# POWER SYSTEM MODEL GUIDELINES

## DRAFT REPORT AND DETERMINATION

Published: **14 May 2018**

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

# NOTICE OF SECOND STAGE CONSULTATION – POWER SYSTEM MODEL GUIDELINES

## National Electricity Rules – Rule 8.9

## Date of Notice: 14 May 2018

This notice informs all Registered Participants and interested parties (**Consulted Persons**) that AEMO is commencing the second stage of its consultation on the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet*.

This consultation is being conducted under clause S5.5.7 of the National Electricity Rules (**NER**), in accordance with the Rules consultation requirements detailed in rule 8.9 of the NER.

## Invitation to make Submissions

AEMO invites written submissions on this Draft Report and Determination (**Draft Report**).

Please identify any parts of your submission that you wish to remain confidential, and explain why. AEMO may still publish that information if it does not consider it to be confidential, but will consult with you before doing so.

Consulted Persons should note that material identified as confidential may be given less weight in the decision-making process than material that is published.

## Closing Date and Time

Submissions in response to this Notice of Second Stage of Rules Consultation should be sent by email to ModelGuidelines@aemo.com.au, to reach AEMO by 5.00pm (Melbourne time) on **29 May 2018.**

All submissions must be forwarded in electronic format (both pdf and Word). Please send any queries about this consultation to the same email address.

Submissions received after the closing date and time will not be valid, and AEMO is not obliged to consider them. Any late submissions should explain the reason for lateness and the detriment to you if AEMO does not consider your submission.

## Publication

All submissions will be published on AEMO's website, other than confidential content.

# EXECUTIVE SUMMARY

The publication of this Draft Report and Determination (**Draft Report**) commences the second stage of the consultation conducted by AEMO to develop the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* under the National Electricity Rules (**NER**).

The National Electricity Amendment (Generating System Model Guidelines) Rule 2017 No.11 (**Amending Rule**) will commence on 1 July 2018. Clause S5.5.7 in the Amending Rule requires AEMO to *publish* the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* in accordance with the *Rules consultation procedures*.

AEMO commenced the consultation on 5 March 2018 by *publishing* proposed Guidelines and an Issues Paper, and called for submissions. AEMO received nine submissions in response.

The submissions expressed various concerns on the proposed Guidelines, but there were three issues that AEMO regarded as material. These are summarised in the table below, together with AEMO's response:

| Issue | AEMO's response |
|---|---|
| **Cost of compliance vs benefits** | Some Consulted Persons suggested that the costs of compliance with the proposed Guidelines would far exceed the benefits. AEMO notes the multiplicity of uses to which models are put by AEMO (a factor not recognised in submissions) and considers that AEMO's ability to operate the *market* and *power system* are highly dependent on having appropriate models. Accordingly, the benefits are far greater than assumed in the submissions. Moreover, over the last two years, a number of manufacturers (**OEMs**) have developed models that are currently available for use as suggested by AEMO. |
| **Intellectual property & confidentiality of models** | AEMO recognises the sensitivity of this issue for OEMs and notes that only AEMO is entitled to source code. 'Black-boxed' models will be provided to *Registered Participants* entitled to receive models and related information under the NER. |
| **EMT vs RMS models** | Three submissions suggested that RMS models of certain plant are identical to EMT models and that there is no need for EMT models. AEMO runs large-scale studies using EMT and RMS models daily, examining phenomena that cannot be studied by using RMS models alone. Moreover, NSPs will need access to EMT models to carry out *system strength impact assessments*. |

In total, over fifty issues were raised, all of which are noted and addressed in section 4 and Appendix B.

AEMO's draft determination is to make the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* in the form *published* with this Draft Report.

# CONTENTS

# 1. STAKEHOLDER CONSULTATION PROCESS

As required by clause 5.5.7 of the NER, AEMO is consulting on the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* in accordance with the Rules consultation process in rule 8.9.

AEMO's indicative timeline for this consultation is outlined below. Future dates may be adjusted depending on the number and complexity of issues raised in submissions, although the NER require AEMO to make the Guidelines by 1 July 2018.[1].

| Deliverable | Indicative date |
|---|---|
| **Notice of First Stage Consultation and Issues Paper published** | 5 March 2018 |
| **First Stage submissions closed** | 12 April 2018 |
| **Draft Report and Determination & Notice of Second Stage Consultation published** | 14 May 2018 |
| **Submissions due on Draft Report and Determination** | 29 May 2018 |
| **Final Report and Determination published** | 29 June 2018 |

The publication of this Draft Report marks the commencement of the second stage of consultation.

A glossary of terms used in this Draft Report can be found in **Appendix A**. Italicised terms are defined in the NER.

[1] Clause 11.102 of the NER

# 2. BACKGROUND

## 2.1 NER requirements

AEMO is required by clause S5.5.7 of the NER to develop and *publish* the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet*. Clause S5.5.7 provides additional guidance to AEMO by detailing the content of these documents and the matters AEMO must take into consideration when developing these.

The relevant requirements are detailed below for the sake of completeness.

### 2.1.1 Description

Clause S5.5.7(a) describes each of these documents and their use at a high level:

(1) a *Power System Design Data Sheet* describing, for relevant *plant technologies*, *plant* design parameters including *plant* configurations, impedances, time constants, non-linearities, ratings and capabilities to be provided under clauses 3.11.5(b)(5), 3.11.9(g), 4.3.4(o), 5.2.3(j), 5.2.3(k), 5.2.3A(a), 5.2.4(c), 5.2.4(d), 5.2.5(d), 5.2.5(e), 5.3.9(b)(2), S5.2.4, S5.3.1, S5.3a.1 and this schedule 5.5;

(2) a *Power System Setting Data Sheet* describing, for relevant *power systems* and *control system* technologies, the *protection system* and *control system* functions and their settings, including configurations, gains, time constants, delays, deadbands, non-linearities and limits to be provided under clauses 3.11.5(b)(5), 3.11.9(g), 4.3.4(o), 5.2.3(j), 5.2.3(k), 5.2.3A(a), 5.2.3A(b), 5.2.4(c), 5.2.4(d), 5.2.5(d), 5.2.5(e), 5.3.9(b)(2), S5.2.4, S5.3.1, S5.3a.1 and this schedule 5.5; and

(3) *Power System Model Guidelines* describing, for relevant *power system* technologies at the *transmission system* and *distribution system* level, *AEMO's* requirements when developing mathematical models for *plant*, including the impact of their *control systems* and *protection systems* on *power system security* to be provided under clauses 3.11.5(b)(5), 3.11.9(g), 4.3.4(o), 5.2.3(j), 5.2.3(k), 5.2.3A(a), 5.2.3A(b), 5.2.4(c), 5.2.4(d), 5.2.5(d), 5.2.5(e), 5.3.9(b)(2), S5.2.4, S5.3.1, S5.3a.1 and this schedule 5.5.

### 2.1.2 Purpose

The purpose of the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* is detailed in clause S5.5.7(b), which AEMO must have regard to when developing these documents:

(1) allow *plant* and equipment to be mathematically modelled by *AEMO* 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) the assessment of proposed *negotiated access standards*;

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

  (iv) the efficient procurement of *system restart ancillary services* and *network support and control ancillary services*; and

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

### 2.1.3 Additional Matters for Consideration

Additional matters AEMO must take into consideration are detailed in clause S5.5.7(c) as follows:

(1) have regard to the reasonable costs of efficient compliance by *Registered Participants* with those guidelines and data sheets compared to the likely benefits from the use of the information provided under the guidelines and data sheets;

(2) have regard to any requirements to protect the intellectual property and confidential information of third parties, including where those third parties are not *Registered Participants*; and

(3) have regard to *Distribution Network Service Providers'* and *Transmission Network Service Providers'* requirements for data and modelling information that is reasonably necessary for the relevant provider to fulfil its obligations under the *Rules* or *jurisdictional electricity legislation.*

### 2.1.4 Content

The content of the *Power System Model Guidelines* is specified in clause S5.5.7(b1) as follows:

(1) the information, including the types of models, that:

(i) *Generators* must provide under clause 5.2.5(d), clause 5.2.5(e), clause 5.3.9(b)(2), clause S5.2.4 and clause S5.5.6;

(ii) *Network Service Providers* must provide under clause 4.3.4(o), clause 5.2.3(j) and clause 5.2.3(k);

(iii) *Network Users* must provide under clause 5.2.4(c), clause 5.2.4(d) and clause S5.3.1(a1);

(iv) *Market Network Service Providers* must provide under clause 5.2.3A(a), clause 5.2.3A(b) and clause S5.3a.1(a1);

(v) prospective *NSCAS* tenderers must provide under clause 3.11.5(b)(5); and

(vi) prospective *SRAS Providers* must provide under clause 3.11.9(g);

(2) the model accuracy requirements that are applicable to each type of model provided, as well as the types of *generating systems* and *plant* and equipment that the model accuracy requirements apply to;

(3) when information to which the *Power System Model Guidelines* relates must be provided;

(4) a process to be followed in circumstances where a person is unable to provide information required to be provided under clauses 3.11.5(b)(5), 3.11.9(g), 4.3.4(o), 5.2.3(j), 5.2.3(k), 5.2.3A(a), 5.2.3A(b), 5.2.4(c), 5.2.4(d), 5.2.5(d), 5.2.4(e), 5.3.9(b)(2), S5.2.4, S5.3.1, S5.3a.1, S5.5.6, schedule 5.5 or as otherwise required by the *Power System Model Guidelines*, *Power System Design Data Sheet* or *Power System Setting Data Sheet*;

(5) guidance on the factors that *AEMO* will take into account when determining the circumstances under which *AEMO* will request information to be provided, including the *power system* conditions that necessitate the usage of a certain type of model in order to achieve the desired level of accuracy;

(6) the format in which information must be provided and any material *AEMO* requires to assess the accuracy of information provided to it; and

(7) the circumstances in which model source code is required to be provided.

## 2.2 Context for this Consultation

The National Electricity Amendment (Generating System Model Guidelines) Rule 2017 No.11 (**Amending Rule**) will commence on 1 July 2018.[2] The transitional provisions in the Amending Rule require that AEMO commence this consultation considering the Amending Rule.

[2] The transitional provisions in Schedule 5 of the Rule commenced on 19 September 2017.

The *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* represent an evolution from the *Generating System Model Guidelines, Generating System Design Data Sheet* and the *Generating System Setting Data Sheet*, respectively.

## 2.3 First Stage Consultation

AEMO issued a Notice of First Stage Consultation on 5 March 2018 along with a draft of the proposed *Power System Model Guidelines* and a short Issues Paper.

A draft of the proposed *Power System Model Guidelines* was developed by AEMO with input from the Power System Modelling Reference Group, which included representatives from industry experts, *Network Service Providers* and AEMO. AEMO sought to:

- Leverage the practical knowledge gained since the development of the *Generating System Model Guidelines*.
- Clarify long-standing issues in the application of the *Generating System Model Guidelines*.
- Capture the modelling requirements to be able to securely operate and plan the *NEM* with a rapidly changing mix of *power system, generation* and other *plant* technologies.
- Capture the modelling requirements for the extended set of studies now required under the NER to correctly assess *plant* performance under reduced system strength conditions.

