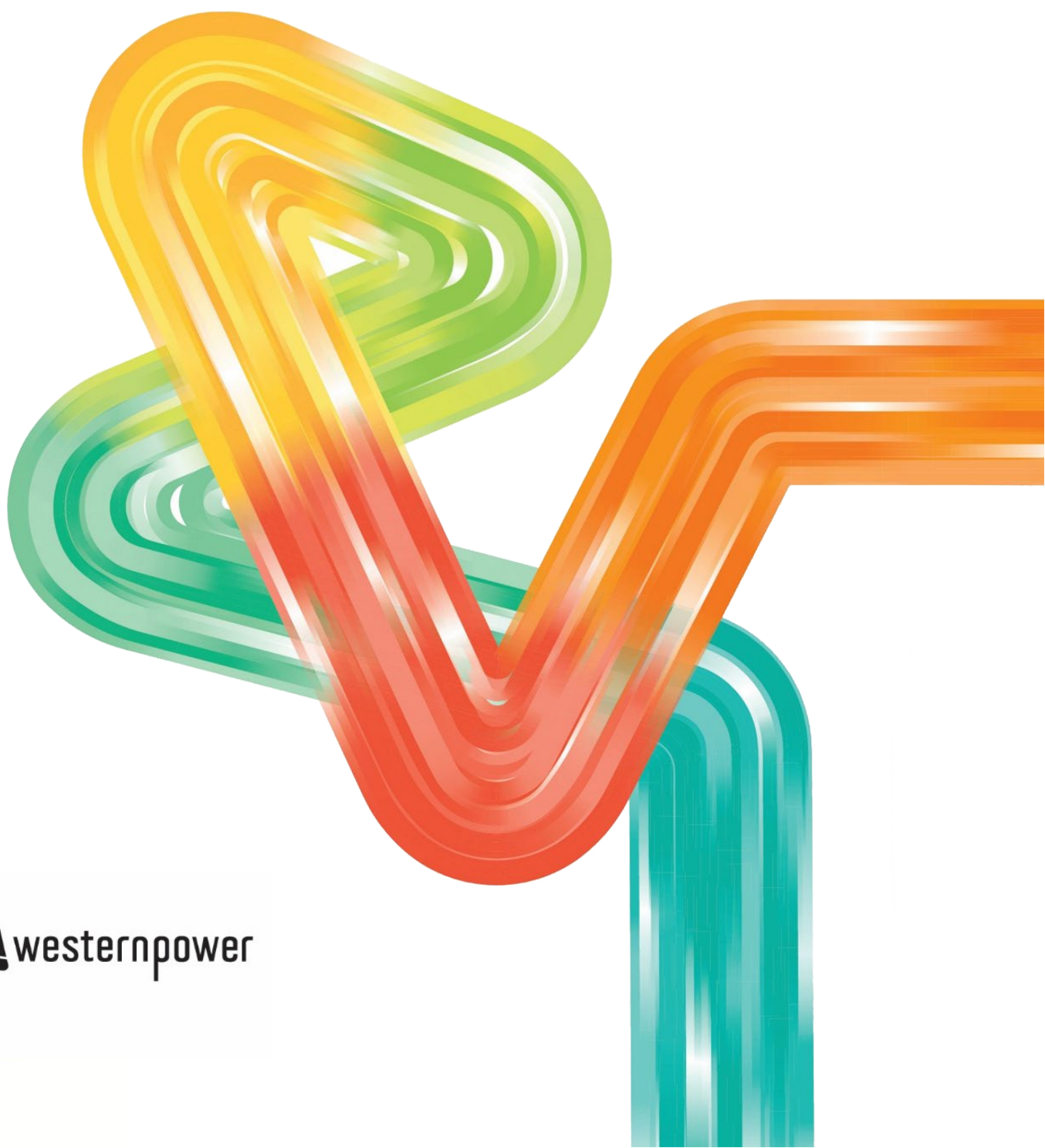


GENERATOR AND LOAD MODEL GUIDELINES

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Glossary

This table defines key terms used in this document (these are formatted in *italics*). Where an italicised term is not listed in this table, its meaning is consistent with that defined in the Technical Rules.

Access application	Refers to either a Transmission Generator Access Application form or Transmission Load Access Application form.
CMD	Contracted Maximum Demand.
Generator and Load Model Guidelines	This document.
Design report	A report describing the methodology and studies undertaken to tune model performance to meet Technical Rules/WEM Rules requirements at the nominated <i>connection point</i> to the Western Power Network.
DSOC	Declared Sent Out Capacity.
EMT	Electromagnetic transient.
Model assessment	An assessment of a User's computer model, documented in a Works Planning Report (WPR).
Model development report	A report describing the model development, usually with reference to control system block diagrams and/or models in other software packages.
R2 data, model validation and performance report	A report providing details of the tests conducted, assessed performance, model validation results, and registered (R2) data including final models and control system settings.
SWIS	South West Interconnected System.
Technical data assessment	An assessment of Users <i>access application</i> , documented in a WPR.
User	The Technical Rules clause 1.3(b)(3) defines a User as follows: "Users of the transmission or distribution system who, for the purposes of these Rules include: A. every person who seeks access to <i>spare capacity</i> or <i>new capacity</i> on the <i>transmission or distribution system</i> or makes an <i>access application</i> under the <i>Access Code</i> in order to establish a connection point or modify an existing <i>connection</i> ; B. every person to whom access to <i>transmission</i> and <i>distribution</i> capacity is made available (including every person with whom the <i>Network Service Provider</i> has entered into an <i>access contract</i> or <i>connection agreement</i>)."
User manual	A document describing the setup and operation of a computer model.
WPN	Western Power Network

WPR	Works Planning Report: a consolidated report documenting the outcome of studies undertaken at various stages of the connection process, including a computer model assessment.
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1. Introduction

1.1 Purpose and scope

The *Generator and Load Model Guidelines* clarifies Western Power's approach to developing and maintaining accurate computer models, and clarifies *Users'* requirements for provision of computer models and associated information for new connections¹ or modifications² to existing *facilities*. In particular, the objectives of the *Generator and Load Model Guidelines* are to:

1. Describe *Users* requirements for provision of computer models for *facilities* connected or proposed to connect to the Western Power Network, including:
 1. Model functional requirements.
 2. Model acceptance test and model performance requirements.
 3. Model documentation and *user manual* requirements.
 4. Model validation, registered data and model accuracy requirements.
2. Provide details of Western Power's methodology for assessing compliance with the above requirements to assist *Users* with providing the required models and associated model information.

Technical Rules clause 1.8.2 and WEM Rules 12.17.2 requires that Western Power ensure that computer modelling data used for planning, design and operational purposes is complete and accurate. This is fundamental to the safe and reliable operation of the power system within its' technical envelope.

This document does not discuss other requirements for data to be submitted to Western Power as part of an *access application* or request by a *User* to modify its existing equipment. Its focus is on the computer model representation of the customer *facility* and the data, parameters, diagrams and schematics required to substantiate that computer model.

1.2 Application of the Generator and Load Model Guidelines

The *Generator and Load Model Guidelines* apply to all *generating systems*³ (including *inverter* and *converter coupled generating units*), dynamic reactive control devices and *loads*, and to both new connections and modifications to existing *facilities* (including settings and configuration changes).

The Technical Rules clauses below should be reviewed to assist with understanding the need for computer modelling information and the obligations of Western Power and *Users* for provision and maintenance of accurate computer models.

¹ For an overview of the connection process and data requirements for new connections, see Overview of connection process and data requirements.

² Modifications may include upgrades, settings changes and configuration changes.

³ A *generating system* comprises one or more *generating units*.

Generating systems

A computer model is generally required for all *generating systems* whose rating exceeds 10 MW.

- 3.2.4 Power System Simulation Studies
- 3.3.2 Provision of Information
- 3.3.3 Detailed Technical Requirements Requiring Ongoing Verification
- 3.3.9 Computer Model
- 4.1.3 Tests to Demonstrate Compliance with Connection Requirements for Generators
- 4.1.7 Power System Tests

Small generating units

For *generating units* in a small power station of aggregate between 5 and 10 MW, Western Power will assess the need for computer models to perform dynamic simulation studies. If deemed to be required, the same model requirements as for large *generating systems* may apply.

- 3.6.3 Information to be provided by the Generator

Loads

For *load* connections Western Power will assess the *load* characteristics (including *load* size, motor composition, harmonic emissions etc.), *connection point*, and capability of the local *transmission* or *distribution system* in the vicinity of the *connection point* to determine the extent of modelling information required. Western Power may also request a computer model, although typically this would only be required for large *load* connections or those connections in weaker parts of the Western Power Network.

- 2.3.7.2 Short Term Voltage Stability
- 3.4.2 Overview
- 3.4.5 Provision of Information

1.3 Confidentiality

Information provided to Western Power may be released to third parties in accordance with Technical Rules clause 3.2.4(b).

"The *Network Service Provider* may provide any information it so receives to any *User* who intends to connect any *equipment* to the *transmission system* for the purposes of enabling that *User* to undertake any *power system* simulation studies it wishes to undertake, subject to that *User* entering into a confidentiality agreement with the *Network Service Provider*, to apply for the benefit of the *Network Service Provider* and any *User* whose information is so provided, in such form as the *Network Service Provider* may require."

2. Model requirements

As part of a new or amended *access application* Western Power requires certain data and documentation to be provided with a computer model. This section provides details of Western Power and Technical Rules/WEM Rules requirements for provision of this information. For existing *Users* seeking to modify their *equipment* where an *access application* is not required, these guidelines for model provision still apply.

