28 October 2016

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Mr John Pierce
Chairman
Australian Energy Market Commission
PO Box A2449
Sydney South NSW 1235

By online submission

Dear Mr Pierce,

Rule change request- Generating System Model Guidelines

The Australian Energy Market Operator (AEMO) requests the Australian Energy Market Commission (AEMC) to consider making a rule change under section 91 of National Electricity Law. Details of the proposed rule change are summarised below.

1. Background

Clause S5.5.7 of the National Electricity Rules (*Rules*) requires AEMO to develop and publish *Generating System Design Datasheets*, *Generating System Setting Datasheets* (Datasheets) and *Generating System Model Guidelines* in accordance with the *Rules consultation procedures*. The current *Generating System Model Guidelines* (Guidelines) were published in February 2008, and focus on accurately modelling synchronous *generation* for *power system* simulation.

Since the first release of the Guidelines, the proliferation of new *generation* technologies and experience gained from past connection projects has triggered a need to review them to ensure that they remain relevant and effective. With increased penetration of *intermittent generation*, failure to adequately cater for new and emerging technologies can have a material impact on the secure operation of the *power system*. It is necessary to ensure the right information can be requested for new technologies.

Furthermore, the review of the Guidelines recognises the growing importance of other aspects of the power system, such as embedded generation, voltage support equipment, and control and protection systems for accurate planning, operation and analysis. These aspects are not adequately addressed by the current Guidelines.

2. Objectives

The key objectives of the proposed Rules are to allow for:

- Broadening the Guidelines and Datasheets to include non-*generating system power system* components.
- More detailed and accurate modelling and simulation of the *power system* to manage *power system security* with rapidly changing *power system* dynamics and *generation* technologies.

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NEW SOUTH WALES QUEENSLAND SOUTH AUSTRALIA VICTORIA AUSTRALIAN CAPITAL TERRITORY TASMANIA WESTERN AUSTRALIA

- More efficient procurement of *ancillary services*, and more accurate understanding of the technical capability of *plant* for the provision of new *ancillary services.*

If the proposed Rules changes are approved by the AEMC, AEMO will amend the Guidelines within 12 months of the commencement of the proposed Rules.

3. Benefits

The Rule change submission elaborates on how the proposed Rules are likely to contribute to the achievement of the National Electricity Objective. The benefits of having access to more data and models can be summarised as follows:

- Efficient investment in *transmission network* services.
- Efficient investment in and use of electricity, and more certainty for *Generators*.
- Economic procurement of Contingency FCAS and SRAS, and accurate evaluation of new ancillary services.

For further details of if you would like AEMO to meet with you regarding this proposed rule change please do not hesitate to contact AEMO's Group Manager Systems Capability, Mark Stedwell on (03) 9609 8563 or mark.stedwell@aemo.com.au.

Yours sincerely

Mike Cleary
Chief Operating Officer

Attachment:

1. Rule change submission for revision of AEMO's Generating System Model Guidelines

ELECTRICITY
RULE CHANGE PROPOSAL

RULE CHANGE SUBMISSION FOR REVISION OF AEMO'S GENERATING SYSTEM MODEL GUIDELINES

Dated: **October 2016**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

CONTENTS

1. SUMMARY

Clause S5.5.7 of the National Electricity Rules (*Rules*) requires AEMO to develop and publish *Generating System Design Datasheets*, *Generating System Setting Datasheets* (Datasheets) and *Generating System Model Guidelines* in accordance with the *Rules consultation procedures*. The current *Generating System Model Guidelines* (Guidelines) were published in February 2008, and focus on accurately modelling synchronous *generation* for *power system* simulation.

Since the first release of the Guidelines, the proliferation of new *generation* technologies and experience gained from past connection projects has triggered a need to review them to ensure that they remain relevant and effective. With increased penetration of *intermittent generation*, failure to adequately cater for new and emerging technologies can have a material impact on the secure operation of the *power system*. It is necessary to ensure the right information can be requested for new technologies.

Furthermore, the review of the Guidelines recognises the growing importance of other aspects of the power system, such as embedded generation, voltage support equipment, and control and protection systems for accurate planning, operation and analysis.

Hence, AEMO proposes to change the provisions in the *Rules* relating to the provision of *power system* modelling information. The key objectives of the proposed Rules are to allow for:

- Broadening the Guidelines and Datasheets to include non-*generating system power system* components.
- More detailed and accurate modelling and simulation of the *power system* to manage *power system security* with rapidly changing *power system* dynamics and *generation* technologies.
- More efficient procurement of *ancillary services*, and more accurate understanding of the technical capability of *plant* for the provision of new *ancillary services.*

If the proposed changes are approved, AEMO will amend the Guidelines within 12 months of the commencement of the proposed Rules.

2. BACKGROUND

2.1 Objectives

Should the *AEMC* approve the proposed Rules, AEMO proposes to amend the Guidelines within 12 months of the commencement of the proposed Rules, with amendments to the Datasheets to follow. This Rule change proposal provides an indication of the types of changes AEMO proposes to make to the Guidelines, which include:

- Standardised and consistent modelling approaches for all *plant* where, in AEMO's reasonable opinion, there is a risk that the *plant* will adversely affect *network capability*, *power system security*, quality or *reliability* of supply, inter-*regional* power transfers or the use of a *network* by another *Network User*.
- More systematic and consistent acquisition of *generating systems'* protection information to model those that can have a major impact on *power system security*.
- Assessment of *power system* phenomena with a dynamic response time of up to two minutes, or longer, that can have a material impact on the dynamic response of a *generating system*, *regional networks* or inter-*regional* power transfers. Examples include evaluating the response of slow-acting *control systems* in wind and solar farms, and assessing contingency *frequency* control *ancillary services* (FCAS).

2.2 PMRG review

AEMO convenes the Plant Modelling Reference Group (PMRG), which provides subject matter expertise on all matters related to the modelling of *power systems*, and includes representatives from all TNSPs. The PMRG reports to the National Electricity Market Operations Committee.

In July 2015, the PMRG conducted a review of the Guidelines and the *Rules* to identify potential gaps. The PMRG review provided a basis for AEMO to engage informally with various stakeholders prior to submitting a formal Rule change proposal.

2.3 Informal stakeholder consultation

Following the PMRG review, AEMO conducted two informal public consultations with a wide range of relevant stakeholders, including NSPs, *Generators*, *power system* equipment manufacturers, the *AEMC*, and relevant consultants. The key objective of this consultation was to receive feedback on the proposed revisions to the Guidelines prior to submitting a Rule change proposal. The consultation comprised the following two meetings:

- First round introductory meeting with all stakeholders on 1 September 2015.
- Second round of consultation occurred between 21 September and 20 October 2015 comprising one-on-one detailed discussions with several interested stakeholders.

All feedback received from stakeholders has been addressed in this Rule change proposal.

3. THE NEED FOR A RULE CHANGE AND REVISION OF THE GENERATING SYSTEM MODEL GUIDELINES

This section discusses specific issues with the *Rules* and Guidelines based on recent incidents, and highlights the risks associated with the current requirements and the overall added value to the *market* by acquiring additional models and data from *Registered Participants*. A summary of recent examples identifying concerns with the *Rules*, and how the proposed Rules address those concerns, can be found in Appendix A.

3.1 Specific issues concerning the existing Rules

3.1.1 Scope of Generating System Model Guidelines

The Guidelines were *published* with synchronous *generating systems* in mind. However, other *plant* such as network dynamic *reactive support plant*, high-voltage direct current *transmission* links, large variable speed motor drives, and protective functions have a significant impact on the performance of a *transmission network*, both at a local level and across *regions*.

The *Rules* and Guidelines do not require the provision of model information about such *plant*.

The following sub-sections outline a number of other related proposed Rules.

3.1.2 The need for electromagnetic transient-type models

Clause S5.2.4(b)(5) of the *Rules* requires *Generators* to submit data necessary for AEMO and relevant NSPs to conduct load flow and dynamic studies. The type of models to be provided has not been explicitly specified. To date, *Generators* have submitted RMS-type models that are sufficient for simple steady state and time-domain dynamic analyses.

This section discusses circumstances where the use of RMS-type models would not be adequate or appropriate.

Accurate power electronic converter model for large-scale stability studies

Over many decades of experience with multi-machine power systems it was established that 'fast-transient' phenomena, with decay time constants in the order of one ac cycle or less (16 ms on a 50 Hz system), were immaterial to the stability problems of practical relevance.

Measurement data collected from field testing of non-synchronous generating systems has shown that RMS-type models could fail to meet the statutory model accuracy requirements set out in the Guidelines. This is often due to limitations of RMS-type models, rather than the inaccuracy of model parameters or the plant's transfer function.

The potential for simulation inaccuracies increases where weak networks that have low available fault levels are studied. Conversely, the quantity of remote and isolated non-synchronous generation connection applications that most commonly have low available fault levels are increasing across the *NEM*. Wind turbine and solar inverter manufacturers tend to apply caveats to their RMS-type models suggesting that model response cannot be guaranteed in areas with low available fault levels.

Several control loops in the power electronic converters respond on timescales comparable to, or shorter than, one ac cycle. These phenomena cannot be accounted for in RMS-type simulation tools. Therefore, depending on the strength of a connection point, the use of three phase EMT-type models may be necessary to accurately represent the plant.