The Issues Paper covered the following:

- Data Sheets had not yet been developed, but that they would be based largely on the content of the *Power System Model Guidelines.*
- Although AEMO had made provision for exemptions from the requirement to provide some plant models, submissions were sought on any additional circumstances where the full suite of modelling information might not be required.
- Details of proposed amendments to the NSCAS Tender Guidelines and the SRAS Guideline were discussed. These amendments would be as consequential to the development of the *Power System Model Guidelines* and, for reasons of efficiency, would be made using AEMO's power to make administrative and minor changes.

AEMO received five valid written submissions in the first stage of consultation. Four late submissions were received, which AEMO has also considered.

All written submissions, minutes of meetings and issues raised in forums (excluding any confidential information) have been published on AEMO's website at: http://aemo.com.au/Stakeholder-Consultation/Consultations/Power-System-Model-Guidelines-and-System-Strength-Impact-Assessment-Guidelines.

# 3. SUMMARY OF MATERIAL ISSUES

The key material issues arising from the proposal and raised by Consulted Persons are summarised in the following table:

| No. | Issue | Raised by |
|---|---|---|
| 1. | Cost of Compliance vs Benefits | Australian Energy Council<br>Senvion |
| 2. | Intellectual Property & Confidentiality of Models | General Electric<br>Senvion |
| 3. | EMT vs RMS Models | DIgSILENT<br>General Electric<br>Senvion |

A detailed summary of issues raised by Consulted Persons in submissions, together with AEMO's responses, is contained in **Appendix B**.

AEMO also met with members of the PSMRG on 2 May 2018 to gain a better understanding of some of the issues raised in submissions. Minutes of that meeting have been published on AEMO's website at: http://aemo.com.au/Stakeholder-Consultation/Consultations/Power-System-Model-Guidelines-and-System-Strength-Impact-Assessment-Guidelines.

# 4. DISCUSSION OF MATERIAL ISSUES

## 4.1 Cost of Compliance vs Benefits

### 4.1.1 Issue and Submissions

Several submissions referred to the issue of whether the cost of compliance with the requirements of the proposed Guidelines exceeded the benefits.

Below are relevant extracts from submissions:

**Australian Energy Council**:

> The significant cost of providing the new comprehensive model requirements compared to the existing model requirements may outweigh the benefit to be obtained. While Table 2 of the proposed Guidelines sets out limited exemptions for small plant, the Guidelines as a whole are very prescriptive in terms of the model types, model requirements and model accuracy which applicants for connection to the grid must provide, and AEMO's attention is drawn to the new NER S5.5.7(c)(1), which requires AEMO to "have regard to the reasonable costs of efficient compliance by Registered Participants with those guidelines and data sheets compared to the likely benefits from the use of the information provided under the guidelines and data sheets".
>
> The cost and time needed by applicants to provide the necessary models and information may also affect the returns of new entrants and those considering capacity expansions, particularly if they result in connection delays. It is important that AEMO takes this into account when deciding the detail required from applicants for its power system modelling.
>
> It is important for AEMO to consider the costs (including market costs) to applicants of providing the requested models and information, and when making its assessment of the costs to applicants of doing so versus the benefits of AEMO obtaining the information, AEMO should be transparent in its decision-making processes. Therefore the Energy Council supports the inclusion in the Guideline of the methodology and process to be used in quantifying costs and benefits in the assessment process.

**Senvion**:

> EMT model developments are cost and labor intensive especially in case of an EMT model being required for wind turbines currently operating. Model requirements from the past and current model requirements under discussion are very different. Processes are in place to meet the current requirements for current wind turbines.

The submissions referred to in section 4.4 of this Draft Report also raise this issue, as do issues 5, 25, 39 and 50 in Appendix B.

### 4.1.2 AEMO's Assessment

AEMO has considered the reasonable costs of efficient compliance and compared that with the benefits to be obtained, and refers to its rule change request to the *AEMC* (leading to the Amending Rule) in which a number of examples were detailed.[3]

In assessing the costs of compliance against the benefit to system planning and security management, appropriate and accurate data and modelling information is not only an enduring obligation, but a necessity. The purpose of the provision of data and models is multi-faceted – the initial use to assess the suitability of proposed *plant* and its proposed *performance standards* is just one aspect. The determination of *plant* capability to achieve its *performance standards* and the ongoing management and assessment of *power system security* confirm that the provision and use of models is not just a simple hurdle between application and *connection*. Once *plant* is in service, its models are used in long-term *power system* planning, assessment of new proposed *connections*, development of *constraint* equations, procurement of *ancillary services*, short-term operational planning and incident investigations, and in real-time operations through stability assessment tools. Given this ongoing use of *power system* models and data, and the criticality of their accuracy, any associated cost to the *market* must be considered over the

[3] https://www.aemc.gov.au/sites/default/files/content/3799ab08-dd3d-49b4-b171-8e4ad631e860/Rule-change-request.pdf.

lifetime of the *plant* rather than focusing on a certain stage, such as the negotiation of proposed *performance standards*.

AEMO also notes that both the RMS and EMT-type models of *asynchronous plant* have been provided to AEMO by several OEMs, and their capability has been growing rapidly over the past two years. In many cases, OEMs not only already have the required models, but use them for their internal design studies. An approach adopted by a growing number of OEMs is that the *power system* simulation model is a one-to-one dump of *plant* control code. This infers no manual intervention in the development of the *power system* simulation models, and makes the model updates very straightforward.

AEMO has achieved significant savings to date by being able to conduct more detailed analyses in the procurement of *ancillary services* and in the avoidance of *major supply disruptions*.

In each case, AEMO considers the cost of developing appropriate models for various studies in light of the technical benefit to be gained, which is then considered in light of what is likely to be of benefit in the longer term to consumers. Factors considered to assess whether additional models and data are required for existing *plant* include the age of the *plant*, technology used and whether supported by an existing OEM, total installed capacity across the *NEM*, and *adverse system security impact* due to lack of more accurate models and data. For example, AEMO may grant exemption from the requirement to provide EMT models for a wind farm whose plant is based on 20-year-old obsolete technology, if the total installed capacity of wind farms based on this technology is limited across the *NEM,* e.g. less than 30 MW.

Lastly, in response to the AEC's comment on accuracy requirements, AEMO notes that the proposed *Power System Model Guidelines* prescribe more relaxed and flexible accuracy requirements compared to the *Generating System Model Guidelines*.

### 4.1.3 AEMO's Conclusion

AEMO does not propose to make any changes to the proposed Guidelines specifically to address the issue of cost vs benefit.

## 4.2 Intellectual Property & Confidentiality of Models

### 4.2.1 Issue and Submissions

Two OEMs raised issues around the protection of their intellectual property rights and the need for confidentiality in the sharing of models and related information.

Below are relevant extracts from submissions:

**General Electric**:

> Section 5.4.2: Additional requirements for frequency stability studies
>
> "include any mechanical actuator limits e.g. fuel valve open/close rate of change limits, pitch limits, open/close position limits, exhaust temperature limits, internal turbine limits, active power limits or other physical limits within the control system that cause a limit on power output and/or fuel flow;"
>
> Information on, exhaust temperature limits, internal turbine limits, etc. are proprietary design know-how and protected intellectual property. This type of information cannot be provided without further understanding what is the purpose of such requests and preference is to provide a black box type function.
>
> …
>
> Section 5.4.8: RMS model source code
>
> There are instances for which a source code, or part of it, cannot be disclosed in an unencrypted/open format (e.g. if controller, or portion of it, is protected by IP rights, etc.). Exceptions and allowance for black box or simplified model should be granted for such cases.
>
> If models provided by an OEM are under a Non-disclosure agreement, the OEM must agree to the release of the models to any third parties. Alternatively, the Generator should be able to provide a black box model in situations where this model is required to be released to other Connection Applicants, ie. other Participants.

**Senvion**:

> The EMT models are IP restricted and not to be shared with third parties without consent of IP holders. The current power system model guidelines stipulates the release of those information without regards of confidentiality. E.g. original source code request.
>
> A separate NDA with between the third party and Senvion must be signed. The release of the EMT model must be done by the manufacturer. Market participants who are our competitors or competitors of sub supplier must be excluded from model provision.

### 4.2.2 AEMO's Assessment

AEMO is entitled to obtain models and other information, including unencrypted source code, about *plant connected* to, or about to be *connected* to, the *national grid*. Although that information is required from *Registered Participants* and *Connection Applicants*, AEMO recognises that it comes from OEMs, sometimes directly, and AEMO accepts the models and other information from the OEMs as the relevant *Registered Participant's* or *Connection Applicant's* agent.

The framework in the NER around the provision of models and related information is as follows:

- AEMO is entitled to obtain data it requires from *Registered Participants* and *Connection Applicants* for various purposes under various provisions in the NER, such as under clause S5.2.4 in the case of *Generators* and *Connection Applicants* seeking the *connect* new *generation* to the *national grid*.
- AEMO is entitled to the source code associated with models of *plant* to be *connected* to the *national grid* in an unencrypted form under clause 4.3.4(o)(2), S5.2.4(b)(6), S5.3.1(a1)(2)(iv) and S5.3a.1(a) of the NER. For EMT models AEMO accepts encrypted models, provided they meet the requirements set out in *Power System Model Guidelines*.
- *Registered Participants* are entitled to request specified parts of those models and other information AEMO holds under clause 3.13.3(k) of the NER to assist them in carrying out *power system* studies. Other provisions in clause 3.13.3 regulate how that information may be disseminated by AEMO and which information is *confidential information*. For example, *Registered Participants* are not entitled to receive unencrypted source code.

That is the law in the *NEM*. In that context, non-disclosure agreements are unnecessary and create the potential for conflict with the legal framework.

In response to specific comments made in the submissions:

- AEMO's obligations as to confidentiality are addressed in section 54 of the *National Electricity Law* and *Registered Participants'* obligations are addressed in clause 8.6 of the NER.
- Anyone who an OEM considers to be a competitor but who is also a *Registered Participant* has a legal right to obtain certain models and other information that the OEM considers to be proprietary, and AEMO has no power to deny that information to that *Registered Participant*.
- Models provided to AEMO intended to be provided to NSPs and other *Registered Participants* can be 'black-boxed', as permitted by clause 3.13.3(l)(2) of the NER.

### 4.2.3 AEMO's Conclusion

AEMO will continue to seek and disseminate models and related information in accordance with the NER. As comprehensive legal frameworks exist to protect intellectual property rights and confidential information, AEMO does not propose any changes to the proposed Guidelines on these issues.

AEMO notes that provision of source code for RMS models to AEMO only is acceptable, and consistent with existing practice.

## 4.3 RMS vs EMT Models

### 4.3.1 Issue and Submissions

Some submissions suggested that RMS models might, in certain circumstances, be adequate for AEMO's purposes and so EMT-type models should not be required as it imposes an unnecessary expense on *Registered Participants* and *Connection Applicants*.

Below are relevant extracts from submissions:

**DIgSILENT**:

Section 2.1:

> *"Furthermore, a Generator who has previously provided adequate RMS models and associated information to AEMO will be required to provide up-to-date EMT models if required by an NSP who carries out a system strength impact assessment, as these are the only types of models that will result in an accurate assessment."*

It is certainly correct that EMT models could show responses that cannot be accurately simulated in an RMS environment. In the case of synchronous machines, the RMS and EMT models are identical. Modelling the control systems in EMT will likely provide no benefit because of their time constants. An EMT model of a synchronous machine is thus an additional and, arguably, unnecessary cost on synchronous generating systems. It would be helpful if there was some form of analytical support demonstrating the inadequacy of existing synchronous generator models.

