Update on BPA Wide Area Damping Control Project

CERTS ILC Meeting

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Dave Schoenwald, Ray Byrne, Ryan Elliott, Jason Neely, Dakota Roberson

Sandia National Labs

Dan Trudnowski, Matt Donnelly
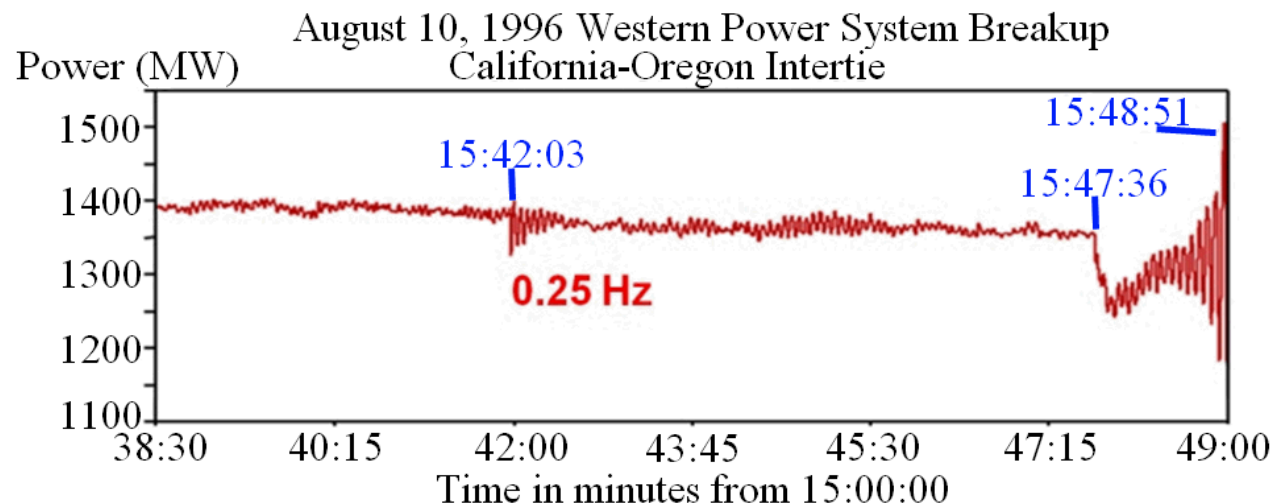
Montana Tech University

Acknowledgements

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- DOE Transmission Reliability Program managed by Dr. Phil Overholt of the DOE Office of Electricity

- DOE Energy Storage Program managed by Dr. Imre Gyuk of the DOE Office of Electricity

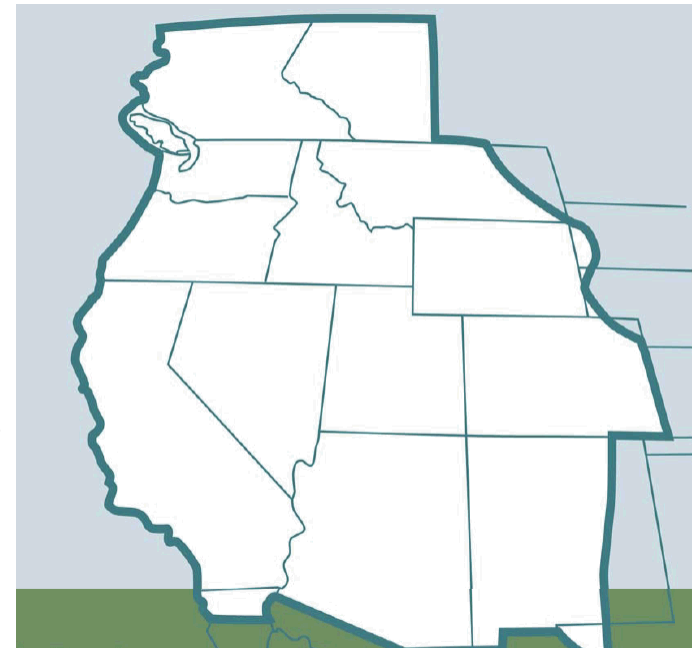# Inter-Area Oscillations Jeopardize Grid Integrity