An emerging issue is the connection of non-synchronous generating systems in close electrical proximity to each other. Complicating this further is that such non-synchronous generation concentrations are often located in already weak parts of the network; examples include South Australia, North West Victoria, and North Queensland. Moreover, connection of electrically close non-synchronous generation results in a reduction in the available fault level for each power electronic interfaced generating system compared to a single isolated non-synchronous generating system described above. This is because multiple power electronic interfaced generating systems would need to share an already low available fault level. Operation under such circumstances poses several concerns, including potential unexpected tripping of power electronic interfaced generating systems with or without a network fault.

In summary, the *Rules* requirements for provision of information such as *plant* models are inadequate as they do not fully cover new and emerging *generation* technologies. This will result in inefficient methods to manage the uncertainty in accounting for the impact of new *generation* on *network* transfer capability, such as conservative limit calculations or investment in *network plant* that provides higher than needed *network* performance. Additionally, inadequate modelling and simulation methods gives rise to inadequate understanding of the impact of power electronic interfaced *generation systems* on *power system security*. This increases the risk of their unexpected *disconnection*, and consequent involuntary *load shedding*.

EMT-type models for specialised power system studies

In addition to the inadequacy of RMS-type models for an accurate assessment of non-synchronous generating plant response in scenarios with high penetration of power electronic interfaced generating systems, these models are not adequate or appropriate for several types of specialised power system studies for the following key reasons:

- The impact of phase unbalances in the three phase power system can be significant during fault clearance or system restoration processes; a full three phase representation is, therefore, necessary to accurately model the phase quantities[1];

[1] Assuming positive-sequence RMS-type simulation tools and models are used. There are the most widely used type of simulation tools for large-scale power system simulation studies and account for one phase of a three phase system.

- Investigation of phenomena exhibiting a dominant frequency outside the permissible system frequency range, i.e. outside the 46-55 Hz on a 50 Hz system[2];
- Detailed representation of control and protection systems, such as fast acting controllers used in wind turbines and solar inverters may require smaller simulation time steps than applicable in standard RMS-type simulation tools; and
- High level of non-linearities in the model or network are not suitable for RMS-type simulations. This is because most non-linearities, e.g. transformer saturation characteristics or inrush currents, cannot be accurately accounted for in RMS-type models.

Examples of such specialised power system studies include:

- System restoration or black start studies;
- Investigating possible adverse interaction between multiple power system equipment such as:
  - Sub-synchronous interaction between series compensated lines and nearby plant;
  - Sub-synchronous interaction between large variable speed drives and nearby plant;
  - Interaction between HVDC links and the interconnected ac systems; and
  - Interaction between multiple power electronic interfaced devices.

3.1.3 Procurement of ancillary services

Model and data required by clause S5.2.4(b)(5) of the *Rules* are primarily intended for *connection* and operation of *generation* in the *energy market*. Clause 3.11.9(g) outline the requirements for tenders of SRAS in terms of “models and parameters of relevant *plant*, sufficient to facilitate a thorough assessment of the *network* impacts and *power station* impacts of the use of the relevant *system restart ancillary service*”. Accurate assessment of the performance of proposed SRAS necessitates provision of more detailed modelling information and data not generally sought by clause 3.11.9(g).

Provision of an insufficient level of model and data for evaluating tenders of NSCAS or SRAS can result in an excessive or insufficient acquisition of the relevant *ancillary service*. Provision of a sufficient level of model and data allows an efficient and economic procurement with precise quantity and quality of *ancillary services* required. Such a fact-based, data-driven analysis allows understanding the capability of each *ancillary service* in conjunction with the rest of the *network* eliminating issues such as:

- Compromised safety and integrity of *power system* equipment involved during system restoration due to incorrect assessment of the capability of each SRAS, or adopting energisation paths not modelled and simulated accurately.
- Involuntary or excessive *load shedding* due to inadequate assessment of the capability of each Contingency FCAS.

Detailed modelling information as proposed for *connection* and operation of *generation* in the *energy market* allows analysing and mitigating the above circumstances. It is, therefore, prudent to specify the requirements for tenders of NSCAS and SRAS consistent with the proposed clause S5.2.4(b)(5), as discussed in section 3.1.2.

3.2 How the proposed Rules address the issues

3.2.1 Scope of Guidelines and Datasheets

AEMO recommends that the modelling requirements in the *Rules* should be extended to include all critical *network elements*. It is, therefore, proposed to change references to “Generating System” in the title of the *Generating System Design Datasheets*, *Generating System Setting Datasheets*, and *Generating System Model Guidelines* to “Power System”.

[2] EMT-type simulation tools are applicable for simulating all these phenomena except for assessment of low-frequency electromechanical oscillations, where a small-signal stability is generally used.

The requirement for the provision of simulation models and other data for *plant* should be assessed by reference to the risk that *plant* will adversely affect *network capability*, *power system security*, quality or *reliability* of supply, inter-*regional* power transfers or the use of a *network* by another *Network User*. Factors such as size of the *plant*, *connection point* specifications, and the presence of adjacent *plant* will be among the criteria that should be considered when requiring such models, and the level of detail required.

3.2.2 The need for electromagnetic transient-type models

The use of EMT-type models assists in determining confidence in the conclusions made by RMS-type models as primarily used for large-scale power system studies, and provides accurate and adequate methods to manage impact of new generation on power system security and network transfer capability. The following key benefits are sought from more detailed model and data:

- Avoid building extra *transmission network* capacity that cannot be utilised fully in practice due to adverse impact of power electronic interfaced *generation* on *power system security* or adverse interaction between multiple *power system* equipment.
- Evaluate the efficacy of potential options considered during a *regulatory investment test for transmission* (RIT-T) intended to allow higher integration of renewables *intermittent generation*, while maintaining *power system security*.
- Evaluate the efficacy of potential options considered for new services, or changes to existing services, intended to allow higher integration of *intermittent generation*, while maintaining *power system security*.
- More efficient operation by increasing confidence in *power system* dynamics under changed system conditions with higher penetration of non-synchronous generation.
- Increase *power system security* by avoiding involuntary *load shedding* due to unexpected *generation* tripping through more robust *control system* design.
- More certain and adequate design of the necessary control and protection schemes at the *network* or *generating system* levels in line with the above benefits.
- Ability to assess more accurately the potential for adverse interaction between power electronic interfaced devices that, if unattended, could result in spurious tripping of these *generating systems*.

A requirement for EMT-type models also supports AEMO's ability to conduct specialised power system studies for situations where conventional RMS-type models are not adequate or appropriate. Section 3.1.2 presents examples of this type of analysis.

The proposed Rules set out the following criteria and conditions as to when EMT-type models would be required when:

(i) the *generating system* includes power electronic interfaced technologies:

a. at the *transmission system* level; or

b. at the *distribution system* level where the installed capacity of the *plant* to be installed is greater than 10% of the available fault level at the point of connection; or

(ii) in AEMO's reasonable opinion, there is a risk that the *generating system* will adversely affect other *Network Users* or *power system security* or quality or *reliability* of the *power system*.

3.2.3 Procurement of ancillary services

Specifying more requirements for tenders of NSCAS and SRAS consistent with the proposed clause S5.2.4(b)(5) allows for provision of more adequate and appropriate modelling information and data. This assists in a more efficient procurement of NSCAS and SRAS, and Contingency FCAS. In addition to a more efficient outcome, provision of more detailed model and data assists in improved management of *power system security* by a more accurate analysis of circumstances where NSCAS or SRAS are to be used, including:

- Optimising energisation paths during system restoration, hence preserving the safety and integrity of *power system* equipment involved during system restoration.
- More accurate understanding of capability of each proposed source of Contingency FCAS, and procuring the required Contingency FCAS accordingly.
- More accurate understanding of the technical capability of *plant* for the provision of new services in the future in support of *power system security* with higher penetration of non-synchronous *generation* sources.

3.3 How the proposed Rules are likely to contribute to the achievement of the National Electricity Objective

The benefits of having access to more data and models can be summarised as follows:

- Efficient investment in *transmission network* services through:
  - Improved utilisation of *interconnectors* by understanding and mitigating the risk of adverse interaction between series compensated *transmission lines* and nearby *generating systems*.
  - Significant increase in the number of *intermittent generating systems* would result in the *network* capability steadily degrading. At some point, it would be necessary to augment the *network* so that reliability and security of *supply* can be maintained. The proposed Rules would allow better a understanding of the extent to which existing *network* capability can be maintained, and determine the most appropriate *network* augmentation options.
- Efficient investment in and use electricity, and more certainty for *Generators* by:
  - Managing the impact of their proposed *generating systems* on *power system security* and therefore reducing the risk of being *constrained-off* by the NSP or AEMO in its day-to-day operation.
  - Reducing the risk of being *constrained-off* as a result of later developments, e.g. new power electronic interfaced *generation* development or retirement of conventional synchronous *generation*, which could reduce the capability of the adjacent *network*.
  - Facilitating increased penetration of *intermittent generation* while maintaining *power system security*.
  - Avoiding involuntary *load shedding* due to mal-operation of *network* and *generation* components of the *power system* or their associated protective functions.
- Economic procurement of Contingency FCAS and SRAS, and accurate evaluation of new ancillary services.