When developing a computer model there are general requirements that apply to all models, irrespective of the type of *facility*, as well as specific requirements that are applicable depending on whether the *facility* is a *generating system*, *load* or other type of equipment, such as a dynamic reactive device (STATCOM, SVC, etc.).

2.1 Software

Computer models must be in native unencrypted DigSILENT PowerFactory format suitable for use in the version of PowerFactory currently used by Western Power⁴ and suitable for integration with the Western Power model of the South West Interconnected System ("SWIS").

EMT models provided to Western Power must be compatible with PSCAD™/EMTDC™ version 4.6.3 and Intel Parallel Studio XE Composer Edition for Fortran 2015. Models must not be dependent on a specific Intel Visual FORTRAN version to run. EMT models compiled in or requiring Intel Fortran Composer or Compaq Visual FORTRAN to run will not be accepted.

EMT models should not have dependencies on additional external commercial software, however dependencies on free, commonly available redistributable libraries may be acceptable.

2.2 General requirements

The following general model requirements apply:

1. The model and its associated data and parameters must be consistent with the information provided as part of an *access application*, or otherwise the *Users* request for modification to an existing *facility*. This should include, but is not limited to:
 - Consistency with Single Line Diagram (SLD) layouts and other schematics provided to Western Power.
 - Consistency with relevant network data provided including all network impedances and ratings, voltage levels, transformer specifics (location, rating, vector groups, winding configuration, tap changer specifics etc), auxiliary loads and reactive devices etc.

⁴ Contact Western Power to confirm the version of DigSILENT PowerFactory currently in use.

- Consistency with generating system or load specifics provided such as maximum capability and loading, active and reactive power ranges, generator reactance's etc. Loads, including generator auxiliary loads, must be modelled such that the load power factor is representative of the facilities actual performance under typical operating conditions.
- 2. In general, overhead *transmission* lines should be modelled using geometric tower models and conductor data.
- 3. The model must be suitable for balanced and unbalanced power flow studies, and for calculation of balanced and unbalanced short-circuit currents using 'Complete' and 'IEC' methods.

2.3 EMT model specific requirements

The following are EMT model specific requirements:

1. The model must have a bandwidth of at least DC to 10 kHz and settle to the correct final value for the applicable power system conditions and applied Disturbance(s);
2. EMT models provided to Western Power must be compatible with PSCAD™/ EMTDC™ version 4.6.3 and Intel Parallel Studio XE Composer Edition for Fortran 2015
3. The model should run accurately for the timestep of 50 microsec or above.
4. The model must include detailed representation of all control loops of the plant (inner and outer control loops); i.e. un-encrypted model is required
5. Full representation of switching algorithms of power electronic converters for power system studies is not required
6. The model must be based on plant design data and rigorously tested against factory acceptance tests for the corresponding version of plant;
7. The model must represent all electrical and control features pertinent to the type of study being done;
8. The model must have all relevant protection systems modelled which are required for EMT studies;
9. The model must be configured to match expected site-specific equipment settings;
10. The model must allow plant capacity to be scaled;
11. The transient stability EMT-type models must operate with a time-step greater than or equal to 50 microsecond;
12. The model must be capable of self-initialisation, with initialisation to user defined terminal conditions within three seconds of simulation time;

13. The model must warn the user by way of a message to the progress output device when the system conditions are beyond plant operational limits or otherwise not consistent with valid operating conditions for the plant; and
14. The applicant must clearly identify the manufacturer's EMT model release version and the applicable corresponding hardware firmware version.
15. The EMT model provided must account for the most restrictive electrical, mechanical, or thermal protection of the plant with respect to multiple voltage disturbances in quick succession and calculate dynamically and accumulatively the impact of multiple voltage Disturbances.
16. The EMT model must have the following components modelled as accurately as possible:
 - Source and system side converters including switches, diodes, filters, smoothing reactors and linking capacitors.
 - Source side machines and PV arrays limited to transients being observed at the DC link and/or the system.
 - Source side and system side converters controller circuits including the PWM circuits, input filters, RMS and/or component extractions, all control loops including dynamic/static limiters and dead bands.

2.4 Static load and motor model requirements

Pursuant to Technical Rules clause 3.4.5, the following requirements apply for static load and motor models. These requirements are intended as a guide and should be agreed with Western Power prior to model preparation.

Model configuration requirements

- For loads where a model is assessed as being required, in general, all motors with a rating of 1 MW or more should be modelled explicitly. Smaller motors may be lumped into equivalents, however should be clearly identified in the supporting documentation and the PowerFactory model. The model may be required in both a detailed representation and to be aggregated to an equivalent model for integration with Western Power's model of the South West Interconnected System ("SWIS").
- Where various loads are represented as a single lumped (static) load, they must be modelled with complex load parameters based on the constituent loads (VSD's, induction machines and other loads), and with suitable voltage dependent parameters.
- Simplification of load model representation should be consistent with the requirements of AS 3851 and good electricity industry practice to ensure that equipment fault level contributions are appropriately represented.

Steady-state model requirements

- Explicitly modelled motors with a rating of 1 MW or more must have starting method parameters defined in the model (e.g. direct online, soft-starter).

Other model requirements

- Explicitly modelled motors with a rating of 5 MW or more must have harmonic current emissions modelled.
- Explicitly modelled motors with a rating of 5 MW or more must have mechanical characteristics of the drive load (torque-speed characteristic) and total mechanical inertia parameters modelled.
- Load shedding facilities, including under- and over-voltage and under- and over-frequency relays should be described and modelled.
- Any other special protection schemes or requirements should be described.
- Western Power will determine the need for an EMT model to assess the impact of the load, generating unit or generating system on other Users.

2.5 Dynamic model requirements

2.5.1 General dynamic model requirements

The following requirements apply to dynamic controller models, including farm/point of connection controllers, dynamic reactive control devices, generator control systems and inverter control systems, etc.

Model representation

- The functional blocks in the model must be represented using standard Laplace block diagram format to the extent practicable.⁵ Use of any "black boxes" encrypted code or external DLLs is not acceptable.
- Use of DlgSILENT Simulation Language (DSL) expressions to represent functions that could otherwise be represented by standard PowerFactory library macro block definitions should be avoided to the extent practicable.
- Inclusion of multiple (unique) equipment control functions within a single macro block definition should be avoided.
- The number of lines of code within a single macro block definition - excluding parameter definitions, initial conditions and comments – should generally not exceed 30. The intent of this requirement, in conjunction with item 3 above, is to provide guidance to the model developer and to improve macro code readability and model usability (it is not intended to result in increased complexity of macro equations or detract from macro code readability).

Initialisation

- When the dynamic model is opened and executed with the PowerFactory software version used by Western Power,⁶ it must automatically initialise its

⁵ See IEE421.5 for illustrations of computer model representation in functional block diagram format.

⁶ Contact Western Power to confirm the version of DlgSILENT PowerFactory currently in use.

parameters from load flow simulations without warnings or errors, must not result in initialisation or run time warnings or errors, and there must not be any interactions or conflicts with other models.

- Dynamic model initialisation must be invariant to simulation start time (i.e. not require the simulation to be initialised at a particular time).
- Where parameters need not be recalculated at each time step, the DSL commands `selfix()`, `limfix()` and `outfix()` must be used instead of `select()`, `limits()` and `output()` so that they are only calculated at initialisation.

Model configuration requirements

- The control mode and droop settings must be configured according to the usual operation, and configured for both steady-state and dynamic simulations.
- The model must include all functional controllers and ancillary *equipment* that materially affect the performance of the *equipment* over the typical timeframes of a dynamic simulation (up to several minutes), and accurately represent the performance for all possible conditions where the *equipment* would be in operation.
- In PowerFactory, each controller is linked to a "slot". To enable the complete dynamic model to be removed from service without the need to remove each of the controllers from service, the "Main Slot" checkbox should be selected for the slot which relates to the generator element (e.g. the synchronous machine).
- The dynamic model must resemble the physical design of the *equipment* and controllers to allow Western Power to assess the suitability of proposed settings.
- The dynamic model must support both balanced and unbalanced time domain simulations and the response of each of the phases must be observable.
- Where the equipment has the capability to respond per phase, a full three-phase model must be provided.
- Dynamic model parameters should have parameter names, descriptions and units defined in the DIgSILENT Simulation Language (DSL) models, for example "Kp Proportional gain [pu]".
- The PowerFactory DSL model must compile to C code without warnings or errors.

Performance

- The dynamic model must adequately represent the performance of the *equipment* over its load range and over the system voltage and frequency operating range described in Section 2.2 of the Technical Rules.
- The model may include non-convergence warnings for some simulation events, however this may indicate issues with the dynamic model, have an adverse impact on simulation performance and/or cause the simulation to collapse. Care should be taken and unnecessary warnings avoided when developing the model.
- The model must be numerically stable for all possible ranges of system strength (short-circuit ratio and X/R ratio) where it would be in operation.

- The model should include relevant protection relays and settings to simulate the performance of the *facility* during power system disturbances. This includes, but is not limited to, under and overvoltage protection, under and over-frequency protection, etc.
- For protection events (e.g. Wind Farm controller operation) the simulation events, including initial detection, operation, and time-out, should be reported to the PowerFactory output window during the simulation.

Integration time step

- The dynamic model must support time domain simulations with a minimum integration step size of 0.002 s.
- The model must not include algorithms that require use of a particular integration step size (for example the model should not fail to solve, or the response be materially different for an integration step size of 0.001 s).
- Time constants below 5 ms should only be included if their inclusion is critical to the performance of the dynamic model and are required to meet the accuracy requirements (see Section 3).
- Internal integration algorithms should only be included if their inclusion is critical to meeting the accuracy requirements, and should not materially detract from model simulation speed performance.

