Technology Innovation

SAND2014-0390C

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

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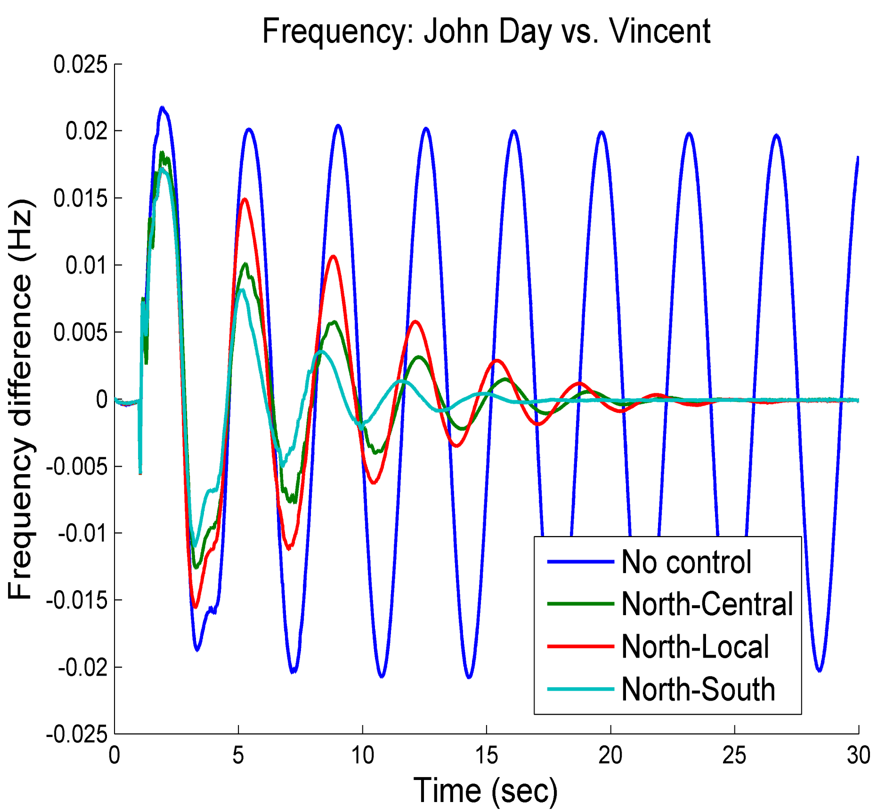
Project Synopsis

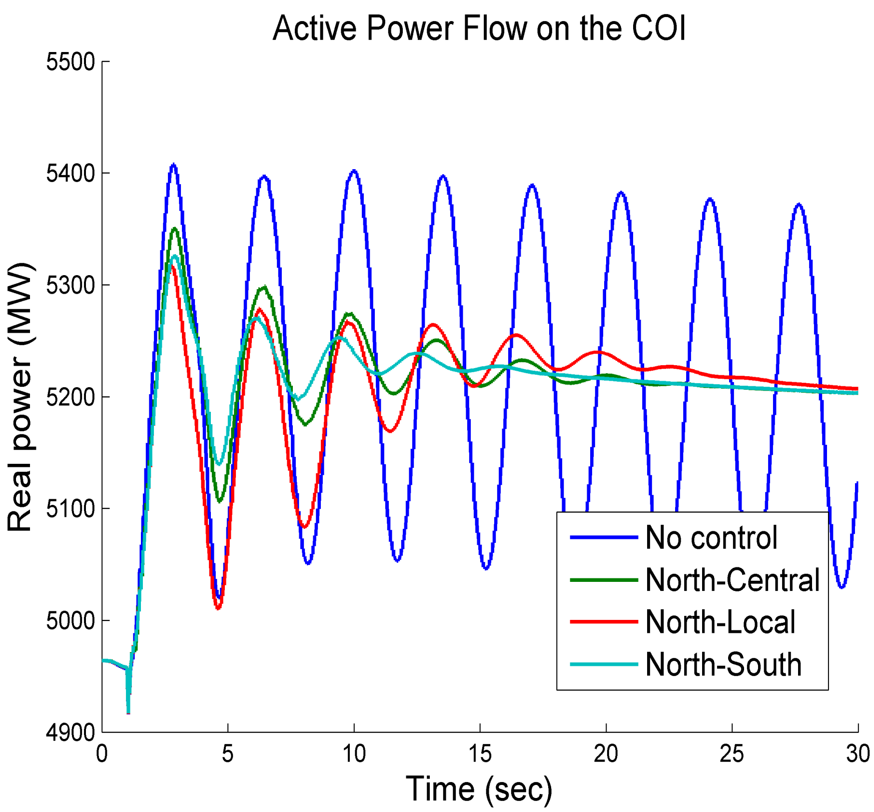
- **Goal:** Significantly increase the technology readiness level (TRL) of wide area damping control systems such that the next step is a capital project.
  - Early stage R&D project
  - Current TRL = 2 → Project Goal is TRL = 6
- **Potential Impact to BPA:**
  - Reduces the probability of a system break-up, which translates to reduced costs/loss of revenue
  - Improves system reliability without the need for new transmission infrastructure
- **Primary Deliverable:** Develop a prototype damping control system to be deployed in BPA synchrophasor lab

