1 August 2017

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

Dear Sir,

Comments to proposed rule change in relation to: Generator System Model Guidelines

Thank you for the opportunity presented to DIgSILENT Pacific to comment to the draft rule change your reference ERC0219.

Company background

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.

RMS and EMT

RMS modelling and simulations are commonly used throughout the world for most grid analysis. Various RMS software platforms are available including PSS/E, PowerFactory, and many others. Each software product has its own limitations and advantages.

EMT modelling tools are less commonly used and normally not on a grid wide system, mostly due to practical considerations. These include the very slow simulation speed and the significantly more detailed models required. Again there are many software products available in the market, including EMTP-RV, PSCAD and PowerFactory. Also in the case of EMT simulation software platforms, each software platform has its own limitations and advantages.

The difference between EMT and RMS is that EMT always considers instantaneous values of voltage and current, whilst RMS only considers the fundamental frequency values. This means that EMT simulations can also be used to model very high frequency phenomena (such as lightning or switching surges).

It is important that we do not confuse specific software limitations with general limitations of RMS or EMT modelling and vice versa. For instance, some RMS software can only model balanced systems (i.e. positive sequence) and is therefore not able to model individual phase values. Also some EMT software cannot or are difficult to start in the steady state, meaning that each simulation starts with a transient even before an event happens.

Both EMT and RMS models are only models that will always respond slightly different from the reality. Both EMT and RMS models must be validated. It cannot be assumed that an EMT model is less or more accurate than an RMS model without thorough validation of both. Because EMT models consider higher frequency phenomena, it is generally more difficult to validate other than in a laboratory environment.

Hybrid studies are also possible, using RMS modelling of the whole power system with some (a small number) plant represented by an EMT model. This will provide some benefits and confidence in extreme cases where control system stability is suspected to be an issue. Most competent analysis tools provide this hybrid capability.

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DIgSILENT example

DIgSILENT obtained actual measured test response data as well as dynamic models of an electronic inverter in different simulation platforms. We conducted three-phase as well as two-phase to ground fault simulations and compared the results with the measured data. Unfortunately, due to confidentiality, we cannot publish these graphs, but we would be able to demonstrate the results to the AEMC if requested.

Simulations were conducted in PSCAD, PowerFactory and PSS/E. Both positive sequence and negative sequence values of currents, voltages and powers were compared. The results were quite interesting:

1. Three-phase fault: Interestingly, it was found that both PowerFactory and PSS/E models align very well with measurement while the PSCAD alignment is the least accurate.
2. Two-phase to ground fault: In the unbalance fault test case, only the PowerFactory model aligns well with measurements while PSS/E and PSCAD models are both less accurate (in different ways). As could be expected, the PSCAD model shows faster transient responses than both PowerFactory and PSS/E models. The fast transient responses of the PSCAD model align quite well with measurement but not the fundamental frequency responses during faults. In other words, the overall response of the PSCAD model is not as accurate as the PowerFactory model response. Also in the case of the two-phase to ground fault, the PSS/E model could not show negative sequence values.

These simulations were not "doctored" to claim that PowerFactory is more accurate – that outcome was purely coincidental and would not always be the case. The objective was to show that there is no magic bullet when it comes to modelling and simulation and outcomes are very dependent on the quality of the model and the capability of the simulation tool. The most effective validation is against high quality measurements. However, it is clear that a positive sequence tool cannot be expected to accurately simulate unbalanced conditions.

Current state of the art control strategies of solar inverters and wind turbines require measured voltages in individual phases or positive/negative/zero sequences. These individual phase/sequence voltages will be used to calculate the current injections during faults as well as to determine protection actions. Therefore, a balanced, positive sequence only RMS platform is not sufficient to always simulate the correct responses of modern inverters.

AEMC considerations

In its draft rule determination, the AEMC lists statements about RMS and EMT simulations that are incorrect or incomplete and therefore might have resulted in misinformed arguments that could lead to suboptimal decisions. Some examples are listed:

a. *"RMS-type models represent the voltages and currents variables in the power system as balanced 3-phase sine waves with a magnitude and phase angle."* RMS refers to the fact that a sinewave phasor is represented by a vector with magnitude and phase angle. RMS does not imply that the model should be otherwise simplified into a balanced system or even that the system should be limited to three-phase systems. RMS simulations can also be conducted using unbalanced modelling and simulation for systems with any number of phases. This is however software dependent and several RMS software packages are commercially available that offer full three-phase modelling and the capability of simulating unbalanced systems.

b. *"However, RMS-type models are not always capable of accurately modelling non-synchronous generating systems and how such equipment may interact with each other when there is low system strength"* This is a vague statement and should be clarified and quantified to be able to understand the actual problem. It is our experience that some models are simplified in the RMS domain but it need not always be the case. It is possible to obtain good results by modelling the phase locked loops and linkages with current controllers in the RMS domain. It is really only in extreme operating conditions that it is essential to model sub-systems of the network in EMT fidelity.

c. *"Unlike RMS-type models, EMT-type models provide the means to simultaneously and accurately assess all three phases in the power system."* This is not correct. RMS models can also assess all three phases in a power system. However, not all RMS software platforms have this capability, but this is not a limitation of RMS modelling technology.