Section 4.1:

> *"The second type is the three-phase RMS model where all three-phases, hence the resultant sequence components are accounted for. This would not, however, have any impacts on other general capabilities/ limitations of the RMS-type models described below."*

This statement hides the fact that there are also software specific limitations in accurately modelling three-phase systems.

Section 4.1.3:

> *"However, very short-term, sub-transient phenomena in either the network or connected plant, with response times shorter than an AC cycle, cannot be adequately represented with an RMS model, and phenomena exhibited by RMS models on such short time scales are not necessarily reflective of real-world behaviour."*

DIgSILENT strongly agrees with this statement. The question is when do we need to consider the sub-transient phenomena in our studies.

**General Electric**:

Section 2.1 states the following:

> *"Furthermore, a Generator who has previously provided adequate RMS models and associated information to AEMO will be required to provide up-to-date EMT models if required by an NSP who carries out a system strength impact assessment, as these are the only types of models that will result in an accurate assessment."*

EMT type model for existing plants involves substantial amount of investment and effort to develop due to unavailability of data requiring, in some instances, on-site testing. There is a considerable cost for the Generator/OEM if such EMT models are requested.

…

Appendix C. modelling component requirements - C.6 Synchronous machines and generators

AEMO's need for EMT transient stability simulations is fully understood, given the increasing number of converter-based generation connected to the Australian grid. For conventional generation technology though, RMS models are generally adequate to represent the plant dynamic behavior. Particularly for turbine/governor systems, the dynamic response is time-decoupled from fast phenomena normally captured by EMT simulations; adding them to an EMT simulation would significantly increase the computation time, especially on a system-wide model.

We appreciate an EMT model of conventional power plant's components might be necessary in some instances but, given the cost and effort to put together these models, these circumstances should be evaluated carefully and the EMT model be requested only if strictly necessary.

…

General comments and suggestions

Many of the proposed requirements have a significant cost impact on new generation and might put manufacturers in a difficult position.

Many types of the control equipment use only the RMS & sequence values. This is correct for Governors, PSS, Excitation and Excitation limiters, etc. Furthermore, some of this equipment operate a discrete control based on a certain time step. This type of equipment can be modelled only by RMS-type models. However, these RMS-type models can be implemented in both RMS-analysis and EMT-analysis software. Implementation in the EMP-analysis software do not add any accuracy on the top of the purely RMS-analysis. Classifying this type of models as EMT might be a bit mis-leading.

AEMO may consider a more flexible re-use of the RMS-type models in both types of analysis. For example, for more efficient cost sharing between all involved parties, more flexible interfaces for inclusion of the RMS-models into EMT-analysis software may be developed, e.g. by AEMO initiative. Another option is co-simulation platforms for more efficient running of purely EMT-processes versus purely RMS-models.

We believe the overall development may benefit from more alternatives in cost-benefit options.

**Senvion**:

EMT models are required for different type of studies

We agree that different type of studies require different type of models. We propose that AEMO specifies clearer the study requirements and validation methods. We have years of experience to be able to propose a model to meet AEMO's requirements for specific studies.

EMT specific models can only be example guidance models and not prescriptive requirements to secure high quality of results from studies under consideration of wind turbines designs.

### 4.3.2 AEMO's Assessment

#### RMS vs EMT models of synchronous machines and associated control systems

AEMO agrees with the statement that RMS and EMT models of *synchronous* machines may be identical, however, when AEMO uses a *synchronous* machine model, AEMO does not consider it in isolation. AEMO needs to consider it in the context of a full system model, which is based on both RMS and EMT models. A piecemeal approach with some models in EMT and some others in RMS is not an option.

#### EMT models for existing plant

Section 4.1.2 highlights the considerations AEMO will take into account when assessing whether an EMT model for existing *plant* is required.

AEMO notes that the requirement for EMT models of *synchronous* machines largely applies to new and modified *plant*. This is because AEMO has developed many *synchronous* machine models located in various *regions*. In these circumstances, AEMO does not require provision of EMT models, but will require EMT models from *Registered Participants* where the level of data provided previously is insufficient for AEMO to develop the necessary EMT models.

It is also noted that the ''do no harm'' policy that underpins the *system strength impact assessment guidelines* means that the *Generator* for a new or modified *generation system* must ensure that their *connection* does not adversely impact the performance of an existing *plant*. Provision of accurate EMT models for existing *plant* will ensure that any such adverse impacts are identified early, so that existing *plant* is protected against unintended *disconnection* or damage.

#### Consideration of sub-transient phenomena

AEMO's submission[4] to the AEMC's initiation of the rule change on *Generating System Model Guidelines* includes practical examples where the use of EMT simulation models that correctly capture the fast

[4] https://www.aemc.gov.au/sites/default/files/content/0f5595e7-b976-4159-b471-6cdc5fd376f0/AEMO.pdf

control of power electronics used in *asynchronous plant* is critical. It is noted that all these phenomena relate to *power system* stability rather than insulation coordination and switching and lightning transients.

Additionally, EMT models are used for analysing slower transients. An example is the adverse interaction of several *asynchronous plant* due to low *frequency* control interaction and associated instabilities. Results obtained from corresponding EMT simulation studies indicate that RMS models will fail to predict such adverse interactions due to their inability to accurate represent the control of power electronics.

### 4.3.3 AEMO's Conclusion

Large-scale *power system* studies using EMT models are conducted by AEMO on a day-to-day basis focusing on both conventional *power system* stability problems (referred to as sub-transient phenomena), and slower transients and interactions not predicted by RMS simulation. To perform these studies, there is a need to access models of both *synchronous* and *asynchronous plant*, for both existing and new/modified *plant*.

Furthermore, NSPs undertaking *system strength impact assessments* will need accurate models of both existing and new/modified *plant* to ensure that the performance of existing *plant* is not adversely impacted by a new or modified *connection*.

# 5. OTHER MATTERS

## 5.1 Deletion of section 4

Most of section 4 of the proposed Guidelines was included to provide context to readers who might have been unfamiliar with some of the concepts. The submissions, however, indicate that most of the content did not add value to Consulted Persons' understanding of the issues and AEMO has determined to delete most of section 4.

The section on mid- and long-term dynamics was retained and moved to the new section 4.3.1.

## 5.2 Corrections

AEMO has made several corrections to the proposed Guidelines as follows:

- Improvements to express some concepts more clearly.
- Cross-referencing errors.

For ease of reading, typographical, punctuation, formatting and italicisation corrections are not change-marked.

## 5.3 NSCAS Tender Guidelines and SRAS Guideline

For completeness, no issues were raised on AEMO's proposed consequential changes to the NSCAS Tender Guidelines and the *SRAS Guideline*.

# 6. DRAFT DETERMINATION

Having considered the matters raised in submissions, AEMO's draft determination is to:

- make the *Power System Model Guidelines, Power System Design Data Sheet* and the *Power System Setting Data Sheet* in the form *published* with this Draft Report in accordance with clause S5.5.7 of the NER;
- amend the NSCAS Tender Guidelines and *SRAS Guideline* in the form published with this Draft Report in accordance with clause 3.11.5(d) and 3.11.7(g) of the NER, respectively.

# APPENDIX A - GLOSSARY

| Term or acronym | Meaning |
|---|---|
| **Amending Rule** | National Electricity Amendment (Generating System Model Guidelines) Rule 2017 No.11. |
| **Data Sheets** | The *Power System Design Data Sheet* and *Power System Setting Data Sheet*, collectively. |
| **Draft Report** | This document. |
| **DER** | Distributed energy resources. |
| **Disturbance** | See the proposed Guidelines. |
| **DNSP** | *Distribution Network Service Provider*. |
| **EMT** | Electromagnetic transients. |
| **FCAS** | *Frequency* control *ancillary services.* |
| **Guidelines** | *Power System Model Guidelines*. |
| **IEC** | International Electrotechnical Commission. |
| **NER** | National Electricity Rules. |
| **NSCAS** | *Network Support and Control Ancillary Services* |
| **NSCAS Tender Guidelines** | The guidelines *published* under clause 3.11.5(b) of the NER. |
| **NSP** | *Network Service Provider*. |
| **OEM** | Original equipment manufacturer. |
| **OPDMS** | Operations and Planning Data Management System. |
| **PSCAD™/EMTDC™** | Power Systems Computer Aided Design / Electromagnetic Transient with Direct Current |
| **PSS®E** | Power System Simulator for Engineering |
| **PSMRG** | Power System Modelling Reference Group. |
| **R2** | Registered data after *connection*, as derived from on-system testing and designated as 'R2' in the Data Sheets and as described further in clause S5.5.6 of the NER. |
| **RMS** | Root mean square. |
| **SRAS** | *System restart ancillary services*. |
| **TNSP** | *Transmission Network Service Provider*. |

