Generator Performance Standards: Guideline for the Assessment of Technical Requirements

Version 2

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Western Power

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Document Information

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Document History

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0.1	16 June 2022	Manager- Transmission Grid Strategy & Planning	Public draft
1.0	1 July 2022	Regulatory Compliance	Release Version
1.1	8 September 2022	Manager- Transmission Grid Strategy & Planning	Updated release incorporating GPS Technical Requirement Interpretation and Application for A12.4, A12.5 and A12.6
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2	30 January 2023	Manager- Transmission Grid Strategy & Planning	Updated release incorporating GPS Technical Requirement Interpretation and Application for A12.2, A12.3 and A12.17 The whole document is updated in accordance with Tranche 6 of WEM Rules

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Abbreviations

The following table provides a list of abbreviations and acronyms used throughout this document. Terms defined in the WEM Rules, including in Appendix 12, and/or the Technical Rules for Western Power's Network are identified in this document by capitals.

Term	Definition
AC	Alternating current
AEMO	Australian Energy Market Operator
AVR	Automatic voltage regulator
CFCT	Critical fault clearance time
CUO	Continuous uninterrupted operation
DC	Direct current
EMT	Electromagnetic transient
ERA	Economic Regulation Authority
GPS	Generator Performance Standard
GW	Gigawatt
GWh	Gigawatt hour
HVRT	High voltage ride through
LVRT	Low voltage ride through
MVAR	Megavolt ampere reactive
MW	Megawatt
MWh	Megawatt hour
OCGT	Open cycle gas turbine
OEL	Over excitation limiter
OEM	Original equipment manufacturer
PFR	Primary frequency response
POC	Point of connection
PPC	Power plant controller
PQ	Power quality
PSCC	Primary speech communication channel
PSS	Power system stabiliser
RCE	Remote control equipment
RGM	Relevant Generator Modification
RME	Remote monitoring equipment
RMS	Root mean square (stability analysis functions)

Term	Definition
ROCOF	Rate of change of frequency
SCADA	Supervisory control and data acquisition
SMIB	Single machine infinite bus
SWIS	South West Interconnected System
TR	Technical Rules[1]
THD	Total harmonic distortion
TW	Terawatt
TWh	Terawatt hour
UEL	Under excitation limiter
UFLS	Under frequency load shedding
WEM	Wholesale Electricity Market
WEM Rules	The Wholesale Electricity Market Rules established under the Electricity Industry (Wholesale Electricity Market) Regulations 2004 (WA)

1 Technical Rules (1/12/16 Revision 3) version at the time of the study. Microsoft Word - TECHNICAL_RULES - 1ST_DECEMBER_2016_VERSION_REV_3 - FRI - RIM - EDM_40546182.docx (erawa.com.au)

1 Introduction

In 2021 the Wholesale Electricity Market (WEM) Rules introduced the Generator Performance Standards (GPS) for Market Participants responsible for a Transmission Connected Generating System. GPS is described in Chapter 3A and Appendix 12 of the WEM Rules and other associated documentation.

This guideline provides information to Market Participants as to how the standard or technical level of performance in respect of each Technical Requirement will be assessed for each type of Generating Unit and has been produced in accordance with WEM Rules clause 3A.4.4:

3A.4.4.	**A Network Operator must:** **(a) prepare guidelines in consultation with AEMO, to provide information to Market Participants as to how the standard or technical level of performance in respect of each Technical Requirement will be assessed for each type of Generating Unit; and** **(b) publish those guidelines on its website.**

1.1 Structure of this document

This guideline is separated into two parts:

- Part A: Practical Guideline for the completion of a GPS Submission (Chapter 2)

  This part provides Market Participants with guidance on how to complete the GPS Template, predominantly focussing on how to draft a statement of compliance.

- Part B: GPS Technical Requirements guide (Chapter 3)

  This part will clarify and interpret each Technical Requirement in Appendix 12 and will describe an expected response each Generating System should provide as the basis of performance negotiation. It will also include instructions and recommended methodologies to assess WEM Rules Appendix 12 Technical Requirement to evidence compliance of a Generating System with the WEM Rules.

This guideline will cover the fundamentals and the importance of the clauses of Appendix 12 and how they relate to a secure and reliable operation of the SWIS, including some theoretical and practical discussions.

2 Practical guideline for the completion of a GPS submission

2.1 Introduction

A Generator Performance Standard (GPS) Submission must be made by a Market Participant using the GPS Template[2]. This chapter provides guidance on how to complete the GPS Template and how the statement of compliance should be formulated for the purpose of completing a GPS Submission.

2.2 Statement of compliance

A GPS Submission that is submitted by a Market Participant and becomes a Registered GPS for a Transmission Connected Generating System consists of a completed GPS Template and accompanying supporting documentation. A key piece of information in the GPS Submission is the statement of compliance within the GPS Template as this statement formally captures a Generating System's registered performance.

In principle, the statement of compliance should be able to be read without context of other documents and include values specific to how that Generating System performs and should align with the Technical Requirements outlined in WEM Rules Appendix 12.

On this basis, a statement of compliance should be written using a clear and measurable structure, statements such as "Meeting requirements" or justification statements such as "AVR step response shows adequate damping" would not be acceptable. The statement of compliance should not be vague and should reflect how the Generating System behaves by providing a measurable level of performance. Additionally, statements like "The Generating System does not meet the 5 second settling time" must be avoided, noting that a GPS Registration intends to collect information about what a Generating System does, not what it doesn't do.

For some Technical Requirements, Appendix 12 of the WEM Rules requires complex data structures to be defined and referred to in the statement of compliance, hence the statement of compliance could refer to an Annexure or Attachment document.

Example statement of compliance for clause A12.2.3.2:

This Generator Performance Standard for Active Power Capability includes Temperature Dependency Data up to and including the maximum ambient temperature of **50°*C***:

(a) For the Generating System measured at the Connection Point it can be found in < ***Temp Data FacilityXXX Unitxxx.xlsx>***; and

(b) For the Synchronous Generating Unit designated ***ABC G1*** measure at its terminal it can be found in ***< Temp Data FacilityXXX Unitxxx.xlsx >.***

Note the following regarding this statement of compliance:

- The statement follows a similar sentence structure to the WEM Rules clause with added values that reflects the performance of the Generating System.
- The terminology is consistent with WEM Rules, including capitalisation of WEM Rules defined terms.

[2] The GPS Template is available on the Western Power website (https://www.westernpower.com.au/industry/manuals-guides-standards/generator-performance-standards/).

- The statement has included values specific to the Generating System including:
- – The value of the maximum ambient temperature of <**50*°C***>.
- – References to complex data attached to the submission:

<**Attachment *A*>** containing the Temperature Dependency Data for the Generating System's Active Power capability at the Connection Point; and

<**Attachment *B*>** containing the Temperature Dependency Data for the Synchronous Generating Unit's terminal.

The complex data attached as Attachment document should be provided in a format/template as agreed with Western Power

- The ***ABC G1*** designation for the *Synchronous Generating Unit* to denote which Generating Unit is being described (note that name of Generating Unit must be consistent with name used in the GPS Template "Facility Summary" page).

2.3 Examples of suitable statements of compliance

2.3.1 Technical Requirement: Active Power Capability [A12.2]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Specified Measurement Location for this Technical Requirement	**[A12.2.1.1]**. In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	The statement of compliance should specify the location which the Active Power capability requirements are to be applied. Example 1: *The Generating System's Active Power capability requirements apply at the Connection Point.* Example 2: *The Synchronous Generating System's Active Power capability requirements apply at the Synchronous Generating Unit's terminal.*
Temperature Dependency Data including Rated Maximum Active Power	**[A12.2.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Active Power capability. **[A12.2.3.2]** The Generator Performance Standard for Active Power capability must include Temperature Dependency Data up to and including the Maximum Temperature, which must include the Rated Maximum Active Power, maximum ambient temperature specified by the Network Operator, and including ambient temperatures above the Maximum Temperature after which the Active Power capability is reduced: (a) for the Generating System measured at the Connection Point; and (b) for each Synchronous Generating Unit measured at the Generating Unit terminal.	The statement of compliance should specify: - Temperature Dependency Data, to be provided in a template format provided by Western Power - For all Generating Systems the Active Power capability must be provided at the Connection Point - For each Synchronous Generating Units additional Active Power capability should be provided at the terminals - The Maximum Temperature is specified by AEMO in consultation with Western Power

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example: *This Generator Performance Standard for Active Power capability includes Temperature Dependency Data up to, including and above the Maximum Temperature of* ***<Maximum Temperature Value>*** *°C.:* *(a) For the Generating System measured at the Connection Point it can be found in* ***<Temp Data FacilityXXX .xlsx >*** *(b) For the Synchronous Generating Unit designated <Generating Unit 1 Designation > measure at its terminal it can be found* ***in < Temp Data FacilityXXX Unitxxx.xlsx>*** *(remove if not applicable)* *(c) For the Synchronous Generating Unit designated <Generating Unit 2 Designation> measure at its terminal it can be found in* ***< Temp Data FacilityXXX Unitxxx.xlsx >*** *(remove if not applicable)*
Rated Maximum Active Power	**[A12.2.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Active Power capability. **[A12.2.3.4]** Subject to clause A12.2.3.5 and energy source availability, the Generating Unit or Generating System, as applicable, must be capable of maintaining Continuous Uninterrupted Operation and meeting all other Technical Requirements while achieving and maintaining the relevant Active Power output levels at the temperatures specified in A12.2.3.2	The statement should only specify: - The Rated Maximum Active Power as defined in section A12.1 of the WEM Rules: ○ in relation to a Generating System, subject to the energy source availability, the combined maximum amount of Active Power that its Generating Units can deliver at the Connection Point or any other agreed measurement location, when its Generating Units are operating at their Maximum Active Power (adjusted for temperatures up to, including and above the Maximum Temperature as specified by AEMO). ○ Rated Maximum Active Power is the combined maximum amount of Active Power that its Generating Units can deliver at the Connection Point or any other agreed measurement location whilst remaining compliant with all other Technical Requirements from the Registered GPS.

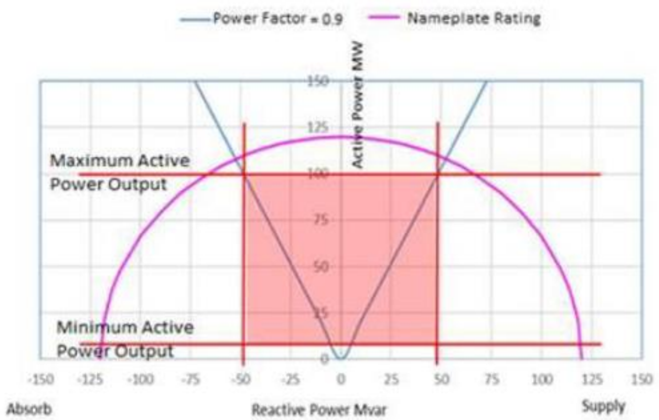
Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		- If, and only if, there exist agreements to Temporary Active Power reduction **[clause A12.2.3.5]** then add the 'subject to' criteria into the statement. Example1: *The Generating System, as applicable, can maintain Continuous Uninterrupted Operation and meeting all other Technical Requirements whilst achieving and maintaining the relevant Active Power output levels at the temperatures specified in A12.2.3.2 with Rated Maximum Active Power of <**Rated Maximum Active Power**> MW.* Example2: *Subject to clause A12.2.3.5 and energy source availability, the Generating System, as applicable, can maintain Continuous Uninterrupted Operation and meeting all other Technical Requirements whilst achieving and maintaining the relevant Active Power output levels at the temperatures specified in A12.2.3.2 with Rated Maximum Active Power of <**Rated Maximum Active Power**> MW.*
Temporary Active Power reduction	**[A12.2.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Active Power capability. **[A12.2.3.5]** Clause A12.2.3.4 does not apply to the extent that a temporary reduction in Active Power has been agreed to by the Network Operator in order to achieve the required Reactive Power Capability under Maximum Temperature conditions as set out in Part A12.3 of this Appendix 12.	This statement should specify any agreements with AEMO and Western Power to allow for temporary reduction in Rated Active Power to achieve required Reactive Power Capability at maximum ambient temperature conditions. Example where no agreements exist: *The Generating System does not have a temporary reduction in Active Power in order to achieve the required Reactive Power Capability under Maximum Temperature conditions as set out in Part A12.3 of this Appendix 12.* Example where there is an agreement:

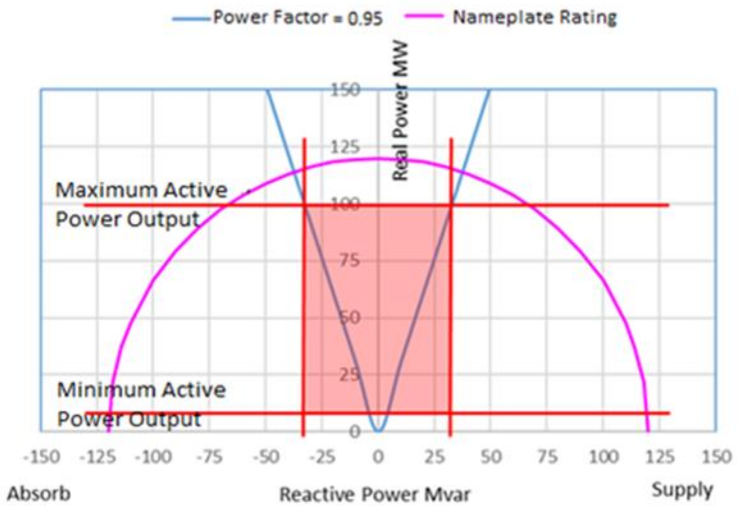
Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Note: in this example the Generating System will agree to reduce its output level to 80 MW when ambient temperature is greater than 41°C in order to provide the Reactive Power Capability of ±48.4 MVAr. *The Generating System temporarily reduces its Active Power output to below 80 MW to provide ±48.4 MVAr Reactive Power Capability at the Connection Point when ambient temperatures are above 41°C.*
Active Power Limit	**[A12.2.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Active Power capability **[A12.2.3.6]** Unless otherwise directed under these WEM Rules, Generating Systems and Generating Units, as applicable, must not exceed the relevant Active Power levels at the temperatures specified in A12.2.3.2.	Example: *The Generating System does not exceed the relevant Active Power levels as shown in Temperature Dependency Data provided in A12.2.3.2 at the temperatures specified unless otherwise directed under these WEM Rules*

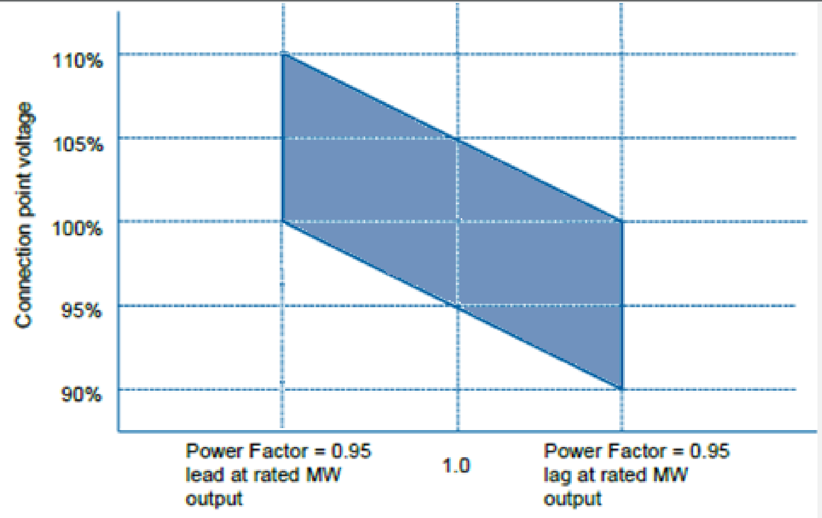
2.3.2 Technical Requirement: Reactive Power Capability [A12.3]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Specified Measurement Location for this Technical Requirement	**[A12.3.1.1]** In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	The statement of compliance should specify the location which the Reactive Power Capability requirements are to be applied. Example 1: *The Generating System's Reactive Power Capability requirements apply at its Connection Point.* Example 2: *The Synchronous Generating System's Reactive Power Capability requirements apply at the Synchronous Generating Unit's terminal.*
Generator Capability Chart	**[A12.3.1.2]** The Generator Performance Standard must include a Generator Performance Capability Chart, including data up to and including the Maximum Temperature and including ambient temperatures above the Maximum Temperature after which the performance is reduced.	The statement of compliance should specify: - The Generator Performance Chart as defined in section A12.1 of the WEM Rules: Generator Performance Chart: Means a chart defining the capability of a Generating System or Generating Unit to produce Active Power while producing or consuming Reactive Power. The capability is provided for specified ambient conditions and voltage levels at the agreed Measurement Location based on a template provided by the Network Operator. The chart shows the Reactive Power capability continuously achievable, subject to energy source availability, for a given level of Active Power output for a range of ambient temperatures, while not exceeding limits necessary to prevent damage to Equipment and ensure compliance with other Technical Requirements - The format of the Generator Performance Chart should be provided in the format of the template provide by Western Power.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example: *The Generator Capability Chart for the Generating System is provided in **<attach reference>** as measured at the Connection Point, it includes data for the Maximum Temperature of **<Maximum Temperature Value>**°C.*
No limitations to Reactive Power within defined Performance Chart	**[A12.3.1.3]** There must be no control system limitation, protection system or other limiting device in operation that would prevent the Generating System from providing the Reactive Power output within the area defined in the Generator Performance Chart.	The statement of compliance should specify that whilst the Generating System is operating within the region defined by the Generator Performance Chart can do so continuously without causing limiters to change output levels (either in Active Power or Reactive Power) to protect equipment within the Generating System from damage, trigger protection elements from disconnecting equipment, or resulting in damage to equipment within the Generating System. Example where the Generator Capability Chart strictly follows the criteria provided in the definition in section A12.1 of the WEM Rules: *There is no control system limitation, protection system or other limiting device in operation that would prevent the Generating System from providing the Reactive Power output within the area defined in the Generator Capability Chart shown in **<attach reference>**.*
Capability to dispatch Active Power and Reactive Power	**[A12.3.1.5]** Each Generating System's Connection Point must be capable of permitting the Dispatch of the full Active Power and Reactive Power Capability of the Generating System.	This statement is to ensure that physical limitations of connection equipment does not prevent the Generating System to provide its stated Generator Performance chart at the Connection Point. Example: *The Generating System's Connection Point is capable of permitting the Dispatch of the full Active Power and Reactive Power Capability of the Generating System.*
Reactive Power Capability	**[A12.3.2.1 (Ideal)]** For all operating conditions including temperatures up to and including the Maximum Temperature, each Generating Unit within the Generating System must be capable of supplying or absorbing Reactive	The statement of compliance should specify or reiterate:

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	Power continuously of at least the amount equal to the product of the Rated Maximum Active Power output of the Generating Unit at nominal voltage and 0.484 while operating at any level of Active Power output between its maximum Active Power output level as specified in the Temperature Dependency Data under A12.2, and its Rated Minimum Active Power output level ..  **Figure A12.3.2.1: Example Reactive Power Capability required to meet Ideal Generator Performance Standard** **[A12.3.3.1 (Minimum)]** Subject to clause A12.3.3.3, for all operating conditions including temperatures up to and including the Maximum Temperature, the Generating System must be capable of supplying or absorbing Reactive Power continuously of at least the amount equal to the product of the Rated Maximum Active Power output of the Generating System and 0.329 while operating at any level of Active Power output level between its maximum Active Power output level as specified in the Temperature Dependency Data under A12.2,and Rated Minimum Active Power output level as agreed by the Network Operator and .	- The Rated Maximum Active Power at the agreed location per section A12.2 of the WEM Rules. - Maximum Active Power output level which is the same as relevant active power in Temperature Dependency Data (A12.2.3.2) - Minimum Active Power output level which is the same as Rated Minimum Active Power. - Calculated maximum reactive power absorption/supply i.e. Reactive Power Capability. To meet ideal standard this must equal to the product of 0.484 and the Rated Maximum Active Power, and for a negotiated standard these must not be less than the product of 0.329 and the Rated Maximum Active Power. Example: *For all operating conditions including temperatures up to and including the Maximum Temperature, the Generating System is capable of supplying and absorbing <**Calculated maximum reactive power absorption/supply**> MVAR at the Connection Point whilst operating at an Active Power output level between <**Maximum Active Power output level**> MW and <**Minimum Active Power output level**> MW.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	 **Figure A12.3.3.1: Example Reactive Power Capability required to meet the Minimum Generator Performance Standard**	
Continuous Reactive Power Capability	**[A12.3.2.2 (Ideal)]** The required levels of Reactive Power Capability must be able to be delivered continuously for voltages at the Connection Point within the allowable steady state voltage ranges as specified in the Technical Rules. **[A12.3.3.2 (Minimum)]** The Reactive Power Capability may be varied as shown in Figure A12.3.3.2 when the voltage at the Connection Point varies between 0.9 per unit and 1.1 per unit, where the Generating System must be capable of absorbing or supplying Reactive Power continuously when operating anywhere inside the curve specified in Figure A12.3.3.2.	The statement of compliance should specify the region in terms of Connection Point voltage and Generating System Power Factor whilst operating at its maximum Active Power output, and include the: - Lowest leading power factor, for ideal standard this should not be higher than 0.9 leading and for negotiated standard this should not be higher than 0.95 leading. - Lowest lagging power factor, for ideal standard this should not be higher than 0.9 lagging and for negotiated standard this should not be higher than 0.95 lagging. - Highest Connection Point voltage at lowest leading power factor, this should not be lower than 110%.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	 **Figure A12.3.3.2: Relaxation of Reactive Power requirement with Connection Point voltage**	- Lowest Connection Point voltage at lowest leading power factor, for ideal this should not be higher than 90%, for negotiated standard this should not be higher than 100%. - Highest Connection Point voltage at lowest lagging power factor, for ideal this should not be lower than 110%, and for negotiated standard this should not be lower than 100%. - Lowest Connection Point voltage at lowest lagging power factor, this should not be higher than 90%. Example where the Ideal standard is met: *The Generating System output continuously any Active Power and Reactive Power output within its registered Reactive Power Capability at any Connection Point voltage between 90% and 110%.* Example for a negotiated standard to be at Minimum: *The Generating System can output continuously any Active Power and Reactive Power output if operating within the region linearly between:* - *the Connection Point voltage is between 100% and 110% at 0.95 leading; and* - *the Connection Point voltage is between 90% and 100% at 0.95 lagging.* *As demonstrated in Figure A12.3.3.2.*
Agreement to reduce Active Power if ambient temperature > 25 degrees	**[A12.3.3.3]** Transmission Connected Generating Systems containing Intermittent Generating Systems may, with the Network Operator's agreement, achieve the Reactive Power Capability specified in clause A12.3.3.1 by reducing Active Power output when the ambient temperature exceeds 25 degrees Celsius in their location, with the conditions forming part of the Generator Performance Standard.	The statement of compliance should specify the agreement with the Network Operate the conditions of the agreement with respect to clause A12.3.3.3 of the WEM Rules. Example where the Generating System is not a Non-Scheduled Generator: *The Generating System does not have any agreement to reduce Active Power if ambient temperature is greater than 25°C.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example where the Generating System has an agreement to reduce its maximum Active Power output by 0.5 MW for each degree the ambient temperature is above 35°C. *The Generating System reduces its maximum Active Power output by 0.5 MW for each degree the ambient temperature is above 35°C and up to Maximum Ambient Temperature.*

2.3.3 Technical Requirement: Voltage and Reactive Power Control [A12.4]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Specified Measurement Location for this Technical Requirement	**[A12.4.1.1]** In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	Example: *The Measurement location for the requirements of Voltage and Reactive power control is at the connection point* Example when a different Measurement Location is determined: *The Measurement location for the requirements of Voltage and Reactive power control of the Generating Unit <**Generating Unit 1 Designation** > is at the Generating Unit Terminal*
Compliance when operating at any Range of Active and Reactive Power and Temperature	**[A12.4.1.2]** In relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this Appendix, and at all temperatures up to and including the Maximum Temperature.	Example: *In relation to the application of Voltage and Reactive power control, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this GPS, and at all temperatures up to and including the Maximum Temperature of <**Maximum Temperature °C**>*
Power system oscillations damping adequacy	**[A12.4.2.2(a) (Ideal)]** The Generating System must have Equipment capabilities and Control Systems, including, if necessary, a power system stabiliser, sufficient to ensure that power system oscillations, for the frequencies of oscillation of the Generating System against any other Generating System or device, are Adequately Damped. **[A12.4.3.2(a) (Minimum)]** A Generating System must have Equipment capabilities and Control Systems, including, if necessary, a power system stabiliser, sufficient to ensure that power system oscillations, for the	The statement of compliance should specify the damping ratio achieved by the Generating System. Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/media/4981/power-system-stability-requirements-guideline-20210511.pdf) for further information on stability requirement and Adequate Damping. Example:

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	frequencies of oscillation of the Generating System against any other Generating System or device, are Adequately Damped.	*The Generating System has Equipment capabilities and Control Systems that power system oscillations, for the frequencies of oscillation of the Generating System against any other Generating System or device, are Adequately Damped and achieve a damping ratio of no less than 0.1 and a halving time of less than 5 seconds.*
No degradation of damping performance of power system	**[A12.4.2.2(b) (Ideal)]** The Generating System must have Equipment capabilities and Control Systems, including, if necessary, a power system stabiliser, sufficient to ensure that operation of the Generating System does not degrade the damping of any critical mode of oscillation of the power system. **[A12.4.3.2(b) (Minimum)]** A Generating System must have Equipment capabilities and Control Systems, including, if necessary, a power system stabiliser, sufficient to ensure that operation of the Generating System is Adequately Damped.	Example for Ideal standard: *The Generating System's control system has Equipment capabilities and Control Systems which does not degrade the damping of any critical mode of oscillation of the power system.* Example for negotiated standard at Minimum: *The Generating System has Equipment capabilities and Control Systems sufficient to ensure that power system oscillations are Adequately Damped by achieving a damping ratio of at least 0.1 and halving time of less than 5 seconds.*
Power system stability requirement	**[A12.4.2.2(c) (Ideal)]** The Generating System must have Equipment capabilities and Control Systems, including, if necessary, a power system stabiliser, sufficient to ensure that operation of the Generating System does not cause instability (including hunting of Tap-Changing Transformer Control Systems) that would adversely impact other Equipment connected to the SWIS.	Example: *The Generating System has Equipment capabilities and Control Systems sufficient to ensure that operation of the Generating System does not cause instability (including hunting of Tap-Changing Transformer Control Systems) that would adversely impact other Equipment connected to the SWIS.*
Control System testing equipment requirements	**[A12.4.2.3 (Ideal)]** Control Systems on Generating Systems that control voltage and Reactive Power must include permanently installed and operational, monitoring and recording equipment for key variables including each input and output, and equipment for testing the Control Systems sufficient to establish their dynamic operational characteristics. **[A12.4.3.2(c) (Minimum)]** A Generating System must have Equipment capabilities and Control Systems, including, if necessary, a power system	The statement of compliance for the ideal standard, should specify if the signals that are monitored on site or with Remote Monitoring Equipment could be used to validate dynamic operational characteristics during an unplanned disturbance. Otherwise, at a minimum the Control Systems should have been tested during commissioning to establish the dynamic operational characteristics.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	stabiliser, sufficient to ensure that Control Systems can be sufficiently tested to establish their dynamic operational characteristics.	Example for Ideal standard: *The Control Systems on the Generating Systems that control voltage and Reactive Power has included permanently installed and operational, monitoring and recording equipment for the following key variables:* • ***<input or output variable 1>*** • ***<input or output variable 2>*** • *…* • ***<input or output variable n>*** *for testing the Control Systems sufficient to establish their dynamic operational characteristics.*
Ability to operate in all control modes	**[A12.4.2.4(a) (Ideal)]** A Generating System must have Control Systems capable of regulating voltage, Reactive Power and Power Factor, with the ability to operate in all control modes. **[A12.4.3.3 (Minimum)]** A Generating System must have a Control System to regulate: (a) voltage; or (b) either of Reactive Power or Power Factor, with the agreement of AEMO and the Network Operator.	Example for Ideal standard: *The Generating System has Control Systems capable of regulating voltage, Reactive Power and Power Factor, with the ability to operate in all control modes.* Example for a negotiated standard at Minimum: *The Generating System has a Control System to regulate the voltage only.*
Ability to switch between control modes	**[A12.4.2.4(b)]** A Generating System must have Control Systems capable of regulating voltage, Reactive Power and Power Factor, with the ability to switch between control modes, as demonstrated to the reasonable satisfaction of the Network Operator and AEMO. Where a Generating System has been commissioned with more than one control mode, a procedure for switching between control modes must be agreed with	Example: *The Generating System has the Control Systems capable of regulating voltage, Reactive Power, and Power Factor, with the ability to switch between control modes. The procedure for switching between control modes is agreed with AEMO and Western Power as part of the Generator Performance Standard*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	AEMO and the Network Operator as part of the Generator Performance Standard.	Example where a Generating System can only perform a single mode of control: The Generating System only operates in voltage control mode.
Voltage Control System - voltage regulation location and accuracy	**[A12.4.2.5(a) (Ideal)]** A Generating System must have a voltage Control System that regulates voltage to within 0.5% of the Target Setpoint, where that setpoint may be adjusted to incorporate any voltage droop or reactive current compensation agreed with AEMO and the Network Operator. **[A12.4.3.4(a) (Minimum)]** A voltage Control System for a Generating System must regulate voltage to within 2% of the Target Setpoint, where that setpoint may be adjusted to incorporate any voltage droop or reactive current compensation agreed with AEMO and the Network Operator.	Example for Ideal standard: *A Generating System has a voltage Control System that regulates voltage at the Measurement Location within 0.5% of the Target Setpoint where that setpoint may be adjusted to incorporate any voltage droop or reactive current compensation agreed with AEMO and Western Power* Example for a Synchronous Generating Unit which controls its terminal voltage: *A Synchronous Generating Unit has a voltage Control System that regulates voltage at the terminal of the Synchronous Generating System to within 0.5% of the Target Setpoint.* Example for a negotiated standard at Minimum: *A voltage Control System for a Generating System regulates voltage at the Connection Point to within 2% of the Target Setpoint.*
Voltage Control System - support network voltage during fault	**[A12.4.2.5(b)]** A Generating System must have a voltage Control System that regulates voltage in a manner that helps to support network voltages during faults and does not prevent the requirements for voltage performance and stability in the Technical Rules from being achieved.	Example: *The Generating System has a voltage Control System that regulates voltage in a manner that helps to support network voltages during faults and does not prevent the requirements for voltage performance and stability in the Technical Rules from being achieved.*
Voltage Control System -	**[A12.4.2.5(c) (Ideal)]** A Generating System must have a voltage Control System that allows the voltage to be continuously controllable in the range of at least 95% to 105% of the target voltage (as determined by the Network Operator), without reliance on a Tap-Changing Transformer and	The target voltage is determined and specified by Western Power. This can be a single target voltage or a range of target voltages. The voltage control

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
continuous controllability	subject to the Generator Performance Standards for Reactive Power Capability with the voltage control location agreed with AEMO and the Network Operator **[WEM A12.4.3.4.(b) (Minimum)]** A voltage Control System for a Generating System must allow the voltage Target Setpoint to be controllable in the range of at least 98% to 102% of the target voltage (as determined by the Network Operator), subject to the Reactive Power Capability agreed with AEMO and the Network Operator under Part A12.3 of this Appendix 12.	location for the target voltage must be agreed with AEMO and Western Power. Example for Ideal standard where the voltage control location is at the Connection Point and the target voltage is explicitly stated: *The Generating System has a voltage Control System that allows the voltage to be continuously controllable in the range of at least 95% to 105% of the Target Setpoint <**target voltage p.u**.> at the Measurement Location without reliance on a Tap-Changing Transformer and subject to the Generator Performance Standards for Reactive Power Capability.* Example for Ideal standard where the target voltage is referenced in an Operational Philosophy document that has been approved by AEMO and Western Power: *The Generating System has a voltage Control System that allows the voltage to be continuously controllable in the range of at least 95% to 105% of the target voltage as indicated in **<reference document>** at the Measurement Location without reliance on a Tap-Changing Transformer and subject to the Generator Performance Standards for Reactive Power Capability.* Example for a negotiated standard at Minimum where the voltage control location is at the Connection Point and the target voltage range is explicitly stated: *The Generating System has a voltage Control System that controls the voltage to a setpoint in the range of at least 98% to 102% of the target voltage <**target voltage p.u**.> at the Measurement Location without reliance on a Tap-Changing Transformer and subject to the Generator Performance Standards for Reactive Power Capability.* Example a negotiated standard at Minimum for a Synchronous Generating Unit where the voltage control location is at the Generating Unit terminal:

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		The Generating System has a voltage Control System that controls the voltage to a setpoint in the range of at least 97% to 104% of the target voltage (1 p.u.) at the Generating Unit terminal.
Voltage Control System - limiting devices	**[A12.4.2.5(d)]** A Generating System must have a voltage Control System that 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 continuous stable while under the control of any limiter. Limiters must not detract from the performance of any stabilising circuits and must have settings applied which are coordinated with all Protection Systems.	Example: *The Generating System has a voltage Control System that has limiting devices to ensure that a voltage disturbance does not cause the Generating Unit to trip at the limits of its operating capability. The Generating System is capable of continuous stable operation while under the control of any limiter. Limiters do not detract from the performance of any stabilising circuits and have settings applied which are coordinated with all Protection Systems.*
Power System Stabiliser control structure and testing requirements	**[A12.4.2.6]** Where installed, a power system stabiliser must have: (a) two washout filters for each input, with ability to bypass one of them if necessary; (b) 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 Unit; (c) monitoring and recording equipment for key variables including inputs, output and the inputs to the lead-lag transfer function blocks; and (d) equipment 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.	Example: *The Generating System has an installed power system stabiliser that has:* *(a) two washout filters for each input, with ability to bypass one of them if necessary;* *(b) 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 Unit;* *(c) monitoring and recording equipment for the following key variables that including inputs, output and the inputs to the lead-lag transfer function blocks:* ***<key variable 1>**,* ***<key variable 2>**,* *...* ***<key variable n>***

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		(d) equipment 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.
Reactive Power Control System - regulation location and accuracy	**[A12.4.2.7(a) (Ideal)]** A Reactive Power, including a Power Factor, Control System must regulate Reactive Power or Power Factor (as applicable to within: (i) for a Generating System operating in Reactive Power mode, 2% of the Rated Maximum Apparent Power of the Generating System from the Target Setpoint; or (ii) for a Generating System operating in Power Factor mode, a Power Factor equivalent to 2% of the Rated Maximum Apparent Power of the Generating System from the Target Setpoint; **[A12.4.3.5(a) (Minimum)]** A Generating System's Reactive Power or Power Factor Control System must regulate Reactive Power or Power Factor (as applicable) to within: (i) for a Generating System operating in Reactive Power mode, 5% of the Rated Maximum Apparent Power of the Generating System from the Target Setpoint; or (ii) for a Generating System operating in Power Factor mode, a Power Factor equivalent to 5% of the from the Target of the Generating System from the Target Setpoint	The statement of compliance should specify: - The error at a % value of the Generating Rated Maximum Apparent Power. For ideal Performance the % value must be 2% or below, and for negotiated standard it must be 5% or below. The error is the Control Systems desired MVAR value as indicated by Target Setpoint and the actual value. For Power Factor control the desired MVAr value is determined based on the Active Power measured at the Connection Point and the power factor Target Set point. - Rated Maximum Apparent Power: Means the maximum Apparent Power level that a Generating Unit or Generating System, as applicable, can continuously deliver at the agreed Measurement Location, subject to energy source availability, when operating at the extent of the Generator Performance Chart provided under A12.3 and the ambient temperature is at the Maximum Temperature. - The reactive power control mode including Power Factor control. Example for Ideal standard: *The Generating System has a Reactive Power, including a Power Factor, Control System which regulates Reactive Power or Power Factor at the Measurement Location, to within:* *(i) for a Generating System operating in Reactive Power mode, 2% of the Rated Maximum Apparent Power of < **Rated Maximum Apparent Power MVA**> from the Target Setpoint; and*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		for a Generating System operating in Power Factor mode, a Power Factor equivalent to 2% of Rated Maximum Apparent Power < ***Rated Maximum Apparent Power MVA****> from the Target Setpoint* Example for negotiated standard at Minimum: *The Generating System has a Control System capable of regulating Reactive Power* ***[or Power Factor]*** *at the Measurement Location to within 5% of the Rated Maximum Apparent Power of, <* ***Rated Maximum Apparent Power >*** *MVA.*
Reactive Power Control System - continuous controllability of setpoint	**[A12.4.2.7(b) (Ideal)]** A Reactive Power, including a Power Factor, Control System must allow the Reactive Power or Power Factor Target Setpoint to be continuously controllable across the Reactive Power Capability range specified in the relevant Generator Performance Standard. **[A12.4.3.5(b) (Minimum)]** A Generating System's Reactive Power or Power Factor Control System must allow the Reactive Power or Power Factor Target Setpoint to be continuously controllable across the Reactive Power Capability defined in the relevant Generator Performance Standard.	Example: *The Generating System has a Reactive Power Control System that allows the Reactive Power* ***[or Power Factor]*** *to be continuously controllable across the Reactive Power Capability range.*
Control structure and settings approval	**[A12.4.2.8]** 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 the Network Operator and AEMO as part of the Generator Performance Standard.	Example: *The Generating System has a Control System which the structure and parameter settings of all components is approved by Western Power and AEMO.*
Control System damping adequacy	**[A12.4.2.9]** Each Control System must be Adequately Damped.	The statement of compliance should specify the damping ratio achieved by the Generating System. *Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/media/4981/power-system-stability-requirements-guideline-20210511.pdf) for further information on Stability requirement and adequate damping definition.* Example:

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		The Generating System has Control Systems that are adequately damped achieving a damping ratio no less than 0.1 and halving time of less than 5 seconds.
Excitation control system - operation at 105% of nominal voltage	**[A12.4.2.10(a)]** Each Synchronous Generating Unit must have an Excitation Control System that is capable of operating the stator continuously at 105% of nominal voltage when operating at the maximum Active Power output specified in the Temperature Dependency Data provided under A12.2 for the relevant temperature.	The statement of compliance should specify the designation of the Synchronous Generating Unit. Example: *All Synchronous Generating Units within Generating System have an Excitation Control System that is capable of operating the stator continuously at 105% of nominal voltage when operating at the maximum Active Power output specified in the Temperature Dependency Data provided under A12.2 for the relevant temperature* Example where the Generating System does not contain Synchronous Generating Units: *The Generating System does not have a Synchronous Generating Unit and therefore an Excitation Control System used for a Synchronous Generating Unit.*
Excitation control system - excitation ceiling voltage	**[A12.4.2.10(b) (Ideal)]** Each Synchronous Generating Unit must have an Excitation Control System that has an excitation ceiling voltage of at least: (i) for a Static Excitation System, 2.3 times; or (ii) for other Excitation Control Systems, 1.5 times, the excitation required to achieve generation at the rated output, rated speed and nominal voltage e in accordance with the relevant Australian or ISO Standard for Synchronous Generating Units;. **[A12.4.3.6(a) (Minimum)]** Each Synchronous Generating Unit within the Generating System, with an Excitation Control System required to regulate voltage must have excitation ceiling voltage of at least 1.5 times the	The statement of compliance should specify if a Static Excitation System exists or not. Example for a Synchronous Generating Unit with a Static Excitation System: *All Synchronous Generating Units within Generating System have a Static Excitation System that can achieve a ceiling voltage of 2.3 per unit.* Example for a Synchronous Generating Unit with an Excitation system other than a Static Excitation System:

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	excitation required to achieve generation at the rated output, rated speed and nominal voltage in accordance with the relevant Australian or ISO Standard for Synchronous Generating Units.	*The Synchronous Generating Unit, <Designation>, has a* ***[AC Excitation System] [or Rotating Rectifier Excitation System]****, that can achieve a ceiling voltage of at least 1.5 per unit.* Example where the Generating System does not contain Synchronous Generating Units: *The Generating System does not have a Synchronous Generating System and therefore no Excitation Control System is used.*
Excitation control system - Power System Stabilizer frequency	**[A12.4.2.10(c)]** Each Synchronous Generating Unit must have an Excitation Control System that 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 statement of compliance should specify the power system stabiliser is tuneable and that the range of frequency can cover at least frequencies between 0.1 Hz and 2.5 Hz. Example statement of compliance: *All Synchronous Generating Units within Generating System have an Excitation Control System with a power system stabiliser that can be tuned to dampen mode frequencies between the range from 0.1 Hz to 2.5 Hz.* Example statement of compliance which the Generating System does not contain Synchronous Generating Units: *The Generating System does not have a Synchronous Generating System and therefore no Excitation Control System is used.*
Excitation control system - minimum equivalent gain	*Synchronous Generating Systems* **[A12.4.2.10(d)]** Each Synchronous Generating Unit must have an Excitation Control System that achieves a minimum equivalent gain of 200. **[A12.4.2.14]** A Generating System, comprised of Asynchronous Generating Units, must have a control system capable of achieving a minimum equivalent gain of 200.	Example for a Synchronous Generating System: *The Synchronous Generating Units has an Excitation Control System that can achieve a minimum equivalent gain of 200.* Example where a Generating System includes Asynchronous Generating Units: *The Generating System has a voltage control system with a Minimum equivalent gain of 200.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Power System Stabiliser measurement requirements	**[A12.4.2.12(a)]** Where provided, a power system stabiliser must have measurements of rotor speed and Active Power output of the Generating Unit as inputs.	The statement of compliance should specify the inclusion of speed and active power (electrical power) as input signals. Example: *The Generating System has an Excitation System with a power system stabiliser which has speed and active power signals as inputs.*
Power System Stabiliser limiter requirements	**[A12.4.2.12(b)]** Where provided, a power system stabiliser must have an output limiter, which is continually adjustable over the range of –10% to +10% of stator voltage.	Example: *The Generating System has an Excitation System with a power system stabiliser that has an adjustable limiter over the range of -10% and +10% of stator voltage.*
Power oscillation damping capability	**[A12.4.2.13]** A Generating System, comprised of Asynchronous Generating Units, must have a voltage and Reactive Power 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. Any power system stabiliser must have measurements of power system frequency and Active Power output of the Generating Unit as inputs.	The statement of compliance should: - specify the power oscillation damping capability of the Generating System can be optimised and tuneable over the range of frequencies between 0.1 Hz and 2.5 Hz; and - clarify that it uses input signals that include system frequency and generated Active Power of Generating Units. Example: *The Generating System has power oscillation damping capability that can be optimised and flexible to dampen modes with frequencies between 0.1 Hz and 2.5 Hz. The power oscillation dampening system has input signals that include system frequency and generated Active power from Generating Units within itself.*
Rise Time	**[A12.4.2.11]** The performance characteristics required for AC exciter, rotating rectifier and Static Excitation Systems are specified in Table A12.4.2.11.	Example for Static Excitation System: *The performance characteristics of the Generating System's Static Excitation system is so that, the rise time of field voltage, rising from rated field*

<table>
<tr><th>Criteria description</th><th>WEM Rules clause(s)</th><th>Guidance and example statements of compliance</th></tr>
<tr>
<td></td>
<td>
<table>
<tr><th>Performance Item</th><th>Units</th><th>Static Excitation</th><th>AC exciter or rotating rectifier</th><th>Notes</th></tr>
<tr><td>**Generating Unit Field voltage *Rise Time:*** In relation to field voltage rising from rated field voltage to excitation ceiling voltage following the application of a short duration impulse to the voltage reference.</td><td>Second</td><td>0.05 max</td><td>0.5 max</td><td>1, 2</td></tr>
<tr><td colspan="5">**Notes:**
1. Rated field voltage is that voltage required to give nominal Generating Unit terminal voltage when the Generating Unit is operating at its Rated Maximum Apparent Power.
2. For rotating rectifier excitation system where the field voltage is not accessible for direct measurement, the main exciter field voltage must comply with this clause A12.4.2.11.</td></tr>
</table>
Table A12.4.2.11: Synchronous Generating Unit Excitation Control System performance requirements

[A12.4.2.15] The performance characteristics required for the voltage and Reactive Power Control Systems of all Asynchronous Generating Systems are specified in Table A12.4.2.15.
<table>
<tr><th>Performance Item</th><th>Units</th><th>Limiting Value</th><th>Notes</th></tr>
<tr><td>***Rise Time:*** The controlled parameter (voltage or Reactive Power output)</td><td>Second</td><td>1.5 max</td><td>1 and 3</td></tr>
</table>
</td>
<td>*voltage to excitation ceiling voltage following the application of a short duration impulse to the voltage reference is no longer than <0.05seconds>.*

Example for rotating rectifier Excitation System:

The performance characteristics of the Generating System's rotating rectifier Excitation system is so that, the rise time of field voltage, rising from rated field voltage to excitation ceiling voltage following the application of a short duration impulse to the voltage reference is no longer than < 0.5 seconds>.

Example for Asynchronous Generating System:

*The performance characteristics of the **[voltage] [and Reactive Power]** Control Systems of the Generating Systems is that the rise time of **[voltage] [and Reactive Power],** following the application of 5% step change to the Control System is **<1.5 seconds>.***</td>
</tr>
</table>

<table>
<tr><th>Criteria description</th><th>WEM Rules clause(s)</th><th>Guidance and example statements of compliance</th></tr>
<tr><td></td><td>
<table>
<tr><td>following the application of a 5% step change to the Control System reference.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Notes:
1. The step change is 5%, or a lesser value specified by the Network Operator such that it is the largest step change that results in the required Settling Time at the Connection Point.
2. The step change is specified by the Network Operator such that it is the largest step change that results in the required Settling Time at the Connection Point.
3. The step change is to be recorded for future assessment.</td></tr>
</table>
Table A12.4.2.15: Asynchronous Generating System Control System performance requirements
</td><td></td></tr>
<tr><td>Settling Time</td><td>
[A12.4.2.11 (Ideal)] The performance characteristics required for AC exciter, rotating rectifier and Static Excitation Systems are specified in Table A12.4.2.11.
<table>
<tr><th>Performance Item</th><th>Units</th><th>Static Excitation</th><th>AC exciter or rotating rectifier</th><th>Notes</th></tr>
<tr><td>Settling Time with the Generating Unit unsynchronized following a disturbance equivalent to a 5% step change in the sensed Generating Unit terminal voltage.</td><td>Second</td><td>1.5 max</td><td>2.5 max</td><td>2</td></tr>
</table>
</td><td>
Example for Static Excitation System:

The performance characteristics of Static Excitation Systems is so that the Settling Time, with Generating Unit synchronized and unsynchronized following a disturbance equivalent to a 5% step change in the sensed Generating Unit terminal voltage is <1.5 seconds> The Settling Time is met at all operating points within the Reactive Power Capability and between Maximum Rated Active Power and Rated Minimum Active Power.

