Incorporating Electromagnetic Transient Studies into the Generator Interconnection Process at ATC

Damien Sommer, Chengyue Guo, Josh Kerr

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Agenda

- Introduction
- Pre-Kick Off – SCR Screening
- Phase 1 – PSCAD Model Verification & PSCAD Transmission Network Model Development
- Phase 2/3 – PSCAD Analysis
- Post Phase 3 – Material Modification Study
- Summary
Introduction – ATC Footprint

• A multi-state, transmission-only electric utility
• Own and operate more than 560 substations and more than 9,800 miles of transmission lines
• Have a peak load of about 13,000 MW
• Have about 600 employees
• MISO TO member
Introduction – Recent ATC GI Queues

- ATC had over 7 GW of IBR requests in three recent queues

<table>
<thead>
<tr>
<th>Queue Cycle</th>
<th>Wind (MW)</th>
<th>Solar (MW)</th>
<th>Energy Storage (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 August WI Cycle</td>
<td>341</td>
<td>1,299</td>
<td>0</td>
</tr>
<tr>
<td>2018 April Cycle</td>
<td>300</td>
<td>3,240</td>
<td>170</td>
</tr>
<tr>
<td>2019 April Cycle</td>
<td>232</td>
<td>1,239</td>
<td>269</td>
</tr>
</tbody>
</table>
Introduction – MISO & ATC PSCAD Study Requirements

**MISO BPM-15**

- PSCAD models required for all IBRs
- Study to be determined by local Planning Criteria in combination with MISO’s evaluation

**ATC Planning Criteria**

- PSCAD models required for all IBRs
- PSCAD studies required for IBR connecting to an area with low short circuit strength
Introduction - ATC PSCAD Study in MISO GI Process

• The Overarching Challenge
  – Hard to complete in MISO System Impact Study (SIS) timelines and require significant stakeholder collaborations
    • MISO (RTO)
    • ATC (TO)
    • Consultant hired by ATC
    • Interconnection Customer (IC)
    • Consultant hired by IC
    • Inverter manufacturer
Introduction - ATC PSCAD Study in MISO GI Process
Pre-Kick Off - SCR Screening

• Problems to solve
  – What G-T requests require a PSCAD study?
  – If a PSCAD study is required what faults need to be studied?
Pre-Kick Off - SCR Screening

• ATC Criteria to Determine if a PSCAD Study is Needed
  – Proximity to known weak grid area
  – Proximity to Mackinac HVDC, Benson Lake SVC
  – SCR below 3 (N-0, N-1, N-2)
  – WSCR below 1.5 (N-0, N-1, N-2)
Pre-Kick Off - SCR Screening

• ATC developed python tool for rapid SCR evaluation of numerous IBR plants

**Inputs**
1. List of POI buses
2. List of Plant MW capabilities
3. Starting bus
4. # of branches away from starting bus

**Python SCR Screening Tool**

**Output**
Excel File with SCRs under N-0, N-1 and N-2
Pre-Kick Off - SCR Screening

- Use the output of the python SCR screening tool to select the contingencies to study in PSCAD

<table>
<thead>
<tr>
<th>BUS #</th>
<th>BUS NAME</th>
<th>CONTINGENCY</th>
<th>SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>SOLAR POI 138.00 - GREEN SUB 138.00 + RED SUB 138.00 - PURPLE SUB 138.00</td>
<td>1.069278</td>
</tr>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>SOLAR POI 138.00 - GREEN SUB 138.00 + FARM SUB 138.00 - TOWN SUB 138.00</td>
<td>1.932069</td>
</tr>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>FARM SUB 138.00 - TOWN SUB 138.00 + DISCO SUB 138.00 - BLUES SUB 138.00</td>
<td>2.71061</td>
</tr>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>SOLAR POI 138.00 - GREEN SUB 138.00</td>
<td>3.012894</td>
</tr>
<tr>
<td>987654</td>
<td>WIND POI</td>
<td>WIND POI 138.00 - BLUE SUB 138.00 + RED SUB 138.00 - PURPLE SUB 138.00</td>
<td>4.104188</td>
</tr>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>FARM SUB 138.00 - TOWN SUB 138.00 + FACTORY SUB 138.00 - TOWN SUB 138.00</td>
<td>5.713749</td>
</tr>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>TURKEY SUB 138.00 - ITALIAN SUB 138.00</td>
<td>6.401166</td>
</tr>
<tr>
<td>123456</td>
<td>SOLAR POI</td>
<td>BASE CASE</td>
<td>10.39853</td>
</tr>
<tr>
<td>987654</td>
<td>WIND POI</td>
<td>WIND POI 138.00 - BLUE SUB 138.00</td>
<td>11.12908</td>
</tr>
<tr>
<td>987654</td>
<td>WIND POI</td>
<td>BASE CASE</td>
<td>13.45873</td>
</tr>
</tbody>
</table>
Pre-Kick Off - SCR Screening

