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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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 in Figure 1 below.

![Figure 1: Illustration of performance band](image)

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 voltages 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.
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 supplying 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.

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

Registered data is specified in Attachment 3 of the Technical Rules
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 supplying 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

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.

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

<table>
<thead>
<tr>
<th>Performance Item</th>
<th>Units</th>
<th>Static Excitation</th>
<th>AC Exciter or Rotating Rectifier</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity:</strong> 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.</td>
<td>Gain (ratio)</td>
<td>200 minimum</td>
<td>200 minimum</td>
<td>1</td>
</tr>
<tr>
<td><strong>Field voltage rise time:</strong> 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.</td>
<td>second</td>
<td>0.05 maximum</td>
<td>0.5 maximum</td>
<td>2,4</td>
</tr>
<tr>
<td><strong>Settling time</strong> with the generating unit unsynchronised following a disturbance equivalent to a 5% step change in the sensed generating unit terminal voltage.</td>
<td>second</td>
<td>1.5 maximum</td>
<td>2.5 maximum</td>
<td>3</td>
</tr>
<tr>
<td><strong>Settling time</strong> 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.</td>
<td>second</td>
<td>2.5 maximum</td>
<td>5 maximum</td>
<td>3</td>
</tr>
<tr>
<td><strong>Settling time</strong> 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.</td>
<td>second</td>
<td>5 maximum</td>
<td>5 maximum</td>
<td>3</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Performance Item</th>
<th>Units</th>
<th>Limiting Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity:</strong> A sustained 0.5% error</td>
<td>Gain</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>between the reference voltage and the</td>
<td>(ratio)</td>
<td>minimum</td>
<td></td>
</tr>
<tr>
<td>sensed voltage must produce an output</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>change of not less than 100% of the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reactive power generation capability of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the generating unit, measured at the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>point of control.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rise time:</strong> Time for the controlled</td>
<td>second</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>parameter (voltage or reactive power</td>
<td></td>
<td>maximum</td>
<td></td>
</tr>
<tr>
<td>output) to rise from the initial value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to 90% of the change between the initial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>value and the final value following the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>application of a 5% step change to the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>control system reference.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Small disturbance settling time:</strong></td>
<td>second</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>Settling time of the controlled parameter</td>
<td></td>
<td>maximum</td>
<td></td>
</tr>
<tr>
<td>with the generating unit connected to the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>transmission or distribution network</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>following a step change in the control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>system reference that is not large</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>enough to cause saturation of the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>controlled output parameter. Must be</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>met at all operating points within the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>generating unit’s capability.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Large disturbance settling time</strong></td>
<td>second</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Settling time of the controlled parameter</td>
<td></td>
<td>maximum</td>
<td></td>
</tr>
<tr>
<td>following a large disturbance, including</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a transmission or distribution network</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fault, which would cause the maximum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>value of the controlled output parameter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to be just exceeded and a limiter to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>operate.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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:
  1. maintaining and changing its active power output in accordance with its dispatch instructions; and
  2. 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:
  1. 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;
  2. limiting its active power output, to or below the level specified in subparagraph (i); and
  3. 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

<table>
<thead>
<tr>
<th>Data Description</th>
<th>Units</th>
<th>Data Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Circuit Ratio</td>
<td></td>
<td>S, D, R</td>
</tr>
<tr>
<td>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.</td>
<td>Numeric ratio</td>
<td></td>
</tr>
</tbody>
</table>

In addition, all generators should undertake a preliminary assessment of system strength 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:

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• 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

![Overfrequency and Underfrequency trip zones](image)

**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.

![RoCoF variation](image)

**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](image)

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.
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.

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.

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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.
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 asynchronous 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 supplying 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:
  - include synchronous generating units; or
  - 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 asynchronous 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 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 must have facilities capable of supplying 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 (i.e., 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 supplying 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:

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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, 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 providers 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.

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.