More detailed information about the proposed benefits by reference to known issues in the NEM, is detailed in Appendix A.

AEMO can only estimate the costs of compliance with the proposed rule based on its own experience. During its most recent acquisition of SRAS, AEMO's technical assessment was carried out after obtaining some additional data on a voluntary basis from *Generators*. AEMO then developed its own models to conduct the types of studies referred to in this proposal. Based on this experience and assuming average engineering consultancy fees, AEMO considers that the costs associated with the gathering of the required data and development of a model for a piece of infrastructure, such as a *generating system*, was approximately $75,000.

When compared with some of the benefits articulated in Appendix A, AEMO considers that this represents a sound investment for consumers.

Moreover, it should be noted that such voluntary provision of data is unlikely to be repeated in the future.

3.4 Description of the proposed Rules

A draft of the proposed Rules is presented in Appendix B.

3.5 Specific issues concerning the existing Generating System Model Guidelines

3.5.1 Model requirements for fault level studies

Static models based on Thevenin equivalent representation have been traditionally used for calculating fault current contribution of synchronous generation (i.e. voltage source behind a reactance). A similar approach has sometimes been applied to converter-connected generation technologies to develop an equivalent fault study representation of a wind farm or large scale solar PV generating systems. More specifically, equivalent source impedances and time constants are estimated for the converter-connected generation. The main disadvantage of this approach is the reduced accuracy of results when this methodology is applied to remote faults.

To develop more detailed models of converter-connected generation technologies for fault level studies, it is necessary to appreciate the key difference between the performance of conventional synchronous machines and converter-connected generation technologies, which is the "active'' control of the converter during fault conditions. In the case of the converter, this results in the fault current magnitude to vary significantly depending on the factors discussed below:

- Fault level studies are quasi steady-state type analyses, and transients caused by converter components during a fault are not generally accounted for. This includes the action of crowbars or dynamic braking choppers.
- The sequence of actions taken by the fault ride-through control of the converter results in a different response at different instances during the fault and after fault clearance.
- Such fault contributions are presently not reflected in models of converter-connected generating system AEMO is provided with by *Generators*.

3.5.2 Model requirements for harmonic studies

Harmonic studies are broadly divided into two categories:

- **Harmonic Emission**: This type of analysis can be performed with common harmonic load flow tools, and there is no significant accuracy gain by using EMT-type models. The discussion in this chapter primarily focuses on the modelling methodology for this type of analysis.
- **Harmonic Susceptibility and Resonance**: Examples include investigation of the possibility of power electronic converters exciting a network resonance point, or harmonic filter switching studies. Such studies are better classified as specialised electromagnetic transient (EMT)-type studies, discussed in Section 3.2.2.

When carrying out harmonic emissions analysis, good electricity industry practice is to consider harmonic-generating devices as ideal harmonic current sources. This method has been applied to line-commutated converters and diode rectifiers.

With converter-connected generation technologies, however, the observed connection point voltage and current harmonics are grid dependent, while also being influenced by the grid background harmonics. More specifically, some harmonics are generated by the voltage source converter, whereas others are due to background harmonics generated elsewhere in the network and seen at the connection point.

Power electronic interfaced generation technologies can only be represented as an ideal current source if the change of terminal voltage or the voltage imbalance present in the external network does not change the "harmonic profile" of the device. In practice, however, harmonics generated by the voltage source converters used in wind turbines and solar inverters do not remain constant, but vary according to the grid conditions, generation operating conditions, and the converter control action.

3.5.3 Model accuracy requirements

The Guidelines do not specify the operating conditions and types of disturbances and faults for which the model accuracy requirements will apply. AEMO's experience gained from wind farm commissioning and R2 testing indicates that an accuracy requirement of +/-10% is not practically achievable for all disturbances. This applies to both converter-connected generating units and dynamic reactive power support plant. As most large-signal disturbances recorded in practice are of an unbalanced nature, this creates a shortfall of the RMS-type model.

3.5.4 Protective function modelling

Some of the protective functions of generating systems, such as out-of-step, loss of excitation, over-flux (V/Hz) relays, can have a major impact on stability of the generating system and the power system. Despite being listed as a modelling requirement in the Guidelines, computer models of protection systems have rarely been provided by *Generators*. To ensure accurate investigation of ongoing performance of the power system using modelling and simulation tools, it is considered necessary to require models (or otherwise all necessary information on operating principles of a relay to allow AEMO and NSP to develop the models) and detailed relay settings for protection systems if requested by AEMO or the TNSP.

3.5.5 Model requirements for mid- and long-term dynamics

Section 8 of the Guidelines sets out the requirements for mid-term and long-term dynamics in the following form:

> "There is no requirement for the provision of distinct Medium Term Dynamic Models. Medium Term simulations will be based on Transient Stability Models (as described in section 7.1) and other models derived from data provided in the Data sheets for equipment such as onload tap changer (OLTC) controllers, turbine governors, over-excitation or stator current limiters and any other thermal, voltage or frequency related controller with a time-delayed response".

This has sometimes been interpreted as there being no need for submission of simulation models representing phenomena that only manifest during longer timeframes i.e. tens of seconds. Examples include on-load transformer tap changer, wind farm central plant controller and automatic capacitor switching.

Experience gained during wind farm commissioning and R2 testing has shown that inclusion of transformer tap changer model can have a significant impact on meeting model accuracy requirements, but there is presently no requirement for a *Generator* to provide models for slow-acting dynamic plant such as on-load transformer tap changer.

Additionally, experience gained from simulating large-scale network frequency disturbances and comparisons against respective measured responses has demonstrated inaccuracy of turbine-governor models in simulating events lasting several seconds. This is primarily attributed to simplifications made to prime mover and turbine modelling.

Lastly, the excerpt refers to "mid-term" dynamics only. Section 3.6.5 proposes a change to consolidate the terms "mid-term" and "long-term" dynamics.

3.6 Proposed changes in Generating System Model Guidelines

3.6.1 Model requirements for fault level studies

It is proposed that *Generators* who operate converter-connected *generation* technologies state the overall duration within which short circuit related parameters of the supplied model are appropriate.

It is also recommended that these *Generators* provide information on the magnitudes and phase angles of the phase-current *connection point* contributions that their equipment is expected to make (as a function of *connection point voltage*-dip magnitude and duration) for the following types of *voltage* dips:

- In only one phase;
- Equal dips in two phases and none in the third; and
- Equal dips in three phases.

3.6.2 Model requirements for harmonic studies

While the existing practices for modelling conventional *generation* technologies for harmonic studies is adequate and appropriate, the proposal for more accurate modelling of converter-connected *generation* technology harmonic sources is based on the non-ideal current sources that these more recently developed systems represent.

A *voltage* source converter can be better characterised by a Norton or Thevenin equivalent source. To realise such a representation, there is a need for dedicated harmonic models accounting for frequency dependency of harmonic impedance rather than providing harmonic current injection profiles only. A Norton or Thevenin representation is necessary when assessing compliance with *performance standards*, and determining the contribution of a *generating system* to the overall *network* harmonic distortion levels.

To correctly account for harmonic signature of devices based on *voltage* source converters, it is necessary to include appropriate models of these harmonic sources, the simulated harmonic impedance profile of the *network* as seen by the harmonic source, along with the frequency dependent behaviour of the network elements.

3.6.3 Model accuracy requirements

Time-domain accuracy requirements

To apply the model accuracy requirements to all types of *generating systems* and prime movers the following amendments will be introduced in section 7.3 of the Guidelines:

The following accuracy requirements are applied to each of the RMS-type and EMT-type models:

- For positive-sequence simulation models, the magnitude of measured responses must be within 10% of the simulated response magnitude with a confidence interval of 95% for transient responses for all relevant measured results.

  When using positive-sequence type models for simulation of unbalanced disturbances, it is necessary for *Generators* to provide information on any possible changes in the model parameters within the same model to simulate various types of faults.
- For both RMS-type and EMT-type models, it is acceptable to require the measured responses to remain inside the +/-10% accuracy bands with a confidence interval of 95%. At present, a 100% confidence interval is required.

The following additional amendments and clarifications are proposed with regard to the model accuracy requirements:

- The +/-10% accuracy bands are to be applied to the simulated response rather than the measured response.
- Considerations for relaxation of the accuracy requirements may be given if AEMO and the relevant NSP agree that dynamic changes in the interconnected *network* has contributed to violation of model accuracy requirements.[3]
- At present, the Guidelines' accuracy requirements are only applied to terminal quantities of the *generating units*. Experience gained from commissioning and R2 testing has shown that, in many cases, the simulated internal quantities can deviate significantly from the measured responses despite terminal quantities meeting the accuracy requirements. It is, therefore, proposed to apply reasonable model accuracy requirements to the closed loop response of the internal quantities of the *generating units*. Measured responses should remain inside the +/-10% accuracy bands with a confidence interval of 90% for the overall measurement period including both the transient and steady-state responses.
- Examples of important internal quantities to be recorded include:
  - Field current and voltage for the excitation system of synchronous *generating units.*
  - Pitch control, and dc-link voltage for wind turbine *generating systems.*
  - Fuel flow and valve position for speed governors of synchronous *generating units.*

A list of internal quantities that are proposed to be included for measurement will be included in a revised version of AEMO's R2 Testing Guideline that will also be developed.