Project Synopsis

System Response: BC-ALB Separation

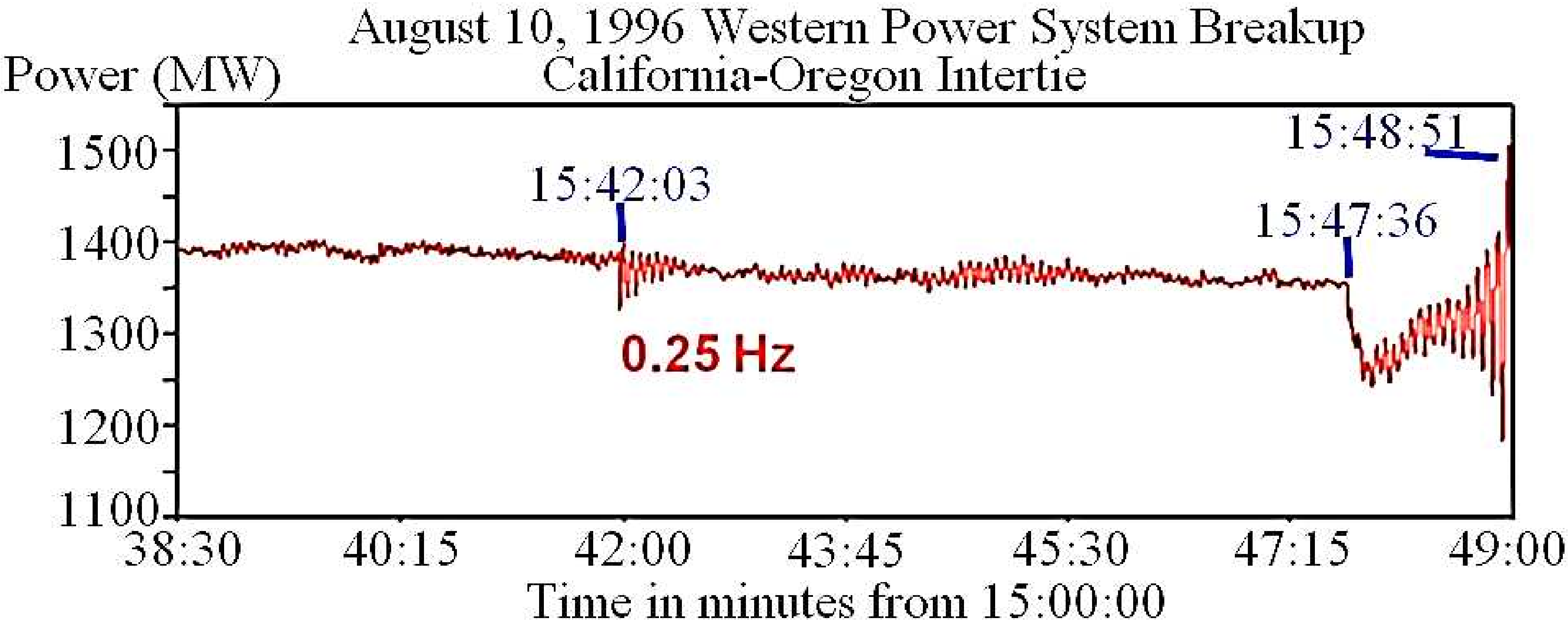
- Without damping control, the system response is nearly undamped.
- With PDCI damping control, the oscillation decays very quickly.