- Large generation and load complexes separated by long transmission lines can develop inter-area oscillations
  - These oscillations are the result of a low damping condition
  - Growing oscillations can result in equipment damage or system breakup

1996 breakup caused by low-frequency oscillations

August 10, 1996 Western Power System Breakup
California-Oregon Intertie

Damping Controls for Grid Stability

- There are several low frequency oscillation modes in the Western Electricity Coordinating Council (WECC) region[1]
    - "North-South" mode nominally near 0.25 Hz;
    - "Alberta-BC" mode nominally near 0.4 Hz;
    - "BC" mode nominally near 0.6 Hz; and,
    - "Montana" mode nominally near 0.8 Hz.
- Researchers at Montana Tech and Bonneville Power Administration (BPA) have investigated damping controls for the WECC for many years
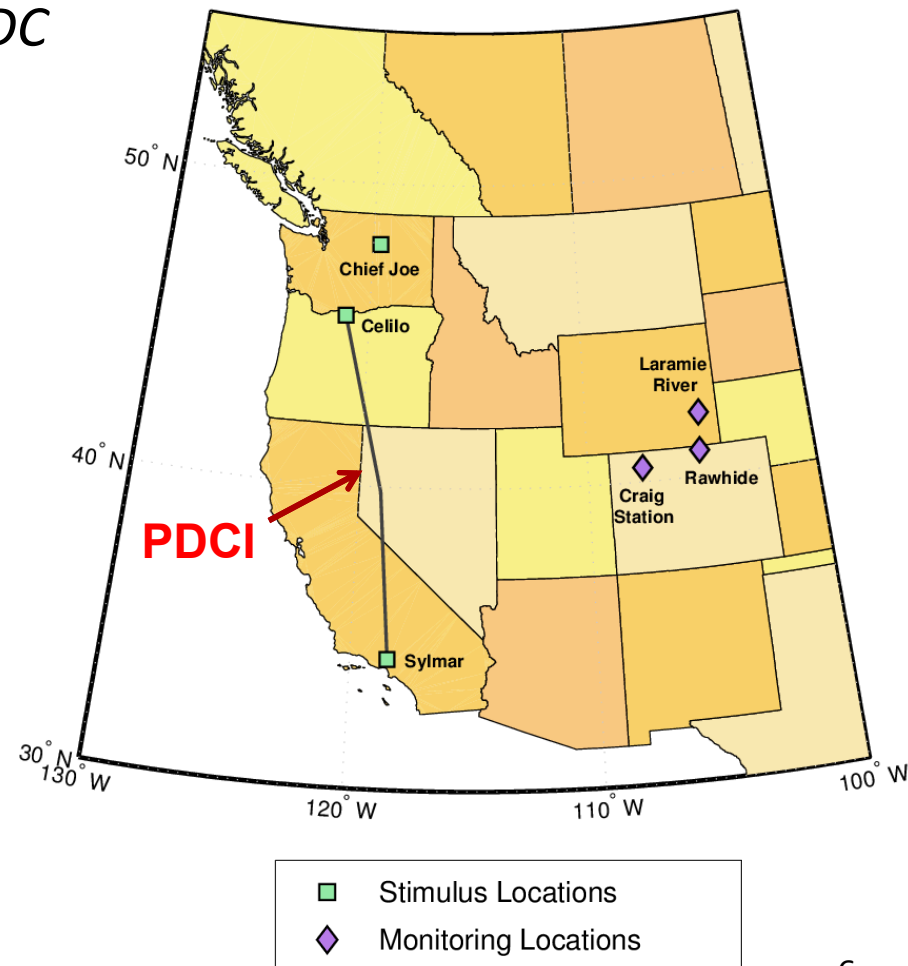- This project builds on their results

[1]D. Trudnowski, "Baseline Damping Estimates," Report to Bonneville Power Administration, September 2008.