2.5.2 Generating system model requirements

Pursuant to Technical Rules clauses 3.2.4 and 12.17.2, the following requirements apply.

Model configuration requirements

- The generator active and reactive power ranges must be defined in the model according to the generator capability, consistent with the requirements of Technical Rules and WEM Rule Clauses
- For a synchronous generator, the following control system models would typically be included⁷:
 - Synchronous machine modelled with exact parameters.⁸
 - Excitation system, load drop compensation and exciter.
 - Turbine-governor including speed droop and power control loops, turbine, boiler dynamics, temperature and power control/limiting functions, and other relevant control mode and protection functions.
 - Power system stabiliser (PSS) including synthesised speed.
 - Under-excitation limiter (UEL).
 - Over-excitation limiter (OEL).

⁷ Controller models such as AVR, PSS, OEL and UEL for synchronous generators should be modelled as unique DSL models and not combined into a single DSL model unless agreed with Western Power.

⁸ PowerFactory uses 'Exact' parameters as opposed to other software, which may use 'Classical' parameters (for further details, refer to P. Kundur 'Power System Stability and Control').

- Other limiters, such as stator current limiter, volts per hertz limiter, over-fluxing limiter.
- Power station controller.
- Other control and protection systems, including loss of excitation protection and pole-slip protection relays.
- For a non-synchronous generator, the following control systems would typically be included:
 - Generator model(s).
 - Reticulation network including other relevant equipment such as static or dynamic reactive equipment, and harmonic filters.
 - Farm-level control system with measurement points/control points (including Phase Locked Loops) appropriately configured.
 - Other control and protection systems.

Other model requirements

- For synchronous generators, there is no specific requirement for the provision of distinct models for sub-synchronous resonance studies. Sub-synchronous resonance studies will be based on transient stability models and the mechanical shaft model which is provided with the user manual and access application.
- For non-synchronous generators, harmonic current and flicker emissions must be included in the model.
- Western Power will determine the need for protection relay models.

2.6 Small signal model requirements

The model must be capable of being executed in eigenvalue studies using both the QR method and Arnoldi method without modification.⁹

2.7 Aggregation

For some detailed *load* models and for *generating systems* comprising a large number of *generating units*, there may be a requirement for the model to be aggregated.¹⁰ The methodology¹¹ for aggregating *generating units*, *loads*, other *generating equipment* and the reticulation system and studies demonstrating the equivalence between the detailed and aggregated models must be provided. As a minimum this must illustrate the alignment of time-domain simulation overlays for voltage, active power and reactive power for the nearest and farthest generating unit and the aggregated generating unit, for:

⁹ Damping performance is assessed against the requirements of Technical Rules clause 2.2.8.

¹⁰ Contact Western Power to discuss the requirement for model aggregation.

¹¹ For reference, see Kostrov et. al., Method of Equivalencing for a Large Wind Power Plant with Multiple Turbine Representation, NREL, 2009.

- Zero impedance balanced three-phase to earth and zero impedance two-phase to earth faults at the connection point.
- Voltage, reactive power, power factor and active power step response.

For *generating systems*, the aggregation should not prevent access to generator terminal quantities.

3. Model documentation requirements

This section describes the requirements for model block diagrams and *user manual* documentation.

3.1 Block diagrams

The following requirements apply to model block diagrams.

- The model block diagrams must illustrate all input and output signals including set-point signals on the model block diagrams and model frames, and clearly illustrate the interconnection of the various functional controllers.
- The model block diagrams must illustrate all derivative states including derivative state variable names consistent with the block diagrams.
- All required control and output signals should be available for dynamic (RMS) simulations and clearly illustrated on the model block diagrams. These signals would typically include, but are not limited to the following:
 - Active and reactive power.
 - Machine and exciter current and voltage.
 - Applicable set-points, including:
 - Active power set-point.
 - Frequency and/or speed reference set-point.
 - Voltage set-point.
 - Reactive power and/or power factor set-point.
 - Where applicable, park controller, capacitor bank and SVC set-points, etc.
 - Other signals depending on the technology type.
- The model block diagrams must clearly illustrate whether limits are windup or non-windup,¹² and provide details as to which state variable is limited and the relationship between the limit value and state variable that is being affected by that limit. For example, for a lead-lag function, whether the state variable or the feedback to the 'integrator' within the equivalent lead-lag representation is limited.¹³
- The model block diagram documentation must include descriptions of any arithmetic or mathematical functions, such as protection events (e.g. Wind Farm crow bar controller operation) or voltage ride-through sequences.
- The model block diagrams must show all relevant non-linearities, such as limits, arithmetic or mathematical functions, events, dead bands and saturation.
- The model block diagrams and documentation must show all controller settings and settings ranges. Non-configurable settings should be identified on the block diagrams.

¹² See Benedito et. al., A Circuit Approach for the Computer Modelling of Control Transfer Functions, PSCC, 2002.

¹³ See Kundur, Power System Stability and Control, EPRI, 1994, page 360.

- The model block diagram documentation must identify any internal integration algorithms.
- The model block diagrams must identify the lookup table interpolation method (e.g. spline, linear).
- Settings shown on the model block diagrams must align with the computer model.
- Where a controller uses input measurements or control outputs, these must be appropriately configured and identified on the functional block diagrams.

3.2 User manual

A *user manual* should be submitted to Western Power with the computer model. The *user manual* must contain sufficient information to enable Western Power to use the computer model to carry out power system studies for planning, design and operational purposes in accordance with clause 1.8.2 (b)(5) of the Technical Rules. The *user manual* should not contain confidential information that cannot be released to third parties under Technical Rules clause 3.2.4 (b).

Information to be provided in the *user manual*, must include, but is not limited to the following:

- A description of the model components and parameters, and data category of each parameter (refer to Schedules of Technical Details in the Western Power Technical Rules¹⁴ - Section A3.5 for a description of data categories).
- Information about how the model parameter values vary with the operating state or output level of the equipment or with the operating state or output level of any associated equipment (e.g. excitation system automatic and manual control, configuration of voltage and power factor control modes).
- Protection system settings and algorithms relevant to load flow or dynamic simulation studies (e.g. under- and over-voltage or frequency protection settings).
- Any special control or protection schemes that are relevant to load flow or dynamic simulation studies (e.g. runback schemes, low voltage ride-through schemes, active power reduction schemes).
- Information provided in accordance with Technical Rules clause 3.3.2 only to the extent that the information is not a part of the model or the model parameters and that it is reasonably necessary to allow modelling of the generating unit, generating system, load or related equipment in power system studies.
- Connection point details including single line diagrams, its parameters and values, location, associated network augmentations or modifications (if applicable) and other relevant connection information, sufficient to identify where to connect the equipment in the Western Power power system model.

¹⁴ Technical Rules 2011:
http://www.westernpower.com.au/documents/WE_n6800863_v9E_TECHNICAL_RULES_OF_23_DECEMBER_2011.pdf

- How the model is to be set up for power system analysis including, but not limited to:
- Expected operational practice.
- Specific software simulation setup such as integration algorithm, EMT or RMS simulation options, etc.
- Special setup for any associated auxiliary equipment or reactive compensation equipment.
- Details of modifications required to "scale-up" an aggregated generating system model and/or complex load model.
- Special setup required to enable, disable and configure protection functions.
- For a *generating system*, *generating unit* or *load* incorporating any power electronic devices, a description of how that device should be included in the short-circuit fault calculation.
- Any other information the *User* considers relevant to the performance of the *equipment* for the model's intended use or to achieve the relevant accuracy requirements.

3.3 Other documentation

As applicable, other documentation should be provided such as:

- Equipment data sheets associated with the computer model.
- If available, a report describing how the model was developed (*model development report*).
- Protection settings and model tuning report (*design report*).
- For inverter connected generators, fault ride-through performance and model validation report.
- Other relevant documentation, such as model validation reports or type test reports.
- For synchronous generators, the max stator current limiter, OEL (max field current limiter), UELs (min field current limiter, p-Q limiter), V/Hz) and PSS circuit in AVR) with their settings and type of the limiter shall be included.
- For synchronous generator type test data including generator impedances, time constants and characteristics curves (Open circuit/short circuit, PQ and V-curve characteristics should also be provided).

4. Model accuracy requirements

4.1 Steady-state model accuracy requirements

The steady-state computer model accuracy requirements apply to both *loads* and *generating systems*, including dynamic reactive plant. The general requirements are as follows:

- The difference between the actual and simulated response of any measured quantity must not exceed 10%.
- The model must accurately represent the performance of the *load, generating unit or generating system* at its terminals (or *connection point* for aggregated model) and not show any characteristics not present in the actual *equipment* response.

4.2 Dynamic model accuracy requirements

The dynamic model accuracy requirements apply performance measures to assess the alignment between simulated and measured responses of *generators* and dynamic reactive *equipment* (e.g. SVC, STATCOM, synchronous condenser). At present, Western Power has adopted accuracy requirements consistent with those specified by the Australian Energy Market Operator in their Generating System Model Guidelines.¹⁵ These requirements are reproduced below:¹⁶

- For any control system models, the overall linear response over a frequency bandwidth of at least 0.1-5Hz must be within the following tolerances:
 - a) magnitude must be within 10% of the actual control system magnitude at any particular frequency; and
 - b) phase must be within 5 degrees of the actual control system phase at any particular frequency.
- For time domain responses that include non-linear responses or performance, as well as responses to switching or controlled sequence events (e.g. operation of fault ride-through schemes and converter mode changes), the key features of the response are within the following tolerances:
 - c) rapid slopes in the simulated response, compared with the actual *equipment* response must be within the less restrictive of:
 - 10% of the change; and
 - from the start to finish of the slope, 20 milliseconds.
 - d) for rapid events caused by control sequences (such as some fault ride-through control schemes) or switching events, the sizes of peaks and troughs (measured over the total change for that peak or trough) must be within 10% of the change;

¹⁵ AEMO, Generating System Model Guidelines, 2008.