Project Synopsis

Growing oscillations can result in a system breakup



Project Synopsis

- **Objectives:**
  - Develop a prototype damping control system to be deployed at BPA
  - Evaluate the benefits & risks of PDCI modulation for wide area damping control
  - Assess the potential of energy storage technologies for use in a damping control system
  - Create high fidelity models and perform simulations to validate control system performance using BPA data
  - Design a supervisory controller to monitor the damping control system, and ensure it can never destabilize the grid, that is:

Do No Harm

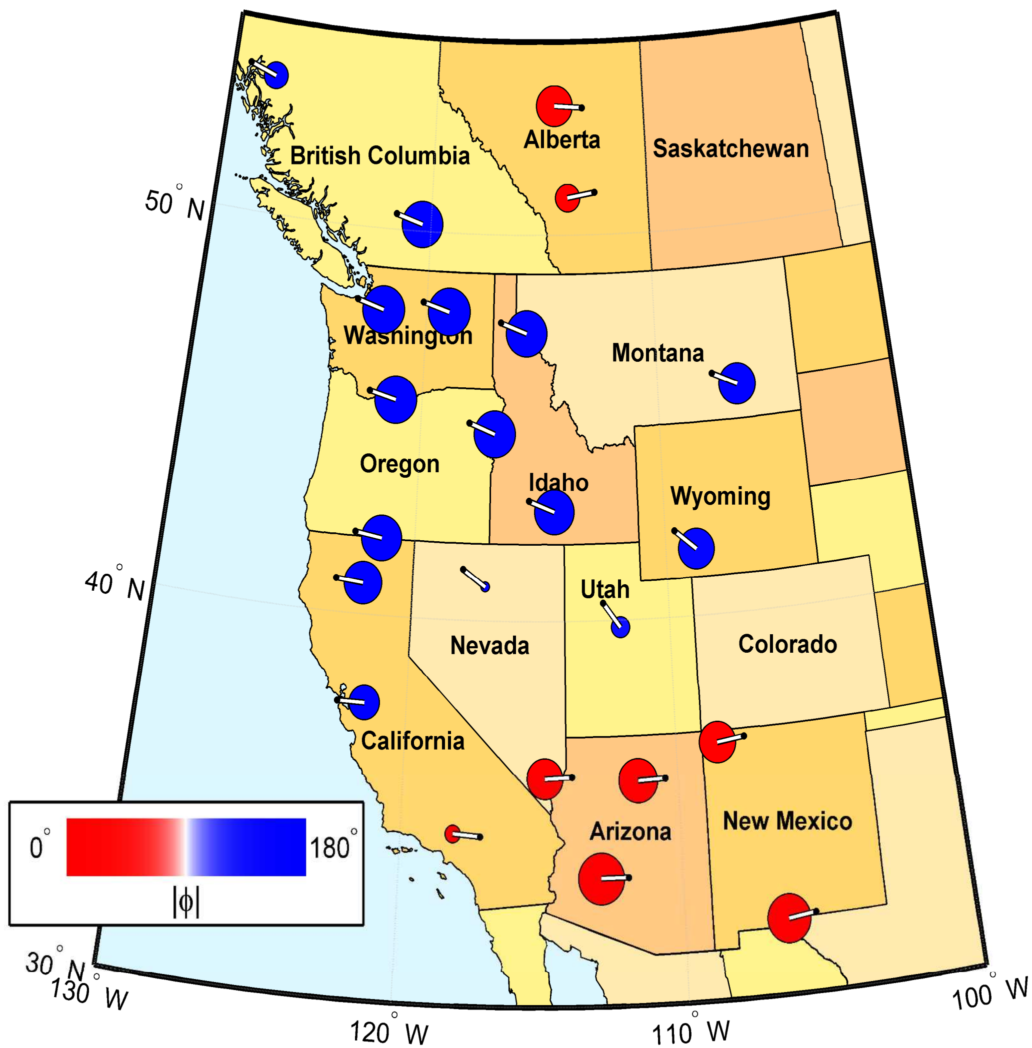
Accomplishments

- Developed an extensive set of analytical tools for conducting oscillatory mode analysis on large-scale models with both simulated and real data
- Designed prototype control system architecture with primary functions of damping and supervisory controllers identified
- Conducted PSLF simulation studies showing benefits/limitations of proposed controllers (e.g. PDCI modulation, energy storage)
- Demonstrated a map-based approach to visualizing oscillation mode shapes
- Designed most of the signal conditioning block for the PMU-based feedback control signal