Project Goals

- Significantly increase the technology readiness level of wide area damping control systems to increase the damping of inter-area oscillation modes in the WECC

  - Investigate the use of HVDC (High Voltage DC) by modulation of the PDCI (Pacific DC Interconnect)

  - Assess storage technologies for the damping control system

  - Design high fidelity models and perform PSLF simulations to validate damping performance using BPA provided data

  - Develop safeguards for a supervisory control system to ensure that the damping controller can never destabilize the grid, i.e. **Do No Harm**

- Implement a prototype control system to be deployed at BPA in 2015

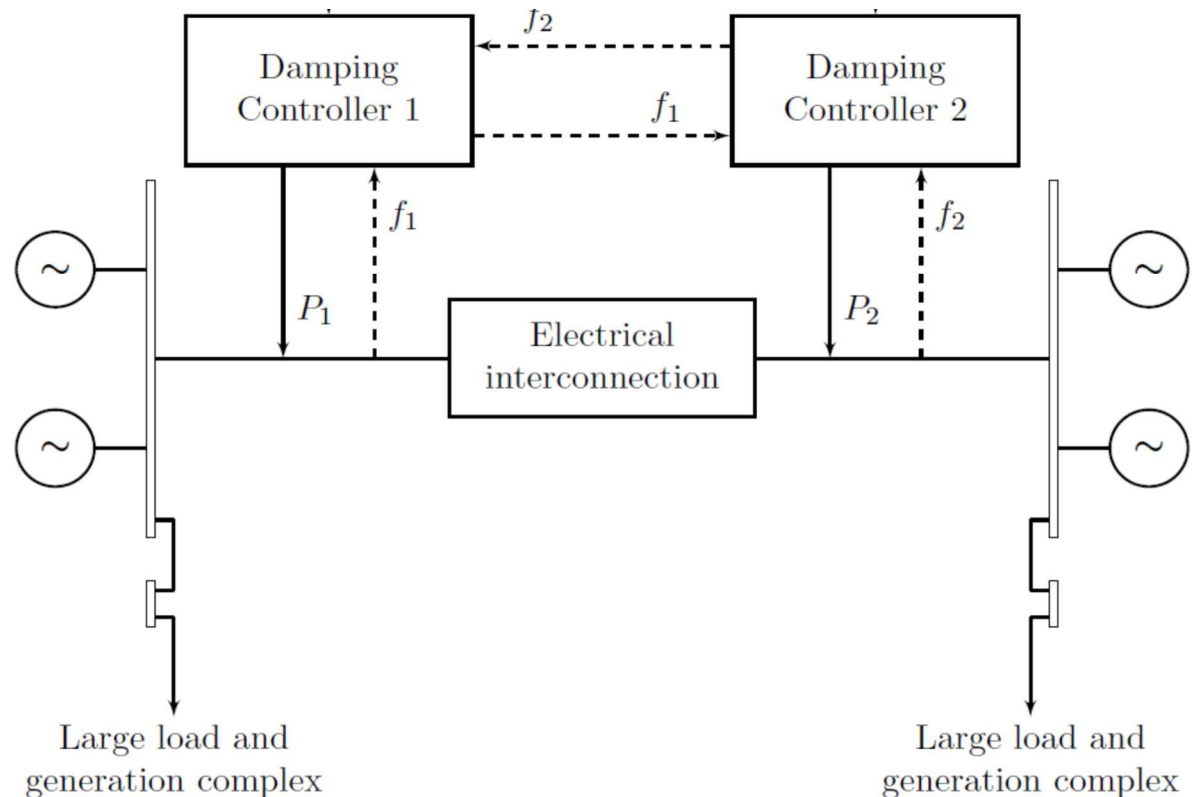# PDCI Modulation is a Promising Candidate Damping Control Scheme

- Oscillation damping using the *Pacific DC Inter Tie* (PDCI) is being investigated
  - High power capacity
  - Existing infrastructure

- Simulation results in PSLF have shown improved damping of primary North-South mode using PDCI modulation without destabilizing other modes