Example for AC exciter Excitation System:

The performance characteristics of AC exciter Excitation System is so that the Settling Time, with Generating Unit synchronized and unsynchronized following a disturbance equivalent to a 5% step change in the sensed Generating Unit terminal voltage is <2.5 seconds>. The Settling Time is met
</td></tr>
</table>

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	<table><tr><td>***Settling Time*** with the Generating Unit synchronized following a disturbance equivalent to a 5% step change in the sensed Generating Unit terminal voltage. It must be met at all operating points within the Generating Unit capability.</td><td>Second</td><td>2.5 max</td><td>5 max</td><td>2</td></tr><tr><td colspan="5">**Notes:** 1. Rated field voltage is that voltage required to give nominal Generating Unit terminal voltage when the Generating Unit is operating at its Rated Maximum Apparent Power. 2. For rotating rectifier excitation system where the field voltage is not accessible for direct measurement, the main exciter field voltage must comply with this clause A12.4.2.11.</td></tr></table> **Table A12.4.2.11: Synchronous Generating Unit Excitation Control System performance requirements** **[A12.4.3.6(b) (Minimum)]** Each Synchronous Generating Unit within the Generating System, with an Excitation Control System required to regulate voltage must 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, subject to the Generating Unit operating at a point where such a voltage disturbance would not cause any limiting device to operate. **[A12.4.2.15 (Ideal)]** The performance characteristics required for the voltage and Reactive Power Control Systems of all Asynchronous Generating Systems are specified in Table A12.4.2.15.	*at all operating points within the Reactive Power Capability and between Maximum Rated Active Power and Rated Minimum Active Power.* Example for Asynchronous Generating Units: *Settling Time of the controlled parameter in voltage and Reactive Power control mode is no more than 2.5 second following 5% step change in the Control System reference such that it does not cause saturation of the controlled output parameter. The Settling Time is met at all operating points within the Reactive Power Capability and between Maximum Rated Active Power and Rated Minimum Active Power.*

<table>
<tr><th>Criteria description</th><th>WEM Rules clause(s)</th><th>Guidance and example statements of compliance</th></tr>
<tr><td></td><td>
<table>
<tr><th>Performance Item</th><th>Units</th><th>Limiting Value</th><th>Notes</th></tr>
<tr><td>Settling Time of the controlled parameter with the Generating System connected to the Transmission System following a step change in the Control System reference such that it is not large enough to cause saturation of the controlled output parameter. It must be met at all operating points within the Generating Unit’s capability.</td><td>Second</td><td>2.5 max</td><td>1, 2, 3</td></tr>
<tr><td colspan="4">Notes:
1. The step change is 5%, or a lesser value specified by the Network Operator such that it is the largest step change that results in the required Settling Time at the Connection Point.
2. The step change is specified by the Network Operator such that it is the largest step change that results in the required Settling Time at the Connection Point.
3. The step change is to be recorded for future assessment.</td></tr>
</table>
Table A12.4.2.15: Asynchronous Generating System Control System performance requirements

[A12.4.3.7 (Minimum)] A Generating System, comprised of Asynchronous Generating Units, with a voltage Control System must have a Settling Time of less than 7.5 seconds for a 5% voltage disturbance subject to the Generating Unit being electrically connected to the SWIS and operating at a point where such a voltage disturbance would not cause any limiting device to operate.
</td><td></td></tr>
</table>

<table>
<tr><th>Criteria description</th><th>WEM Rules clause(s)</th><th>Guidance and example statements of compliance</th></tr>
<tr><td>Settling Time (with control output saturation)</td><td> [A12.4.2.11] The performance characteristics required for AC exciter, rotating rectifier and Static Excitation Systems are specified in Table A12.4.2.11.
<table>
<tr><th>Performance Item</th><th>Units</th><th>Static Excitation</th><th>AC exciter or rotating rectifier</th><th>Notes</th></tr>
<tr><td>Settling Time following any disturbance which causes an excitation limiter to operate.</td><td>Second</td><td>5 max</td><td>5 max</td><td>2</td></tr>
<tr><td colspan="5"> Notes: 1. Rated field voltage is that voltage required to give nominal Generating Unit terminal voltage when the Generating Unit is operating at its Rated Maximum Apparent Power. 2. For rotating rectifier excitation system where the field voltage is not accessible for direct measurement, the main exciter field voltage must comply with this clause A12.4.2.11. </td></tr>
</table>
Table A12.4.2.11: Synchronous Generating Unit Excitation Control System performance requirements
[A12.4.2.15] The performance characteristics required for the voltage and Reactive Power Control Systems of all Asynchronous Generating Systems are specified in Table A12.4.2.15. </td><td> Example for Synchronous Generating System:
Settling Time of the controlled parameter in voltage and Reactive Power control mode is no more than 2.5 second following 5% step change in the Control System reference such that it does cause saturation of the controlled output parameter. The Settling Time is met at all operating points within the Reactive Power Capability and between Maximum Rated Active Power and Rated Minimum Active Power.
Example for Asynchronous Generating System:
Settling Time of the controlled parameter in voltage and Reactive Power control mode is no more than 2.5 second following 5% step change in the Control System reference such that it does cause saturation of the controlled output parameter. The Settling Time is met at all operating points within the Reactive Power Capability and between Maximum Rated Active Power and Rated Minimum Active Power. </td></tr>
</table>

<table>
<tr><th>Criteria description</th><th>WEM Rules clause(s)</th><th>Guidance and example statements of compliance</th></tr>
<tr><td></td><td>
<table>
<tr><th>Performance Item</th><th>Units</th><th>Limiting Value</th><th>Notes</th></tr>
<tr><td>Settling Time of the controlled parameter with the Generating System connected to the Transmission System following any disturbance that is large enough to cause the maximum value of the controlled output parameter to be just exceeded.</td><td>Second</td><td>5 max</td><td>2, 3</td></tr>
<tr><td colspan="4">Notes:
1. The step change is 5%, or a lesser value specified by the Network Operator such that it is the largest step change that results in the required Settling Time at the Connection Point.
2. The step change is specified by the Network Operator such that it is the largest step change that results in the required Settling Time at the Connection Point.
3. The step change is to be recorded for future assessment.</td></tr>
</table>
Table A12.4.2.15: Asynchronous Generating System Control System performance requirements
</td><td></td></tr>
<tr><td>Agreed controlled parameters to meet performance</td><td>[A12.4.2.16] The controlled parameters used to meet the requirements specified in Table A12.4.2.15. and measurement of the parameters must be agreed with the Network Operator and AEMO as part of the Generator Performance Standard.</td><td>This statement should be used to re-iterate the control parameters which was selected to apply performance under clause A12.4.2.11 or A12.4.2.15 of the WEM Rules as applicable.
Example:
The controlled parameters used to meet the requirements specified in Table A12.4.2.15. and measurement of the parameters are agreed with the</td></tr>
</table>

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Network Operator and AEMO as part of the Generator Performance Standard.
Reactive Power Control System - limiting devices requirements	**[A12.4.3.5(c)]** A Generating System's Reactive Power or Power Factor Control System must have 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, which are coordinated with all Protection Systems, and must be included as part of the Generator Performance Standard.	Example: *The Generating System is capable of stable operation for indefinite periods while under the control of any limiter. Limiters do not detract from the performance of any stabilising circuits and have settings applied, which are coordinated with all Protection Systems.*
Highest level a Generating System can reasonably achieve	**[A12.4.4.1]** A Proposed Negotiated Generator Performance Standard 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.	The statement of compliance should be a statement on how the Generating System has reasonably achieve the best performance it can possibly achieve.

2.3.4 Technical Requirement: Active Power Control [A12.5]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Compliance with Dispatch Systems Requirements	**[A12.5.1.1]** All Generating Systems must be capable of meeting the Dispatch Systems Requirements.	The Dispatch Systems Requirements are defined in section 2.35 of the WEM Rules. In principle, to meet the Dispatch System Requirements all communications and control system requirements must be specified. Example where the Generating System is not under the direct control of AEMO: *The Generating System meets the Dispatch Systems Requirements.*
Arrangement for Access to limit Active Power output	**[A12.5.1.2]** Any arrangements put in place as part of the Arrangement for Access to limit Active Power output in order to manage constraints on the Network must be included as part of the Generator Performance Standard.	The statement of compliance should specify the Arrangement for Access which the Generating Unit connected under. Examples include but not limited to the Generating System connected being under a partial constrained dispatch scheme (i.e., Generator Interim Access). Example where the Generating System does not have any arrangements: *The Generating System does not have any arrangements in place as part of the Arrangement for Access to limit Active Power output to manage constraints on the Network.*
Control System damping adequacy	**[A12.5.1.3]** Each Control System must be Adequately Damped.	The statement of compliance should specify the damping ratio achieved by the Generating System. The Technical Rule 2.2.8(a) would require a damping ratio no less than 0.1. Example: *The Active Power Control System is Adequately Damped achieving a damping ratio no less than 0.1 and halving time of less than 5 seconds.*
Provision of disconnection settings	**[A12.5.1.4.]** Any relevant disconnection settings must be included as part of the Generator Performance Standard.	The purpose of this clause is to capture those disconnection settings related to Active Power that exist as part of the Arrangement for Access which

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		normally would not be required for most Generating Systems. Examples include but are not limited to the Generating System being connected: - under a fast runback scheme; or - under an inter-trip scheme. Example where there are no relevant disconnection settings: *The Generating System does not have any relevant disconnection settings.* Example where Generating System is part of a post-contingency fast runback scheme: *The Generating System will disconnect by a fast runback scheme whenever any of the following conditions are met:* *(a) When loading on line A is above <pick up level A>.* *(b) When loading on line B is above <pick up level B>.* Example where Generating System is part of an inter-trip scheme: *The Generating System will disconnect from the network following the trip of line A.*
Maintaining Active Power output	**[A12.5.1.5]** Subject to energy source availability and any other agreement by the Network Operator, where dispatch by AEMO a Generating System must be capable of maintaining its Active Power output consistent with its last received dispatch level in the event RME, RCE or Communications are unavailable.	The statement of compliance should only specify if there exist any agreements with Western Power those conditions that permits the Generating System to change its output level RME, RCE or Communication are unavailable. Example: *Subject to energy source availability, the Generating System maintains its Active Power output consistent with its last received dispatch level in the event of Remote Monitoring Equipment, Remote Control Equipment or Communications become unavailable.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
A12.5 requirements do not override Active Power ramping in A12.6	**[A12.5.1.6]** The requirements in this Part A12.5 do not override any specific Active Power ramping requirements specified in Part A12.6 in response to frequency deviations.	Example: *The requirements in this Part A12.5 do not override any specific Active Power ramping requirements specified in Part A12.6 in response to frequency deviations.* .
Compliance when operating at any Range of Active and Reactive Power and Temperature	**[A12.5.1.7]** In relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this Appendix, and at all temperatures up to and including the Maximum Temperature.	*In relation to the application of Active power control, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this GPS, and at all temperatures up to and including the Maximum Temperature of <Maximum Temperature °C>*
Active Power Control System capability	**[A12.5.2.1 (Ideal)]** A Non-Intermittent Generating System within a Transmission Connected Generating System must have an Active Power Control System capable of: (a) maintaining and changing its Active Power output in accordance with Target Setpoints; (b) ramping its Active Power output linearly from one Target Setpoint to another; and (c) in a thermally stable state, changing Active Power output in response to a change in Target Setpoint at a rate not less than 5% of the Rated Maximum Active Power per minute. **[A12.5.3.1 (Minimum)]**, A Non-Intermittent Generating System within a Transmission Connected Generating System must have an Active Power Control System capable of maintaining and changing its Active Power output in accordance with a Target Setpoint, and must be capable of changing Active Power generation at a rate not less than 5% of its Rated Maximum Active Power per minute.	Example for Ideal standard if the Generating System is Non-Intermittent: *Generating System has an Active Power Control System which:* *(a) maintains and changes its Active Power output in accordance with Target Setpoints* *(b) changes its Active Power output linearly from one Target Setpoint to another; and* *(c) in a thermally stable state, Changes Active Power generation in response to a Dispatch Instruction at a rate not less than 5% of the Rated Maximum Active Power per minute.* Example for Intermittent Generator: *N/A as the Generating System is not a Non-Intermittent Generator.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Rate of change of Active Power	**[A12.5.2.2 (Ideal)]** Subject to energy source availability, a Generating System within a Transmission Connected Generating System must be able to change its Active Power output in accordance with Target Setpoints and must not change its Active Power output at a rate greater than 10 MW per minute or 15% of the Rated Maximum Active per minute, whichever is the lower or as agreed with the Network Operator and AEMO. **[A12.5.3.2. (Minimum)]** Subject to energy source availability, an Intermittent Generating System within a Transmission Connected Generating System must ensure that any change of Active Power output in a 5 minute period does not exceed a value agreed with AEMO and the Network Operator.	The statement of compliance should specify: - The ramp rate limit that is achievable to meet the Ideal standard. The limit needs to be able to prevent a change greater than lowest of the following 10 MW per minute or 15% of the Generating System's aggregated Nameplate Rating per minute. - For a negotiated standard, the agreed change in Active Power allowed over a 5minute period. Example for Ideal standard for Non-Scheduled Generator: *Subject to energy source availability, the Generating System does not change its Active Power output by <**X**> MW per minute.* Example for a Non-Scheduled Generator with a negotiated standard: *Subject to energy source availability, the Generating System does not change its Active Power output more and 45 MW over a minute period.* Example statement of compliance for a Scheduled Generator: *N/A as this is Scheduled Generator.*
Compliance of Transmission Connected Generating System with Dispatch Systems Requirements	**[A12.5.2.3]** A Transmission Connected Generating System must be able to meet the Dispatch Systems Requirements.	Example: *The Transmission Connected Generating System meets the Dispatch Systems Requirements.*

2.3.5 Technical Requirement: Inertia and Frequency Control [A12.6]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Control System damping adequacy	**[A12.6.1.1]** All Control Systems must be Adequately Damped.	The statement of compliance should specify the damping ratio achieved by the Generating System. Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/media/4981/power-system-stability-requirements-guideline-20210511.pdf) for further information on Stability requirement and adequate damping. Example: *The Frequency Control System is adequately damped achieving a damping ratio no less than 0.1 and halving time of less than 5 seconds.*
Maximum ramp rate expression requirements	**[A12.6.1.2]** The recorded maximum ramp rate for the Generating System must be expressed as the change in Active Power (measured in MW) achievable across 6 seconds.	The statement of compliance should specify maximum ramp rate for the Active Power as measured as MW/6s. Example: *The recorded maximum ramp rate for the Generating System is expressed as the change in Active Power of* ***<10 MW/6s>.***
Provision of disconnection settings	**[A12.6.1.3]** Any relevant disconnection settings must be provided as part of the Generator Performance Standard.	The statement of compliance should specify disconnection setting relating to Frequency control system of protection scheme implemented with respect to clause A12.6.1.6 of the WEM Rules with agreement with AEMO and Western Power.
Control System testing equipment requirements	**[A12.6.1.4]** Control Systems on Generating Systems that control Active Power must include permanently installed and operational monitoring and recording equipment for key variables including each input and output, and equipment for testing the Control System sufficient to establish its dynamic operational characteristics.	The statement of compliance should specify the key variables that are monitored by highspeed recorders. Example: *The Control Systems of the Generating Systems that control Active Power includes permanently installed monitoring and recording equipment for the*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		following key variables sufficient to establish its dynamic operational characteristics: - ***<Key variable 1>*** - ***<Key variable 2>*** *…* - ***<Key variable n>*** *For testing and establishing its dynamic operational characteristics.*
Control behaviour after frequency control	**[A12.6.1.5]** After having met the relevant requirements for altering and holding Active Power output to arrest and correct changes in power system frequency, the Generating System, or Generating Units where relevant, must adhere to relevant requirements of A12.5 when returning to regular Active Power output (subject to any agreements under A12.6.1.6).	Example: *After having met the relevant requirements for altering and holding Active Power output to arrest and correct changes in power system frequency, the Generating System adheres to relevant requirements of A12.5 when returning to regular Active Power output*
Avoid use of protection or other disconnection schemes unless agreed	**[A12.6.1.6]** Unless otherwise agreed by the relevant Network Operator and AEMO, protection or other schemes that disconnect the Generating System or elements of the Generating System, must not be used in order to meet the requirements of this Part A12.6.	The statement of compliance should specify if it exist any agreement with Western Power AEMO to use protection schemes to achieve requirements in Frequency Control. Example if no agreement exists: *The Generating System does not use protection or other schemes that disconnect the Generating System or elements of the Generating System to meet its Frequency Control requirements.*
Automatic variable Active Power control characteristic	**[A12.6.1.7]** A Generating System must: (a) have an automatic variable Active Power control characteristic; and	The statement of compliance should specify the existence of a: - variable Active Power control that responds to system frequency; or

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	(b) where the Generating System contains a Generating Unit with a Turbine Control System, it must include equipment for both speed and Active Power control.	- Turbine Speed Governor that changes speed and Active Power output in response to system frequency. Example: *The Generating System has an automatic variable Active power control that responds to system frequency.*
Capability for continuous operation in frequency control mode	**[A12.6.1.8]** All Generating Units, or the Generating System, as applicable, must operate in a mode in which it will automatically alter its Active Power output to arrest and correct changes in power system frequency, unless instructed otherwise or approved for testing purposes by AEMO.	The statement of compliance should specify that it will operate mode to arrest system frequency. Example: *The Generating System operates in a mode in which it automatically alters its Active Power output to arrest and correct changes in power system frequency, unless instructed otherwise or approved for testing purposes by AEMO.*
Frequency dead band	**[A12.6.1.9]** The Frequency Dead Band on each Generating Unit, or the Generating System, as applicable, must be no greater than ±0.025 Hz around 50.0Hz.	The statement of compliance should specify the size of the Frequency Dead Band and must centre around 50Hz and cannot be larger than ±0.025Hz. Example: *The Generating System's frequency controller has a Frequency Dead Band of ±0.025Hz around 50Hz.*
Droop response (frequency reduction)	**[A12.6.1.10(a)]** Unless otherwise stated in this Part A12.6, the overall required frequency response of each Generating Unit, or Generating System, as applicable, must be settable and be capable of automatically achieving an increase in Active Power output proportional to a change in power system frequency of not less than 5% of the maximum Active Power specified in the Temperature Dependency Data provided under A12.2 for each 0.1 Hz reduction in power system frequency from the lower level of	The statement of compliance should specify: - The size of active power increase is settable for each reduction in 0.1 Hz change in system frequency. The setting must allow for a change of at least 5% of the Generating System's maximum Active Power specified in the Temperature Dependency Data. - The Minimum Active Power of the Generating System.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	Frequency Dead Band, provided the output is above the Rated Minimum Active Power.	- Example: *The Generating System has frequency droop setting of 2% and automatically achieves an increase in Active Power output proportional to a change in power system frequency of not less than 5% of maximum Active Power as specified in the Temperature Dependency Data provided under A12.2 for each 0.1Hz reduction in power system frequency from the lower level of Frequency Dead Band, provided the output is above the Rated Minimum Active Power of <**X**> MW.*
Droop response (frequency increase)	**[A12.6.1.10(b)]** Unless otherwise stated in this Part A12.6, the overall required frequency response of each Generating Unit, or Generating System, as applicable, must be settable and be capable of automatically achieving a reduction in Active Power output proportional to a change in power system frequency of not less than 5% of the maximum Active Power specified in the Temperature Dependency Data provided under A12.2 for each 0.1 Hz increase in power system frequency from the upper level of Frequency Dead Band, provided this does not require operation below the Rated Minimum Active Power.	The statement of compliance should specify: - The size of active power decrease is settable for each increase in 0.1Hz change in system frequency. The setting must allow for a change of at least 5% of the Generating System's maximum Active Power specified in the Temperature Dependency Data. - The Minimum Active Power of the Generating System. Example: *The Generating System has frequency droop setting of 2% and automatically achieves a decrease in Active Power output proportional to a change in power system frequency of not less than 5% of the maximum Active Power as specified in the Temperature Dependency Data provided under A12.2for each 0.1Hz increase in power system frequency from the lower level of Frequency Dead Band, provided the output is above the Rated Minimum Active Power of <**X**> MW.*
Frequency control response conditions	**[A12.6.1.11]** The frequency response capability described in clause A12.6.1.10:	The statement of compliance should specify the agreed delay for the frequency controller to respond to the initial change to power system frequency.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	(a) must not exhibit any step changes in Active Power as the power system frequency changes, unless otherwise agreed by the relevant Network Operator and AEMO under clause A12.6.1.6; (b) must commence responding with a delay no greater than that required to ensure stable operation or to allow for control system latency, as agreed by the relevant Network Operator and AEMO; (c) must not increase Active Power output in response to an increase in power system frequency; and (d) must not decrease Active Power output in response to a decrease in power system frequency.	Example: *The frequency response of the Generating System incorporates the following:* *(a) does not exhibit step changes in Active Power as power system changes;* *(b) responds with a delay no greater than **<x>** ms that is required to ensure stable operation;* *(c) does not increase Active Power output in response to increase in power system frequency; and* *(d) does not decrease Active Power output in response to decrease in power system frequency.*
Specified Measurement Location for this Technical Requirement	**[A12.6.1.12]** In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	Example: *The Measurement location for the requirements of Inertia and Frequency control is at the connection point* Example when a different Measurement Location is determined: *The Measurement location for the requirements of Inertia and Frequency control of the Generating Unit <**Generating Unit 1 Designation** > is at the Generating Unit Terminal*
Compliance when operating at any Range of Active and	**[A12.6.1.13]** In relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted	Example: *In relation to the application of Inertia and Frequency control, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Reactive Power and Temperature	or required under the other Technical Requirements in this Appendix, and at all temperatures up to and including the Maximum Temperature.	*required under the other Technical Requirements in this GPS, and at all temperatures up to and including the Maximum Temperature of* ***<Maximum Temperature °C>***
Ability to comply with Droop response	**[A12.6.2.1(a) (Ideal)]** The Ideal Generator Performance Standard requires that control ranges, response times and sustain times, are achieved for Generating Units, or the Generating System, as applicable, such that, subject to energy source availability: the required frequency response in clause A12.6.1.10(a) can be complied with for any initial output up to the maximum Active Power specified in the Temperature Dependency Data provided under A12.2 for the relevant temperature; **[WEM A12.6.3.2.(a) & (b) (Minimum)]** Subject to energy source availability, a Generating System is required to have control ranges and response times for each Generating Unit, or Generating Systems as applicable, such that: (a) it is able to comply with the required frequency response specified in clause A12.6.1.10(a), up to 85% of Rated Maximum Active Power output; and (b) for initial outputs above 85% of Rated Maximum Active Power output, each Generating Unit's or Generating System's, as applicable, response capability must be agreed with the relevant Network Operator and AEMO and included as part of the relevant Generator Performance Standard.	The statement of compliance should specify: - The control range which the Generating System will respond to changes in power system frequency. For Ideal standard the Generating System should achieve a response that will not prevent it to achieve its Minimum Rated Power or maximum Active Power specified in the Temperature Dependency Data from any initial output level, subject to energy source availability. - For a negotiated standard, whether the response of the Generating System cannot achieve a response up to its Rated Maximum Active Power output then it should state a % value of the Rated Maximum Active Power. The % value must be at least 85%. - For initial outputs above the 85% or aforementioned % value then state the agreed response. For example, the agreed response maybe that the Generating System will maintain its initial output level for a reduction in power system frequency. Example for Ideal standard: *Subject to energy source availability, the Generating System complies with the frequency response required in clause A12.6.1.10(a) for any initial output up to maximum Active Power as specified in the Temperature Dependency Data provided under A12.2.* Example for the negotiated standard where Western Power and AEMO agreed that that for an initial Active Power output above 85% of Rated Maximum Active Power the Generating System will maintain constant Active Power output:

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Subject to energy source availability, the Generating System: *a) complies with the frequency response required in clause A12.6.1.10(a) for any initial output up to 85% of Rated Maximum Active Powe output; and* *b) maintains constant Active Power output in response to any frequency disturbance for initial Active Power output above 85% of Rated Maximum Active Power.*
Rate of response	**[A12.6.2.1(b) (Ideal)]** The Ideal Generator Performance Standard requires that control ranges, response times and sustain times, are achieved for Generating Units, or the Generating System, as applicable, such that, subject to energy source availability: (b) for Synchronous Generating Systems, for any frequency disturbance where the change in power system frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power, the Generating Unit or Generating System achieves at least 90% of the required frequency response specified in clause A12.6.1.10 within 6 seconds. **[A12.6.3.2(c) (Minimum)]** Subject to energy source availability, a Generating System is required to have control ranges and response times for each Generating Unit, or Generating Systems as applicable, such that: (c) for Synchronous Generating Systems, for any frequency disturbance where the change in frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power output, the Generating Unit or Generating System achieves at least 60% of the required frequency response specified in clause A12.6.1.10 within 6 seconds, and 90% of the required frequency response specified in clause A12.6.1.10 within 15 seconds. **[A12.6.2.1(c) (Ideal)]** The Ideal Generator Performance Standard requires that control ranges, response times and sustain times, are achieved for	The statement of compliance should specify: - The % value of the required response for a change in power system frequency. For the ideal standard the % value should be 90%. For negotiated standard it allows for two different values at different response times, for the first response it must achieve at least 60% of final response within 6 seconds, then 90% of its response within 15 seconds. - The % change value of Maximum Rated Active Power. The % change value must be at most 5%. Example for the Ideal standard for a Synchronous Generating Unit: *For any frequency disturbance where the change in power system frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power, the Generating System achieves at least 90% of the required frequency response specified in clause A12.6.1.10 within 6 seconds.* Example for the Ideal standard for an Asynchronous Generating System: *For any frequency disturbance where the change in power system frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power, the Generating System achieves at least 90% of the required frequency response specified in clause A12.6.1.10 within 2 seconds.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	Generating Units, or the Generating System, as applicable, such that, subject to energy source availability: (c) for Asynchronous Generating Systems, for any frequency disturbance where the change in power system frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power, the Generating Unit or Generating System achieves at least 90% of the required frequency response specified in clause A12.6.1.10 within 2 seconds. **[A12.6.3.2(d) (Minimum)]** Subject to energy source availability, a Generating System is required to have control ranges and response times for each Generating Unit, or Generating Systems as applicable, such that (d) for Asynchronous Generating Systems, for any frequency disturbance where the change in frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power output, the Generating Unit or Generating System achieves at least 60% of the required frequency response specified in clause A12.6.1.10 within 6 seconds, and at least 90% of the required frequency response specified in clause A12.6.1.10 within 15 seconds.	Example for the negotiated standard to be at Minimum: *For any frequency disturbance where the change in power system frequency is sufficient to change the Active Power of the Generating System by at least 5% of its Rated Maximum Active Power, the Generating System achieves at least 60% of the required frequency response specified in clause A12.6.1.10 within 2 seconds.*
Capability to sustain frequency response	**[A12.6.2.1(d) & (e) (Ideal)]** The Ideal Generator Performance Standard requires that control ranges, response times and sustain times, are achieved for Generating Units, or the Generating System, as applicable, such that, subject to energy source availability: d) the required frequency response specified in clause A12.6.1.10 is sustained for not less than a further 10 seconds beyond the timeframes specified in clause A12.6.2.1(b) and clause A12.6.2.1(c), as applicable, subject to a restoration of power system frequency in which case the Active Power output must be changed in proportion to the power system frequency in accordance with the required frequency response specified in clause A12.6.1.10; and	The statement of compliance should specify: - The duration the Generating System can sustain its required droop response after it has achieved 90% of its required output. The duration must be at least 10 seconds. - Where the Generating System can sustain the response further than 10 seconds then it should state how much further. Example for Asynchronous Generating System at the Ideal standard with frequency response for 25 seconds and coming back to Active Power as per dispatch instruction afterwards: *Subject to energy source availability:*

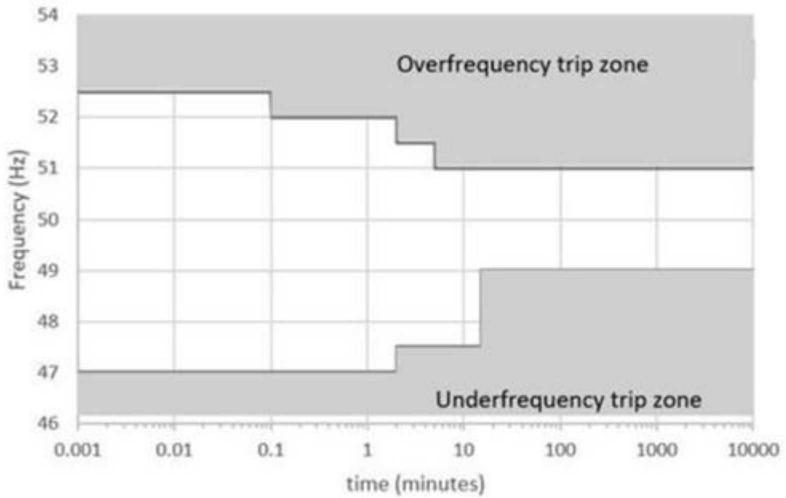
Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	e) each Generating Unit's or Generating System's, as applicable, capability to sustain response beyond the timeframe specified in clause A12.6.2.1(d) must be included as part of the relevant Generator Performance Standard. **[A12.6.3.2(e) & (f) (Minimum)]** Subject to energy source availability, a Generating System is required to have control ranges and response times for each Generating Unit, or Generating Systems as applicable, such that: (e) the required frequency response specified in clause A12.6.1.10 is sustained for not less than a further 10 seconds beyond the latest timeframe specified in clause A12.6.3.2(c) and clause A12.6.3.2(d), as applicable, subject to a restoration of power system frequency in which case the Active Power output must be changed in proportion to the power system frequency in accordance with the required frequency response specified in clause A12.6.1.10; and (f) each Generating Unit's or Generating System's, as applicable, capability to sustain response beyond the timeframe specified in clause A12.6.3.2(e) must be included as part of the relevant Generator Performance Standard.	*a) the Generating System sustains the required frequency response specified in clause A12.6.1.10 for not less than a further 10 seconds beyond the timeframes specified in clause A12.6.2.1(c), subject to a restoration of power system frequency in which case the Active Power output is changed in proportion to the power system frequency in accordance with the required frequency response specified in clause A12.6.1.10; and* *b) Subject to a restoration of power system frequency, Generating System maintains its frequency response specified in section a) of this statement of compliance for further 15 seconds and after that time Active Power output is changed in proportion to the power system frequency in accordance with the required frequency response specified in clause A12.6.1.10 and A12.6.2.1(c).*
Active Power and its rate of change requirements	**[A12.6.4.1]** A Negotiated Generator Performance Standard must require that there is no requirement for a Generating System to operate with an Active Power output: (a) below its Rated Minimum Active Power in response to a rise in the frequency of the SWIS as measured at the Connection Point; (b) above its the relevant maximum Active Power output specified in the Temperature Dependency Data provided under A12.2 for the relevant temperature, in response to a fall in the frequency of the SWIS as measured at the Connection Point; or	These are negotiation conditions of performance standard. The Market Participant should state how this requirement was applied in the negotiation. Example: *The Negotiated Generator Performance Standard meets the negotiation criteria.*

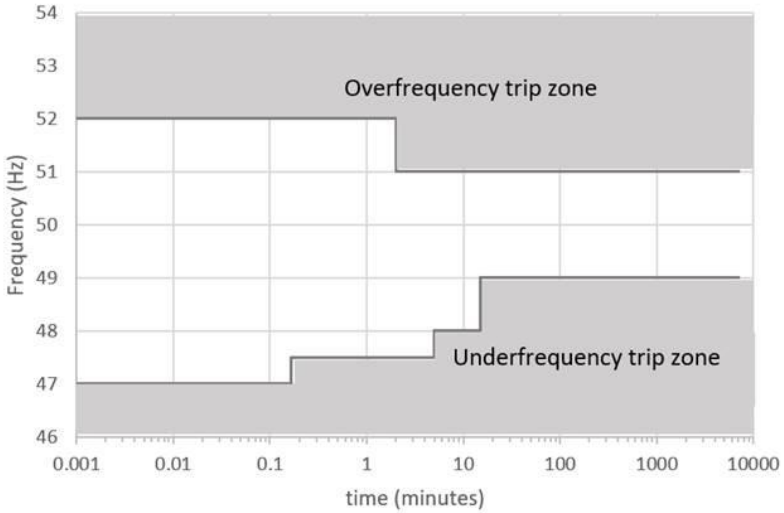
Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	(c) to deliver a rate of change in output exceeding the specified maximum ramp rate.	
Requirements of additional source of inertia and frequency control	**[A12.6.4.2]** An additional source of Inertia or frequency control may be included within the Generating System. The Control System for the additional source of Inertia or frequency control must be coordinated with the remainder of the Generating System and, together, must meet the performance requirements of the relevant Technical Requirements.	This is applicable if the Generating System has multiple sources of inertia and frequency control (e.g., installation of a flywheel). Example where there are additional source of Inertia and frequency control: *The Generating System coordinates the response from its <**Additional source of Inertia specific technology**> and Generating Units to meet the frequency control requirements.*

2.3.6 Technical Requirement: Disturbance Ride Through for a Frequency Disturbance [A12.7]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Specified network location for this Technical Requirement	**[A12.7.1.1]** In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	The statement of compliance should specify the location which frequency is monitored when access compliance with the Agreed Generator Performance Standard. Example: *The Generating System response to Disturbance Ride Through requirements for a Frequency Disturbance apply at the Connection Point.*
Provision of disconnection settings	**[A12.7.1.2]** Any relevant disconnection settings must be provided as part of the Generator Performance Standard.	The statement of compliance should specify disconnection setting of frequency-based protection elements that include, for example: - Under Frequency - Over Frequency - Rate of Change of Frequency - Vector Surge It should also include, where applicable, disconnection settings.
Schemes agreed as part of A12.6 are not taken to be a breach of A12.7	**[A12.7.1.3]** Where the relevant Network Operator and AEMO have agreed to a protection, or other scheme, that will disconnect the Generating System or elements of the Generating System, to satisfy the requirements of Part A12.6, the operation of those schemes based on their agreed parameters will not be taken to be a breach of the requirements of this Part A12.7.	The statement of compliance should specify any agreements of protection settings and network conditions which the protection schemes are active. Example where no agreements exist: *There are no agreements with Western Power and AEMO for the Generating System to have a protection, or other scheme, that disconnects the Generating System or its elements, in order to satisfy the Technical Requirement for Inertia and Frequency Control from Part A12.6 of these Generator Performance Standards.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Compliance when operating at any Range of Active and Reactive Power	**[A12.7.1.4]** In relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this Appendix.	Example: *In relation to the application of Disturbance Ride Through for a Frequency Disturbance, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this GPS.*
Continuous Uninterrupted Operation - frequency requirements	**[A12.7.2.1 (Ideal)]** A Generating System must maintain Continuous Uninterrupted Operation where a power system disturbance causes the frequency to: a) reach 52.5 Hz for a period of up to 6 seconds; b) reach 52 Hz for a period of up to 2 minutes; c) reach 51.5 Hz for a period of up to 5 minutes; d) operate between 49.0 Hz to 51.0 Hz continuously; e) reach 47.5 Hz for a period of up to 15 minutes; or f) reach 47.0 Hz for a period of up to 2 minutes, as shown in Figure A12.7.2.1.	The statement of compliance should specify explicitly the over/under frequency levels and durations which the Generating System can maintain Continuous Uninterrupted Operation for any condition. Example for Ideal standard: *The Generating System remains in continuous Uninterrupted Operation where a power system disturbance causes frequency to:* *(a) reach 52.5Hz for a period of up to 6 seconds;* *(b) reach 52Hz for a period of up to 2 minutes;* *(c) reach 51.5Hz for a period of up to 5 minutes;* *(d) operate between 49.0Hz to 51.0Hz continuously;* *(e) reach 47.5Hz for a period of up to 15 minutes; or* *(f) reach 47.0Hz for a period of up to 2 minutes.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	 **Figure A12.7.2.1 Frequency variations that a Generating System must ride through to meet the Ideal Generator Performance Standard** **[A12.7.3.1 (Minimum)]** A Generating System must maintain Continuous Uninterrupted Operation where a power system disturbance causes the frequency to: (a) reach 52.0 Hz for a period of up to 2 minutes; (b) operate between 49.0 Hz to 51.0 Hz continuously; (c) reach 48.0 Hz for a period of at least 15 minutes; (d) reach 47.5 Hz for a period of at least 5 minutes; or (e) reach 47.0 Hz for a period of at least 10 seconds, as shown in Figure A12.7.3.1.	

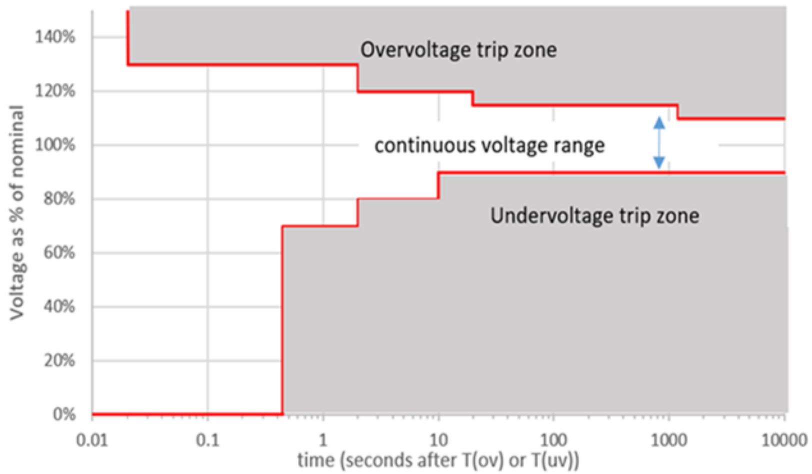
Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	 **Figure A12.7.3.1: Frequency variations that a Generating System must ride through to meet the Minimum Generator Performance Standard**	
Continuous Uninterrupted Operation - ROCOF requirements	**[A12.7.2.2 (Ideal)]** A Generating System must maintain Continuous Uninterrupted Operation where a power system disturbance causes the RoCoF to: (a) reach 4 Hz/s over 250 milliseconds during the disturbance; or (b) reach 3 Hz/s over 1 second during the disturbance. **[A12.7.3.2 (Minimum)]** A Generating System must maintain Continuous Uninterrupted Operation where a power system disturbance causes the RoCoF to: (a) reach 2 Hz/s over 250 milliseconds during the disturbance; or	The statement of compliance should specify the frequency rate or change limits and durations that the Generating System can maintain Continuous Uninterrupted Operation. Example for Ideal standard: *The Generating System will remain in Continuous Uninterrupted Operation for any power system disturbance that causes the RoCoF to:* *(a) reach 4 Hz/s over 250 milliseconds during the disturbance; or* *(b) reach 3 Hz/s over 1 second during the disturbance.*

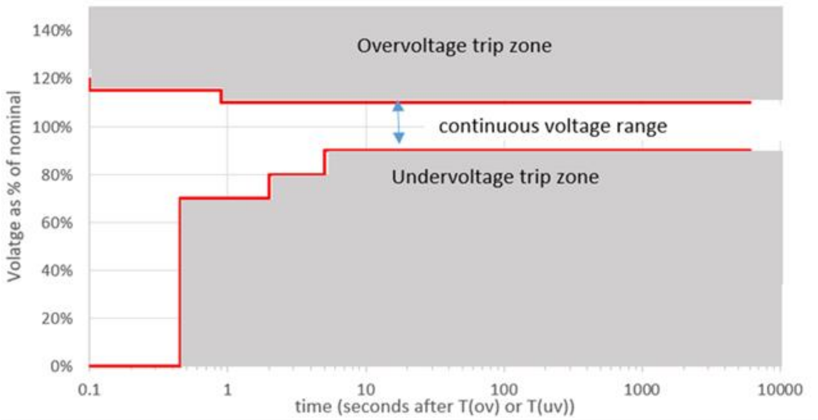
Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	(b) reach 1 Hz/s over 1 second during the disturbance.	
Agreement about frequency fall below described bound	**[A12.7.4.1]** A Proposed Negotiated Generator Performance Standard for disturbance ride through for a frequency disturbance may be accepted provided the Network Operator and AEMO agree that the frequency would be unlikely to fall below the lower bound of the single contingency event band specified in the Frequency Operating Standard.	This is a requirement that constrains the how a Propose Negotiated Generator Performance Standard. The statement of compliance should specify how it was applied.

2.3.7 Technical Requirement: Disturbance Ride Through for a Voltage Disturbance [A12.8]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Specified network location for this Technical Requirement	**[A12.8.1.1]** In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	The statement of compliance should specify the location where voltage is monitored when access compliance with the Agreed Generator Performance Standard. Example: *The Generating System response to Disturbance Ride Through requirements for a Voltage Disturbance apply at the Connection Point.*
Continuous Uninterrupted Operation - 90% < nominal voltage < 110%	**[A12.8.1.2]** The Generating System and each of its operating Generating Units is required to remain in Continuous Uninterrupted Operation while the Connection Point voltage remains within 90% to 110% of nominal voltage.	Example: *The Generating System remains in Continuous Uninterrupted operation while the Connection Point voltage remains within 90% and 110% of nominal voltage.*
Provision of disconnection settings	**[A12.8.1.3]** Any relevant disconnection settings must be provided as part of the Generator Performance Standard.	The statement of compliance should specify disconnection setting of voltage magnitude-based protection elements that include, for example: - Under voltage - Over voltage This should be accompanied by disconnection settings where applicable.
Compliance when operating at any Range of Active and Reactive Power	**[A12.8.1.4]** In relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this Appendix.	*Example* *In relation to the application of the Disturbance Ride Through for a voltage Disturbance, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this GPS.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Continuous Uninterrupted Operation - specified voltage ranges	**[A12.8.2.1 (Ideal)]** A Generating System must maintain Continuous Uninterrupted Operation where a power system disturbance causes the voltage to vary within the following ranges: (a) voltage exceeds 130% of nominal voltage for not more than 0.02 seconds after T(ov); (b) voltage does not exceed 120% of nominal voltage for more than 2.0 seconds after T(ov); (c) voltage does not exceed 115% of nominal voltage for more than 20.0 seconds after T(ov); (d) voltage does not exceed 110% of nominal voltage for more than 20.0 minutes after T(ov); (e) voltage remains at 0% of nominal voltage for no more than 450 milliseconds after T(ov); (f) voltage does not stay below 70% of nominal voltage for more than 450 milliseconds after T(uv); (g) voltage does not stay below 80% of nominal voltage for more than 2.0 seconds after T(uv); and (h) voltage does not stay below 90% of nominal voltage for more than 10.0 seconds after T(uv). Where: **T(ov)** means a point in time when the voltage first varied above 110% of nominal voltage before returning to between 90% and 110% of nominal voltage; and	The statement of compliance should specify the voltage levels and durations which the Generating System was designed to maintain Continuous Uninterrupted Operation. Example: *The Generating System remain in Continuous Uninterrupted Operation where a power system disturbance causes the voltage to vary within the following ranges:* *(a) voltage exceeds 130% of nominal voltage for not more than 0.02 seconds after T(ov);* *(b) voltage does not exceed 120% of nominal voltage for more than 2.0 seconds after T(ov);* *(c) voltage does not exceed 115% of nominal voltage for more than 20.0 seconds after T(ov);* *(d) voltage does not exceed 110% of nominal voltage for more than 20.0 minutes after T(ov);* *(e) voltage remains at 0% of nominal voltage for no more than 450 milliseconds after T(ov);* *(f) voltage does not stay below 70% of nominal voltage for more than 450 milliseconds after T(ov);* *(g) voltage does not stay below 80% of nominal voltage for more than 2.0 seconds after T(ov);* *(h) voltage does not stay below 90% of nominal voltage for more than 10.0 seconds after T(ov).*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	T(uv) means a point in time when the voltage first varied below 90% of nominal voltage before returning to between 90% and 110% of nominal voltage.  **Figure A12.8.2.1: Voltage variations that a Generating System must ride through to meet the Ideal Generator Performance Standard** **[A12.8.3.1]** A Generating System must maintain Continuous Uninterrupted Operation where a power system disturbance causes the voltage to vary within the following ranges: (a) voltage does not exceed 120% of nominal voltage after T(ov); (b) voltage does not exceed 115% of nominal voltage for more than 0.1 seconds after T(ov); (c) voltage does not exceed 110% of nominal voltage for more than 0.9 seconds after T(ov);	

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	(d) voltage remains at 0% of nominal voltage for no more than 450 milliseconds after T(uv) subject to clause A12.8.3.2; (e) voltage does not stay below 70% of nominal voltage for more than 450 milliseconds after T(uv); (f) voltage does not stay below 80% of nominal voltage for more than 2.0 seconds after T(uv); and (g) voltage does not stay below 90% of nominal voltage for more than 5.0 seconds after T(uv). Where: **T(ov)** means a point in time when the voltage first varied above 110% of nominal voltage before returning to between 90% and 110% of nominal voltage; and **T(uv)** means a point in time when the voltage first varied below 90% of nominal voltage before returning to between 90% and 110% of nominal voltage.  	

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	Figure A12.8.3.3: Voltage variations that a Generating System must ride through to meet the Minimum Generator Performance Standard	
Agreement of zero percent voltage level duration	**[A12.8.3.2]** The duration of the zero percent voltage level may be relaxed through agreement with the Network Operator and AEMO but shall not be lower than the maximum Total Fault Clearance Time with no circuit breaker fail as specified in the Technical Rules.	The statement of compliance should specify: - The agreement with Western Power and AEMO to reduce the time for zero percent voltage below minimum standard in clause A12.8.3.1 of the WEM Rules. - The maximum Total Fault Clearance time with no circuit breaker fail which could result in zero percent voltage level. This should also be reflected in the statement of compliance for the *Continuous Uninterrupted Operation - specified voltage ranges* requirement. The agreement with Western Power and AEMO should be attached with the GPS submission. Example: *The duration of the zero percent voltage level from the clause A12.8.2.1.is relaxed to 390 ms on the basis that Western Power and AEMO agreed that Total Fault Clearance Time with no circuit breaker fail as specified in the Technical Rules is 390 ms* Example where no agreement exists: *There is no agreement to relax the zero percent voltage level condition duration below 450 milliseconds.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Provision of operational arrangements	**[A12.8.3.3]** Any operational arrangements necessary to ensure the Generating System and each of its operating Generating Units will meet its Generator Performance Standard must be provided as part of the Generator Performance Standard.	The statement of compliance should specify all operation arrangement that are required for the Generating System to meet the requirements in its agreed Disturbance Ride Through for a Voltage Disturbance Performance Standard. This could include: - Adjusting internal voltages within the Generating System to ensure internal equipment can remain connected during and following the disturbance. - Constraining output (if required) during specific network conditions.