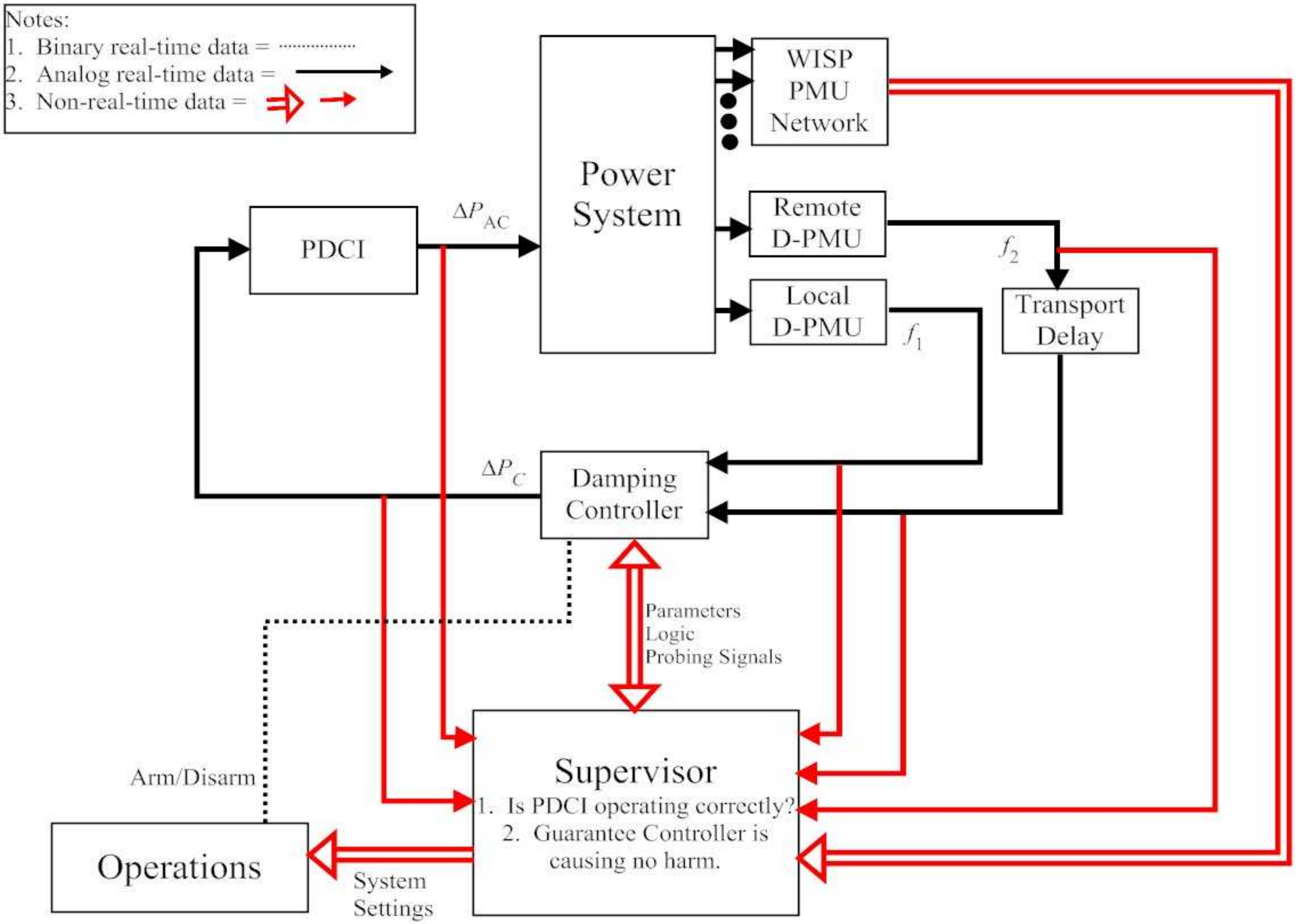
Accomplishments

Mode Shape Visualization

- Simulation of North-South B Oscillatory Mode
- 2015 Heavy Summer WECC Base case
- Mode is observable throughout the WECC
- 0.36 Hz modal frequency
- 13.7% Damping



