Project Title: Eastern and Western Interconnection Baselining – Part 2

Organization: PNNL (and Montana Tech)

Presenter(s): Tom Ferryman (PNNL) and Dan Trudnowski (Montana Tech)

FY 2010 Funding: $400K

Overall Project Purpose and Objectives:
This project has two major facets: (1) Eastern Interconnect Baseline study, AND (2) Western Interconnect Baseline study. They have different goals and use different data and techniques but both do research aimed to better understand power grid baseline characteristics and identify outliers.

The Eastern Interconnect Baseline study has as its primary goal: to investigate phase angle differences between site pairs, characterize typical patterns, identify atypical events, and recommend upper and lower limits for “normal” operation. Two distinctly different techniques were used: (1) Adapting the Power Grid Monitoring and Alerting multivariate software to work with phase angle differences, and (2) a Date/Time based prediction model.

The Western Interconnect Baseline study has as its primary goal to begin to relate steady-state power-system conditions (e.g., path flows and generator outputs) with the system’s electromechanical modal properties (modal frequency, damping, and energy). This is closely related to the fundamental goal is to better understand the modal properties of the WECC system and how these properties vary under changing system operating conditions.

Understanding these issues will likely result in increased grid reliability and optimum operation by providing proactive insight to the current and envisioned state of the grid (through phase angle difference insight and through better understanding of how Mode Meter metrics relate to fundamental grid measurements).

2010 Approach and Results:
The approach for the Eastern Interconnect Baseline study is to (1) involve PJM (Mahendra Patel) to provide State Estimator data for their grid, (2) involve EPG (Bharat Bhargava and Jim Dyer) to do related investigations (discussed separately), and (3) for PNNL (Tom Ferryman) to develop two methods to investigate the issue. This required adapting old research level code and creating new research level code to (3a) Ingest state estimator data, (3b) Adapt the Power Grid Monitoring and Alerting Multivariate Statistical Analysis technique for the Phase Angle Differences and use it to identify typical and atypical angle differences limits for various sites, (3c) Development of a statistical model.

Figure 1. Atypical Plots for 15 months
characterizing phase angle differences by site as a function of date and time; (hence its name, DTM (Date/Time Model)) to generated implied limits for alarms, (3d) Correlate atypical patterns and events to grid conditions as reported by PJM, and (3e) Suggested alarm limits for angle difference pairs to be monitored in real-time.

The results were impressive. The first PNNL investigation, Adapt the Power Grid Monitoring and Alerting Multivariate Statistical Analysis technique resulted code that processed 15 months of data, identified when atypical events occurred (see the graphical peaks found in Figure 1), identified the characteristics of those atypical events and enabled detailed drilldown capability (see Figure 2) to enable domain experts to see exactly what happened, where and when. Additionally, typical patterns were identified and characterized; thus providing a baseline of “normal” activity based on 15 months of State Estimator Data.

The second PNNL investigation developed a distinctly different approach to the investigation; create a Date/Time based model to predict phase angle differences (and uncertainty limits). The same State Estimator data was used. We considered: (1) Seasonality (13 seasons), (2) Day-of-week and (3) Time-of-day (3-hour blocks). The model was assessed using cross-validation (80% train / 20% test) and showed good performance. (See figures 3 and 4.) The model was set up to make predictions (and upper/lower bounds) for every 3-hour period for 54 different site-pairs for 2011. The results are stored in Excel worksheets for easy reference.

The approach for the Western Interconnect Baseline study is to (1) involve BPA (Dmitry Kosterev) to provide 365+ days of PMU and SCADA data, (2) involve Montana Tech (Dan Trudnowski) to do engineering investigations of the observed phenomena, and (3) for PNNL (Tom Ferryman) to investigate identifying a math/stat linkage between Mode Meter metrics and the PMU/SCADA data. This required PNNL to (3a) Ingest PMU/SCADA data and Mode Meter metrics, (3b) Calculate correlation coefficients for Mode estimation results with steady-state intertie flows and select generator real-power outputs and (3c) Fit multiple regressions to Mode Meter metrics as a function of PMU or SCADA data. The investigation shows a weak relationship that is statistically significant but not impressively robust. Additional investigations may result in better insight.

2011 Plans and Expectations:
The natural next steps for the Eastern Interconnect Baseline study is to hold a technical
session with PJM, EPG, PNNL, and other stakeholders (including interested utilities), review methodology and results, identify possible enhancements and investigations, and upgrade the code and apply to new data.

The natural next steps for the Western Interconnect Baseline study is for PNNL/Statistics to apply more powerful and resourceful tools to relate the Mode Meter metrics to PMU and/or SCADA data, hold a technical session with Montana Tech to review the results of the improved code to gain technical insight and suggest additional paths for investigation. This should lead to a joint technical review session with BPA, Montana Tech, PNNL and other stakeholders (including interested utilities) that jointly reviews the analysis results and formulates additional insights.

A very intriguing opportunity exists. We have 15 months of PJM State Estimator data and 12 months of BPA data. With the data owners’ authorization, we could perform data mining to gain insights from the mountain of data and brief appropriate personnel (as determined by the data owners and DOE). It is impossible to estimate what “gems” might be discovered, but the mine is likely to be rich in insight.

**Technology Transfer, Collaboration, Partnerships:**
This effort builds on work done for NASA, TVA and Southern Company, PNNL IR&D, and past DOE projects. Key to the research was the collaboration and willingness to share data access by PJM and BPA. Additional R&D is needed but is envisioned to bring insight that can be shared with all stakeholders.