2.3.8 Technical Requirement: Disturbance Ride Through for Multiple Disturbances [A12.9]

The following documents/specification to be submitted with the GPS Submission:

- Protection Systems Design and Setting Data as per the format outlined in Attachment 5 of the Technical Rules
- Agreed Operational Agreement during abnormal network conditions where applicable
- The location specified by Western Power that is required under clause A12.9.5, A12.9.5.6, A12.9.2.4(a), A12.9.2.4(b) and A12.9.3.4(a) of the WEM Rules
- Calculation of the Maximum Continuous Current required under clause A12.9.5, A12.9.6, A12.9.2.4(a), A12.9.2.5(a), A12.9.3.5(a) and A12.9.2.8 of the WEM Rules where applicable
- For Asynchronous Generating Systems 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 Technical Requirement required under clause A12.9.5.6.(c) of the WEM Rules

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Provision of disconnection settings	**[A12.9.1.2]** Any relevant disconnection settings must be provided as part of the Generator Performance Standard.	Example: *The disconnection settings for the Generating System are provided in the attached Protection Systems Design and Setting Data,* ***<attachment file reference>****.*
Operational arrangement under abnormal conditions	**[A12.9. 1.3]** The Generator 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.	If operational agreements exist, then outline the agreement using WEM Rules terminology. Example where no agreement is in place: *There are no operational arrangements for the Generating System under abnormal Network or Generating System conditions.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Operation of auto-reclose requirement	**[A12.9.1.4]** When assessing multiple disturbances, a fault that is re-established following operation of automatic reclose Protection Scheme shall be counted as a separate disturbance.	When assessing multiple disturbances, a fault that is re-established following operation of automatic reclose Protection Scheme is counted as a separate disturbance.
Reactive current contribution capability	**[A12.9.1.5]** For a Generating System comprised solely of Synchronous Generating Units, the reactive current, must be equal or exceed 250% of the Maximum Continuous Current of the Generating System. For a Synchronous Generating Unit in any other Generating System, the reactive current contribution must equal or exceed 250% of the Maximum Continuous Current of that Synchronous Generating Unit. **[A12.9.1.6]** For a Generating System comprised of Asynchronous Generating Units: (a) the reactive current contribution must equal or exceed the Maximum Continuous Current of the Generating System, including all operating Asynchronous Generating Units; (c) 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 the Network Operator for the types of disturbances specified in this Technical Requirement; and (d) the Generator Performance Standard must record all conditions (which may include temperature) considered relevant by AEMO and the Network Operator under which the reactive current response is required.	Example for Synchronous Generating System *The Generating System provides at the Measurement Lcoation reactive current of at least 250% during a voltage disturbance of its Maximum Continuous Current, <**calculated Maximum Continuous Current**> kA.* Example for Synchronous Generating System if assessment location is at the Synchronous Generating Unit terminals as specified by Western Power: *The Generating Unit can provide at its terminal, reactive power contribution greater than 250% of its Maximum Continuous Current, <**calculated Maximum Continuous Current**> kA.* Example for a Generating System which partially comprises of Synchronous Generating Units: *The Synchronous Generating Unit <**unit designation**> within the Generating System is capable of providing at the Measurement Location the reactive current of at least 250% of Maximum Continuous Current of this Synchronous Generating Unit, <**calculated Maximum Continuous Current**> kA.* For Asynchronous Generating Units, the statement of compliance should specify: - The agreed negative sequence and positive sequence component ratio in the reactive current contribution for different types of faults. - The agreed network and environmental conditions which may impact the amount of reactive current contribution.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example for Asynchronous Generating System: *The Generating System:* *(a) Provides a reactive current contribution at the Measurement Location of at least its Maximum Continuous Current, <**calculated Maximum Continuous Current>** kA.* *(b) The ratio of negative sequence k-factor and positive sequence k-factor for the disturbance type is tabulated below:* - *Single Phase Fault the ratio is <k_{neg}/k_{pos}>* - *Phase to Phase Fault the ratio is <k_{neg}/k_{pos}>* - *Phase to Phase to Ground Fault ratio is <k_{neg}/k_{pos}>* *(c) Has the following conditions which impacts its ability to provide reactive current contribution:* • *Temperature: <expression to calculate maximum reactive current contribution>*
Specified Measurement Location for this Technical Requirement	**[A12.9.1.7] I**n relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	Example: *The Measurement location for the requirements of Disturbance Ride Through for Multiple Disturbances is at the <Connection Point>*
Compliance when operating at any Range of Active and Reactive Power and	**[A12.9.1.8]** In relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this Appendix, and the Market Participant responsible for the Transmission Connected	Example: *In relation to the application of Disturbance Ride Through for Multiple Disturbances, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
any Specific Thermal Limit	Generating System must specify any thermal limitations that may limit the output of the Generating System or Generating Unit in relation to this Technical Requirement	*Power level as permitted or required under the other Technical Requirements in this GPS.*
Continuous Uninterrupted Operation – Specified Disturbance Requirements	**[A12.9.2.2 (Ideal)]** A Generating System and each of its operating Generating Units must remain in Continuous Uninterrupted Operation for any disturbances caused by: a) a Credible Contingency; b) a three-phase fault in a Transmission System cleared by all relevant primary Protection Systems; and c) 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 clause A12.9.2.2.(c)(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 SWIS by removing Network elements from service or as a result of the operation of an existing inter-trip, Protection Scheme or runback scheme approved by the Network Operator and AEMO. **[A12.9.3.2 (Minimum)]** A Generating System and each of its operating Generating Units must remain in Continuous Uninterrupted Operation for any disturbance caused by: (a) a Credible Contingency; or (b) a single phase to ground, phase to phase or two-phase to ground fault or three phase fault in a transmission or distribution system	Example: *The Generating System and all its operating Generating Units remains in Continuous Uninterrupted Operation for any disturbances caused by:* *a) a Credible Contingency;* *b) a three-phase fault in a Transmission System cleared by all relevant primary Protection Systems; and* *c) 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 clause A12.9.2.2.(c)(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 SWIS by removing Network elements from service or as a result of the operation of an existing inter-trip, Protection Scheme or runback scheme approved by Western Power and AEMO*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	cleared in the longest time expected to be taken for all relevant primary Protection Systems to clear the fault, provided that the event is not one that would disconnect the Generating Unit from the SWIS by removing Network elements from service or as a result of the operation of an inter-trip, Protection Scheme or runback scheme approved by the Network Operator and AEMO.	
Continuous Uninterrupted Operation - series of disturbances requirements	**[A12.9.2.3 (Ideal)]** A Generating System and each of its operating Generating Units must remain in Continuous Uninterrupted Operation for a series of up to 15 disturbances within any 5-minute period. **[A12.9.3.3 (Minimum)]** A Generating System and each of its operating Generating Units must remain in Continuous Uninterrupted Operation for a series of up to 6 disturbances within any 5-minute period.	The number of sequential disturbances within close time proximity that a Generating System can remain Continuous Uninterruptible Operation is typically programmed into protection scheme or controller firmware. The statement of compliance should specify: - The number of disturbances it can remain connected whilst meeting all other technical requirements. For Ideal standard this number must be at least 15, and for negotiated the number must be at least 6. - The time frame which the number of disturbances may occur, this time frame must be at most 5 minutes. Example for Ideal standard: *The Generating System remains in Continuous Uninterruptable Operation for a series of up to 15 any disturbances from the clause A12.9.2.2 within any 5-minute period.* Example for a negotiated standard at Minimum: *The Generating System remains in Continuous Uninterruptable Operation for a series of up to 6 any disturbances from the clause A12.9.2.2within any 5-minute period.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Reactive current contribution during the fault	**[A12.9.2.4(a) (Ideal)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, a Generating System comprised of Synchronous Generating Units, in respect of the faults referred to in clause A12.9.2.2, must supply to, or absorb from, the Network: (a) 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 or another agreed location in the SWIS (including within the Generating System) during the fault. **[A12.9.2.5.(a) (Ideal)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generation System's reasonable control, a Generating System comprised of Asynchronous Generating Units, for the faults referred to in clause A12.9.2.2, must have equipment 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 a specified threshold level within the under-voltage range of 85% to 90% of nominal voltage, except where a Generating System is directly connected to the SWIS with no step-up or connection Transformer and voltage at the Connection Point is 5% or lower of nominal 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	For Synchronous Generating Systems, the statement of compliance should specify: - For Ideal standard only, the Generating System must increase capacitive reactive current greater than the pre-fault level. - Output a % value of the Maximum Continuous Current for each 1% reduction in the pre-fault voltage at agreed location. The % value must be at least 4% to achieve ideal, otherwise it is a negotiated standard. Example for Synchronous Generating Systems for Ideal standard: *Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, for faults referred to in clause A12.9.2.2, the Generating System comprised of Synchronous Generating Units is capable of supplying to, or absorbing 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 or another agreed location in the SWIS (including within the Generating System) during the fault.* For Asynchronous Generating Systems, the statement of compliance should specify: - If the Generating System is connected via a step-up or connection transformer, the under-voltage threshold within the range between an upper UV % value and lower UV % value of nominal voltage at the agreed location. For the ideal standard the threshold value should be between the upper UV % value of 90% and the lower UV % value of 85%. For the negotiated standard, the threshold value should be between the upper UV % value of 90% and the lower UV % value of

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	absence of a disturbance) for each 1% increase of voltage at the Connection Point above a specified threshold level within the over-voltage range of 110% to 115% of nominal voltage, during the disturbance and maintained until Connection Point voltage recovers to between 90% and 110% of nominal voltage, or such other range agreed with the Network Operator and AEMO. **[A12.9.2.6 (Ideal)]** The under-voltage and over-voltage range referred to in clause A12.9.2.5(a)(i) and clause A12.9.2.5(a)(ii) may be varied with the agreement of the Network Operator and AEMO (provided the magnitude of the range between the upper and lower bounds remains at 5%). **[A12.9.3.5(a) (Minimum)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, a Generating System comprised of Asynchronous Generating Units, for the faults referred to in clause A12.9.3.2, must have equipment 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 a specified threshold level agreed by the Network Operator and AEMO within the under-voltage range of 80% to 90% of nominal voltage, except where 1. voltage at the Connection Point is 15% or lower of nominal voltage; or 2. where the Generating System is directly connected to the SWIS with no step-up or connection Transformer and voltage at the Connection Point is 20% or lower of nominal voltage; and	80% but if the threshold is below 85% it must be agreed by Western Power and AEMO. - If the Generating System is directly connected to the SWIS without a step-up or connection transformer, the % deviation value from agreed location's nominal voltage. For the ideal standard the % deviation value is 5% of the Connection Point nominal voltage. - the level of additional capacitive reactive current that can be injected by the Generating System as a % value of Maximum Continuous Current the Generating System can provide during a fault for each 1% drop between the upper UV % value and lower UV % value, or below % deviation where applicable. - The over-voltage threshold within the range between the lower OV % value can upper OV % value of nominal voltage at the agreed location. For the ideal standard the threshold value should be between lower OV % value of 110% and the upper OV% value of 115%. For the negotiated standard the threshold value should be between lower OV % value of 110% and the upper OV% value of 120% and if the threshold is above 115% it must be agreed by Western Power and AEMO. - the level of additional reactive current as a % value of Maximum Continuous Current for each 1% the agreed location's voltage is above the lower OV % value up to the upper OV % value. - The agreed range of for post-fault voltage recovery. For Ideal Standard it must be between 90% and 110% of nominal. - If negotiating for a standard between ideal and minimum a cut-of-voltage in % value can be specified which additional capacitive current is not required to be provided. The cut-of-voltage cannot be lower than 15% if Generating System connected via a step-up or connection transformer; or 20% if Generating System is directly connected to the SWIS without a step-up or connection transformer.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	(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 a specified threshold level agreed by the Network Operator and AEMO within the over-voltage range of 110% to 120% of nominal voltage, during the disturbance and maintained until the Connection Point voltage recovers to between 90% and 110% of nominal voltage, or such other range agreed with the Network Operator and AEMO. **[A12.9.3.6 (Minimum)]** The under-voltage and over-voltage range referred to in clause A12.9.3.5(a)(i) and clause A12.9.3.5(a)(ii) may be varied with the agreement of the Network Operator and AEMO (provided the magnitude of the range between the upper and lower bounds remains at 10%).	Example for Generating System connected via a step-up or connection transformer for Ideal standard: *Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, the Generating System, for the faults referred to in clause A12.9.2.2, supplies or absorbs from, the Network during the disturbance and maintained until Connection Point voltage recovers to between 90% and 110% of nominal voltage:* *a) capacitive reactive current in addition to its pre-disturbance level of at least 4% of the Maximum Continuous Current of the Generating System for each 1% reduction of voltage at the Connection Point below the < **Threshold level%** > of nominal voltage, and* *b) inductive reactive current in addition to its pre-disturbance level of at least 6% of the Maximum Continuous Current of the Generating System for each 1% increase of voltage at the Connection Point above < **Threshold level%** of nominal voltage.*
Reactive Power requirements after the fault clearance	**[A12.9.2.4(b)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, a Generating System comprised of Synchronous Generating Units, in respect of the faults referred to in clause A12.9.2.2, must supply to, or absorb from, the Network after clearance of the fault, Reactive Power sufficient to ensure that the Connection Point voltage or another agreed location in the SWIS (including within the Generating System) is within the range for Continuous Uninterrupted Operation.	Example: *The Generating System after the fault is cleared, subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, continues to inject or absorb reactive power to ensure that the voltage at the Measurement Location remains within the range for Continuous Uninterrupted Operation*
Active Power recovery after the fault clearance	*Synchronous Generating Systems* **[A12.9.2.4.(c) (Ideal)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, a Generating System comprised of Synchronous Generating Units, in respect of the faults referred to in clause A12.9.2.2,	The statement of compliance for Synchronous Generating Systems, should specify: - A time frame following fault clearance the Synchronous Generating System can return to post-fault steady state active power level. For ideal this time frame must be no longer than 100 milliseconds. For

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	must supply to, or absorb from, the Network from 100 milliseconds after clearance of the fault, Active Power of at least 95% of the level existing just prior to the fault. **[A12.9.3.4.(a) & (b) (Minimum)]** After clearance of a fault, a Generating System comprised of Synchronous Generating Units, in respect of the faults referred to in clause A12.9.3.2 must: (a) deliver Active Power to the Network, and supply or absorb leading or lagging Reactive Power, sufficient to ensure that the Connection Point voltage or another location in the SWIS (including within the Generating System), as specified by the Network Operator, is within the range for Continuous Uninterrupted Operation agreed under the relevant Generator Performance Standard; and (b) return to at least 95% of the pre-fault Active Power output within a period of time agreed by AEMO and the Network Operator. **[A12.9.2.5.(b) (Ideal)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generation System's reasonable control, a Generating System comprised of Asynchronous Generating Units, for the faults referred to in clause A12.9.2.2, must have equipment capable of supplying to, or absorbing from, the Network: b) 100 milliseconds after clearance of the fault, Active Power of at least 95% of the level existing just prior to the fault. **[A12.9.3.5.(b) (Minimum)]** Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, a Generating System comprised of Asynchronous Generating Units, for the faults referred to in clause A12.9.3.2, must have equipment capable of supplying to, or absorbing from, the Network returning to at least 95% of the pre-fault Active Power output, after clearance of the fault, within a period of time agreed by the operator, AEMO and the Network Operator.	negotiated standard this must be agreed by both AEMO and Western Power. - The post-fault active power level with a % value of pre-fault active power level. For ideal and negotiated this value must be at least 95%. - For negotiated standard only: - Location which the range of Continuous Uninterrupted Operation voltage is to be checked. Example statement of compliance if ideal standard is met: *Subject to any changed power system conditions or energy source availability beyond the operator of the Generating System's reasonable control, a Generating System comprised of Synchronous Generating Units, in respect of the faults referred to in clause A12.9.2.2, supplies or absorb from the Network, from 100 milliseconds after clearance of the fault, Active Power of at least 95% of the level existing just prior to the fault.* Example statement of compliance for a negotiated standard: *In respect of the faults referred to in clause A12.9.3.2, the Generating System:* *(a) after clearance of fault delivers Active Power to the Network, and supplies or absorbs leading or lagging Reactive Power into the Network to ensure that the Connection Point remains within the range for Continuous Uninterrupted Operation; and* *(b) Returns to at least 95% of pre-fault Active Power within 200 milliseconds.* The statement of compliance for an Asynchronous Generating System should specify: - A time frame following fault clearance the Synchronous Generating System can return to post-fault steady state active power level. For ideal this time frame must be no longer than 100 milliseconds. For

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		negotiated standard this must be agreed by both AEMO and Western Power. *g)* The post-fault steady state active power level with a % value of pre-fault active power level. For ideal and negotiated this value must be at least 95%. Example for Ideal standard: *Subject to any changed power system conditions or energy source availability beyond the operator of the Generation System's reasonable control, the Generating System, for the faults referred to in clause A12.9.2.2, supplies or absorbs from the Network, 100 milliseconds after clearance of the fault, Active Power of at least 95% of the level existing just prior to the fault*
Reactive current Rise Time, Settling Time and damping adequacy	**[A12.9.2.7 (Ideal)]** The reactive current response referred to in clause A12.9.2.5(a)(i) and clause A12.9.2.5(a)(ii) 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. **[A12.9.3.7 (Minimum)]** Where AEMO and the Network Operator require the Generating System to sustain a response duration of 2 seconds or less, the reactive current response referred to in clause A12.9.3.5(a)(i) and clause A12.9.3.5(a)(ii) must have a Rise Time of no greater than 40.0 milliseconds and a Settling Time of no greater than 70.0 milliseconds and must be Adequately Damped. **[A12.9.3.8 (Minimum)]** Where AEMO and the Network Operator require the Generating System to sustain a response duration of greater than 2 seconds, the reactive current Rise Time and Settling Time must be as soon as practicable and must be Adequately Damped. The Rise Time and Settling Time must be provided as part of the Generator Performance Standard.	The statement of compliance should specify: - For the reactive power current provided during a fault: ○ A quantified Rise Time. The ideal standard must achieve a Rise Time no more than 40 milliseconds. ○ A quantified Settling Time. The ideal standard must achieve a Settling Time no more than 70 milliseconds. ○ A quantified Damping Ratio. Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/media/4981/power-system-stability-requirements-guideline-20210511.pdf) for further information on Stability requirement and adequate damping definition. - For a negotiated standard the duration that AEMO and Western Power agree that is required for the Generating System to sustain its reactive current injection.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example for Ideal standard: *The reactive current response referred to in clause A12.9.2.5(a)(i) and clause A12.9.2.5(a)(ii) has a Rise Time of no greater than 40 milliseconds and a Settling Time of no greater than 70 milliseconds and is Adequately Damped* Example for a negotiated standard and a sustained response time of 1 second is required: *The Generating System can sustain a 1 second reactive current injection with a Rise Time of at least 40 milliseconds, Settling Time of 70 milliseconds and damping ratio of 0.1.* Example for a negotiated standard and a sustained response time of 3 seconds is required: *The Generating System can sustain a 3 second reactive current injection with a Rise Time of at least 80 milliseconds, Settling Time of 140 milliseconds and damping ratio of 0.1.*
Capability to maintain Rated Maximum Apparent Power during over-voltages	**[A12.9.2.8.(a)]** Subject to a Generating System's thermal limitations as specified in clause A12.9.1.8 and energy source availability, a Generating System must make available at all times sufficient current to maintain rated output in accordance with the relevant Australian or ISO Standard for Asynchronous Generating Units 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) despite the amount of reactive current injected or absorbed during voltage disturbances, except that AEMO and the Network Operator may agree limits on active current injection where required to maintain Power System Security and/or the Quality of Supply to other Equipment connected to the SWIS.	The statement of compliance should specify: - The over voltage threshold at the Connection Point voltage that the criteria require the Generating System to make available the injection of current equivalent to rated output. The threshold must be at least 115%. - If exist the agreed limit on active current injection, typically to prioritise reactive power injection to maintain Power System Security. Example: *Subject to a Generating System's thermal limitations and energy source availability, the Generating System makes available at all times sufficient current to maintain rated output of the Generating System for all*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Connection Point voltages above 115% despite the amount of reactive current injected or absorbed during voltage disturbances
Capability to maintain Maximum Continuous Current during under-voltages	**[A12.9.2.8(b)]** Subject to a Generating System's thermal limitations and energy source availability, a Generating System must make available at all times 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) despite the amount of reactive current injected or absorbed during voltage disturbances, except that AEMO and the Network Operator may agree limits on active current injection where required to maintain Power System Security and/or the Quality of Supply to other Equipment connected to the SWIS.	The statement of compliance should specify: - The under-voltage threshold at the Connection Point voltage that the criteria require the Generating System to make available the injection of current equivalent to Rated Maximum Apparent Power. The threshold must be at most 85%. - If exist the agreed limit on active current injection, typically to prioritise reactive power injection to maintain Power System Security. Example: *Subject to a Generating System's thermal limitations and energy source availability, the Generating System makes available at all times the Maximum Continuous Current of the Generating System for all Connection Point voltages below 85% despite the amount of reactive current injected or absorbed during voltage disturbances.*
Accepted performance level to not cause other connections to trip	**[A12.9.4.1]** A Proposed Negotiated Generator Performance Standard may be accepted if the connection of the Generating System at the proposed performance level would not cause other Generating Systems or Loads to trip as a result of an event, when they would otherwise not have tripped for the same event.	Example: *The Generating System's performance within its negotiated Performance Standard does not result in other Generating Systems or Loads to trip when they would otherwise not have tripped for the same event.*

2.3.9 Technical Requirement: Partial Load Rejection [A12.10]

The following documents/specification to be submitted with the GPS Submission:

- Calculation of the Generating System's Rated Maximum Active Power output level
- Calculation of the Generating System's Rated Minimum Active Power output level

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Specified Measurement Location for this Technical Requirement	**[A12.10.1.1]** In relation to the application of this Technical Requirement, the requirements apply at the Connection Point unless otherwise specified in the relevant clause, or the Network Operator or AEMO determines that the Technical Requirement must be measured at a different location for the particular Generating Unit or Generating System, in which case the measurement location must be recorded as part of the relevant Generator Performance Standard.	Example: *The Measurement location for the requirements Disturbance Ride Through for Partial Load Rejection is at the connection point* Example when a different Measurement Location is determined: *The Measurement location for the requirements Disturbance Ride Through for Partial Load Rejection the Generating Unit* ***<Generating Unit 1 Designation*** *> is at the Generating Unit Terminal*
Compliance when operating at any Range of Active and Reactive Power and Temperature	**[A12.10.1.2] I**n relation to the application of this Technical Requirement, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this Appendix, and at all temperatures up to and including the Maximum Temperature.	Example: *In relation to the application of Disturbance Ride Through for Partial Load Rejection, unless otherwise specified in the relevant clause, the requirements apply when operating at any Active Power and Reactive Power level as permitted or required under the other Technical Requirements in this GPS, and at all temperatures up to and including the Maximum Temperature of <Maximum Ambient Temperature °C>*
Continuous Uninterrupted Operation - sudden	**[A12.10.2.1 (Ideal)]** A Generating System and each of its operating Generating Units must be capable of Continuous Uninterrupted Operation during and following a sudden reduction in Active Power generation as a result of a Contingency Event, provided that the reduction is less than 30%	The statement of compliance should specify: The volume if sudden reduction in required Active Power generation in % value of the Generating System's Rated Maximum Active Power. For the

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
reduction in Active Power	of the Generating System's Rated Maximum Active Power and the Active Power generation remains above the Generating System's Rated Minimum Active Power output level. **[A12.10.3.1 (Minimum)]** A Generating System must be capable of Continuous Uninterrupted Operation during and following a sudden reduction in Active Power generation as a result of a Contingency Event, provided that the reduction is less than 5% of the Generating System's Rated Maximum Active Power and the Active Power generation remains above the Generating System's Rated Minimum Active Power output level.	ideal the % value must be at least 30% and for a negotiated standard it must be at least 5%. Example for Ideal standard: *The Generating System is capable of Continuous Uninterrupted Operation during and following a sudden reduction in Active Power generation as a result of a Contingency Event, provided that the reduction is less than 30% of the Generating System's Rated Maximum Active Power of <calculated Rated Maximum Active Power> MW, and the resulting Active Power generation is above the Generating System's Rated Minimum Active Power, <calculated Rated Minimum Active Power> MW.* Example for negotiated standard: *The Generating System is capable of Continuous Uninterrupted Operation during and following a sudden reduction in required Active Power generation as a result of a Contingency, provided that the reduction is less than 30% of the Generating System's Rated Maximum Active Power of <calculated Rated Maximum Active Power> MW, and the resulting Active Power generation is above the Generating System's Rated Minimum Active Power, <calculated Rated Minimum Active Power> MW.*

2.3.10 Technical Requirement: Disturbance Ride Through for Quality of Supply [A12.11]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
No disconnection requirement for specified Quality of Supply	**[A12.11.2.1 (Ideal)]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Disturbance Ride Through for Quality of Supply. **[A12.11.3.1 (Minimum)]** A Generating System including each of its operating Generating Units and reactive Equipment, must not disconnect from the SWIS as a result of voltage fluctuation, harmonic voltage distortion and voltage unbalance conditions at the Connection Point within the levels specified for flicker, harmonics and negative phase sequence voltage in the Technical Rules.	The statement of compliance should specify the background emission of power quality quantities that the Generating System will not disconnect: - The level of voltage fluctuations in flicker severity index for short term and long-term severity index. - The level of harmonic voltage distortion [% of fundamental] from second order through to 20th order (or more if required by Western Power), and inter-harmonics. - The level of negative sequence voltage in % of positive sequence voltage. Example: *The Generating System will not disconnect if the:* *(a) The level of flicker at the Connection Point does not exceed:* *i. Short term severity (Pst) index of 0.2* *ii. Long severity index (Plt) of 0.3* *(b) The level of harmonic voltage distortion does not exceed the values listed below:* *i. h = 2 equal to (Planning Level (%))* *ii. h = 3 equal to (Planning Level (%))* *iii. ..* *iv. h = 20 equal to (Planning Level (%))*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		v. THD equal to (Planning Level (%)) *(c) The level of negative sequence voltage does not exceed 1% of positive sequence voltage.*

2.3.11 Technical Requirement: Quality of Electricity Generated [A12.12]

The following documents/specification to be submitted with the GPS Submission:

- Voltage fluctuation limits allocated by Western Power
- Voltage distortion limits allocated by Western Power
- Voltage Imbalance limits allocated by Western Power

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Voltage imbalance allocation	**[A12.12.1.1]** A Generating System, when generating and when not generating, must not produce, at any of its Connection Points for generation, voltage imbalance greater than the limits determined by the Network Operator as necessary to achieve the requirements specified for negative phase sequence voltage at the Connection Point in the Technical Rules.	The statement of compliance should specify the voltage unbalance limits determined by Western Power. Example: *The Generating System when generating and when not generating, does not produce, at any of its Connection Points for generation, voltage imbalance greater than the allocated voltage unbalance emission limit of 0.2% of Connection Point positive sequence voltage.*
Voltage fluctuation allocation	**[A12.12.2.1(a) (Ideal)]** 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 the Network Operator 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. **[A12.12.3.1(a)]** 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 the Network Operator through the negotiation using the stage 3 evaluation procedure defined in AS/NZS 61000.3.7:2001, with the Market Participant responsible for the Transmission Connected Generating System agreeing to fund any works necessary to mitigate adverse effects from accepting this emission level.	The statement of compliance should specify the allocation stage in AS/NZS 61000.3.7:2001 which was applied to the Generating System needs to be considered. Note, if Generating System passes Stage 1 evaluation process no emission limits would have been allocated, since the size of Generating System when compared to the short-circuit power at the Connection Point is insignificant. Otherwise under Stage 2 the evaluation process will result in allocation of emission limits. Stage 3 is only applied if the emission limits under stage 2 is too restrictive to meet without significant investment in mitigation solutions, more suitable emission limits are developed considering other factors not taken to account in Stage 2.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example where Generating System passes stage 1 procedure: *The Generating System will not add to voltage fluctuations at its Connection Point voltage greater than the limits indicated by Western Power as mentioned in **<reference file>**.* Example where Generating System has Stage 2 or Stage 3 allocation limits: *The Generating System will not generate voltage fluctuations greater than the following limits at the Connection Point voltage:* *(a) Over a weekly observation period the 95^{th} percentile of the short-term severity index (Pst) will not exceed 0.2.* *(b) Over a weekly observation period the 95^{th} percentile of the Long-term severity index (Plt) will not exceed 0.3.*
Harmonic voltage allocation	**[A12.12.2.1(b)]** A Generating System, when generating and when not generating, must not produce at any of its Connection Points for generation harmonic voltage distortion greater than emission limits allocated by the Network Operator 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. **[A12.12.3.1(b)]** A Generating System, when generating and when not generating, must not produce at any of its Connection Points for generation Harmonic voltage distortion greater emission limits determined by the Network Operator through the negotiation using the Stage 3 evaluation procedure defined in AS/NZS 61000.3.6:2001 with the Market Participant responsible for the Transmission Connected Generating System agreeing to fund any works necessary to mitigate adverse effects from accepting this emission level.	The statement of compliance should specify the allocation stage in AS/NZS 61000.3.6:2001 which was applied to the Generating System needs to be considered. Note, if Generating System passes Stage 1 evaluation process no emission limits would have been allocated, since the size of Generating System when compared to the short-circuit power of the Connection Point is insignificant. Otherwise under Stage 2 the evaluation process will result in allocation of emission limits. Stage 3 is only applied if the emission limits under stage 2 is too restrictive to meet without significant investment in mitigation solutions, more suitable emission limits are developed considering other factors not taken to account in Stage 2. Example where Generating System passes stage 1 procedure: *The Generating System will not add to the voltage distortion at any harmonic or inter-harmonic order at its Connection Point voltage greater than the limits allocated by Western Power described in **<reference file>**.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
		Example where Generating System has Stage 2 or Stage 3 allocation limits: *The Generating System when making weekly observations the 95th percentile of harmonic distortion will not exceed the following listed limits:* - *h = 2 equal to (Planning Level (%))* - *h = 3 equal to (Planning Level (%))* - *..* - *h = 20 equal to (Planning Level (%))* - *THD equal to (Planning Level (%))*
No prevention from meeting Network Operator obligations	**[A12.12.4.1]** A Proposed Negotiated Generator Performance Standard must not prevent the Network Operator meeting each SWIS Operating Standard or contractual obligations to existing holders of Arrangements for Access.	This requirement will be treated as a constraint when negotiating a performance standard between Ideal and Minimum standard. The statement of compliance can be a statement on how this clause was applicable.

2.3.12 Technical Requirement: Generation Protection Systems [A12.13]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Protection requirements as per the Technical Rules	**[A12.13.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation Protection Systems. **[A12.13.3.1]** A Generating System must meet the protection requirements specified in the Technical Rules for both Generating Systems and the Transmission System (where relevant), including the requirement for faults to be cleared within maximum Total Fault Clearance Times specified in the Technical Rules or, where specified, a Critical Fault Clearance Time developed by the Network Operator.	The statement of compliance should specify: - Maximum fault clearance times that can be achieved for any faults within the Generating System. - The fault requirement time required in Technical Rules clauses 3.5.3 (a), 2.9.4 and 2.9.5. Example: *The Generating System has the maximum Fault Clearance Time of 390 milliseconds which is within the requirement of the Technical Rules requirement of 400 millisecond for 132 kV Connection Point.*
Redundancy and fault clearance requirements	**[A12.13.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation Protection Systems. **[A12.13.3.2]** All Protection Schemes must have the relevant level of redundancy as specified in the Technical Rules and must operate to clear faults within the prescribed times.	Example: *All protection schemes within the Generating System meets the requirements specified in the Technical Rules for two fully independent protection schemes of differing principles.*
Anti-islanding protection requirements	**[A12.13.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation Protection Systems. **[A12.13.3.3]** Anti-islanding protection must be installed and made available to ensure the Generating System is prevented from supplying an isolated portion of the SWIS when it is not secure to do so. The details regarding the performance requirements for anti-islanding systems for Transmission Connected Generating Systems are documented in accordance with the guidelines produced by the Network Operator under clause 3A.4.4.	The statement of compliance should specify a reference to an approved Anti-Islanding solution. The need for an anti-islanding solution should be discussed with Western Power and AEMO. Example for a Generating System with an approved anti-islanding solution: *The Generating System has the approved anti-islanding protection which is described in the attached document <reference>.*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Protection Schemes necessary for abnormal conditions	**[A12.13.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation Protection Systems. **[A12.13.3.4]** All Protection Schemes necessary to disconnect the Generating System during abnormal conditions in the power system that would threaten the stability of the Generating System, or risk damage to the Generating System, must be installed and available. The settings of these Protection Schemes must deliver the required performance for disturbance ride through specified in Part A12.7, Part A12.8 and Part A12.9 of this Appendix 12 and form part of the Generator Performance Standard.	The statement of compliance should specify the: - the abnormal conditions that require the disconnection of the Generating System; and - settings of the protection scheme that disconnects the Generating System or equipment within the Generating System. These abnormal conditions are specific to the Generating System and the location of its connection; and only discovered during the early connection studies. Example where no abnormal condition exists for the Generating System: *The Generating System is not required to be disconnected for any abnormal conditions.*
Provision of all Protection Scheme settings	**[A12.13.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation Protection Systems. **[A12.13.3.5]** All Protection Scheme settings referred to in this Appendix must be made available to the Network Operator and AEMO.	Attached with the GPS submission is the *Protection Systems Design and Setting Data* as per the format outlined in Attachment 5 of the Technical Rules. Example: *All the Protection Scheme settings for the Generating System is provided in the attached Protection Systems Design and Setting Data,* ***<attachment file reference>****.*

2.3.13 Technical Requirement: Remote Monitoring Requirements [A12.14]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Installation of Remote Monitoring Equipment	**[A12.14.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Monitoring Requirements. **[A12.14.3.1]** The Network Operator or AEMO may require Remote Monitoring Equipment to be installed in order to enable the Network Operator or AEMO to monitor the performance of a Generating Unit (including its dynamic performance) remotely, where this is necessary in real time for control, planning or Power System Security.	The statement of compliance should specify: - the signals and its sampling time; and - reference to a single line diagram that clearly shows the location of the source of measurements for each signal. Example: *The attached single line diagram of the Generating System is included, <attachment file reference>, to show the location of the signals indicated in* ***<reference file>*** *measured with sampling rate of 2 seconds.*
Conformance to Communication Standard	**[A12.14.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Monitoring Requirements. **[A12.14.3.2]** All Remote Monitoring Equipment installed, upgraded, modified or replaced (as applicable) under clause A12.14.3.1, must conform to the Communication Standard as it applies Remote Monitoring Equipment and must be compatible with the Network Operator's and AEMO's SCADA system, including the requirements of the Nomenclature Standards.	The statement of compliance needs to assure that the Market Participants intention is to install, upgrade, modify or replace Remote Monitoring Equipment that it conforms with the Communication Standards defined in the WEM procedure referred to in clause 2.36A.1 of the WEM Rules so that it is compatible with Western Power and AEMO's SCADA systems. Example: *The Remote Monitoring Equipment within the Generating System conforms to the Communication Standard of WEM procedure referred to in* ***[WEM 2.36A.1]*** *such that it is integrated with Western Power and AEMO's SCADA systems.*
Provision of specified signals for Remote Monitoring Equipment	**[A12.14.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Monitoring Requirements.	The statement of compliance should specify those signals that were include in the *Installation of Remote Monitoring Equation* because of the requirements of the WEM procedure referred to in clause 2.35.4 of the WEM Rules.

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
	[A12.14.3.3] The Remote Monitoring Equipment must provide for the signals specified in the WEM Procedure described in clause 2.35.4 and such other information required by the Network Operator or AEMO.	Example: *The signals described in **<reference file>** are included as required by the WEM procedure referred to in clause 2.35.4.*
Availability of Remote Monitoring Equipment	**[A12.14.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Monitoring Requirements. **[A12.14.3.4]** The Remote Monitoring Equipment must be kept available at all times, subject to Outages as agreed by AEMO.	Example: The Remote Monitoring Equipment is kept available at all times, subject to Outages as agreed by AEMO.

2.3.14 Technical Requirement: Remote Control Requirements [A12.15]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Installation of Remote Control Equipment	**[A12.15.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Control Requirements. **[A12.15.3.1]** The Network Operator or AEMO may, for any Generating Unit which may be unattended when connected to the Transmission System, require Remote Control Equipment to be installed in order to enable the Network Operator or AEMO to disconnect a Generating Unit from the Transmission System.	A result of correct implementation of Remote Control Equipment requirements is to enable AEMO to disconnect Generating Equipment with the Generating System or Generating System itself. Example: *The Generating System has the Remote Control Equipment as described in <reference>I which allows for the Generating Units within the Generating System and the whole Generating System to be remotely disconnected from the Transmission System.*
Conformance to Communication Standard	**[A12.15.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Control Requirements. **[A12.15.3.2]** All Remote Control Equipment installed, upgraded, modified or replaced (as applicable) under clause A12.15.3.1 must conform to the Communication Standard and must be compatible with the Network Operator's SCADA system, including the requirements of Nomenclature Standards.	The statement of compliance needs to assure that the Market Participants intention is to install, upgrade, modify or replace Remote Control Equipment that it conforms with the Communication Standards defined in the WEM procedure referred to in clause 2.36A.1. Example: *The Remote Control Equipment to disconnect the Generating System conforms to the Communication Standard of WEM procedure referred to in clause 2.36A.1 of the WEM Rules and is integrated with AEMO's SCADA system.*
Availability of Remote Control Equipment	**[A12.15.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Remote Control Requirements. **[A12.15.3.3]** The Remote Control Equipment must be kept available at all times, subject to Outages as agreed by AEMO.	Example: *The Remote Control Equipment is kept available at all times, subject to Outages as agreed by AEMO.*

2.3.15 Technical Requirement: Communications Equipment Requirements [A12.16]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Provision and maintenance of communication paths for specified equipment	**[A12.16.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Communications Equipment Requirements. **[A12.16.3.1]** Communications paths must be provided and maintained (with redundancy consistent with the standard developed by AEMO to meet the Communication Standard) between the Remote Monitoring Equipment and Remote Communication Equipment installed at any of its Generating Units to a communications interface at the relevant Power Station and in a location acceptable to the Network Operator. Communications systems between this communications interface and the Network Operator's Control Centre are the responsibility of the Network Operator, unless otherwise agreed.	The concern for the Market Participant is to have redundant communication paths designed between the Remote Monitoring Equipment and Remote Communication Equipment. An attached diagram of the Communications paths between the various Remote Monitoring Equipment and Remote Communication Equipment's interface. It is not the Market Participant's concern for the design of the communication paths between the Generating System's Remote Communication Equipment's interface with Western Power's Control Centre. Example: *The Generating System has communications paths between the Remote Monitoring Equipment and Remote Communication Equipment as provided in the document **<reference document>** and the paths are maintained (including redundancy which meets the Communication Standard)*
Provision and maintenance of speech communication channel for specified calls	**[A12.16.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Communications Equipment Requirements. **[A12.16.3.2]** A Market Participant responsible for the Transmission Connected Generating System must provide and maintain a speech communication channel (Primary Speech Communication Channel) by means of which routine and emergency control telephone calls may be established between the operator of the Generation System and AEMO or the Network Operator, whichever is applicable.	Example: *The Generating System provides a speech communication channel through which, routine and emergency control telephone calls between the operator of the Generating System, AEMO and Western Power can be established*

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Conformance of the speech communication channel with the Communication Standard	**[A12.16.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Communications Equipment Requirements. **[A12.16.3.3]** The Primary Speech Communication Channel must meet any requirements specified in the Communication Standard.	The statement of compliance should specify how the requirements of PSOP Communications and Control Systems[3] and relevant requirements in the Technical Rules **[TR 3.3.4.3]**.
Public switched telephone network requirements	**[A12.16.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Communications Equipment Requirements. **[A12.16.3.4]** Where the public switched telephone network is to be used as the Primary Speech Communication Channel, a sole-purpose connection must be provided, which must be used only for operational communications. **[TR 3.3.4.3(c)(1)]** Where the public switched telephone network is to be used as the primary speech communication channel, a sole-purpose connection, which must be used only for operational communications, must be provided.	Example: *The Generating System has the public switched telephone network as the Primary Speech Communication Channel with a sole-purpose connection provided and used only for operational communications.*
Availability of communication path	**[A12.16.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Communications Equipment Requirements. **[A12.16.3.5]** The communications paths to any applicable Remote Monitoring Equipment or Remote Communication Equipment must be kept available at all times, subject to Outages as agreed by AEMO.	Example: *The communications paths to Remote Monitoring Equipment or Remote Communication Equipment are available at all times, subject to outages approved by AEMO.*

3 POWER SYSTEM OPERATION PROCEDURE: COMMUNICATIONS AND CONTROL SYSTEMS (https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/wa_wem_consultation_documents/2018/aepc_2018_03/psop-communications-and-control.pdf?la=en&hash=ADED2BBE3334612D970F19E5AC159838)

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Maintenance of Primary Speech Communication Channel	**[A12.16.2.1.]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Communications Equipment Requirements. **[A12.16.3.6.]** The Primary Speech Communication Channel must be maintained in good working order.	Example: *The Primary Speech Communication Channel is maintained in good working order.*

2.3.16 Technical Requirement: Generation System Model [A12.17]

Criteria description	WEM Rules clause(s)	Guidance and example statements of compliance
Provision of modelling data	**[A12.17.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation System Model. **[A12.17.3.1]** All modelling data described in the WEM Procedure referred to in clause 3A.4.2 must be provided to the Network Operator within the timeframes specified in the WEM Procedure, as updated from time to time.	Example: *The Market Participant has provided all modelling data described in the WEM Procedure referred to in clause 3A.4.2 to Western Power within the timeframes specified in the latest WEM Procedure, as updated from time to time.*
Adequacy of modelling data	**[A12.17.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation System Model. **[A12.17.3.2]** The modelling data provided must be sufficient to enable the Network Operator or AEMO to predict the output of the Generation System under all power system conditions.	Example: *The modelling data provided by the Market Participant allows Western Power or AEMO to predict the output of the Generation System under all power system conditions.*
Accuracy of modelling data	**[A12.17.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation System Model. **[A12.17.3.3]** The observed performance of the Generation System must match the predicted performance of the Generation System using the Generation System Model, as assessed by the Network Operator or AEMO.	Example: *The observed performance of the Generation System matches the predicted performance of the Generation System using the Generation System Model, as assessed by Western Power or AEMO.*
Provision of Generating System Model updates	**[A12.17.2.1]** The Ideal Generator Performance Standard is the same as the Minimum Generator Performance Standard for Generation System Model. **[A12.17.3.4]** The relevant Market Participant must provide updates to the Generation System Model in order to meet the requirements of this Technical Requirement in accordance with the timeframes specified in the WEM Procedure referred to in clause 3A.4.2, as updated from time to time.	Example: *Market Participant responsible for the Generating System will provide updates to the Generation System Model in order to meet the requirements of this Technical Requirement in accordance with the timeframes specified in the latest WEM Procedure referred to in clause 3A.4.2, as updated from time to time.*

3 GPS Technical Requirement interpretation and application

3.1 Introduction

This chapter provides clarification and interpretations of each Technical Requirement in Appendix 12, and describes sample responses each Market Participant should use to inform the basis of the performance negotiation for a Generating System. It also includes guidance and recommended methodologies to:

- help Market Participants assess the Technical Requirements in Appendix 12 of the WEM Rules; and
- provide evidence that demonstrates how their Generating System complies with the WEM Rules.

This guideline also describes how the clauses of Appendix 12 relate to the secure and reliable operation of the SWIS, including some theoretical and practical discussions where relevant.

For most of the clauses, Market Participants are required to run simulations on a verified computer model of the Generating System connected to an equivalent model of the SWIS. The Performance of the Generating System against the technical requirements of Appendix 12 is ascertained from the result of these simulations. It should be noted that this is a requirement during the planning stage and before issuance of Approval to Generate Notification. A commissioning test will be conducted, and the performance levels in the registered GPS must be verified by running tests on constructed Generating System. AEMO publishes the GPS Commissioning Test Procedure form to assist WEM Market Participants in developing a proposed GPS Commissioning Test Plan[4]. After completion of the commissioning test, the performance of the Generating System is reassessed using the commissioning test report. If any of the applicable Registered Generator Performance Standards is not met, the Market Participant (As outline in WEM Rules 3A.8.5) notify AEMO and provide details of the noncompliance and:

- propose and make required modification to the Generating System to meet the Registered Generator Performance Standards and/or
- renegotiate any applicable Registered Generator Performance Standards

Should Market Participants need further information in the interim, please contact Western Power via system.analysis@westernpower.com.au.

[4] available at: https://aemo.com.au/en/energy-systems/electricity/wholesale-electricity-market-wem/procedures-policies-and-guides/procedures

3.2 Technical Requirement: Active Power Capability [A12.2]

3.2.1 Introduction to A12.2

The active power capability is one of most fundamental clauses of the WEM rules. The Generating System demonstrates its ability to deliver their declared Rated Maximum Active Power continuously. Apart from contractual agreement and market remunerations, the Rated Maximum Active Power that a Generating System can produce is the input to several Essential System Services (such as contingency raise) related to active power and frequency control, system flexibility and ramp rate, active power adequacy for system restoration and others.

The nameplate rating of a Generating System, either conventional thermal power plants or renewables is a function of ambient conditions (pressure and temperature). For the installation at various sites, the temperature varies throughout the year and so does the maximum active power that a Generating System can deliver. These temperature dependencies of available power from a Generating System are also crucial information for the power system operators.

3.2.2 Explanation of individual clauses

3.2.2.1 Measurement Location and Rated Maximum Active Power (A12.2.1.1.)

The Measurement location where the Active Power capability is assessed, is at the Connection Point of the Generating System, unless otherwise specified by AEMO and Western Power. In some specific cases, Western Power and AEMO may determine another location for a Generating Unit or a Generating System. It should be noted that the change in measurement location should be due to technical constraints that make the assessment infeasible at the connection point (e.g., specific Generating System Topology) and the measurement location could not be changed due to non-compliance at the Connection Point. If the Measurement Location is changed for a specific clause, this should be mentioned in the statement of compliance. For example, if the Temperature Dependency Data is provided at a location other than Connection Point, the location should be clearly mentioned in the Statement of Compliance.

The Rated Maximum Active Power is the level of active power that the generating system can continuously supply at Maximum Temperature. The Maximum Temperature for a Generating system is the maximum ambient temperature based on an assessment of where the Generating System or Unit is physically located. The Maximum Temperature is to be specified by AEMO and Western Power and the methodology of indicating the Maximum Temperature is published by AEMO in accordance WEM Rules 3A.1.5[5].

The Rated Maximum Active Power must be specified at the Connection Point. For Generating System with only Synchronous Generating Unit, the Rated Maximum Active Power will be specified at the Synchronous Machine terminal and is translated to the Connection Point. For other Asynchronous or Hybrid Generating Systems, the Rated Maximum Active Power is specified at the Connection Point unless otherwise agreed by AEMO and Western Power. The following two examples are provided on how the Rated Maximum Active Power should be specified.

Example 1: A thermal power plant with one unit has a nameplate rating of 160MW at ISO conditions[6]. At the installation site, the Maximum Temperature is 40 degrees Celsius and as such the machine is derated to 150MW. The maximum active power at the unit terminal is then 150MW. The facility has 5 MW of internal consumption and losses to deliver the 150 MW at the Connection Point so the Rated Maximum Active Power that can be delivered to the system is 145MW. Both 150MW and 145MW should be specified

5 Available at: https://aemo.com.au/energy-systems/electricity/wholesale-electricity-market-wem/system-operations/gps-framework

6 The standard conditions used by the gas turbine industry are 59 F/15 C, 14.7 psia/1.013 bar and 60% relative humidity, which are established by the International Standards Organization (ISO) and frequently referred to as ISO conditions.

at the corresponding documentation of the GPS and in the statement of compliance, it should be mentioned that the former is at the Generating Unit Terminal and the Latter is at the Connection Point.

Example 2: A wind farm that consists of 10 wind turbines which are rated 4MW (Each Turbine) at ISO condition but can only generate 3MW at 44 degrees. The Maximum Temperature of the installation site is 44 degrees. Due to losses and internal consumptions, at the Connection Point, the wind farm can deliver and maintain 28MW continuously. In this case, the Rated Maximum Active Power must be registered as 28MW.

3.2.2.2 Temperature Dependency Data (A12.2.3.2.)

Per A12.2.3.2, the active power capability of a Generating System should include the Temperature Dependency Data. This data is showing the relationship between the maximum active power supplied by a Generating System at each temperature. All Generating Systems must provide the Temperature Dependency Data at the Connection Point. For all Synchronous Generating Units, the data must be provided at Generating Unit terminal as well. Table 3-1 specifies the required data and the format required to be supplied as part of the GPS regarding temperature dependency. The data should also include active power for temperatures beyond Maximum Temperature. The temperature should be up to the ambient temperature after which Active Power capability is reduced (Derating). If the derating happens at temperatures below Maximum Temperature, the data must be provided for temperatures up to at least 5 °C above Maximum temperature. AEMO and Western Power may request the data to be provided for higher temperatures depending on the physical location of the Generating System. The required temperature range is shown in Figure 3-1 for two Generating systems: Generating System 1 that the Active Power is reducing before Maximum Temperature. Generating System 2 that the Active Power is reducing after Maximum Temperature.

Figure 3-1 Sample Temperature Dependency diagram of Generation Systems Active Power Capability

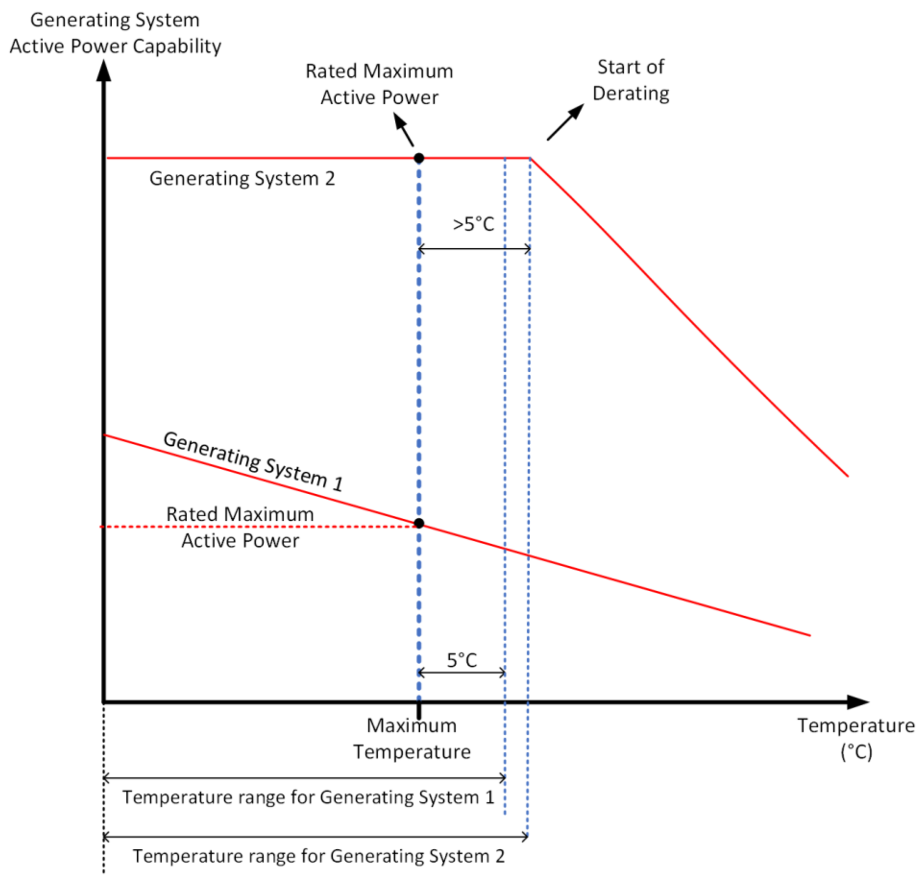


Table 3-1 Temperature Dependency Data

Technology	Required Data	Location	Format
Generating System Comprised solely of Synchronous Generating Unit	Active Power at each temperature up to Maximum Temperature and including ambient temperature above Maximum Temperature as depicted in Figure 3-1	• Generator terminal for each Synchronous Generating Unit • Connection Point for Generating System	Template (Excel file) Provided by Western Power (Synchronous Generating System)
Generating System Comprised solely of Asynchronous Generating Unit	As Above	• Connection Point	Template (Excel file) Provided by Western Power (Asynchronous Generating System)
Generating System Comprised of Synchronous Generating Units and Asynchronous Generating Units	As Above	• Generator terminals for each Synchronous Generating Unit • Connection Point for Generating System	• For each Synchronous Generating Unit: Template (Excel file) Provided by Western Power (Synchronous Generating System) • For the whole Generating System: Template (Excel file) Provided by Western Power (Synchronous Generating System)

3.2.2.3 The active power capability criteria (A12.2.3.4, A12.2.3.5 and A12.2.3.6)

A Generating System should be able to deliver and maintain its declared relevant Active Power output levels at the temperatures specified in Temperature Dependency Data if the energy source is available per A12.2.3.4. Network outages and operating conditions should not deter the Generating System from achieving its Active Power output levels. For example, if AEMO dispatches a facility at the Rated Maximum Active Power and there is energy source available, the facility should be able to achieve and maintain Continuous Uninterrupted Operation while achieving that Rated Maximum Active Power registered in GPS irrespective of outages, temperature, and other generators dispatched in the vicinity of the facility. This clause specifically requires generators to be designed suitable for the site where they are intended to be installed. For example, if per manufacturer data a candidate wind turbine can generate only 80% of its nominal power when the site temperature is at 40 degrees, then the whole facility will be derated at 80% so more turbines are required to be installed to achieve the intended MW at the Connection Point. Also, if a Generating System cannot operate at the Maximum Temperature specified by AEMO, it will not satisfy the minimum generator performance standard and cannot be connected to SWIS.
One exemption applies to maintaining Active Power levels during higher ambient temperatures per A12.2.3.5. A Generating System can have an agreement with the Network Operator to reduce its maximum Active Power temporarily to be able to produce the required Reactive Power per A12.3 requirements. In this case, the Rated Maximum Active Power of the facility remains the same, but an extra condition is applied for the period when the site temperature is higher than a specified limit at which the active power of the facility

is limited to an agreed level below the Active Power levels in Temperature Dependency Data. The temperature at which the derating applies and the amount of reduction in Active Power will have to be specified and agreed upon in Generator Performance Standard.

It should also be noted that the relevant Active Power of a Generating System and Generating unit, as applicable, must not exceed the relevant Active Power levels as defined in their Temperature Dependency Data as per A12.2.3.6 of the WEM Rules Unless otherwise directed under these WEM Rules.

3.2.3 Evidence of compliance

3.2.3.1 OEM documents and test certificates

The certified copy of the manufacturer data specifying the nameplate rating and temperature dependency data of the Generating Units are to be provided as evidence. In the Datasheet, the relevant International or Australian Standards used by the manufacturer should be specified.

3.2.3.2 Computer Model and simulations

A model of the Generating System can be used to estimate the active power at the Connection Point when specifying the Rated Maximum Active Power. A load flow and dynamic study on a SMIB model can be used to estimate the power injection at the Connection Point. It should be noted that a complete model of the Generating System should be used which includes all equipment that is related to active power capability (Full reticulation system, Step-up Transformer Auxiliary and inhouse load etc). For a Generating System, to find the Rated Maximum Active Power at Measurement Location, a steady state load flow simulation should be run when all the Generating Units are set to their maximum active power injection at Maximum Temperature and all the auxiliary loads are set to their maximum power demand.

The result of the steady state load flow should be tested further through an RMS dynamic load flow to test that the control and protection systems do not limit the output active power at the Measurement Location. The result of the steady state should be set as the initial condition for the RMS simulation and the simulation should be run for a period sufficient to capture all control or protection action. If the result of simulation indicates that the active power is reduced due to control or protection actions, the steady state simulation should be repeated considering the new limits.

It should be noted that providing the result of simulation on a computer model is not sufficient for the completion of this clause and it should always be accompanied with certified manufacturer data.

3.3 Technical Requirement: Reactive Power Capability [A12.3]

3.3.1 Introduction to A12.3

Maintaining the voltage profile around nominal voltage is essential to power system operators for secure power transfer from generation to load. In AC transmission systems the ability to control voltage depends on the reactive power flow. The Generating Systems are the dynamic reactive power providers which enable voltage control by absorbing or injecting reactive power at their Connection Point while transferring power over system driving point impedances. The reactive power capability of the Generating Systems also helps to maintain overall system voltage control capability and stability margins. All technical codes specify minimum requirements for Generating Systems' reactive power capability and for SWIS, WEM Rules A12.3 stipulates the technical requirements.

3.3.2 Explanation of common requirements

3.3.2.1 Performance Chart, Temperature Dependency Data, and Measurement Location (A12.3.1.1 and A12.3.1.2)

The WEM Rules require all Generating Units to submit a set of reactive power Generator Performance Charts. The set of Performance Charts should include Temperature Dependency Data up to and including the Maximum Temperature and temperatures above the Maximum Temperature, up to and including at least 5 degrees above the Maximum Temperature or up to and including the temperature at which performance is reduced, whichever is the greater.

The Maximum Temperature for a Generating system is the maximum ambient temperature based on an assessment of where the Generating System or Unit is physically located. The Maximum Temperature is to be specified by AEMO and Western Power and the methodology for indicating the Maximum Temperature is published by AEMO in accordance with WEM Rules 3A.1.5[7]. The Performance Chart must be provided for ±10% of the nominal voltage of the Connection Point.

The default Measurement Location for reactive power capability and where the Performance Chart should be provided is at the Connection Point unless otherwise specified by AEMO and Western Power. In some specific cases, Western Power and AEMO may determine another location for a Generating Unit or a Generating System. It should be noted that the change in measurement location should be due to technical constraints (e.g., specific Generating System Topology) and the measurement location could not be changed due to non-compliance at the Connection Point. If the Measurement Location is changed for a specific clause, this should be mentioned in the statement of compliance.