Proposed Damping Schemes use Frequency Difference Feedback

- Damping control designs have thus far focused on
  - Frequency difference feedback between two areas
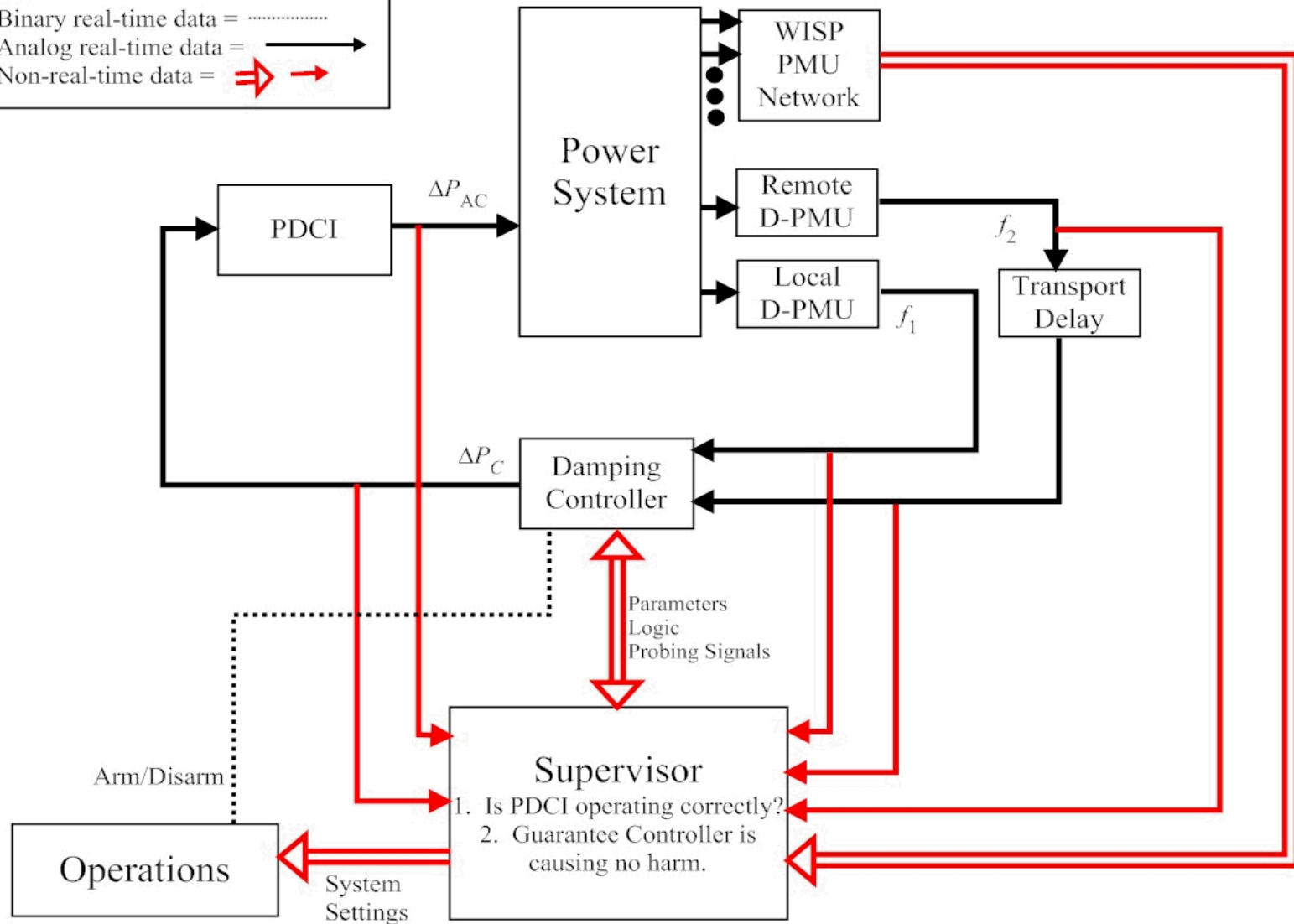 - Symmetrical Power Modulation

$$P_1 = -K_d\left(f_1 - f_2\right)$$
$$P_2 = K_d\left(f_1 - f_2\right)$$

Overall View of PDCI Modulation
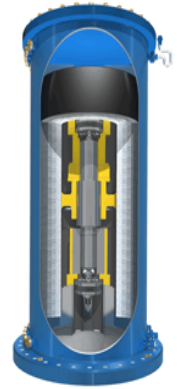
Damping Control Properties

- Controller Robustness – control system dampens all modes of interest for all operating conditions without destabilizing peripheral modes

- Controller should NOT worsen transient stability (first swing) of the system.