# APPENDIX B - SUMMARY OF SUBMISSIONS AND AEMO RESPONSES

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 1. | Australian Energy Council, Senvion | **Cost of Compliance vs Benefits**<br>See section 4.1.1 | See sections 4.1.2 & 4.1.3. |
| 2. | General Electric, Senvion | **Intellectual Property & Confidentiality of Models**<br>See section 4.2.1. | See sections 4.2.2 & 4.2.3. |
| 3. | DIgSILENT, General Electric | **RMS vs EMT Models**<br>See section 4.3.1. | See sections 4.3.2 & 4.3.3. |
| 4. | DIgSILENT | **Software Selection**<br>The draft model guidelines emphasise the AEMO choice of software platforms, namely PSS/E and PSCAD. PSS/E is a historical tool, but PSCAD is a newly nominated AEMO software of choice. By AEMO prescribing the use of this software, it has to be understood that the entire industry is forced to adopt it. Hence, such selection should not be made without considering of alternatives and in particular the impact on industry wide productivity. As far as we know there has been no official program or process of evaluating alternative software platforms. We are therefore keen to understand why it was decided to standardise on PSCAD and what process was followed to make this selection.<br>DIgSILENT agrees that AEMO faces many new challenges due the continued changes of the NEM and in particular the uptake of renewable generation. DIgSILENT PowerFactory software is a modern platform with many unique functionalities specially developed to address these challenges. The question is if the very significant benefits of other modern software platforms were considered by AEMO prior to committing to its current selections. | AEMO's choice of PSCAD™/EMTDC™ was made because the majority of OEMs and NSPs use it and AEMO has developed full system models of South Australia and Tasmania using PSCAD™/EMTDC™. Duplication of system models in different types of software is expensive and unlikely to be in the long term interests of consumers.<br>Furthermore, while PowerFactory has EMT simulation capability, the PowerFactory models provided by many OEMs are RMS only and provide no tangible added value for EMT-type simulations.<br>It is impractical and expensive for AEMO to maintain system models in more than one format. The format is well-publicised and *Registered Participants* have not expressed any concerns about the required format.<br>AEMO and NSPs use PowerFactory for a range of studies, including power quality, protection coordination, and fault current calculation studies. Additionally, in some *regions* such as New South Wales, this tool is used for *power system* dynamic studies in addition to PSS®E and PSCAD. However, AEMO does not consider the use of all-in-one tools appropriate for analysing all *power system* phenomena, and will not be substituting PSCAD™/EMTDC™ with PowerFactory. |
| 5. | General Electric | Section 4.2.1 Transient Stability:<br>"AEMO and NSPs use PSCAD™/EMTDC™ to perform EMT studies in the NEM".<br>Not all OEM use PSCAD™/EMTDC™ to develop EMT type models and the use of this software to provide EMT type models should not be mandatory. It should be possible to provide EMT type models in other software platforms such as EMTP-RV, ATP or DigSiLENT.<br>…<br>Section 5.4.9: RMS model format<br>A manufacturer may not have access to more than one RMS-type simulation tool, and duplicating the same model in a different software has significant cost and time implications. | See AEMO's response to issue 4.<br>Some comments in this submission appear to contradict each other, and other comments discussed in section 4.3.1 that cast doubts on the usefulness of EMT models. In AEMO's experience, it is unlikely for an OEM to develop and maintain EMT models in multiple platforms and RMS models in one platform only. RMS is required by all power system operators worldwide with at least five major RMS simulation tools in use. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 6. | General Electric | **Up-to-Date Models**<br>Section 2.1 states the following:<br>*"Generators should ensure that all models and other information provided to AEMO in accordance with these Guidelines remain up to date";*<br>This requirement places a lot on the generator manufacturers side, because every time it is decided the model is not "good enough", the cost is expected to be covered by the manufacturers. | AEMO will require up-to-date models if one of the conditions referred to in section 2 of the draft Guidelines is met. That is not an arbitrary decision that a model previously provided is 'not "good enough"'.<br>AEMO also notes that both AEMO and NSPs have the power under clause 5.7.6 of the NER to require the testing by a *Generator* of any *generating unit connected* to the *network* of an NSP to determine, amongst other things, analytic parameters for modelling purposes. |
| 7. | Australian Energy Council | It is also unclear from the Issues Paper if the new model requirements would apply to existing generators which have not undertaken any plant modifications post original commissioning but are simply applying for the replacement of their connection agreement when the existing connection agreement expires. The Energy Council does not believe that this should be the case. | AEMO will still require an EMT model as well as the originally submitted RMS model in the circumstances described. In some cases, AEMO has already developed the necessary EMT models and does not require submission of an EMT model by the *Generator*. |
| 8. | Pacific Hydro | Updated models for existing participants should not trigger additional cost as participants pay for AEMO to conduct the engineering work required to operate the power system. Maintaining the system model is included in the market fees. Issues with models that occur as part of connection studies and achieving a working model should be covered by the intending participant. | The requirement to update models can arise for several reasons, only some of which will relate to an *application to connect* from a third party. The NER are silent on the cost of updating these models and AEMO has no mandate to transfer that cost to another party. The circumstances requiring submission of an updated model are set out in section 5.9 of the proposed *Power System Model Guidelines*. It is noted that the trigger for an updated model are changes made by *Registered Participants* or their OEMs to the physical *plant*, plant *control systems* or because changes are made to improve the performance of the simulation models. Accurate and up-to-date models resulting from these circumstances cannot be developed by AEMO or another *Registered Participant.* |
| 9. | Pacific Hydro | **Definition of Applicant**<br>The definition is problematic as it includes "Generators, NSPs, Network Users to whom these Guidelines apply." This captures existing participants and intending participants into the one category as if all are applying to connect. The System Model Guidelines must cover all models for the power system — not just new connections. Lumping together everyone as new participants is not suitable. This becomes problematic in the model "update" section 5.9. | The definition is driven by clause S5.5.7(b1), which means that it is not restricted to *Connection Applicants*. It designed to capture all possible types of *Registered Participant* to whom the Guidelines might apply.<br>Looking at it from the point of view of *Connection Applicants* only is to ignore the fact that AEMO now has the power to seek models and other information from *Registered Participants* in certain circumstances.<br>We are unclear as to the nature of the problem in the context of the use of the term in section 5.9. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 10. | Pacific Hydro & Tilt Renewables | **Definition of Disturbance**<br>"Disturbance" is defined as "One or more of the following, in any combination". Given that the OEMs are required to demonstrate the suitability of their models for "Disturbances", this definition is too broad. It is unlikely that a generator would be subjected to a "Disturbance" comprising a combination of all listed items.<br>Tilt Renewables thinks that the definition should be drafted as "One of the following". Should the Modelling Guidelines need to consider multiple Disturbances, it should be clearly drafted to enable the OEMs to understand which combinations are relevant and need to be considered when demonstrating the suitability of their models. | AEMO notes that section 7.1 of the *Generating System Model Guidelines,* which have been in place since 2008, require submitted models to demonstrate dynamic performance for a combination of disturbances.<br>As detailed in section 4.1.2, AEMO and NSPs use these models not only for *connection* studies, but amongst other things, to evaluate *plant* and *power system* performance following *power system* events, which can consist of multiple Disturbances, and the specific combination of Disturbances cannot be pre-determined. AEMO believes it reasonable to expect that a well-designed model will provide a correct representation of *plant* dynamic performance for more than a single event in succession, rather than being a "one-shot" variant.<br>For consistency, AEMO has amended the definition to remove the voltage vector phase shift requirement, as this will be a consequence of a Disturbance, rather than a Disturbance in its own right. Hence model and *plant* performance in response to rapid voltage vector phase shifts will still be studied. |
| 11. | Pacific Hydro | The definition of "Disturbance" contradicts that provided by AEMO to the AEMC in the document titled: "AEMO report updated proposed multiple fault withstand obligation" (p 7.) A disturbance must be singular, it cannot include 40,320 combinations of "disturbances" which is what is implied in the definition given in p 6 of the guideline. A singular "Disturbance" must remain by definition singular.<br>The inclusion of different disturbances to that provided to the AEMC is also problematic. The voltage vector phase shift is unnecessary as it will be studied in anti-islanding protection studies, and the size of changes in active power output caused by cloud cover will be dependent on the size, design and location of PV plant as to whether it would be significant. | Voltage vector phase shift is not a phenomenon solely associated with islanding. In low system strength conditions voltage vector phase shifts can occur due to various types of disturbances, including *disconnection* of a line. AEMO is aware of several *distribution-connected* and some *transmission-connected generation* utilising this protection. Additionally, this type of protection is used in *distribution networks*. The impact of this protection is not therefore limited to anti-islanding situations, and its operation can have a wider impact on system stability than that analysed by a *Generator* as part of their anti-islanding studies.<br>The reference to energy source changes (e.g. cloud cover) was included, as in the past, because AEMO has been provided with models that assume wind or solar irradiation is always 100%, and cannot be changed. AEMO needs to be sure that a causation chain can be studied that includes variations in the energy source. |
| 12. | General Electric | **Section 2: "Reasonable Opinion"**<br>The term, "in AEMO's reasonable opinion", is used in several places within the guidelines. Use of such terminology should be avoided since there are commercial and financial implications for Participants based on what AEMO deems as reasonable opinion. Alternatively, "reasonable opinion" could be a defined term where the boundaries are defined. | On each occasion this term is used, it simply reflects what is in the NER. The terminology cannot be avoided because it is embedded in the NER and forms the basis on which AEMO determines whether certain risks exist. |
| 13. | General Electric | **Section 2.1: Time for Provision of Models**<br>AEMO asks to have generator models within 15 to 20 business days in case they find it necessary under the assumptions shown in this section. The time line should be greater, and it could be anywhere between 3 to 12 months.<br>…<br>EMT type models may be requested for existing plant, however it should be noted that development of such models could take a few months to put together vs the 15-20 business days as proposed in the issues paper. | The timing requirement is not being imposed by AEMO. It is required by the NER. See the relevant provisions referred to in section 2 of the draft Guidelines. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 14. | Energy Queensland Group | **Section 2.1:**<br>Support the requirement for generators to provide their models to NSPs to enable them to perform system stability studies and ensure network security. | Noted. |
| 15. | Energy Queensland Group | **Section 2.2(a): Requirements on NSPs**<br>It is noted that NSPs will be required to provide models and other information to AEMO within specified timeframes. However, we are concerned that it will be administratively onerous to provide this information on an ad hoc basis via email. We therefore suggest that consideration is given to a mechanism to manage this obligation, for example, an annual upload into a central repository established and maintained by AEMO. | Noted. AEMO will discuss the concept of an annual or biannual upload of models with NSPs separately from this consultation. |
| 16. | General Electric | **Section 3.3: Exemptions**<br>From table 2: the first exemption from EMT says "≤5 MVA AND SCR>10", with "SCR>10" the exemption should be automatic. If that's the case, the plants impact would be MINIMAL. | Noted. AEMO proposes that exemptions will be automatic unless the *connecting* NSP advises otherwise. See the changes made to section 3.3. |
| 17. | DIgSILENT | **Section 4.1.2: Fault level**<br>*"Additionally, state-of-the-art control of power electronic converters allow for separate control of positive and negative sequence components of the fault current. Design variations exist covering intentional negative sequence injection to full cancellation."*<br>DIgSILENT strongly agrees with this statement. PowerFactory can simulate this negative sequence response in both RMS and EMT platforms. | Noted. |
| 18. | DIgSILENT | **Section 4.2.2 Switching and lightning**<br>Page 28<br>Switching and lightning phenomena are associated with plant design that are not conducted by AEMO. It is unsure why there is reference to these phenomena in the AEMO draft guidelines. | AEMO has deleted most of the previous content of section 4. This was included to provide context to readers unfamiliar with some of the concepts for the purposes of the consultation. This information has been removed, as the proposed Guidelines set out the legally binding modelling requirements on *Registered Participants*. |
| 19. | General Electric | **Section 4.2.2 Switching and lightning (German Grid Code)**<br>AEMO mentions that for temporary over voltages, the RMS model would not be able to accurately represent them if they are greater than 1.15-1.2pu. For example, this contradicts the German grid code where they accept RMS models for the analysis of OVs up to 1.3pu. | AEMO is unclear as to the relevance of the German grid code to the Guidelines, which are being developed under the NER, namely, for the *NEM*.<br>In any event, AEMO has deleted most of the previous content of section 4. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 20. | DIgSILENT | **Harmonic analysis**<br>Section 4.4 & 4.4.1:<br>*"EMT time domain models and simulations may be required for assessment of harmonic susceptibility, including de-stabilization of network operation due to harmonics.*<br>*This type of analysis is generally performed with commonly used harmonic analysis tools, which are Quasi-Steady State simulation tools. However, EMT-type models may be occasionally used to allow for more accurate representation of the harmonic performance of power electronic connected devices in time-domain, especially under low system strength conditions."*<br>EMT simulations would not be of adequate accuracy to show compliance with NSP required emission limits. For higher order harmonics individual harmonic emission limits of 0.1% are commonly found. For an EMT simulation to show individual harmonic responses of this accuracy would be remarkable. Furthermore, much work has been conducted by CIGRE [2] and Australian utilities in the use of so-called harmonic source impedance polygons that would be difficult to conduct in an EMT environment.<br>Harmonic compliance is also probabilistic in nature, considering time averages and probabilities of exceedance.<br>EMT simulations are useful in assessing harmonic susceptibility, but should ideally be conducted in conjunction with frequency scans.<br>Section 4.4.2:<br>*"When considering plant harmonic susceptibility, the level of Steady State harmonic distortion is not the main point of interest. The primary interest is the potential destabilization of the operation of plant, network components, or excitation of a system resonant frequency."*<br>It is important to identify the frequencies at which the inverter dynamic impedance and the grid impedance intersect and to ensure sufficient phase margin at these frequencies through inverter control design. A very convenient technique for assessing the risk of such harmonic instability, would be the use of steady state frequency scans of the grid. | AEMO has deleted most of the previous content of section 4.<br>AEMO agrees that EMT simulation for determining harmonic susceptibilities should be ideally conducted in conjunction with *frequency* scan tools, with the latter being used as a screening analysis to determine selected operating conditions that need to undergo detailed EMT simulation of the wider *network*. However, it is noted that the complex response of fast control of power electronics in *asynchronous plant* necessitates the use of more detailed and dynamic *frequency* scanning tools. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 21. | DIgSILENT | Is it feasible to study the sub-transient phenomena of the entire NEM grid in particular when the entire NEM load model is simplified?<br>…<br>**Section 5.2: Load model**<br>The draft guidelines do not refer to load modelling for dynamic simulations at all. It is known that dynamic load models have a very significant impact on all stability studies and therefore each and every security assessment. The data requirements here are attempting to increase the overall accuracy of models and simulation results but it is not clear why such an significant issues as load models are just ignored.<br>With the uptake of embedded PV generation at residential and commercial load level, the aggregate load models could also be expected to change adding to further uncertainties. | AEMO recognises that the industry is moving to a new paradigm whereby more accurate and appropriate models of loads and distributed energy resources (**DER**) is becoming critical for power system analysis to capture the distinct and discrete response of different types of *loads* and DER, the majority of which are interfaced through power electronics. AEMO, through the PSMRG, has started a number of projects with TNSPs, DNSPs, and academia in this area, and will publish learnings from these activities, including appropriate models of *loads* and DER, in due course.<br>AEMO notes that the purpose of the *Power System Model Guidelines* is to establish legally binding requirements on *Registered Participants*. This is not practicable in the context of *loads* and DER as they are not generally owned or directly operated by *Registered Participants*. |
| 22. | General Electric | **Section 5.4.1: General requirements - Model multiple operating modes and control functions**<br>In a pumped storage plant there are mode changes that cannot occur automatically (e.g. from turbine/generator to pumping/motor mode) and cannot be necessarily represented in the same model. This is especially true for variable speed hydro pumped storage plant. | AEMO understands that there might be issues with the provision of both pump and *generation* in one model for some of the pump storage technologies. Therefore, AEMO accepts that if any Applicant cannot represent the two in one model, they can seek approval for an alternative, by applying for approval to do so in accordance with the alternative process in the new section 8. |
| 23. | DIgSILENT | **Section 5.4.1: Protection**<br>*"Relevant protection relays must be included in the model, explicitly where practically possible."*<br>DIgSILENT agrees with this statement. Consideration should also be given to include the transmission system primary protection relays as well. PowerFactory software includes a very large library of protection relays that can be used in the steady state or time domain (RMS and EMT) simulations. | Noted. |