The Performance Chart for Synchronous Generators is to be specified at the Generator's Terminals. This Performance Chart is required to have the machine's capability as well as limiters set by the AVR control system (see Section 3.3.2.2).

For Generating Systems with Asynchronous Generating Units e.g., wind and solar farms, Performance Chart must be provided at the Connection Point. This usually requires a simulation of the aggregated capability at the Connection Point. Table 3-2 lists the requirements and evidence to be submitted for the Performance Chart

For Generating Systems with Asynchronous Generating Unit e.g., wind and solar farms or other inverter-based generation, the Performance Chart at Connection Point is derived by performing simulations. The simulations must be performed on a complete model of the Generating System (full reticulation system, step-up transformers, Auxiliary load and equipment etc.) In those cases, both steady state (load flow) and dynamic simulations must verify CUO within area defined in the Generator Performance Chart. Refer to Section 3.3.4 for more information on simulation required.

[7] Available at: https://aemo.com.au/energy-systems/electricity/wholesale-electricity-market-wem/system-operations/gps-framework

For Synchronous Generators the Performance Chart is usually specified at 1 p.u. terminal voltage. The variation of voltage will result in the movement of the Performance Chart as shown in Figure 3-4. The capability and the limiters adjusted for terminal voltage variation must be supplied with the Performance Chart.

3.3.2.2 Inclusion of limiters (A12.3.1.3)

The Performance Chart information should include any limiters or protection systems which can prevent the Generating Unit or Generating System to operate continuously in between the limits of the capability curve. To evidence this, the data tabulated in Table 3-2 shall be provided. The Generator Performance Chart of the Generating System would be the area that is confined by all limiters. The same area is also assessed against the requirements of A12.3.2.1 and A12.3.3.1 of the WEM Rules.

3.3.2.3 Dispatch of the full Active Power and Reactive Power Capability of the Generating System (A12.3.1.5)

If the maximum active power and reactive power per Performance Chart results in voltage or thermal loading beyond the permitted operating range of the network elements at the Connection Point, the Generating System cannot be registered at the full active and reactive power specification. The Generating System should demonstrate that full reactive power of the Generating System at full active power can be delivered at the Connection Point. Western Power can provide a model of the SWIS and other technical information so that Market Participant can confirm that the Connection Point has the capacity for the full active and reactive power capability of the Generating System.

3.3.3 Ideal and minimum standards requirements

Figure 3-3 shows the min and ideal requirements for reactive power capability that should be overlayed to Performance Chart.

3.3.3.1 Ideal performance

The ideal performance requires the Generating System to provide reactive power, shown in Figure 3-3, of at least 0.484 times the Rated Maximum Active Power at on each side and the reactive power of 0.484 of Rated Maximum Active power should be maintained in all active power between minimum and maximum in both leading and lagging sides. The reactive power must also be supplied or absorbed for±10% of nominal voltage at the Connection Point.

3.3.3.2 Minimum performance

As for the minimum performance, the Generating System must be able to absorb or generate reactive power, shown in Figure 3-3, of at least 0.329 times the Rated Maximum Active Power at 1 p.u. terminal voltage on each side and maintained in all active power between minimum and maximum in both leading and lagging sides. The Rated Maximum Active Power is the maximum active power at the measurement location.
With respect to voltage variation, the minimum performance relieves the reactive power supply at high voltages and reactive power absorption at lower voltages per A12.3.3.2. Table 3-3 lists the range of active power capability when the voltage at the Connection Point deviates from nominal.

Table 3-2 Performance Chart requirements

Technology	Required Data	Location	Variations	Format
Generating System with only Synchronous generating Unit (See note 1 and 2)	Machine's capability chart Overexcitation limiters (i.e. maximum field current limiter and stator over excited current limiter) Under excitation limiters (Minimum field current limiter, PQ limiter and stator under excited current limiter) All relevant protection settings (overvoltage/undervoltage) See Figure 3-2 for typical limiters of a synchronous machine	Generator Terminals	ISO up to Maximum Temperature and including ambient temperature after which the performance is reduced or 5 °C above Maximum Temperature whichever comes first ±10% variation of Connection Point voltage	Template (Excel file) Provided by Western Power (Synchronous Generating System)
Generating System with Asynchronous Generating System (Wind/Solar farms and BESS etc) (See note 1 and 2)	Aggregated capability chart including all limiters on control loops All relevant protection settings (overvoltage/undervoltage)	Connection Point	Simulated capability curve steady state and dynamic for: ISO up to Maximum Temperature and including ambient temperature after which the performance is reduced or 5 °C above Maximum Temperature whichever comes first ±10% variation of Connection Point voltage	Template (Excel file) Provided by Western Power (Asynchronous Generating System

Note 1: the voltage profile while operating at all points within the Performance Chart along the internal busbars should stay within the safe operating range and away from protection trip settings.

Note 2: the Generating System should be able to operate within Performance Chart continuously as verified by both steady state and dynamic simulations

Figure 3-2 Typical limiters for synchronous generators

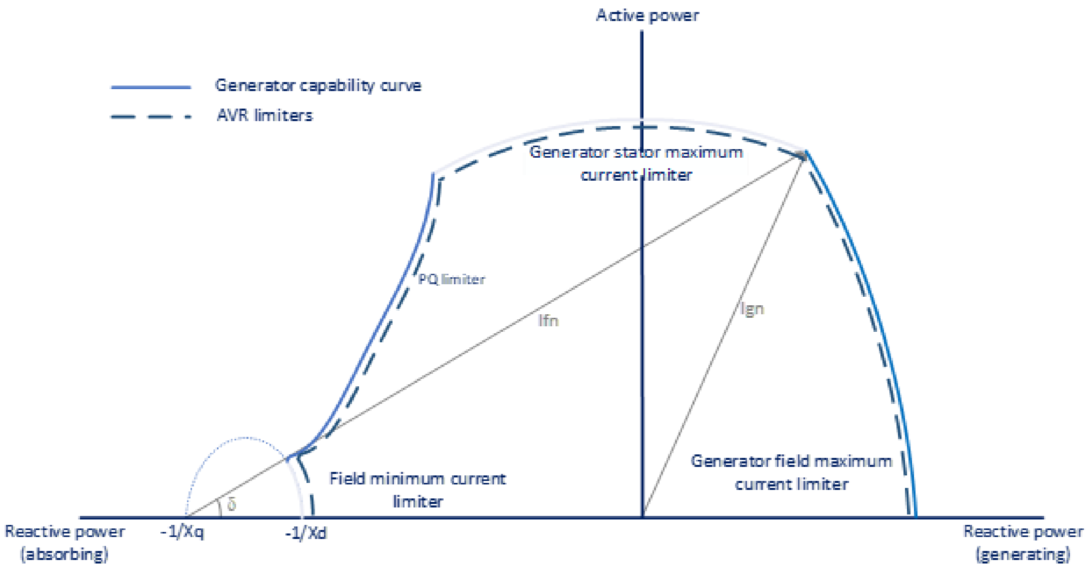


Figure 3-3 Reactive Power capability curve ideal and min requirements

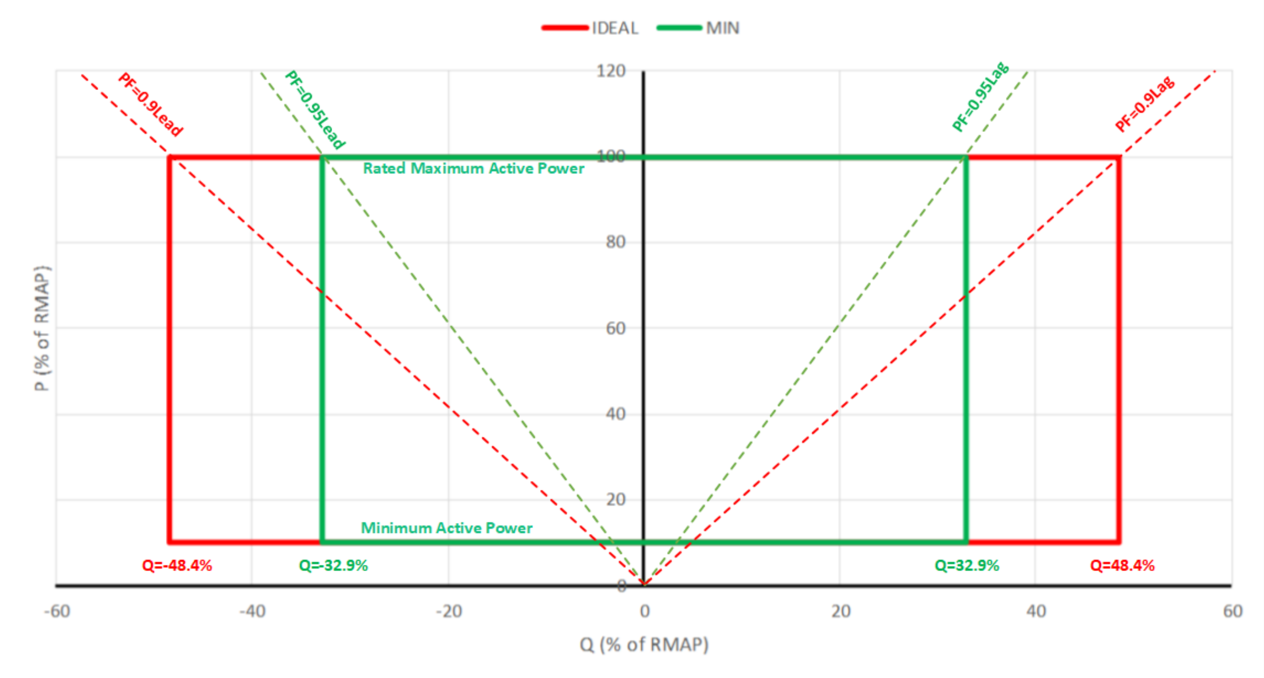


Table 3-3 Points of demonstration for reactive power dependency to terminal voltage min performance

Voltage at Connection Point (pu)	PF Range	Reactive power range (pu)
0.9	0.95lagging	0.329 supplying
0.95	0.95lagging to 1	0 to 0.329 supplying
1	0.95 lagging to 0.95 leading	0.329 absorbing to 0.329 supplying
1.05	1 to 0.95 leading	0 to 0.329 absorbing
1.1	0.95 leading	0.329 absorbing

Within the minimum requirement for reactive power capability, when the temperature at the location of the Generating System is above 25 degrees, Intermittent Generating Systems can negotiate to achieve the reactive power requirement by reducing the active power output as per A12.3.3.3. This performance and extent of the change of active power must be evaluated and agreed with the Western Power and being registered as part of the GPS.

3.3.4 Simulated PQ capability curve at the Connection Point

For Generating Systems with Asynchronous Generating Units, the Performance Chart is required to be evaluated at the Connection Point (See Table 3-2) unless another measurement location is determined and agreed upon with Western Power and AEMO. These facilities comprising solar and wind farms as well as battery storage systems will have reactive power and voltage controllers to support the system voltages. The capability of inverters which are provided by manufacturers is required to be translated into aggregate Performance Chart at the Connection Point. In this exercise, the reticulation system, internal transformers, and voltage controlling devices all come into play for the Performance Chart at the Connection Point.
With respect to the configuration of the Generating Systems and philosophy of voltage control, the reactive power capability can be evaluated at the Connection Point or agreed measurement location. Table 3-4 lists typical configuration of inverter connected generation systems. Table 3-5 lists typical arrangement of voltage controllers and recommended method of varying the reactive power between max and min achievable at the Connection Point. The method applied to a Generating System might change with respect to the type of controls and generating units so the methods that have been applied to produce the Performance Chart at the Connection Point must be provided and explained in detail in the Market Participant submission.

Table 3-4 Typical type of Generating System arrangement with respect to voltage controllers

Generating Systems	Optional fixed compensators
Induction generators plus BESS/SVC/STATCOM	Capacitor banks and/or filters
DFIG and BESS/SVC/STATCOM	
Solar Inverters and/or BESS/SVC/STATCOM	
Wind turbine inverters and/or BESS/SVC/STATCOM	

Table 3-5 Voltage control philosophies and methods of varying reactive power at Connection Point in simulations

Dynamic compensator	Connection transformer	Recommended method to vary the reactive power
Reactive power devices control the voltage at Connection Point	On load tap changer controlling LV	Use the controller voltage setpoint to scan the reactive power* Switch to reactive power control with P priority and set Q beyond the inverter limits at each side* On-load tap transformers have with their AVR setpoint enabled.
Reactive power devices control the LV voltage of SUT	On load tap changer controls HV	Use the tap changer range to vary the reactive power*

* If there is a Power Plant Controller (PPC) limit to keep the reactive power of the site within the technical code limits, its setting is required to be widened to allow full reactive power contribution from the devices providing reactive power support inside the facility.

The following explains a common method to evaluate the PQ at the Connection Point:

1. Set the Connection Point at a fixed voltage level (i.e. 1pu, 0.9pu and 1.1pu)
2. Vary the active power at generating units to emulate the active power variation at Connection Point between Pmin and Pmax. A small Pstep results in smoother reactive power capability curve.
3. For each active power level, vary the controller per Table 3-5 methodology, run a load flow ensuring the elements contributing to voltage/reactive power controls within the facility are at their maximum absorbing or generating capability.
4. Check the voltage at all internal busbars are within the safe operating range and away from voltage protection trip settings. Also, check the loading capacity of internal elements. If voltages are not safe or elements are overloaded, readjust the reactive power to ensure safe internal operation and repeat step 3.
5. At the same operating point of step 4, initialise and run a dynamic simulation for 30-50 seconds. We expect no changes in reactive power due to the activation of controller's limiters. If so, the reactive power must be adjusted to lower level to avoid limiters action and step 3 repeated.
6. Record both load flow and dynamic (P,Qmin) and (P,Qmax) operating points along confirmation of safe voltage range at each evaluation point.

We also need to ensure the inverters' PQ capability are set for Maximum Temperature for the above procedure. Figure 3-4 and Figure 3-5 shows examples of reactive power capability plots for voltage variation and ambient temperature variation at the Connection Point respectively. A table of discrete values using the Template excel sheet provided by western Power must also accompany the plots when submitting GPS.

Figure 3-4 Example for reactive Power capability curve and variation in voltage in POC and maximum ambient temperature

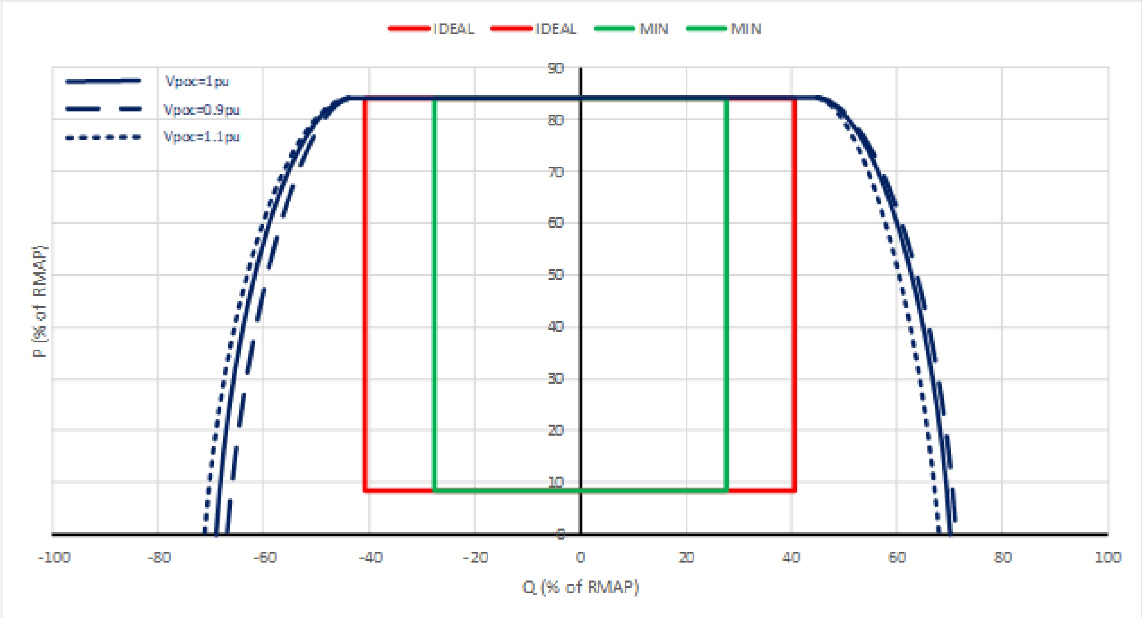
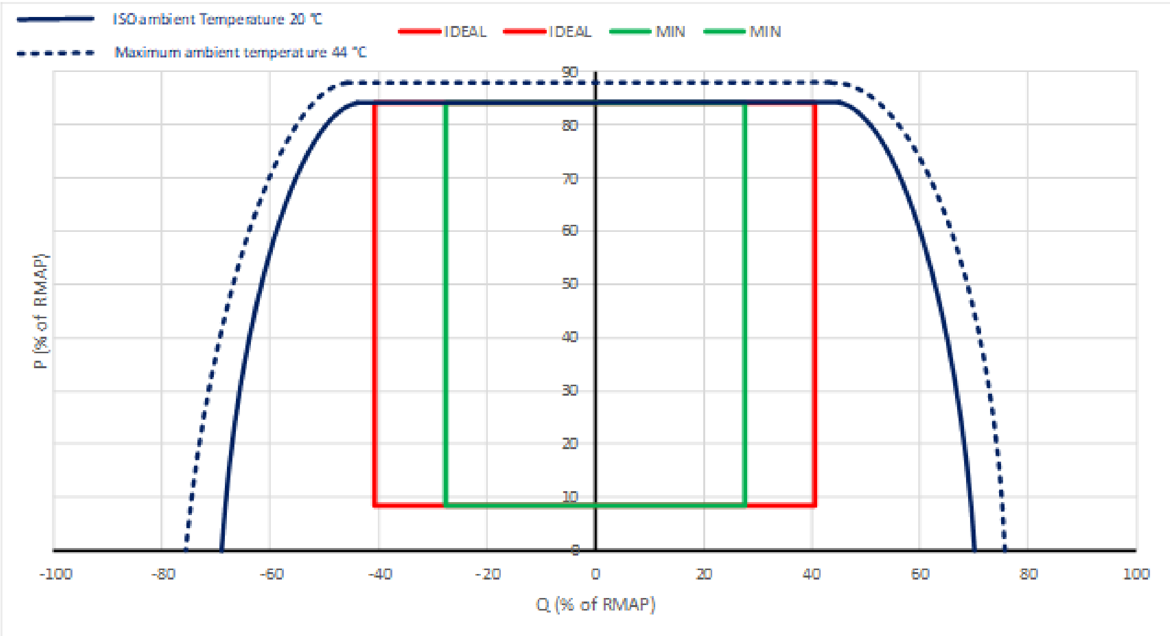


Figure 3-5 Example for reactive Power capability curve ISO and maximum ambient temperature for nominal voltage at Connection Point



3.4 Technical Requirement: Voltage and Reactive Power Control [A12.4]

3.4.1 Introduction to section A12.4 of the WEM Rules

Section A12.4 of the WEM Rules sets out the basis for the design and operation of voltage, reactive power, and power factor controllers of Generating Systems by specifying controller performance requirements.

The following Technical Requirements for voltage and reactive power controllers are covered in section A12.4 of the WEM Rules:

- Type of controllers
- Speed and sensitivity of controllers
- Structure and performance of stabilizing control logics
- Damping requirements

These requirements are verified during the design stage through simulations and design documents and the registered performance is tested during the commissioning test.

To assess the Technical Requirements in this section, RMS simulation (using the DIgSILENT PowerFactory software tool) will be performed on a network equivalent model. Western Power will provide the parameters of the network equivalent model.

3.4.2 Explanation of individual Technical Requirements

Table 3-6 lists the requirements for each category of compliance. It shows the Ideal and Minimum standards with respect to voltage and reactive power control.

Table 3-6: Voltage control philosophies and methods of varying reactive power at Connection Point in simulations

Category	Ideal standard	Minimum standard
Type of controllers	• Voltage, Reactive Power, and Power Factor	• Voltage or Reactive Power/Power Factor with the agreement of AEMO and Western Power
Measurement Location	• At the Connection Point or other location as determined by Western Power and AEMO	
Controller range	• The required performance should be met when operating at any Active and Reactive Power level as specified in A12.2 and A12.3 and at all temperature up to and including Maximum Temperature	• The required performance should be met when operating at any Active and Reactive Power level as specified in A12.2 and A12.3 and at all temperature up to and including Maximum Temperature
Controller range	• Voltage: capability to continuously control the voltage between 95% to 105% of the Voltage Target Setpoint, which is specified by Western Power, without reliance on tap-changing transformer, and subject to Reactive Power Capability • Reactive Power or Power Factor: capability to continuously control the reactive power across registered reactive power capability range	• Voltage: capability to continuously control the voltage between 98% to 102% of the Voltage Target Setpoint, which is specified by Western Power • Reactive Power or Power Factor: capability to continuously control the reactive power across registered reactive power capability range

Category	Ideal standard	Minimum standard
Controller accuracy	• Voltage: capability to regulate voltage at Connection Point or another Measurement Location in the SWIS to within 0.5% of the Target Setpoint • Reactive Power: capability to achieve the reactive power Target Setpoint with an error margin equal to 2% of the Rated Maximum Apparent Power of the Generating System.[8] For Power Factor control mode, the respective response in MVAR should have the same error margin	• Voltage: capability to regulate voltage at the Connection Point or another Measurement Location in the SWIS to within 2% of the Target Setpoint • Reactive Power: capability to achieve the reactive power setpoint with an error margin equal to 5% of the Rated Maximum Apparent Power of the Generating System. For PF control the respective response in MVAR should have the same error margin
Controller sensitivity	• Minimum equivalent gain of 200	• Not specified
Control system limiters	• Voltage Limiters must be implemented to ensure voltage disturbances do not cause a Generating Unit to trip by protection at the limits of the Performance Chart • Continuous stable operation when voltage limiters are active • The voltage regulator should support network voltages during faults and support system stability • For synchronous generators: a minimum excitation system ceiling factor of 2.3 for static type and 1.5 for other types	• Voltage Limiters should be implemented to ensure voltage disturbances do not cause a Generating Unit to trip at the limits of the Performance Chart • Continuous stable when voltage limiters are active • For synchronous generators: a minimum excitation system ceiling factor of 1.5
Step response rise time	**Synchronous Generating Systems:** • Generating Unit Field voltage rise time of 0.05s or less for static excitation systems and 0.5s or less for other excitation systems **Asynchronous Generating Systems:** • Rise time of 1.5s or less for reactive power or voltage, whichever is controlled after a 5% step is applied to the voltage setpoint	• Not specified
Step response settling time	**Synchronous Generating Systems:** • Unsynchronised: 1.5s or less for static excitation systems and 2.5s or less for other excitation systems • Synchronised: 2.5s or less for static excitation systems and 5s or less for other excitation systems • When excitation limiters activate: 5s or less **Asynchronous Generating Systems:**	• 7.5s or less for a 5% step into the voltage reference point provided that no limiter becomes active at such a voltage step.

[8] For example, if a Generating System's Nameplate Rating at the Connection Point is 100MVA, the error margin should not be greater than 2 MVAR.

Category	Ideal standard	Minimum standard
	• If no limiter is not affecting the controlled output: 2.5s or less • If limiters activated affecting controlled output: 5s or less	
Damping requirements	• Power system oscillations against any other Generating System or the system must be adequately damped • Operating the Generating System does not degrade the damping of any critical oscillatory modes of the system • Operating the Generation System does not cause instability	• Power system oscillations against any other Generating System or the system must adequately damp at all operating condition
Stabilising control logic	**Power system stabiliser (PSS) structure when installed:** • Two washout filters for each input with possibility to bypass one • More than two lead-lags blocks with adjustable settings • Monitoring available for inputs, outputs and internal signals • Equipment to permit testing and tuning of the PSS in isolation **Synchronous Generating Systems:** • Must have a PSS to be tuned for maximum damping on the frequency range 0.1Hz to 2.5Hz • Equipped with input signals of rotor speed and active power • Equipped with output limiters which are adjustable to results in PSS additional signal within ±10% of stator voltage **Asynchronous Generating Systems:** • Must have a voltage and reactive power control system that has a power oscillation damping capability • Stabilising circuit should be able to be tuned for damping performance as required by Western Power on the frequency range 0.1Hz to 2.5Hz • Equipped with input signals of power system frequency and active power output	• Not specified
Recording and monitoring	• Permanently installed and operational recording devices to monitor key variables	• Equipment to ensure the control systems can be sufficiently tested to establish their dynamic operational characteristics

Category	Ideal standard	Minimum standard
	including inputs, outputs, and key internal signals[9] • Equipment to ensure the control systems can be sufficiently tested to establish their dynamic operational characteristics	

The following is to be noted for the requirements set out in the above table:

- For all Generating Systems, voltage control is required as part of a negotiated performance standard.
- When evaluating voltage control accuracy, the 0.5% error margin applies between the Target Setpoint and the achieved response.
- If the Generating System has a reactive power controller or a power factor controller, it is recommended to have a ramp limiter on the setpoint signal applied by operators, to achieve the setpoint within 5-10 seconds.
- The excitation system ceiling factor for a Synchronous Generating System is the ratio of the maximum excitation voltage to the excitation voltage required to operate the machine at rated active power, nominal speed, and nominal terminal voltage in accordance with the relevant Australian or ISO Standard for Synchronous Generating Units. The manufacturers of Synchronous machines assign these ratings based on relevant standards[10].
- Field voltage rise time is evaluated following the application of a short duration step change to the voltage regulator reference voltage. The step signal for this test should be large enough to cause the excitation system to reach its ceiling voltage. Refer to the following section for the definition of the rise time and settling time Section 3.4.2.2.
- The rise time for Asynchronous Generating Systems must be verified for voltage or reactive power signals. If the facility has both controller systems, the rise time requirement applies to both control modes.
- The settling time for Synchronous Generating Systems is evaluated when running at nominal speed for both synchronised (i.e., connected to the system) and unsynchronised (i.e., islanded) conditions. The step response should resemble a 5% voltage step at the generator terminal. The unsynchronised settling time is only affected by the performance of the excitation system. Therefore, the settling time is expected to be lower. When connected to the system, the voltage changes are compensated by both the system and the generator thus, a slower response is allowed. It is also the case when a disturbance is large enough to activate excitation system limiters (over excitation limiter (OEL), under excitation limiter (UEL), current limiter, PQ Limiter, V/Hz etc) in which case a slower response is allowed.
- For Asynchronous Generating Systems, if the disturbance or step into the controllers is small such that it does not activate any limiter clamping the output signal (voltage or reactive power whichever is under control), the settling time must be below 2.5 seconds. This time also needs to be maintained at all operating points in the Performance Chart. If the disturbance results in the activation of the limiters, then a settling time of 5 seconds or less is required. The largest practical

[9] Refer to Appendix B.5 of WEM Procedure: Communication and Control Systems for detailed requirement available at: https://aemo.com.au/en/energy-systems/electricity/wholesale-electricity-market-wem/procedures-policies-and-guides/procedures

[10] Example of standards: AS 60034 Rotating Electrical machines

step test should be applied in each case when testing for compliance with this Technical Requirement.

- As per WEM Rules clause A12.4.1.2, all the requirements of section A12.4 apply to all allowed operating points within the Performance Chart as provided under A12.3 and at all temperatures up to and including the Maximum Temperature. This means that all the requirements should be met when operating at any Active and Reactive power within the Performance Chart and as indicated by the Temperature Dependency Data of Active and Reactive Power. If any of the requirements are not met or partially met for the full range boundaries of the Performance Chart, then the Performance Chart needs to be further limited to a range that the requirements are met.

3.4.2.1 Definition of Adequately Damped

Adequately Damped is defined in the *Power System Stability Requirements Guideline*[11], which expands upon the oscillatory stability requirements described in the Technical Rules. An adequately damped system oscillation must conform to the following criteria:

- A damping ratio of at least 0.1 (10% or more)
- Oscillation halving time of 5 seconds or less
- Allow generators to maintain Continuous Uninterrupted Operation

The above is applied to oscillatory response after large and small disturbances. More information on the evaluation of the damping factor and halving time is provided in Appendix B of this guideline.

3.4.2.2 The definition of Rise Time and Settling Time

The Rise Time for a step response of a control system is defined as the time for output quantity to rise from its initial value to 90% of the final value. The starting point to evaluate the rise time is the time at which the output quantity starts moving from the initial value. If the output quantity moves from its initial value but has not moved in the direction of the response, or moves slowly, that time is also counted as part of the rise time.

The Settling Time for a control system step response is defined as the time it takes for the output quantity to settle within 10% of the final value. The starting point to evaluate the settling time is the time at which the control system step has been applied. The delay time for a control system is counted as part of the settling time.

Appendix A provides more information on the Rise Time and Settling Time evaluation in various cases.

3.4.3 Required set of tests to evaluate the controller performance

3.4.3.1 Step tests

Controller setpoint step tests are the standard method of evaluating the performance of a controller. These tests are done on the computer model only. Requirements for commissioning and compliance test are captured in the GPS Commissioning Test Plan, which is attached to the WEM Procedure referred to in clause 3A.9.1(a) of the WEM Rules.

Several controller performance criteria are verified through step tests. Table 3-7 provides a list of required tests and their associated WEM Rules criteria. A test plan detailing the test procedure is required to be

[11] Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/industry/manuals-guides-standards/generator-performance-standards/) for further information on Stability requirements and adequate damping definition.

submitted to and agreed upon by Western Power and AEMO. Similar tests will be performed in simulation at the planning phase on a validated computer model of the Generating System for performance verifications. For example, during simulation, Market Participant should apply step up and step down in a single simulation run and verify that the controller will return to the starting point. As long as the test plan is clearly explained, the test setup is flexible and can be amended beyond Table 3-7.

Table 3-7: Required simulations to establish and verify Generating System performance

Applied to	Generating System	Simulation description	Operating points / Test conditions	Criteria
AVR setpoint – not synchronised	Synchronous	±2.5%, ±5% step into AVR setpoint while machine is not synchronised	No load	Verify: • Field voltages rise time (A12.4.2.11) • Settling Time (A12.4.2.11., A12.4.3.6.(b))
AVR setpoint – synchronised within limiters	Synchronous	±2.5%, ±5% step into AVR setpoint Repeat PSS on and off	• Min MW output • 50% MW output • 100% MW output • Max lead MVAR output • 0 MVAR output • Max lag MVAR output • Close to 0 MVAR so that the step transfer Lead MVAR to Lag MVAR and reverse • Tap-Position Locked	Verify: • Field voltages rise time (A12.4.2.11) • Settling Time for 5% step (A12.4.2.11., A12.4.3.6.(b)) • Droop (if applicable) • Final value error and equivalent gain (A12.4.2.5(a), A12.4.3.4.(a), A12.4.2.10.(d)) • continuous controllability (A12.4.2.5(c), A1.4.3.4.(b)) • Adequate damping (A12.4.2.2., A12.4.2.9.)
AVR setpoint – synchronised Step into OEL/UEL limiters		5% step into AVR setpoint (positive or negative to activate the limiters) see note blow	• Min MW output • 25% MW output • 50% MW output • 100% MW output • Max lead MVAR output • Max lag MVAR output •	Verify: • Field voltage rise time (A12.4.2.11) • Settling Time for 5% step

				(A12.4.2.11., A12.4.3.6.(b)) • Adequate damping (A12.4.2.2., A12.4.2.9.)
AVR setpoint – synchronised excitation ceiling		5-10% short time pulse into AVR setpoint	• 100% MW output • 0 MVAR output	Verify: • Excitation ceiling voltage (A12.4.2.10.(b))
Q/PF setpoint		Step for 5-10% MVAr	• 100% MW output	Verify: • Final value error (A12.4.2.7.(a), A12.4.3.5.(a)) • Adequate damping (A12.4.2.2., A12.4.2.9.)
V or Q control setpoint Within limiters	Asynchronous	±2, ±5% step into controller setpoint Repeat POD on and off	• 50% MW output • 100% MW output • Max Lead MVAR output • 0 MVAR output • Max lag MVAR output •	Verify: • Field Voltage rise time (A12.4.2.15) • Settling Time for 5% step (A12.4.2.15, A12.4.3.7) • Droop (if applicable) • Final value error and equivalent gain (A12.4.2.5(a), A12.4.3.4.(a), A12.4.2.14) • continuous controllability (A12.4.2.5(c), A1.4.3.4.(b)) • Adequate damping (A12.4.2.2., A12.4.2.9.)
V or Q control setpoint Step into limiters		5% step into controller setpoint (positive or negative to activate the limiters)	• 50% MW output • 100% MW output • Max lead MVAR output • Max lag MVAR output	Verify: • Settling Time for 5% step

				(A12.4.2.15, A12.4.3.7) • Adequate damping (A12.4.2.2., A12.4.2.9.)

Note: The step change into limiters should be from a point which is 2.5% away from limiter. So, the Q point (MVAR) should be set to a point from which, a 2.5% step would be almost touching the limiter and a 5% step would be sufficient to step beyond the limiter.

3.4.3.2 Steady state error and controller equivalent gain

A12.4.2.10 and A12.4.2.14 of the WEM Rules describe an Ideal standard as having an equivalent gain of 200. This is to be achieved by the proportional and integral part of the voltage controller for both Synchronous and Asynchronous Generating Systems. The maximum error between the target voltage and measured voltage at the terminal or connection point must not be greater than 0.5% of the voltage Target Setpoint in accordance with clause A12.4.2.5 of the WEM Rules.

This section explains how these values are interrelated and how evidence of compliance is achieved after a step test, considering the control system shown in Figure 3-6. For a pure proportional controller, the steady state error after applying a step change to the setpoint can be calculated as:

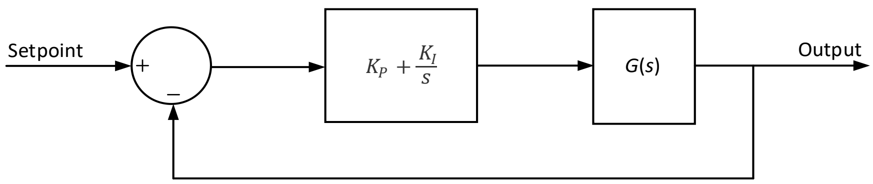
Equation 3-1

$$Final\ Value\ Error = \frac{1}{K_P G(0)+1}$$

Where, K_p is the proportional gain and $G(0)$ is the open loop gain of the system from exciter to generator terminals.

Considering that modern AVR systems gains are greater than 1, the final value error is proportional to the inverse of the controller gain. Achieving the steady state error of 0.5% or lower and equivalent gain of 200 are interrelated. The final value error between the expected output value and measured final value during step response test must be observed to verify the steady state error and equivalent gain requirements.

Figure 3-6: A generic proportional integral (PI) controller applied on a plant with a linear transfer function of G(s)



If the controller has a small integration component, the final value error will become zero. In real system implementations, there are still small errors between the expected value and the achieved value that need to be below 0.5% (ideal) and 2% (minimum) per section A12.4 of the WEM Rules. Equation 3-1 cannot be used to evidence the equivalent gain in this case. Achieving a steady state error below 0.5% is deemed adequate for such controllers.

In the simulation environment, setting up a test as per the steps below can be used to provide evidence of the minimum equivalent gain. Setting up tests for Synchronous Generating Systems differs from Asynchronous Generating Systems, this is discussed further in the following sections.

3.4.3.2.1 Minimum equivalent gain for Synchronous Generating Systems

For a Synchronous Generating System, the minimum equivalent gain must be verified by observing the change in the excitation field voltage as a fixed error signal is simulated at the voltage controller as follows:

A. Setup the Generating System in a single unit infinite bus system single machine infinite bus (SMIB). The Generating System should be connected directly to an ideal voltage source (zero impedance between the generator's terminal and the voltage source) for which the voltage magnitude is controllable.

B. Initialise the voltage source and voltage setpoint such that the reactive power of the unit is close to zero.

C. Apply a +0.005p.u. voltage step at a selected time to the ideal voltage source magnitude and let the simulation run until the generator's voltage and reactive power settle down to a steady state value.

D. Check the excitation voltage step change of the Generating System from the initial value to the maximum value. The step change in the excitation voltage of 1 pu verifies the minimum equivalent gain of 200.

E. Repeat steps C and D for a -0.005pu voltage step.

Notes for this procedure:

- When performing these simulations, the excitation control system may activate the limiters like OEL, UEL and field current limiter (IF Limiter). The limiters will distort the assessment of main AVR gain by clamping the controller output. Therefore, the evaluation should be done prior to the activation of the limiters.
- If the unit is setup to work on the voltage droop, the evaluation of the minimum equivalent gain will be affected by the droop value, so the droop value must be set to zero or the droop controller must be disabled for this evaluation.
- It is recommended to check the limiters in the controllers are set correctly to prevent it from limiting the step change in excitation voltage to reach to 1 p.u.

3.4.3.2.2 Minimum equivalent gain for Asynchronous Generating Systems

For Asynchronous Generating Systems, the minimum equivalent gain is verified by achieving the maximum reactive power at the Connection Point while a fixed error signal is simulated at the voltage controller as follows:

A. The Generating System at Connection Point will be connected directly to an ideal voltage source (zero impedance between terminal and the voltage source) for which the voltage magnitude is controllable.

B. Initialise the voltage source and voltage controller of the Generating System near 1pu to get the reactive power of the unit close to zero.

C. Apply a +0.005pu voltage step at a selected time to the ideal voltage source magnitude and let the simulation run until generators voltage and output reactive power settles down at final steady state values.

D. Check reactive power of the Generating System at the Connection Point. If the reactive power absorption of the Generating System reaches the maximum level of the Performance Chart, it verified that the 200 minimum equivalent gain is achieved.

E. Repeat steps C and D for a -0.005pu voltage step.

Notes for this procedure:

- When performing above simulations, set the Generating System to control the voltage at Connection Point. Also let tap changer of main transformer correct the LV side voltage.
- If the Generating System works on a voltage droop, the evaluation of the minimum equivalent gain will be affected by the droop value, so the droop value must be set to zero or the droop controller disabled for this evaluation.
- If the voltage controller is a PI controller, for any step applied the output reactive power will reach the maximum MVAR value (due to saturation of integral part). If it does not, the limiters in controllers may have limited the reactive power generation. In such cases, evaluation should be undertaken at a time prior to limiter activation or alternatively the simulation should be started at a lower or higher voltage away from the limiter's activation thresholds.

3.5 Technical Requirement: Active Power Control [A12.5]

3.5.1 Introduction to section A12.5 of the WEM Rules

Section A12.5 of the WEM Rules describes the technical requirements for active power controllers installed at the Generating Systems. The active power control balances the active power output of Generating Systems by following Target Setpoints (normally sent through Dispatch Instruction). It also enables ramping of the active power of the Non-Intermittent generators and limiting the maximum power of the Intermittent Generating Systems.

This section mainly covers:

- The performance requirement of the active power controller
- The minimum ramp limit requirements of Non-Intermittent Generators
- The maximum ramp limit of Intermittent Generators
- Non-Intermittent and Intermittent Generators are defined in section 3.5.2.6

To assess the requirements in this section, RMS simulation will be performed on a network equivalent model. The parameters of the network equivalent model will be provided by Western Power.

3.5.2 Explanation of individual requirements

3.5.2.1 Meeting dispatch requirements

The Generating System must be able to fit into AEMO's central dispatch arrangement as per section 2.35 of the WEM Rules. The WEM Procedures: Communication and Control Systems[12] published by AEMO must be followed for Generating Systems receiving Dispatch Instructions. The Facility Operation Agreement can be used as evidence of compliance.

3.5.2.2 Performance of the active power controller

Actions performed by the active power controller when ramping up or down the facility output or maintaining a limit should be adequately damped per clause A12.5.1.3 of the WEM Rules. The definition of Adequately Damped is as per the *Power System Stability Requirements Guideline*[13]. More information is also provided in Appendix B of this guideline.

The requirement of section A12.5 of the WEM Rules applies to the system normal operation. If the frequency deviates outside the Frequency Dead Band because of a frequency event, the Generating Systems are required to provide a fast response to capture the frequency deviation as specified in section A12.6 of the WEM Rules. As per clause A12.5.1.6 of the WEM Rules, the requirements of section A12.6 are prioritised over the requirement of section A12.5. As an example, the Active Power output of the Generating System is allowed to deviate from Target Setpoint in case of a frequency event.

3.5.2.3 Managing constraints and disconnection agreement

During the connection process, arrangements may have been put in place to manage overloading of the elements in the network, or to limit the active power output of a Generating System for other reasons. Control schemes like overloading run backs, or inter-tripping of embedded loads or part of the generation,

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12 Available at: https://aemo.com.au/en/energy-systems/electricity/wholesale-electricity-market-wem/procedures-policies-and-guides/procedures

13 Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/industry/manuals-guides-standards/generator-performance-standards/) for further information on Stability requirement and adequate damping definition.

are examples of such schemes. Per clause A12.5.1.2 of the WEM Rules a registered GPS must include such schemes and is required to detail the following:

- The conditions initiating the scheme
- The agreed response level and speed of the Generating System
- The conditions for releasing the limitation of active power

Similarly, any disconnection arrangement and settings must be recorded as part of the Registered GPS that is negotiated in accordance with clause A12.5.1.4. of the WEM Rules. A disconnection might be triggered by an inter-tripping signal received from upstream elements of the SWIS. This is applicable for any type of protection or controller that can issue a trip signal to disconnect the Generating System as part of an active power control scheme. Examples include reverse or low power protection tripping due to large oscillations in active power.

3.5.2.4 Loss of communication

In accordance with clause A12.5.1.5 of the WEM Rules, Generating Systems that receive their active power Target Setpoint issued as Dispatch Instruction from the central system must maintain the last received healthy Target Setpoint in case of failure of Remote Monitoring Equipment (RME) or Remote Control Equipment (RCE) or losing the communication channel between the central station and the facility or between RME and RCE and controller. This is to prevent the Generating System from ramping down during these events. The last received healthy Target Setpoint should be maintained until the new dispatch instruction is received.

If the Generating System is under local active power control (like embedded generators inside of a process facility) and does not receive a setpoint from the central control, the failure of the RME or communication should not result in an unnecessary ramping of load/generation within that facility.

3.5.2.5 Compliance when operating at any Range of Active and Reactive Power and Temperature

As per WEM Rules clause A12.5.1.7, all the requirements of section A12.5 apply to all allowed operating points within the Performance Chart as provided under A12.3 and at all temperatures up to and including the Maximum Temperature. This means that all the requirements should be met when operating at any Active and Reactive power within the Performance Chart and as indicated by the Temperature Dependency Data of Active and Reactive Power. If any of the requirements are not met or partially met for the full range limits of the Performance Chart, then the Performance Chart needs to be further limited to a range that the requirements are met.

3.5.2.6 Active Power ramping requirements

The ramping requirements of the active power controller of the Generating System per clauses A12.5.2.1, A12.5.2.2, A12.5.3.1 and A12.5.3.2 of WEM Rules are listed in Table 3-8

Non-Intermittent Generators receive Dispatch Instructions from AEMO and have a firm capacity to maintain the Active Power at the Target Setpoint requested. The Synchronous Generating Systems in power plants installed mainly for delivery of the electric power to the network are Non-Intermittent generators. Other types of Generating Systems such as Battery Energy Storage Systems (BESS) may be registered as Non-Intermittent Generators, which means they must meet the requirements of clause A12.5.2.1 of the WEM Rules. Generators such as wind farms, solar farms and other renewable generators which cannot maintain a fixed level of scheduled Active Power are Intermittent Generators. These definitions are applied throughout this guideline.

Non-Intermittent Transmission Connected Generating Systems that receive Target Setpoints should follow the Dispatch Instruction i.e., ramp up/down to the dispatched value and maintain the Active Power output until another Target Point is received[14]. These facilities must have a minimum ramp rate of 5% of the rated Maximum Active Power of the facility per minute for Ideal performance.

Transmission Connected Intermittent Generating Systems, which are subject to energy source availability, must limit their ramp rates. The maximum ramp rate of 10MW/min or 15% (whichever is lower) of the Rated Maximum Active power is specified in the Ideal standard. The ramp rates may also be negotiated conditionally in between Ideal and Minimum standards. To meet the minimum requirement, a Transmission Connected Intermittent Generating System must demonstrate that any change of Active Power output in a 5 minute period does not exceed a value agreed upon with AEMO and the Western Power

Table 3-8: The ramping requirements of active power controller of the Generating Systems

<table>
<tr><th>Category</th><th>Ideal standard</th><th>Minimum standard</th></tr>
<tr><td>All Generating System</td><td colspan="2">Active Power controllers must:
• Meet all the following requirements for any Active and Reactive power allowed in Performance chart and any Temperature up to Maximum Temperature
• Maintain last dispatch level if Communications are unavailable
• Be Adequately Damped
• Be capable to respond to a fixed target (Individual Generating System Controllability)</td></tr>
<tr><td>Non-Intermittent Generators</td><td>Active Power controllers must:
• Linearly ramp active power
• If thermally stable, have a ramp rate of not less than 5% (of Rated Maximum Active power of the Generating System) per minute or higher
• meet the dispatch requirement (Overall Transmission Connected Generating System)</td><td>Active Power controller must:
• If thermally stable, have a ramp rate of not less than 5% (of Rated Maximum Active power of the Generating System) per minute or higher</td></tr>
<tr><td>Intermittent Generators</td><td>Active Power controllers must ensure:
• Subject to energy source availability, the Active Power output of the Generating System's instantaneous ramp up or down at Connection Point should not exceed more than the lower of:
– 10MW per minute; or
– 15% of the aggregated MW rating of the Generating System</td><td>Active Power controllers must ensure that:
• Subject to energy source availability, the variation of Active Power output of the facility over 5 minutes doesn’t exceed the limit agreed by Western Power and AEMO</td></tr>
</table>

[14] Refer to WEM PROCEDURE: COMMUNICATIONS AND CONTROL SYSTEMS published by AEMO for complete list of requirements

	• meet the dispatch requirement (Overall Transmission Connected Generating System) • The above ramp rates can be negotiated and agreed with Western Power and AEMO.	

Note: For Generating Systems that cannot be defined solely as a Non-Intermittent or Intermittent Generating System (e.g., a wind farm equipped with a BESS which is registered as a Scheduled Generator), the requirements of Table 3-8 should be applied only after consultation with Western Power and AEMO.

3.5.3 Simulations to be performed

The following simulation must be performed and included in supporting documents when submitting the GPS

Table 3-9 Simulations required to establish and verify Generating System performance

Requirement	Simulation description	Operating points / test conditions	Criteria
Active Power Control System Capability (Non-Intermittent))	• 5 % step increase in MW Target Setpoint • -5 % decrease in MW Target Setpoint	• 50-85% of rated MW-MW output / Single Machine Infinite BUS	• Ramping Linearly • Ramp rate of 5% of Rated Maximum Active Power
Active Power Control System Capability (Intermittent))	• 5 % step increase in MW Target Setpoint • -5 % decrease in MW demand signal	• 50-85% of rated MW-MW output / Single Machine Infinite BUS	• Ramp rate of 10MW/min or 15% of the Rated Maximum Active Power

Note: Generating System characteristics may require the step changes to be larger. Larger changes may be considered to more accurately determine equipment performance (e.g., A step size of 10% or 20%).

3.6 Technical Requirement: Inertia and Frequency Control [A12.6]

3.6.1 Introduction to section A12.6 of the WEM Rules

Section A12.6 of the WEM Rules describes requirements for the frequency control capability of Generating Systems. The frequency control in a power system is the most crucial security task of power system operators. Every Generating System in a power system, unless instructed otherwise, is required to have a local frequency controller. The goal of these controllers is to measure the frequency of the system as an indicator of the balance between the supply and demand of energy, and then react by increasing MW when frequency declines and reducing MW when frequency increases. The speed at which these responses can be achieved as well as the response level have a direct effect on the performance of the system frequency security.

The Technical Requirements for frequency controllers of Generating Systems are:

- The activation of the frequency response and the sensitivity of the response
- The speed of the response
- Duration of the response and reverting to normal operation

To assess the requirements in this section, RMS simulation must be performed on a network equivalent model. The parameters of the network equivalent model will be provided by Western Power.

3.6.2 Explanation of individual requirements

3.6.2.1 Measurement, recording and testing facilities

In the Common Requirements section under clause A12.6.1.4 of the WEM Rules, a Generating System must have permanently installed recording and monitoring devices so that the frequency response of the Generating System can be assessed after an event and during normal operation. The inputs and outputs to the frequency controller (i.e., active power, frequency, a command issued to other units, or other limiting signals that might affect the dynamic response), must be recorded during its activation. This data must be sufficient to allow evaluation of the dynamic behaviour of the controller and of the overall response. As per clause A12.6.1.12, the requirement of frequency control (where the Active Power is measured in response to frequency) is applied to Connection Point unless Western Power and AEMO determine a different Measurement Location (e.g., for a Synchronous Generator the Measurement Location is determined to be at Generator Terminal i.e., the active power will be monitored at the generator terminal).

3.6.2.2 Compliance when operating at any Range of Active and Reactive Power and Temperature

As per WEM Rules clause A12.6.1.13, all the requirements of section A12.6 apply to all allowed operating points within the Performance Chart as provided under A12.3 and at all temperatures up to and including the Maximum Temperature. This means that all the requirements should be met when operating at any Active and Reactive power within the Performance Chart and as indicated by the Temperature Dependency Data of Active and Reactive Power. If any of the requirements are not met or partially met for the full range limits of the Performance Chart, then the Performance Chart needs to be further limited to a range that the requirements are met.

3.6.2.3 Protection settings

All protection settings relevant to power frequency control, in particular frequency protection (under/over frequency, ROCOF relay setting), must be made available and be registered as part of the GPS Submission as per clause A12.6.1.3 of the WEM Rules. Any relevant agreed performance and disconnection settings must also be included in the GPS Submission.

3.6.2.4 Maximum ramp rate

A Generating System must have a normal ramp rate of active power control that complies with section A12.5 of the WEM Rules, between the Market Participant, Western Power and AEMO. If frequency deviates outside the Frequency Dead Band (as per clause A12.6.1.9 of the WEM Rules), the normal ramp rate of active power control will be overridden by the frequency control.