- Controller should NOT interact with frequency regulation (e.g. speed governors).

Supervisory Control Properties

- Actions:
  - Apply all settings to damping controller
  - Monitor and collect key status and signals from damping controller
  - Send status to Operations
  - Enable/Disable damping control system
- Primary Duties:
  - Monitor Grid
    - $\Delta P_{AC} \approx \Delta P_C$
  - Ensure damping controller is causing NO HARM
    - Monitor loop frequency-domain Transfer Function
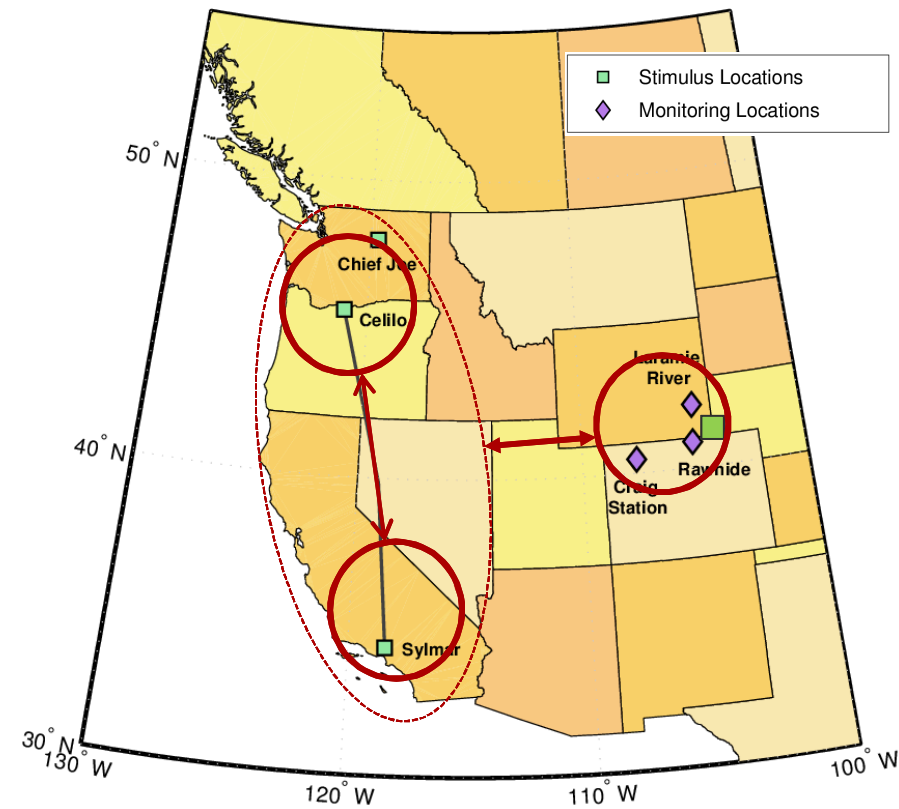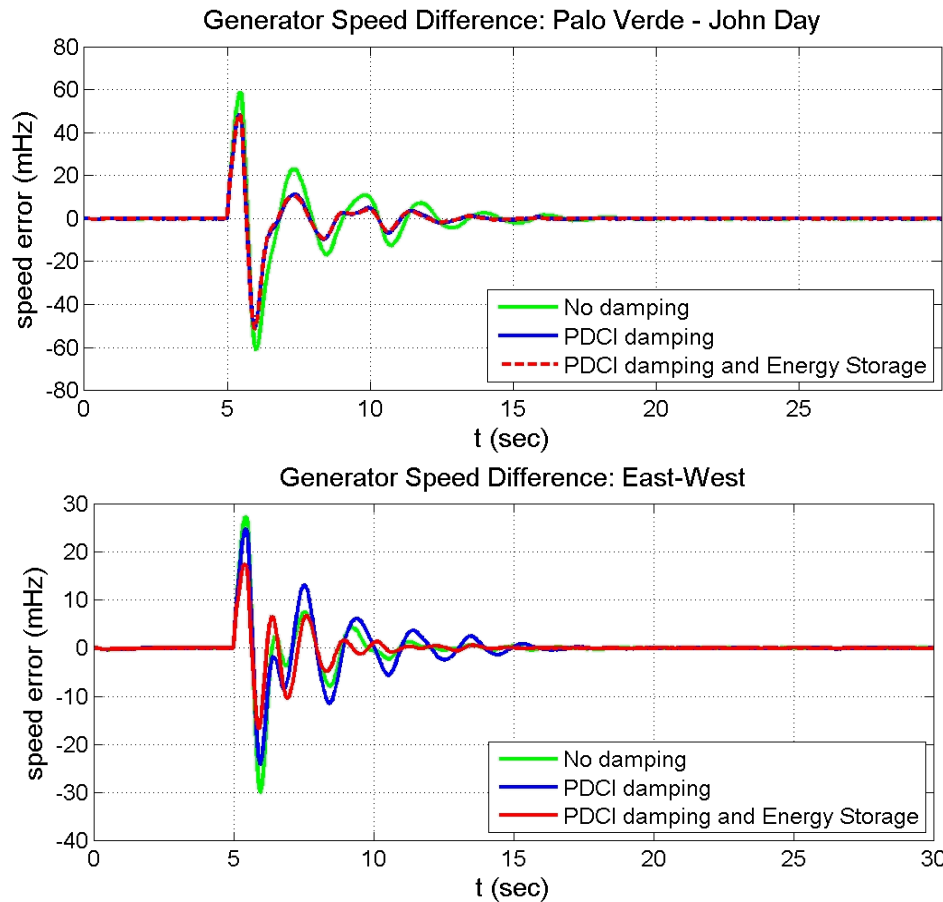   - Compare closed-loop and open-loop damping

