Electromagnetic transient simulation models for large-scale system impact studies in power systems having a high-penetration of inverter connected generation

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• Comparison of RMS and EMT modelling approaches and impact on results
• Large-scale EMT model development in AEMO
• Considerations when conducting large-scale EMT studies
Comparison of RMS and EMT modelling approaches and impact on results
Applicability range of RMS- and EMT-type tools

- EMT-type models
- RMS-type models

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>1 Hz</th>
<th>10 Hz</th>
<th>100 Hz</th>
<th>1 kHz</th>
<th>10 kHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time-constant / (Period time for 50 Hz systems)</td>
<td>160 ms</td>
<td>16 ms</td>
<td>1.6 ms</td>
<td>160 μs</td>
<td>16 μs</td>
</tr>
</tbody>
</table>

X Slow converter control
X Fast converter control
X PLL
RMS- and EMT-model accuracy: Solar Farm response to fault on a SMIB model
RMS- and EMT-model accuracy: Solar Farm response to fault in a full-scale system model

- Sustained post fault voltage oscillations with a frequency of less than 10 Hz.
- Unacceptable oscillations due to:
  - breach of flicker requirements
  - not being adequately damped
RMS- and EMT-model accuracy: HVDC link response to fault in a full-scale system model

RMS model does not predict sustained commutation failure and subsequent disconnection of LCC HVDC link
RMS- and EMT-model appropriateness: South Australia black system event (1)

RMS model stops working as soon as SA system becomes islanded
Accurate simulation of voltage phase angles being the key indicator of loss of synchronism conditions
RMS- and EMT-model appropriateness

Voltage, active/reactive power before connection of new asynchronous generation

Voltage, active/reactive power after connection of new asynchronous generation
Large-scale EMT model development in AEMO
Summary

• Large-scale EMT models of four of the five regions are currently complete in Australian national electricity markets (NEM)

• This corresponds to an installed generation capacity of more than 30 GW, with several hundreds of busbars and approximately 100 large-scale inverter connected generators.

• These models are used for a variety of applications including:
  • Generator interconnection studies for inverter-connected generation
  • Determining system strength and inertia requirements at the transmission network level
  • Determining minimum must run synchronous generators in each region
  • Designing system-wide special protection schemes
AEMO uses PSCAD/ETMDC and PSS/E for large-scale simulation studies. Other capable tools may exist in the industry.

PSCAD load flow cases are developed automatically from PSS/E load flow files sourced from actual system snapshots.

An auxiliary tool is used to draw network single line diagram in PSCAD, and map PSCAD to PSS/E.

Another auxiliary tool is used to apply element status, correct tap position and machine setpoints in PSCAD.

This allows obtaining correct initial conditions without manual intervention.
Network and generator Splitting

- **Network splitting**
  - To increase the simulation speed (see the example).

- **Generator splitting**
  - Models of inverter connected generators often run at different time-steps, sometimes as low as 1-2 µs.
  - The slowest model(s) will largely determine the overall simulation speed.
  - Each model run at a different case to support their needs for different time steps without slowing down the overall simulation.
Generator model dynamic model development and integration

**Synchronous**
- Source codes are available to AEMO
- Often no major differences between respective RMS and EMT models
- Fast to simulate
- Placed in network cases
- Often developed by AEMO internally

**Inverter-connected**
- Highly confidential and vendor specific
- Appreciable differences between respective RMS and EMT models
- Relatively slow to simulate
- Placed in separate cases
- Obtained from OEMs
Model confirmation

Individual plant

• Playback of real measured disturbances into each individual model in isolation
• Compare measured and simulated responses
• Confirm the accuracy of each model in isolation

System-wide

• Run system-wide studies
• Apply a known fault at a known location that occurred in practice
• Often requires adjusting fault impedance to obtain the same voltage dip as occurred in practice
• Confirm the accuracy of system-wide models including impact of multiple generators and loads
Example of a thermal synchronous generator model confirmation

Plant Active Power Validation
- Active Power (MW) vs. Time (s)
- ±10%, PSCAD, Measured

Plant Reactive Power Validation
- Reactive Power (MVAr) vs. Time (s)
- ±10%, PSCAD, Measured

+/-10% bands are statutory model accuracy requirements in Australian NEM.
System-wide model confirmation

Voltage, active and reactive power for a substation close to the faulted point
Considerations when conducting large-scale EMT studies
Considerations when conducting large-scale EMT studies

- Simulation speed and hardware implications
- Obtaining vendor-specific EMT models from OEMs
  - Not an issue in Australian NEM due to legally binding requirements set out in AEMO’s Power System Model Guidelines
- Are there screening methods for determining when RMS and EMT simulations are required?
- The extent of the system that needs to be modelled in EMT domain
- Hybrid RMS and EMT simulation
- Offline vs real-time EMT simulation

The newly formed CIGRE WG C4.56 looks at some of these aspects in more details