¹⁶ This is a quotation and so words or phrases shown in italics may not necessarily be defined in the Technical Rules nor attributed the same meaning as the given in the Technical Rules.

- e) oscillations in *active power*, *reactive power* and *voltage* in the frequency range 0.1 to 5Hz must have damping¹⁷ and frequency of the oscillation within 10% of the actual response of the *equipment*. The phase of the oscillations (relative to the other quantities - e.g. *active power* versus *reactive power*) must be within 5 degrees in terms of the dominant oscillatory mode. This does not apply to rapid events under item (b), but does apply to any subsequent oscillations;
- f) the timing of the occurrence of the rapid slopes, events or the commencement of oscillation described in paragraphs (a) - (c) must be consistent with the *equipment* characteristic that initiates the response.¹⁸
- the deviation of the equipment model response from the actual equipment response for active power and reactive power must not exceed 10% of the total change in that quantity. During periods of oscillatory behaviour, this criterion applies to:
 - a) the first cycle of the oscillatory response after the transient period (i.e. if associated with a fault, then after clearance of the fault and the transient recovery from the fault); and
 - b) after the first cycle of the oscillatory response, to the upper and lower bounds of the envelope of the oscillatory response.
- the final active power or reactive power value at which the model settles is within the more restrictive of:
 - a) the final value at which the actual equipment response would settle $\pm 2\%$ of the equipment's nameplate rating; or
 - b) the final value at which the actual equipment response would settle $\pm 10\%$ of the total change in the final value of the quantity

Where measurement results can be shown to have been affected by changes in supply source (e.g. the wind strength for a wind turbine), this shall be taken into consideration when assessing this criterion, so long as sufficient evidence can be shown to demonstrate the cause of the input power change.

- the model response must not show characteristics that are not present in the actual equipment response.

¹⁷ Measured as a rate of decay of the oscillation (e.g. halving time).

¹⁸ Switching events or rapid control actions initiated as a result of passing a threshold level in a measured quantity and any time delays in the design of the equipment should be straightforward to assess. The recommended fallback criteria for this requirement are:

- a) the response must be explainable; and
- b) any inconsistency in the response should lead to an investigation to establish a plausible reason for the inconsistency. A revision to the model should be considered in the latter circumstance.

Assessment of compliance with these requirements can be conducted by a combination of visual inspection of results, results plots including accuracy tolerances, and mathematical calculations. Particularly for cases where the modelled response deviates from the simulated response there is a need to demonstrate the extent of that deviation and the impact on plant performance. For reference, see Appendix B for example illustrations of the above accuracy requirements. Note that for convenience it is acceptable to apply accuracy tolerance bands to the simulated response rather than the measured response.

5. Model assessment

5.1 Model assessment

Western Power undertakes a due diligence assessment (*model assessment*) of the computer model to assess its performance against the requirements of the Technical Rules.

As part of the *model assessment* Western Power will identify to what extent the computer model meets the relevant criteria defined in the *Generator and Load Model Guidelines*. Some aspects of Western Power's due diligence assessment can be performed using an infinite bus model with no knowledge of the *facilities* actual *connection point* to the Western Power Network. This can only provide an initial assessment of the impact of the *facility* on power system performance and other *Users*.

In order to perform a thorough investigation of the suitability of a computer model more detailed power system steady state, dynamic and small signal studies must be performed. These studies have due consideration to where the *facility* is connected to the Western Power Network so that the impact of the *facility* on the surrounding network, as well as the interaction between *Users facilities*, can be assessed.

Table 1 provides a summary of the Technical Rules/WEM Rule clauses which are typically investigated by Western Power during a *model assessment*. Generally, the model adequacy can be assessed against Technical Rules chapter 3 clauses and WEM Rule Appendix 12 clauses using an infinite bus model. Chapter 2 clauses typically need to be investigated as part of detailed power system studies involving the simulation of faults in the network. Importantly, if these studies identify the *facility* is not meeting the requirements in the Technical Rules then the issue may not be a shortcoming of the computer model itself. In some cases Technical Rule/WEM Rule compliance requires network augmentation and/or additional equipment installed within the *facility* to be compliant.

Before commencing a *model assessment* the proponent should either:

1. Seek details of the characteristics of Western Power Network at the nominated *connection point* and tune the model to best meet the performance requirements of the Technical Rules/WEM Rules. The report prepared to document the tuning methodology and results is generally referred to as a *design report* (see section 5.2). Western Power can provide a model of the South West Interconnected System ("SWIS") and other technical information to support the *Users* tuning of the model upon request. Western Power will thence conduct an independent *model assessment*.
2. Engage Western Power to undertake a *model assessment*. Should the *model assessment* identify the need for retuning or augmentation (such as additional voltage control devices) the proponent should address the deficiencies, after which time Western Power will repeat or update the *model assessment*.

Table 1: Technical Rules/WEM Rules Appendix 12 clauses typically assessed in a model assessment report

Clause	Description	Typical assessment method
3.2.4 & 3.3.9, WEM Rules Appendix 12 – 12.17	Power System Simulation Studies & Computer Model	<ul style="list-style-type: none"> • Tabulate assessment of the computer model against the requirements of Chapter 2 of this document. • Demonstrate that model initialises in SMIB and SWIS models without warnings or errors generated in the PowerFactory output window (option 'Validate Initial Conditions' must be selected in the Initialisation options). • Assess impact of model on simulation speed of SWIS model. • Demonstrate that, for each mode of operation, and at minimum, half and full output at maximum leading and lagging power factor, the model initialises and runs for a 10 second dynamic simulation without material fluctuation or drifting in terminal and connection point quantities.
2.2.2	Steady State Power Frequency Voltage	<ul style="list-style-type: none"> • Compare voltage protection settings to clause 2.2.2 requirements. • Assess connection point and terminal voltage step change on sudden disconnection for the maximum source impedance case at 50 %, 75 % and 100 % active power output and maximum leading and lagging power factor.
2.2.7 & 12.9	Transient Rotor Angle Stability & Post-Fault Reactive Power of a Power Station with Non-Synchronous Generating Units	<ul style="list-style-type: none"> • Assess transient stability for solid three-phase fault at the connection point for the maximum permitted fault clearance time (see Technical Rules Table 2.10). • For synchronous machines, assess the Critical Fault Clearing Time (CFCT) at maximum active power, maximum leading power factor in the maximum source impedance case.
2.2.8	Oscillatory Rotor Angle Stability	<ul style="list-style-type: none"> • Assess damping ratio for small disturbances (voltage step changes) and large disturbances (faults) for minimum and maximum source impedance over the operating capability of the generating system.

		<ul style="list-style-type: none"> Conduct eigenvalue study and present root-locus plot identifying local and, if relevant, inter-machine modes.
2.2.9	Short Term Voltage Stability	<ul style="list-style-type: none"> Assess post-fault voltage recovery. In the simulation plots, identify when limiters operate, and identify at what time the voltage recovers to 0.8 pu and 0.9 pu.
2.2.10	Temporary Over-voltages	<ul style="list-style-type: none"> Overlay transient overvoltage curve from Technical Rules figure 2.1 with voltage response for solid three-phase fault and solid two-phase fault at the connection point.
2.3.8	Determination of Power Transfer Limits	<ul style="list-style-type: none"> For the purpose of a Model Assessment it is sufficient to provide a qualitative assessment of the impact on power transfer limits based on known limitations in the vicinity of the connection point (for example transient voltage recovery, synchronous stability limitations). See Western Power's Annual Planning Report for details.¹⁹
2.5.8	Maximum Fault Currents	<ul style="list-style-type: none"> Assess maximum three-phase and phase-ground fault current contribution at the connection point.
3.2.1	Power System Performance Standards	<ul style="list-style-type: none"> Compare protection settings to system voltage and frequency operating standards.
A12.2: Active Power Capability	Active Power Capability	<ul style="list-style-type: none"> The customer needs to provide the active power capability up to the maximum temperature of the location of the generating system. Need to come from manufacturer.
WEM Rules Appendix 12 – clause 12.3	Reactive power capability	<ul style="list-style-type: none"> Plot reactive capability for individual generating units, and reactive capability at the connection point. Confirm that limiter settings align with reactive capability.
3.3.3.3(b) & 3.3.3.3(d) or WEM Rules Appendix 12 – 12.7	Immunity to Frequency Excursions & Immunity to Rate-of-change-of-Frequency	<ul style="list-style-type: none"> Ramp the equivalent external grid from nominal to maximum operating frequency and nominal to minimum operating frequency at 4 Hz/s, at unity and leading power factor for maximum and