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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.
<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active energy</strong></td>
<td>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 <em>connection point</em>, expressed in <em>watthours</em> (Wh).</td>
</tr>
<tr>
<td><strong>Active power</strong></td>
<td>The rate at which <em>active energy</em> is transferred.</td>
</tr>
<tr>
<td><strong>Adequately damped</strong></td>
<td>In relation to a <em>control system</em>, when tested with a step change of a feedback input or corresponding reference, or otherwise observed, any oscillatory response at a <em>frequency</em> of:</td>
</tr>
<tr>
<td></td>
<td>(a) 0.05 Hz or less, has a damping ratio of at least 0.4;</td>
</tr>
<tr>
<td></td>
<td>(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);</td>
</tr>
<tr>
<td></td>
<td>(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.</td>
</tr>
<tr>
<td></td>
<td>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 <em>power system</em>, must remain within the small disturbance rotor angle stability criteria and the <em>power system</em> must return to a stable operating state following the disturbance. The small disturbance rotor angle stability criteria are:</td>
</tr>
<tr>
<td></td>
<td>(a) The damping ratio of electromechanical oscillations must be at least 0.1.</td>
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<tr>
<td></td>
<td>(b) For electro-mechanical oscillations as a result of a small disturbance, the damping ratio of the oscillation must be at least 0.5.</td>
</tr>
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<td></td>
<td>(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.</td>
</tr>
<tr>
<td><strong>AEMC</strong></td>
<td>The Australian Energy Market Commission, which is established under section 5 of the Australian Energy Market Commission Establishment Act 2004 (SA).</td>
</tr>
<tr>
<td><strong>AEMO</strong></td>
<td>The Australian Energy Market Operator</td>
</tr>
<tr>
<td><strong>AEMO advisory matter</strong></td>
<td>Advice on the acceptability of the negotiated performance standards for all areas of technical performance except the quality of electricity generated, is known as <em>AEMO advisory matters</em>.</td>
</tr>
<tr>
<td>Word</td>
<td>Definition</td>
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<tr>
<td>Apparent power</td>
<td>The square root of the sum of the squares of the active power and the reactive power.</td>
</tr>
<tr>
<td>Asynchronous generating unit</td>
<td>A generating unit that is not a synchronous generating unit.</td>
</tr>
<tr>
<td>Connect, Connected, Connection</td>
<td>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.</td>
</tr>
<tr>
<td>Connection point</td>
<td>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.</td>
</tr>
<tr>
<td>Contingency</td>
<td>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.</td>
</tr>
<tr>
<td>Continuous uninterrupted operation</td>
<td>In respect of a generating system or operating generating unit operating immediately prior to a power system disturbance:</td>
</tr>
<tr>
<td></td>
<td>(a) not disconnecting from the power system except in accordance with its performance standards,</td>
</tr>
<tr>
<td></td>
<td>(b) during the disturbance, contributing active and reactive current as required by its performance standards;</td>
</tr>
<tr>
<td></td>
<td>(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</td>
</tr>
<tr>
<td></td>
<td>(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</td>
</tr>
<tr>
<td>Control system</td>
<td>Means of monitoring and controlling the operation of the power system or equipment, including generating units connected to a transmission or distribution network.</td>
</tr>
<tr>
<td>Customer</td>
<td>A person who: engages in the activity of purchasing electricity supplied through a transmission or distribution system to a connection point</td>
</tr>
<tr>
<td>Dispatch</td>
<td>The act of in committing to service all or part of the generation available from a generating unit.</td>
</tr>
<tr>
<td>Distribution</td>
<td>Activities pertaining to a distribution system including the conveyance of electricity through that distribution system.</td>
</tr>
<tr>
<td>Word</td>
<td>Definition</td>
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<tr>
<td>Distribution network</td>
<td>A network which is not a transmission network.</td>
</tr>
<tr>
<td>Distribution system</td>
<td>A distribution network, together with the connection assets associated with the distribution network, which is connected to another transmission or distribution system.</td>
</tr>
<tr>
<td>Excitation control system</td>
<td>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).</td>
</tr>
<tr>
<td>Frequency</td>
<td>For alternating current electricity, the number of cycles occurring in each second.</td>
</tr>
<tr>
<td>Generating unit</td>
<td>The plant used in the production of electricity and all related equipment essential to its functioning as a single entity.</td>