• SCR Screening Results for Three MISO Queue Cycles

<table>
<thead>
<tr>
<th>Queue Cycle</th>
<th># IBR Requests</th>
<th># Requiring PSCAD Study</th>
<th># Contingencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 August WI Cycle*</td>
<td>12</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>2018 April Cycle</td>
<td>24</td>
<td>14</td>
<td>36</td>
</tr>
<tr>
<td>2019 April Cycle</td>
<td>18</td>
<td>13</td>
<td>33</td>
</tr>
</tbody>
</table>

* Prior to ATC Python Screening Tool and Contingency Selection Guidelines
Phase 1 – PSCAD Model Verification

• Model Challenge
  – Although the PSCAD model requirements were provided to ICs prior to model submittals, the requirements were usually not fulfilled.

  http://www.electranix.com/publication/pscad-requirements-rev-9-may-2020/
Phase 1 – PSCAD Model Verification

• Common Modelling Issues
  – Generic Models (not “real code”)
  – No Power Plant Controller (PPC)
  – Use Default Parameters
  – Not Project Specific
  – Not Matching Application Data
Phase 1 – PSCAD Model Verification

- Model Verification Statistics

<table>
<thead>
<tr>
<th>Queue Cycle</th>
<th># IBR PSCAD Models Studied</th>
<th># IBR PSCAD Models Needing Tuning</th>
<th>Longest Time to Get Model Resolution (Weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 August WI Cycle</td>
<td>9</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>2018 April Cycle</td>
<td>14</td>
<td>12</td>
<td>24</td>
</tr>
</tbody>
</table>
## Phase 1 – PSCAD Model Verification

### Visual Inspection

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The manufacturer’s name and the specific version of the inverter model should be clearly observable in the .psc file.</td>
</tr>
<tr>
<td>2</td>
<td>The PSCAD model documentation should be provided. It should match the model version in the .psc file and should include instructions for setup and running of the model.</td>
</tr>
<tr>
<td>3</td>
<td>The .psc file should contain the modeling of all the facilities from the inverters to POI including, but not limited to, the following facilities listed in 3a - 3h. The facilities should be site specific. The data in the .psc file should match PSSE steady state modeling data.</td>
</tr>
<tr>
<td>3a</td>
<td>Generator dispatched at the requested MW level</td>
</tr>
<tr>
<td>3b</td>
<td>Equivalent pad mount transformer</td>
</tr>
<tr>
<td>3c</td>
<td>Equivalent collector system</td>
</tr>
<tr>
<td>3d</td>
<td>Main step-up transformer</td>
</tr>
<tr>
<td>3e</td>
<td>Gen-tie line</td>
</tr>
<tr>
<td>3f</td>
<td>Cap banks, STATCOM or any other types of voltage control device</td>
</tr>
<tr>
<td>3g</td>
<td>AC equivalent source at the POI with manufacture designed minimum stable SCR for the inverter</td>
</tr>
<tr>
<td>3h</td>
<td>60 Hz grid frequency base</td>
</tr>
</tbody>
</table>
Phase 1 – PSCAD Model Verification