¹⁹ Western Power: Annual Planning Report,
<http://www.westernpower.com.au/corporate-information-annual-planning-report.html>

		minimum source impedance at the connection point.
WEM Rules Appendix 12 – clause 12.8	Immunity to Voltage Excursions & Immunity to High Speed Auto Reclosing	<ul style="list-style-type: none"> Apply the undervoltage curve in Technical Rules figure 3.5 /WEM Rules Appendix 12 -Figure: A12.8.2.1 and high speed auto-reclosing curve in figure 3.6 at the connection point for minimum and maximum source impedance cases for maximum active power at unity and maximum leading power factor.
WEM Rules Appendix 12 – Clause 12.9	Multiple Ride through	<ul style="list-style-type: none"> Apply multiple credible contingencies to see whether generator can ride through
WEM Rules- Appendix 12 Clause 12.7, 12.9	Continuous Uninterrupted Operation	<ul style="list-style-type: none"> Assess continuous uninterrupted operation for all studies (in particular, credible contingency studies, load rejection studies described above).
WEM Rules Appendix 12 – Clause 12.10	Sudden Reduction In Active Power Requirement	<ul style="list-style-type: none"> Depending on the technology type, alter the fuel source input or apply a frequency (speed) bias or network frequency step to achieve a step change reduction in active power of 30 %.
WEM Rules Appendix 12: Clause 12.5, 12.6	Ramping Rates	<ul style="list-style-type: none"> Demonstrate the generating units ramp rate capability from minimum to maximum active power output and maximum to minimum active power output.
WEM Rules Appendix 12: Clause 12.6	Frequency Control	<ul style="list-style-type: none"> Identify model functionality relating to load control and droop control, and identify dead band and droop settings. Conduct simulations for frequency steps of +/- 0.025 Hz, +/- 0.03 Hz and +/- 0.1 Hz to demonstrate dead band settings and droop control at minimum output, half output , 85 % output and maximum power output. Assess the rate of response (see Appendix B).
WEM Rules Appendix 12: Clause 12.4	Voltage Control Systems	<ul style="list-style-type: none"> Assess voltage step response settling time at minimum, half and maximum active power output, at unity, maximum lagging and maximum leading power factor, for the minimum and maximum source impedance cases by applying 5 % voltage steps (see Appendix B).

		<ul style="list-style-type: none"> Assess limiter settling time by applying appropriate steps. For synchronous machines, apply 10 % impulse to assess excitation system ceiling voltage.
3.4.2	Overview	<ul style="list-style-type: none"> Undertake suitable studies for load models based on type, size and location. This may include voltage step change studies and transient stability studies.
3.4.7	Power Factor Requirements	<ul style="list-style-type: none"> Undertake calculations or simulations to assess power factor range at the connection point.

All simulation plots must, as a minimum, include terminal voltage, active power, reactive power, applied input signal (e.g. voltage reference step change, grid voltage step change) and other relevant signals (e.g. PSS output, SVC reactive power). Also refer to AEMO Model Acceptance Testing Guideline for additional information on simulations that may be undertaken to assess model functionality and performance.²⁰

5.2 Model tuning

This section provides general information regarding the tuning methodology and requirements for synchronous generators. The methodology should be adapted based on plant functionality and technology type.

A *design report* must include at least the following:

1. Open-loop gain margin and phase margin of the AVR and Generator. The gain margin and phase margin shall be compared with values that are considered good design practice of 6 dB and 40 degrees respectively.
2. Unsynchronised step response settling time.
3. The selection of PSS inputs, the nature of the speed measurement (if applicable), and justification for selection of washout filter settings and PSS output limits (generally 5 to 10 %).
4. Details of system Pvr transfer functions (including system conditions and generator operating points) used to tune PSS.
5. Root locus plots demonstrating selection of optimal PSS gain for maximum and minimum source impedance, operating points across the generators capability, and for relevant combinations of machines online (for example, 1, 2 and 4 machines online for a generating system comprising 4 machines).
6. Demonstrate that damping is positive over the frequency range of 0.1 to 2.5 Hz (see Technical Rules clause 3.3.4.5).
7. Tabulate eigenvalue results (damping, damping ratio and frequency of oscillatory modes) and voltage step-response settling time results for:

²⁰ AEMO, Dynamic Model Acceptance Guideline, 2013

- a. Maximum and minimum source impedance, for relevant combinations of machines online, for
 - b. operating points across the generating units capability without engaging limiters (typically at minimum, half and full active power output, at unity power factor and maximum leading and lagging power factor), and
 - c. operating points across the generating units capability which do engage limiters (typically at minimum, half and full active power output, at maximum leading and lagging power factor).
8. Assess large disturbance damping ratio in response to solid three-phase fault at the connection point.

Note that Technical Rules clause 2.2.8 and clause 3.3.4.5 state damping ratio and settling time requirements.

Please contact Western Power prior to commencement of model tuning to discuss and agree on control system configuration and tuning methodology.

5.3 Model acceptance tests

In cases where a *User* seeks to develop a *facility* with a particular technology type, but where a site and/or *connection point* has not yet been selected (e.g. as part of an Enquiry), the *User* may seek to have Western Power provide an initial assessment of the computer model and associated information against the requirements of the Technical Rules and the *Generator and Load Model Guidelines*.

This assessment would be conducted using an infinite bus model for a range of system strengths to emulate different connection locations. This assessment would therefore not assess electromechanical interactions with generators, which could later be assessed using the complete model of the SWIS once the *connection point* is known.

6. Model validation and performance

6.1 General

Technical Rules clause 4.1.3 identifies that data associated with the relevant *access application* must be validated and submitted to Western Power following tests. The data to be validated includes, but is not limited to, the computer model, generator and control system parameters. The schedule of tests for performance verification and model validation for synchronous *generating units* is provided in Attachment 11 of the Technical Rules, which also includes details of the requirements for test equipment and measurement signals. Additional tests could be conducted to validate the models if necessary. Western Power will specify test requirements for non-synchronous *generating systems* and *loads*.

Technical Rules clauses 4.1.3 and 4.2.4 describe the obligations of both Western Power and *Users* for the preparation of commissioning programs, test procedures, setup of test *equipment* and provision of test data. It should be noted that only approved settings may be applied, and that control system settings or configuration may not be modified without prior approval from Western Power. Technical Rules clause 3.3.9 (c) states that:

"The final parameter settings must not be varied without prior approval of the *Network Service Provider*."

6.2 Test witnessing

In accordance with Technical Rules clause 4.1.3, Western Power has the right to witness performance testing.²¹ During test witnessing, Western Power assesses whether:

1. Tests are conducted in accordance with the approved test procedure.
2. Tests pose any risk to *power system security or stability*, safety or to other *Users*, in which case there may be a requirement to omit particular tests (for example, for a *synchronous generator*, omit some tests with the Power System Stabilizer out of service) or cease testing.

In lieu of attending site for test witnessing Western Power may request the *User* submit test results and plots with relevant performance analysis to Western Power.²² For commissioning tests there may be a requirement for results to be provided before Western Power provides approval for *generating units* to be synchronised and before they can operate at progressively higher *active power* output levels. Following tests, in accordance with Technical Rules clause 4.1.3 (a) (6):

²¹ Test procedures and test plans must be submitted to Western Power, and test plans submitted to System Management via the website: <http://www.westernpower.com.au/electricity-retailers-generators-commissioning-tests.html>

²² These results must ultimately be included in the *R2 data, model validation and performance report* (see Section 6.3)

"All test results and associated relevant information including final transfer function block diagrams and settings of automatic *voltage* regulator, *power system* stabiliser, under excitation limiter and over excitation limiter must be forwarded to the *Network Service Provider* within 10 *business days* after the completion of the test." Western Power may also request specific test result information for loads which require a computer model.

6.3 R2 data, model validation and performance report

As stated in Attachment 3 of the Technical Rules, data is coded into categories, according to the accuracy of the information available. Throughout the process of a new *connection application* or modification to an existing *facility*, data accuracy is refined over time until it is validated during commissioning tests and R2 validation tests.

Following completion of tests an *R2 data, model validation and performance report* must be submitted to Western Power for approval within three months or as otherwise agreed as reasonable between Western Power and the *User*. The *R2 data, model validation and performance report* must include:

1. Details of the tests undertaken.
2. Details of any discrepancies between the tests conducted and the agreed test procedures.
3. Results, measurements, analysis techniques used and any relevant information to assist Western Power with performing a due diligence assessment.
4. Specific assessments of the performance against relevant clauses of the Technical Rules²³ should be documented, and illustrated on results plots (for reference, see Appendix B). The performance should also be tabulated in a registered performance spreadsheet in the format defined in Table 2 below.
5. Model validation assessment with respect to the requirements outlined in this document, including overlays of measured and simulated responses with accuracy bands (for reference, see Appendix B).
6. Final model and model documentation (computer model, block diagrams and settings, updated *user manual*, etc).
7. Updated *access application* with registered (R2) data. For upgrades or modifications this should be the updated R2 data relevant to the upgrade. Consistent with the AEMO's R2 Testing Guideline,²⁴ parameters to be derived from on-site tests are as follows:
 5. Parameters designated as "R2" in the Technical Rules Attachment relevant to the *facility*.

²³ If there are differences in R1 and R2 parameters, there may be a requirement to demonstrate the impact of these differences on the technical performance.

²⁴ AEMO, R2 Testing Guideline, 2013.

6. Parameters, other than those designated as "R2" in the Technical Rules that contribute most significantly to the accuracy of the model for fault, voltage and frequency disturbances in the power system, must be derived from on-site tests, where possible. Where parameters are not designated as "R2" in the Technical Rules, there remains the requirement to validate the value of these parameters (in aggregate) through the validation of the overall performance of the system, device, unit or controller to which they pertain.

Table 2: Performance standard table format

Clause	Sub-clause	Clause description	Compliant (Yes/No/Exempt)	Detailed description of performance including references	Western Power remarks
Clause and relevant Technical Rules version	Sub-clause	Clause description	If exempt, include relevant supporting information	Details of simulated or validated performance and specific references.	-

6.4 Review of test reports

Within three months of receiving complete test reports and associated supporting information, Western Power will advise one of the following outcomes:

1. Acceptance of the test report, associated data, parameters, model(s) and performance assessment.
2. Request for further information, further testing and/or model changes.

