Wide Area Damping Control:
Proof of Concept
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- Project Team:
  - Sandia National Labs – Dave Schoenwald, Ray Byrne, Ryan Elliott, Jason Neely
  - Montana Tech University – Profs. Dan Trudnowski and Matt Donnelly
  - Project Consultant – Dr. John Undrill
Phase I Project Objectives: FY13-FY15

• Overall Project Goal:
  – **Significantly increase the TRL** (Technology Readiness Level) of wide area damping control systems such that the **next phase is deployment oriented**

• Primary Phase I Deliverables:
  – **Assessment of energy storage** for damping control
    – Coordinated control of distributed energy storage
    – HVDC (High Voltage DC) modulation augmented with energy storage
  – **Prototype PDCI-based (Pacific DC Intertie) damping control system** to be installed, tested, and validated at BPA Synchrophasor Laboratory

• Control Design Features:
  – Real-time Phasor Measurement Unit (PMU) Feedback
  – Supervisory level control to monitor damping effectiveness
Wide Area Oscillations Jeopardize Grid Integrity

- Large generation and load complexes separated by long transmission lines can develop inter-area oscillations.

1996 breakup caused by low-frequency oscillations.
Visualization of Wide Area Oscillations

- Simulation of North-South B Oscillatory Mode using PSLF
- 2015 Heavy Summer WECC Base case
- Mode is observable throughout the Western U. S. grid
- 0.36 Hz modal frequency
- 13.7% Damping
Visualization of Wide Area Oscillations

- Classical generator model behaves like mass-damper system

![Diagram of mass-damper system with electrical angle (radians) on the y-axis and two mass areas: Southern Area and Northern Area. The diagram illustrates the oscillation between the two areas with an angular displacement Δθ.](image-url)
Active control has the potential to significantly improve damping of inter-area oscillations

Example: British Columbia - Alberta Separation

- Without damping control, the system response is nearly undamped
- With damping control, the oscillation decays very quickly.
Benefits from Active Damping Control for Inter-area Oscillations

- Improved system reliability
- Additional contingency in a stressed system condition
- Economic benefits
  - Avoidance of costs from an oscillation-induced system breakup
    - 1996 outage costs: > $1B overall impact
  - Reduced need for new transmission capacity
    - Capital cost savings in excess of $1M per mile
  - Potential for increased flows in California-Oregon Interconnect (COI)
    - Ability to meet demand on hot summer days in SoCal
Proposed Damping Schemes use Frequency Difference Feedback

Control Objectives:
- Dampen all modes of interest for all operating conditions without destabilizing peripheral modes
- Do NOT worsen transient stability (first swing) of the system
- Do NOT interact with frequency regulation (e.g. speed governors)
- Example – PDCI modulation:

Feedback control signal should be proportional to the frequency difference between two areas
Three Node Damping Control Scheme: PDCI augmented with Energy Storage

Addition of energy storage improves damping of East-West A mode

![Generator Speed Difference: Palo Verde - John Day](image1)

![Generator Speed Difference: East-West](image2)

![Map of Pacific DC Intertie](map)

- **Stimulus Locations**
- **Monitoring Locations**

Locations:
- Chief Joe
- Celilo
- Craig Station
- Cheyenne River

**Energy Storage** locations:
- Sylmar
- Pacific DC Intertie

![Map of Test System](test_system_map)
Three Node Damping Control Scheme: Improved Controllability of E-W Mode
Project Accomplishments: FY13 - FY14

- Development of hardware and real-time software:
  - Damping control design based on real-time PMU feedback
  - Supervisor control design to monitor:
    - System operation to assure all control settings are correct
    - Open loop gain and phase margins
  - 3 copies of prototype controller have been built and delivered:
    1. BPA Synchrophasor Lab
    2. Sandia Grid Resiliency Lab
    3. Montana Tech Power Oscillation Lab

- Damping control strategies incorporating energy storage:
  - Optimal allocation of distributed energy storage for active damping
  - PDCI modulation augmented with energy storage to mitigate E-W mode
Upcoming Tasks and Project Follow-on

- Transition plan from **prototype to deployment** (phase 1 → phase 2)
  - Rigorous testing & refinement of the prototype control system
    - Address data quality and latency issues
  - Comprehensive risk assessment of proposed control strategies
  - Outline testing strategy for deployment phase
  - Interface with BPA operations

- Focus on **Distributed** Energy Storage as a damping option
  - Placement and control strategy in distributed storage implementation
  - Technology & Power Requirements
Project Publications

- **Conference Proceedings**
  - 2012 Modeling, Simulation and Optimization for the 21st Century Electric Power Grid (Engineering Conferences International)
  - 2013 & 2014 IEEE Power and Energy Society General Meeting (PESGM)
  - 2013 Electrical Energy Storage Application and Technology (EESAT)

- **Journal Paper in submission process**
  - IEEE Transactions on Smart Grid (optimal location of distributed energy storage)
Questions?

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