Power System Network Model / Application Maintenance

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Maintenance Background...

- **Southern California Edison**
  - 50,000 mi² service territory
  - 14 million + people
  - Peak Load 20,000+ MW

- **Network Model**
  - 1600+ Buses
  - 30000+ Breakers/Disconnects
  - 2000+ Lines
  - 1700+ Loads
  - 700+ Transformers
  - 250+ Generators
  - 500+ Shunts/Reactors
Maintenance Background...

• San Diego Gas & Electric
  – 4,100 mi² service territory
  – 1.4 million + people
  – Peak Load 4,000+ MW

• Network Model
  – 650+ Buses
  – 6000+ Breakers/Disconnects
  – 700+ Lines
  – 450+ Loads
  – 337+ Transformers
  – 214+ Generators
  – 100+ Shunts/Reactors
Model Footprint

Transmission
525/230 kV

Sub-Transmission
161/115/69 kV

Distribution
< 69 kV

External Utilities

Municipalities

Limited / No Telemetry

Limited / No Telemetry / ICCP

Customer Generation

Via ICCP

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Model Footprint
Network Model Applications

- Once a solid, accurate model is established, applications such as:
  - Real Time State Estimation
  - Power Flow Analysis
  - Real Time Contingency Analysis

utilize the defined model combined with SCADA telemetry to solve very complex systems.

- As we know, a utility’s grid is always evolving; expanding to accommodate the growth of renewables and the growing demand for energy.

- However, regardless of the utility’s and size of the model, the question remains:

—“How do we maintain the model?”
Responsibility

- At SCE within the EMS group – Advanced Application Group / Net Apps Group
  - Model updates and maintenance
  - Network application maintenance
  - Network database maintenance
  - Application displays maintenance
  - Troubleshooting
  - Support Operations Engineering / Grid Control
  - Single point of contact
At SDG&E, responsibility for model and net applications maintenance is shared between various groups:

- Grid Operation Services
- Grid Control Technical Support Team
- EMS Operations

**GOS:**
- Model maintenance
- Application maintenance
- Troubleshooting Support

**GCTST:**
- Model maintenance
- Real Time Calculations
- SCADA Displays
- Application Displays
- DB maintenance request

**EMSO:**
- Model maintenance
- Application maintenance
- Platform updates
- SCADA DB maintenance
- Troubleshooting Support
Responsibility

Regardless of how your company maintenance process is structured it is important to remember that support is needed by the various groups:

- Planning
- Operation Engineering
- SCADA Team
- Grid Operations
- Network Team

It is best practice to have one entity, person or group, be responsible for the model and net apps as a primary function.
4 Components to Maintenance

- Topology/Connectivity
- System Parameters
- SCADA / ICCP
- Testing and Implementation
Topology/Connectivity

- Substation reconfigurations
- Branch reconfigurations
- New equipment

- Internal Area
  - Work is typically scheduled with advance notification.

- External Area
  - No visibility on configuration changes
  - Unless notified, configuration changes are “stumbled” upon.
Topology
Topology

SDG&E

SCE
System Parameters

• Impedances
• Operational ratings/Limits/De-Rates
• Transformer Tap Settings
• Schedules

– Internal Area
  • Internal area parameters provided by Operations Engineering.
  • Convert to the correct base.
  • Biggest challenge was to determine and confirm the transformers’ LTC settings between what was out in the field versus how it was represented in SCADA, then defining the appropriate model settings.

– External Area
  • Ideal to use a common source of data CAISO/WECC
  • Data is not always accurate
  • Contact external utility for data
System Parameters

– Tap Settings:
  • How are the tap settings defined in the EMS?
    – 8L-8R
    – 16L-16R
    – 1-17
    – 1-33

– Transformer nominal voltages versus base voltages.
  • 525/220 kV vs. 500/230 kV.
  • Will affect tap step sizing.
New RTU/HMI
Analog points
Status points
Calculated points
Point calibration
ICCP points

– Driving force behind the model and network apps.

– SCADA group directly impacts the network apps:
  • Additions/removals_updates of status points
  • Ad hoc database work
  • Mislabeling points
  • Wrong SCADA display linkages
Several transactions take place before the metered value can be associated to the model:

- Adding necessary field equipment.
- Configuring the RTU/HMI.
- Adding points to SCADA Database.
- Linking points to SCADA display.

Correctly linking points to the SCADA display is extremely important.

- Comparison of Substation Drawing versus SCADA display.
- Incorrectly linked points may require further investigation/field confirmation.
- Adverse effect especially for state estimation.

Naming convention

- Can aid in determining positioning of CB’s / Disconnects in the substation.
Testing

- Functionality
- Model Changes
- Telemetry
- Solution

- Separate environment from production.
  - Allows for testing complex model changes in terms of external model reduction / expansion / equivalency
  - Application parameter changes
  - Debug / Troubleshooting
  - Less down time
  - System restarts without impacting others
Testing

– Test Environment Challenges:
  • Fully functional applications
  • Latest SCADA database
  • Live data feed
  • Quarterly sync with production or as needed
Things to Remember

- The network model is point driven. It has to be implemented in parallel with SCADA or ICCP data implementation or after. Best practice is to make sure the SCADA/ICCP database is finalized, in production, and the points are scanning correctly before proceeding with model updates.

- More detail may yield a better solution but may complicate maintenance. Apply model reduction/equivalency where feasible, especially in areas with little observability.

- Consider the impact of including or excluding the modeling of circuit breaker disconnects. This will impact your solution.