If an *R2 data, model validation and performance report* is not accepted, Western Power will inform the *User* of the reason(s) and work collaboratively with the *User* to expedite resolution of any issues preventing acceptance of the test report. Sufficient evidence has to be provided by Western Power if it requires the *User* to carry out additional tests. Western Power and the *User* must co-operate to reach agreement on the scope to address any deficiencies within a reasonable period.

6.5 Technical Rules/WEM Rule non-compliance

Western Power may accept the *R2 data, model validation and performance report* as an accurate reflection of the *facility*. This does not necessarily mean the *facility* is compliant with the Technical Rules. Should the final performance not comply with the requirements of the Technical Rules there is a requirement for this to be addressed. Options may include:

Changes to installed plant (settings, configuration, or additional plant requirements).

The *User* to seek an exemption request for the non-compliance. The exemption request would need to discuss the reasons for the non-compliance and why compliant performance cannot be met.²⁵

²⁵ Western Power guidelines for exemption requests are available from:
http://www.westernpower.com.au/documents/Guidelines_for_requests_for_exemptions_May_2010.pdf

Western Power to direct the *User* to operate at a particular output or in a particular mode of operation until the matter is resolved. Technical Rules clause 4.1.3 (e) states:

"...the *Network Service Provider* or, where relevant, *System Management*, may direct the relevant *Generator* to operate the relevant *generating unit* at a particular *generated* output or in a particular mode of operation until the relevant *Generator* submits evidence reasonably satisfactory to the *Network Service Provider* or, where relevant, *System Management*, that the *generating unit* is complying with the relevant technical requirement. If such a *direction* is given orally, the *direction*, and the reasons for it, must be confirmed in writing to the *Generator* as soon as practicable after the *direction* is given."

It should also be noted that Technical Rules clause 4.1.2 describes *Users* obligations to undertake testing if a requesting party believes that equipment owned or operated by, or on behalf of, another party may not comply with the *Access Code*, the Technical Rules or the *connection agreement*.

6.6 Registered data and performance standards

The generators registered data and performance standards consist of the following artefacts:

1. Test report(s) including:
 - a. *R2 data, model validation and performance report* (with R2 data and performance standards attachments).
 - b. Model tuning report (*design report*).
 - c. Various study reports conducted by Western Power on behalf of the proponent to assess performance of the facility with respect to the Technical Rules and the relevant *connection agreement*. This must include any due diligence studies conducted by Western Power following receipt of the *R2 data, model validation and performance report*.
2. Final computer model and block diagrams.
3. Approved exemptions from the requirements of the relevant version of the Technical Rules.
4. For performance covered by Technical Rules clause 1.9.4, demonstrated performance with respect to the relevant technical requirements prior to the *Rules commencement date*. It is necessary for the proponent to show evidence there has been no degradation in performance over previous agreed performance standards.
5. Any special conditions specified in the *connection agreement*.

There is a requirement for *Users* to demonstrate ongoing compliance with the Technical Rules and the relevant *connection agreement* by conducting routine tests in accordance with an agreed compliance monitoring program.²⁶

²⁶ See Technical Rules clause 4.1.3.

7. Variation Requests

Unless Western Power agrees otherwise in writing, a *User* must provide all of the information required by these *Generator and Load Model Guidelines*. In an approach similar to that taken by AEMO to assess variations from model guidelines,²⁷ the suggested format of a variation request is provided below. In response to a variation request, Western Power will assess the impact on the ability of the *User* to meet the requirements of the Technical Rules. The Variation Request should summarise:

1. The specific guideline(s) that cannot be met.
2. Documentary evidence (including options considered) of the reasons for being unable to meet a guideline, sufficient to satisfy Western Power that meeting the guideline is technically unachievable.
3. If there is a discrepancy between a guideline and what can be provided, a description and extent of the discrepancy.
4. If a guideline can be met at a later date, an undertaking as to when and how it would be met.
5. If the discrepancy between a guideline and what can be achieved could be reduced at a later date, an undertaking as to when and how this would be provided.
6. The extent to which that guideline might affect the ability to assess the compliance of the *User* under the requirements of the Technical Rules.

Western Power would consider a Variation Request in terms of its impact on:

1. The computer model (to which the Variation Request is related), and how it should be used.
2. Western Power's certainty over its ability to accurately model the facility in power system studies, including determination of power transfer limits and providing advice to *System Management* when requested.
3. Quality or security of supply to other *Users*.
4. The ability for Western Power, the *User* or any other party to conduct studies for connection applications.
5. The extent of changes to the operation of the generating system under Technical Rules clause 4.1.3.
6. *System Management's* ability to ensure secure operation of the *power system*.

Following consideration of the Variation Request, Western Power must:

1. Accept or reject it. In the event that the Variation Request is rejected, the *User* may be required to submit a Technical Rules exemption request.²⁸
2. Propose alternatives or options for the *User* to consider.

²⁷ AEMO, Generating System Model Guidelines, 2008.

²⁸ Western Power guidelines for exemption requests are available from:
http://www.westernpower.com.au/documents/Guidelines_for_requests_for_exemptions_May_2010.pdf

3. Request further information.

Appendix A: Overview of connection process and data requirements

Data provided to Western Power for both new connections and existing *facility* modifications or upgrades should be refined throughout the project as updated information becomes available. Figure 1 provides an overview of the phases of the connection process applicable to new *facilities*. For an existing *facility* undergoing alterations or upgrades aspects of this process may apply, depending on the nature of the change. In general, for a change that result in a change to plant performance and/or computer model an updated *access application* should be submitted to Western Power with relevant information.

The data and model prerequisites are shown at each phase. For example, a pre-requisite for proceeding to detailed steady-state and dynamic studies is a satisfactory outcome of the *model assessment*, and provision of (or update of) Design (D) category data. For additional information, refer to:

1. Western Power's website²⁹ for detailed information on activities conducted at each stage of the connection process.
2. The Applications and Queuing Policy.³⁰
3. Schedules of Technical Details (Western Power Technical Rules³¹ - Section A3.5).

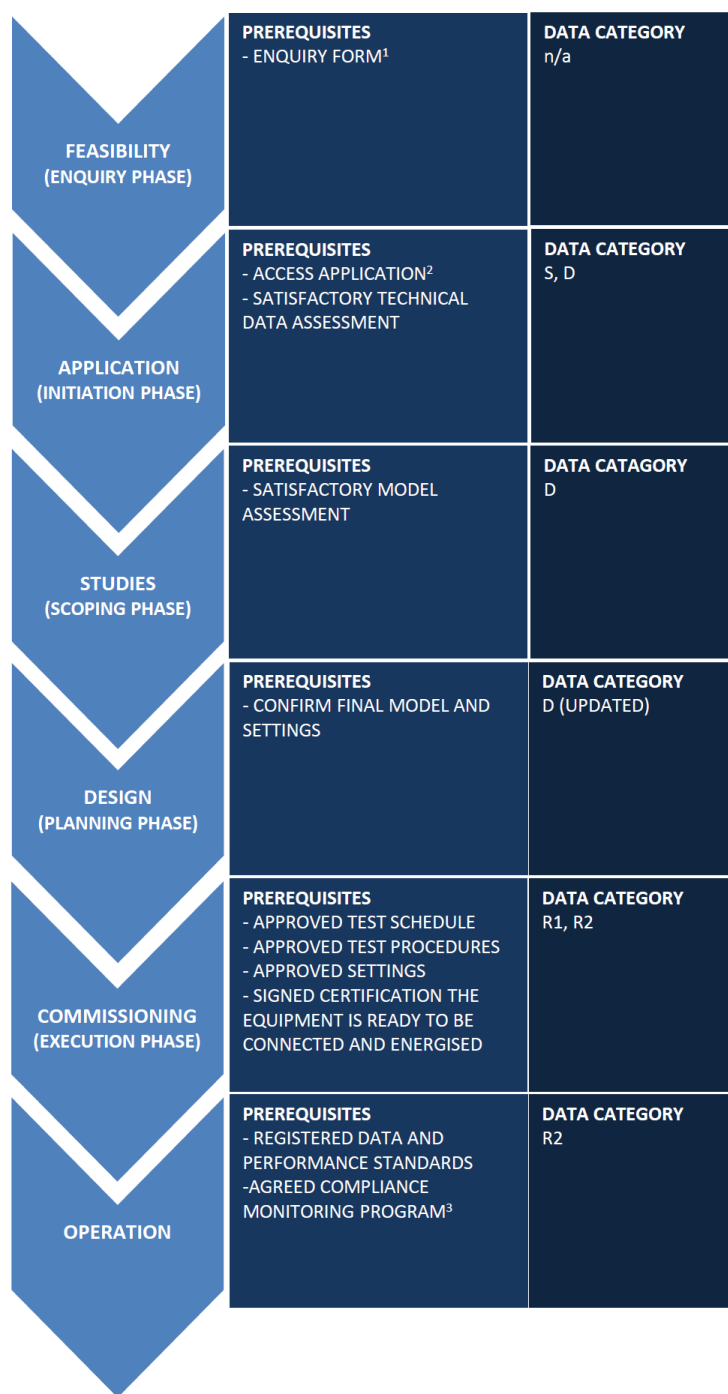
²⁹ Information on generator and transmission connections is available from:

<http://www.westernpower.com.au/electricity-retailers-generators-generator-and-transmission-connections.html>

³⁰ Applications and Queuing Policy:

http://www.westernpower.com.au/documents/application_queuing_policy.pdf

³¹ Technical Rules 2016: <https://www.westernpower.com.au/media/2312/technical-rules-20161201.pdf>

Figure 1: Data and model requirements at various stages of new project**Notes:**

1. The enquiry form should include details such as size (DSOC and/or CMD), location, operational details, and required in-service date. For an existing *facility*, the enquiry form should include details of proposed upgrades/changes.