3.6.4 Protective function modelling

Section 16.1 of the *Generating System Design Datasheet* and *Generating System Setting Datasheet* requires *Generators* to provide information on a number of protective functions, including:

- For all *generation* technologies:
  - Over- and under-*voltage* protection;
  - Over-and under-*frequency* protection;
  - Any protection sensitive to rate of change of *frequency*;
- Additionally, for synchronous *generation* technologies:
  - Under-excitation protection;
  - Over-excitation protection;
  - Stator current protection;
  - Over-flux (*V/f*) protection;
  - Loss of field protection; and
  - Pole-slip protection (or equivalent).

3.6.5 Model requirements for mid-term and long-term dynamics

AEMO intends to modify the second paragraph of section 8 of the Guidelines to the following:

> "Dynamic Models covering phenomena with a dynamic response time of up to two minutes or longer are necessary whenever they can have a material impact on the dynamic response of the *generating system*, and thereby on meeting model accuracy requirements. Any dynamic models provided by a *Generator* are expected to be adequate for simulation of the response of equipment such as onload tap changer (OLTC) controllers, turbine governors, over-excitation or stator current limiters and any other thermal, *voltage* or *frequency* related controller with a time-delayed response''.

[3] In such cases, measured voltage phase angle at the connection point may be used as an indication of the extent of network dynamic changes.

4. TRANSITIONAL RULES

4.1 Limited Retrospectivity

Generators, TNSPs, or other *Registered Participants* operating *power system* equipment referred to in this document registered prior to the Rule proposal becoming effective will be exempt from having to provide information for existing *plant* unless, in AEMO's reasonable opinion, there is a risk that the *plant* will adversely affect *network capability power system security*, quality or *reliability* of supply, inter-*regional* power transfers or the use of a *network* by another *Network User*

4.2 Changes to Equipment

Changes to existing *plant*, including those to *generating systems* covered by clause 5.3.9 of the Rules, even if they are considered to be 'like-for-like', should automatically trigger a request for updated models and other data referred to in this proposal.

APPENDIX A. HISTORICAL EXAMPLES OF WHERE GREATER POWER SYSTEM MODELLING DETAILS WERE REQUIRED

Issue	Recent examples	Affected regions	Risks and added value
Sub-synchronous interaction	Heywood Interconnector upgrade project and the potential for both sub-synchronous control interaction and sub-synchronous torsional interaction through introduction of series capacitors	SA and VIC	RISKS 1) Damage to wind turbines and series compensated lines 2) Involuntary tripping of wind farms VALUE 1) Improved utilisation of Heywood Interconnector capacity upgrade 2) Although the net market benefit of the Interconnector upgrade was assessed at $190.8M,[4] without more accurate modelling, the full benefits of the use interconnector might not be realised due to the potential for having to constrain its capacity to operate within stability boundaries.
System black start simulations	2015 AEMO SRAS procurement process	All	RISKS 1) Excessive procurement of SRAS 2) Insufficient procurement of SRAS 3) Compromised safety and equipment integrity during system restoration due to unproven energisation paths VALUE 1) Economic procurement of SRAS required to meet System Restart Standard 2) Optimisation of energisation paths 3) Procurement costs for the 2015 SRAS were reduced by $34M from the previous period[5]. These reductions are a direct result of a more confident prediction of the black start process, including optimisation of restart paths.[6] This was poss ble only through the voluntary provision of additional data from Generators and AEMO's investment in developing the required models.

[4] http://www.aemo.com.au/media/Files/Other/planning/RITTs/SA_VIC_Heywood_Interconnector_Upgrade_RIT_T_PACR.pdf
[5] https://www.aemo.com.au/media/Files/Electricity/Market%20Operations/SRAS/2015/SRAS%20completion%20report.pdf
[6] AEMO acknowledges that the SRAS did not perform as expected following the recent black system in South Australia, and notes that the reasons for this are still under investiga ion. See: http://www.aemo.com.au/Media-Centre/Update-to-report-into-SA-state-wide-power-outage for AEMO's latest update report on this event.

Issue	Recent examples	Affected regions	Risks and added value
Frequency stability	AEMO's investigation of the 1 November 2015 SA system separation event revealed mismatches in measured and modelled *frequency* response of relevant *plant*.	SA and QLD	RISKS 1) Excessive procurement of Contingency FCAS 2) Insufficient procurement of Contingency FCAS 4) Involuntary or excessive *load shedding* VALUE 1) Economic procurement of Contingency FCAS. 2) Ability to operate SA and QLD as viable islands with increased penetration of non-synchronous generation 3) Involuntary load shedding cost in SA during the 1 November 2015 event is estimated at $3.9M[7]. Accurate prediction of power system response and implementation of counter measures, based on more accurate models, would have reduced the risk of such involuntary load shedding.
Remote non-synchronous grid connection	Inadequacy of RMS models to study the compliance of the Musselroe Wind Farm in NE Tasmania with its *performance standards*.	All	RISKS 1) Unexpected tripping of wind farms 2) Adverse impact on the *network*, e.g. excessive over-voltages 3) Retailers' inability to meet their Large Scale Renewable Energy Target (LRET) by purchasing Large-Scale Generation Certificates (LGCs) from renewable generation to meet 2020 federal targets is estimated at $0.25M/MW [8]. The projected shortfall between currently installed and committed renewables in November 2015 was projected to be 5,000 MW. The costs of not reaching these targets would be passed to consumers. VALUE 1) Design/modify necessary control and protection schemes at the *network* or *generating system* level, or both 2) Avoid involuntary *load shedding*, with reduced risk of unserved energy costs.
Concentrated non-synchronous generation	Interaction of multiple electrically close wind farms in Western Victoria and Northern South Australia that reduce the effective SCR for the *generating plant*.	SA, VIC, QLD	RISKS 1) Steady-state or transient instability or both 2) Uneconomic constraint of *generation* 3) Involuntary tripping of wind farms 4) Retailers inability to meet their Large Scale Renewable Energy Target (LRET) by purchasing Large-Scale Generation Certificates (LGCs) from renewable generation to meet 2020 federal targets is estimated at $0.25M/MW [9]. The projected shortfall between currently installed and committed renewables in November 2015 was projected to be 5,000 MW. The costs of not reaching these targets would be passed to consumers. VALUE 1) Design/modify necessary control and protection schemes at the *network* or *generating system* level, or both 2) Avoid building extra *transmission network* capacity that cannot be utilised in practice 3) Evaluate veracity of potential RIT-T options to allow higher integration of non-synchronous generation 4) Avoid involuntary *load shedding*

[7] The cost of lost load is based on the outage duration of 107 minutes for 55 MW of load. The estimated cost of unserved energy (VCR) in the NEM is $40.22/kW.
[8] Based on a post-tax long term marginal cost of renewable genera ion of $93/MWh and an average annual capacity factor of installed renewable generation of 30%.
[9] Based on a post-tax long term marginal cost of renewable genera ion of $93/MWh and an average annual capacity factor of installed renewable generation of 30%.

Issue	Recent examples	Affected regions	Risks and added value
Island operation	Emerging issue that considers island operation with concurrent high penetration on non-synchronous *generation*.	SA, TAS, NQ	RISKS 1) "Edge of grid" *power systems* might not be capable of viable island operation following separation – uneconomic Contingency FCAS or AUFLS procurement VALUE 1) Determine maximum penetration of *non-synchronous generation* and the minimum number of synchronous machines required to operate the *power system* stably 2) Design necessary control and protection schemes on the *network* or *generating system* 3) Avoid involuntary *load shedding*

APPENDIX B. PROPOSED RULE CHANGES

[Based on version 82]

3.11.5 Tender process for network support and control ancillary services

(a) In this clause 3.11.5:

NSCAS tender guidelines means the guidelines developed and *published* by *AEMO* in accordance with paragraph (b) as in force from time to time, and includes amendments made in accordance with paragraphs (c) and (d).

(a1) If *AEMO* proposes to acquire a *network support and control ancillary service*, *AEMO* must call for offers from persons who are in a position to provide the *network support and control ancillary service* in accordance with the NSCAS tender guidelines.

(b) *AEMO* must determine and *publish* the NSCAS tender guidelines. The NSCAS tender guidelines must contain the following:

(1) a requirement for *AEMO* to call for *NSCAS* expressions of interest before issuing an *NSCAS* invitation to tender in relation to any required *network support and control ancillary services*;

(2) a requirement that a person who is to provide *network support and control ancillary services* under an *ancillary services agreement* has the *facility* tested in accordance with the NSCAS tender guidelines;

(3) a requirement for a *Network Service Provider* or other *Registered Participant* to assist a prospective tenderer in identifying and, if possible, resolving issues that would prevent the delivery of effective *network support and control ancillary services* proposed by a prospective tenderer;

(4) the timeframes over which *AEMO's* assessment of *NSCAS* expressions of interest, *NSCAS* tenders and physical testing of selected *network support and control ancillary services* will occur;

(5) a requirement for a tenderer to provide sufficient data, models and parameters of relevant *plant* in the form of updated *Power System Model Requirements*, a *Power System Design Datasheet* and a *Power System Setting Datasheet*, ~~sufficient~~ to facilitate a thorough assessment of the *network* impacts and *power station* impacts of the use of the relevant *network support and control ancillary service*;

(6) the terms and conditions of the *ancillary services agreement* that a successful tenderer would be expected to enter into with *AEMO*;

(7) the principles *AEMO* will apply in assessing *NSCAS* expressions of interest and *NSCAS* tenders; and

(8) any other matter considered appropriate by *AEMO*.

