Comparative Analysis of Time-Series Studies and Transient Simulations for Impact Assessment of PV Integration on Reduced IEEE 8500 Node Feeder

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Introduction

Software tools available to perform power system analysis studies for distributed energy resource (DER) integration at distribution levels usually divide into two major types: electromagnetic transient analysis software such as PSCAD/EMTDC or steady-state analysis tools, such as OpenDSS. The studies have to be performed over several time periods to allow investigation of potential impact on time-dependent control devices due to intermittency in generation and variation in feeder load for selected feeder operation conditions. This study compares the simulation results and response of feeder control devices. The aim is to test the validity of the simulation results for OpenDSS and determine what minimum time-step can be used to obtain the valid results.

Methodology

- The feeder under study is modeled in both PSCAD and OpenDSS
  - Control elements, variable generation and loads are implemented
- 15 minute profiles are used for PV generators and variable loads
  - All 3 generators follow the same intermittency profile
  - All loads follow different profiles both for real and reactive power
- Simulations are conducted in PSCAD (fix steps) and different time steps in OpenDSS
  - The selected time steps are 5, 10, 15, 30, 40 and 50 seconds
- The comparison between the different time steps and PSCAD is made based on minimum and maximum tap settings, as well as number of changes for the different control elements of the feeder.

System Under Study

- The system studied is derived from the IEEE 8500 node feeder; introduced by the IEEE distribution system modeling working group.
- Due to the impracticality of modeling all 8500 nodes in PSCAD, the system was reduced to 139 nodes, representing the primary backbone feeder and associated branches.
- The nodes associated with the secondary load connection points were combined into spot loads at the 12 kV level.
- Variable generators (representing solar PV plants) and loads were added to the system to analyze the feeder behavior under changing conditions.
- The generators were sized and positioned to reverse the power flow through regulator #3 when fully generating (100% production).
- The variable loads replaced large loads throughout the feeder. Each load was given a different profile for both real and reactive power.

Simulated System

- 139 Nodes
- 12 kV
- 1 Source Transformer Load Tap Changer - 30s activation delay
- 3 Voltage Regulators - Individual phase controls - 45s activation delay
- 4 Capacitors - 1 Fixed, 3 Controlled - 60s activation delay - 300s dead-time
- 3 PV Generators
- 6 Variable Loads

Diagram of the simulated system

Effect of Sampling Rates

The 5 sec. interval was chosen to provide a good comparison between PSCAD and OpenDSS. Above 30 seconds, the step size is too large to allow for timely operation of the control devices. Changing in the simulation time steps also affects the profiles. As the time step becomes larger, some fast changes will be eliminated because of sampling.

Simulation Results

Simulation were performed using different cases, the results shown here are for full PV generation penetration and includes variable loads.

<table>
<thead>
<tr>
<th>Load tap changer</th>
<th>PSCAD</th>
<th>OpenDSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max # of changes</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Min</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Max</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Min # of changes</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Max</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Min # of changes</td>
<td>15</td>
<td>9</td>
</tr>
<tr>
<td>Max</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Min # of changes</td>
<td>14</td>
<td>11</td>
</tr>
</tbody>
</table>

In OpenDSS, both capacitors operate early, but in PSCAD, Cap #4 does not operate until much later. In PSCAD, the first capacitor operates a fraction of a second before Cap #4 would. This time difference is enough to bring the voltage at Cap #4 below the maximum and prevent switching, which is delayed until the second generation peak. The sampling rates in OpenDSS do not allow for this precision.

Conclusion

- Even with maximum PV penetration and variable loads, the OpenDSS simulations using a 5 sec time steps yielded similar results to the PSCAD simulations.
- When using correctly selected sampling periods, the overall results as seen in the number of tap changers operation and tap limits remain very similar.
- OpenDSS simulations are orders of magnitudes faster than PSCAD.
- OpenDSS also allows for far more expansive networks to be simulated. As such, it is very well suited for time-series analysis of variable generation and loads, especially ones requiring the simulation of multiple cases on large networks.
- Future Work: Implementing Voltage and VAR correction scheme for PV generators

Acknowledgements

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