2. The *access application* should include model block diagrams, an unencrypted PowerFactory model ,PSCAD model and model *user manual*. For an existing *facility*, the *access application* should also include details of proposed upgrades/changes.
3. During operation, ongoing compliance tests are conducted or network events assessed at agreed frequencies.

Appendix B: Performance and validation plot examples

Figure 2 illustrates the voltage step response settling time for a 5 % change to the automatic voltage regulator reference voltage at 2.0 s. In this example, the simulated response settling time is 3.628 s and the measured settling time is 2.536 s. Note that since there is no load drop compensation in this example, the final value of the terminal voltage is equal to the sum of the initial voltage and the applied step change.

Figure 2: Voltage step response settling time

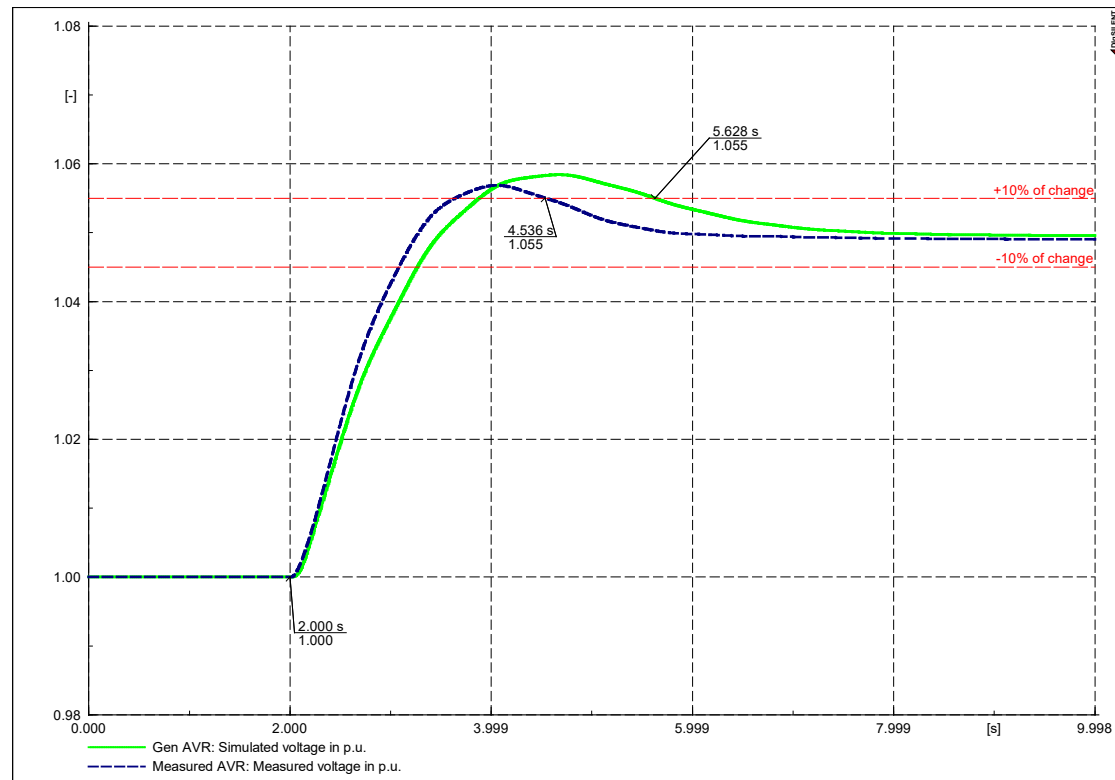


Figure 3 illustrates the active power rate of response. In the example a step change to governor speed reference of 0.525 Hz is applied at 2.0 s. Based on the droop setting of 4 % and the dead band of ± 0.025 Hz the calculated active power response is 20 MW. The figure illustrates that the measured response achieves 90 % of the change in 6 s, and the simulated response achieves 90 % of the change in 6.558 s. The response achieved in 6 s is also illustrated.

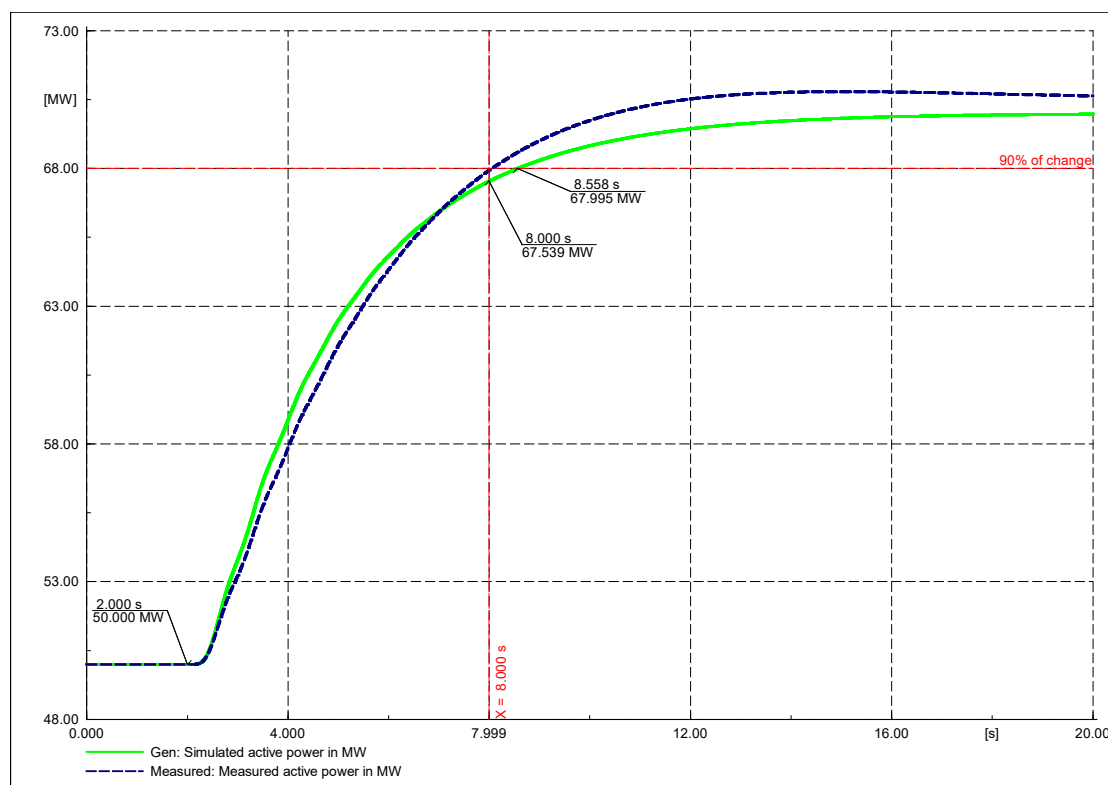
Figure 3: Active power rate of response

Figure 4 shows the voltage step response including +/- 10 % tolerance bands. The tolerance bands are calculated based on 10 % of the total (not maximum) change.

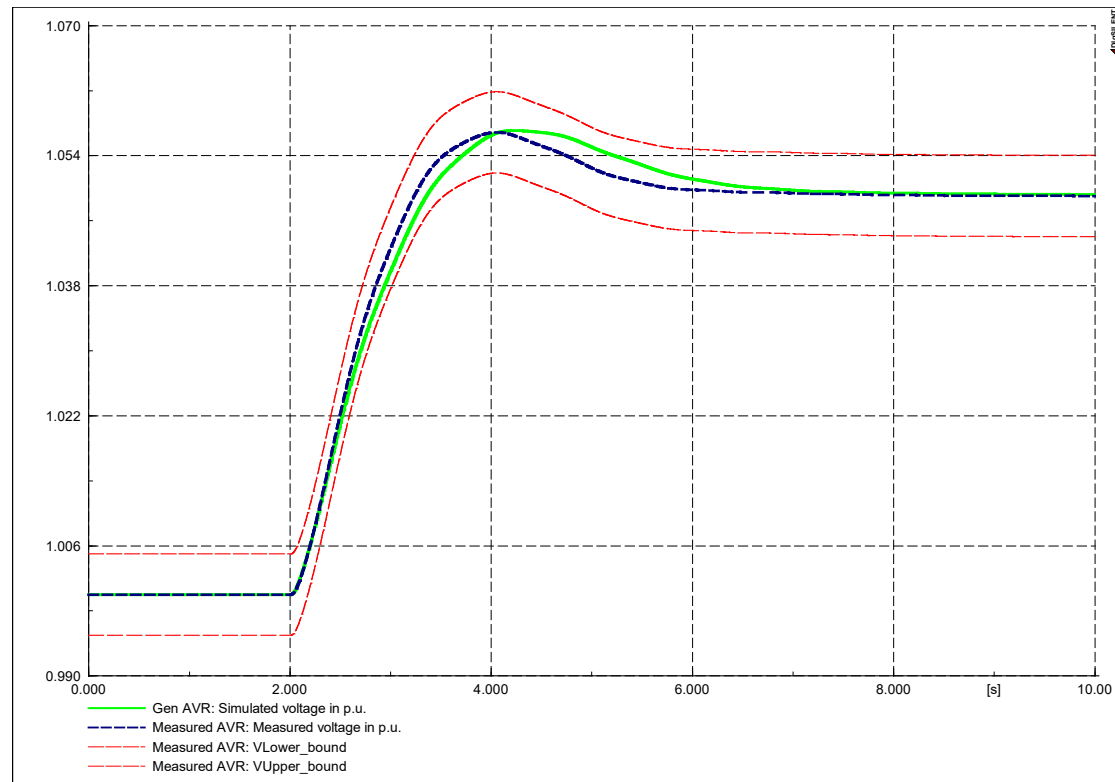
Figure 4: Voltage step response tolerance bands

Figure 5 illustrates the active power response to a step change in terminal voltage. The tolerance bands are illustrated based on $\pm 10\%$ of the maximum change in active power, in this case, 10% of approximately 48 to 52 MW, i.e. 0.4 MW.