(c) *AEMO* may amend the NSCAS tender guidelines, subject to paragraph (d), and must comply with the *Rules consultation procedures* when making or amending the NSCAS tender guidelines.

(d) *AEMO* may make minor and administrative amendments to the NSCAS tender guidelines without complying with the *Rules consultation procedures*.

(e) *AEMO* is not under any obligation to accept the lowest priced *NSCAS* tender or any *NSCAS* tender in response to an *NSCAS* invitation to tender.

(f) A *Network Service Provider* must:

(1) negotiate in good faith with a prospective tenderer in respect of issues the NSCAS tender guidelines require a prospective tenderer to discuss and, if possible, resolve with a *Network Service Provider*; and

(2) participate in, or facilitate, testing of a *network support and control ancillary service* required by the NSCAS tender guidelines where it is reasonable and practicable to do so, and when participating in or facilitating such activities, the *Network Service Provider* will be entitled to recover from the relevant prospective tenderer all reasonable costs incurred by the *Network Service Provider* and for such purposes the activities of the *Network Service Provider* will be treated as *negotiable services*.

(g) Where a person submits an *NSCAS* tender in response to an *NSCAS* invitation to tender and *AEMO* wishes to negotiate an aspect of that *NSCAS* tender, *AEMO* and that person must negotiate in good faith concerning that aspect.

(h) In assessing any tenders submitted to meet a particular *NSCAS gap*, *AEMO* must first determine whether those tenders are competitive. The tenders submitted to meet a particular *NSCAS gap* will be deemed to be competitive if the quantity of *NSCAS* that *AEMO* is seeking can be supplied from the conforming tenders received by *AEMO* with any one conforming tender discarded or all conforming tenders from any one party discarded. If the tenders submitted to meet a particular *NSCAS gap* are not deemed to be competitive, *AEMO* and *NSCAS preferred tenderers,* must negotiate in good faith to agree reasonable terms and conditions for the supply of the relevant type of *NSCAS*, taking into account the need to:

(1) subject to subparagraph (h)(2), so far as practicable minimise the overall cost of supply of that service; and

(2) appropriately remunerate the providers of the relevant *NSCAS* for that service.

(i) If *AEMO* and a *NSCAS preferred tenderer* cannot agree on the terms and conditions for the supply of a *NSCAS* after 21 *business days* from delivery to the preferred tenderer of a written notice from *AEMO* to negotiate, either *AEMO* or the preferred tenderer may refer the matter to the *Adviser* for the determination of a dispute as to those terms and conditions in accordance with rule 8.2.

(j) If *AEMO* calls for offers under paragraph (a1), *AEMO* must give a notice to *Registered Participants* and *NSCAS providers* when the tender process is complete.

(k) Within 5 *business days* of *AEMO* giving a notice under paragraph (i), *AEMO* must *publish* the total estimated annual costs and quantities of each type of *NSCAS* acquired by *AEMO* under *ancillary services agreements* in respect of each *region* and in total and provide a breakdown of those costs and quantities relating to each *facility* contracted under those agreements.

(l) An *NSCAS provider* must comply with an *ancillary services agreement* under which they provide one or more *network support and control ancillary services*.

(m) *AEMO* may from time to time require an *NSCAS Provider* which provides a *network support and control ancillary service* under an *ancillary services agreement* to demonstrate the relevant *plant's* capability to provide the *network support and control ancillary service* to the satisfaction of *AEMO* according to standard test procedures. An *NSCAS Provider* must promptly comply with a request by *AEMO* under this clause.

3.11.9 Acquisition of system restart ancillary services by AEMO

(a) If *AEMO* proposes to acquire a *system restart ancillary service*, *AEMO* must enter into an *ancillary services agreement* with a prospective *SRAS Provider* following the completion of any procurement process to acquire *system restart ancillary services* which *AEMO* is satisfied will enable it to meet the *SRAS Procurement Objective*.

(b) Subject to paragraph (c), *AEMO* must only acquire *system restart ancillary services* from a person who is a *Registered Participant*.

(c) *AEMO* may enter into an agreement to acquire *system restart ancillary services* with a person who is not a *Registered Participant* if that agreement includes a condition for the benefit of *AEMO* that no *system restart ancillary services* will be provided under the agreement until that person becomes a *Registered Participant*.

(d) An *SRAS Provider* must comply with an *ancillary services agreement* under which they provide one or more *system restart ancillary services*

(e) A dispute concerning any aspect, (other than the aspect of price), of a *system restart ancillary services* agreement or a call for offers conducted by *AEMO* for the acquisition of *system restart ancillary services*, must be dealt with in accordance with rule 8.2.

(f) *AEMO* may from time to time require an *SRAS Provider* which provides a *system restart ancillary service* under an *ancillary services agreement* to demonstrate the relevant *plant's* capability to provide the *system restart ancillary service* to the satisfaction of *AEMO* according to standard test procedures. An *SRAS Provider* must promptly comply with a request by *AEMO* under this clause.

(g) A prospective *SRAS Provider* must provide to *AEMO* sufficient data, models and parameters of relevant *plant* in the form of updated *Power System Model Requirements*, a *Power System Design Datasheet* and a *Power System Setting Datasheet*, ~~sufficient~~ to facilitate a thorough assessment of the *network* impacts and *power station* impacts of the use of the relevant *system restart ancillary service*.

(h) If *AEMO* seeks to enter into an *ancillary services agreement* with a prospective *SRAS Provider*, *AEMO* and that *SRAS Provider* must negotiate in good faith as to the terms and conditions of the *ancillary services agreement*.

(i) A *Network Service Provider* must:

(1) provide any information to *AEMO* which *AEMO* reasonably requires in order for *AEMO* to assess the capability of a *system restart ancillary service* to meet the *system restart standard*;

(2) negotiate in good faith with a prospective *SRAS Provider* in respect of identifying and, if possible, resolving issues that would prevent the delivery of effective *system restart ancillary services* proposed by a prospective *SRAS Provider*; and

(3) participate in, or facilitate, testing of a *system restart ancillary service* proposed to be provided by a prospective *SRAS Provider* where it is reasonable and practicable to do so, and when participating in or facilitating such activities, the

Network Service Provider will be entitled to recover from the prospective *SRAS Provider* all reasonable costs incurred by the *Network Service Provider* and for such purposes the activities of the *Network Service Provider* will be treated as *negotiable services*.

4.3.4 Network Service Providers

(a) Each *Network Service Provider* must use reasonable endeavours to exercise its rights and obligations in relation to its *networks* so as to co-operate with and assist *AEMO* in the proper discharge of the *AEMO power system security responsibilities*.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(b) Each *Network Service Provider* must use reasonable endeavours to ensure that *interruptible loads* are provided as specified in clause 4.3.5 and clause S5.1.10 of schedule 5.1 (including without limitation, through the inclusion of appropriate provisions in *connection agreements*).

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(c) Each *Network Service Provider* must arrange and maintain, in accordance with the standards described in clause 4.3.4(e), controls, monitoring and secure communication systems to facilitate a manually initiated, rotational *load shedding* and restoration process which may be necessary if there is, in *AEMO's* opinion, a prolonged major *supply* shortage or extreme *power system disruption*.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(d) Each *Network Service Provider* must advise *AEMO* of any *ancillary services* or similar services provided under any *connection agreement* or *network support agreement* to which it is a party, and in respect of *network support and control ancillary services* provided under any *network support agreement* must provide to *AEMO* and update *AEMO* if there has been a material change to the information provided to *AEMO*, details of the following:

(1) a description of the *network support and control ancillary service*, including:

(i) the nature of the network support and control ancillary service;

(ii) the purpose for which the *network support and control ancillary service* has been acquired;

(iii) *connection points* at which the *network support and control ancillary service* is to be provided (to the extent that this information can be reasonably anticipated and provided);

(iv) the quantity or range of quantity of the *network support and control ancillary service* that can be provided, described in a manner relevant to the stated purpose (to the extent that this information can be reasonably anticipated and provided);

(v) the period of any notice that has to be given to the provider of the *network support and control ancillary service* for it to be enabled;

(vi) the response time to any instruction for use once the *network support and control ancillary service* has been enabled; and

(vii) the communication protocols related to the enabling and use of the *network support and control ancillary service* and the notification of changes to its availability;

(2) the availability of the *network support and control ancillary service*, including:

(i) the period over which the *network support and control ancillary service* will be available;

(ii) any possible restrictions on the availability of the *network support and control ancillary service*; and

(iii) whether the *network support and control ancillary service* is available for the use of parties other than the *Network Service Provider*;

(3) advice on any changes to the formulation of network limits to reflect the enabling or use of the *network support and control ancillary service*; and

(4) if the *network support and control ancillary service* is to be *dispatched* by *AEMO*, the form of instructions for the *dispatch* of the *network support and control ancillary service* by *AEMO*.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(d1) Where *NSCAS* is to be acquired by the *Network Service Provider*, the *Network Service Provider* must develop, in consultation with *AEMO*, the arrangements for the enabling and use of the *network support and control ancillary service*, and those arrangements must be consistent with meeting the relevant *NSCAS need*.