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|---|---|---|---|
| 24. | DIgSILENT | **Section 5.4.3: Model Adequacy**<br>*"to avoid excessive simulation burden when integrating RMS models into OPDMS and DSA tools the minimum permissible values of the numerical integration time step and acceleration factors are 1 ms and 0.2, respectively. The RMS model must not attempt to implement dynamic functionality with an intrinsic time constant shorter than 5 ms. Where this is necessary to achieve an adequate performance, a simplified numerical integration algorithm may be implemented within the model subroutine itself;"*<br>In principle, this requirement is a constraint on accuracy because of other tools that are used by AEMO. It is clear that inverter-based equipment can have time constants in the RMS domain of well under 5ms and time steps of fractional ms may be required. Limiting the time step size will therefore miss some dynamics.<br>It is worth noticing that the PowerFactory solver is optimized for efficient and accurate simulation of such networks. A report [4] prepared by DIgSILENT GmbH of benchmark simulations on the European grid between PowerFactory and PSS/E including conventional synchronous generators only. This model includes 21,500 buses and 1,150 synchronous generators. Some of the benchmark study most relevant findings are listed:<br>• Simulations conducted show that PSS/E results are sensitive to the simulation step-length. Any deviation from a 1ms step size shows inaccuracies. Choosing an inappropriately large PSS/E integration step size will result in mode shifts towards characteristics with lower damping and lower mode frequencies. On the other hand PowerFactory simulation results show a maintained accuracy for large step sizes.<br>• In the study PowerFactory simulations could be accurately conducted in much shorter time than PSS/E due the ability to increase step size without sacrificing accuracy. This report also found that when applying the general frequency and voltage dependent load model a step size of 2.5ms or smaller is required for obtaining numeric stability with PSS/E.<br>• It was found that the PSS/E network solution parameter Acceleration should be set to the default value of 0.998. Any setting deviating from the default value resulted in an unacceptable offset of the steady value of variables such as the grid frequency. In such a case, PSS/E simulation results would no longer be compatible with those of PowerFactory.<br>DIgSILENT experience with the simulation of the European grid for the year 2030 case (24,000 busbars, 3,500 synchronous generators and 1,500 wind farms), where the conventional generation in Germany decreases down to 10% is, that wind turbine and PV generator models must include time constants below 5ms requiring step-sizes of below 1ms. In PowerFactory this works very efficient with the adaptive simulation algorithm where step-sizes may reduce down to 0.5ms during fault periods | The relevant text in section 4.3.3 has been amended to account for this issue. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| | | and will then recover up to 100ms when transients are starting to damp out. | |
| 25. | General Electric | **Section 5.4.3: RMS model-specific requirements**<br>*"models must be rigorously tested within a NEM-wide simulation for integration compatibility for large-scale power system studies. Experience has shown that SMIB simulations do not always reveal new models' adverse interactions with other models in the system"*<br>It is not clear how the Generator/OEM can test the developed model in a NEM-wide simulation? Please provide details on how this would be done and what participation is required of the Generator/OEM. | AEMO provides standard OPDMS snapshots to *Registered Participants*, so they can tune their models in a full system and observe how they behave with other models in the *NEM*. |
| 26. | General Electric | **Section 5.4.4: EMT model-specific requirements**<br>*"have the full representation of switching algorithms of power electronic converters for power system harmonic studies"*<br>The OEM of the power plant may have purchased the converter equipment from a sub-supplier and therefore have no access to the proprietary design of switching algorithms of power electronic converters. In such case it is not possible to provide full representation of switching algorithms. Please advise what are the alternatives.<br>*"allow model re-entry (e.g. PSCAD™/EMTDC™ snapshot) to facilitate integration into larger system models".*<br>Please provide detailed explanation to the meaning of model re-entry.<br>*"clearly identify the manufacturer's EMT model release version and the applicable corresponding hardware firmware version"*<br>Not all hardware firmware upgrade will impact the functionality/ performance of the EMT model, therefore only relevant and major hardware firmware upgrade will only mandate an EMT model release version update. | The choice to outsource the production of components of their equipment remains with OEMs, however, so does the risk associated with the quality of the model that incorporates those components. AEMO's requirements for participation in the *NEM* are well known and have been in place for some time. AEMO does not intend to make changes that will degrade those standards. As elsewhere in the world, it may be necessary for OEMs to adjust their processes to meet the requirements in the *NEM*.<br>An explanation on model re-entry has been provided in section 4.3.4 of the proposed Guidelines.<br>On firmware upgrades, AEMO agrees with General Electric. See the new section 4.8.2 of the proposed Guidelines, which states that AEMO will only want a new model if there's a material difference in the performance after a firmware change.<br>The reference to a clear identification of model release information means that AEMO would prefer a simple piece of text in the EMT model that clearly identifies the version, and the corresponding hardware version to which it applies. AEMO currently receives several poorly named or poorly identified simulation models, and it is very challenging to determine to which physical firmware version they apply. |
| 27. | General Electric | **Section 5.4.4: Multiple voltage disturbances**<br>*"Torsional stress and fatigue on shaft drive train and prime mover"*<br>A reduced lumped mass shaft drive train model can only be provided as the full shaft drive train model is OEM proprietary information. | AEMO does not object to the use of simplifying assumptions to represent non-electrical phenomena that could have a material impact on determining *plant* response to multiple *voltage* disturbances in quick succession. However, the onus lies with the *Generator* and OEM to decide on the level of modelling details required. AEMO is not concerned about precise modelling of shaft and drive train dynamics, but how they are represented to show any restrictions to multiple *voltage* disturbances that could manifest over a maximum of 30 minutes. |

| No. | Consulted person | Issue | AEMO response |
|---|---|---|---|
| 28. | Senvion | **Section 5.4.4: Multiple voltage disturbances**<br>**Torsional stress, fatigue and thermal design limits**<br>"Torsional stress and fatigue on shaft" and "thermal design limits of the integral assembly of the plant" is not required to study full performance during system impact studies. Further different simulation models types would be required to answer those topics properly – this is typically out of scope for grid simulation models. | Refer to AEMO's response to issue 27.<br>As to whether a susceptibility mechanism needs to be modelled, that depends on whether the associated protection/failure mechanism can occur within 30 minutes. Failure mechanisms taking longer to manifest need not be represented. |
| 29. | Pacific Hydro | **Section 5.4.4: Multiple Voltage Disturbances**<br>We would like to draw attention to the expectation that the EMT model can include the following:<br>*"must account for electrical mechanical or thermal limitations of the plant with respect to multiple voltage disturbances in quick succession, and calculate dynamically and accumulatively the impact of multiple voltage disturbances, including but not limited to the following factors:*<br>• *Heat dissipation across the dynamic braking resistors (if applicable);*<br>• *Capability of auxiliary supplies: e.g. uninterrupted power supply (UPS);*<br>• *Torsional stress and fatigue on shaft drive train and prime mover;*<br>• *Thermal design limits of the integral assembly of the plant; and*<br>• *Any other relevant electrical, mechanical or thermal protection."*<br>This is beyond practical engineering and will create a situation in which many reputable manufacturers may cease to provide equipment to the Australian NEM. Given the mathematics to calculate the torsional stress and fatigue on a shaft would use a completely different set of mathematics to that in EMT it is doubtful that this can be solved in the power system modelling packages. It is impractical to think that system or connection studies require this type of detail. Furthermore, it is questionable as to whether even the most skilled user of such detailed models could achieve meaningful results without a high risk of misleading the market. | This section has been amended to limit the requirements to the most restrictive protections with the onus on *Generators* and OEMs to decide which aspects applies to their *plant*, and which are the most restrictive. For example, heat dissipation across the dynamic braking resistors and torsional stress protection and fatigue on shaft drive train and prime mover do not apply to solar inverters, and need not be modelled.<br>With regard to the comment that OEMs may cease to provide equipment, it is AEMO's understanding that most reputable OEMs can meet the specified requirements in some form, with the understanding that not all requirements apply to all technologies concurrently.<br>On torsional stress, and fatigue on a shaft, see AEMO's response to issue 27 and 28. |
| 30. | General Electric | **Section 5.4.6: Model outputs – Synchronous machines**<br>"External protection relay(s) status", please provide detailed explanation as to what is meant by this output. | AEMO has added another footnote to the new Table 4 to provide an explanation. |

| No. | Consulted person | Issue | AEMO response |
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| 31. | Pacific Hydro | **Section 5.4.6: Model Output**<br>The section on model outputs appears to extend the requirement to the provision of a complete wind or solar farm model in the following passage,<br>*"in addition...models should provide access to the aggregated network and point of connection or unit transformer LV and HV to demonstrate the complete generating system performance."*<br>If AEMO is no longer seeking a lumped model but wants to investigate the full model, this becomes a much larger modelling issue and one that will not work in the system model due to the number of nodes and complexity. Furthermore, the full model extends to behind the meter performance for which the participant is responsible. Not only is there no justification provided for requesting this expansion to the modelling information, but it is also confusing as this request contradicts the section on model aggregation. | AEMO considers that there is a misunderstanding here and has added a diagram in the new section 4.7.3 to illustrate what is required. It is no different to a standard PSS®E model in this regard. It should not complicate matters, as it is consistent with the long-standing manner in which PSS®E models are submitted already. |
| 32. | Energy Queensland Group | **Section 5.4.7: Integration Compatibility**<br>We concur with the statement that the Single Machine Infinite Bus model may not reflect reality and the interactions with the full system. | Noted. |
| 33. | Energy Queensland Group | **Section 5.4.9: RMS Model Format**<br>This clause requires that Root Mean Square models submitted to AEMO must be compatible with Power System Simulator for Engineering (PSSE) version 34. However, our understanding is that there have been some issues with PSSE version 34 and that version 32 is still being used by proponents and NSPs for GPS compliance studies. We recommend that it would be prudent to continue using version 32 for the time-being and update the Guideline when participants have more confidence in version 34 | AEMO agrees that there have been issues with version 34 and has updated the proposed Guidelines to permit the use of version 32. |
| 34. | Pacific Hydro | AEMO often update the version of the software (PSS/E is now going to v 34) and the decision to alter the software version can cause model issues. This should not trigger a cost allocation to participants as the manufacturers provide updated and tested models. If issues are found with those models the bugs are corrected. | See AEMO's response to issue 33.<br>For the record, AEMO does not undertake software upgrades often. In the last ten years, the PSS®E version that AEMO accepts has changed twice (v29 to v32, and v32 to v34). Of these two changes, support is currently maintained for both v32 and v34. |