</tr>
<tr>
<td>Generating system</td>
<td>A system comprising one or more generating units and includes auxiliary or reactive plant that is located on the Generator’s side of the connection point and is necessary for the generating system to meet its performance standards.</td>
</tr>
<tr>
<td>Generator</td>
<td>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.</td>
</tr>
<tr>
<td>Generation</td>
<td>The production of electrical power by converting another form of energy in a generating unit.</td>
</tr>
<tr>
<td>Load</td>
<td>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.</td>
</tr>
<tr>
<td>Load shedding</td>
<td>Reducing or disconnecting load from the power system.</td>
</tr>
<tr>
<td>Nameplate rating</td>
<td>The maximum continuous output or consumption in MW of an item of equipment as specified by the manufacturer, or as subsequently modified.</td>
</tr>
<tr>
<td>NEM</td>
<td>The National Electricity Market.</td>
</tr>
<tr>
<td>NER</td>
<td>The National Electricity Rules</td>
</tr>
<tr>
<td>Word</td>
<td>Definition</td>
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<tr>
<td><strong>Network</strong></td>
<td>The apparatus, equipment, <em>plant</em> and buildings used to convey, and control the conveyance of, electricity to <em>customers</em>. When referring to Western Power, means a <em>network</em> owned, operated or controlled by Western Power.</td>
</tr>
<tr>
<td><strong>Network Service Provider</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Network User</strong></td>
<td>A Generator, a Transmission network Customer, or a Distribution Network Customer.</td>
</tr>
<tr>
<td><strong>Maximum continuous current</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Plant</strong></td>
<td>In relation to a connection point, includes all equipment involved in generating, utilising or transmitting electrical energy.</td>
</tr>
<tr>
<td><strong>Power factor</strong></td>
<td>The ratio of the active power to the apparent power at a metering point.</td>
</tr>
<tr>
<td><strong>Power system</strong></td>
<td>The electric power system constituted by the South West interconnected system <em>Network</em> and its connected generation and loads, operated as an integrated system.</td>
</tr>
<tr>
<td><strong>Power system security</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Power transfer</strong></td>
<td>The instantaneous rate at which active energy is transferred between connection points.</td>
</tr>
<tr>
<td><strong>Protection system</strong></td>
<td>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.</td>
</tr>
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</tbody>
</table>
| 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 *transformers* 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. |
<p>| South West interconnected system or SWIS | The <em>transmission system</em> and <em>distribution system</em> 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 <em>excitation control system</em> in which the power to the rotor of a <em>synchronous generating unit</em> is transmitted through high power solid-state electronic devices.                                             |
| Supply                             | The delivery of electricity.                                                                                                                                                                               |
| Synchronous generating unit        | The alternating current <em>generating units</em> which operate at the equivalent speed of the <em>frequency</em> of the <em>power system</em> in its normal operating state.                                                      |</p>
<table>
<thead>
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<tbody>
<tr>
<td><strong>Tap-changing transformer</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Technical minimum</strong></td>
<td>The minimum continuous active power output of a generating unit.</td>
</tr>
<tr>
<td><strong>Thermal generating unit</strong></td>
<td>A generating unit which uses fuel combustion for electricity generation</td>
</tr>
<tr>
<td><strong>Transformer</strong></td>
<td>A plant or device that reduces or increases the voltage of alternating current.</td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td>Activities pertaining to a transmission system, including the conveyance of electricity through that transmission system.</td>
</tr>
<tr>
<td><strong>Transmission network</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Transmission system</strong></td>
<td>A transmission network, together with the connection assets associated with the transmission network, which is connected to another transmission system or distribution system.</td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>The electronic force or electric potential between two points that gives rise to the flow of electricity.</td>
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</tbody>
</table>