(d2) A *Network Service Provider* who enters into a *network support agreement* must negotiate in good faith with *AEMO* on the form of instructions it will provide to *AEMO* under paragraph (d)(4) to dispatch the netw*ork support and control ancillary service* to ensure those instructions are both comprehensive and practicable for *AEMO* to implement in *central dispatch* if required.

(e) *AEMO* must develop, and may amend, standards in consultation with *Network Service Providers* in accordance with the *Rules consultation procedures* which must be met by *Network Service Providers* in arranging and maintaining the controls, monitoring and secure communication systems referred to in clause 4.3.4(c).

(f) Until the standards contemplated by clause 4.3.4(e) are issued by AEMO, each Network Service Provider must maintain the control, monitoring and secure communication systems referred to in clause 4.3.4(c) that were in place at 13 December 1998 so as to achieve substantially the same performance and functionality as they did over the 12 months prior to 13 December 1998.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(g) Each *Network Service Provider* must plan or operate its *transmission system* or *distribution system* in accordance with the *power system* stability guidelines described in clause 4.3.4(h).

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(h) *AEMO* must develop, and may amend, guidelines for *power system* stability but only in consultation with *Registered Participants* in accordance with the *Rules consultation procedures*, and must *publish* the guidelines for *power system* stability.

(i) The *power system* stability guidelines developed in accordance with clause 4.3.4(h) must detail the policies governing *power system* stability so as to facilitate the operation of the *power system* within stable limits.

(j) Each *Network Service Provider* must provide the information required by clause S5.3.1(a1) to *AEMO* in respect of any alteration to any *network element* if, *AEMO's* reasonable opinion, there is a risk that the alteration to the *network element* will adversely affect *network capability*, *power system security*, quality or *reliability* of supply, inter-*regional* power transfers or the use of a *network* by another *Network User*.

5.3.9 Procedure to be followed by a Generator proposing to alter a generating system

(a) This clause 5.3.9 applies where a *Generator* proposes to alter:

(1) a *connected generating system*; or

(2) a *generating system* for which *performance standards* have been previously accepted by *AEMO*,

in a manner that will ~~affect the performance of the *generating system* relative to any of the technical requirements set out in clauses S5.2.5, S5.2.6, S5.2.7 and S5.2.8~~, in *AEMO's* reasonable opinion, ~~there is~~ pose a risk that the alteration will adversely affect *network capability*, *power system security*, quality or *reliability* of supply, inter-*regional* power transfers or the use of a *network* by another *Network User*.

(b) A *Generator* to which this clause applies, must submit to the *Network Service Provider* with a copy to *AEMO*:

(1) a description of the nature of the alteration and the timetable for implementation;

(2) in respect of the proposed alteration to the *generating system*, details of the *generating unit* design data and *generating unit* setting data in accordance with the ~~*Generating*~~ *Power System Model Guidelines*, ~~*Generating*~~ *Power System Design Data Sheet*, or ~~*Generating*~~ *Power System Setting Data Sheet*; and

(3) in relation to each relevant technical requirement for which the proposed alteration to the equipment will affect the performance of the *generating system*, the proposed amendments to:

(i) the applicable *automatic access standard*; or

(ii) a proposed *negotiated access standard*.

(c) Clause 5.3.4A applies to a submission by a *Generator* under paragraph(b)(3)(ii).

(d) Without limiting subparagraph (b)(3), for the purposes of that subparagraph (unless *AEMO* and the *Network Service Provider* otherwise agree), a proposed alteration to the equipment specified in column 1 of the table set out below is taken to affect the performance of the *generating system* relative to technical requirements specified in column 2, thereby necessitating a submission under subparagraph (b)(3).

Altered Equipment	Clause
machine windings	S5.2.5.1, S5.2.5.2, S5.2.8
power converter	S5.2.5.1, S5.2.5.2, S5.2.5.5, S5.2.5.12, S5.2.5.13, S5.2.8
reactive compensation plant	S5.2.5.1, S5.2.5.2, S5.2.5.5, S5.2.5.12, S5.2.5.13
excitation control system	S5.2.5.5, S5.2.5.7, S5.2.5.12, S5.2.5.13
voltage control system	S5.2.5.5, S5.2.5.12, S5.2.5.13
governor *control system*	S5.2.5.7, S5.2.5.11, S5.2.5.14
power *control system*	S5.2.5.11, S5.2.5.14
protection system	S5.2.5.3, S5.2.5.4, S5.2.5.5, S5.2.5.7, S5.2.5.8, S5.2.5.9
auxiliary supplies	S5.2.5.1, S5.2.5.2, S5.2.8
remote control and monitoring system	S5.2.5.14, S5.2.6.1, S5.2.6.2

(e) The *Network Service Provider* may as a condition of considering a submission made under paragraph (b), require payment of a fee to meet the reasonable costs anticipated to be incurred by the provider, other *Network Service Providers* and *AEMO*, in the assessment of the submission.

(f) The *Network Service Provider* must require payment of a fee under paragraph (e) if so requested by *AEMO*.

(g) On payment of the required fee referred to in paragraph (e), the *Network Service Provider* must pay such amounts as are on account of the costs anticipated to be incurred by the other *Network Service Providers* and *AEMO*, as appropriate.

(h) If the application of this clause 5.3.9 leads to a variation to an existing *connection agreement* the *Network Service Provider* and the *Generator* must immediately jointly advise *AEMO*.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

5.7.6 Tests of generating units requiring changes to normal operation

(a) A *Network Service Provider* may, at intervals of not less than 12 months per *generating system*, require the testing by a *Generator* of any *generating unit connected* to the *network* of that provider in order to determine analytic parameters for modelling purposes or to assess the performance of the relevant *generating unit* or *generating system* for the purposes of a *connection agreement*, and that provider is entitled to witness such tests.

(b) If *AEMO* reasonably considers that:

(1) the analytic parameters for modelling of a *generating unit* or *generating system* are inadequate; or

(2) available information, including results from a previous test of a *generating unit* or *generating system*, are inadequate to determine parameters for an applicable model developed in accordance with the ~~*Generating*~~ <u>*Power*</u> *System Model Guidelines*, or otherwise agreed with *AEMO* under clause S5.2.4(c)(2),

AEMO may direct a *Network Service Provider* to require a *Generator* to conduct a test under paragraph (a), and *AEMO* may witness such a test.

(c) Adequate notice of not less than 15 *business days* must be given by the *Network Service Provider* to the *Generator* before the proposed date of a test under paragraph (a).

(d) The *Network Service Provider* must use its best endeavours to ensure that tests permitted under this clause 5.7.6 are conducted at a time which will minimise the departure from the *commitment* and *dispatch* that are due to take place at that time.

(e) If not possible beforehand, a *Generator* must conduct a test under this clause 5.7.6 at the next scheduled *outage* of the relevant *generating unit* and in any event within 9 months of the request.

Note

This clause is classified as a civil penalty provision under the National Electricity (South Australia) Regulations. (See clause 6(1) and Schedule 1 of the National Electricity (South Australia) Regulations.)

(f) A *Generator* must provide any reasonable assistance requested by the *Network Service Provider* in relation to the conduct of tests.

(f1) If requested by a *Network Service Provider* who required the test under clause 5.7.6(a), a *Generator* must provide to the *Network Service Provider* any relevant information relating to the *plant* which is the subject of a test carried out under this clause 5.7.6, including model source code provided to *AEMO* under clause S5.2.4(b)(6).

(g) Tests conducted under this clause 5.7.6 must be conducted in accordance with test procedures agreed between the *Network Service Provider* and the relevant *Generator* and a *Generator* must not unreasonably withhold its agreement to test procedures proposed for this purpose by the *Network Service Provider*.

(h) A *Generator* must provide the test records obtained from a test under paragraph (a) to the *Network Service Provider*, who must derive the analytical parameters for the applicable model developed in accordance with the ~~*Generating*~~ <u>*Power*</u> *System Model Guidelines*, or otherwise agreed with *AEMO* under clause S5.2.4(c)(2) and provide them and any new or revised model source code to the relevant *Generator*.

(i) The *Generator*, the *Network Service Provider* and *AEMO* must each bear its own costs associated with tests conducted under this clause 5.7.6 and no compensation is to be payable for financial losses incurred as a result of these tests or associated activities.

S5.2.4 Provision of information

(a) A *Generator* or person who is negotiating a *connection agreement* with a *Network Service Provider* must promptly on request by *AEMO* or the *Network Service Provider* provide all data in relation to that *generating system* specified in schedule 5.5.