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual Inspection (cont.)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Protection settings are implemented.</td>
</tr>
<tr>
<td>4a</td>
<td>Generator voltage and frequency protection settings should match PSSE .dyr file.</td>
</tr>
<tr>
<td>4b</td>
<td>Option to disable protection models is present.</td>
</tr>
<tr>
<td>5</td>
<td>Model uses a simulation timestep of 10 µs or higher.</td>
</tr>
<tr>
<td>6</td>
<td>Model compiles using Intel FORTRAN version 12 or higher.</td>
</tr>
<tr>
<td>7</td>
<td>Model uses PSCAD version 4.6 or higher.</td>
</tr>
<tr>
<td>8</td>
<td>Model supports the PSCAD “snapshot” feature.</td>
</tr>
<tr>
<td>9</td>
<td>Model supports the PSCAD “multiple run” feature.</td>
</tr>
<tr>
<td>10</td>
<td>Model can be scaled to represent any number inverters/turbines, either using a scaling transformer or internal scaling. Model should not be using current injection to scale the plant.</td>
</tr>
<tr>
<td>11</td>
<td>Model includes power plant controller (PPC)</td>
</tr>
<tr>
<td>12</td>
<td>PPC accepts an external active power setpoint.</td>
</tr>
<tr>
<td>13</td>
<td>PPC accepts a voltage setpoint of 1.02 pu at POI. PPC is in voltage control mode.</td>
</tr>
<tr>
<td>14</td>
<td>PPC has a mechanism to implement a settable voltage droop</td>
</tr>
</tbody>
</table>
## Phase 1 – PSCAD Model Verification

### Performance Evaluation

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Description</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>Model initializes to the setpoints specified in the PPC in 5 sec or less and meets ATC Stability Criteria for 20 sec of simulation after all values have initialized.</td>
<td>20 sec flat run</td>
</tr>
<tr>
<td>16</td>
<td>If auxiliary plant voltage control devices are included in the plant, the voltage control of these devices should be coordinated with the PPC to prevent circulating VARs.</td>
<td>20 sec flat run</td>
</tr>
<tr>
<td>17</td>
<td>Model is able to ride-through, recover and meet ATC Stability Criteria from a 6-cycle, 3PG fault at the POI while dispatched at 100% of PMAX.</td>
<td>20 sec run with a 3PG fault</td>
</tr>
<tr>
<td>18</td>
<td>Model is able to ride-through, recover and meet ATC Stability Criteria from a 6-cycle, 3PG fault at the POI while dispatched at 20% of PMAX.</td>
<td>20 sec run with a 3PG fault</td>
</tr>
<tr>
<td>19</td>
<td>Determine the actual minimum stable SCR for the plant.</td>
<td>Minimum stable SCR test</td>
</tr>
<tr>
<td>20</td>
<td>Model responds to a step increase in frequency (overfrequency excursion event) by decreasing its active power meeting the performance specified in Table 2.1 of NERC IRPTF 2019 Reliability Guideline.</td>
<td>FERC Order 842 test</td>
</tr>
</tbody>
</table>
## Phase 1 – PSCAD Model Verification

<table>
<thead>
<tr>
<th>Performance Evaluation (cont.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>21</strong></td>
<td>Model responds to a step change in PPC voltage setpoint meeting the performance specified in Table 2.2 of NERC IRPTF 2019 Reliability Guideline.</td>
</tr>
<tr>
<td><strong>22</strong></td>
<td>Model trips or blocks when terminal voltage rises above 1.3 pu for 1 sec.</td>
</tr>
<tr>
<td><strong>23</strong></td>
<td>Model trips or blocks when terminal voltage falls below 0.2 pu for 1 sec.</td>
</tr>
<tr>
<td><strong>24</strong></td>
<td>The closed-loop dynamic response of the overall inverter-based resources, as measured at the POM, should have the capability to meet or exceed the performance specified in Table 2.3 of NERC IRPTF 2019 Reliability Guideline.</td>
</tr>
<tr>
<td><strong>25</strong></td>
<td>Model is compliant with NERC PRC-024 with momentary cessation disabled.</td>
</tr>
<tr>
<td><strong>26</strong></td>
<td>Model is compliant with FERC order 827.</td>
</tr>
</tbody>
</table>
Phase 1 - Transmission Network Model Development