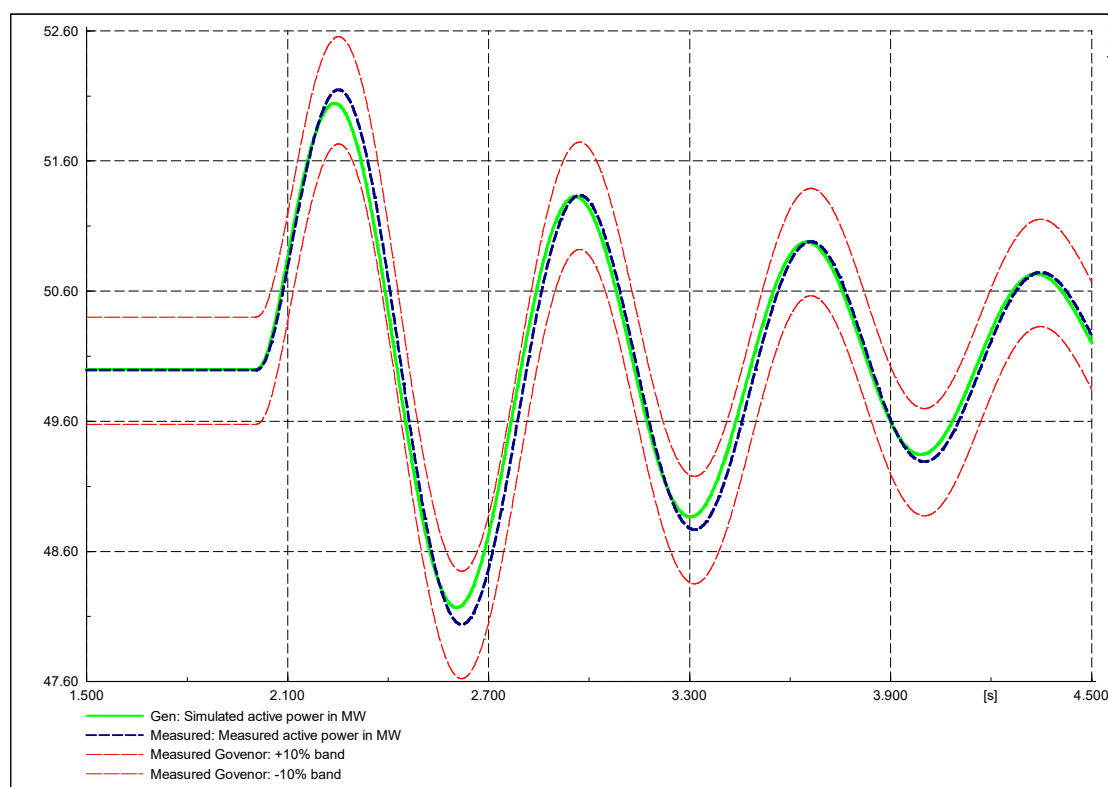
Figure 5: Power oscillation tolerance bands

Figure 6 illustrates the active power response to a 0.225 Hz at 2.0 s. Based on the droop setting of 4 % and the dead band setting of ± 0.025 Hz the expected change in active power is 8 MW. The figure illustrates that the response steady-state error settles to within both 10 % of the change and 2 % of the nameplate rating.

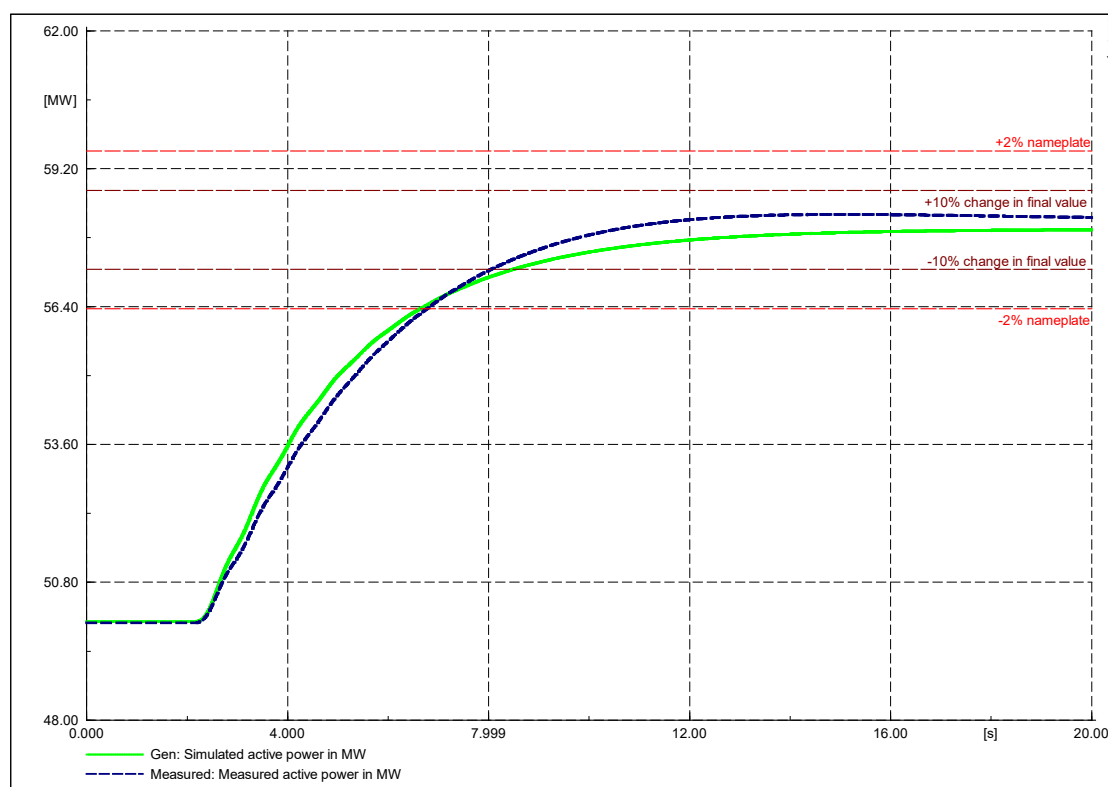
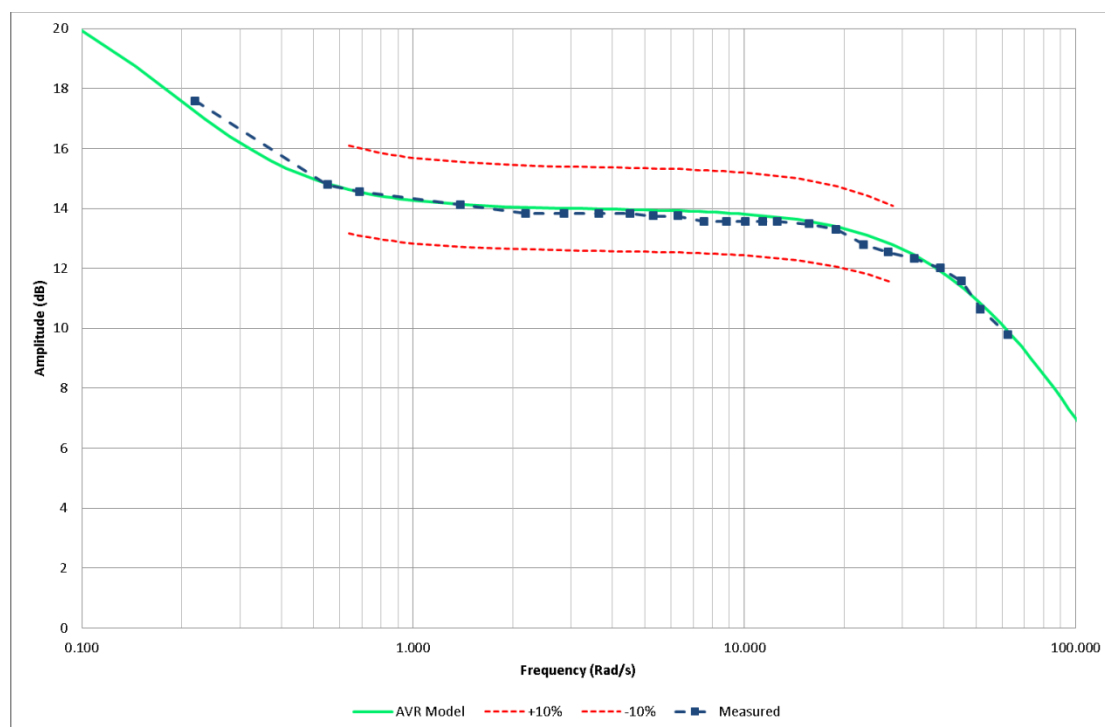
Figure 6: Active power final value tolerances

Figure 7 and Figure 8 illustrate an automatic voltage regulator calculated and measured transfer function. The figures illustrate that the amplitude (in dB) is within 10 % and the phase within 5 degrees over the frequency range of 0.1 to 5 Hz (approximately 0.6 to 30 r/s).

Figure 7: Transfer function magnitude tolerances**Figure 8: Transfer function phase tolerances**