(b) A *Generator*, or person required under the *Rules* to register as the *Generator* in respect of a *generating system* comprised of *generating units* with a combined *nameplate rating* of 30 MW or more, by the earlier of:

(1) the day on which an *application to connect* is made under clause 5.3.4(a);

(2) the day on which amendments to *performance standards* are submitted under rule 4.14(p) or clause 5.3.9(b);

(3) three months before commissioning of a *generating system* or planned alteration to a *generating system*; or

(4) 5 *business days* before commissioning of a *generating system* alteration that is repairing *plant* after a *plant* failure, if *plant* performance after the alteration will differ from performance prior to the *plant* failure,

must provide:

(5) to *AEMO* and the relevant *Network Service Providers* (including the relevant *Transmission Network Service Provider* in respect of an *embedded generating unit*) the following information about the *control systems* of the *generating system*:

(i) a set of functional block diagrams, including all functions between feedback signals and *generating system* output;

(ii) the parameters of each functional block, including all settings, gains, time constants, delays, deadbands and limits; ~~and~~

(iii) the characteristics of non-linear elements~~,~~; and

(iv) encrypted models in a form suitable for the software simulation products nominated by *AEMO*,

with sufficient detail for *AEMO* and *Network Service Providers* to perform load flow and dynamic simulation ~~studies~~;

(5A) to *AEMO*, all data required to perform specialised *power system* studies based on electromagnetic transient simulation analysis if:

(i) the *generating system* includes power electronic interfaced technologies:

a. at the *transmission system* level; or

b. at the *distribution system* level where the installed capacity of the *plant* to be installed is greater than 10% of the available fault level; or

(ii) in *AEMO's* reasonable opinion, there is a risk that the *generating system* will adversely affect other *Network Users*, *power system security* or quality or *reliability of supply* of the *power system*.

(6) to *AEMO*, model source code associated with the load flow and dynamic simulation model in subparagraph (5) in an unencrypted form suitable for at least one of the software simulation products nominated by *AEMO* and in a form that would allow conversion for use with other software simulation products by *AEMO*;

(7) **[Deleted]**

(8) to *AEMO* and the relevant *Network Service Providers* (including the relevant *Transmission Network Service Provider* in respect of an *embedded generating unit*) a *releasable user guide*.

(c) The information provided under paragraph (b) must:

(1) encompass all *control systems* that respond to *voltage* or *frequency* disturbances on the *power system*, and which are either integral to the *generating units* or otherwise part of the *generating system*, including those applying to *reactive power* equipment that forms part of the *generating system*; and

(2) conform with the applicable models developed in accordance with the ~~*Generating*~~ *Power System Model Guidelines*, or an alternative model agreed with *AEMO* to be necessary to adequately represent the *generating plant* to carry out load flow and dynamic simulations and (where applicable) specialised *power system* studies.

(d) The *Generator* must provide to *AEMO* information that updates the information provided under clause S5.2.4(b) and must provide to the relevant *Network Service Providers* information that updates the information provided under clause S5.2.4(b)(5):

(1) within 3 months after commissioning tests or other tests undertaken in accordance with clause 5.7.3 are completed;

(2) when the *Generator* becomes aware that the information is incomplete, inaccurate or out of date; or

(3) on request by *AEMO* or the relevant *Network Service Provider*, where *AEMO* or the relevant *Network Service Provider* considers that the information in incomplete, inaccurate or out of date.

(d1) A *Generator* is only required to provide new information under clause S5.2.4(d) to the extent that it is different to the information previously provided under clause S5.2.4(b).

(e) For the purposes of clause S5.2.4(e1), a *Connection Applicant* must be registered as an *Intending Participant* in accordance with rule 2.7.

(e1) For the purposes of clause 5.3.2(f), the technical information that a *Network Service Provider* must, if requested, provide to a *Connection Applicant* in respect of a proposed *connection* for a *generating system* includes:

(1) the highest expected single phase and three phase fault levels at the *connection point* with the *generating system* not *connected*;

(2) the clearing times of the existing *protection systems* that would clear a fault at the location at which the new *connection* would be *connected* into the existing *transmission system* or *distribution system*;

(3) the expected limits of *voltage* fluctuation, harmonic *voltage* distortion and *voltage* unbalance at the *connection point* with the *generating system* not *connected*;

(4) technical information relevant to the *connection point* with the *generating system* not *synchronised* including equivalent source impedance information, sufficient to estimate fault levels, *voltage* fluctuations, harmonic *voltage* distortion (for harmonics relevant to the *generating system*) and *voltage* unbalance; and

(5) information relating to the performance of the *national grid* that is reasonably necessary for the *Connection Applicant* to prepare an *application to connect*, including:

(i) a model of the *power system*, including relevant *considered projects* and the range of expected operating conditions, sufficient to carry out load flow and dynamic simulations; and

(ii) information on *inter-regional* and *intra-regional power transfer capabilities* and relevant *plant* ratings.

(f) All information provided under this clause S5.2.4 must be treated as *confidential information*.

S5.3.1 Information

(a) Before a *Network User connects* any new or additional equipment to a *network*, the *Network User* must submit the following kinds of information to the *Network Service Provider*:

(1) a single line diagram with the protection details;

(2) *metering system* design details for any metering equipment being provided by the *Network User*;

(3) a general arrangement locating all the equipment on the site;

(4) a general arrangement for each new or altered *substation* showing all exits and the position of all electrical equipment;

(5) type test certificates for all new switchgear and *transformers*, including measurement *transformers* to be used for *metering* purposes in accordance with Chapter 7 of the *Rules*;

(6) earthing details;

(7) the proposed methods of earthing cables and other equipment to comply with the regulations of the relevant *participating jurisdiction*;

(8) *plant* and earth grid test certificates from approved test authorities;

(9) a secondary injection and trip test certificate on all circuit breakers;

(10) certification that all new equipment has been inspected before being *connected* to the *supply*; and

(11) operational arrangements.

(a1) Before a *Network User connects* any new or additional equipment to a *network* that is intended to consume or use in excess of 20,000 MWh per annum, the *Network User* must submit the following kinds of information to *AEMO* about the *control systems* of the equipment:

(1) a set of functional block diagrams, including all functions between feedback signals and output;

(2) the parameters of each functional block, including all settings, gains, time constants, delays, deadbands and limits;

(3) the characteristics of non-linear elements; and

(4) encrypted models in a form suitable for the software simulation products nominated by *AEMO*,

with sufficient detail for *AEMO* to perform load flow and dynamic simulation.

(b) For the purposes of clause 5.3.2(f) of the *Rules*, the technical information that a *Network Service Provider* must, if requested, provide to a *Connection Applicant* in respect of the proposed *connection* includes:

(1) the highest expected single phase and three phase fault levels at the *connection point* without the proposed *connection*;

(2) the clearing times of the existing *protection systems* that would clear a fault at the location at which the new *connection* would be connected into the existing *transmission system* or *distribution system*;

(3) the expected limits of *voltage* fluctuation, harmonic *voltage* distortion and *voltage* unbalance at the *connection point* without the proposed *connection*;

(4) technical information relevant to the *connection point* without the proposed *connection* including equivalent source impedance information, sufficient to estimate fault levels, *voltage* fluctuations, harmonic *voltage* distortion and *voltage* unbalance; and

(5) any other information or data not being *confidential information* relating to the performance of the *Network Service Provider's facilities* that is reasonably necessary for the *Connection Applicant* to prepare an *application to connect*;

except where the *Connection Applicant* agrees the *Network Service Provider* may provide alternative or less detailed technical information in satisfaction of this clause S5.3.1.(b).

Schedule 5.5 Technical Details to Support Application for Connection and Connection Agreement

S5.5.2 Categories of data

Data is coded in categories, according to the stage at which it is available in the build-up of data during the process of forming a *connection* or obtaining access to a *network*, with data acquired at each stage being carried forward, or enhanced in subsequent stages, eg. by testing.

Preliminary system planning data

Preliminary system planning data is required for submission with the *application to connect*, to allow the *Network Service Provider* to prepare an offer of terms and conditions for a *connection agreement* and to assess the requirement for, and effect of, *network augmentation* or *extension* options. Such data is normally limited to the items denoted as Standard Planning Data (S) in the ~~*Generating*~~*Power System Model Guidelines*, ~~*Generating*~~*Power System Design Data Sheet*, ~~*Generating*~~*Power System Setting Data Sheet* and in schedules 5.5.3 to 5.5.5.

The *Network Service Provider* may, in cases where there is reasonable doubt as to the viability of a proposal, require the submission of other data before making an offer to *connect* or to amend a *connection agreement*.

Registered system planning data

Registered system planning data is the class of data which will be included in the *connection agreement* signed by both parties. It consists of the preliminary system planning data plus those items denoted in the attached schedules as Detailed Planning Data (D). The latter must be submitted by the *Registered Participant* in time for inclusion in the *connection agreement*.

Registered data

Registered Data consists of data validated and agreed between the *Network Service Provider* and the *Registered Participant*, such data being:

(a) prior to actual *connection* and provision of access, data derived from manufacturers' data, detailed design calculations, works or site tests etc. (R1); and

(b) after connection, data derived from on-system testing (R2).

All of the data will, from this stage, be categorised and referred to as Registered Data; but for convenience the schedules omit placing a higher ranked code next to items which are expected to already be valid at an earlier stage.

S5.5.4 Data Requirements

Schedules 5.5.3 to 5.5.5 cover the following data areas:

(a) schedule 5.5.3 - Network Plant Technical Data. This comprises fixed electrical parameters.