• For each PSCAD study
  – Define modeling area in the vicinity of the new IBRs using engineer judgement
  – Develop detailed frequency dependent transmission line models based on conductor types, bundle configurations, and tower geometries
  – Develop fault logics
  – Generation dispatch sensitivities
Phase 2/3 - PSCAD Analysis

• Problems to solve
  – How to define IBR stability performance deficiency?
  – What are the mitigation options to consider?
Phase 2/3 - PSCAD Analysis - ATC IBR Control Stability Criteria

- No tripping for any Planning Events
- Continue current injection inside PRC-24 “No Trip Zone”
- No re-entering fault ride-through mode more than once in the time period beginning 6 cycles after the fault clears until the end of the 20 second simulation

Figure 3.3: Example of Control Instability (Mode Cycling) at Wind Plant Connected to Weak Grid [Source: Electronix]
Phase 2/3 - PSCAD Analysis - ATC IBR Control Stability Criteria

- Damping Criteria for P & Q at terminal buses, V at POIs
  - 50% or greater reduction in oscillation magnitude over the last four oscillation periods of the 20 second simulation
  OR
  - Peak-to-peak magnitudes during the last two sec of the 20 sec simulation not exceeding 3% of their rated values
Phase 2/3 - PSCAD Analysis - Mitigation Development

• Interconnection Customer Options:
  – Control System Tuning
  – Lower Impedance from Generator to POI
  – Reduced Plant Capacity
  – Temporary RAS (not preferred)

• TO Options:
  – Transmission Reinforcement
  – Operating Restrictions for N-1-1
Phase 2/3 - PSCAD Analysis - Mitigation Development

- Identified Mitigations for Two MISO Queue Cycles

<table>
<thead>
<tr>
<th>Queue Cycle</th>
<th>IC Control System Tuning</th>
<th>Transmission Reinforcement</th>
<th>EMT Stability Operating Restriction for N-1-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017 August WI Cycle</td>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2018 April Cycle</td>
<td>12</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>
Phase 2/3 - PSCAD Analysis - Mitigation Development

PSCAD: P, Q, POI Voltage Under the Worst N-1

Unstable Results!

PSSE: POI Voltage Under Worst N-1

Stable Result!

After the New Transmission Line Project is Included
Post Phase 3 - Material Modification Study

MISO GI Process

Pre - Kick off

Decision Point #1

Phase 1 SIS 90 days

Decision Point #2

Phase 2 SIS 45 days

Phase 3 SIS 30 days

GIA 150 days

Post GIA

Inverter Included In Application

Inverter Modification Request (Example)
Post Phase 3 - Material Modification Study

• Interconnection Customer to Submit a Detailed Analysis
  – To demonstrate that the proposed change is not a Material Modification
  – Steady-state, reactive power, short circuit, and stability analyses

• PSCAD Restudy Required by ATC
  – If a PSCAD study including the generator was performed during SIS
  – Same study scope after model verification
Summary

<table>
<thead>
<tr>
<th>Key Issues</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>What to study in PSCAD?</td>
<td>Develop screening criteria and a screening tool</td>
</tr>
<tr>
<td>Is the PSCAD model appropriate?</td>
<td>Develop a model verification process and complete it prior to PSCAD analysis</td>
</tr>
<tr>
<td>How to identify performance deficiency?</td>
<td>Develop IBR control stability criteria</td>
</tr>
<tr>
<td>How to efficiently implement the PSCAD study in GI process?</td>
<td>Get the models and faults ready as early as possible</td>
</tr>
</tbody>
</table>
Questions?
Contact Information

• Josh Kerr  
  – jkerr@atcllc.com

• Chengyue Guo  
  – cguo@atcllc.com

• Damien Sommer  
  – dsommer@atcllc.com