Practical considerations

There is a very good reason why RMS simulations are used throughout the world to assess system stability. High frequency phenomena are generally not important when studying the stability of a power system. However individual phase values are very important – in particular since less than 5% of all system faults would be balanced faults. The over-whelming majority of faults are unbalanced events that should be assessed. (In fact, a three-phase transmission line fault is not even considered to be a credible contingency in the NEM.) It is therefore extremely important to be able to model these faults accurately which of course would not be possible without the ability to model all three phases individually.

Most consultants in Australia host several different software platforms and manage well with these. As an example here at DIgSILENT, we have PowerFactory, PSS/E and PSCAD software. Most of our competitors in power systems' analysis, both in Australia and internationally, would similarly have the capability of using the software tools adopted by the larger transmission and distributions companies. It is not clear why this would be an impediment for AEMO to similarly host a variety of dynamic modelling tools, particularly where these have wide levels of adoption in the NEM.

Fundamental questions

1. The primary use of EMT models is to examine the electro-magnetic transient behaviour of the plant. If the aim for the power system simulation is to capture fast dynamic controls, full three phase RMS models with shorter simulation time steps is generally sufficient. This approach can optimize the need for both accuracy and efficiency. In fact, modern analysis tools can vary the time step according to the situation, which will deliver even better efficiencies in the conduct of studies. Has this approach been attempted by AEMO?

2. Would the inaccuracies introduced by an unknown dynamic load model (which is constantly changing and gaining dynamic characteristics) as well as other system modelling assumptions invalidate the benefit of grid-wide EMT simulations?

3. If there is a need to examine the EMT interaction between inverters, all inverters within a generating system have to be modelled individually as they are electrically closer to one another than inverters from another farm. More importantly the inverters electrically closest to the grid connection point may behave differently to those far removed from the grid connection (but within the same generating facility) due to the additional impedance between these inverters. Would AEMO be able to conduct such detailed network simulations in an EMT environment within practical time periods?

4. All power system models rely on modelling assumptions. If a wide area EMT simulation study uses aggregate wind and solar farm models, this represents yet another assumption which may qualify the accuracy of the study results. Are there any local measurements that validate the EMT simulation results under the low system strength conditions that are of concern?

ERCOT study

The AEMC refers to dynamic studies conducted by ERCOT. The publicly available report for ERCOT by Electranix titled "System Strength Assessment of the Panhandle System PSCAD Study" dated 23 February 2016 makes for some interesting reading on several issues. In its conclusion, the report states the following:

> *"As the short circuit strength drops, these differences are expected to become more pronounced. For general studies in the Panhandle, assuming sufficient system strength (e.g. WSCR of at least 1.5 in this case), PSS/E analysis is still useful and quite accurate, although periodic checks are recommended in PSCAD to validate models and ensure key negative behaviors are caught and understood.*
>
> *For these short circuit levels, analysis of faults outside the Panhandle region was mainly the same, whether the Panhandle was modeled in PSCAD or not."*

The context is that this report studies a wind generating capacity of around 4 GW with no significant local load – hence almost all power is being transmitted from the Panhandle to remote load centres in Texas. (In South Australia there is currently a market constraint set to 1.2 GW of wind generation.)

This report conclusion supports DIgSILENT's thesis that RMS simulations using accurate RMS models are generally adequate and that a blanket requirement for EMT studies may be too severe. It also confirms that all models should be thoroughly validated.

Proposed rule change

The newly proposed Clause S5.5.7 (c) (2) reads that (AEMO must) "use reasonable endeavours to accept a range of software simulation products and versions; and"

This clause does not require AEMO to do anything and based on experience to date, the opportunity to the industry for AEMO to accept RMS and EMT models from alternative software platforms will be lost. In our first submission to this rule change request as well as earlier submissions, DIgSILENT already identified the benefits to the industry if access to commonly used software was also possible. The clause as it stands now does not address this issue and would result in higher costs to the entire Australian power industry.

Recommendation

It is recommended to change Clause S5.5.7 (c) (2) to read that (AEMO must) "maintain the NEM model in a range of software simulation products and versions and accept dynamic RMS and EMT models developed in a range of alternative software simulation products and versions; and"….

DIgSILENT would appreciate an opportunity to further discuss this submission with the AEMC, should this be possible within the consultation process.

Yours sincerely

Koos Theron
Director