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| 35. | Senvion | **Section 5.4.9: Source Code submission**<br>*"AEMO accepts RMS model source code natively developed in FORTRAN 90 or higher."*<br>Senvion provides models including source code and compilation routines without only using FORTRAN code. Apart from that the models are in line with the guideline.<br>We would propose to accept C – Code (or similar) additionally, as C is a common programming language, widely used and taught at universities and can be handled by the majority of engineers. Conversion of any source code into FORTRAN code not only creates additional costs and does not have a direct benefit but may even create additional risks for translation errors.<br>The Senvion approach also includes the flexibility to use the same simulation model in different simulation software and is therefore more future-proof. We would be pleased to present AEMO our source code proposal. | Although C-Code is a common programming language, it is not directly used as a model source code. While this might change in the future and for the reasons referred to in Senvion's submission around translation errors, AEMO does not see this as an appropriate blanket change at this stage, but will consider source codes based on C/C++ on a case-by-case basis.<br>Anyone wishing to discuss this with AEMO in respect of a particular model should use the alternative process referred to in new section 8 of the proposed Guidelines. |
| 36. | General Electric | **Section 5.5.1: Black start model requirements**<br>Modeling all auxiliaries can be an issue. There are simply too many individual components. We recommend they make a simplification or assumption and see all auxiliaries as ONE value. It would come from manufacturer side to guarantee that the auxiliaries would behave in the way the assumption specifies it. | AEMO notes that the provision only requires modelling of auxiliaries of more than 1 MW only. Smaller loads are not required to be modelled.<br>For black-start studies, a key criterion of success is to determine if black-start *generating units* can energise the major auxiliary components of other *generating units*. These components are typically large induction motors, such as boiler feed pumps, induced draft fans, and forced draft fans and are typically not energised simultaneously due to their large starting currents. Combining all of these models in a single representation would be very pessimistic (due to the combined starting current) and would not be an accurate reflection of black start processes in most *plant* in the *NEM*.<br>The reference to "any" fans and pumps has been changed to "large" fans and pumps to make this clearer. |
| 37. | Huawei | **Section 5.6: Small-Signal Model Requirements**<br>We would like to get a confirmation if the "SMALL SIGNAL MODEL REQUIREMENTS "also holds good for Asynchronous generator type based on power electronics like – PV Inverters. In other words should "PV inverter manufacturer" also provide and satisfy small-signal model requirements as the document highlights only "synchronous generator".<br>More detailed technical information and model requirements in this regard would be appreciated. | AEMO and NSPs develop small signal linearised models for use in custom stability analysis tools. From an Applicant or OEM perspective, AEMO and the NSP need to receive a copy of the model block diagrams, which are required under clause S5.2.4 of the NER. There is no additional special information that needs to be provided by OEMs in this regard. |

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| 38. | DIgSILENT | **Section 5.7.1: Harmonic Emissions**<br>*"Harmonic current injection models used for harmonic frequency scans and harmonic distortion analysis in conventional power system harmonic analysis tools must provide:*<br>• *frequency-dependent Norton equivalences of each type of generating unit;*<br>• *harmonic current injection profiles (for each harmonic order) at each generating unit, including:*<br>– *harmonic current magnitude, e.g. in Amperes, or in percentage of fundamental current;*<br>– *harmonic current phase angle;"*<br>Considering these harmonic emissions are determined from measurements over a time period, it would be very difficult to assess the phase currents of high frequency harmonics; in particular when these harmonics would have small amplitude complicating measurements in addition to the estimation only of the phase delay due to instrumentation. If the proposed methodology of arithmetic summation of harmonics as has been proposed by CIGRE [2], then the phase angle of harmonic currents would not be required.<br>The method of testing RES generator harmonic emissions involve harmonic current measurements outside the Norton equivalent circuit. Introducing the Norton equivalent impedance has the benefit of considering the generator internal sinking of harmonic emissions, but may produce overly optimistic results | AEMO agrees that a correct estimate of harmonic current phase angle requires measurements over extended periods. For this reason, the section has been amended to require this aspect only if the calculation method advised by the relevant NSP requires this information. |
| 39. | Pacific Hydro | **Section 5.9.2: Updates to account for changes in the plant including parameter changes**<br>The onerous requirements in section 5.9.2 that cover "firmware" updates requiring a trigger for re-commissioning and new R2 data testing is excessive, expensive and highly problematic as it will discourage all participants from undertaking any upgrades to their control systems. The intrusive nature of this requirement will lead to a continued decline in the reliability of the power system as there is already a reluctance to undertake control system upgrades. The market needs a collaborative approach to control system upgrades that does not lead to excessive costs and high regulatory risk on existing participants. | If *generating plant* changes affect its performance, the *Generator* will need to re-do R2 testing and model validation. AEMO requires accurate models and needs confirmation from the *Generator* that the *plant* can meet its *performance standards*. This has been a long-standing and consistent requirement.<br>Differences between *generation* technology result in varying ease of upgrade. For example, an upgrade to a *synchronous generating unit* may take months and often require significant hardware replacements. Given the amount of work required, it is typically undertaken less often, sometimes once in every 2-3 decades. Conversely, an upgrade/change to an inverter could take seconds as new software is downloaded, so there may be a tendency to consider such changes as "inconsequential". In both cases, however, they are still changes that affect *plant* dynamic performance, and must be properly evaluated.<br>To be clear, in the context of firmware or setting changes, AEMO only needs models when the dynamic performance of *plant* is changed as a result of the firmware or setting change, as already detailed in section 5.9.2 of the proposed Guidelines. |

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| 40. | General Electric | **Section 5.9 Models and plants updates**<br>Models should be updated only in case of changes that significantly impact performance. There are considerable costs associated with such requests which should be taken into consideration. | See AEMO's response to issue 39. |
| 41. | Energy Queensland Group | **Section 7.2: Model Performance Measures**<br>Highlight the need to encourage Applicants to optimise their performance. For example, a Power Quality Analyser (PQA) may create a 0.8 sec delay, but as long as the GPS is complied with, the PQA inefficiency is acceptable. | AEMO's agrees with this suggestion, but considers it outside the scope of the *Power System Model Guidelines*. |
| 42. | Powerlink | **Section 7.2.1: Accuracy Criteria**<br>Section 7.2.1 and Appendix E of the Draft Guidelines define a set of analytical metrics that must be satisfied. Powerlink believe that the assessment methodologies and accuracy criteria need further development and testing to ensure that:<br>• the accuracy criteria are meaningful and practical;<br>• set an appropriate standard that supports AEMO and NSPs meet their Rule obligations;<br>• there are no unintended consequences and;<br>• appropriate and practical transitional provisions have been considered taking into account the connection processes in the NER; | The proposed Guidelines were developed with the assistance of a working group in which Powerlink is a member (PSMRG) and Powerlink was specifically involved in the development of the accuracy criteria. AEMO appreciates the submission on this issue, however, in the absence of any specific suggestions for improvement AEMO has made no further changes at this stage.<br>AEMO developed this section based on the *Generating System Model Guidelines*, and attempted to clarify elements that have caused confusion among stakeholders.<br>On the need for transitional arrangements, AEMO notes that the industry has been aware of the nature of these changes for some time. AEMO's rule change request was published on 31 October 2016 following informal consultation with NSPs and other stakeholders, and the Amending Rule was made by the *AEMC* on 19 September 2017. The Amending Rule requires AEMO to develop and *publish Power System Model Guidelines* by 1 July 2018 that meet the requirements of the Amending Rule, so AEMO considers it would not be appropriate to include transitional provisions in the proposed Guidelines. |
| 43. | DIgSILENT: | **Section 7.2.2:**<br>"Positive-sequence simulation models are expected to meet the model accuracy requirements specified in Section 7.2.1 for balanced Disturbances. Comparison of the response to different types of unbalanced faults is more qualitative, and the accuracy requirements do not strictly apply."<br>Most power system events with significant impact on power system stability are unbalanced events. Three phase faults are not considered as credible contingencies in the NEM transmission system. Hence, there is no requirements to conduct balanced dynamic simulations.<br>There is a risk of imposing overly conservative requirements on generators if realistic network conditions are not analysed. In effect, this results in the generating systems being gold-plated, reflecting higher costs back to consumers. | Three-phase faults are sometimes considered as *credible contingency events*. The statement made in the submission is, therefore, not accurate.<br>AEMO has amended section 7.2.2 of the proposed Guidelines to read:<br>''Positive-sequence simulation models are expected to meet the model accuracy requirements specified in Section 6.2.1 for balanced Disturbances. For comparison of the response to different types of unbalanced faults a positive-sequence model can still be used if it can achieve the required accuracy requirements.<br>When a positive-sequence model fails to meet the accuracy requirements by a material margin, the use of EMT-type or three-phase RMS simulation models is permissible provided that the simulation model chosen can demonstrate compliance with the model accuracy requirements''. |