- Take advantage of verification tools provided by vendors, or create your own scripts that check the integrity of the model.
Things to Remember

• Create EMS displays for the external model. This will make it easier and faster to troubleshoot any divergence due to external data.

• Use State Estimation to your advantage.
  
  – Estimated bus voltages below/above operational limits, centered in an isolated area, may indicate incorrectly defined transformers.
  
  – Persistent ICCP telemetry flagged as bad data, may indicate that an external configuration change has taken place.
  
  – Some telemetry points may be flagged as a bad value or in violation of operational limits only under certain system conditions. Use this opportunity to verify your data and troubleshoot the root cause to determine whether it is model or SCADA related.
External Model Replacement and Maintenance

Presented by Les Jarriel (l.f.jarriel@ieee.org)
Power Software & Consulting Inc.
Purpose of External Model

• Avoid having to model your entire interconnection in detail.
• Improve performance and convergence.
• Provide a reasonable (not perfect) simulation of the external system, especially loop flows.
• Provide realistic external inertia and frequency responses for your Training Simulator.
• The external model improves your Contingency Analysis and other Analysis results. It does NOT improve State Estimator results.
External Model

The cut buses and connections are ignored completely.

The network to be eliminated will be replaced by a reduced equivalent.

The network to be retained is a detailed-model buffer zone.

The internal network is modeled in detail.

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Modeling Steps

• Step 1. Determine and create the external Network Model “footprint”. Using a External Network Analysis Program. Need a good PSS/E Case!

• Step 2. Create a CUT Internal Model and test for several weeks. Add Equivalent Loads at Boundaries.

• Step 3. Convert External PSS/E to vendor format and Clean up after the conversion. Cut out Internal portion of model.

• Step 4. Merge internal and external models and perform desired renumbering, renaming, etc.

• Step 5. Tune and Debug State Estimator and CA.

• Step 6. Prepare data for next external model replacement.
Step 1. Determining the Network Model “footprint”.

• Define contingencies to compare equivalent to full cases.
• Equivalent network should NOT contain large shunts. Use equivalent generations to control voltage instead.
• Low voltage / high impedance circuits should not be equivalized. These should be CUT with appropriate load/gen at each connection to the low voltage network. Better to over-predict overloads and voltage issues.
• Key issues:
  – Use an External Network Modeling application.
  – Use an “Operations” PSS/E Case. Most up-to-date current case.
  – A list of 30 to 70 contingencies to run. Not just N-1.
  – List of monitored buses. Those you are responsible for.
  – Compare full results of powerflow. Not just violations.
## Sample Sensitivity Results

Reduction Case: C:\UserFiles\Jobfiles\ABCompany\pti\Summer2011-v32.raw

Timestamp: 04/28/2011 11:00:13

### External Bus Retention Sensitivities reported in percent rating

<table>
<thead>
<tr>
<th>Rank</th>
<th>Bus No.</th>
<th>Bus Name</th>
<th>kV</th>
<th>Area Name</th>
<th>% Error</th>
<th>From-bus name</th>
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Step 2. Create “CUT” internal model.

• Do in parallel with Step 1.
• Remove external system at boundary bus.
• Include external system as internal where detail is already implemented and trusted.
• Add Equivalent Loads in place of boundaries with pseudo switches.
• Can do device renumbering / renaming at this time.
Step 2. Load “Cut” Model and Test.

• Load in BUCC and possibly Online and test over a few weeks.
• Worked on SE bad data issues.
• Will determine if current issues are internal or external.
• Will provide better model for vendor support if needed.
Step 3. Clean up after the PSSE to Vendor conversion.

• Typically there are many issues that should be addressed after doing this conversion so the model will require the least amount of manual modification. Some of the issues to possibly address:
  – Change bus and device numbers to get better ordering on the displays. Do this for internal also.
  – Create appropriate branch names with from/to stations.
  – Group buses into stations.
  – Replace small or zero impedance branches with pseudo switch or appropriate device.
  – Remove or adjust sigma’s created by the conversion.
  – Any generator / transformer / shunt issues that need to be cleaned up?
• Perform minimal testing of external as needed.
Step 4. Merge internal and external models.

• Merge models and load.
• Keep boundary pseudo loads but open pseudo switches by default. May help with solving boundary mismatch issues.
• Load model on BUCC and then Production.
Step 5. Tune and Debug State Estimator.

- Test State Estimator and Contingency Analysis.
- A lot of SE tuning will have been done in the “Cut” internal model effort.
- Add back in missing details and telemetry in the external model as needed.
- Test CA Cases against planned outages.

• Retain model sensitivity information from the external model replacement.

• Update external model status and reference in the vendor database if available.

• Create procedures to determine if external model needs replacement.
  – Based on changes in sensitivities.
  – Based on changes in accuracy analysis of full model to reduced model using the same retention statuses.
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Accuracy Analysis Sample

Original flow-voltage file:
C:\test\DAT\13hs2ap_v31a.flow
Equivalent flow-voltage file:
C:\test\13hs2ap_v31a_equiv.flow

<table>
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<tr>
<th>TYPE</th>
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<th>NAME</th>
<th>TO BUS NO.</th>
<th>NAME</th>
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</table>
Other Suggestions.

• Look at emergency versus operating limits and extreme contingencies.
• What should voltage limits be set to?
• Use PSS/E Summer case to get summer limits.
• Adjust node numbers or names and create process to do so. (So busbars and connections to devices are clearly identified).
• Customize displays for Network Applications.
• Compare results with what the ISO or RC is getting or other companies.
• Auto Save RT cases hourly for 3-21 days.
Thank You.

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