The frequency controllers are required to respond at a much faster rate. In accordance with clause A12.6.1.2 of the WEM Rules, the speed of response is to be specified as a recorded ramp rate of MW change over 6 seconds (as per clause A12.6.1.2 of the WEM Rules). The maximum ramp rate is the maximum response expected from the Generating System when the frequency deviates outside the Frequency Dead Band. The 6 seconds is selected as identical to the Ideal speed of response of Synchronous Generating Systems, which is coherent with the natural inertial time constant of the SWIS. The maximum ramp rate is representative of MW response that a Generating System (Synchronous and Asynchronous) contributes to maintaining frequency.

3.6.2.5 Disconnection on over-frequency

The use of protection and other schemes that disconnect a Generating System to comply with the Technical Requirements of section A12.6 of the WEM rules should generally be avoided. However, schemes of this type may be able to be used after negotiation with Western Power and AEMO in accordance with clause A12.6.1.6 of the WEM Rules. Due to the criticality of these controllers to the system security, such disconnections are generally avoided and should not be considered as part of a preferred solution.

3.6.2.6 Required specification for frequency control

The standard performance and characteristics of the frequency controller are listed in Table 3-10.

Table 3-10: Power frequency controller requirements

Category	WEM Rules clause	Ideal standard	Minimum standard
Capability and operating modes	A12.6.1.7	• All Generating Units with a Generating System must have an automatic power frequency controller • If the Synchronous Generating System is driven by turbines, a speed controller should also be included	
Operation	A12.6.1.8	All Generating Systems should operate in frequency control mode unless: a. Approved for testing by AEMO b. Agreed by Western Power and AEMO and instructed to operate in different mode	
Control performance	A12.6.1.1	The control systems associated with power-frequency control or speed control should be Adequately Damped in all operating conditions.	
Frequency Dead Band	A12.6.1.9	No greater than ±25mHz symmetrical around 50Hz.	
Droop response (Frequency reduction and increase)	A12.6.1.10 (a) and (b)	Response with a frequency droop not greater than 4% for both over and under frequency events. Refer to section 3.6.2.7	

Response delay	A12.6.1.11(b)	Frequency response is required to act as immediately as practicably possible. A delay that is greater than that required to ensure stable operation or to allow for control system latency, must be agreed by Western Power and AEMO.	
Initial output	A12.6.2.1 (a), A12.6.3.2(a), A12.6.3.2(b)	Frequency control response for underfrequency events to be provided for initial output levels between Rated Minimum and the maximum Active Power as specified in the Temperature Dependency Data (as provided under A12.2)	• Frequency control response for underfrequency events to be provided for initial output levels between rated minimum and 85% of Rated Maximum Active Power • Above 85% of Rated Maximum Active power, provide a frequency response to underfrequency events with an agreed sensitivity
Speed of response	A12.6.2.1 (b), (c) A12.6.3.2(c), (d)	**For Synchronous Generating Systems:** • Achieve 90% of expected response within 6 seconds of the event, if expected MW change is at least 5% of the Rated Maximum Active Power **For Asynchronous Generating Systems:** • Achieve 90% of expected response within 2 seconds of the events if expected MW change is at least 5% of the Rated Maximum Active Power	Achieve 60% of expected response within 6 seconds and 90% within 15 seconds after the event if expected MW change is at least 5% of the Rated Maximum Active Power
Response duration	A12.6.2.1 (d), A12.6.3.2(e)	• Maintain the frequency control response for at least 10 seconds after the Generating Unit has reached 90% of response whilst frequency is still outside the Frequency Dead Band of controller • The maximum time and response characteristic that the Generating Unit can maintain the frequency response at expected level beyond the required minimum 10 seconds must be included as part of the unit's GPS and the ramp rate used while the Generating System returns to dispatch set point as specified in Active Power control in A12.5	
Step Change in Response	A12.6.1.11 (a)	• The frequency response must not exhibit any step changes in Active Power as the power system frequency changes, unless otherwise agreed by Western Power and AEMO under clause A12.6.1.6 (Refer to Section 3.6.2.9 for more details)	
Capability to sustain frequency response	A12.6.2.1 (d) A12.6.3.2 (e) A12.6.1.5	• Refer to section 3.6.2.8 of this guideline for more details	

Notes:

- The Market Participant must demonstrate that the delay of the frequency control response is only due to the processing time of the control system and/or maintaining Generating Unit's stability. Western Power and AEMO will assess the impact and must agree to any proposed delays
- Both the frequency and active power controls regulate the active power of the Generating Unit. When a frequency event happens, the transition between these controllers must be smooth. The following section explains the required response and the transition between normal active power control and frequency response.

3.6.2.7 Droop Response

The power-frequency controller droop is defined as below:

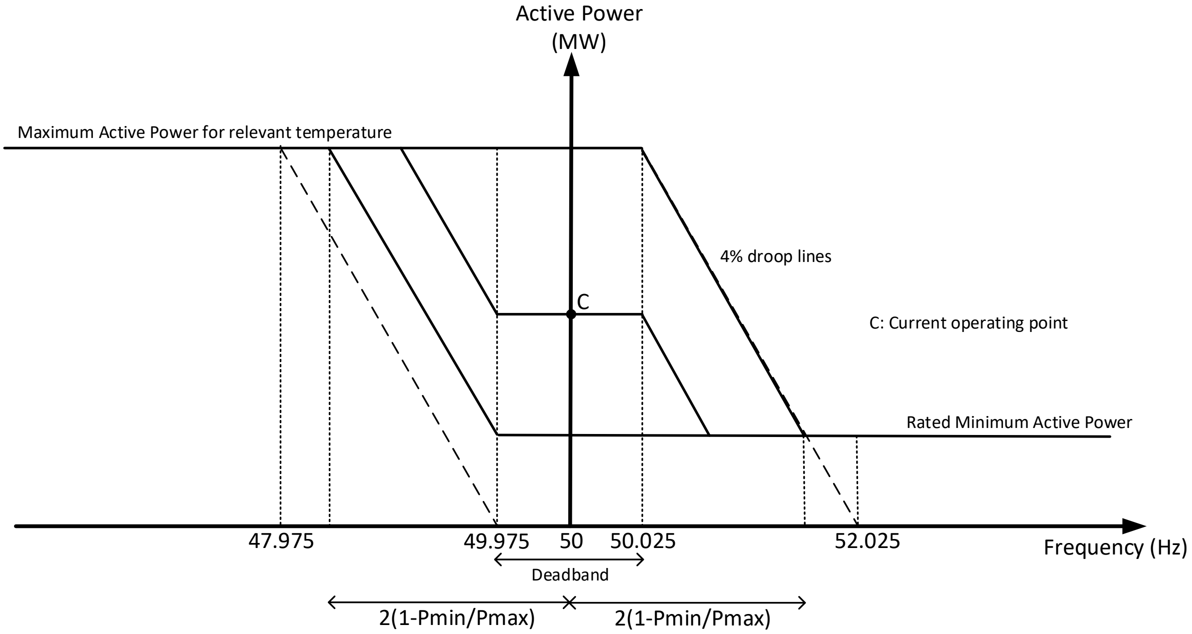
Equation 3-2

$$Droop(\%) = 100 \times \frac{\Delta F / 50}{\Delta P / P_{Max}}$$

Where ΔF is the frequency deviation beyond the limit of the affected Generating System Frequency Dead Band (in Hz), and ΔP is the change in active power (in MW) of the Rated Maximum Active Power at the location agreed in clause A12.2.3.1 of the WEM Rules.

A maximum droop of 4% must be achieved by the frequency controller. It translates into a 5% change in active power for every 0.1Hz change in frequency. This response is required for active power operating points above Rated Minimum Active Power and up to the maximum active power specified in the Temperature Dependency Data provided under A12.2 for the relevant temperature (at least for ideal performance). Figure 3-7 demonstrates the response and droop lines for a 4% droop setting. From Figure 3-7, at any operating point between minimum and maximum (for a generator performing at ideal standard), a droop response is required when the frequency deviates outside of the Frequency Dead Band. If the Rated Minimum Active Power is zero, then the 4% droop line requires active power changes equal to the full range of active power up to maximum active power for the relevant temperature of the facility for a 2Hz frequency change outside the Frequency Dead Band. As shown in Figure 3-7, a Generating System with non-zero minimum rated active power reaches its minimum power before the frequency reaches the 2Hz mark. Other droop setting arrangements (i.e., multiple droop setting) will be assessed on a case-by-case basis.

Figure 3-7: Frequency control droop lines and Frequency Dead Band



3.6.2.8 Frequency response and hold time requirements

Figure 3-8 and Figure 3-9 demonstrate the frequency response speed requirement and the transition between frequency control and normal Active Power control (normal ramp rate) during and after the hold time under different system frequency events. For modelling purposes, the frequency step change is applied to simulate when the system frequency deviates outside of the Frequency Dead Band and then restores back to within the Frequency Dead Band.

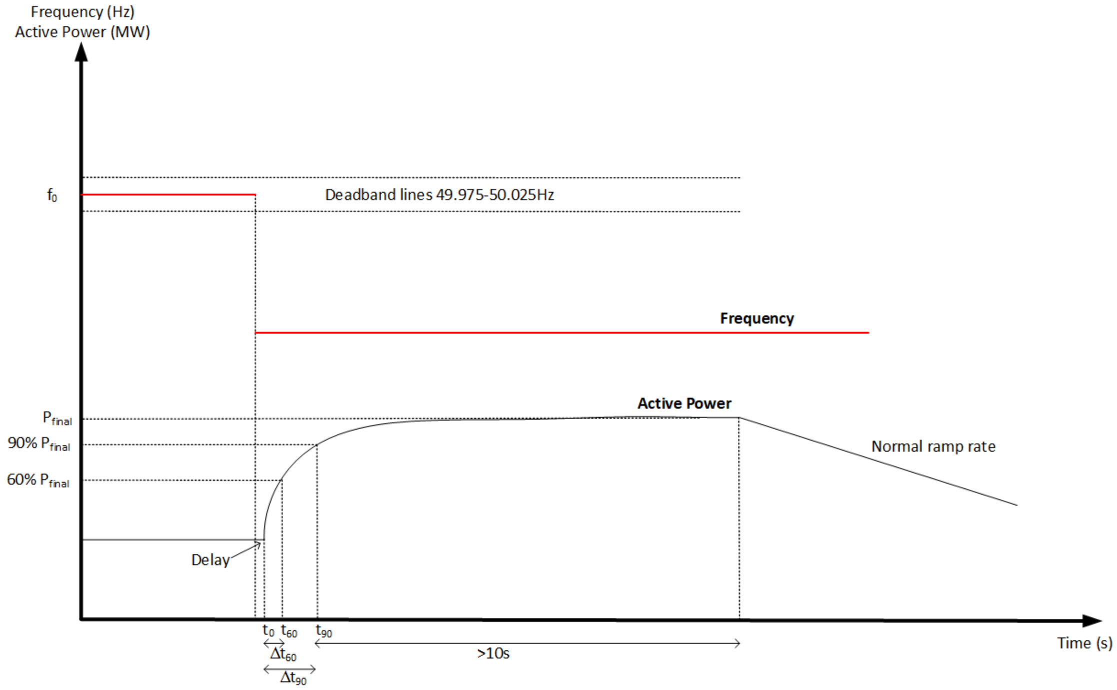
The ideal standard requires that the Δt_{90} be below 6 seconds for Synchronous Generating Systems and below 2 seconds for Asynchronous Generating Systems. The minimum performance monitors the Δt_{60} below 6 seconds and Δt_{90} below 15 seconds for both Synchronous and Asynchronous Systems. Note a small delay might exist before the response of the facility, which is not included in the response time above. This delay must be agreed with Western Power and AEMO and must be kept as small as practicably possible.

After reaching 90% of the response (t_{90} in Figure 3-8), a 10 second hold time is required. In the event the frequency is restored back to the Frequency Dead Band or crossed the Frequency Dead Band from underfrequency to over-frequency, or vice versa, the 10 second timer must be reset.

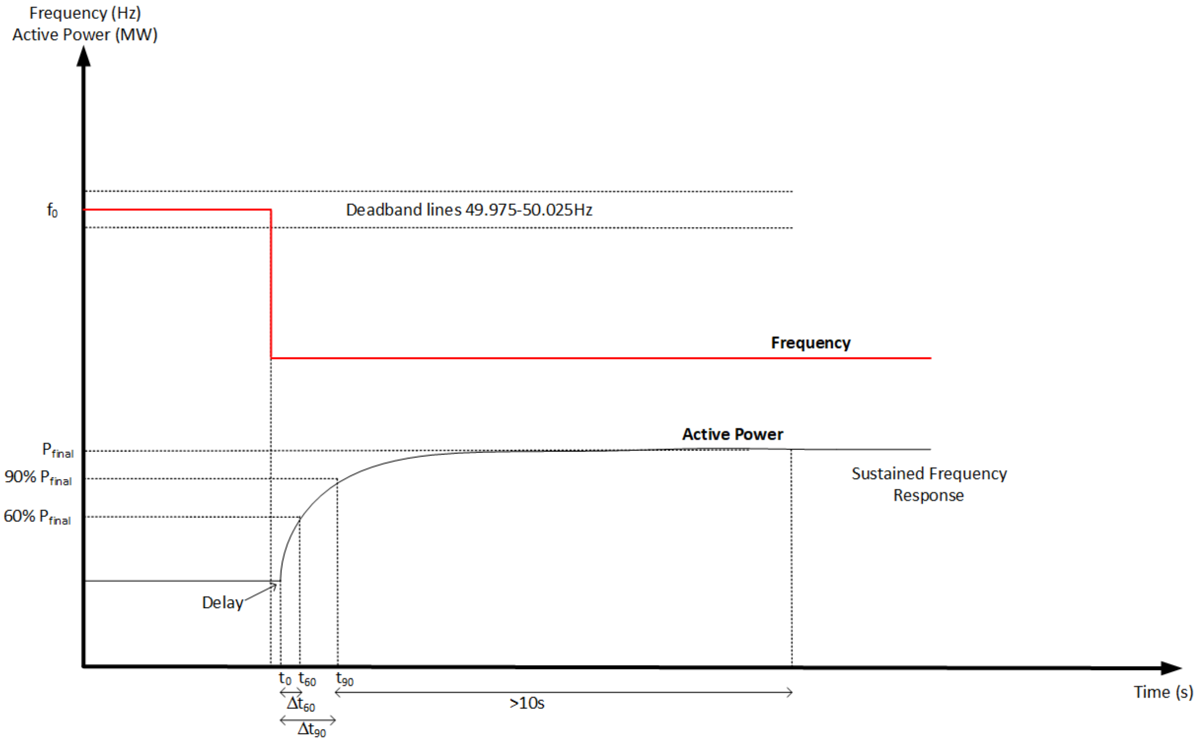
The frequency droop control is active during hold time, meaning that if the frequency varies, the response should vary accordingly. For example, if 10 seconds elapses and the frequency is still outside the Frequency Dead Band, the Generating System should ramp back to the starting operating point at the normal ramp rate (as required under section A12.5 of the WEM Rules). If the frequency returns to the Frequency Dead Band within the 10 second hold time, the response will follow the active frequency control loop, which brings the Generating System back to the starting operating point.

Figure 3-8: Frequency control and hold time demonstration for system under-frequency events; (a) frequency stays outside Frequency Dead Band after 10 seconds of reaching 90% of the final response, (b) frequency stays outside Frequency Dead Band and frequency response sustains after 10 seconds of reaching 90% of the final response, (c) frequency returns to Frequency Dead Band before 10 seconds passes, (d) frequency returns to Frequency Dead Band just after 10 seconds passes

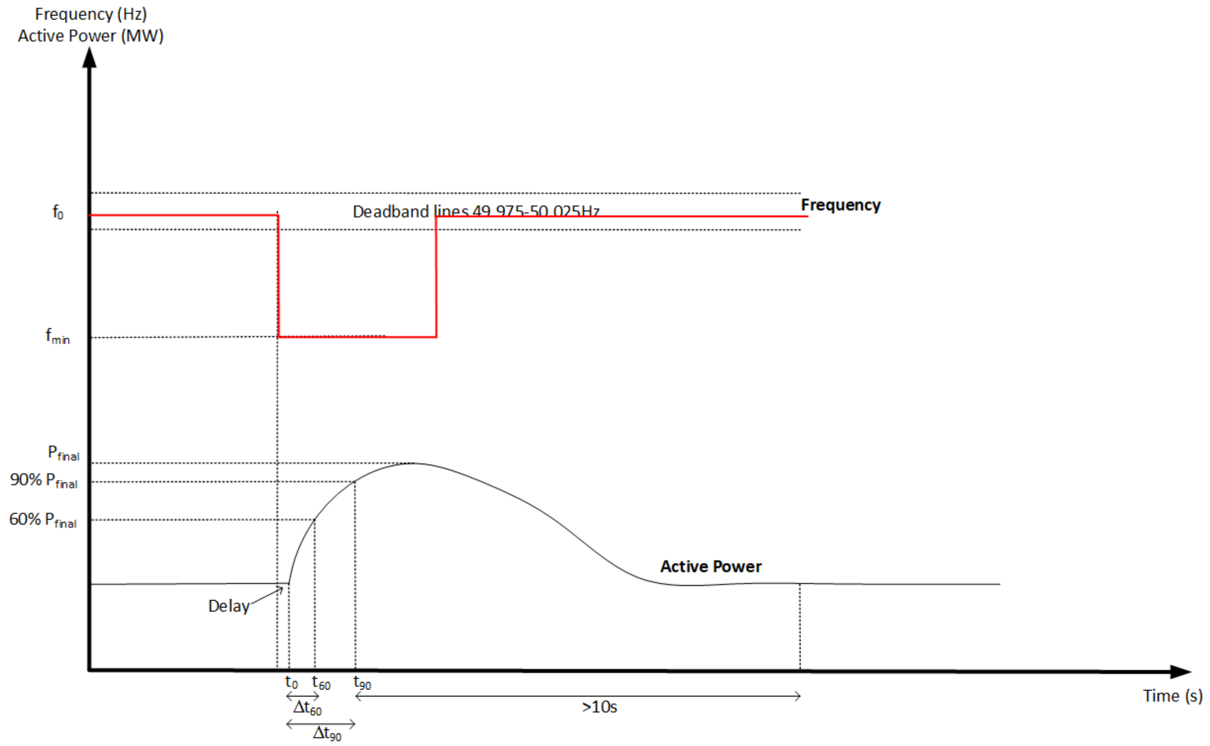
(a)



(b)



(c)


Frequency (Hz)
Active Power (MW)
f_0
Deadband lines 49.975-50.025Hz
Frequency
f_{min}
P_{final}
90% P_{final}
60% P_{final}
Active Power
Delay
t_0
t_{60}
t_{90}
Δt_{60}
Δt_{90}
>10s
Time (s)

(d)

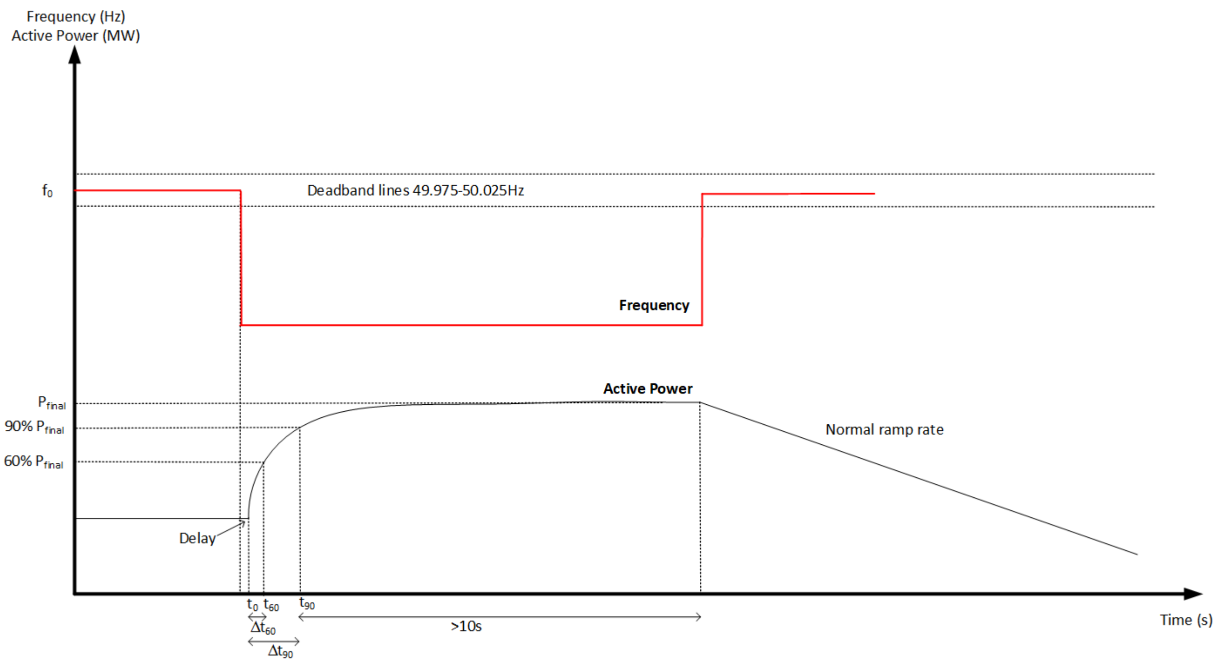
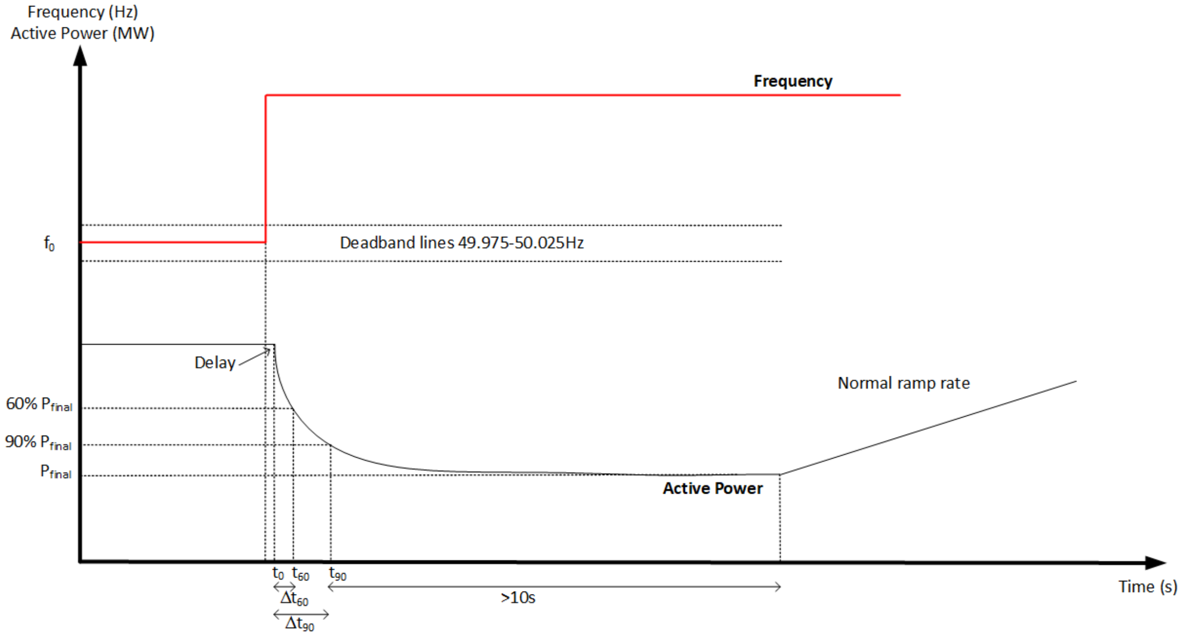
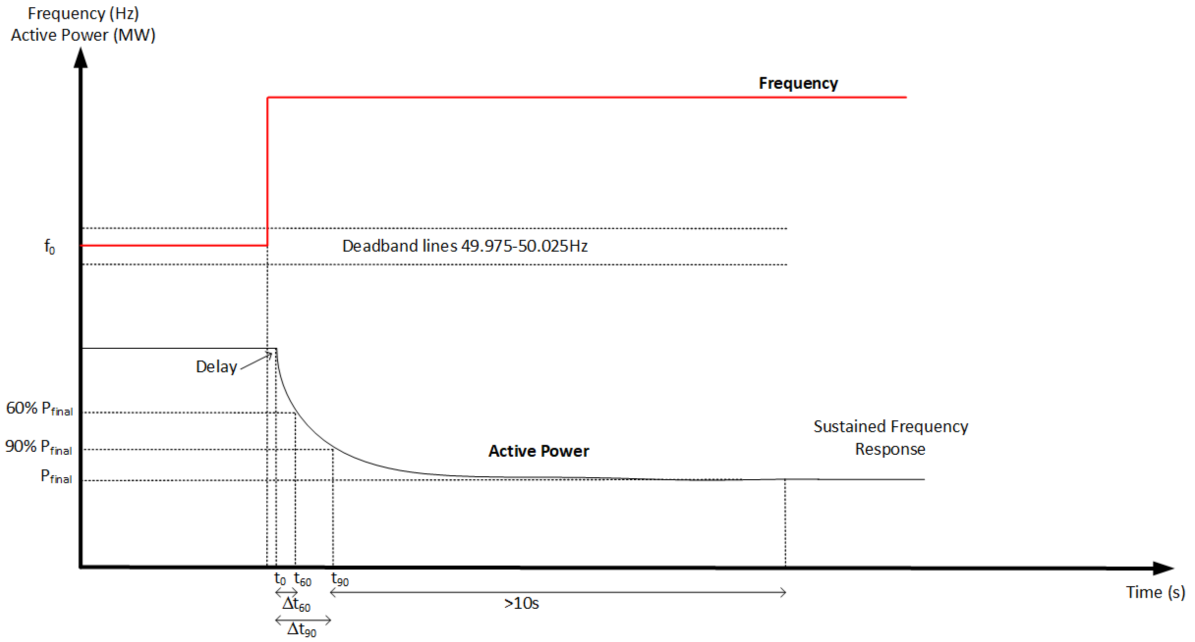

Frequency (Hz)
Active Power (MW)
f_0
Deadband lines 49.975-50.025Hz
Frequency
Active Power
P_{final}
90% P_{final}
60% P_{final}
Normal ramp rate
Delay
t_0
t_{60}
t_{90}
Δt_{60}
Δt_{90}
>10s
Time (s)

Figure 3-9: Frequency control and hold time demonstration for system over-frequency events; (a) frequency stays outside Frequency Dead Band after 10 seconds of reaching 90% of the final response, (b) frequency stays outside Frequency Dead Band and frequency response sustains after 10 seconds of reaching 90% of the final response, (c) frequency returns to Frequency Dead Band before 10 seconds passes, (d) frequency returns to Frequency Dead Band after 10 seconds passes

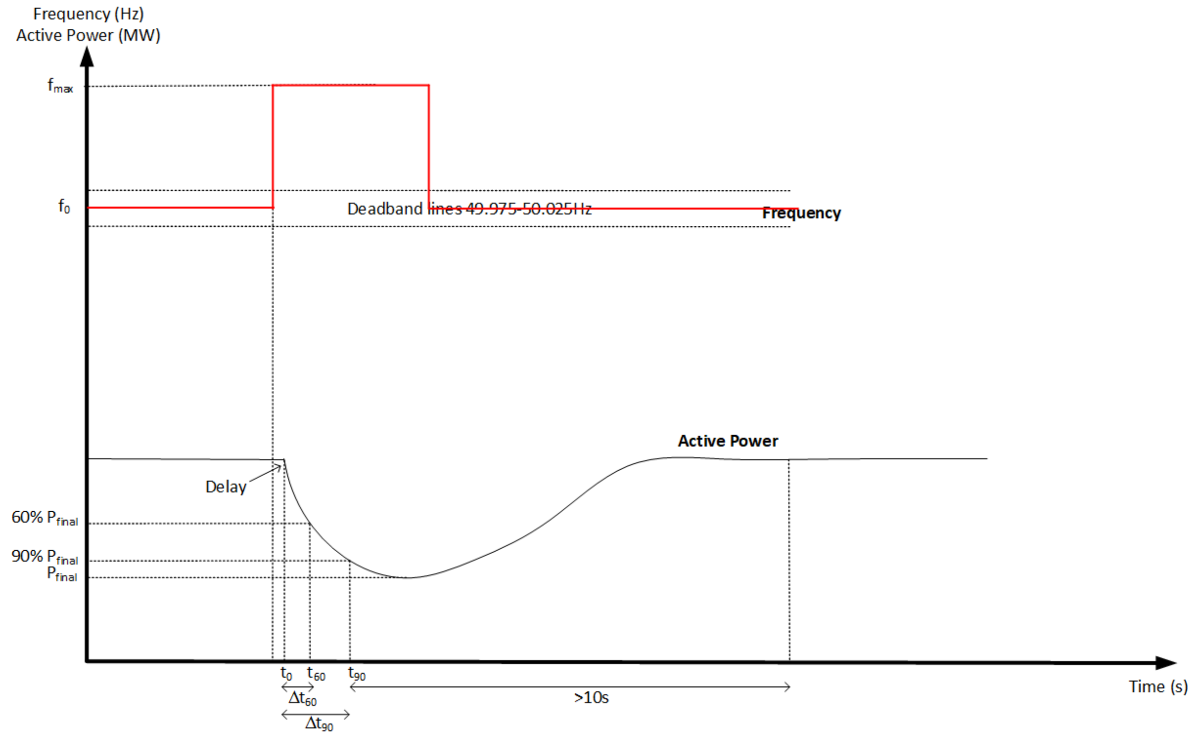
(a)



(b)

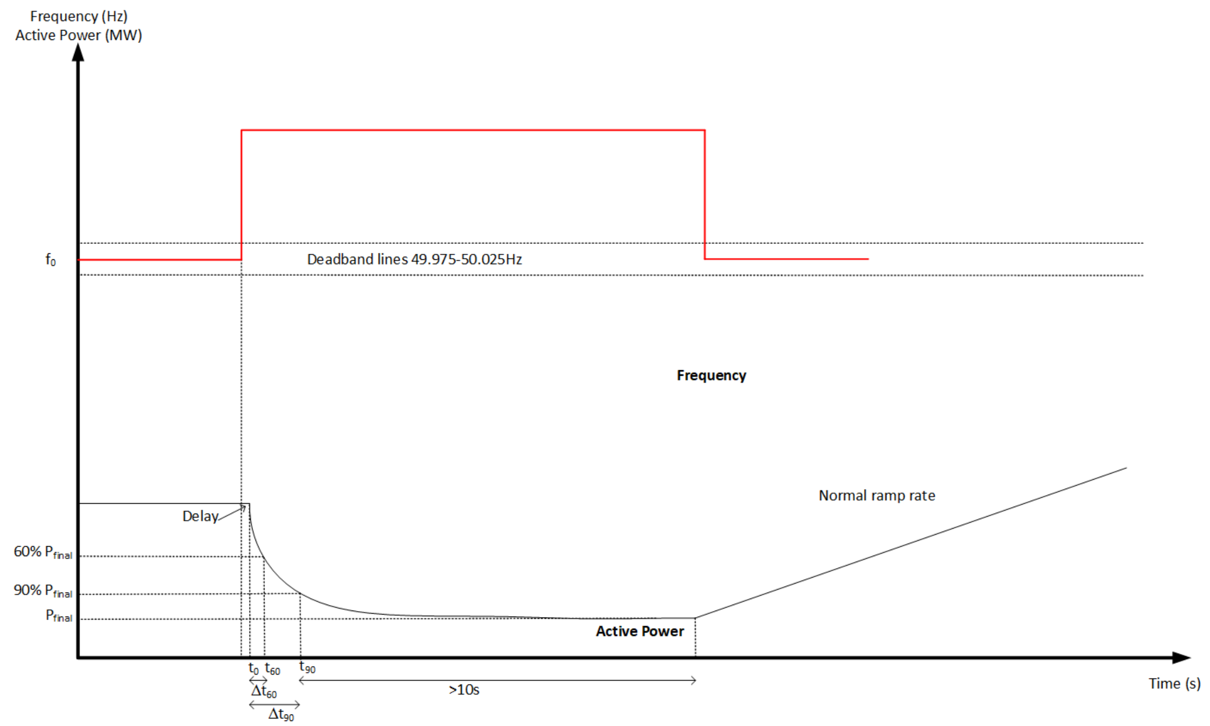


(c)



Frequency (Hz)
Active Power (MW)
f_{max}
f_0
Deadband lines 49.975-50.025Hz
Frequency
Active Power
Delay
60% P_{final}
90% P_{final}
P_{final}
t_0 t_{60} t_{90}
Δt_{60}
Δt_{90}
>10s
Time (s)

(d)

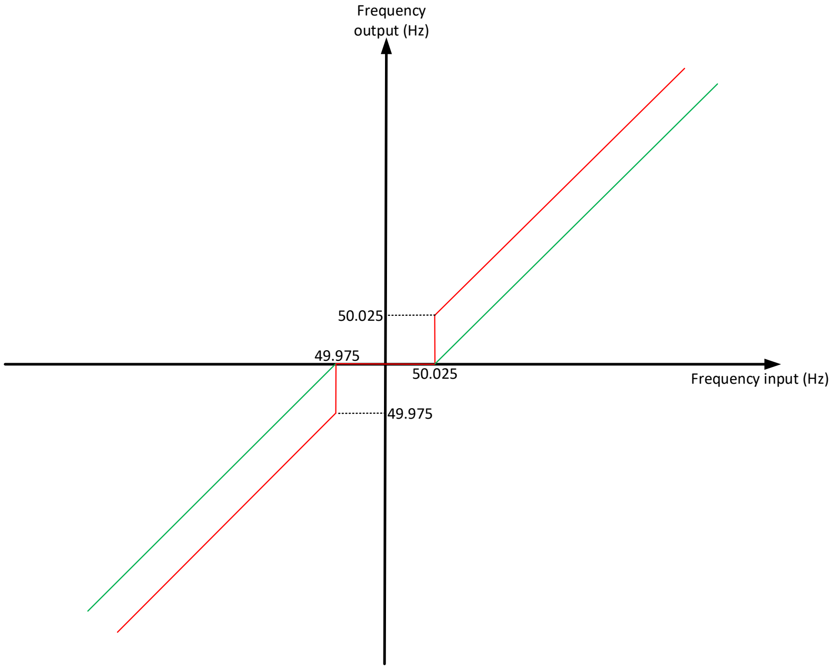


Frequency (Hz)
Active Power (MW)
f_0
Deadband lines 49.975-50.025Hz
Frequency
Normal ramp rate
Delay
60% P_{final}
90% P_{final}
P_{final}
Active Power
t_0 t_{60} t_{90}
Δt_{60}
Δt_{90}
>10s
Time (s)

3.6.2.9 *Implementation of Frequency Dead Band*

The implementation of the Frequency Dead Band controller should comply with the requirements of clause A12.6.1.11(a) of the WEM Rules. When moving outside the Frequency Dead Band (see Figure 3-10), the green line represents a compliant implementation while the red line does not.

Figure 3-10: Implementation of the Frequency Dead Band; green: compliant, red: non-compliant



3.6.3 Simulations to be performed

Simulations must be performed in an RMS or EMT environment with a full Generating System model and a simplified network model. Simulation results must be analysed, and relevant quantities should be calculated by the Market Participant and, where possible, presented on plots. Presented plots must include at minimum the following signals: Voltages, Active Power, Reactive Power, Frequency, Frequency control trigger. In Table 3-11 the description of required simulation for each requirement is provided

Table 3-11: Simulations required to establish and verify Generating System performance

Requirement	Simulation description	Operating points / test conditions	Criteria
Frequency Dead Band (A12.6.1.9)	• Iterative increase / decrease in system frequency by 0.001 Hz until upper/lower limit of Frequency Dead Band is crossed	• 50% MW output / Single Machine Infinite BUS	• No change in MW output within the Frequency Dead Band and change in MW output as soon as Frequency Dead Band is crossed
Sensitivity of response (A12.6.1.10 (a) and (b)) and initial MW output (A12.6.2.1 (a),	• Steps of ±0.125 Hz, and ±0.525/1.025/2.025 Hz in frequency measurement (or equal in speed measurement) as in Figure 3-8 (a) and Figure 3-9 (a)	• Min MW output • 25% MW output • 50% MW output	• Ideal: The change in MW output response should not be less than 5% of maximum Active Power specified in the Temperature Dependency Data provided under A12.2for each 0.1 Hz change in frequency

A12.6.3.2(a), A12.6.3.2(b))		• 85% MW output • 95% of maximum active Power • 100% Of maximum Active Power • / Single Machine Infinite BUS	(droop of 4%) for all MW output range • Minimum: The change in MW output response should be equal to 5% of Maximum Active Power (droop of 4%) at least up to 85% MW output range • No step change in MW response (the change in MW output should be smooth as in Figure 3-8 (a) and Figure 3-10
Response Delay A12.6.1.11(b)	• Steps of ±0.125 Hz, and ±0.525/1.025/2.025 Hz in frequency measurement (or equal in speed measurement)	• 50% of maximum Active Power • / Single Machine Infinite BUS	• The delay in MW response should be within acceptable range and change in Active Power output opposes frequency deviation
Speed of response A12.6.2.1 (b), (c) A12.6.3.2(c), (d)	• Steps of ±0.125 Hz, and ±0.525/1.025/2.025 Hz in frequency measurement (or equal in speed measurement) as in Figure 3-8 (a) and (b)	• 50% of maximum Active Power • / Single Machine Infinite BUS	• **Synchronous Generating Systems:** • Ideal: 90% of response should be achieved in 6 seconds (Δt_{90}) as in Figure 3-8 (a) • Minimum: 90% of response should be achieved in 15 seconds (Δt_{90}) as in Figure 3-8 (a) • • **Asynchronous Generating Systems:** • Ideal: 90% of response should be achieved in 2 seconds (Δt_{90} as in Figure 3-8(a) • Ideal: 60% of response should be achieved in 6 seconds (Δt_{60}) and Ideal: 90% of response should be achieved in 15 seconds (Δt_{90}) as in as in Figure 3-8(a)
Response duration A12.6.2.1 (d), A12.6.3.2(e) A12.6.2.1(e) and A12.6.3.2.(f)	• A step of ±0.1 Hz in frequency measurement (or equal in speed measurement) as in Figure 3-8 (a) and sustained for more than 10 seconds	• 50% of maximum Active Power • / Single Machine Infinite BUS	• The MW response should be sustained for a minimum of 10 seconds and be consistent with Statement of Compliance for A12.6.2.1(e) or A12.6.3.2(f)
Ramp Rate during and after frequency event	• A step of ±0.1 Hz in frequency measurement (or equal in speed measurement) and back to normal before 10 seconds as in Figure 3-8(c) and Figure 3-9 (c) • A step of ±0.1 Hz in frequency measurement (or equal	• 50% of maximum Active Power • / Single Machine Infinite BUS	• Before 10 seconds, ramp rate should be indicative of 4% droop • After 10 seconds ramp rate should be normal ramp rate as specified in A12.5

	in speed measurement) and back to normal after 10 seconds as in Figure 3-8 (d) and Figure 3-9 (d)		

3.7 Technical Requirement: Disturbance Ride Through for a Frequency Disturbance [A12.7]

3.7.1 Introduction to section A12.7 of the WEM Rules

For a power system dominated by Synchronous Generating Units, the disconnection of a Generating System will have an immediate impact on system frequency. In the dispatch process, AEMO requires to ensure that there is a sufficient reserve in place to control system frequency within the frequency standard as listed in WEM Rules Appendix 13 during and after a single credible contingency event.

In the event of multiple contingency events, under frequency load shedding (UFLS) schemes are deployed to avoid a total system collapse. One enabler of such management schemes is the capability of the connected generators to ride through frequency events. A Generating System cannot ride through every severe frequency deviation. Section A12.7 of the WEM Rules indicates the extent of the frequency deviation between which the system operator expects a Generating System to stay connected and ride through, including:

- The over-frequency envelope below which a Generating System must maintain Continuous Uninterrupted Operation (CUO)
- The under-frequency envelope above which a Generating System must maintain in CUO
- The maximum Rate of Change of Frequency (ROCOF) that the Generating System must maintain CUO

3.7.2 Explanation of individual requirements

3.7.2.1 Point of assessment

The disturbance ride through for a frequency disturbance is assessed at the Connection Point. However, any frequency protection in an internal system that disconnects the whole or part of the Generating System, must be considered when assessing the CUO criteria. If the assessment at Connection Point is not achievable for a Generating System due to complexity, Western Power and AEMO may agree to specify another location.

3.7.2.2 Provision of protection settings

All the protection settings relating to the frequency disconnection of the Facility or part of the Generating System must be included in the GPS. This also includes any internal protection that is sensitive to frequency.

3.7.2.3 Coordination between requirement of sections A12.6 and A12.7

If Western Power and/or AEMO have agreed for a protection system to disconnect the Generating System or a part of the Generating System to comply with frequency control requirements of section A12.6 of the WEM Rules, then when frequency deviates above the nominal frequency, the operation of those protection schemes is not considered a breach of the A12.7 requirements. It is to be noted that such protection schemes should be avoided whenever possible (as discussed in section 3.6.2.5 of this guideline).

3.7.2.4 Negotiation on under-frequency ride through envelope

If a Generating System cannot meet the requirements for ideal frequency ride through performance, the Market Participant should seek to register a proposed negotiated performance standard and provide evidence and explanation of why the Ideal performance could not be met. A negotiated performance standard can only be considered if Western Power and AEMO agree that the frequency would be unlikely to fall below 48.75Hz, as required under section A13 of the WEM Rules.

3.7.2.5 Compliance when operating at any Range of Active and Reactive Power and Temperature

As per WEM Rules clause A12.7.1.4, all the requirements of section A12.7 apply to all allowed operating points within the Performance Chart as provided under A12.3 and at all temperatures up to and including the Maximum Temperature. This means that all the requirements should be met when operating at any Active and Reactive power within the Performance Chart and as indicated by the Temperature Dependency Data of Active and Reactive Power. If any of the requirements are not met or partially met for the full range limits of the Performance Chart, then the Performance Chart needs to be further limited to a range that the requirements are met.

3.7.3 Frequency disturbance ride thorough criteria

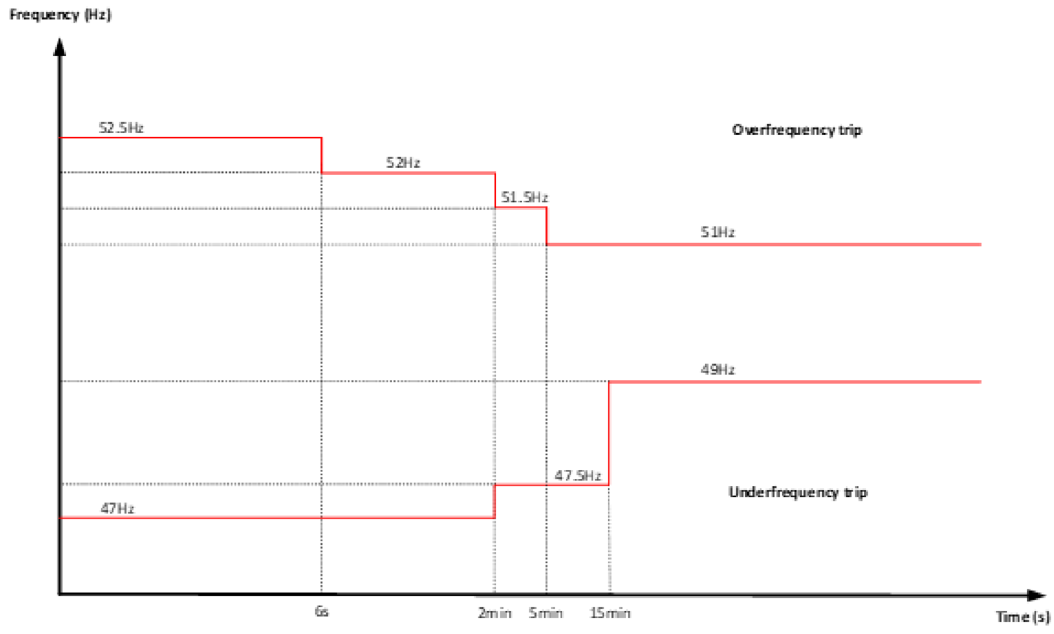
3.7.3.1 Over and underfrequency ride through envelopes

A Generating System must maintain CUO if the frequency at the Connection Point varies between the envelopes shown in

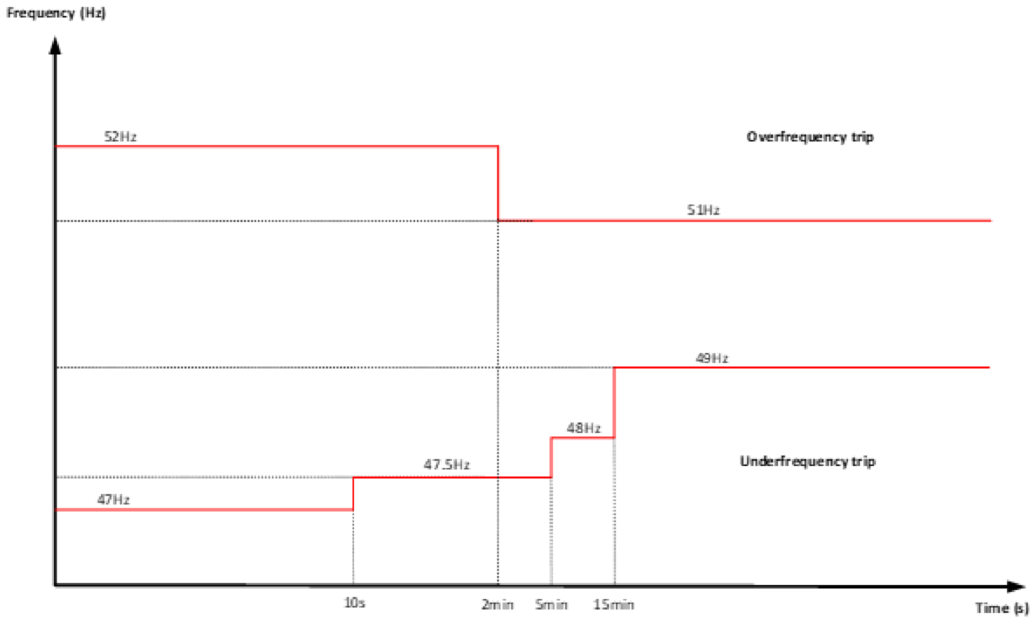
Figure 3-11 to comply with clause A12.7.2.1 or A12.7.3.1 of the WEM Rules. The Ideal and Minimum standards are shown in (a) and (b) part of this figure respectively.

Figure 3-11 Ride through requirement of generating facilities; (a) ideal performance standard, (b) minimum performance standard

(a)



(b)



3.7.3.2 Requirement to withstanding ROCOF

In accordance with clauses A12.7.2.2 and A12.7.3.2 of the WEM Rules, a Generating System is required to withstand ROCOF levels listed in Table 3-12, measured at the Connection Point.

Table 3-12 The ROCOF withstand requirements

Category	Ideal standard	Minimum standard
Short term ROCOF (measured over 250ms)	4Hz/s	2Hz/s
Long term ROCOF (measured over 1 seconds)	3Hz/s	1Hz/s

The ROCOF is divided into short term and long term which are assessed over periods of 250ms and 1 second respectively. Both positive (frequency increasing) and negative (frequency decreasing) ROCOF are to be considered when assessing the ROCOF criteria.

3.7.3.3 Assessment of ride through capability

When determining the ride through capability of a Generating System, the frequency protection settings and the controller response of the Generating Unit(s) must be assessed separately.

3.7.3.3.1 Frequency protections

Frequency protection at the Connection Point and internal to the Generating System that can trip the whole or part of the Generating System, should be assessed against the criteria listed in sections 3.7.3.1 and 3.7.3.2

of this guideline. Any internal protections inside inverters that can trip due to frequency excursions should also be considered.

3.7.3.3.2 Controller response

The dynamic response of the Generating System to frequency deviations also needs to be assessed. This is usually done by replicating the envelope (discussed in section 3.7.3.1 and limits in section 3.7.3.2 of this guideline) in a dynamic study, and assessing whether the Generating System issues a trip or deviates from any of CUO criteria provided in Appendix 12 of the WEM Rules. In such studies the following notes should be considered:

- Both positive and negative ROCOFs are to be included in the simulation
- When applying frequency envelopes, the transition between limit frequencies is behind the short term ROCOF. A step to frequency is not required in this case
- The short term ROCOF should be assessed at pre-event frequencies of 49Hz, 50Hz and 51Hz. The long term ROCOF is to be evaluated at 50Hz

It should be noted that when assessing the long term positive ROCOF for the Ideal standard, the frequency might reach 52.5Hz. This is above the over frequency envelope of

Figure 3-11. If a protection trip is issued due to over-frequency, it does not translate to a noncompliance. The simulation can be repeated with the over-frequency temporary deactivated or from a lower pre disturbance frequency. All other CUO requirements must be fulfilled to pass the requirement.

3.7.3.4 Simulations to be performed

Table 3-13 provides a summary of required simulations and relevant criteria.

Table 3-13 Required simulations to be performed for A12.7

Requirement	Simulation description	Operating points /Test Conditions	Criteria
CUO - frequency requirements A12.7.2.1 A12.7.3.1	A range of frequency disturbances covering the boundary of frequency ride through envelope modelled as a step-in frequency of the voltage source at Connection Point Two types of frequency change should be applied: 1. A single step from normal range to levels in the envelop and back to normal range 2. A sequence of steps from normal range to highest (or lowest) level in envelope, then change to the next lower (or higher level) until all levels have been covered and the next range is the normal range	• Rated Minimum Active Power (if applicable) • 50% of Rated Maximum Active Power • Rated Maximum Active Power • Frequency control enabled as per normal operations of the Generating System • / SMIB Model (RMS simulation with voltage source connected to the Infinite Bus)	• Meeting CUO requirements • Stable dynamic behaviour during and after frequency disturbance • If the model has included protection system: ○ Inclusion of signals, input, and output of sufficient to show adequate operation of protection system ○ If the model does not have protection system included, overlay of simulation result with all relevant external and internal protection system e.g., pole slip protection relay etc to demonstrate that

	Examples of disturbance for single step for a Generating System with ideal ride through envelope: • A step in the frequency from 50Hz to 52.5Hz with duration of 6s • A step in measured frequency from 50Hz to 46.5Hz with duration of 6s • A step in measured frequency from 50Hz to 47Hz with duration of 2 min Example of disturbance for sequence of steps for a Generating System with ideal ride through envelope: • A step in frequency from 50Hz to 52.5Hz with duration of 6s, then back to 52Hz for duration of 1 min and 54s then back to 51.5Hz for duration of 3 min and back to 51Hz		protection system would not prevent from meeting this technical requirement
CUO - ROCOF requirements A12.7.2.2. A12.7.3.2.	A frequency disturbance with a Rate of change equivalent with the Ideal (or minimum performance): ±4Hz/s for 250 ms and ±3Hz/s for 1s Note: the pre-disturbance frequency can be adjusted to the limit of the band so that the ramp in frequency over the duration of the disturbance does not exceed the envelope boundary. Should comply for all frequency within the envelope, starting from boundaries. The disturbance could be a ramp change in the frequency of the voltage source at the Infinite Bus.	Same as above	Same as above

3.8 Technical Requirement: Disturbance Ride Through for a Voltage Disturbance [A12.8]

3.8.1 Introduction to section A12.8 of the WEM Rules

Voltage disturbances in a power system are inevitable. A Generating System will face various types of voltage disturbances, caused by faults, tripping or energisation of nearby facilities or system elements, changes in loads or generation, and other factors.

