HIGH PENETRATION PV
INTERCONNECTION MODELING AND REDUCTION OF DISTRIBUTION FEEDERS

Matthew J. Reno\textsuperscript{1,2}, Robert J. Broderick\textsuperscript{1}, Kyle Coogan\textsuperscript{2}, Jimmy Quiroz\textsuperscript{1}, and Santiago Grijalva\textsuperscript{2}

\textsuperscript{1} Sandia National Laboratories \quad \textsuperscript{2} Georgia Institute of Technology
Distribution System Modeling - OpenDSS

- OpenDSS solves the power flow
  - Open source three-phase distribution system simulation software from EPRI
- OpenDSS is controlled from MATLAB through COM server
  - Integrates solar data, perform post-simulation analysis, and loop through scenarios
- Sandia toolbox GridPV to interface between OpenDSS and MATLAB
Distribution Feeder Modeling

- 19.8 kV distribution system, LTC with LDC, five feeders
- Feeder - 7.5 MVA peak load, two switched capacitors
- PV scenarios at 100% of feeder peak load
Circuit Reduction Motivation

- A full detailed model of the distribution system can be time consuming to produce and to enter into simulation software. A reduced circuit also improves the ease of converting from one software package to another with few line segments and no propriety full feeder models.
- Time-series simulation of a large distribution system at a high time-resolution requires significant computational processing. Stochastic simulations or multiple study scenarios also involve large amounts of computation for full circuit models.
- Circuit reduction provides faster and more accurate interconnection screening criteria by reducing the circuit to a simpler equivalent representation with only the key circuit parameters.
Load Bus Reduction Formulation

- Reduce a single load bus into adjacent buses
- Assumptions – fixed current loads, balanced system
- Ability to apply recursively and to branches
- Fully equivalent circuit – voltage, line losses, topology
- Complete proofs and methodology shown in SAND report

\[
Z_{eq} = Z_1 + Z_2 \\
L_{eq1} = L_1 + \frac{Z_2}{Z_1 + Z_2} L_2 \\
L_{eq2} = L_3 + \frac{Z_1}{Z_1 + Z_2} L_2
\]
Complex Feeder Representation

Distribution Feeder

Reduced Equivalent Circuit

High Penetration PV Deployment Webinar Series
Distribution Modeling and Model Reduction
29 August 2013
## Validation and Percent Reduction

![Graph showing voltage fluctuations over time for different circuit configurations.](image)

<table>
<thead>
<tr>
<th></th>
<th>Full Circuit</th>
<th>Reduced Circuit</th>
<th>% of Original</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (seconds) to perform a week simulation at 1-second resolution</td>
<td>837.94</td>
<td>15.48</td>
<td>1.85%</td>
</tr>
<tr>
<td>Circuit – Number of Lines</td>
<td>1047</td>
<td>8</td>
<td>0.76%</td>
</tr>
<tr>
<td>Circuit – Number of Transformers</td>
<td>214</td>
<td>2</td>
<td>0.93%</td>
</tr>
<tr>
<td>Circuit – Number of Loads</td>
<td>386</td>
<td>10</td>
<td>2.59%</td>
</tr>
<tr>
<td>Circuit – Number of Buses</td>
<td>1262</td>
<td>11</td>
<td>0.87%</td>
</tr>
</tbody>
</table>
Conclusions

- Circuit reduction allows high-resolution detailed models to be run efficiently and accurately.
- A method was developed for simplifying the complex system to an equivalent representation of the feeder with fewer buses while maintaining an electrically equivalent feeder and topology.
- Circuit reduction was validated to be equivalent for time-series simulations with time-varying load and variable solar generation.
References


Q &A AND DISCUSSION

Matthew Reno – mjreno@sandia.gov
Robert Broderick – rbroder@sandia.gov
www.sandia.gov/pv