Energy Storage Technologies are also being Investigated

- Technology
  - Flywheel
  - UltraCapacitor
  - Valve Regulated Lead Acid Battery
  - Compressed Air

- Performance Evaluated
  - Power Rating
  - Energy Capacity
  - Bandwidth

- Damping requires little energy, but high power, high bandwidth control

Three Node Damping Control Scheme: PDCI augmented with Energy Storage

- PSLF WECC model simulated
- Additional controller improves damping of East-West mode

Current Status

- Developed an extensive set of analytical tools for conducting oscillatory mode analysis (eigensystem analysis) on large models with both simulated and real data

- Designed prototype control system architecture with primary functions/issues of damping and supervisory controllers identified

- Conducted PSLF studies showing benefits/limitations of proposed controllers (e.g. PDCI modulation, energy storage)

- Illustrated geographical displays of mode shape results

Future Tasks

- Continue Design of Supervisory Controller
  - Analyze situations supervisory control system can encounter and mitigating actions supervisor must undertake
  - Conduct design review to select compatible hardware for prototype control system
- Assess PDCI modulation risks and benefits
- Explore Frequency Measurement options
  - With BPA staff, analyze latencies, noise, and failure modes of PMU data
  - Design alternative frequency measurement schemes
- Develop Visualization software for situational awareness
  - Demonstrate geographical mode shape displays
  - Work with BPA staff to determine most effective user interfaces
- Determine feasible feedback signals for damping controller
  - Identify a set of feedback signals based on geographical availability
  - Determine benefits/risks of each potential feedback signal
- Investigate Distributed Energy Storage as a damping option

Contact Information

Sandia Principle Investigators:

    David Schoenwald, Ph.D.

    email: daschoe@sandia.gov

    phone: 505 284-6285

    Ray Byrne, Ph.D.

    email: rhbyrne@sandia.gov

    phone: 505 844-8716

Montana Tech Principal Investigator:

    Prof. Dan Trudnowski

    email: DTrudnowski@mtech.edu

    phone: 406 496-4681