Disconnecting a Generating System to ameliorate the risk caused by these disturbances will only exacerbate the problem or add a new security risk. It is therefore important that any Generating System connected to the network can ride through voltage disturbances.

Section A12.8 of the WEM Rules provides for the following voltage ride through requirements:

- Generating System requirements to maintain CUO while the voltage at the Connection Point varies between 90% to 110% of the nominal voltage
- The overvoltage envelope below which a Generating System must maintain CUO
- The undervoltage envelope above which a Generating System must maintain CUO

3.8.2 Explanation of individual requirements

3.8.2.1 Point of assessment

The ride through capabilities of a Generating System when facing voltage transients must be assessed at the Connection Point. However, if the voltage deviation at the Connection Point causes a protection trip at a Facility's internal system, which disconnects the whole or part of the Generating System, this should be considered when assessing the CUO criteria.

All internal voltages must be monitored and compared against relevant voltage protection during this assessment. As specified in the WEM Procedure: Generation System Model Submission[15], the voltage protection is expected to be fully modelled in the Generation System model.

3.8.2.2 Provision of protection settings

All the voltage sensitive protection settings causing the disconnection of the Generating System or part of the Generating System should be included in the GPS Submission. This also includes any relevant internal protection.

3.8.2.3 Compliance when operating at any Range of Active and Reactive Power and Temperature

As per WEM Rules clause A12.8.1.4, all the requirements of section A12.8 apply to all allowed operating points within the Performance Chart as provided under A12.3 and at all temperatures up to and including the Maximum Temperature. This means that all the requirements should be met when operating at any Active and Reactive power within the Performance Chart and as indicated by the Temperature Dependency Data of Active and Reactive Power. If any of the requirements are not met or partially met for the full range limits of the Performance Chart, then the Performance Chart needs to be further limited to a range that the requirements are met.

15 Available at: https://www.westernpower.com.au/industry/manuals-guides-standards/generator-performance-standards/

3.8.2.4 CUO when voltage varies in between 90% and 110%

Clause A12.8.1.2 of the WEM Rules requires a Generating System to remain in CUO if the voltage at Connection Point varies between 90% and 110% of nominal voltage. This requirement ensures the Generating System will be able to stay connected and contribute to voltage control at the Connection Point even if the voltage varies in the operational band. Specific to this clause is that if a nearby facility or reactive element of the network trips or re-energises causing a voltage step within 90% to 110% at the Connection Point, the facility must still be able to cope and stay in CUO.

This requirement must be evidenced by voltage step up and step down in dynamic simulations during the Generating System planning phase. As the step from 0.9pu to 1.1pu is quite onerous, as a minimum, the Generating System must demonstrate CUO to the below step tests:

- Step up from the normal target setpoint to 1.1pu
- Step down from the normal target setpoint to 0.9pu

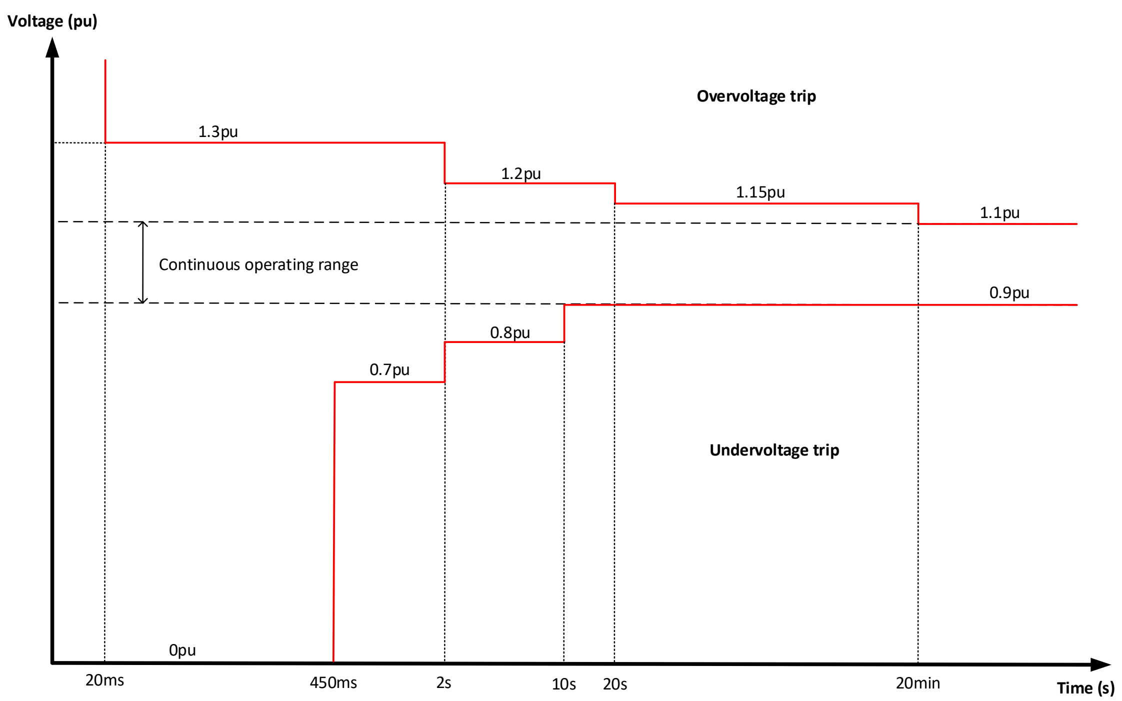
If the Generating System can stay in CUO for steps higher than listed above, it must be included in the GPS Submission.

3.8.3 Voltage disturbance ride through criteria

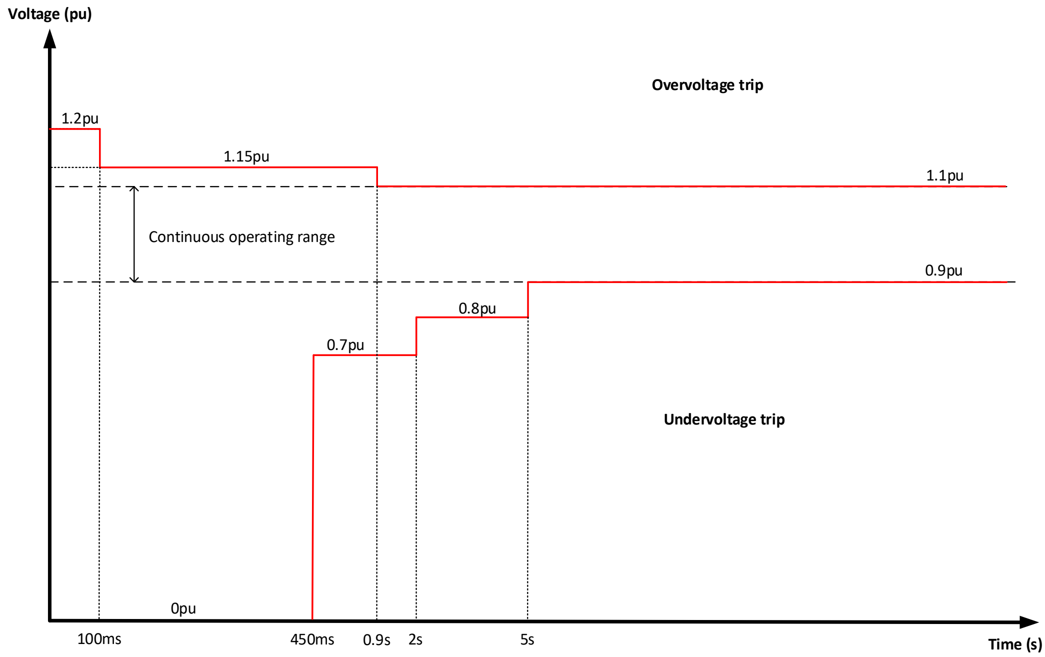
To comply with clauses A12.8.2.1 or A12.8.3.1 of the WEM Rules, a Generating System should stay at CUO if the voltage at the Connection Point varies between the envelopes shown in Figure 3-12 (a) for Ideal and Figure 3-12 (b) for Minimum standards.

Figure 3-12 Ride through requirement of generating facilities; (a) Ideal standard, (b) Minimum standard

(a)



(b)



Note:

- The base value of voltage for p.u. calculation is the nominal operating voltage of the system at Connection Point or determined Measurement Location by Western Power and AEMO.
- The overvoltage and undervoltage envelopes apply to each phase. It means the overvoltage at the Connection Point due to single-phase or two-phase unbalance faults or unbalance tripping of loads or responses from the Facility must be limited to the values shown in Figure 3-12.
- The upper limit of Ideal performance standard envelop below 20ms is not capped. It implies that the transient overvoltage at the Connection Point within one cycle must be tolerated by the Generating System. Transient overvoltage in SWIS is governed per applicable insulation coordination design standards. The SWIS insulation coordination design is based on IEC 60071. Any relevant slow-front, fast-front and very-fast front transient overvoltage must be evaluated, if necessary, to ensure safe operation while helping with standard surge arrester selection, earthing of nearby towers and substations, and shielding requirements. Although the minimum standard requires CUO for overvoltage is up to 120% only, the transient overvoltage due to lightning and switching might be higher than 120%. A proper insulation coordination study is then essential.
- The duration of overvoltage and undervoltage conditions at the Connection Point or other Measurement Location is counted from the moment that the Connection Point voltage deviates below 0.9pu or rises above 1.1pu of nominal voltage.

3.8.3.1 Relaxation of bolted fault duration in minimum standard

The duration of zero percent voltage level for Ideal performance and Minimum standard is 450ms. This value requires that a three-phase fault at the Connection Point, which is cleared by a circuit breaker failure, can still be tolerated by the Generating System. Since such events are rare, provision has been given in the Minimum Standard so if it is agreed between Western Power, AEMO and Market Participant, the required 450ms associated with a bolted balance or unbalance fault can be relaxed. Obviously, that relaxation cannot be shorter than the mandated fault clearance time without circuit breaker failure specified in Technical Rules[16] Tables 2.10 and 2.11.

3.8.3.2 Negotiated operating arrangement

If an operational arrangement has been agreed upon between Western Power, AEMO and the Market Participant to meet the minimum or above minimum operating standard, that arrangement should be submitted as part of the GPS registration of the Generating System.

3.8.3.3 Assessment of ride through capability

The following are to be assessed separately in the process of voltage disturbance ride through capability of The Generating System:

- The voltage protection settings
- The Generating System controller response

3.8.3.3.1 Assessing voltage protection settings

Voltage protection at the Connection Point and at any busbar internal to the Generating System that can trip whole or part of the Generating System, should be assessed against the criteria listed in this section. If there are internal protections inside inverters, they must also be considered.

3.8.3.3.2 Assessing controller response

The dynamic response of the Generating System to frequency deviations must also be assessed. This is usually done by replicating the envelope shown in Figure 3-12 in a dynamic study and assessing whether the Generating System issues a trip or deviates from any of the CUO criteria. Table 3-14 lists the minimum required scenarios when performing these simulations.

Table 3-14 The variations of parameters while assessing voltage disturbance ride through

Variable	Range	Notes
System Thevenin Impedance	Maximum fault level (Zmax) Minimum Fault level (Zmin) Infinite fault level (Zinf)	Corresponding to system maximum and minimum short circuit capacity at Connection Point
System X_{sys}/R_{sys}	Maximum Minimum	If the X/R varies considerably for each system SCC
Control modes of generating facility	All control modes	Study will be repeated for all control models affecting reactive power (where applicable)
Initial operating point of Generating System	Min and Max Active Power Zero, min and max Reactive Power	Study will be repeated for min and max Active Power Depending on control mode, the setpoint is changed to set the Generating System at zero, min and max Reactive Power for each MW setpoint

[16] Available at: https://www.westernpower.com.au/industry/manuals-guides-standards/technical-rules/

3.8.3.4 Simulation to be Performed

Table 3-15 summarises the required simulations and relevant criteria to demonstrate compliance with section A12.8 of the WEM Rules.

Table 3-15 Required simulation to be performed for section A12.8 of the WEM Rules

Requirement	Simulation description	Operating points / Test conditions	Criteria
CUO - specified voltage ranges A12.8.2.1. A12.8.3.1	A range of voltage disturbance within the boundary of ride through envelope modelled as a step-in or voltage set point of voltage source at infinite bus. Example of disturbance, step in voltage of: • 100% voltage drop to zero for 450 ms • 20% voltage drop (to 80% of nominal voltage) for 2 sec • 30% voltage increase (to 130% of nominal voltage) for 0.02 sec The disturbance could be a step change in the voltage setpoint of the voltage source at infinite bus or a short circuit fault at the Connection Point.	As described in Table 3-14	• Meeting CUO requirements • Stable dynamic behaviour during and after voltage disturbance • If the model does not has included protection system: Overlay simulation result with all relevant external or internal protection system (e.g., Step-Up transformer protection) to demonstrate that no protection system would prevent from meeting this Technical Requirement
CUO - 90% < nominal voltage < 110% A12.8.1.2	Step in voltage of the voltage source: • A step in voltage from Target setpoint (As agreed in A12.4) to 1.1 pu • A step in voltage from Target setpoint (As agreed in A12.4) to 0.9 pu	As described in Table 3-14	• As above

3.9 Technical Requirement: Disturbance Ride Through for Multiple Disturbances [A12.9]

3.9.1 Introduction to section A12.9 of the WEM Rules

The disturbance ride through requirements for multiple disturbances are in place to ensure the Generating System will stay connected and performs to help the system during and after transient events. These events can cause the voltage at the Connection Point to drop below or rise above normal operating levels. There are three main performance criteria inherent in section A12.9 of the WEM Rules:

1) The CUO of the Generating System after a single or multiple fault event.
2) Reactive current contribution by Generating System during faults and overvoltage events.
3) The Generating System’s capability to return to pre-event state after the event.

3.9.1.1 Measurement Location

The default Measurement Location for the Technical Requirements under section A12.9 of the WEM Rules for both Synchronous and Asynchronous Generating Systems is the Connection Point. The reasoning behind this is to assess how much the Generating System will contribute to the system stability during network disturbances. It is also to assess the effect of system disturbances on the Generating System’s ability to ride through disturbances.

It should be noted that as per WEM Rules clause A12.9.1.7, the Measurement Location for Reactive Current Contribution may be specified to be another location in SWIS (including within Generating System). In this case, the current measurement should be done at the specified location. If Western Power and AEMO agree to change the assessment location, the Market Participant must demonstrate that the claimed performance at the new location does not cause non-compliance with the minimum performance at the default location (i.e., still a minimum of 2% at the Connection Point for Reactive Current Contribution for every 1% voltage reduction).

3.9.1.2 Compliance when operating at any Range of Active and Reactive Power and Temperature

As per WEM Rules clause A12.9.1.8, all the requirements of section A12.9 apply to all operating points within the Performance Chart as provided under A12.3, and at all temperatures up to and including the Maximum Temperature. This means that all the requirements should be met when operating at any Active and Reactive power within the Performance Chart and as indicated by the Temperature Dependency Data of Active and Reactive Power. If any of the requirements are not met for the full range limits of the Performance Chart, then the Performance Chart needs to be further limited to a range that the requirements are met.

Also, if there are any thermal limitations of any equipment within the Generating System that may limit the output or performance of the Generating System regarding the requirement of A12.9, the Market Participant must specify them in the statement of compliance and supporting documents must be provided. This is of paramount importance in registering the GPS especially if those thermal limitations are not included in the computer model of the Generating System. For example, if a wind turbine is equipped with dump resistors, the thermal capacity and cooling cycles must be registered within GPS.

3.9.1.3 Simulation software and environment

Fault simulations required for this assessment can be evidenced by simulation in either PowerFactory RMS or PSCAD simulation software. An RMS model that replicates the fault ride through mode of the controller is sufficient to demonstrate compliance to this clause. However, in some cases an EMT study might be required due to the limitations of the RMS model, for example:

- The RMS simulations show slow response from the Generating System
- The RMS model and software tool do not represent all behaviour accurately
- The Network condition requires an EMT model e.g., connection to a weak section of the network

Western Power and AEMO will request EMT studies from Market Participants if there is any doubt regarding demonstrated RMS study results. This includes any doubt or concerns relating to LVRT/HVRT threshold levels, LVRT/HVRT mode duration, PPC freezing/unfreezing, negative sequence injection, when the demonstrated Rise Time is above 20ms, post fault behaviour (including Active Power recovery).

3.9.2 Evaluation of reactive currents contribution for the section A12.9 assessment

This section explains the methodology that must be employed to assess the reactive current contribution of Synchronous and Asynchronous Generating Systems during and after disturbances.

3.9.2.1 Evaluation of k factor for Asynchronous Generating Systems

To evaluate the reactive current contribution from the Generating Systems during transient events, the reactive current injection at Connection Point or other agreed Measurement Location must be properly calculated. The reactive current contribution of the Asynchronous Generator is assessed by calculating the ratio of changes in Reactive Current to changes in voltage at Measurement Location, during and pre-disturbance. This ratio is known as K factor and is defined at Connection Point (POC) as shown in

Equation 3-3.

Equation 3-3

$$k_{poc} = \frac{\Delta I_{reac(poc)p.u.}}{\Delta V_{poc\,p.u.}}$$

In Equation 3-3 the per unit value for voltage and current are to be used. The base value for current is the Maximum Continuous Current, which should be ascertain using the methodology described in note 11 below. The voltage based value would be the nominal voltage at Measurement Location.

K-factor is inherently implemented in Generating System behind inverters to shape the fault ride through requirements and has been reflected in grid codes to assess the fault contribution of inverter connected generations. Hence the K factor is a parameter that could be set in an inverter controller (hereafter shown as k_{set}), which mandates the amount of capacitive current to be injected to the system at inverter terminals when terminal voltage drops below the pre-event values. Appendix F provides further information on how reactive current injection at the Connection Point is related to the k_{set} at inverters.

The following are to be noted for this assessment:

1) The k_{POC} or the Reactive Current contribution should be evaluated for the duration of the fault event.

2) Section 3.9.4.1 of this guideline describes the recommended simulation setup and computer model for Network disturbance events. For undervoltage events the duration of the fault is governed by the protection system. The fault events are particularly specified in clauses A12.9.2.2 and A12.9.3.2 of the WEM Rules. For a practical definition, Table 3-18 specifies which fault events are to be considered and their associated clearance time. These fault clearance times will be provided by Western Power.

3) Section 3.9.4.3 of this guideline describes the recommended simulation setup and computer model for over-voltage events. The assessment of reactive current contribution for over-voltage events is done in accordance with simulation cases in section 3.9.4.3. The Generating System is expected to provide reactive current contribution for the whole duration of the fault unless the disturbance is longer than the disconnection settings agreed under section A12.8 of the WEM Rules. An overlay on voltage is helpful to demonstrate the timing considered in evaluations, see Figure 3-13.

4) The reactive current of the facility is the imaginary part of the current vector when referred to the system reference frame and usually different to the q-axis current. Appendix D provides a vector representation of the machine reference frame and the system reference frame.

5) In addition to voltage and current plots as shown in Figure 3-13, Market Participants are required to produce simulation plots and signal overlays that demonstrate claimed performance. The requested signals include but are not limited to (both at Generating System terminal and Connection Point): voltage, Active Power, Reactive Power, Active Current, Reactive Current, total current, total current saturation level, LVRT/HVRT flags, PPC freezing/unfreezing flag.

6) For balanced faults, a positive sequence contribution is required. A positive and negative sequence reactive current contribution are required for unbalance faults (Figure 3-13 (a) and (b)). From Figure 3-13 and Figure 3-14, the K factor of positive and negative sequence components is calculated as below:

Equation 3-4

$$k_{pos} = \frac{\Delta I_{reac(pos)}}{\Delta V_{pos}}$$

Equation 3-5

$$k_{neg} = \frac{\Delta I_{reac(neg)}}{\Delta V_{neg}}$$

7) For unbalanced faults, a negative sequence reactive current injection must be provided as described in section 3.9.3 of this guideline. The assessment of the k_{POC_neg} is identical to the positive sequence process with the difference of using the negative sequence voltage and negative sequence reactive current at Measurement Location (Figure 3-13 (b)).

8) The delta voltage ΔV_{poc} required for k_{POC} calculation is the difference between voltage during disturbance and the triggering level (LVRT or HVRT). It is recommended to overlay the voltage waveform and LVRT/HVRT flag signals in simulation results so that the exact triggering level is indicated. For the requirement of triggering level refer to Section 3.9.3 of this guideline. The Delta current (ΔI_{poc}) required for k_{POC} calculation is the difference between the reactive current during fault from the pre disturbance reactive current. If the reactive current pre disturbance is inductive, it would be shown as a negative current and should be considered in the calculation.

9) The k_{POC} against the WEM rules requirement should be assessed over an assessment window during fault event. The assessment window begins 40ms after the voltage control mode is switched to the fault ride through mode. This is detected by monitoring the LVRT flag. The 40ms delay is considered to account for rise time of reactive current due to control action. The assessment window ends when the voltage at the Connection Point is recovered back to normal range (0.9 pu to 1.1 pu) after clearance of disturbance. If the duration of disturbance is longer than the agreed disconnection Setting Time in section A12.8 of the WEM Rules, the assessment window would end at the agreed disconnection setting time of the protection relay. The reactive current transition toward the final

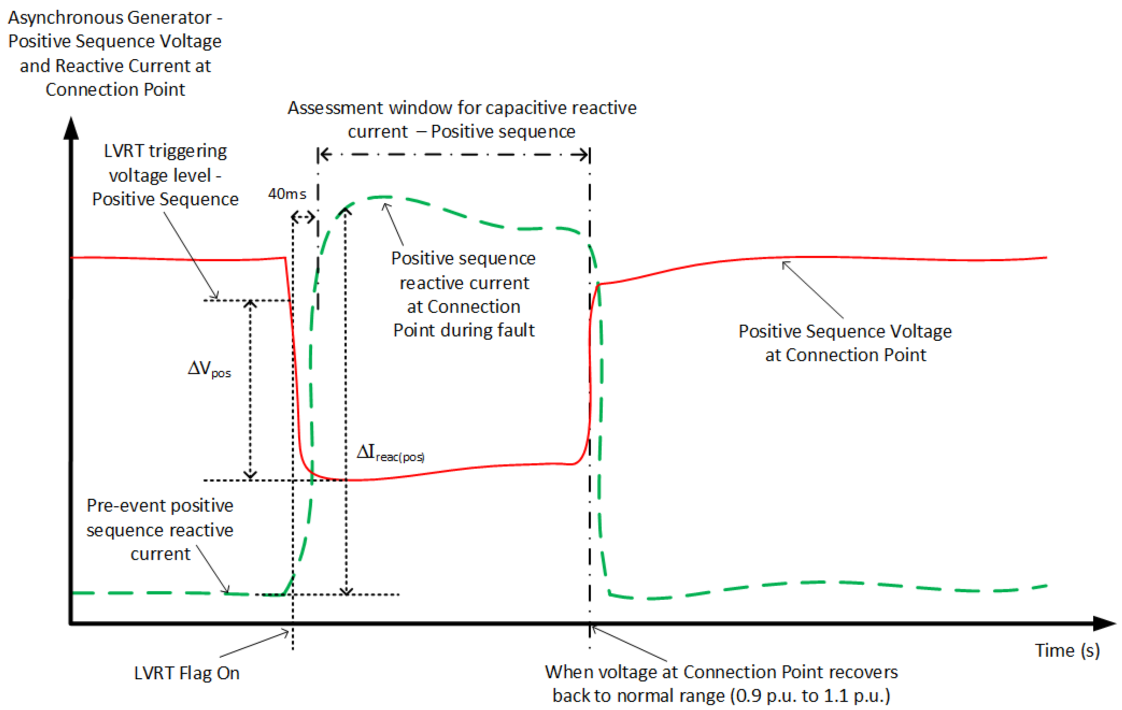
value must be smooth and meet the requirements of settling time and adequate damping, especially if the Rise Time is significantly slower than 40ms.

The k_{POC} should be calculated within the assessment window and it is required to be at or above the WEM Rules limits for reactive current injection within the whole duration of the assessment window. If the reactive current oscillation is significant in a way that the k_{POC} undershoots below the WEM Rules limits in short periods during the assessment window, the performance might be accepted by AEMO and Western Power. In this case, Western Power and AEMO will apply engineering judgment based on the overall number of simulations that the undershoot happen, the depth of the undershoot and its impact on the grid. It is recommended that the duration of undershoot below the limit to be not greater than 5% of the total duration of the assessment window e.g., if the assessment window is 100ms, an undershoot with a duration of 5ms might be ignored.

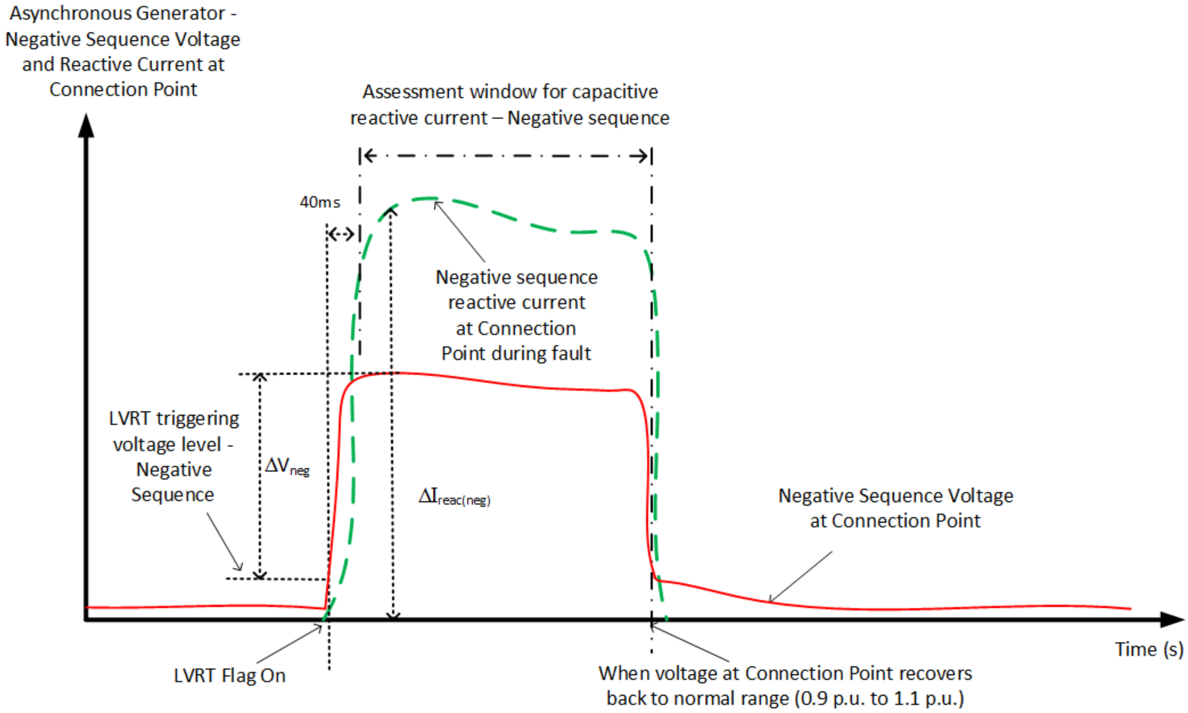
10) The required reactive current to reach the required k_{POC} may exceed the Maximum Continuous Current of the Generating System. The WEM Rules require a Reactive Current contribution equal or exceeding the Maximum Continuous Current in accordance with clause A12.9.1.6.(a) of the WEM Rules. This means the Generating System and all its equipment (e.g., STATCOM) should be able to exploit its overloading capability to meet the k_{POC} limit.

Figure 3-13 Evaluation of the k factor and reactive current contribution for Asynchronous Generating System during fault events; a) positive sequence contribution and b) negative sequence contribution

(a)



b)



11) The Maximum Continuous Current is defined as the maximum current injected at the Connection Point when the Generating System is delivering rated output while the Connection Point voltage is between 90% and 110% of the nominal voltage. The Maximum Continuous Current that a Generating System can deliver depends on the type of technologies of the generators and equipment incorporated in the Generating System. Manufacturers of generators and equipment follow rigorous standards to set the performance of their products. These standards are published for various technologies and the boundary of performance levels are provided regarding operating conditions such as minimum and maximum ambient air temperature, altitude of the site, voltage level etc. Market Participants should consult with the equipment manufacturer and ascertain the Maximum Continuous Current based on the relevant Australian or ISO/IEC standards that have been applied and with respect to the operating condition of the Generating System such as ambient temperature, connection voltage etc. The relevant standard should be provided as a part of the GPS Submission.

Following are examples of these standards for different technologies:

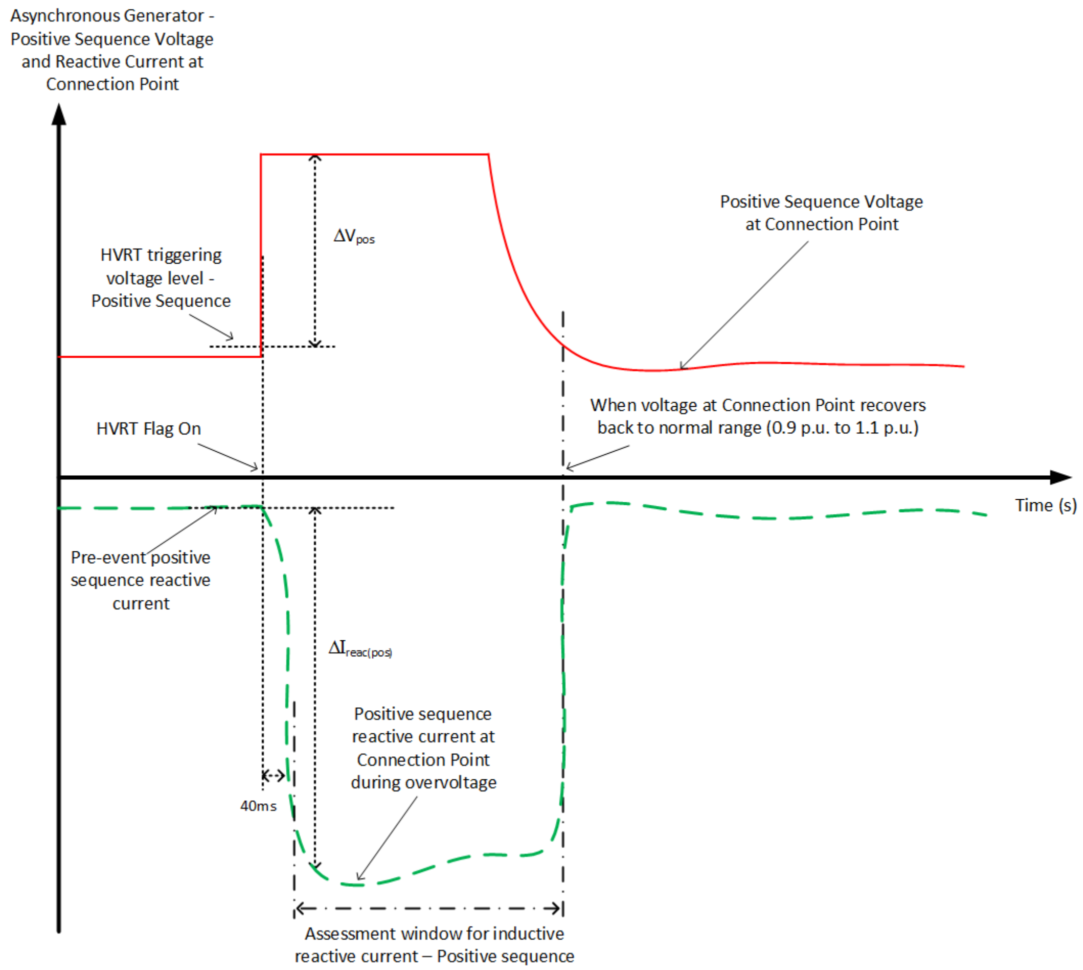
- IEC 60034 Rotating electrical machines
- IEC 61400 Wind turbines
- IEC 62894 Photovoltaic inverters - Data sheet and name plate
- IEC 60146 Semiconductor converters – General requirements and line commutated converters
- IEC 62446 Grid connected photovoltaic systems – Minimum requirements for system documentation, commissioning tests and inspection
- IEC 61215 Terrestrial photovoltaic (PV) modules – Design qualification and type approval
- IEC 61727 Photovoltaic (PV) systems – Characteristics of the utility interface

Where the used standard indicates the maximum current at Generating Unit terminal, the current needs to be projected to and calculated at the Connection Point for the purpose of demonstrating and registering the GPS performance level. To project the maximum current to the Connection Point, nominal operating conditions should be considered i.e., the nominal voltage at the Connection Point and Rated Maximum Apparent Power[17] of all Generating Units and equipment. If the Generating System is connected to the Connection Point through a step-up transformer, the tap position should be set accordingly by the controller (or manually if it is not equipped with an AVR controller) to achieve the nominal voltage at both HV and closest to nominal at LV side. The projection could be done through simple load flow calculation or simulation on a SMIB model.

12) For over-voltage events, the inductive reactive current contribution level should be assessed. The assessment is identical to undervoltage disturbance as explained in point 9 above, except the HVRT flag is observed to indicate the start of assessment window, see Figure 3-14[18].

13) The evaluation of the Rise Time and Settling Time are to be done on reactive current contribution of the Generating System. The rise time and settling time of current contributions are recommended to be verified with EMT studies if the RMS simulations rise time are above 20ms.

Figure 3-14 Evaluation of the K factor and reactive current contribution for Asynchronous Generating System during over-voltage events



17 The maximum apparent power is used here to imply that the current injection from Generating Unit and other equipment at the terminal should be at the maximum current as indicated by the relevant standards.

18 The reactive current contribution for an overvoltage event is inductive, and it is shown as negative current to represent absorbing reactive power. For rise time calculation, the absolute value of current should be considered.

3.9.2.2 Minimum reactive current contribution requirement for Synchronous Generators

For a Synchronous Generating System, the current contribution of at least 2.5 times the Maximum Continuous Current of the Generating Unit is required for minimum performance. The reactance of a Synchronous Generating Unit drops considerably when a fault is applied, and as time passes the impedance increases back to steady state values. To evaluate this clause, the short circuit current observed at Connection Point for a three-phase fault during the sub-transient period is recommended.

The short circuit current at POC during transient period can be written as:

Equation 3-6

$$I_{sc} = \frac{E'_d}{R_{st}+R_c+j(X'_d+X_c)}$$

Equation 3-7

$$I_n = \frac{S_{nG}}{\sqrt{3}V_{nHV}}$$

Equation 3-8

$$I_{sc} > 2.5I_n$$

Where S_{nG} is the rated apparent power of the generator and V_{nHV} is the rated voltage at the Connection Point (usually the HV side of the generator's unit transformer). A three-phase short circuit study at Connection Point while setting the driving impedance of the Generating Unit at X'_d will be adequate to demonstrate this criterion. This must be evaluated through an RMS simulation and applying a three-phase short circuit event with zero fault impedance at Connection Point and measuring the reactive current at the Connection Point.

3.9.2.3 Evaluation of reactive current contribution for synchronous generators in multiple fault scenarios

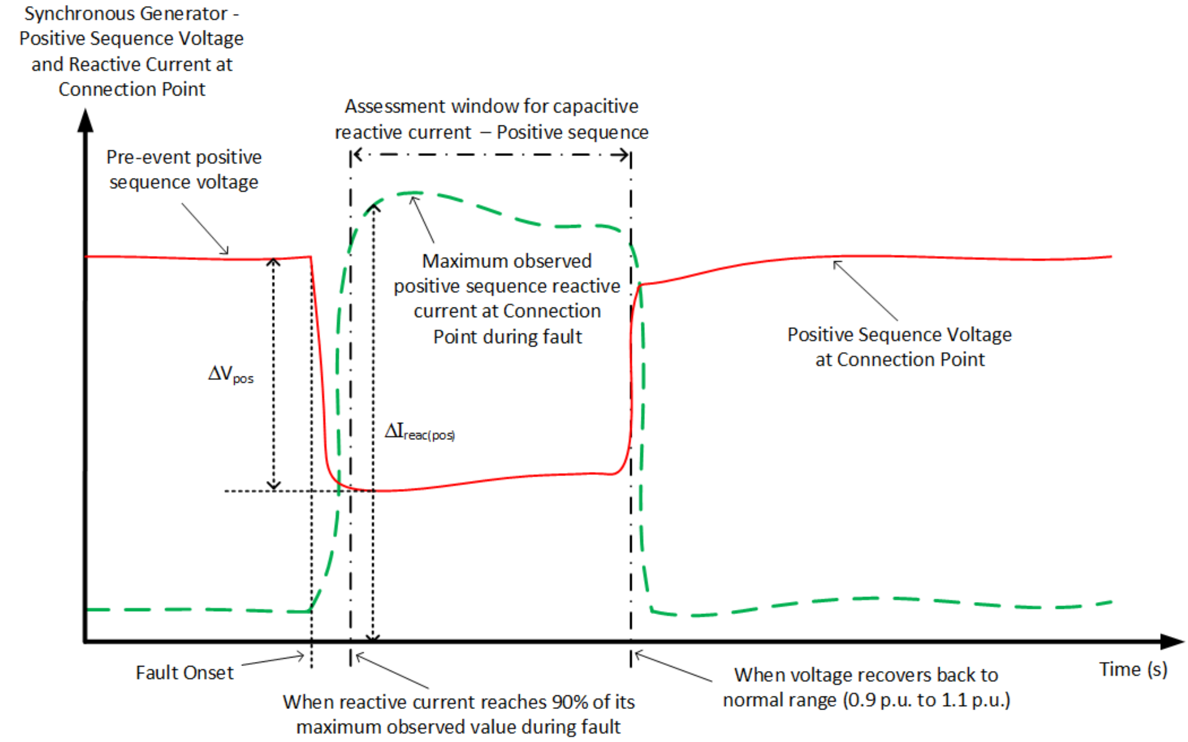
The reactive current contribution of Synchronous Generators should meet the requirement with regard to voltage drop during different fault events. For Ideal Standard, the WEM Rules require a reactive current level of 4% of Maximum Continuous Current for each 1% reduction of the Connection Point voltage from the pre disturbance level. To evaluate this requirement, an RMS simulation should be performed using a model as explained in section 3.9.4 of this guideline.

Different fault types as described in Table 3-18 should be applied at the Connection Point or other agreed Measurement Location. For every fault event, the percentage of voltage drop compared to the pre-disturbance voltage at the Measurement Location is measured, and each 1% drop is multiplied by 4% of the maximum reactive current to find the required reactive current contribution. The duration of assessment starts when the reactive current reaches 90% of the maximum reactive current observed after the inception of the fault, and ends when the voltage is recovered back to the normal range (0.9 pu to 1.1 pu) after clearance of the fault as shown in Figure 3-15. Over this assessment window, the ratio of reactive current (in pu) to delta voltage (in pu) should be calculated for each data point. The average of these calculated ratios must meet the WEM Rules requirement (4% of current for each 1% voltage reduction for Ideal standard). The delta voltage here is the deviation of voltage during fault from per disturbance voltage.

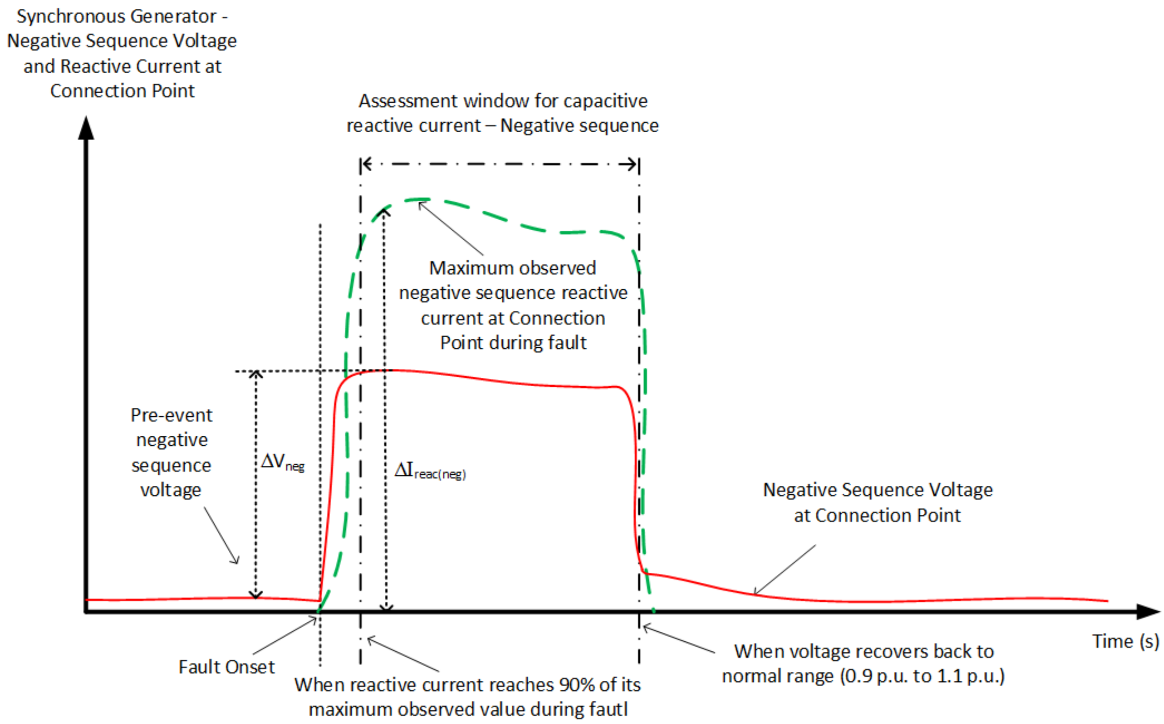
It should be noted that if the required level of reactive current, obtained as explained above, is lower than the pre-disturbance fault, the Generating System should maintain its pre disturbance Reactive Current Level.

Figure 3-15 : Evaluation of the reactive current contribution for Synchronous Generating System during fault events; a) positive sequence contribution and b) negative sequence contribution

(a)



(b)



3.9.3 The compliance criteria for active and reactive current contribution during and after fault

The compliance criteria for reactive current contribution during disturbances are listed in Table 3-16 for Synchronous and Asynchronous Generating Systems. The compliance criteria per WEM rules A12.9 is evaluated for the magnitude of current injection, the speed of response for current injection, and the recovery to pre-event status of active/reactive power after the event has cleared.

Table 3-16 The compliance criteria for Synchronous and Asynchronous Generating Systems

Facility and response type		Common performance	Minimum standard	Ideal standard
Synchronous Generator	**Response during events**	A reactive current contribution of at least 2.5 times maximum continuous current of the generating unit for fault events.		A reactive current contribution of 4% of Maximum Continuous Current for each 1% drop in voltage at Measurement Location if the required reactive current to achieve this is higher than the pre-disturbance reactive current. If the pre-disturbance fault is greater, it should keep the pre-disturbance fault
	Response after the event		• Return to 95% of pre-fault active power continuously within a period agreed by AEMO and Western Power • Enough reactive current to maintain voltages at Connection Point within CUO range	• Return to 95% of pre-fault active power continuously after 100ms of fault clearance • Enough reactive current to maintain voltages at Connection Point within CUO range
	Quality of response		• Oscillations adequately damped	• Oscillations adequately damped
Asynchronous Generating Systems	**Response during event**	Capability to Provide reactive current contribution equal or greater than the Maximum Continuous Current of the Generating System.	• Capability to provide a capacitive and inductive K factor of at least 2% at Connection Point in addition to the pre-event reactive current • The Connection Point voltage at which the reactive current contribution first triggers must be a specified threshold level agreed by the Western power and AEMO within 80-90% for capacitive contribution and 110-120% for inductive contribution	• Capability to Provide a capacitive K factor of at least 4 and an inductive K factor of at least 6 during fault at Connection Point in addition to the pre-event reactive current • The Connection Point voltage at which the reactive current contribution first triggers should be a specified threshold level within 85-90% for capacitive contribution and 110-115% for reactive contribution • Sustain the response during the fault event

			• Sustain the response during the fault event • Reactive current contribution is not required if Connection Point voltage deviates below 15% for Generating Systems with main connecting transformer and below 20% for Generating Systems without main connecting transformer (See Appendix C for connection arrangements) • The performance is subjected to thermal limitation as specified in A12.9.1.8	• Reactive current contribution is not required if Connection Point voltage deviates below 5% for generating systems without main connecting transformers (See Appendix C for connection arrangements) • Make available Maximum Continuous Current of the Generating System for Connection Point voltages below 85% (subject to thermal limitations and energy source availability) and (the 85% can be negotiated and agreed) • Make available reactive current equivalent for maintaining maximum apparent power of Generating System for Connection Point voltages above 115% (subject to thermal limitations and energy source availability) and (the 115% can be negotiated and agreed)
	Response after the event		Return to 95% of pre-fault active power within an agreed time with Western Power	Return to 95% of pre-fault active power after 100ms of fault clearance
	Quality of response		• Oscillatory reactive current response is adequately damped • If fault contribution is required to be sustained for 2s or below: • Maximum rise time of reactive current response is 40ms or less • Maximum settling time of reactive current response is 70ms or less • Otherwise for fault contribution duration greater than 2s: • The reactive current response to be set as fast as possible and the rise time and settling time to be provided as part of GPS	• Oscillatory reactive current response is adequately damped • Maximum rise time of reactive current response is 40ms or less • Maximum settling time of reactive current response is 70ms or less

The following are to be noted when applying the criteria listed in Table 3-16:

1) Refer to section 3.9.2.1 and Appendix F to this guideline for the description of K factor and maximum current contribution.

2) The Rise Time and Settling Time requirement for reactive current contribution is defined for the steps in voltages due to the introduction of faults or overvoltage. Appendix A provides definitions of Rise Time and Settling Time.

3) Appendix B provides the definition of Adequately Damped. It is also referred to the Power System Stability Requirements Guideline[19] and is explained in the Technical Rules.

4) The Maximum Continuous Current and rated output of the Generating System are evaluated with all Generating Units operating.

5) The Synchronous Generator response is evaluated for fault events. Asynchronous Generating Systems will have to provide a reactive current response to fault events as well as overvoltage events.

6) The reactive current contribution required from the Synchronous and Asynchronous Generating System is not required when the voltage at the Connection Point is within the normal operating range of ±10%. This means Asynchronous Generating Units are not allowed to be in LVRT/HVRT mode (Fault Ride Through Mode) when the voltage at Connection Point is within the normal operating range of ±10%.

7) When evaluating the K factor at the Connection Point (k_{POC}), the fault current contribution of the Generating System should be considered including the reactive current contribution from all equipment required to meet the GPS such as STATCOMs, which might reside inside the Generating System.

8) For Asynchronous Generating Systems, as the k_{set} is set at the Generating Units away from Connection Point, the activation point of ride through mode (LVRT or HVRT) varies with fault current contributions from units (See Appendix F of this guideline). A range of 10% (for minimum performance) and 5% (for ideal performance) is allowed for the triggering of reactive current contribution. In accordance with clauses A12.9.3.6.and A12.9.2.6 of the WEM Rules, these ranges can be negotiated and changed; however, the range itself should be maintained. For example, a Market Participant may negotiate to provide the required reactive response at the absorption side when the Connection Point voltage is above 112% to 122% of nominal voltage for minimum performance. Western Power (in agreement with AEMO) will evaluate the risk associated with the offsets in triggering and agrees or disagrees with the proposal.

9) The activation points for LVRT mode, must be triggered when the voltage at the Connection Point drops below a specified threshold within the range of 85% to 90% of nominal voltage (or any agreed range given that the magnitude of 5% remains). This Threshold Level impacts the calculation explained in section 3.9.2.1 and must be registered in the statement of compliance. For overvoltage events, the activation points for HVRT mode must be triggered when the voltage at the Connection Point rises above a specified threshold within range of 110% to 115% of nominal voltage (or any agreed range given that the magnitude of 5% remains) For the Minimum standards, the range could be extended to 80% to 100% for LVRT and 110% to 120% for HVRT (or any agreed range given that the magnitude of 10% remains). However, if the specified threshold is below 85% (or above 115%)

[19] Refer to Power System Stability Requirements Guideline (https://www.westernpower.com.au/media/4981/power-systemstability-requirements-guideline-20210511.pdf) for further information on Stability requirement and adequate damping definition.

an agreement from Western Power and AEMO is required. If the specified threshold is not agreed, the performance should be assessed against a threshold within the Ideal standard range

10) For an Asynchronous Generating System, a negative sequence reactive current contribution is also desired for undervoltage events. The required negative K factor ($k_{POC-neg}$) level and the ratio of the negative sequence to positive sequence components of the reactive current contribution must be negotiated and agreed upon with Western Power and AEMO. It is recommended that a $k_{POC-neg}$ of at least 2 is achievable.

11) Per clause A12.9.2.8 of the WEM Rules, an Asynchronous Generating System should be able to provide the maximum continuous current when the Connection Point voltage dives below 85%. This means the Generating System should provide the active current as well as the required reactive current to deliver the full continuous current. As an example, if the Generating System can provide a k_{POC} of 4, and the Connection Point voltage is at 85%, the reactive current injection of 0.6 pu is required. The Facility should be able to set for 0.8 pu active current at this voltage to maintain the Maximum Continuous Current of the Generating System (1 pu).

12) On the absorption side, the Generating System should provide enough current to maintain the rated power of the Generating System for the Connection Point voltages above 115%. This also means the Generating System should inject active power in addition to the reactive power for overvoltage scenarios. If a k_{POC} of 6 requires reactive current absorption of 90%, there should be a percentage of active power injected to maintain maximum apparent power. This is less than 10% since apparent power is a function of voltage, and elevated voltage requires less current to be injected to achieve maximum apparent power. The rated power should be in accordance with relevant Australian or ISO Standards.