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| 44. | Pacific Hydro | **Section 7.3: Continuous monitoring of disturbances**<br>There is an expectation that "continuous monitoring" can be undertaken for what sounds like all disturbances — this is again an unrealistic, expensive burden to place on participants. It is possible to undertake such analysis during the period in which accuracy for R2 and post commissioning is being proven. However, to undertake this type of analysis on a continuous basis is expensive and unnecessary.<br>The response of the plant will depend on the system conditions present at the time of the event. System snapshots from the OPDMS are not actual representations of the network but an approximation due to time delays in the capture of data, perfect overlays to accuracy requirements will not be possible. In order to "overlay" the actual measurements with a model output would require a significant amount of work. It involves taking the connection point measurements and converting them into the vectors (voltage and current) to inject them into the model without the system influences. This is often referred to as the "playback method" and it is not a straightforward task. It is excessive to expect that every system disturbance will trigger a system overlay report. Pacific Hydro considers that the intent of this section should be clarified and limited to the validation and periodic checks, particularly after any model update, and proposes that this section is reviewed with this intent in mind. | AEMO's expectation is that after R2 testing, each *plant* excursion outside the normal range for *voltage* and *frequency* will be reviewed. If dynamic performance changes in such a way, AEMO requires either:<br>• Simulation studies indicating that the performance continues to be consistent with the previously submitted model; or<br>• An update to the previously submitted model.<br>AEMO considers that OPDMS snapshots provide an accurate representation of the state of the *power system* in a steady-state sense, before and after disturbances. The delays mentioned here are of no relevance for determining the load flow cases to be used for model overlays. With those steady-state load flow cases established, one can implement the specific sequence of disturbances, and any *network* switching as captured by high-speed data recorders and status of relays and circuit breakers.<br>AEMO has been conducting model benchmarking studies for major system disturbances, and concludes that reasonable correlation can be obtained between the measured and simulated responses. This applies to both system level model validation, and the playback method.<br>AEMO has been using the playback method as a simpler and first stage approach before undertaking system level model validation, and considers that it would not be unduly complex for an experienced *power system* modelling engineer undertaking this analysis. |
| 45. | Senvion | **Section 7.3: Model validation**<br>It is proposed to base model validation requirements on international standards, such as "IEC 61400-27-1: Wind turbines – Part 27-1: Electrical simulation models – Wind turbines". This standard proposes in chapter 6 detailed methods for demonstrating the quality of model validation by following international standards (such as data sampling methods from IEC 61400-21) and at the same time opens up the possibility to define accuracy limits through the system operator. This standard also includes to judge model validation errors based on per unit data rather than on the specific change of quantity. The proposed method in the Power System Model Guidelines is concerning when evaluating very small changes (getting into numerical issues) - while the effect on system stability is very low. | Senvion's proposal is to incorporate an IEC standard that is not required by the NER. If it were an appropriate standard for the *NEM*, AEMO would have sought its application through the NER. The requirements put forward by AEMO are considered necessary and appropriate for the *NEM*. |
| 46. | General Electric | **Section 7.3.2: Pre-connection model confirmation**<br>Information on system fault level – pre-fault and post fault should be provided by AEMO or NSP. Depending on how much in advance such models are to be submitted, it may not be possible to provide identical control system settings as to the one being installed.<br>If would be helpful if AEMO or NSP provide the range of operating conditions including pre-disturbance active and reactive power levels for the tests to be carried out. | Those who need this information should liaise with the relevant NSP, who is responsible for providing it. |

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| 47. | Pacific Hydro | **Section 7.4: Non conformance**<br>Section 7.4 calls for the application of operational constraints to be imposed until the modelling issues can be resolved. This requirement must have some sensible limits to what constitutes a "modelling issue" as models can have mathematical anomalies that do not occur in reality. The power system simulation studies are approximations and should be treated in that manner; the more detailed the modelling more likely it is that anomalies will occur. Applying operational constraints would need to be based on true electrical control problems and not on modelling anomalies. Unnecessarily applying operational constraints will penalise participants with significant financial consequences. | Section 7.4 refers to the existence of one or more of the following conditions before AEMO can impose operational constraints:<br>• There must be a risk to *power system security.*<br>• There must be an adverse impact on other *Network Users.*<br>• There is an inability to meet *performance standards*.<br>The imposition of operational constraints is one of a number of actions that can be taken by AEMO, or the relevant NSP, or both, to alleviate the conditions that are being experienced until the cause can be identified and addressed. Requiring 'sensible limits' to what constitutes a 'modelling issue' is not practical, as it will depend on the nature of the issue and the surrounding circumstances. It is, as Pacific Hydro has referred to in other parts of its submission, subject to an infinite array of possibilities. An example is the use of models for determining *plant* response to large disturbances. This type of test cannot be exercised often in an *interconnected network*. In the absence of knowledge of the measured response of the *plant*, simulation models are considered as the source of truth. Material anomalies indicated by the simulation models could result in operational constraints subject to any of the three criteria discussed above being met.<br>AEMO does not agree that anomalies are more likely to occur in more detailed models. This is because a widely adopted approach by several OEMs of *asynchronous plant* is to interface the actual and one-to-one control codes of the *plant* with the EMT simulation models. This makes the EMT model effectively a mirror of the *plant's* performance. An EMT model is then used to determine the veracity and impact of any changes before it is implemented in the *plant*. |
| 48. | Energy Queensland Group | **Section 8.2**: **Intellectual Property**<br>Agree that it is appropriate for AEMO to have responsibility for providing model data as required. | Noted. |
| 49. | Pacific Hydro | **Section 8.3.1**: **Provision of information**<br>Section 8.3.1 states on page 49 that AEMO will "never provide the entire network model to a Registered Participant", however, participants do receive the NEM cases (RMS — PSS/E) which represent the network model for the entire NEM for Summer and Winter cases. This is necessary in order to conduct studies, particularly for connection studies. The intention of this section needs to be clarified. Is it the full EMT network model that will not be provided, will limited EMT models be released? | What was meant was that an unencrypted model of the entire *network* would never be provided to a *Registered Participant*. The offending statement has been deleted and readers are pointed to Table 6, detailing which models AEMO will provide.<br>Limited EMT models can only be provided to relevant *Registered Participants* whose *plant* is subject to *system strength impact assessment*, and determined to adversely impact system strength, hence required to contribute to a remediation of system strength. Under these circumstances, those *Registered Participants* are permitted to dispute the outcome of the *system strength impact assessment,* which enables them to receive relevant EMT models. |
| 50. | Energy Queensland Group | **Section 8.3.2**: **Provision of Information and Models to Generators**<br>Further consideration may be required as to whether the Guideline should provide detail regarding single-cast versus aggregated models. There has been some concern raised previously regarding whether those models can be encrypted to a sufficient level to address issues currently being experienced by proponents with respect to obtaining consent from the manufacturer to share models. | There appears to be some lack of understanding of the encryption requirements. AEMO suggests that OEMs discuss with Manitoba Hydro Research Centre as the official vendor of PSCAD™/EMTDC™ on whether PSCAD's encryption standards are sufficient to meet their confidentiality needs. |

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| 51. | Australian Energy Council | **Section 9: Alternative Process**<br>There is a limited ability for applicants who "cannot provide the required information or model" to apply for a variation to the requirement to provide the specified data and models. According to the Guidelines AEMO must consider "the reasonable costs of efficient compliance by Applicants with these Guidelines and the Data Sheets compared to the likely benefits from the use of the information provided under those", the Guidelines lack detail on how the likely benefits will be identified, quantified and compared with the costs of providing the requested information. The Energy Council suggests that the assessment process used by AEMO should be more transparent and clearly defined, including the methodology and process to be used in quantifying benefits. Furthermore, it is important that the assessment of costs includes not only the applicant's direct costs in producing the data and models, but also considers the costs and impacts to consumers of any delays in the connection of new equipment as a result of the request for information. | As with any assessment of cost vs benefit required by the NER, the assessment of the costs vs the benefits of the use of the information to be provided by the models and other information provided under the proposed Guidelines will be guided by the *national electricity objective*.<br>AEMO will take into consideration the costs of compliance with a particular requirement and compare that against the benefits by reference to the longer term interests of consumers, as the *national electricity objective* requires.<br>This requirement applies because of section 7 of the *National Electricity* Law and the Guidelines should not attempt to qualify its scope. |
| 52. | General Electric | **Appendix C. modelling component requirements - C.1.1 Protection systems**<br>Only relevant and existing protection system models can be provided. In addition, not all details of the torsional stress protection can be provided. | AEMO agrees that only those that are relevant to power system stability are required to be modelled.<br>On the torsional stress protection, see AEMO's response to issues 27, 28 & 29. |
| 53. | Senvion | **EMT models for transient stability**<br>The models for transient stability studies are to our understanding the models which are intended to be shared with market participants under consideration of the comments above. As it has to operate correctly over a wide range of time steps (10 – 50µs), simplification are necessary e.g. converter and converter switching representation. Implicitly it would mean to have available a wider variance of model types for different applications (PSS/E models, simplified EMT models, detailed EMT models, …). | The proposed Guidelines state that the model needs to operate with a time-step greater than or equal to 1 microsecond. This also obviates the need for any simplification that would otherwise be needed if the smallest acceptable time step was to be 10 microseconds. This makes it possible for an OEM to submit a single PSCAD™/EMTDC™ model for all phenomena of relevance. An alternative approach is submission of a detailed PSCAD™/EMTDC™ model sufficiently accurate for simulating *power system* stability phenomena (excluding converter switching representation), and additional model including converter switching representation, if requested by AEMO and relevant NSP on a case-by-case basis for harmonic susceptibility and interaction studies.<br>The only models that will be shared by AEMO with *Registered Participants* are PSSE models. A PSCAD™/EMTDC™ model will be provided to NSPs to carry out *system strength impact assessments* and to other *Registered Participants* only following the completion of a Full Assessment (as that term is used in the proposed *system strength impact assessment guidelines*) if they are intending to dispute the outcome.<br>Simplification of parts of a model is permitted and intended for a PSS®E model, provided the requirements specified in the proposed Guidelines are met. |

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| 54. | Pacific Hydro | **General Comments**<br>In many areas Pacific Hydro believes that the requirements in this guideline are unworkable. The guidelines confuse the different mathematics associated with the modelling of physical elements such as the physics associated with metallurgical fatigue, thermal properties and heat dissipation. The guidelines call for a multi-physics simulation which is not an EMT type modelling problem. The guidelines appear to be attempting to capture everything that could ever go wrong, as if modelling without suitable engineering interpretation can give answers to any problem that might happen. Finally, these changes to model system guidelines are unprecedented and diverge from widely-adopted international engineering practices. | Metal fatigue has been addressed by various changes made to the proposed Guidelines and thermal issues can be simply approximated.<br>AEMO is not requiring a multi-physics model, but a model that can explain *plant* electrical behaviour. Physical phenomena are of relevance only to the extent that they will impact short-term electrical behaviour and AEMO needs to understand those impacts to operate the *power system* accordingly.<br>AEMO has been working closely with major OEMs, and been approached by a number of major European and North American system operators with high penetration of *asynchronous generation* in order for those system operators to adopt AEMO's practices and learnings in *power system* analysis and modelling requirements.<br>While AEMO has been at the forefront of the use of large-scale EMT studies, there has been a growing trend amongst some of the major European and North American system operators to develop large-scale EMT models for *power system* stability studies. |

