimum continuous *active power* output of a *generating unit*.
Thermal generating unit	A *generating unit* which uses fuel combustion for electricity *generation*
Transformer	A *plant* or device that reduces or increases the *voltage* of alternating current.
Transmission	Activities pertaining to a *transmission system,* including the conveyance of electricity through that *transmission system*.
Transmission network	A *network* operating at nominal *voltages* of 66 kV or higher, and which forms part of the South West interconnected system *Network*. The *transmission network* includes equipment such as static *reactive power* compensators, which is operated at *voltages* below 66 kV, provided that the primary purpose of this equipment is to support the transportation of electricity at *voltages* of 66 kV or higher.
Transmission system	A *transmission network*, together with the connection assets associated with the *transmission network*, which is connected to another *transmission system* or *distribution system*.
Voltage	The electronic force or electric potential between two points that gives rise to the flow of electricity.
WEM	Wholesale Electricity Market: The market established under section 122 of the Electricity Industry Act 2004.