13) Per clause A12.9.2.8 of the WEM Rules, the 85% and 115% thresholds are negotiable and can be agreed upon between AEMO, Western Power and the Market Participant. Also, AEMO and Western Power can assign or agree on the limitation on active power injection if it can help to maintain the system voltage profile or less disturb the network.

3.9.4 Modelling and simulation methodology

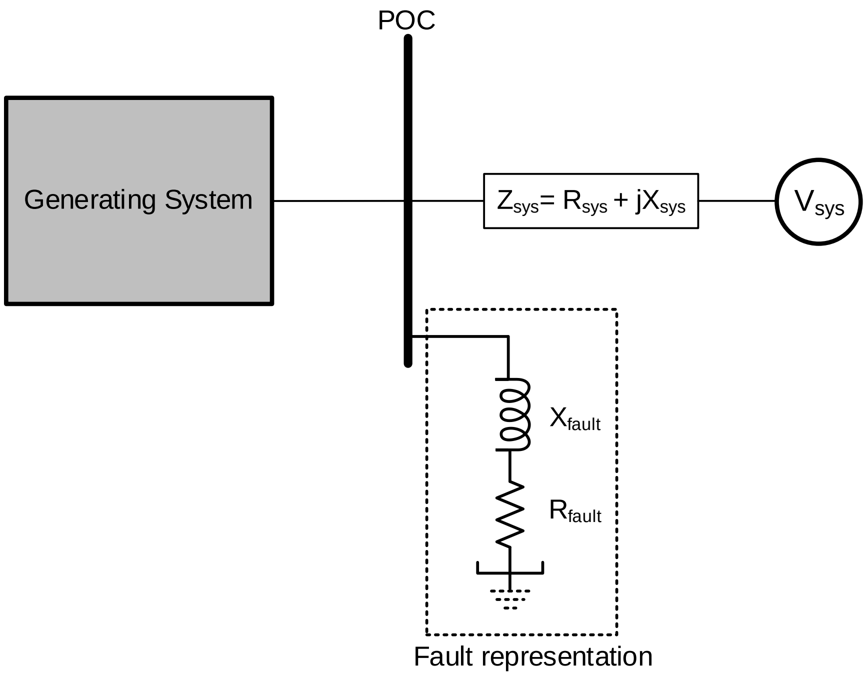
3.9.4.1 Simulation model and performance evaluation method for fault events

A Thevenin equivalent of the system is to be developed for the assessment of the Technical Requirements of section A12.9 of the WEM Rules. Figure 3-16 shows the model of the system and Generating System. With respect to this representation, V_{sys} and Z_{sys} are the Thevenin equivalent voltage and impedance of the system at the Connection Point of the Generating System. These data are provided by Western Power after scanning through various system configurations and dispatches. The system Thevenin corresponding to the minimum and maximum short circuit capacity must be evaluated. If X/R varies considerably for each case, the minimum and maximum X/R are also required for each system impedance level. The angle of the system Thevenin voltage can be set at zero.

Z_{sys} are to be provided in positive, negative and zero sequences to enable unbalance fault simulations.

X_{fault} and R_{fault} are the reactance and resistance of the fault as appears at the Connection Point. This impedance will be varied to simulate the faults which occur far from the Connection Point but result in residual voltages at the Connection Point. The real fault at the Connection Point is purely resistive. However, faults that occur further from the Connection Point have an X/R ratio. A limit of X/R of 3 on the fault impedance is applied corresponding to 70 degrees line impedance angle of the lines.

Figure 3-16 The system and facility model for multiple fault ride through assessment



For the initial operating point of the Generating System, the Generating System will be tested at maximum and minimum Active Power. Depending on the control mode affecting reactive power, the setpoint is varied to test min/max and zero Reactive Power. If the Generating System is equipped with several control modes for Reactive Power (i.e., Q control, PF control and Voltage control modes), the study will be repeated for each control mode. Several fault types and impedance combinations must be simulated to represent the variety of credible events.

Table 3-17 lists the recommended variation of the system parameters for the simulation. The faults in this table will have clearance times as specified in Table 3-18. The compliance criteria, as described in section 3.9.3 of this guideline must be assessed and demonstrated for all the events listed in

Table 3-17. While assessing the reactive current contributions, the methods described in sections 3.9.2.1 and 3.9.2.3 of this guideline should be applied. If protection relays sensitive to voltage deviations are not part of the model, a separate assessment of the protection relay settings overlayed to the response observed should be included to evidence the facility's ride through.

It should be noted that the assessment of the Generating System performance levels specified in clauses A12.9.2.2. and A12.9.3.2 of the WEM Rules, regarding the CUO in response to a single disturbance, should also consider the interaction with the SWIS by using the 'SWIS Base Model'. These interactions are not necessarily observed in the proposed model in Section 3.9.4.1. The Market Participant should consult with Western Power and confirm with Network Access studies and include these interactions in the GPS Submission.

Table 3-17 The variations of parameters while assessing reactive current contribution for faults

Variable	Range	Note
System Thevenin Impedance	Maximum fault level Minimum Fault level	Corresponding to system maximum and minimum short circuit capacity at Connection Point

System X_{sys}/R_{sys}	Maximum Minimum	If the X/R varies considerably for each system SCC
Fault Types	3Ph, 2Ph,2Ph-G,1Ph-G	Note the fault clearance time is a function of fault type per Table 3-18
Residual Voltage	Range from 0% to 90%,	This is achieved by varying the fault impedance. Monitored at Connection Point The granularity of residual voltage level in the range should be appropriately chosen to demonstrate critical behaviour especially near LVRT triggering level
Fault X_{fault}/R_{fault}	Pure R, X/R=3	Applied to all fault types
Control modes of generating facility	All control modes	Study will be repeated for all control models affecting Reactive Power
Initial operating point of the Generating System	Min and Max active power Zero, min and max reactive power	Study will be repeated for min and max active power Depending on control mode, the setpoint is changed to set the generating facility at zero, min and max reactive power for each MW setpoint

3.9.4.2 Duration of the fault (sections A12.9.2.2 and A12.9.3.2 of the WEM Rules)

The duration of the fault or fault clearance time has a direct impact on the performance of the Generating System, as longer faults make the Generating System more vulnerable to either disconnection or less desirable fault current contribution. The type of fault is also another factor affecting the performance of the Facility. Table 3-18 shows the summary of the type of the faults and the fault duration for which the Technical Requirements of A12.9 of the WEM Rules will be assessed on.

Table 3-18: Summary of clearance time of faults which satisfy requirements of A12.9.2.2 and A12.9.3.2

Network	Minimum Performance		Ideal Performance	
	Fault Type	Fault Duration	Fault Type	Fault Duration
Transmission > 66kV	3Ph, 2Ph, 2Ph-G,1Ph-G	Clearance time of the slowest main protection system	3Ph	Clearance time of the slowest main protection system
			2Ph, 2Ph-G,1Ph-G	**If breaker failure protection is installed:** Clearance time of the breaker failure protection *Otherwise:* The longer of 450ms and the clearance time of the slowest primary protection system
Distribution ≤ 66kV	3Ph, 2Ph, 2Ph-G,1Ph-G	Clearance Time of The Slowest Main Protection System	3Ph, 2Ph, 2Ph-G,1Ph-G	**If breaker failure protection is installed:** Clearance time of the breaker failure protection *Otherwise:* The longer of 450ms and the clearance time of the slowest primary protection system

In addition to Table 3-18, the performance criteria of section A12.9 of the WEM Rules also applies to all credible contingencies that result in sudden disconnection of a system component. For example, generators, lines, reactive compensators, or loads can be disconnected from the system to initiate the event. This is particularly useful when assessing the overvoltage fault contribution, which can be a result of reactors, generators, or load tripping. Such events should also be included in the set of analysis.

3.9.4.3 Simulation model and performance evaluation method for over-voltage events (Asynchronous Generating Systems)

An ideal voltage behind impedance is to be used for evaluating the reactive current contribution of Asynchronous Generating Systems. A system model as shown in Figure 3-17 will be used to evaluate the over-voltage response. Table 3-19 lists the minimum system variations and recommended event durations for the over-voltage simulations.

Figure 3-17 Variable voltage source behind impedance for the evaluation of the reactive current contribution for overvoltage events

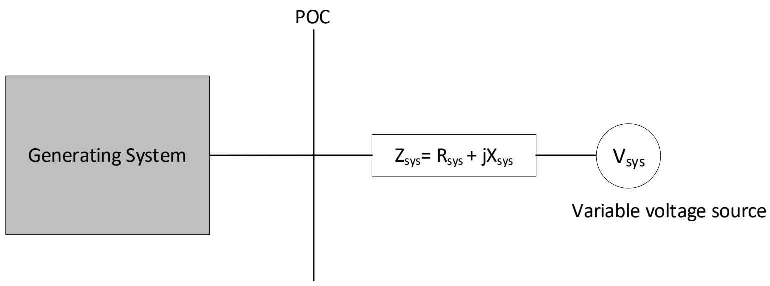


Table 3-19 The variations of parameters while assessing over-voltage ride through

Variable	Range	Note
System Thevenin Impedance	Maximum fault level Minimum Fault level	Corresponding to system maximum and minimum short circuit capacity at Connection Point
System X_{sys}/R_{sys}	Maximum Minimum	If the X/R varies considerably for each system SCC
Overvoltage range at Connection Point	Table 3-20 as minimum	Note the fault clearance time is a function of fault type per Table 3-20
Control modes of generating facility	All control modes	Study will be repeated for all control models affecting reactive power
Initial operating point of generating facility	Min and Max Active Power Zero, min and max Reactive Power	Study will be repeated for min and max Active Power Depending on control mode, the setpoint is changed to set the generating facility at zero, min and max Reactive Power for each MW setpoint

In Table 3-20, recommendations for the levels and duration of over-voltage, to be set on voltage source, are provided. It should be noted that for higher overvoltage levels, the duration is chosen to be very small (20ms) so that it does not violate the ride through envelope of Generating Systems. For these short over-voltage events, there is no need to evaluate the K factor (reactive current contribution) and only active current recovery and CUO should be assessed. The voltage levels and time duration in Table 3-20 are recommendations only. They may be adjusted for different Generating Systems considering their voltage ride through the envelope (as agreed in A12.8 of the WEM Rules).

Table 3-20 Recommended minimum time overvoltage tests for reactive current absorption assessment

Variable	Voltage level and duration
Overvoltage at Connection Point	135% for 0.02s
	130% for 2s
	120% for 20s
	117% for 20s
	115% for 20s
	113% for 20s

The compliance criteria, as described in sections 3.9.2 and 3.9.3 of this guideline, must be assessed and demonstrated for all the events listed in Table 3-19. While assessing the reactive current contribution, the methods described in section 3.9.2.1 should be applied.

3.9.4.4 Simulation model and performance evaluation method for fault ride through for a series of disturbances

Clauses A12.9.2.3 and A12.9.3.3 of the WEM Rules require the Generating System to remain in CUO when exposed to a series of faults within any 5-minute period. A Thevenin representation of the system connected to Generating System as shown in Figure 3-18 will be used for this assessment.

Clause A12.9.3.3 of the WEM Rules requires CUO of the Generating System when exposed to 6 faults within 5 minutes. For ideal performance, CUO is required for 15 faults within 5 minutes. To assess this requirement, a set of faults is defined as; a single phase to ground; a phase to phase to ground; and a three-phase fault. These faults occur in sequence (see Figure 3-19). The recommended setup for fault sets is listed in Table 3-21 and Table 3-22 for minimum and ideal performance assessment respectively.

Figure 3-18 Variable voltage source behind impedance and fault at Connection Point for the evaluation of the series of fault events ride through requirement

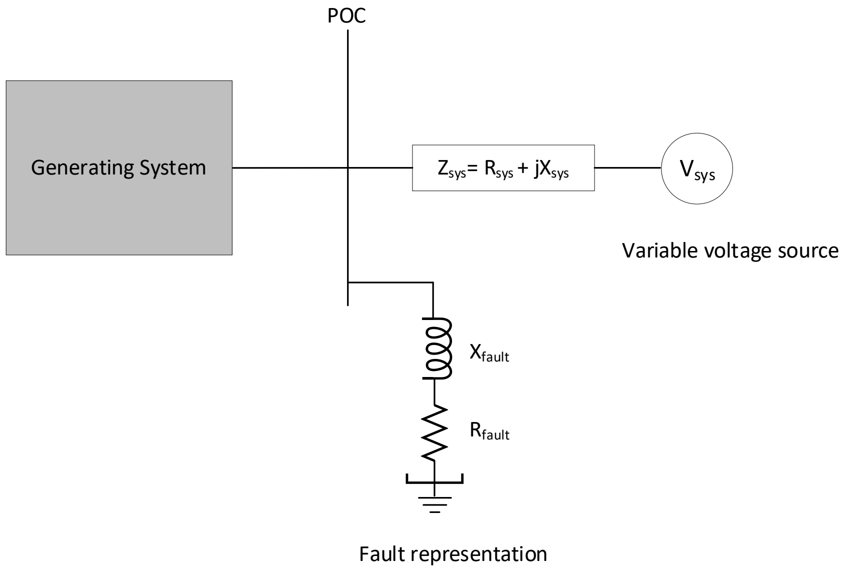


Figure 3-19 A representation of the fault sets for a series of faults and the variable definitions

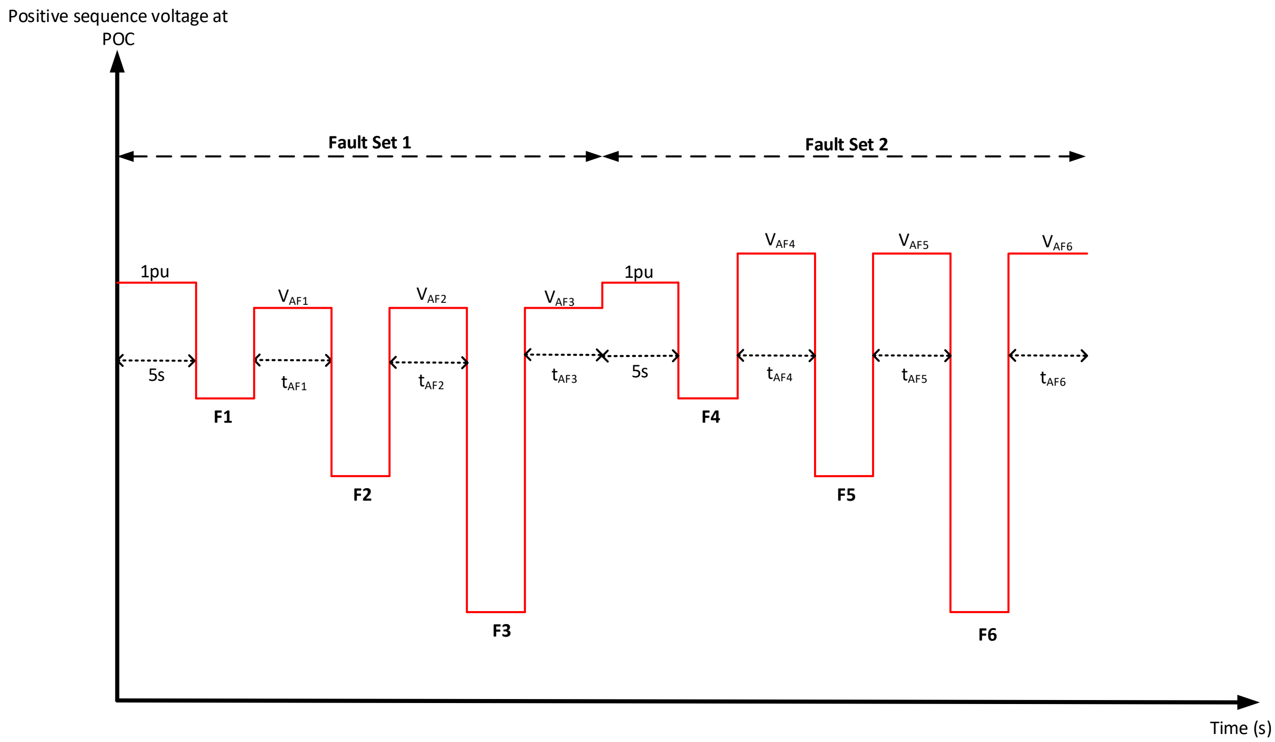


Table 3-21 Recommended simulation fault setup for the assessment of A12.9.3.3 (minimum performance)

Fault Set	ID	Fault type	Voltage after fault (V_{AF})	Fault impedance	Fault clearance time	Time before next fault (t_{AF})
Fault Set 1	F1	1ph-G	0.9pu	Zero		3s
	F2	2ph-G				

	F3	3Ph			Clearance time of the slowest main protection system	
Fault Set 2	F4	1ph-G	1.1pu	Zero	Clearance time of the slowest main protection system	3s
	F5	2ph-G				
	F6	3ph				

Table 3-22 Recommended simulation fault setup for the assessment of A12.9.2.3 (ideal performance)

Fault Set	ID	Fault type	Voltage after fault (V_{AF})	Fault impedance	Fault clearance time*	Time before next fault (t_{AF})
Fault Set 1	F1	1ph-G	0.9pu	Zero	BF	3s
	F2	2ph-G			MPS	
	F3	3Ph			MPS	
Fault Set 2	F4	1ph-G	1.1pu	Zero	MPS	3s
	F5	2ph-G			BF	
	F6	3ph			MPS	
Fault Set 3	F7	1ph-G	0.9pu	Equivalent to 50% residual voltage at Connection Point	BF	3s
	F8	2ph-G			MPS	
	F9	3Ph			MPS	
Fault Set 4	F10	1ph-G	1.1pu	Equivalent to 50% residual voltage at Connection Point	MPS	3s
	F12	2ph-G			BF	
	F12	3Ph			MPS	
Fault Set 5	F13	1ph-G	1	Zero	MPS	3s
	F14	2ph-G			MPS	
	F15	3Ph			BF	

* MPS denotes the clearance time of the slowest main protection system. BF denotes for the clearance time of the breaker failure protection If breaker failure protection is installed and if not, the longer of 450ms and the clearance time of the slowest primary protection system.

To assess compliance, a dynamic (or EMT) study must be performed for the faults as in Table 3-21 and Table 3-22. The system and Generating Systems' set-up are like single fault assessment and are listed in Table 3-23. If protection relays sensitive to voltage deviations exist and are not part of the model, a separate assessment of the protection relay settings should be included to establish the facility's ride through capability.

Table 3-23 The variations of parameters while assessing ride through a series of faults

Variable	Range	Note
System Thevenin Impedance	Maximum fault level Minimum Fault level	Corresponding to system maximum and minimum short circuit capacity at Connection Point
System X_{sys}/R_{sys}	Maximum Minimum	If the X/R varies considerably for each system SCC
Fault X_{fault}/R_{fault}	Pure R	Applied to all fault types
Control modes of generating facility	All control modes	Study will be repeated for all control models affecting Reactive Power
Initial operating point of generating facility	Min and Max Active Power Zero, min and max Reactive Power	Study will be repeated for min and max Active Power Depending on control mode, the setpoint is changed to set the generating facility at zero, min and max reactive power for each MW setpoint

3.9.4.5 Field evidence to verify performance

At the time of planning and commissioning, the compliance against section A12.9 of the WEM Rules is to be relied on the software simulations. For cases or regions of the system that the fault response of the Generating System is critical for system stability, a hardware in the loop test might be requested. In such cases the scope will be agreed between Western Power, AEMO and the Market Participant during the connection process, and is limited to specific faults of concern.

3.10 Technical Requirement: Disturbance Ride Through for Partial Load Rejection [A12.10]

3.10.1 Introduction to section A12.10 of the WEM Rules

A Generating System and each of its operating Generating Units must be capable of CUO during and following a sudden reduction in required Active Power generation as a result of a Contingency Event. Section A12.10 of the WEM Rules specifies the applicable load rejection compliance limits.

3.10.2 Explanation of individual requirements

Table 3-24 specifies the performance requirements due to load rejection event. The Generating System and each Generating Unit are required to remain in CUO during and after an event, provided that reduction does not require operation below the Generating System's Rated Minimum Active Power output level.

Table 3-24 The partial load rejection criteria

Criteria	Ideal Performance Standard	Minimum Performance Standard
CUO in case of a load rejection disturbance as a percentage of Rated Maximum Active Power	30%	5%

3.10.3 Verification methods

A load rejection event would normally cause an increase in power system frequency. Given this, the requirements and performance levels demonstrated in Sections 3.6 and 3.7 could be used as evidence of compliance to section A12.10 of the WEM Rules and no other simulation or assessment is required.

For example, compliance with the ideal performance standard specified in Table 3-24 above can be demonstrated if:

- the Frequency Ride Through envelope of the Generating System meets the ideal envelope requirements as demonstrated in simulations outlined in Section 3.7; and
- a maximum frequency droop of 4% can be achieved by the frequency controller as per Section 3.6.2.5.

If the Frequency Ride Through envelope is smaller than the ideal envelop (as shown in Figure 3-11) or the maximum droop is higher than 4%, the result of the simulation based on the guideline in Table 3-13 could be used to indicate the performance level of the Generating System. It should be noted that the over frequency disturbance injected in the simulation should not cause a steady state power reduction below the Generating System's Rated Minimum Active Power. A simulation based on the guideline in Table 3-13 should demonstrate compliance in a scenario where the step change in frequency results in reduction in output power equal to 30% of Rated Maximum Active Power at the Connection Point[20].

[20] Western Power and AEMO may also run a comprehensive system level analysis to evaluate full impact of load rejection on all variables in system level. If the study shows non-compliance of the Generating System, the relevant Market Participant will be required to change the performance level or develop and implement a rectification plan.

3.11 Technical Requirement: Disturbance Ride Through for Quality of Supply [A12.11]

3.11.1 Introduction to section A12.11 of the WEM Rules

Western Power must monitor and maintain power quality to a standard designed to ensure a consistent quality of service to all network users. In the SWIS, power quality limits are set out in the Technical Rules, and referred to in the WEM Rules.

To achieve this, in accordance with section A12.11 of the WEM Rules, a Generating System, including each of its Generating Units and reactive Equipment must not disconnect from the SWIS as a result of voltage fluctuation, harmonic voltage distortion and voltage unbalance conditions at the Connection Point within the levels for specified flicker, harmonics and negative phase sequence voltage specified in the Technical Rules[21].

3.11.1.1 Verification methods

Market Participants should provide Western Power with the following information, as applicable to a Generating System:

- Where possible resonance conditions including Imbalance conditions could result in excessive off-nominal frequency current or overvoltage, the Market Participant must provide a frequency sweep analysis to determine the resonance frequency.
- The Market Participant must provide evidence that all the equipment within the Generating System meets the power quality ride through requirements. This includes providing Original Equipment Manufacturer (OEM) data sheets showing safe operating tolerances of the Generating Units and other equipment in Generating System as evidence.
- If the Generating System has a protection system or any in-house equipment that may be sensitive to negative sequence, flicker, or harmonics, these must be tested as per the Technical Rules. It should be noted that the emission limits and planning levels are applied at the Connection Point. An analysis might be needed to project the planning level of power quality indices to the location of assessment if the location of assessment of protection system and other equipment is not at the Connection Point.

[21] Refer to Technical Rules Dec 2016, Table 2.3: Planning levels for flicker severity, Table 2.5 Transmission planning levels for harmonic voltage in networks with system voltage above 35 kV and Table 2.6 Limits for negative phase sequence component of voltage (in percent of the positive phase sequence component).

3.12 Technical Requirement: Quality of Electricity Generated [A12.12]

3.12.1 Introduction to section A12.12 of the WEM Rules

Harmonics, imbalance, and flicker must be maintained within acceptable limit to ensure quality of supply. Section A12.12 of the WEM Rules requires a Generating Systems and loads to maintains their quality of supply, so the overall power quality performance of the system can be kept within standard limits. AS/ANZ 61000.3.6:2001, AS/ANZ 61000.3.7:2001 and AS/ANZ 61000.3.13:2012 are used as reference standards in WEM Rules to specify the details of allocation procedure and testing of harmonics, flicker, and imbalance. WEM Rules A12.12 requires Generating Systems to provide evidence that their facility meets the harmonic and flicker emission limits allocated according to these standards in planning, design and after commissioning.

3.12.2 Explanation of individual requirements

3.12.2.1 Requirements for imbalance

A12.12.1.1 of the WEM Rules requires a Generating System whenever connected to the network, even if not generating, to keep the contribution to the voltage imbalance at the Connection Point within the limit allocated by Western Power.

According to the Technical Rules (TR: Table 2.6: Limits for negative phase sequence component of voltage (in percent of the positive phase sequence component)), Western Power must maintain the imbalance factor within planning levels, which are:

- 1% for Connection Point nominal voltages above 100kV;
- 1.5% for Connection Point nominal voltages between 10kV and 100kV; and
- 2% for Connection Point nominal voltages below 10kV.

The imbalance factor is the 10 minute average of negative sequence voltage divided by relevant 10 minute average of the positive sequence voltage:

Equation 3-9

$$\boldsymbol{UF = 100\frac{\overline{V}_2}{\overline{V}_1}}$$

Where $\overline{V}_2$ is the 10 minute average negative sequence voltage, $\overline{V}_1$ is the 10 minute average positive sequence voltage and UF is the imbalance for corresponding 10 minute period.

Western Power applies AS61000.3.13:2012 to determine the planning level of imbalance factor and indicate the emission limits for each Generating System at their Connection Point. The compliance level is the 95th percentile of the imbalance contribution.

As per AS/NZS 61000.3.13:2012, Western Power may also request evidence in relation to compliance with the short term imbalance factor. Compliance is defined as the 99th percentile of a three second average imbalance factor. The allocated limit to this short term is higher than the 10-minute average limit by a factor of 1.25 to 2. This factor or the imbalance limit for the three-second average index must be provided by Western Power.

The Market Participant is required to provide evidence that its Generating System complies with the allocated emission limits. The imbalance currents as expected from the Generating System must be modelled in a

Thevenin equivalent circuit, representing the minimum short circuit capacity of the network at Connection Point to estimate the imbalance factor of the Generating System.

Western Power and/or AEMO may require a Market Participant to perform the analysis on a full or reduced system model instead of a Thevenin equivalent. The parameters of the Thevenin equivalent model (short circuit capacity, Positive, Negative and Zero sequence impedances) for different operating scenarios must be provided by Western Power. A detailed model of the Generating System and Generating Units as applicable should be used to account for all the sources of imbalance (e.g., imbalance reticulation system).

An imbalanced load flow simulation must be performed when the active power injection from all Generating Units is at the Rated Maximum Active Power. The imbalance factor should be calculated at the Connection Point using Equation 3-9. If the imbalance factor is below the allocated limits, the Generating System is compliant.

Under some conditions Western Power may accept an imbalance factor level outside of the allocated limit as a stage 3 evaluation (see section 3.12.2.2 below for an overview of the stage 1 to 3 evaluations). A stage 3 evaluation is conditional and should be assessed when measurements are available from commissioning and testing activities, where 95th percentile results of a minimum of a one week assessment period (using 10-minute intervals) will be verified against the required limits. The conditions associated with the acceptance of the imbalance under stage 3 conditions must be documented in GPS registration via a trigger event associated with the relevant clause. The trigger event must be documented using the template provided by Western Power[22] in accordance with clauses 3A.5.6, 3A.5.7 and 3A.5.8 of the WEM Rules.

If the Generating System is unable to meet the required imbalance levels and a stage 3 evaluation is unable to be accepted, the Market Participant must take corrective actions to mitigate the imbalance injection from Generating System. If Western Power does not grant a conditional acceptance based on a stage 3 assessment, a complete weekly 10-minute simulation must be performed to provide sufficient data to calculate the 95th percentile of imbalance contribution.

3.12.2.2 Requirements for flicker

Voltage fluctuations from the Generating System if connected, even if not generating, must be maintained within allocated limits at the Connection Point. Table 3-25 lists the requirements of section A12.12 of the WEM Rules for compliance to flicker emission limits.

Table 3-25 The flicker requirements

Criteria	Ideal Performance Standard	Minimum Performance Standard
Flicker emission limits	Comply with allocated limit by Western Power per AS/NZS 61000.3.7:2001 stage 1 or stage 2	1. Comply with allocated limit by Western Power per AS/NZS 61000.3.7:2001 stage 3 2. Market Participant must fund any investment required to mitigate the effects of the higher emissions allowed per stage 3

Western Power will determine the planning limits in Technical Rules TR:Table 2.3 that apply to each Generating System per AS/NZS 61000.3.7:2001. The flicker severity is evaluated by short term (P_{st}) and long term (P_{lt}) indices. The short term and long term allocated limits apply to the 99th percentile according to the relevant Technical Rules.

[22] Generator Performance Standard Trigger Event Template could be downloaded from Generator Performance Standards | Western Power.

Depending on the minimum short circuit capacity of the system and the Rated Maximum Apparent Power of the Generating System, Western Power will determine whether a stage 1 or stage 2 evaluation as outlined in AS61000.3.7:2001 will apply to that Generating System. These are outlined in the following sections.

Stage 1: Simplified assessment of the fluctuating facilities

Stage 1 allows connection without detailed assessment.

In stage 1, Western Power evaluates the system for the minimum short circuit capacity at various operating conditions. AS/NZS 61000.3.7:2001 specifies the fluctuating apparent power to system short circuit capacity ratio for various number of changes per minute. The apparent power fluctuation is usually equal to the Rated Maximum Apparent Power of the Generating System, but depending on the nature of fluctuating sources within the Generating System, it might be assumed higher.

It should be noted that in almost all the transmission connected Generating System applications, stage 2 is used for detailed assessment of the emission limits.

Stage 2: Detailed assessment of the emission limits relative to the actual system characteristics

In stage 2, Western Power assesses the fluctuating power of the Generating System in parallel to the already connected Generating Systems and the transfer capacities for the future application. Western Power then allocates a portion of the planning limit to the Generating System.

The emission limit will be given for both (P_{st}) and (P_{lt}) at the Connection Point. The Market Participant must provide evidence of compliance for these limits when submitting reference documents for GPS registration.

Western Power uses a stage 2 evaluation to allocate the flicker limits for transmission connected Generating System in almost all cases.

Stage 3: Acceptance of higher emission levels on a conditional basis (minimum performance standard only)

Western Power, AEMO and the relevant Market Participant may consider a higher emission level following a stage 3 assessment. This may only be considered in scenarios where:

- a Generating System doesn't have a large fluctuating component, or the fluctuating elements are designed not to be in service simultaneously;
- there are no fluctuating facilities installed at the time of submitting the connection application for the Generating System and emissions are reasonably expected to be immaterially above the limits assessed under stage 2; or
- the non-compliance to the limits assessed under stage 2 limits are reasonably expected to occur as a result of a rare contingency or planned outage event.

For any of the above scenarios, a Market Participant must consult with Western Power, who will then perform a detailed assessment of the effect of the Generating System's higher emissions on the power quality of the current and future system, to ensure it is able to meet each SWIS Operating Standard or contractual obligations to existing holders of Arrangements for Access.

A stage 3 assessment of emission limits will be accepted on a conditional basis. Conditions may include a potential future obligation for a Market Participant to fund any necessary investments at the Generating System to mitigate the effect of extra emissions. Western Power may also only approve the higher emission limits on a short term basis or until spare capacity exists.

The conditions considered for acceptance must be documented in the GPS registration via a trigger event associated with the relevant clause. The registered trigger event must define the basis for the stage 3 acceptance, including the changing condition that would result in a review of the acceptance (e.g.: changes to network conditions or a specific period passing after registration) and what actions must be taken by the Market Participant after the trigger conditions have occurred (e.g.: installation of equipment to mitigate the higher emissions).

Trigger events must be documented using the template provided by Western Power in accordance with sections 3A.5.6, 3A.5.7 and 3A.5.8 of the WEM Rules. If the Generating System is unable to meet allocated emission limits and a stage 3 allocation is unable to be accepted, corrective actions should be taken by the Market Participant during the connection process to mitigate emission limits.

3.12.2.3 Requirements for harmonics

Harmonic emission from the Generating System if connected to SWIS, even if not generating, must be maintained within allocated limits at the Connection Point. Table 3-26 lists the compliance requirements specified in section A12.12 of the WEM Rules.

Table 3-26 Harmonics requirements

Criteria	Ideal Performance Standard	Minimum Performance Standard
Flicker emission limits	Comply with allocated limit by Western Power	1. Comply with allocated limit by Western Power defined in AS/NZS 61000.3.6:2001 stage 3 2. Market Participant must fund any investment required to mitigate the effects of the higher emissions allowed per stage 3

Western Power will use the planning limits stipulated in Technical Rules TR:Table 2.4 and 2.5 to allocate emission limit of each Generating System following the procedures stipulated in AS/NZS 61000.3.6:2001. Western Power must also determine a limit to total harmonic distortion (THD) for the Generating System.

The individual harmonic distortion at each harmonic and inter-harmonic frequency as well as THD from the Generating System must stay within these limits.

Stage 1: Simplified assessment of the fluctuating facilities

If the apparent power of the harmonic producing sources are much smaller the system short circuit capacity at the Connection Point, the Generating System can be connected without detailed evaluation according to AS/NZS 61000.3.6:2001. There are two possible evaluation paths for defining the total MVA of harmonic producing sources:

1) Maximum Apparent Power of the Generating System

2) Weighted sum of the MVA of all harmonics producing units/elements in the Generating System

The evaluation method and power of each harmonic source must be agreed between Western Power and the relevant Market Participant.

If the ratio of total MVA calculated above as harmonic source MVA to the minimum short circuit capacity of the Generating System at Connection Point is less than the limits in AS/NZS 61000.3.6:2001, then the Generating System can be connected without further assessment.

According to AS/NZS 61000.3.6:2001, if the above criteria are not met by the Generating System, a detailed assessment is required under stage 2.

In the SWIS, the stage 2 assessment is used to determine the harmonic limit for all Generating Systems.

Stage 2: Detailed assessment of the emission limits relative to the actual system characteristics

In stage 2, Western Power must assess the harmonic sources of the Generating System in parallel to the already connected facilities and the transfer capacities for the future expansions. Under stage 2, Western Power allocates a portion of the harmonic planning limits to the relevant Generating System.

The emission limit will be given for each harmonic frequency voltage distortion (usually up to 50^{th} harmonics order) and THD at the Connection Point. The Market Participant must provide evidence of compliance for these limits when submitting documents for GPS registration.

Western Power uses stage 2 evaluations to allocate the harmonics limits for transmission connected Generating Systems in almost all cases.

Stage 3: Acceptance of higher emission levels on a conditional basis (minimum performance standard only)

Western Power and the relevant Market Participant may consider a higher limit than determined in the stage 2 assessment following a stage 3 assessment. This may only be considered in scenarios where:

- a Generating System does not have large emitting components or the harmonic emitting elements are designed not to be in service simultaneously;
- there are no harmonic emitting facilities installed at the time of submitting the connection application for the Generating System and emissions are reasonably expected to be immaterially above the limits assessed under stage 2; or
- the non-compliance to the limits assessed under stage 2 limits are reasonably expected to occur as a result of a rare contingency or planned outage event.

Western Power must perform a detailed assessment of the effect of the higher emissions by the Generating System considering the power quality of the system current and future to ensure compliance of the system to the planning level of Technical Rules.

A stage 3 assessment of emission limits will be accepted on a conditional basis. Conditions may include a potential future obligation for a Market Participant to fund any necessary investments at the Generating System to mitigate the effect of extra emissions. Western Power may also only approve the higher emission limits on a short term basis or conditionally until spare capacity exists.

The conditions considered for acceptance must be documented in the GPS registration via a trigger event associated with the relevant clause. Trigger events must be documented using the template provided by Western Power in accordance with WEM Rules clauses 3A.5.6, 3A.5.7 and 3A.5.8. If the Generating System is unable to meet allocated emission limits and a stage 3 allocation is unable to be accepted, corrective actions should be taken by the Market Participant during the connection process to mitigate emission limits.

3.12.2.4 The assessment methods for flicker and harmonics

In the planning phase and when submitting the document for GPS registration, a Market Participant must perform an emission study based on the system model provided by the Western Power or a Thevenin equivalent for minimum short circuit capacity of the system combined with flicker and harmonic data of the Generating Units. Western Power will provide the short circuit capacity and impedance data including impedance angle, and sequence impedances. The Market Participant must include the flicker and harmonics emission data in Generating System Model. This information should be obtained from the OEM of all equipment within the Generating System. The flicker and harmonic emission at Connection Point are obtained by running a harmonic load flow analysis.

The study must evidence that the contribution of the Generating System to short term and long term flicker is below the allocated limit. It must also provide evidence that the harmonics voltage distortion and THD due to the current harmonic injection of the Generating System at the Connection Point is below the allocated limits. The original flicker and harmonic data from the manufacturer of the Generating Units must be provided to Western Power and be used in the simulation.

3.12.2.5 The harmonic impedance of the system and filters design

If the Market Participant deems it necessary to design and install filter banks to comply with the allocated harmonic limits, a combination of nearby capacitor banks and reactors must be included to evaluate possible resonance points. The filter design procedure and associated parameters must be included in the power quality report for the Facility and submitted as part of GPS registration.

3.13 Technical Requirement: Generation Protection Systems [A12.13]

3.13.1 Introduction to section A12.13 of the WEM Rules

Appropriate coordination between Generating System's protection and the protection installed in the network is essential.

In accordance with section A12.13 of the WEM Rules, a Generating System must meet the protection requirements specified in the Technical Rules for both Generating Systems and the Transmission System (where relevant), including the requirement for faults to be cleared within maximum Total Fault Clearance Times specified in the Technical Rules or, where specified, a Critical Fault Clearance Time (CFCT) developed by Western Power.

Section A12.13 of the WEM Rules also stipulates the requirements for sharing protection settings relevant to the system with the Western Power and AEMO through GPS.

3.13.2 Explanation of individual requirements

3.13.2.1 Protection design and performance

A Market Participant must ensure all protection systems that apply to a Generating System to comply with the clearance time, sensitivity and redundancy requirements specified in section 3.5 of the Technical Rules. All components within the Generating System (including lines, cables and transformers) must have their own protection. The protection settings of each element must comply with the Technical Rules at the Connection Point.

When there is a possibility of system transient instability, Western Power may specify a CFCT shorter than the Technical Rules clearance times. In such cases, the Market Participant must provide fast protections.

3.13.2.2 Anti-islanding

In accordance with WEM Rules A12.13.3.3, anti-islanding protection must be installed and made available to ensure the Generating System is prevented from supplying an isolated portion of the SWIS when it is not secure to do so.

The design, sensitivity, performance, and redundancy requirements for ant-islanding of transmission connected Generating Systems must be documented in accordance with the guidelines produced by Western Power[23] under clause 3A.4.4 of the WEM Rules.

3.13.2.3 Protection of generating units against abnormal system conditions

In accordance with clause A12.13.3.4 of the WEM Rules, all Protection Schemes necessary to disconnect the Generating System during abnormal conditions in the power system that would threaten the stability of the Generating System, or risk damage to the Generating System, must be installed and available.

The settings of these Protection Schemes must deliver the required performance for disturbance ride through specified in A12.7, A12.8 and A12.9 of the WEM Rules. The settings of these protections must be included as part of the GPS. Table 3-27 shows protections commonly installed for Generating Units.

[23] Anti-Islanding Guideline would be made available by Jan 2023

Table 3-27 List of sample protections commonly installed a Generating Unit

Synchronous units	Asynchronous units
Stator overcurrent	Terminal overcurrent
Stator under-voltage/over-voltage	Terminal under-voltage/over-voltage
Stator under-frequency/over-frequency	Terminal under-frequency/over-frequency
Filed overcurrent	Overloading
Loss of field	Backup distance
V/Hz	Negative phase sequence overcurrent
Loss of synchronism	Reverse power
Backup distance	Generator unit protection (e.g. differential, REF, SEF, stator 100% winding earth fault, rotor earth fault)
Reverse power	Pitch, Yaw, and Rotational Speed protection) (wind turbine)
Negative phase sequence overcurrent and overload	
Generator's unit protection (e.g. differential, REF, SEF, stator 100% winding earth fault, rotor earth fault)	

3.13.2.4 Provision of protection settings

A Market Participant must provide relevant documents and data as a part of GPS submission document.

A list of required documents is provided in Attachment 5 of the Technical Rules. This includes the required data regarding protection and protection settings design philosophy. The documents should provide sufficient evidence that all the requirements mentioned in A12.13 of the WEM Rules are met.

Documentation should include the following:

- Protection single line diagram (PSLD) of the generating system including the generating units, the transformers, and cables.
- Protection type and settings of the relays inside PSLD which should include the relays listed in Table 3-27 as a minimum.
- Protection coordination study report.
- Highlighted agreement on any protection settings which is negotiated to be set below the compliance requirements of A12.7, A12.8 or A12.9 of the WEM Rules.

3.14 Technical Requirement: Remote Monitoring Requirements [A12.14]

3.14.1 Introduction to section A12.14 of the WEM Rules

Western Power and AEMO must have visibility of fundamental parameters of Generating Systems. To achieve this, a Market Participant must install remote monitoring equipment (RME) and a communication channel between the RME and Western Power and AEMO's central monitoring and control systems.

Section A12.14 of the WEM Rules specifies the design and operation requirements for RME.

3.14.2 Explanation of individual requirements

3.14.2.1 Provision of RME (A12.14.3.1)

Western Power or AEMO may require Remote Monitoring Equipment to be installed in order to enable the Network Operator or AEMO to monitor the performance of a Generating Unit (including its dynamic performance) remotely, where this is necessary in real time for control, planning or Power System Security.

The RME can also be used to assess the dynamic performance of the facility during disturbances.

3.14.2.2 Specifications of RME

Any installed, upgraded, modified or replaced RME must:

- comply with the AEMO's WEM Procedure: Communications and Control Systems;
- be compatible with both Western Power's and AEMO's SCADA systems;
- conform with the Western Power's Nomenclature Standards; and
- be kept available at all times, subject to Outages as agreed by AEMO.

AEMO publishes their communication and control system requirements through WEM procedures or guidelines (WEM PROCEDURE: COMMUNICATIONS AND CONTROL SYSTEMS). These requirements will have to be followed for selection of RMEs and their configurations.

3.14.2.3 Monitored signals (A12.14.3.3)

The RME must be able to monitor and make available the information requested by WEM procedures (described in WEM rules 2.35.4) or other signals which are requested by AEMO or Western Power. The WEM procedures for communication and control must be followed as the minimum for the signal provisions.

3.14.2.4 Verification method

At the time of submitting the documents for GPS registration, a Market Participant must provide sufficient evidence that the Generating System is or will be equipped with RME that meets all the requirements of WEM Procedure: Communications and Control Systems. It should be noted that AEMO and Western Power may add specific requirement to a Generating System (e.g., adding an extra monitoring point).

3.15 Technical Requirement: Remote Control Requirements [A12.15]

3.15.1 Introduction to section A12.15 of the WEM Rules

Western Power and AEMO may require control of fundamental parameters of Generating Systems. This is achieved by installing Remote Control Equipment (RCE) and a communication channel between RME and Western Power and AEMO's central monitoring and control systems. RCE may include the breaker open/close controls, active power and reactive power controller settings, limiters, and control modes.

Section A12.15 of the WEM Rules specifies the design and operation requirements for RCE.

3.15.2 Explanation of individual requirements

3.15.2.1 Provision of RCE (A12.15.3.1)

Western Power or AEMO may, for any Generating Unit which may be unattended when connected to the Transmission System, require RCE to be installed in order to enable Western Power or AEMO to disconnect a Generating Unit from the Transmission System. Even if a Generating System is always attended, Western Power and AMEO may still require RCE for that Facility during emergencies.

3.15.2.2 Specifications of the RCE

Any installed, upgraded, modified, or replaced RCE must:

- comply with the AEMO's WEM Procedure: Communications and Control Systems[24];
- be compatible with both Western Power's and AEMO's SCADA systems;
- conform with the Western Power's Nomenclature Standards; and
- be always kept available, subject to Outages as agreed by AEMO.

AEMO and Western Power publish their communication and control system requirements through WEM procedures or guidelines. These requirements will have to be followed for selection of RMEs and their configurations.

3.15.2.3 Verification Method

At the time of submitting the documents for GPS registration, a Market Participant must provide sufficient evidence that the Generating System is or will be equipped with RCE that meets all the requirements of WEM Procedure: Communications and Control Systems and registered in Facility Operation Agreement.

[24] Available at: https://aemo.com.au/en/energy-systems/electricity/wholesale-electricity-market-wem/procedures-policies-and-guides/procedures

3.16 Technical Requirement: Communications Equipment requirements [A12.16]

3.16.1 Introduction to section A12.16 of the WEM Rules

Fast and reliable communication between the Generating Systems RME and RCE, and Western Power and AEMO's central monitoring and control systems is essential for secure operation of the power system.

Section A12.16 of the WEM Rules specifies the communications requirements for Generating Systems.

3.16.2 Explanation of individual requirements

3.16.2.1 Communication path between RME and RCE and central control and monitoring system

In accordance with clause A12.16.3.1 of the WEM Rules, a Market Participant with a Generating System must:

- provide and maintain communication channels with adequate redundancy between all RME and RCE installed at the facility with a communication interface;
- the communication interface must be located at the relevant power station or other location agreed by Western Power.
- provide and maintain a primary speech communication channel (PSCC) between the operator of the Generating System and AEMO and/or Western Power's control centre which:
  - meets the specifications of the communication standard developed and published by AEMO according to A12.16.3.3; and
  - where a public switched telephone network is used as the PSCC, that connection must be solely used for the operational communications (A12.16.3.4);
  - is always available, other than during outages coordinated and agreed with AEMO (A12.16.3.5); and
  - is always maintained in good working order (A12.16.3.6 of the WEM Rules).

The communication system between the communication interface of the Generating System and Western Power's central control and monitoring system is the responsibility of the Western Power unless agreed otherwise.

Adequate redundancy and specifications of the communication channels are defined by AEMO's communication standard (WEM PROCEDURE: COMMUNICATIONS AND CONTROL SYSTEMS).

3.16.2.2 Verification Method

A Market Participant must provide sufficient documentation that demonstrates its communication equipment meets the requirements specified by AEMO and registered in Facility Operation Agreement.

3.17 Technical Requirement: Generation System Model [A12.17]

3.17.1 Introduction to A12.17

The model of the Generating System is an essential asset as it enables Western Power and AEMO to simulate operating scenarios, contingencies and events and predict possible risky operating scenarios and avoid them. WEM rules A12.17 stipulates the obligations of a Generating System to provide a model of a Generating System with adequate details and accuracy.

3.17.2 Explanation of individual requirements

Western Power, as per WEM Rule clause 3A.4.2, 3A.4.3 is obligated to publish a procedure, Generation System Model Submission and Maintenance[25] that addresses the requirements of the Generation System model and the timeframe that the market Participant must ensure that the Generation system model Complies with Generating System Model's requirements. Western Power also publishes a guideline, Generator and Load Model Guidelines[26], that explains what information should be included with a GPS submission by Market Participant and how the provided model's performance would be assessed against Technical Requirements.

3.17.2.1 Completeness of the model (A12.17.3.2)

The model of the Generating System must have enough details to enable the network operator or AEMO to simulate the output of the Generating System at all power system conditions. Specific to this requirement, if an RMS model is deemed insufficient to predict the response of the facility to weak system conditions, an EMT model must be provided. The model should also enable simulation at all existing operating control modes of the facility.

The details of the models and inclusion within each model (Dynamic model and EMT models) are specified in the Generator and Load Model Guidelines.

3.17.3 Accuracy of the model (A12.17.3.3)

As assessed by Western Power (in consultation with AEMO), the simulated performance of the Generating System using the registered model must match the recorded performance of the real Generating System. It must be demonstrated via a model validation report during submission and is evaluated on an ongoing basis when various system disturbances data become available.

If the generating system model is deemed inaccurate at any time or after event analysis, the model must be revised and resubmitted by the Generating System within the time frames specified in WEM procedures.

3.17.3.1 Modifications and model updates (A12.7.3.4)

A market participant must provide updates to the Generating System model to comply with the requirement of A12.17 whenever Western Power or AEMO deem this necessary or the generating system has been modified, upgraded, or replaced. The updates must be provided within the time frames specified in WEM procedures Generation System Model Submission and Maintenance.

25 https://www.westernpower.com.au/industry/manuals-guides-standards/generator-performance-standards/

26 https://www.westernpower.com.au/industry/manuals-guides-standards/

Appendices

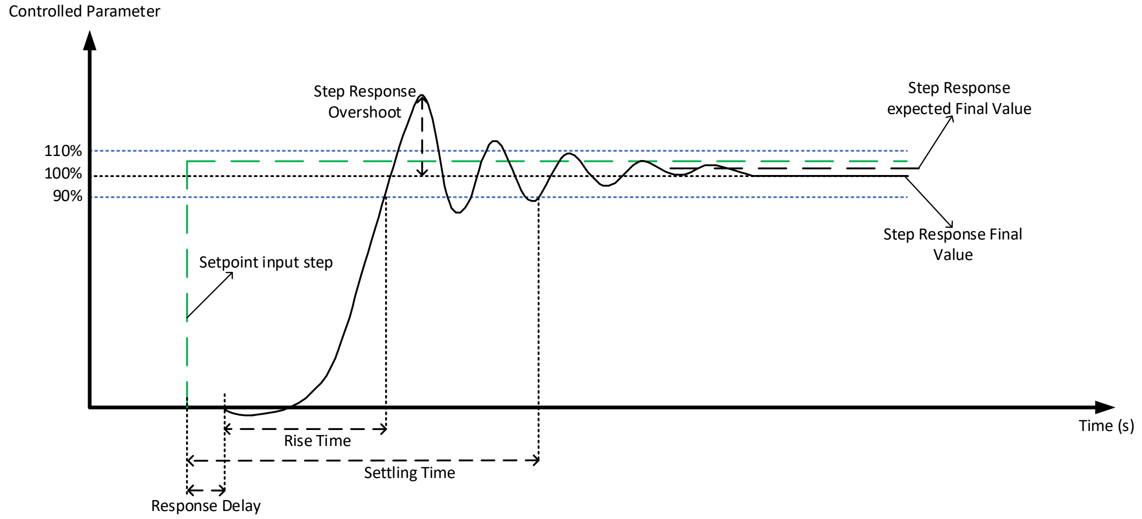
Appendix A Step response of a control system or measured quantity

Several measures have been defined to evaluate the quality of response for a control system in academia and practice. In the WEM Rules, the quality of the step response of a control system is evaluated through rise time and settling time, steady state error, and delays. The same applies for evaluating the quality of response for reactive current contribution of the facility in accordance with section A12.9 of the WEM Rules.