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| 55. | Pacific Hydro | **Model Content**<br>The breadth of what is being asked for in these guidelines encompasses a vast range of physical elements that have not been included in dynamic models in the past. The language used in this document illustrates a desire to cover all possible physical phenomena as if it is possible to study in detail all the possible combinations of operating conditions and events. It is not, as the number of possible conditions are infinite.<br>Including protection relays or settings into the dynamic model alters the use of the model. Dynamic models have always been used to inform engineers of where to set protection, by including the protection settings within the model it means that the protection of the system is being studied rather than the dynamics. The wording "all pertinent protection systems" is vague and subjective. If protection is to be included the language must be specific and state exactly what protection is required.<br>The model compatibility and stability section requires that the model "work for a range of dynamic simulation solution parameters rather than for specific settings only", and "be numerically stable up to a simulation time of 5 minutes". This is unlikely to be achievable given that studies are all subject to the network data in the cases.<br>The discussion regarding transient over voltages and the desire to cover time steps as low as 16 micro seconds illustrates a desire to bury into detailed design. Specialist studies for lightning and insulation co-ordination are not normally the purpose of the dynamic model, these are best left to design engineering and limited to specific plant models designed in detail to study travelling wave phenomena. It is illogical to provide a model that is intended to examine lightning when there has been no mention of surge arrestors. Switching studies alone would require detailed EMT models of each type of circuit breaker in the power system, including the SPAR operation and the insertion resistors. | The *power system* is changing and so are AEMO's modelling requirements, which explains the increase in elements that are now required in dynamic models.<br>The 16-microsecond time step does not indicate any desire to 'bury into detailed design'. Pacific Hydro noted that fast control of power electronics used in *asynchronous plant* infers that most converter *control systems* run at the frequency of 10 kHz and above. Considering this and accounting for enough digital samples, it is common practice for all such simulation models to run at an integration time step between 1 and 50 microseconds. Feedback provided by several OEMs is that an integration time step of 10 microseconds (initially proposed in the Guidelines) could be restrictive. For this reason, AEMO has reduced the minimum acceptable time step to 1 microsecond.<br>EMT-type models often provide a 1:1 representation of *plant*, which, by default, means that all generating unit *protection systems* will be included.<br>In AEMO's experience, dynamic models already have at least some aspect of protection in them. Indeed, AEMO would be seriously concerned if any models previously supplied to AEMO did not.<br>Pacific Hydro suggests a segregation between *power system* protection and dynamics that is no longer representative of the evolving *power system* - where *power system* dynamics, protection and power quality are strongly inter-related. The purpose of requiring models and data on protection system is to determine the impact on system security rather than performing protection coordination studies. RMS dynamic simulations of up to five minutes result in very few computational burdens. These studies are critical for determining responses to *frequency* disturbances and the response of contingency FCAS, and assessing the response of *generating systems* that rely on the action of *transformer tap changers* and static reactive support *plant*. EMT simulation studies have been conducted for up to ten minutes for evaluating SRAS sources, and *power system* response of during restoration. Additionally, AEMO has been running the full-scale PSCAD™/EMTDC™ model of the entire South Australian *power system* for one minute, and will be using these types of models for up to five minutes. Adaptation and the use of state-of-the-art simulation techniques has allowed AEMO to simulate one second's worth of simulation in one minute for the entire PSCAD™/EMTDC™ model of the South Australian *power system*. This means that simulating one minute's worth of simulation takes one hour to complete.<br>On the issue of lightning and surge arresters:<br>• Surge arresters are referred to five times in the proposed Guidelines issued for consultation, three times after the deletion of section 4.<br>• "Switching and lightning" refers to a class of model, not specific studies. AEMO has replaced the term with another: "slow-front and fast-front" models. This is an IEC defined term.<br>With regard to the comment on switching and lightning studies, it should be noted that while AEMO uses *power system* models largely for dynamic studies, other NER mandated requirements prompt the need for the use of other types of models.<br>AEMO performs this type of studies in order to procure the necessary SRAS sources, and to develop the necessary restoration paths. These studies require sufficiently accurate models of synchronous generators and other plant involved during system restoration. Due to technological limitations, asynchronous plant are |

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| | | | not generally involved during system restoration. Such plant are not therefore required to provide any additional data or models unless participate in the system restoration. |

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| 56. | Pacific Hydro | **Protection Systems**<br>Pacific Hydro is concerned that the inclusion of protection settings and relay information to be provided into the dynamic models illustrates a focus on detail that risks distracting from the overarching need to study the power system.<br>The greater the complexity of the power system model the more likely it is to produce abnormal or inconsistent results. Such a model is no longer a study of the system dynamics but rather a study of the protection systems. Using large, complex EMT modelling will make it extremely difficult to achieve reasonable stable results over the longer time periods that are asked for — such as up to 5 minutes. It is not clear whether all models must run for up to 5 minutes and the guideline needs to be clearer about how long the high frequency sample rate models are expected to remain stable: eg: micro second sample rates are more likely to fail to converge over longer periods. | The statement of the purpose of the Guidelines in clause S5.5.7(b)(1)(iii) includes the ability for AEMO to 'assess and quantify' *protection system* settings.<br>Please also refer to AEMO's response to issue 52.<br>AEMO is pleased to note that some of the highest quality simulation models provided to it, include models of all *protection systems* of relevance and significance by default.<br>AEMO is not aware of any practical experience or reliable evidence to support the statements that ''The greater the complexity of the power system model the more likely it is to produce abnormal or inconsistent results'', or that ''Using large, complex EMT modelling will make it extremely difficult to achieve reasonable stable results over the longer time periods that are asked for''. A more detailed response is included in AEMO's response to issue 39. As discussed in response to issue 47, AEMO has been running the full-scale PSCAD™/EMTDC™ of the South Australian *power system* for one minute's worth of simulation. A small number of abnormal responses of specific models were fixed in collaboration with the model providers (OEMs) in conjunction with the respective *Generators*. The current version of AEMO's full-scale PSCAD™/EMTDC™ model of the South Australian *power system* does not show any model non-convergences.<br>AEMO considers that if a model is not converging, it is not of acceptable quality and will need revision. AEMO provides the following example of a full wind farm model provided by a reputable OEM, utilising a 1:1 mapping of turbine source code. The model was run with a 1 microsecond time step (recommended by the OEM) for 300 seconds. As can be seen, there is no indication of any developing instability or model crashing.<br>  |

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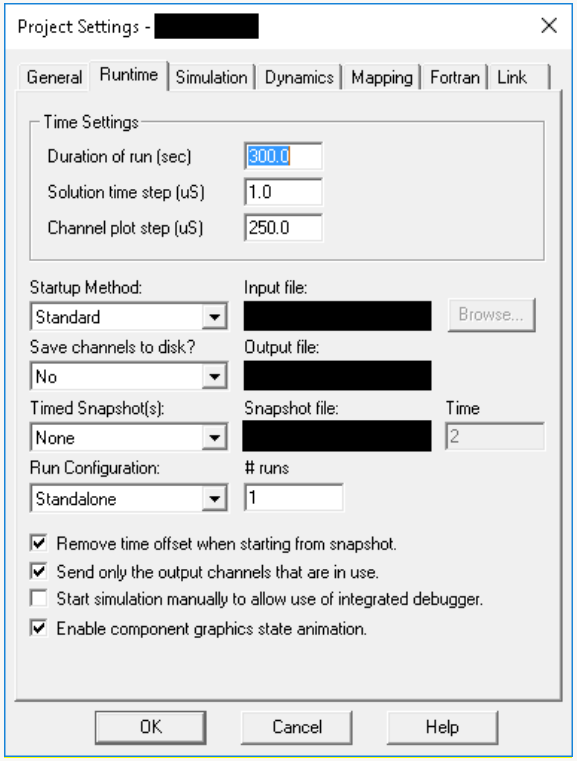
| | | | PSCAD™/EMTDC™ settings for this run (some information redacted to protect anonymity):  |

| No. | Consulted person | Issue | AEMO response |
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| 57. | Pacific Hydro | There is an enormous amount of detail being called for and the inclusion of elements into the model that have not been included before have not really been justified. Another example of this is requirements for details of "VTs and CTS feeding protection mechanisms".<br>Pacific Hydro is concerned that the increased volume of data, the detail of the EMT combined with the onus of proof and accuracy requirements in these guidelines will eliminate many manufacturers from providing equipment to the NEM and be a significant barrier to entry for new technology. This will increase costs and decrease competition, clearly an undesirable outcome. | Section 4 was included to explain where all these requirements were coming from, namely, context, and referencing the studies done by AEMO in meeting its various NER obligations, and not just *generation connection* assessment and GPS negotiations.<br>Insofar as the example is concerned, AEMO notes that only the CT and VT ratios are required and has amended Appendix C to that effect.<br>AEMO has not received any indication from OEMs it is in regular contact with that they might be 'eliminated' from competing in the NEM. AEMO welcomes any specific information Pacific Hydro may have in this regard. |
| 58. | DIgSILENT | **A changing grid**<br>The AEMO draft modelling guidelines propose wide ranging changes. The impact and arguments around these cannot all be fully considered and commented on within a short period of time. Alternative approaches and constructive proposals would require time to develop (for which we have no mandate in any case). For instance; according to some reports, there are developments by German TSO's to change converter control systems from current injection control (CSC) to voltage control (VSC) for wind, photo-voltaic (PV) and HVDC. These developments are conducted in consultation with manufacturers. A test system has been developed in PowerFactory which accommodates 96% RES and one single synchronous generator. Though the NEM is very different from the German grid, it is worth considering these developments as it would have a very strong influence on future RES technologies introduced to the NEM.<br>It is however not only generation that is changing. The NEM load is also changing due to the uptake of embedded renewable generation and battery storage. More dramatic changes could be anticipated as electric vehicles are introduced. | AEMO is aware that the *NEM* is changing and is looking for ways in which AEMO can manage the operation of the grid. AEMO is currently investigating the contribution of gird forming converters to *power system security*. AEMO understands this is what DIgSILENT refers to as changing the control strategy from the commonly adopted practice of constant current to the emerging constant *voltage* control.<br>AEMO notes that none of these matters will impact on *power system* modelling requirements. As the submission does not make a concrete proposal in this regard, AEMO is unable to give any meaningful response.<br>Regarding the impact of *load* and DER refer to AEMO's response to issue 21. |
| 59. | Pacific Hydro | **Testing Requirements**<br>There is an inherent inefficiency caused by the layers of testing and retesting that AEMO expects. | The only new requirement is detailed in new section 6.3.2, dealing with pre-*connection* tests. |
| 60. | Senvion | **Study requirements and validation methods**<br>EMT models are required for different type of studies<br>We agree that different type of studies require different type of models. We propose that AEMO specifies clearer the study requirements and validation methods. We have years of experience to be able to propose a model to meet AEMO's requirements for specific studies.<br>EMT specific models can only be example guidance models and not prescriptive requirements to secure high quality of results from studies under consideration of wind turbines designs. | AEMO is pleased to note Senvion's capability and experience in meeting AEMO's modelling requirements for various types of EMT models.<br>As discussed in response to issue 53, for wind turbine models, AEMO is willing to consider a general EMT model suitable for all relevant phenomena, including *power system* stability, sub-*synchronous* interaction, and harmonic emission and susceptibility studies. Alternatively, AEMO can accept a base EMT model suitable for *power system* stability phenomena, with additional details to be added to the base model on a case-by-case basis to make the model suitable for all other *power system* phenomena, such as sub-*synchronous* interaction, and harmonic emission and susceptibility studies. |

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| 61. | DIgSILENT | **Model Adequacy**<br>Section 7.2.5 (Footnote 46):<br>*"Models that cease output when exposed to conditions outside the intended operating range are not considered inferior, however, the cessation of the model output must not result in instability or crashing of the underlying simulation tool."*<br>The document describes the intended operating range in terms of real and reactive power outputs of plant. The reason for this statement of exemption is not understood. System transients would result in plant to temporarily operate outside steady state intended operating range. | Several *asynchronous generating units* are known to stop/pause/cease current injection during certain operating conditions. Whether this response is acceptable, is to be considered in the context of the *plant's performance standards*. What this requirement infers is that even under these operating conditions the model itself must operate continuously (even if the stop/pause/cease mode is activated) without any crashing or other instabilities that could abort the simulation run. |