(b) schedule 5.5.4 - Plant and Apparatus Setting Data. This comprises settings which can be varied by agreement or by direction of the *Network Service Provider* or *AEMO*.

(c) schedule 5.5.5 - *Load* Characteristics. This comprises the estimated design parameters of *loads*.

The documents and schedules applicable to each class of *Registered Participant* are as follows:

(a) *Generators*: the *~~Generating~~Power System Model Guidelines*, *~~Generating~~Power System Design Data Sheet* and *~~Generating~~Power System Setting Data Sheet*;

(b) *Customers* and *Network Service Providers*: schedules 5.5.3 and 5.5.4; and

(c) *Customers*: schedule 5.5.5.

S5.5.5 Asynchronous generating unit data

A *Generator* that *connects* a *generating system*, that is an *asynchronous generating unit*, must be given exemption from complying with those parts of the *~~Generating~~ Power System Model Guidelines*, *~~Generating~~ Power System Design Data Sheet* and *~~Generating~~ Power System Setting Data Sheet* that are determined by the *Network Service Provider* to be not relevant to such *generating systems*, but must comply with those parts of schedules 5.5.3, 5.5.4, and 5.5.5 that are relevant to such *generating systems*, as determined by the *Network Service Provider*.

S5.5.6 Generating units equal to or smaller than 30MW data

A *Generator* that *connects* a *generating unit* equal to or smaller than 30 MW or a number of *generating units* totalling less than 30 MW to a *connection point* to a *distribution network* will usually be required to submit less registered system planning data and less registered data than is indicated in the *~~Generating~~ Power System Model Guidelines*, *~~Generating~~ Power System Design Data Sheet* and *~~Generating~~ Power System Setting Data Sheet*. In general these data will be limited to confirmation of the preliminary system planning data, marked (S), but other data must be supplied if reasonably required by the *Network Service Provider* or *AEMO*.

Codes:

S = Standard Planning Data

D = Detailed Planning Data

R = Registered Data (R1 pre-*connection*, R2 post-*connection*)

S5.5.7 ~~Generating~~ Power System Design Data Sheet, ~~Generating~~ Power System Setting Data Sheet and ~~Generating~~ Power System Model Guidelines

(a) *~~NEMMCO~~AEMO* must, subject to paragraph (b), develop, ~~and~~ *publish* and maintain ~~by 1 March 2008,~~ in accordance with the *Rules consultation procedures*:

(1) a *~~Generating~~Power System Design Data Sheet* describing, for relevant *plant* technologies, *plant* ~~the *generating system*~~ design parameters, ~~of *generating units* and *generating systems*~~ including *plant* configurations, impedances,

time constants, non-linearities, ratings and capabilities, to be provided under clauses S5.2.4, S5.3.1 and this schedule 5.5;

(2) a ~~Generating~~Power System Setting Data Sheet describing, for relevant ~~generation and control~~ power system technologies, the power system protection system and control system functions and their settings, ~~of generating units and generating systems~~ including configurations, gains, time constants, delays, deadbands, non-linearities and limits, to be provided under clauses S5.2.4 and this schedule 5.5; and

(3) ~~Generating~~Power System Model Guidelines describing, for relevant ~~generation and control~~ power system technologies, ~~NEMMCO~~AEMO's requirements when developing mathematical models for plant ~~generating units and generating systems~~, including the impact of their control systems and protection systems on power system security,.

~~and there must be a Generating System Design Data Sheet, Generating System Setting Data Sheet and Generating System Model Guidelines in place at all times after that date.~~

(b) When developing, ~~and~~ publishing and maintaining the Power~~Generating~~ System Design Data Sheet, Power~~Generating~~ System Setting Data Sheet and Power~~Generating~~ System Model Guidelines ~~under paragraph (a)~~, ~~NEMMCO~~AEMO must have regard to the purpose of ~~developing and publishing~~ the sheets and guidelines, which is to:

(1) allow plant ~~generating units and generating systems~~ to be mathematically modelled by ~~NEMMCO~~AEMO ~~in load flow and dynamic stability assessments~~ with sufficient accuracy to permit:

(i) the power system operating limits for ensuring power system security to be quantified with the lowest practical safety margins;

(ii) proposed access standards and performance standards ~~of generating units and generating systems~~ to be assessed; and

(iii) settings of control systems and protection systems of ~~generating units, generating systems~~ plant and networks to be assessed and quantified for maximum practical performance of the power system; and

(2) identify for each type of data its category in terms of clause S5.5.2.

(c) Any person may submit a request (with written reasons) to AEMO to amend the ~~Generating~~Power System Design Data Sheet, ~~Generating~~Power System Setting Data Sheet or the ~~Generating~~Power System Model Guidelines and AEMO must conduct the Rules consultation procedures in relation to the request.

(d) AEMO can make amendments requested under paragraph (c) or otherwise to the ~~Generating~~Power System Design Data Sheet, ~~Generating~~Power System Setting Data Sheet or the ~~Generating~~Power System Model Guidelines without conducting the Rules consultation procedures if the amendment is minor or administrative in nature.

(e) *AEMO* may at the conclusion of the *Rules consultation procedures* under paragraph (c) or otherwise under paragraph (d), amend the relevant data sheet or guidelines (if necessary).

Schedule 5.5.3 Network and plant technical data of equipment at or near connection point

Data Description	Units	Data Category
Voltage Rating		
Nominal *voltage*	kV	S, D
Highest *voltage*	kV	D
Insulation Co-ordination	kVp	D
Rated lightning impulse withstand *voltage*		
Rated short duration power *frequency* withstand *voltage*	kV	D
Rated Currents		
Circuit maximum current	kA	S, D
Rated Short Time Withstand Current	kA for seconds	D
Ambient conditions under which above current applies	Text	S,D
Earthing		
System Earthing Method	Text	S, D
Earth grid rated current	kA for seconds	D
Insulation Pollution Performance		
Minimum total creepage	mm	D
Pollution level	Level of IEC 815	D
Controls		
Remote control and data transmission arrangements	Text	D
Metering Provided by Customer		
Measurement *transformer* ratios:		D
Current transformers	A/A	D
Voltage transformers	V/kV	D
Measurement *Transformer* Test Certification details	Text	R1
Network Configuration		
Operation Diagrams showing the electrical circuits of the existing and proposed main *facilities* within the *Registered Participant's* ownership including *busbar* arrangements, phasing arrangements, earthing arrangements, switching *facilities* and operating *voltages.*	Single line Diagrams	S, D, R1
Network Impedance		
For each item of *plant*:	% on 100 MVA base	S, D, R1
details of the positive, negative and zero sequence series and shunt impedance, including mutual coupling between physically adjacent elements.		
Short Circuit Infeed to the Network		
Maximum generator 3-phase short circuit infeed including infeeds from *generating units connected* to the *Registered Participant's* system, calculated by method of AS 3851 (1991).	kA symmetrical	S, D, R1

Data Description	Units	Data Category
The total infeed at the instant of fault (including contr bution of induction motors).	kA	D, R1
Minimum zero sequence impedance of *Registered Participant's network* at *connection point*.	% on 100 MVA base	D, R1
Minimum negative sequence impedance of *Registered Participant's network* at *connection point*.	% on 100 MVA base	D, R1
Load Transfer Capability:		
Where a *load*, or group of *loads*, may be fed from alternative *connection points*:		
Load normally taken from *connection point* X	MW	D, R1
Load normally taken from *connection point* Y	MW	D, R1
Arrangements for transfer under planned or fault *outage* conditions	Text	D
Circuits Connecting Embedded Generating Units to the Network:		
For all *generating units*, all connecting lines/cables, *transformers* etc.		
Series Resistance	% on 100 MVA base	D, R
Series Reactance	% on 100 MVA base	D, R
Shunt Susceptance	% on 100 MVA base	D, R
Normal and short-time emergency ratings	MVA	D, R
Technical ~~D~~details of *plant* ~~*generating units* and *generating systems*~~ as per the *Power* ~~*Generating*~~ *System Design Data Sheet*, *Power* ~~*Generating*~~ *System Setting Data Sheet* and the *Power* ~~*Generating*~~ *System Model Guidelines* where such details are not *confidential information*		
***Transformers* at *connection points*:**		
Saturation curve	Diagram	R
Equipment associated with DC Links		
Number of poles	MVA	D, R
Converters per station	Quantity	D, R
Reactive Power consumption of converters	MCAr	D, R
Location and Rating of A.C. Filters	MVAr	D, R
Location and Rating of Shunt Capacitors	MVAr	D, R
Location and Rating of Smoothing *Reactor*	MVAr	D, R
Location and Rating of DC Filter	MVAr	D, R

ABBREVIATIONS

Term	Definition
AEMO	Australian Energy Market Operator
AUFLS	Adaptive Under-Frequency Load Shedding Scheme
EMT	Electromagnetic transients
FCAS	*Frequency* control *ancillary services*
HVDC	High voltage direct current
OLTC	Onload tap changer
NEM	National Electricity Market
NSCAS	Network Support and Control Ancillary Service
NSP	*Network Service Provider*
PMRG	Plant Modelling Reference Group
RIT-T	*Regulatory investment test for transmission*
RMS	Root mean square
SCR	Short-circuit ratio
SRAS	*System restart ancillary services*
TNSP	*Transmission Network Service Provider*