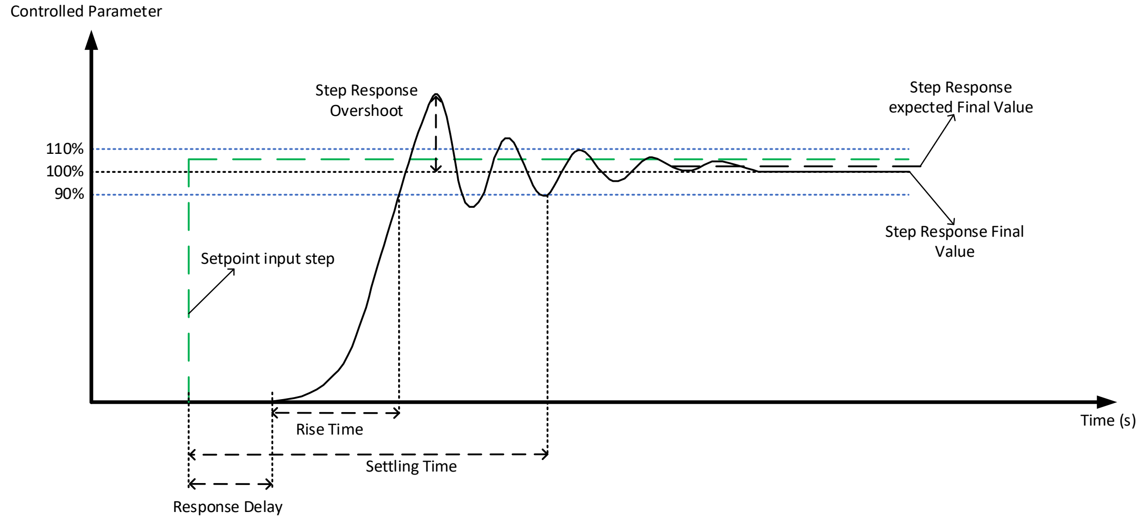
Figure A.1 demonstrates a typical oscillatory step response of a control system in which rise time, settling time, response delay, overshoot and final error are shown. While performing these evaluations, the delay time for a control system is counted as part of the settling time. If the output quantity moves from an initial value but did not move in the direction of the response, or moves slowly, that time is also counted as part of the rise time. If the output quantity stands at its initial value before moving to reach the final value, the start time is from the time the output value moves. Figure A.1 demonstrates an example of this evaluation.

Figure A.1: The step response parameters of a controller or a measured quantity (a) example of the controller initial response in step direction, (b) example of the controller initial lag in response

(a)



(b)



After a step response into a control system, the final step response should settle close to the expected value within a defined error tolerance. A PI controller will always bring the controlled signal to the expected final value; however, the actual response might deviate due to process tolerances. The step response final value might deviate from the step applied if droop control is utilised.

Appendix B The oscillations damping definitions

The oscillatory response of a Facility should be adequately damped as per WEM Rules requirements. The definition of Adequately Damped is adopted from the Technical Rules. As per Technical Rules clause 2.2.8, the adequately damped response should have:

- A damping ratio of at least 0.1
- A halving time of maximum 5 seconds

Several signal processing methods exist to extract damped oscillatory response modes of a Facility and assess the damping ratio. For example, a *Prony analysis* can decompose a recorded signal into the oscillatory modes and extract each modes' damping ratio and frequency. If a single oscillatory mode is of interest, a simple calculation for the oscillatory response depicted in Figure B.1 can be used:

The mode complex eigen value is expressed as:

(B.1) $\lambda = \sigma + j\omega$

The frequency of the mode is expressed as:

(B.2) $\omega = \frac{2\pi}{t_2 - t_1}$

And the damping coefficient of the mode is calculated from:

(B.3) $\sigma = \frac{\ln\left(\frac{y_2}{y_1}\right)}{t_2 - t_1}$

The above calculations can use y_0 and y_1 if not extra peaks are visible in the time domain signal. An average can also be taken between calculated parameters using consecutive peaks.

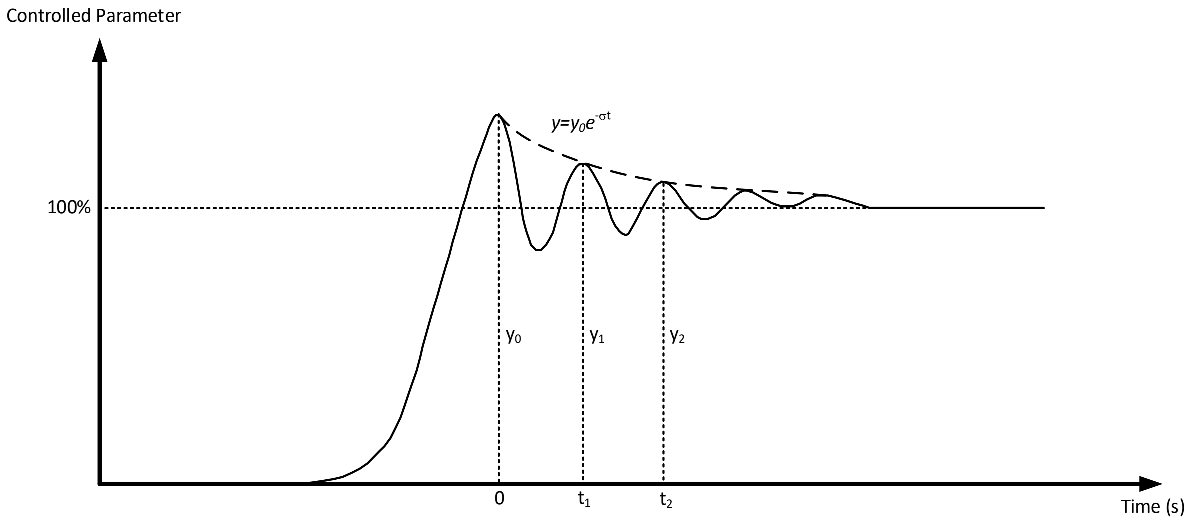
The damping ratio is defined as:

(B.4) $\xi = -\frac{\sigma}{\sqrt{\sigma^2+\omega^2}}$

(B.5) $T_{half} = \frac{\ln(2)}{\sigma} = \frac{0.693}{\sigma}$

A halving time of 5 seconds from (A.5) requires a damping coefficient of -0.138 s^{-1} or lower.

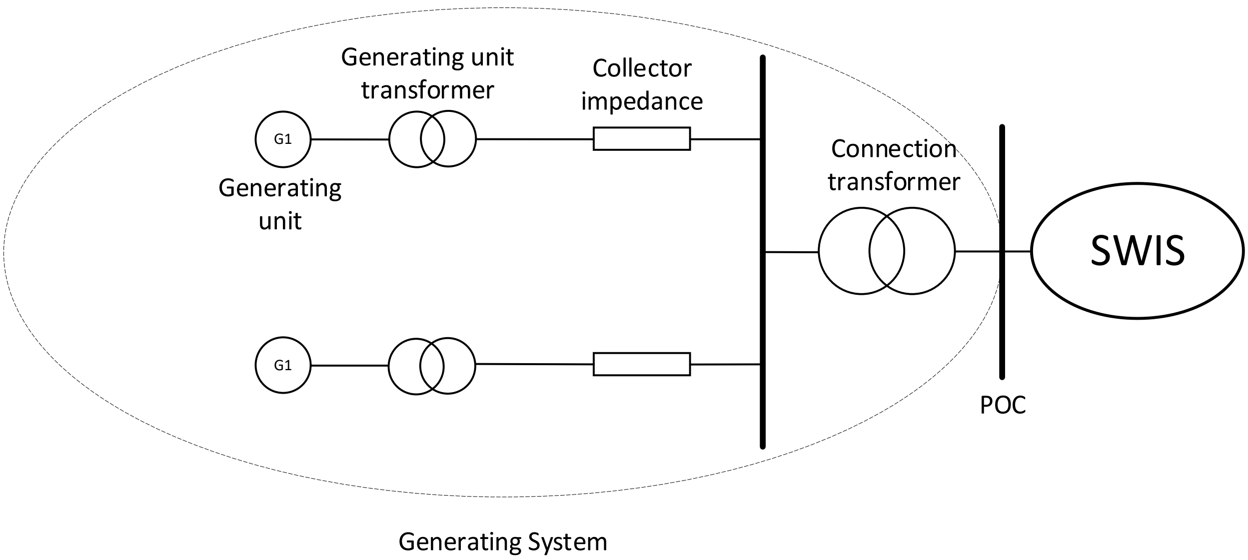
Figure B.1: the damping of an oscillatory response in time domain



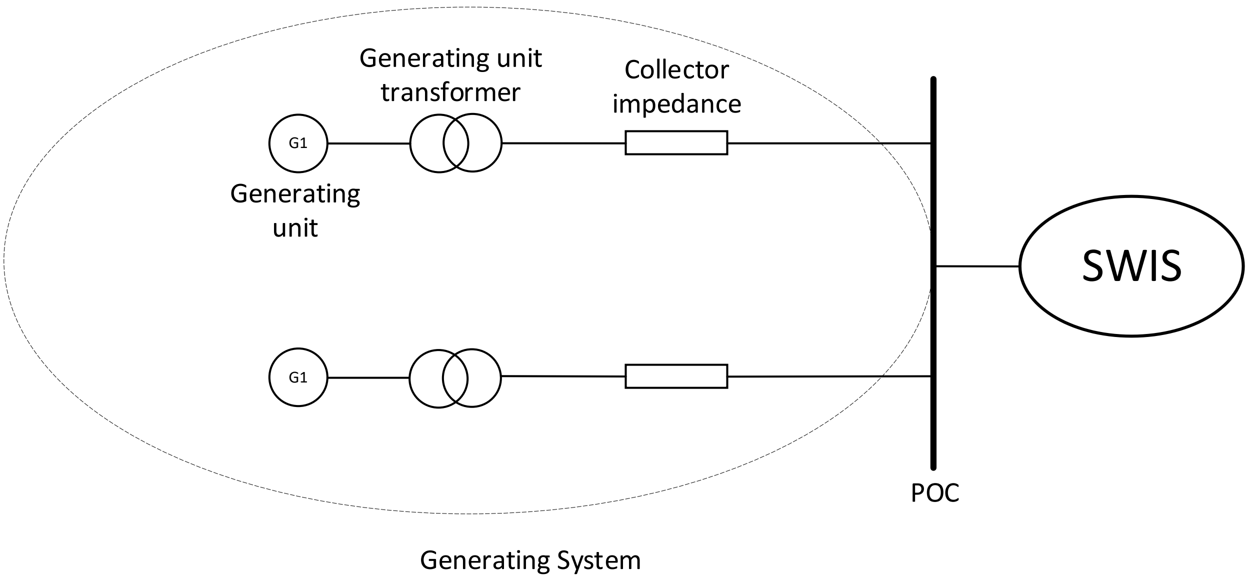
Appendix C Generating Units and Generating Systems

Figure C.1: The Generating Systems and Generating Units a) Generating System connected to the SWIS via main transformer b) Generating System connected directly to the SWIS

a)



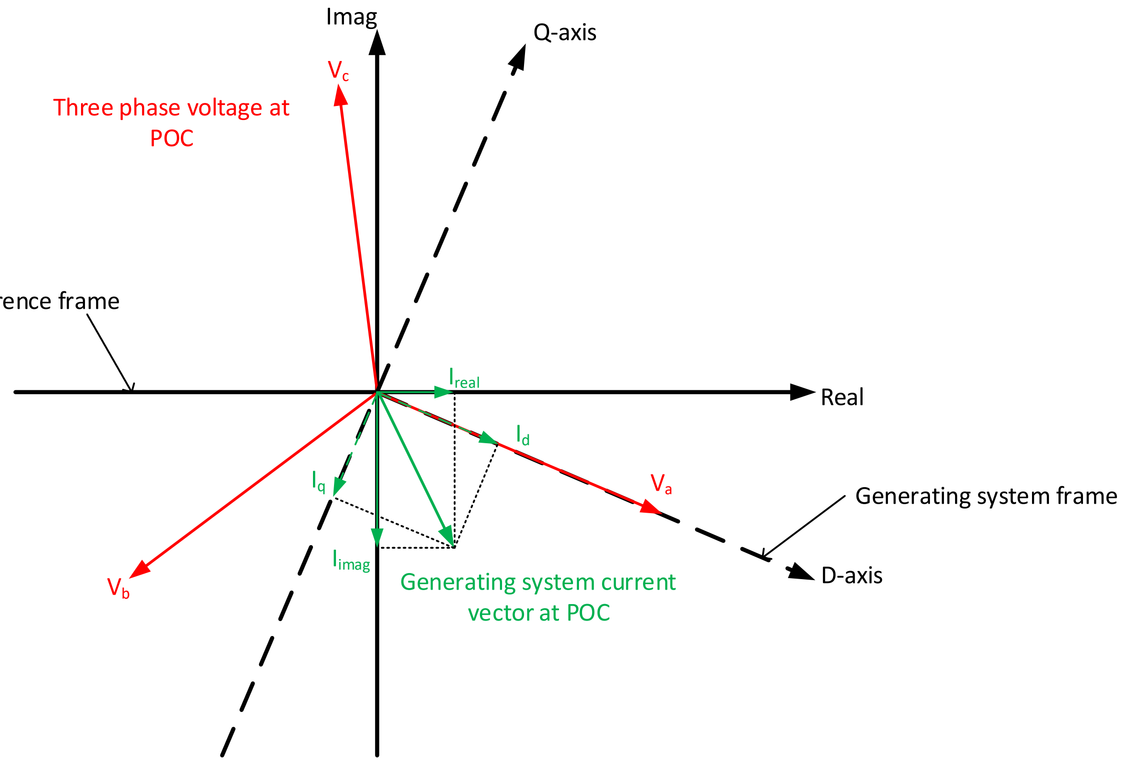
b)



Appendix D Reactive current in system reference frame vs dq current

The reactive current injected by a facility into the system should be referred to the system reference frame. The inverter controls normally decompose the measured system voltages into dq axis on machine frame to perform dq controls and revert this back to system frame using PLL tracking the system reference angle at the generating terminal. For the assessment of reactive current contribution, the current injected or absorbed to the system, on system reference is of interest and it doesn't apply to q axis current on machine reference. Figure D.1 shows the vector diagram of the currents at the machine and system frame for demonstration of this concept.

Figure D.1: The Generating System reactive current in system reference frame and corresponding dq axis current is DQ frame

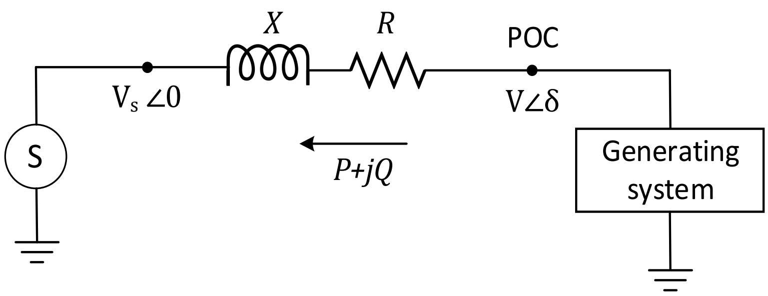


Appendix E Voltage control and the V-Q slope the system at POC

When operating in voltage control modes with droop, a Generating System shares the voltage control with the system at Connection Point (POC). The capability of the Generating System to change the system voltage at the POC depends on the amount of reactive power available from the facility and the characteristic of the system at POC to control the voltage. If system is too strong, the generating facility is not able to vary the voltage at POC. If system is too weak, fast response of the voltage controller can cause instability or oscillations. A comprehensive discussion is provided below to evaluate the system voltage-reactive power characteristic.

Assume the Generating System as shown in Figure E.1 connected to the system via system impedance R and X.

Figure E.1: A Generating System connection to the system at POC behind system impedance



If the centre of the system is controlled at voltage $V_S \angle 0$ and the POC is controlled at $V \angle \delta$, the apparent power transferred to the system at POC can be written as:

(E.1) $S = P + jQ = \vec{V}\vec{I}^*$ and $\vec{I}^* = \frac{P-jQ}{V\angle -\delta}$

Where S, P, and Q are the apparent power, active power, and reactive power at the Connection Point injected to the system. $\vec{V} = V\angle\delta$ is the voltage vector at the Connection Point with respect to the centre of the system and $\vec{I}$ is the current vector at POC. * denotes the complex conjugates.

The voltage at the POC can be written as:

(E.2) $\vec{V} = V\angle\delta = \vec{V_S} + (R + jX)\vec{I}$

From (E.1) and (E.2), it is possible to evaluate the voltage at POC:

(E.3) $V = \sqrt{V_r^2 + V_x^2}$

(E.4) $V_r = \frac{1}{2}\left[V_S + \sqrt{V_S^2 + 4RP + 4XQ - \frac{4(XP-RQ)^2}{V_S^2}}\right]$

(E.5) $V_x = \frac{XP-RQ}{V_S}$

According to (E.4) and (E.5) the voltage at the POC or the characteristics of the system is function of reactive power injection at the POC. The other parameters in these equations are the system resistance and reactance as well as active power injection at POC as well as the voltage of the centre of the system.

The effect of above parameters is shown in Figure E.2 to Figure E.5 (below) for a 100MVA Generating System connected at 132 kV. The voltage of system centre, the X/R and active power offset the system characteristics while the SCC (system impedance) defines the slope of the V-Q characteristics of the system.

The V-Q characteristics of the system should have a positive slope for stable operation. This offset of the V-Q characteristic has a linear trend to the voltage of the system centre, circa linear toward active power generation at POC and exponential trend with respect to X/R observable from Figure E.2 to Figure E.4. The increase of system voltage and the increase in active power generation shift the V-Q characteristic to the left requiring generating facility to absorb more to maintain a certain voltage level at POC. The increase in SCC (or decrease in system driving impedance) makes the slope of the V-Q characteristic shallower (Figure E.5). This means that for a weaker system, the Generating System can vary the voltage at POC by a lesser supply or injection value of reactive power. The Generating System must work much harder to change the voltage for a stronger system. A coordination between the sensitivity of the voltage controller with the slope of the system guarantee a smooth and stable operation. The best coordination is achieved if the controller droop is in the order of the system slope at an operating condition.

Figure E.2: System V-Q characteristic at POC for various voltages of the system centre; X/R=7, P=100MW, SCC=400MVA

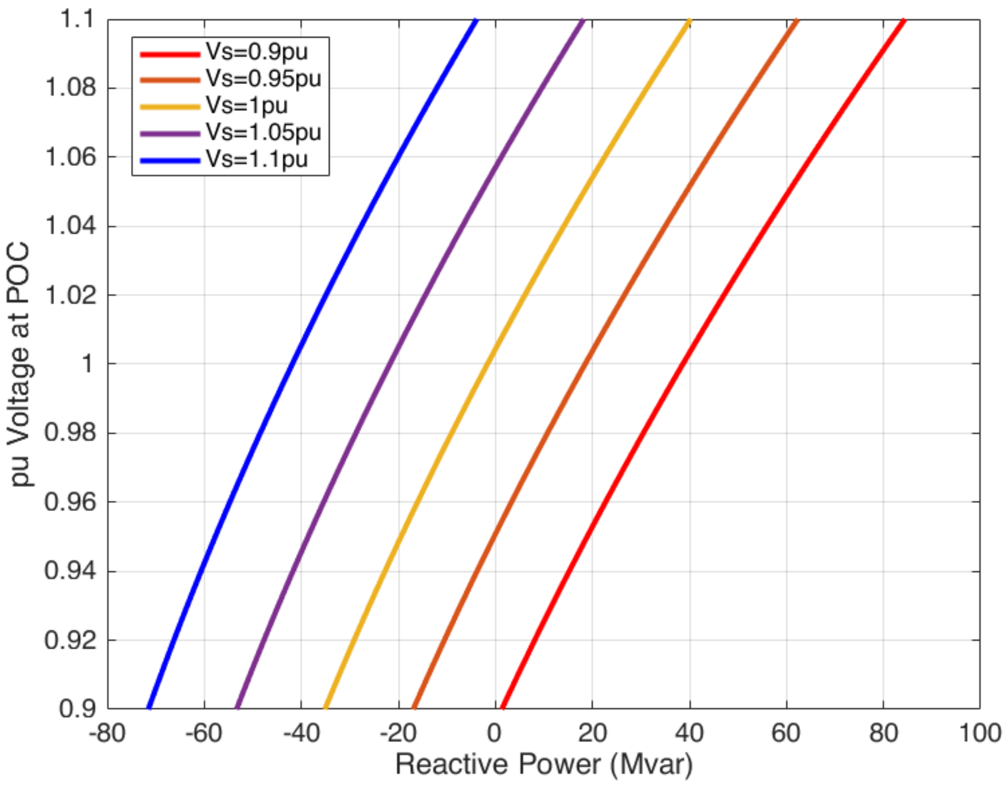


Figure E.3: System V-Q characteristic at POC for various active power; X/R=3, SCC=400MVA, Vs=1pu

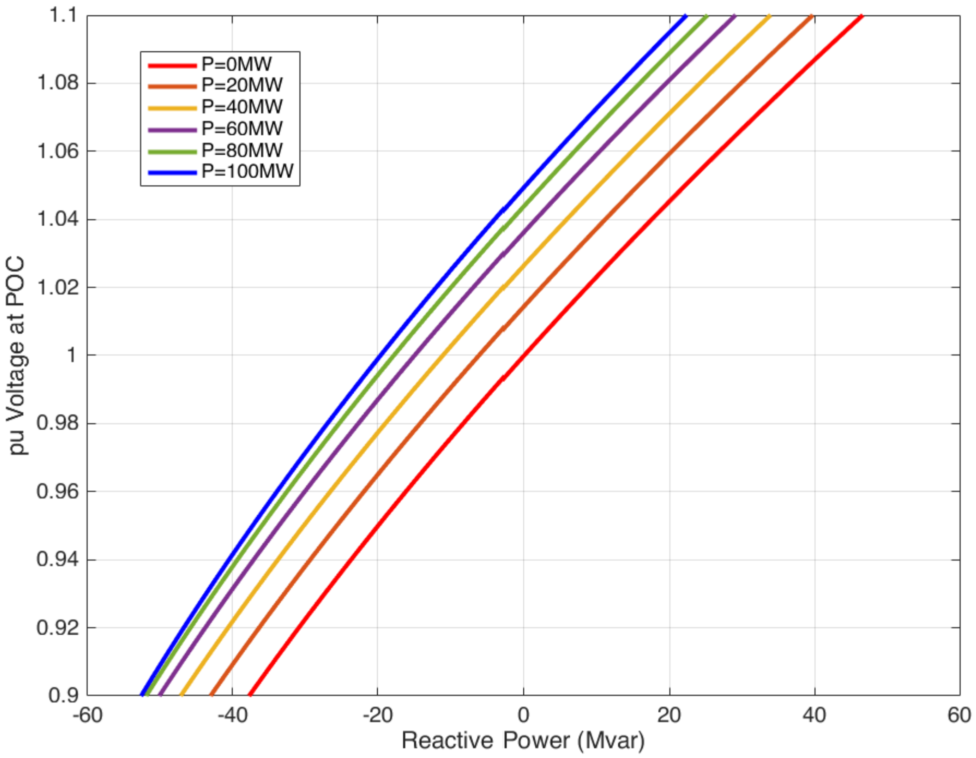


Figure E.4: System V-Q characteristic at POC for various X/R; P=100MW, SCC=400MVA, Vs=1pu

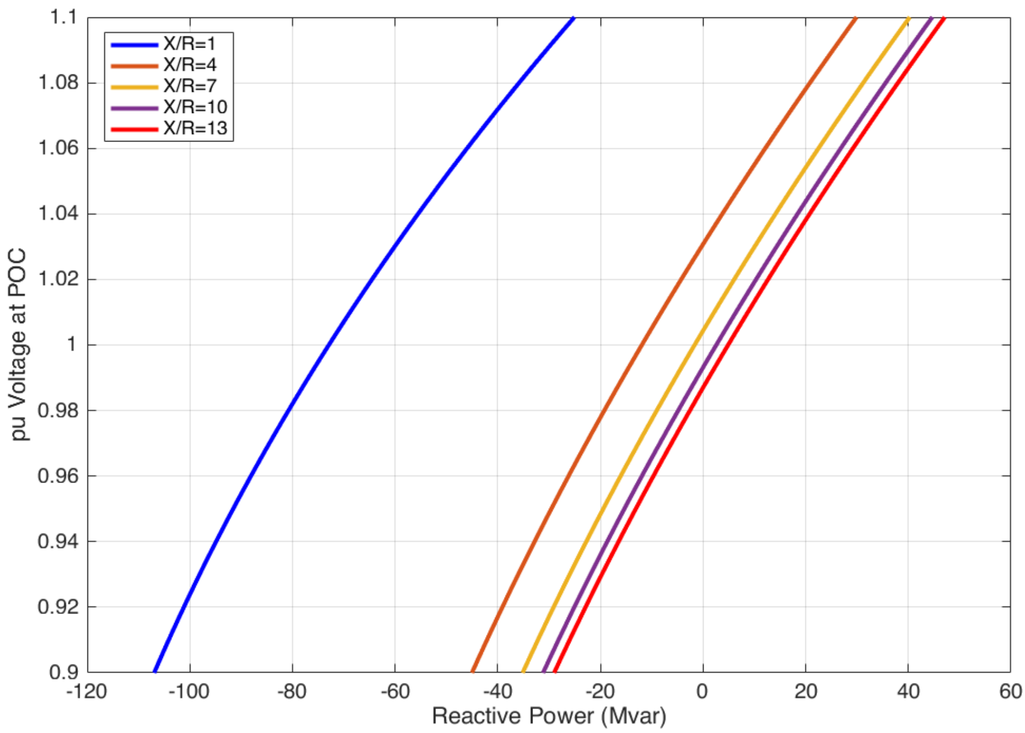
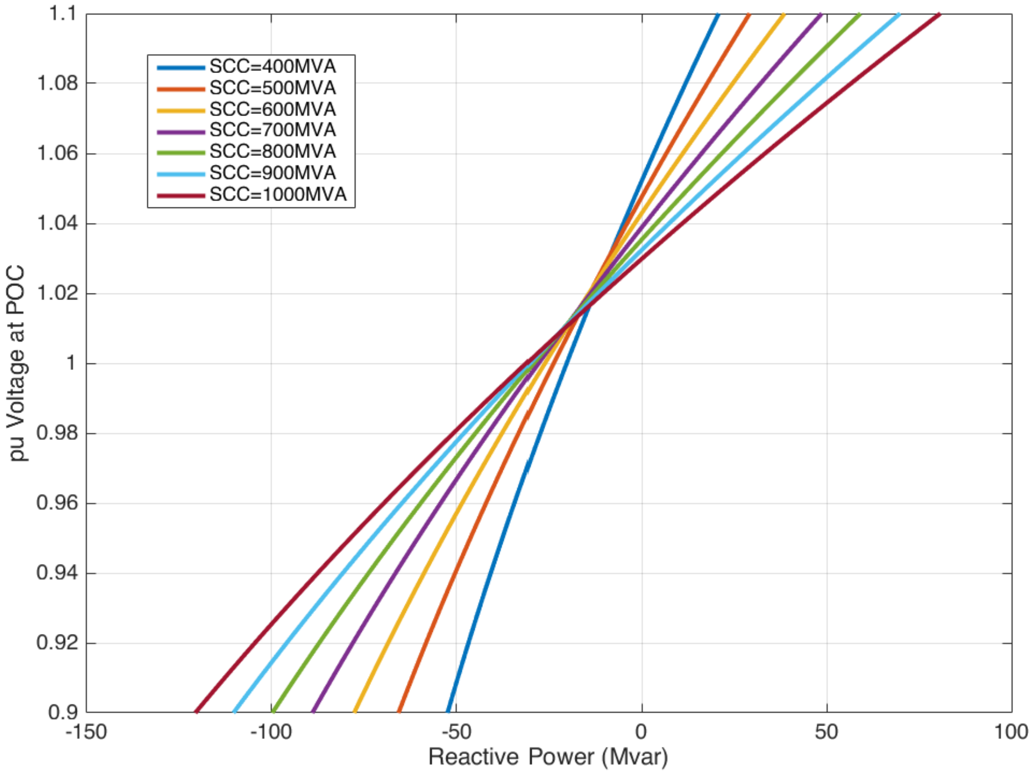


Figure E.5: System V-Q characteristic at POC for various SCC; P=100MW, X/R=3, Vs=1p



Appendix F Theory of reactive current contribution from Generating Systems

The reactive current contribution of a facility is one of the major requirements of section A12.9 of the WEM Rules. The response of Synchronous Generating System is essentially different from Asynchronous Generating System and as such the rules are different regarding their required performance. A short description of the theory of the topic is included below.

Synchronous Generating Systems

A Synchronous Generating Unit contributes to the fault current during system short circuit events depending on transient and sub-transient impedances and the characteristics of the excitation system. The transient and sub-transient periods are determined based on the flux pattern during short circuit on the terminal of a Synchronous Generating System, which creates a decaying AC short circuit current as well as a decaying DC current. These currents will flow through the generator. All modern Synchronous Generating Units are equipped with fast automatic voltage control to regulate the generator's terminal voltage. When a fault occurs, the regulator will force excitation to reach ceiling voltage and so maximises the current contribution from a generator. The reactive nature of the current is governed the impedance observed during fault which is mainly reactive during faults in transmission systems. Assuming a fixed internal voltage, Figure F.1 shows the decaying AC component of the short circuit current of a generator when a three-phase fault occurs at the terminal. Depending on the structure of the generator rotor and number of damper windings a few periods of decaying AC current will be experienced. A typical round rotor generator will experience three phases as follows.

- *Sub-transient period*: in which time the current is quite high due to the main flux pushed out to the air gap resulting in lowest reactance of the machine i.e., sub-transient reactance. This period lasts for a time equivalent to the sub-transient time constant of the machine.
- *Transient period*: in which time the current declines due to the main flux penetrating through the poles, happens at the time current in damper windings decays, manifesting higher reactance of the machine i.e., transient reactance. This period lasts for a time equivalent to the transient time constant of the machine.
- *Steady State period*: if the short circuit current stays for long enough, the flux eventually penetrates the rotor through field winding as the current in field winding decays.

Figure F.1: The decaying AC short circuit current component for faults on a synchronous generator terminal

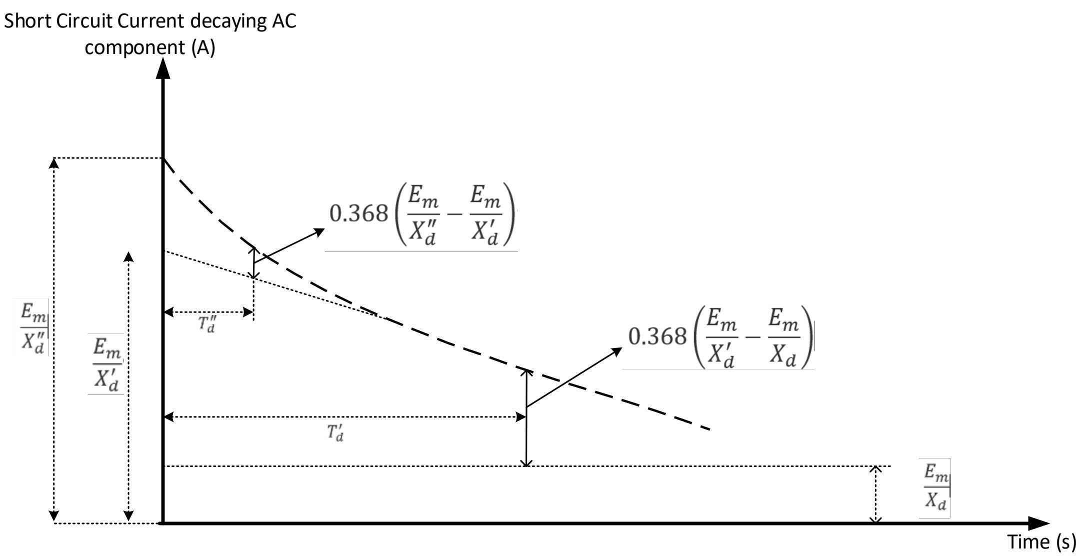
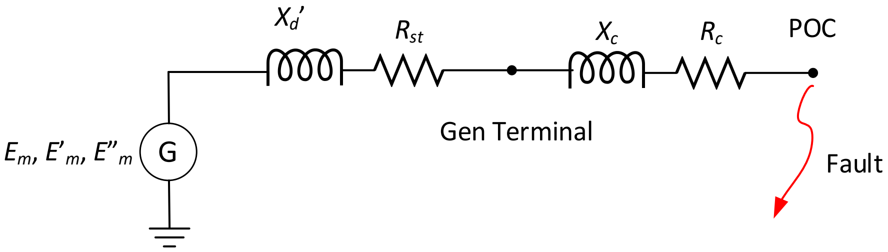


Figure F-0-2: Synchronous generator and fault at POC



For the faults at the Connection Point, the impedances between generator terminal and the fault location affects the current contribution. For each period, the short circuit contribution of such synchronous machine will be as follows:

(F.1) $I'' = \frac{E''_m}{R_{st}+R_c+j(X''_d+X_c)}$

(F.2) $I' = \frac{E'_m}{R_{st}+R_c+j(X'_d+X_c)}$

(F.3) $I = \frac{E_m}{R_{st}+R_c+j(X_d+X_c)}$

Apart from decaying AC currents from the machines, a decaying DC current will also flow. It is apparent that the current contribution from Synchronous Generating Units will vary during faults. The sub-transient period usually stays for around a cycle and the transient period can span from half a cycle to seconds depending on the type of the fault and type of machine.

During unbalance faults, a Synchronous Unit still maintains its field voltage behind impedance and as such it delivers negative and zero sequence currents to the faults. This is an important feature of Synchronous Generating Units, which enables detection of single phase to ground faults by measuring zero or negative sequence currents by protection relays installed in the system.

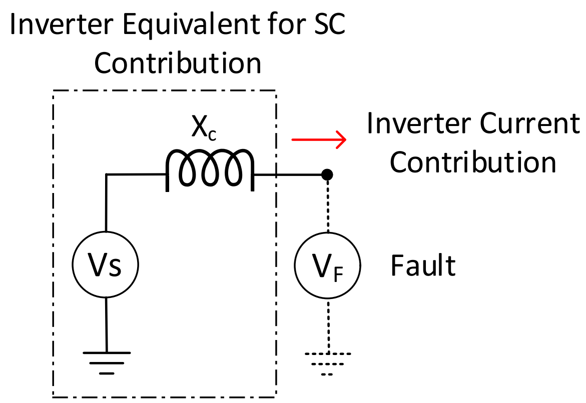
Asynchronous Generating Systems

Inverter-based resources, or induction machines do not naturally make a sustained contribution to the fault current. An induction generator contributes to first peaks of the short circuit current until flux in their rotor decays. For such facilities, legislated reactive power requirements may necessitate inclusion of other equipment such as SVC or STATCOMs, which in turn can contribute to fault currents as required.

The inverter-based resources, if not enabled with designated fault ride through controllers, will not contribute to the faults. With the ever-increasing number of inverter-connected generators, electricity legislation and standards have changed to force inclusion of specific controllers to detect the faulty state of the system, and force inverters to inject currents during faults. The fault ride through mode of the inverter controllers is designated specifically for this function. Unlike Synchronous Generating Units, for which the design of the machine dictates the fault current contributions, the level at which the Asynchronous Generating System can contribute to the fault is to be programmed.

Ideally an inverter-based resource will provide similar fault currents as a voltage source behind impedance. This is like a Synchronous Generating Unit, without the sub-transient and transient behaviour. Figure F.3 shows the equivalent circuit of a voltage behind impedance for a simple equivalent of an inverter-connected generation facility.

Figure F.3: Generator behind inverter equivalent circuit for Short Circuit (SC) contribution



In this circuit, the current contribution of the inverter can be written as:

(F.4) $I_F = \frac{V_S - V_F}{X_c} = \frac{V_S}{X_c} - \frac{V_F}{X_c}$

If the source voltage stays constant and is fixed, the delta current contribution is a function of delta residual voltage:

(F.5) $\Delta I_F = \frac{1}{X_c} \Delta V_F = k\ \Delta V_F$

Where the ΔV_F is the voltage deviation from pre-event voltages. This concept is inherently implemented in generating facilities behind inverters to shape the fault ride through requirements and has been reflected in grid codes to assess the fault contribution of inverter connected generations. It should be noted that the K factor is a parameter that could be set in an inverter controller (hereafter is shown as k_{set}), which mandates the amount of capacitive current to be injected to the system at inverter terminals when terminal voltage drops below the pre-event values. On the same concept, if the terminal voltage goes above the operating threshold, then the inverters will absorb reactive current to maintain the voltage. It should be mentioned here that a normal voltage regulator in a power plant controller appears to do the same for these facilities. However, due to rapid voltage changes of the system during fault and short duration of the faults and the slow response of the voltage regulator, the response of the facility will be poor without inclusion of the special codes for fault ride through and grid compliance. This is another reason for including the response time requirements in grid codes.

The k_{set} factor on capacitive and inductive sides component of the reactive current contribution can be set independently on the inverter controller. It should also be noted that k_{set} could be programmed in inverter in multiple ways and not necessarily as described in equation (F.5)[27].

There are some considerations in setting up the fault contribution based on K factor:

1) The voltage deviation should have a threshold to allow the normal voltage controller to regulate the voltage during normal operation. The activation and deactivation of the controller for reactive current contribution must be tuned by the Market Participant considering the Generating System parameters and location. This control mode is mostly known as low voltage ride through (LVRT)/ high voltage ride through (HVRT) mode, which are enabled if the voltage at terminal or Connection Point deviates out of a specific Dead Band (e.g., 0.9 to 1.1 p.u. or 10% of Nominal Voltage).

2) Utilities require fault current contribution to the system from the Connection Point to maintain system stability. This means that from the utility's perspective, the voltage deviation and current

[27] The relation could even be a nonlinear relation such as $I = k_{set}V^2$

injection are to be referred to the Connection Point. Generating Systems like solar farms and wind farms are distributed spatially so the inverter locations are away from the point of interconnection. Each inverter will see different voltage due to variations in collector systems. Control settings must therefore account for that voltage deviation between the inverter terminal and the Connection Point.

3) In the WEM Rules it is anticipated that the point of assessment of reactive current contribution could be specified in a location other than the Connection Point. Considering item 2), the change of the location must not be used to decrease the performance level, but to indicate the other assessment location due to technical limitations of assessing the performance at the Connection Point.

4) When inverters are injecting capacitive currents due to low voltage at the Connection Point, the voltage at inverter terminals is higher than the Connection Point due to voltage drop on the collector and transformer impedances. When absorbing reactive current, the terminal voltage tends to be smaller than the Connection Point. If the inverters are set to change the mode to fault ride through at 90%, the Connection Point voltages should decrease lower than 90% to activate the controller, and, if the controllers are set to activate at above 110% for reactive current absorption, the Connection Point's voltage should go beyond 110% to activate the FRT controller.

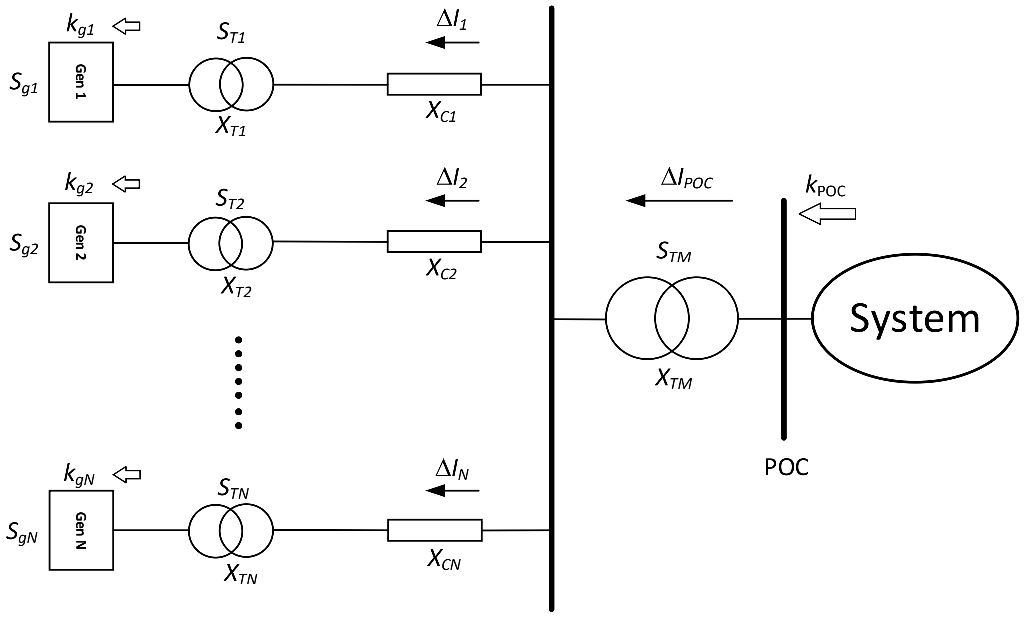
5) The K factor as shown in equation (F.5) is the inverse of impedance between source and location where current is measured. Therefore, for a Connection Point current contribution, the impedances between inverter and Connection Point comes into account. In other words, the k_{set} , as set at inverters appears as a lower K factor at Connection Point (hereafter written as k_{POC}) due to the voltage drop on internal impedances. It is then required to ensure the correct all k_{set} are set on inverters to achieve a desired k_{POC} at the Connection Point.

6) There is a limited range of k_{set}, which can be set on inverters (say between 2 and 6)[28] so, as far as Connection Point contribution concerns, the collector system and impedances should allow the desired k_{POC} to be achieved at the Connection Point while the k_{set}on inverters is varied within the capability of inverters.

A common exercise is to translate how reactive current injection at the Connection Point is related to the k_{set} factor at inverters for a typical Asynchronous Generating System. Figure F.4 shows a Generating System comprising of N generating units each connected via their own transformer to a main transformer, which couples the generating system to its Connection Point. The WEM Rules require the Generating System to have a specific fault current contribution factor of k_{POC}, and we intend to set each inverter's individual k_{set} setting to achieve this.

28 Some Inverters have broader range for k factor setting (e.g., 0 to 10)

Figure F.4: A non-synchronous generating system layout for translation of *k* factor from system to inverters



At POC:

(F.6) $\Delta I_{POC(pu)} = k_{POC}\Delta V_{POC(pu)}$

where $\Delta I_{POC(pu)}$ is the pu change of current from Generating System's Maximum Continuous Current and $\Delta V_{POC(pu)}$ is the pu change in POC voltage when system deviates beyond normal operating voltage.

From Figure F.4 , the current at the Connection Point is the summation of current of individual inverters:

(F.7) $\Delta I_{POC} = \sum_{i=1}^{N} \Delta I_i = \Delta I_{POC(pu)} \times \sum_{i=1}^{N} I_{ni}$

ΔI_{POC} is the actual current contribution of the Generating System at Connection Point and ΔI_i and I_{ni} are the current contribution and nominal current of the generating unit i respectively. Combining (F.6) and (F.7), we will have:

(F.8) $\sum_{i=1}^{N} \Delta I_i = k_{POC}\Delta V_{POC(pu)} \times \sum_{i=1}^{N} I_{ni}$

If we assume each Generating Unit contribute as much as $k_{POC}\Delta V_{POC}$ on their individual rating, then (F.8) will be achieved, so:

(F.9) $\Delta I_i = k_{POC}\Delta V_{POC(pu)} \times I_{ni}$ or $\Delta I_{i(pu)} = k_{POC}\Delta V_{POC(pu)}$

where $\Delta I_{i(pu)}$ is the pu contribution of each generating unit to the fault current based on generating unit's rating.

Now assume a voltage deviation happens at Connection Point, so this voltage variation will transfer to each individual inverter over the connected impedances and from Figure F.4 and based on generating unit i base rating (S_{gi}):

(F.10) $\Delta V_{POC(pu)} = \frac{z_{TM}S_{gi}}{S_{TM}} \sum_{j=1}^{N} \Delta I_{j(pu)} + \left(\frac{z_{Ti}S_i}{S_{Ti}} + Z_{ci}\right) \Delta I_{i(pu)} + \Delta V_i$

where Z_{TM} and S_{TM} are the main transformer pu impedance voltage and rated MVA respectively, Z_{Ti} and S_{Ti} are the Generating Unit i pu impedance voltage and rated MVA respectively, Z_{ci} is the pu impedance of the collector circuit i based on S_{gi} and ΔV_i is the voltage deviation at the terminal of inverter i.

Rewriting (F.10):

(F.11) $$\frac{\Delta V_{POC(pu)}}{\Delta I_{i(pu)}} = \frac{\frac{Z_{TM}S_{gi}}{S_{TM}}\sum_{j=1}^{N}\Delta I_{j(pu)}}{\Delta I_{i(pu)}} + \left(\frac{Z_{Ti}S_{gi}}{S_{Ti}} + Z_{ci}\right) + \frac{\Delta V_i}{\Delta I_{i(pu)}}$$

Assuming each unit contributes to the generating systems response proportional to their rating, we will have:

(F.12) $$\frac{\sum_{j=1}^{N}\Delta I_{j(pu)}}{\Delta I_{i(pu)}} = \frac{\sum_{j=1}^{N} S_{gj}}{S_{gi}}$$

And at individual unit's terminal, the k_{set} is:

(F.13) $$\Delta V_i = k_{set}\Delta I_{i(pu)}$$

Combining (F.11),(F.12) and (F.13) the generating unit's k_{gi} can be expressed as:

(F.14) $$k_{set} = \frac{1}{\frac{1}{K_{POC}} - Z_{TM}\times\frac{\sum_{j=1}^{N} S_{gj}}{S_{TM}} - Z_{Ti}\times\frac{S_{gi}}{S_{Ti}} - Z_{ci}}$$

Equation (F.14) in essence compensates for the impedances between POC and each individual Generating Unit. It is a convenient approximate of the k_{set} on each unit using the desired k_{POC}. As an example, a wind farm comprises of 10 type 4 turbines each rated 2 MVA. The unit transformers are 2 MVA each and have an impedance voltage of 8%. The main transformer is rated 20 MVA and has an impedance voltage of 12%. The WEM Rules requires a K factor of 4 for capacitive current and 6 for inductive current at Connection Point. For simplicity, ignoring the collector impedances, the desired impedance (inverse of K factor) at the Connection Point is 0.5pu, using Equation (F.14), at unit's terminals, this impedance must be less as much as 0.5pu-0.08pu-0.12pu=0.3pu. Reversing for k_{POC}, the unit's k_{set} should be set minimum at 3.33 so a k_{set} of 4 will be set.

If the collector impedances being considered, Equation (F.14) need to be applied. However, another version of (F.14) has also been used in standards for which a factor of 1.1 is applied and the collector impedances are ignored. In our example above, the 3.3*1.1=3.6 is the minimum *k* factor to be set at each unit to achieve a *k* factor of 2 at the Connection Point.

Appendix G: Droop test and system contribution to voltage control

A droop control is the standard method of choice to enable two or more controllers to share the control of a common measured variable without destabilizing or fighting each other. In most of the Generating Systems, the voltage controller operates on a droop mode which then facilitate the voltage control to be shared between the system at the Connection Point and the Generating System itself.
It is usually required to know the predicted final response of the facility when working on droop mode. It is then compared against the actual value achieved in simulation to assess the A12.4.2.5 and A12.4.3.4.
The predicted final value can be evaluated by performing a simple load flow when a voltage control with appropriate droop setting is implemented. The following load flow simulations are required prior to dynamic simulation:

- The load flow with the voltage setpoint at the value prior to the step application
- The load flow with the voltage setpoint at the value after the step application

The measured voltage at the Connection Point in the second load flow is the predicted final value which must be achieved at the end of the dynamic simulation run when a step has been applied or at site test.
For example, assume the system is setup for minimum short circuit capacity and a load flow with voltage setpoint of 1pu for the generating facility controller resulted in 1.01pu at the POC. We intend to apply a step of 5% and simulate the dynamic response. By applying 1.05pu at the voltage setpoint of the voltage controller and running a load flow, a voltage of 1.03pu is measured at the POC. The expected value after the step response in dynamic simulation is then 1.03pu and the POC voltage should move from 1.01pu to 1.03pu during dynamic simulation. If the achieved voltage at the end of the dynamic simulation is within [1.025pu to 1.035pu], the ideal performance per A12.4.2.5 is achieved.
During commissioning and compliance testing of a voltage controller working on droop, the droop value set at voltage controller must be confirmed to be achieved by test16. Several step tests to voltage controller are usually performed to evidence the droop value. During these tests, it is possible to measure the slope of the system characteristic and the voltage controller droop. Figure G.1 demonstrates the concept of voltage droop control when a facility is controlling the voltage at POC using a droop voltage control characteristic. System characteristic is shown as dashed lines in this figure. These characteristics have quadratic patterns; however, for small voltage steps within ±5%, it is safe to assume the system has a linear slope. When a system is voltage stable, capacitive reactive power supplied at the POC increases the voltage at POC and inductive reactive power decreases the voltage at POC. The system characteristics at Figure G.1 has positive slopes. This slope is mainly a function of system driving impedance. The system characteristics will move up and down if the no load system voltage, active power of facility or system X/R varies. See Appendix E for further discussion of system V-Q characteristics.

The droop voltage controllers are designed to inject more reactive current if the voltage drops at POC and shown as solid lines in Figure G.1. The slop of these lines is negative.

Assume we are operating at V_sp1 and a voltage step is applied to the voltage controller by changing the setpoint to V_sp2 The voltage at POC will move from A to B assuming the system stays at the same middle line in Figure G.1 Measuring the reactive power and voltage at A and B, we can calculate the voltage controller droop and the slope of the system characteristic by:

$$ControllerDroop = (V_A - V_sp1)/Q_A = (V_B - V_sp2)/Q_B$$

$$SystemSlope = (V_A - V_B)/(Q_A - Q_B)$$

If a change to the system has been applied rather than the step to voltage controller setpoint, for example tap changer of a transformer or nearby capacitor bank switching, then the controller droop can be verified by:

$ControllerDroop = (V_A - V_C)/(Q_A - Q_C)$

To be noted in that case is that the system characteristics has assumed to be shifted to the right line and hence point C become the operating point.

Figure G.1: Voltage droop control and system sharing voltage control at POC