12 April 2018

The Manager
AEMO
Level 22, 530 Collins Street
Melbourne
VIC 3000

Draft Power System Model Guidelines

Please find attached our comments to the AEMO draft power system model guidelines. The AEMO draft modelling guidelines include wide ranging changes. The impact and arguments around these cannot all be fully considered and commented on within a short period of time.

Yours sincerely

Koos Theron
Director

DIgSILENT

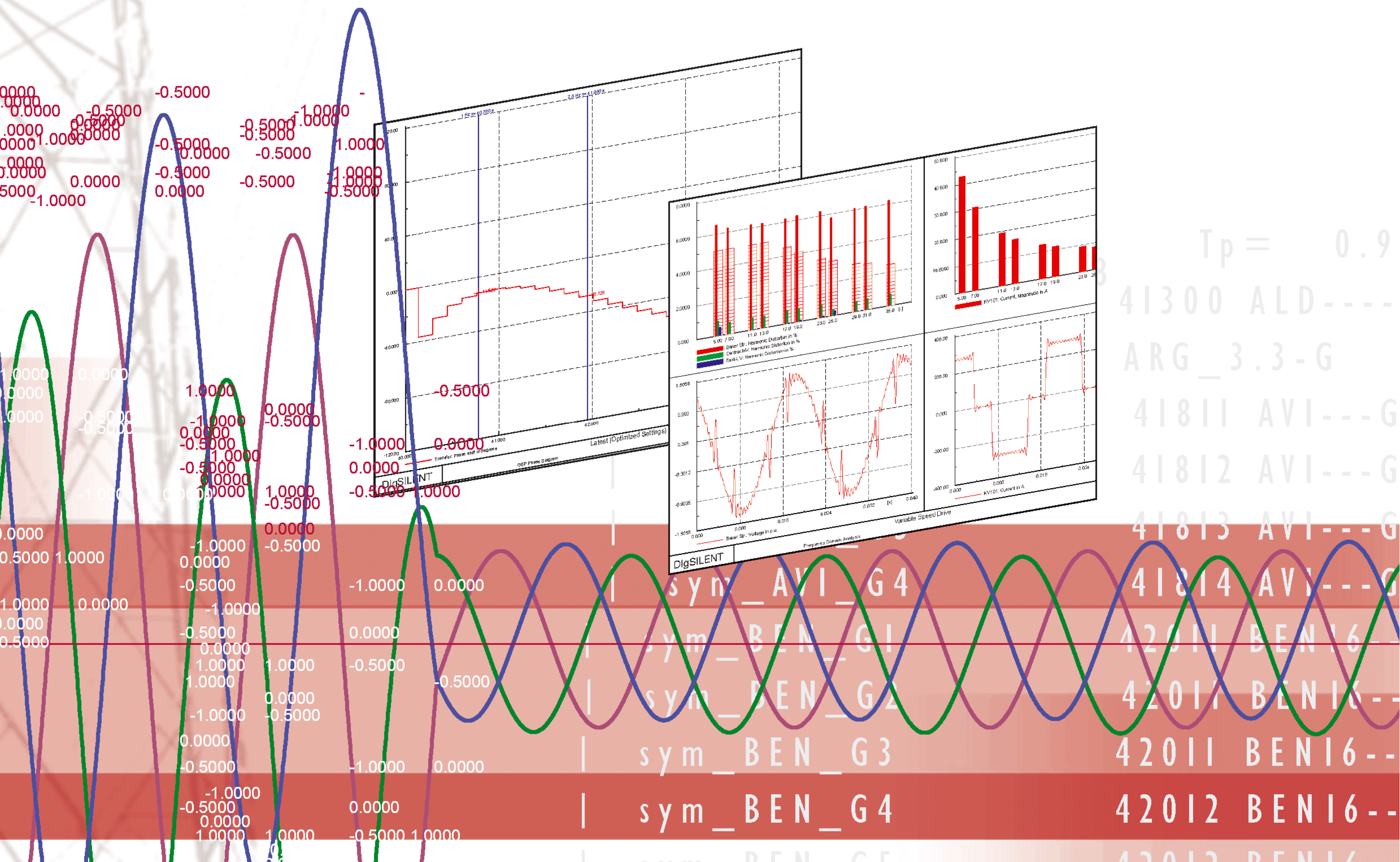
Project Number: 1020

April 12, 2018

Power System Model Guidelines AEMO

Comments to Draft Report

Revision 0



Document prepared by:

DIgSILENT Pacific Pty Ltd
Level 13, 484 St Kilda Road
Melbourne
Victoria, 3004

Revision History

Revision	Author	Date	Reviewed by	Comments
0	Koos Theron	11/04/2018	Martin Schmieg	Draft comments

Executive summary

AEMO published a draft document for consultation with effective date 5 March 2018 titled "Power System Model Guidelines". Our thanks to AEMO for providing this opportunity to contribute to these important issues. DIgSILENT Pacific comments to the model guidelines in this report.

