Technology Innovation Project

*Closing
Project Brief*

TIP 50: Inter-area Oscillation Damping

Context

Power oscillations are an inherent feature of inter-connected AC power systems. As a water drop creates ripples on a water surface, small load-generation imbalances create constant power oscillations across an interconnection.

Unstable oscillations have resulted in the breakup of the power system and derating of major interties for months. Large oscillations and resonance conditions can also lead to catastrophic damage of generating and transmission equipment. Power system models have previously been unreliable in representing oscillation damping.

Therefore, it is necessary to understand the oscillation risks, model them in system studies, and develop mitigation strategies to address the issues.

Description

This project developed a portfolio of solutions to detect, analyze and control power oscillations in the grid. It advanced studies in hydro-governor tuning to coincide with federal upgrades.

The solutions addressed oscillation issues in two main categories:

• Operational solutions –tools operators need to detect oscillations and anticipate their risk, and actions that can be taken to mitigate the risk.

• Control solutions – evaluation of various controls based on their effectiveness, robustness and cost. These include options of what can be done at grid level, supply side, as well changes to end-use loads.

Various oscillation damping control solutions were evaluated for effectiveness and robustness. A cost and feasibility analysis was done to move forward with a preferred option.

The project also included activities to gain better understanding of the regional power oscillations including oscillation baselining and regular system tests, such as Pacific DC Intertie probing.

Benefits

Oscillations can be dangerous when growing in magnitude, often due to high system stress (for example, Aug. 10, 1996 outage), equipment failures or resonance conditions.

They are one of the factors affecting transfer capabilities. Growing oscillations can also result in damage to power system equipment.

This project successfully advanced BPA's capabilities in three main technology areas: (i) activities to improve modeling and analysis of power oscillations, (ii) applications to give system dispatchers awareness of oscillations and low damping conditions, (iii) controls to dampen inter-area power oscillations either on transmission or on generators.

Additionally, the project supports BPA's capital investment in the synchro-phasor technology.

Accomplishments

The project has provided operational solutions that give power system operators greater situational awareness skills in dealng with power oscillations and their risks.

Control solutions provide options for dealing with events at the grid level, with applications for controling generation supply, as well changes to end-use loads.

Applications developed or studied in this project offer tools to provide early warnings to operators when oscillation is at risk (proactive), and tools to alert operators when oscillation is occuring (reactive).

Six applications were created or will be further developed in these areas.

VARPRO – This application provides data on oscillation modes and their frequencies, damping and shape. BPA engineers use it to analyze oscillation ringdown following a system event or a system test.

Prony Robot – The app provides automated analysis and reporting on thousands of simulated oscillation ringdowns. BPA engineers have used Prony Robot in several large-scale planning studies, including Mode Meter studies, Network Open Season studies, and dual-expert studies.

Baseline Inter-area Power Oscillations – This BPA Mode Meter application records and archives characteristics of inter-area power oscillations (frequency, damping, shape) with respect to power system conditions for North-South, BC-US and Montana-NW modes. BPA runs the application continuously on the streaming PMU data and the results are archived continually in OSI Soft PI historian. It can then be used for system performance baselining.

Low level Sustained Oscillation Detection – Low level oscillations could be due to incorrectly tuned equipment or a pre-cursor to equipment failures. This application is still under development focusing on testing self-coherency methods for oscillation detection.

Oscillation Detection – This application alarms dispatchers when sustained high-energy oscillation develops. It provides indication of the oscillation type and risk severity by using a comb RMS energy filter applied to 130+ signals in the BPA system.

Oscillation Mode Meter – The app alarms dispatchers when damping of a major inter-area oscillation mode persists below a required damping margin.

Additionally, by leveraging efforts by DOE, WECC, and NASPI efforts, and using BPA as a test environment, the project was able to assess oscillation risks in the Western Interconnection and used this information to create a roadmap of damping solutions to address those risks.

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Project Start Date: October 1, 2007

Project End Date: September 30, 2015

Deliverables Received

- Oscillation Damping Roadmap
- BPA dispatcher training
- PMU Performance requirements
- Report on using active power modulation for oscillation damping
- Final Report, August 2015

Funding

Total Project Cost: $1,250,000

For More Information Contact:

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Participating Organizations

US Bureau of Reclamation
US Army Corps of Engineers
US Dept. of Energy (DOE)
Western Electricity Coordinating Council (WECC)
North American Synchro-Phasor Initiative (NASPI)
University of Wisconsin

Key Results/Conclusions

- A roadmap of solutions was developed, considering planning, operational and controls related to oscillations.
- The most effective operator action is to reduce BC imports, particularly from generating stations at GM Shrum, Mica and Revelstoke dams.
- Grid-level control solutions to dampen COI power oscillations:
  a) 50 MW to 100 MW of active power modulation by energy/capacity storage. The energy source can be either concentrated (e.g. at Chief Joseph) or distributed (e.g. across Puget Sound area). The further north, the more effective are the controls.

   PDCI power modulation will also work, with careful attention to DC workload.
  b) 10 Ohms of controllable series compensation in each COI line.
  c) Relative frequency difference between North and South provides the best input.

- Supply-side solutions are most cost-effective. Significant dampening improvements can be achieved with better hydro-governor design and tuning.
- Electronic loads have negative effects on dampening because of their constant power nature. Changing the electronic load characteristic from constant power to constant current can dramatically improve dampening.

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