Technology Innovation Project

Closing Project Brief

TIP 289: Wide-Area Damping Control Proof-of-Concept Demonstration

Context

The Bonneville Power Administration (BPA) has identified control schemes that can mitigate inter-area power oscillations through increased damping. There are two main motivations for mitigating power system oscillations. First, if damping is insufficient, oscillations may grow and cause a series of cascading outages. Avoiding large outages provides a significant financial incentive. Second, power flows down major transmission paths are often limited by small signal stability. Additional damping enables greater power flows, and thus greater revenue. Greater power flows down existing transmission paths also provides a potential transmission deferral benefit, along with potential reduced congestion pricing for wholesale electricity consumers.

The supervisory controller is responsible for monitoring system damping, assessing the performance of local control nodes, periodically updating parameters (e.g., local control gains), and disabling the system if improper operation is detected. A well designed supervisory control system is essential for safe and robust operation. Not only must a wide-area-damping controller improve system damping, it should also cause no harm over a range of operating conditions.

Description

The TIP 289 project designed, simulated, tested, and demonstrated a wide-area damping control system that modulates the power flow on the PDCI based on real-time wide-area feedback information acquired from Phasor Measurement Units (PMUs) located throughout the BPA region. The key features of this control system are as follows:

- An effective and safe feedback control strategy based upon further refinement of the concept developed under TIP 50. This included thousands of simulation tests to verify the approach.
- An automated supervisory system to monitor and operate the controller to maintain system safety and integrity. This system utilizes state-of-the-art algorithms to assure the safe operation of the damping controller under all conditions.
- The first wide-area large-scale damping controller ever constructed and operated in the world. This system utilizes real-time PMU feedback acquired over a substantial part of BPA's region to stabilize the entire Western Interconnection (WI). To our knowledge, no other system has ever been built and operated on an actual system.
- The project won an R&D 100 Award in 2017 and a patent application filing is under review.

The damping controller (DCON) has been tested and demonstrated at the Celilo Converter Station in The Dalles, Oregon. The DCON currently resides in the control room at Celilo. The DCON is not connected to the PDCI. However, it is still in a fully functional form, so that if BPA wishes to conduct further tests on the grid, it would require minimal effort to carry out these tests.

Benefits

Full implemented, this project provides the following benefits:

1. Increased revenue: Power flow on certain transmission lines, e.g., the California-Oregon Intertie (COI), is small-signal stability-limited. Increasing these power flows corresponds to additional revenue.
2. Increase stability margins: This work will develop control methods that will increase system stability margins.
3. Opportunity to capitalize on the upgraded phasor measurement units (PMU) data network, PMU data and possible inter-area-damping capability.

Accomplishments

In 2007, BPA initiated the TIP 50 project to investigate the feasibility and effectiveness of multiple types of actuators for active damping controls. The goal was to investigate several potential solutions to improve system oscillatory stability. In 2013, TIP 289 was initiated to focus on the more promising actuator types identified by TIP 50, e.g., thyristor braking, energy storage, and modulation of the Pacific DC Intertie (PDCI). Early on in the TIP 289 project, thyristor braking was dropped as a feasible actuator type due to the lack of such devices and the need for two brakes 100s of miles apart working in tandem. TIP 289 did investigate energy storage and published multiple papers and conducted simulations showing the feasibility of several scenarios, none of which is feasible in the near term. However, the TIP 289 project team quickly determined the feasibility of PDCI modulation, and therefore, the remainder of the project duration was focused on PDCI modulation exclusively.

Deliverables

In addition to the DCON itself, the following deliverables were also part of TIP 289:

- First successful demonstration of wide-area control using real-time PMU feedback in North America much knowledge gained for networked control systems on the grid.
- Control design is actuator agnostic easily adaptable to other sources of power injection. Indeed, the early part of TIP 289 produced algorithms for damping using distributed energy storage. Further, in a different project, the DCON control design required only modest modifications to be effective in damping control by modulating torque on wind turbines.
- Supervisory system architecture and design is modular and readily reusable for future real-time control systems to ensure "Do No Harm" to the grid.
- Algorithms, models, and simulations created to support future implementation of control strategies using distributed grid assets.
- Extensive eigensystem analysis, visualization, and mapping tools developed to support simulation studies and analysis of test results.
- Model development and validation supports multiple levels of fidelity in analysis, design, and simulation studies. These models reside in PSLF and PST (Matlab toolbox used for Mini-WECC).

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Project Start Date: October, 2012

Project End Date: September, 2018

Funding

Total Project Cost: $2,035,000

Reports & References

Related Technology Innovation Projects

TIP 50: Oscillation Damping Controls

Report: "Design and Implementation of a Wide-Area Damping Controller Using High Voltage DC Modulation and Synchrophasor Feedback", submitted to 2017 International Federation of Automatic Control (IFAC) World Congress.

Report: "Open-Loop Testing Results for the Pacific DC Intertie Wide Area Damping Controller", accepted by IEEE PES PowerTech Manchester 2017.

For More Information Contact:

BPA Project Manager:
Gordon Matthews, Technology Innovation
ghmatthews@bpa.gov
Technical Contact:
Dmitry Kosterev, Transmission Planning
dmkosterev@bpa.gov

Principle Investigators:
Dave Schoenwald, Sandia
Dan Trudnowski, Montana Tech

Participating Organizations

United States Department of Energy (USDOE)
Sandia National Laboratories
Montana Tech of the University of Montana

Conclusions

The DCON is the first successful wide-area grid demonstration of real-time feedback control using PMUs in North America. This is a game-changer, enabling the use of widely-distributed networked energy resources that have the potential to transform the existing power grid into the future smart grid. Benefits that the DCON is capable of delivering, once operational, include: (1) Additional reliability to the grid from improved damping of electromechanical oscillations. (2) Additional contingency management of the grid under stressed system conditions. (3) Higher power limits in specific transmission corridors. (4) Reduction and/or postponement in new transmission capacity expansion.