Due to limited time our response only addresses very obvious issues, many of which DIgSILENT have a vested interest in.

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.

Contents

Glossary of terms

AEMC The Australian Energy Market Commission is the expert energy policy adviser to Australian governments.

AEMO Australian Energy Market Operator; AEMO operates the NEM within a broader market governance structure alongside the Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER).

CSC Current Source Converter.

EMT Electro-magnetic transient simulations used for modelling and simulating sub-cycle dynamic responses.

HVDC High-voltage, direct current. Use of direct curent for transmission of electrical power.

NEM National electricity market; the inter-connected electricity grid of the Australian eastern states.

NSP Network Service Provider.

PV Photo voltaic power generation sources.

RES Renewable Energy Source.

RMS Root mean square. Referring to the fundamental frequency response of a power system.

TSO Transmission System Operator.

VSC Voltage Source Converter.

1 Background

AEMO published a draft document for consultation with effective date 5 March 2018 titled "Power System Model Guidelines". Our thanks to AEMO for providing this opportunity to contribute to these important issues. DIgSILENT Pacific comments to the model guidelines in this report.

DIgSILENT Pacific previously commented to the AEMC in response to proposed changes to model guidelines [3]. The views expressed to the AEMC are still valid and not repeated in this document.

DIgSILENT is the developer of PowerFactory software used for power system modelling and simulation. PowerFactory has the functionality to conduct steady state, time domain (Quasi-dynamic, RMS and EMT), frequency domain and stochastic simulations for balanced and unbalanced systems with balanced and unbalanced simulations with balanced and unbalanced results variables defined.

The main commercial activity of DIgSILENT Pacific in Australia is to conduct power system studies for generators, transmission systems, distribution systems, mining and industrial systems. DIgSILENT Pacific uses a variety of software platforms as required by clients and as appropriate for specific tasks.

2 A changing grid

Network changes due to the introduction of renewable energy are dramatic and require careful management and consideration. AEMO has a very important role to play in this regard.

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 Australian NEM grid 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.

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.

3 Comments to issues raised in the AEMO report

DIgSILENT makes the following general comments with reference to specific quotes in the AEMO draft guidelines.

3.1 Software selection

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.

3.2 Three phase RMS modelling

3.2.1 Page 11

> *"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.

3.2.2 Page 14

> *"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.

> *"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."*

DIgSILENT strongly agrees with this statement. PowerFactory can simulate this negative sequence response in both RMS and EMT platforms.

3.2.3 Page 16

> *"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. Is it feasible to study the sub-transient phenomena of the entire NEM grid in particular when the entire NEM load model is simplified?

3.2.4 Page 45

> *"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."*

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. 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.

3.3 Harmonic analysis

3.3.1 Page 19

> *"EMT time domain models and simulations may be required for assessment of harmonic susceptibility, including de-stabilization of network operation due to harmonics.*
>
> *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."*

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.

Harmonic compliance is also probabilistic in nature, considering time averages and probabilities of exceedance.

EMT simulations are useful in assessing harmonic susceptibility, but should ideally be conducted in conjunction with frequency scans.

3.3.2 Page 20

> *"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."*

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.

3.3.3 Page 35

> *"Harmonic current injection models used for harmonic frequency scans and harmonic distortion analysis in conventional power system harmonic analysis tools must provide:*
>
> - *frequency-dependent Norton equivalences of each type of generating unit;*
> - *harmonic current injection profiles (for each harmonic order) at each generating unit, including:*
>   - *harmonic current magnitude, e.g. in Amperes, or in percentage of fundamental current;*
>   - *harmonic current phase angle;"*

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.

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.

3.4 Model Adequacy

3.4.1 Page 28

> *"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;"*

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.

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:

- 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.
- 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.
- 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.

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 and will then recover up to 100ms when transients are starting to damp out.

3.4.2 Page 45

> *"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."*

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.

3.5 Protection

3.5.1 Page 25

> *"Relevant protection relays must be included in the model, explicitly where practically possible."*

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.

3.6 Switching and lightning

3.6.1 Page 28

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.

3.7 Load model

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.

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.

4 Conclusion

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.

References

[1] Cigre Working Group B4.62. TB 671: Connection of wind farms to weak AC networks. Technical report, Cigre, 2016.

[2] Cigre Working Group JWG C4/C6.29. Power quality aspects of solar power. Technical report, Cigre 672, 2016.

[3] DIgSILENT Pacific. Comments to proposed rule change in relation to: Generator system model guidelines, 2017.

[4] Martin Schmieg. Compatibility Issues in Time Domain Simulations with DIgSILENT PowerFactory and SIEMENS PSS/E. Technical report, DIgSILENT GmbH, 2017.