North-American Synchro-Phasor Initiative
Planning Implementation Task Team

Phase Angles Base-lining

Objectives

Planning Implementation Task Team (PITT) and Operational Implementation Task Team (OITT) of North-American Synchro-Phasor Initiative (NASPI) identified base-lining of phase-angles as their highest priority. The base-lining includes relating power system measurements; phase angles, path flows, voltages, reactive reserves with the system performance measures for normal operating conditions and its variations over a period of time and during various limiting conditions like thermal limits, proximity to voltage instability or voltage collapse, frequency and damping of oscillations, voltage collapse, transient angular stability, etc. This kind of analysis will facilitate development of situation awareness tools from wide area measurements.

NASPI PITT and OITT recommend that the base-lining be performed for Western Interconnection, Eastern Interconnection and ERCOT. The baselining efforts include analysis of historic on-line data and off-line system studies. The following process is recommended.

WESTERN INTERCONNECTION:

1. Review the correlation between the phase angle information and historic System Operating Limits

Operators of critical paths conduct seasonal, week-ahead and day-ahead studies to set the System Operating Limits (SOLs). The studies include thermal screening, voltage stability and transient stability studies. The powerflow study cases are typically saved by the path operators.

The study cases can be used to find the sets of phase angles that correlate best with the system stress. Preliminary phase angle limits can be set based on these study cases.

- BPA will correlate phase angle information with SOL limits for California – Oregon Intertie and Pacific HVDC Intertie using historic SOL study cases (by June 1, 2009)
- CISO and SCE will correlate phase angle information with SOL limits for Path 26 (Midway-Vincent), East of the River and SCIT (by June 1, 2009).

2. Baseline historic actual phase angle data

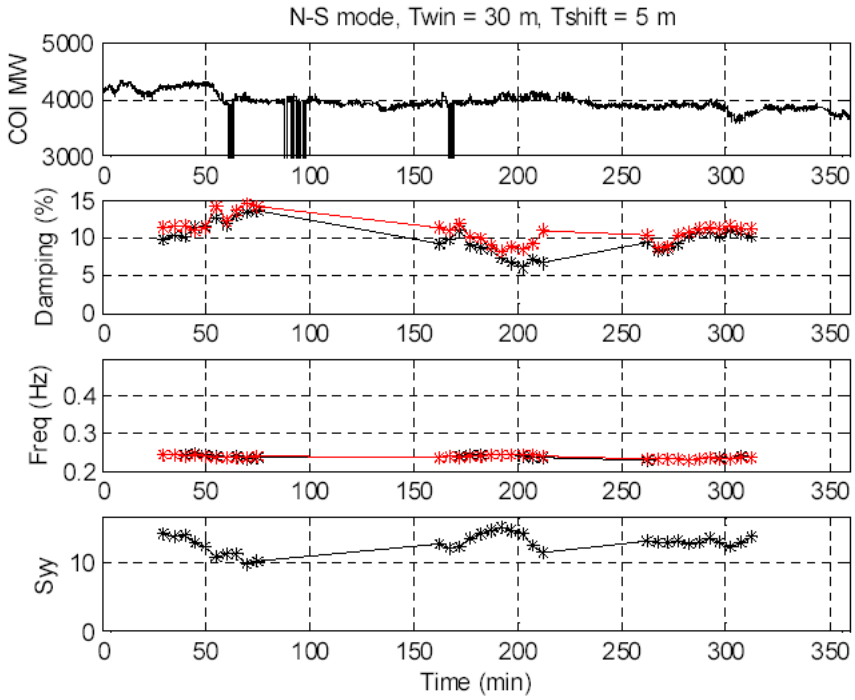
It is also necessary to baseline historic phase angles using available PMU data using the following process:

A. Establish synchro-phasor data sets for analysis.

B. Calculate system performance measures using PMU data. For each 5-minute interval:

- Check for disturbances and data dropouts, discard disturbance effects
- Calculate frequency, damping, energy and shapes for major inter-area modes
- Calculate angle-power sensitivities across major paths
- Calculate voltage stability indicators across major paths

Example of calculating North-South damping in 5-minute intervals for the Western Interconnection from PMU data



C. Using PMU data and 5-minute SCADA data provided by utilities, calculate the following:

- phase angles with respect to selected references
- flows on major paths
- power outputs of major generating facilities
- status of key transmission facilities

D. Perform correlation analysis between system performance measures “B” and power system measurements “C” defined above.

A long-term objective:

E. Develop automated tools that can calculate and archive quantities described in “B” and “C” using streaming data.

- BPA, SCE and CISO will provide historic PMU data for 2008 summer operating season (by June 1, 2009).
- A qualified consultant will perform data analysis as described in steps “B” to “D” above. Potential consultants include Electric Power Group, Battelle PNNL, Quanta Technologies, Washington State University, Rensselaer Polytechnic Institute, Montana Tech University, etc
  - In the West, the focus is on COI, Montana-Northwest, Midaway-Vincent, SCIT and East of the River paths.
  - Oscillation damping for North-South, Alberta, Montana-Northwest and Arizona-California modes will be calculated.

3. Dynamic studies base-lining to find critical angles and to determine corrective actions

Utilities will perform dynamic simulations of critical disturbances in the interconnection. The studies will vary the system stress level to find critical phase angle values when the system becomes unstable. The studies will record key phase angles, bus voltages, reactive reserves, path flows pre-contingency and during the transient.

- WECC Modeling and Validation Work Group will verify that study damping and mode shapes are in line with actual system damping and mode shapes (July 1, 2009)
- BPA, SCE and PG&E will perform system studies to determine critical phase angles as a part of WECC composite load model system impact studies (October 1, 2009)

EASTERN INTERCONNECTION:

1. **Perform statistical analysis of voltage phasor angles in the Eastern Interconnection.**

Eastern Interconnection does not have high enough installations of PMUs that can provide reliable system phasor angle data for a long period at many critical transmission buses within the interconnection. However, due to matured energy markets using LMPs, most large control areas have very reliable and accurate state estimators, and the state estimator solution snapshots of the system are stored every several minutes. These solutions have fairly accurate voltage phasor angles. (Additionally, each control area monitors and models interconnection facilities with its neighboring system, which can provide common phasor angle data points to remove any constant angel bias between different control areas if the analysis needs to be extended beyond one control area.)

The statistical analysis will use the phasor angle data and associated system information from the above mentioned saved EMS snapshots to identify anomalies, trends and tendencies in the wide area angle measurements over different periods, correlations with transmission system congestions and signatures of different system events within the limitations of the bandwidth of the snapshot intervals.

2. **Review the correlation between the phasor angle information and historic System Operating Limits**

Analyze PJM, MISO, NYISO, ISO NE day ahead analysis that identified binding constraints due to thermal, voltage or transient stability limits over various transmission interfaces (flowgates) over a one year period, and determine if phasor angles or phasor angles along with other system parameters provide reliable decision parameters to identify system stress limits for various flowgates. This analysis will facilitate development of situation awareness tools using wide area measurements.

3. **Extreme system operating conditions and associated wide area voltage phasor angles based on system simulations**

Systems are always loaded to reliable operating levels. So analysis of historical data would be unlikely to provide insight in the wide area phasor angles associated with

extreme disturbances and system loading conditions. In that case, this study would perform different extreme scenario analysis for interconnection wide system model using system simulations.