Accomplishments – Control Architecture

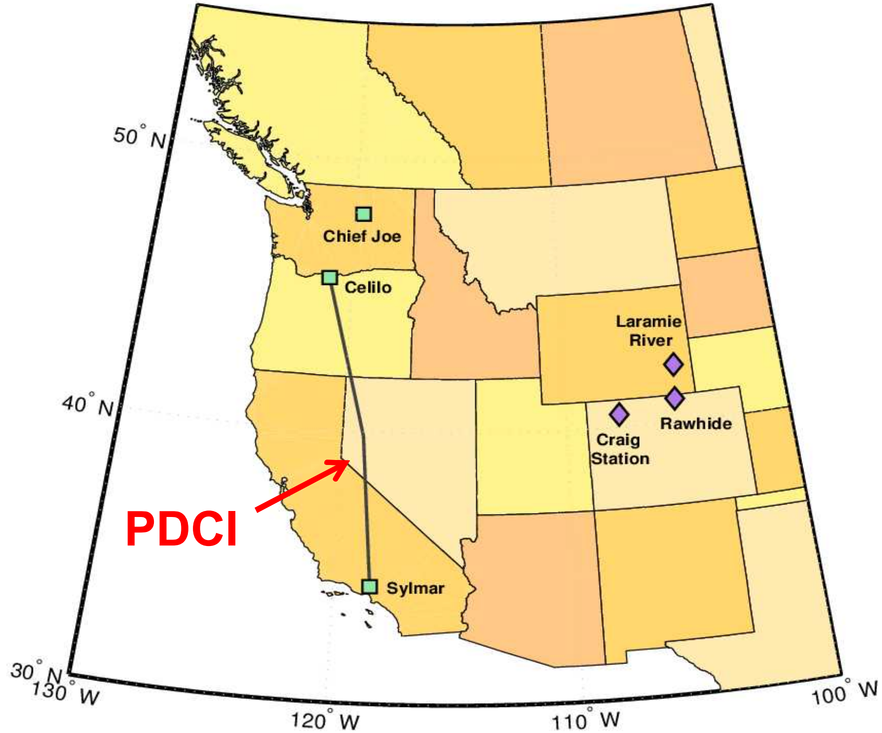


Expected Benefits

- Improved system reliability
- Additional contingency in a stressed system condition
- Potential economic benefits:
  - Avoidance of costs from an oscillation-induced system breakup
    (1996 outage costs: >$10M to BPA, >$1B overall impact)
  - Reduced need for new transmission capacity
    (capital cost savings in excess of $1M per mile)
  - Potential for increased flows in COI
    (additional revenue on hot summer days)

Expected Benefits

- Probability that these benefits will be realized: 90%
- Justification:
  - Extensive analysis and simulation efforts have shown that the damping control scheme is effective.
  - Preliminary hardware design efforts have shown that the control system can be realized with off-the-shelf hardware
  - PMU latencies are well within tolerances



Technology Transfer/Application to BPA

- Ultimate BPA end user is Transmission Operations
- Delivered preliminary PDCI PSLF Model to BPA in March 2013
- Delivered PSLF Chirp/MATLAB ERA software to BPA in September 2013
- Visualization software development added as a task:
  - Preliminary version delivered September 2013
  - Improved version delivered October 2013
  - Upgraded version to be delivered June 2014
- Prototype controller design review in December 2013 engaged diverse BPA staff to ensure network and hardware compatibility
- Testing phase of prototype control system hardware to begin at BPA in July 2014
- A report summarizing options for BPA feedback signals will be delivered in July 2014

Project Direction/Next Steps

- Upcoming Stage Gates:
  - December 2013 – January 2014: Design Review of Supervisory Controller hardware
  - January 15, 2014: Assessment of sensor options
  - February 15, 2014: Assessment of supervisory control scheme
  - July 3, 2014: Review of visualization software
  - July 15, 2014: Assessment of supervisory control prototype hardware
  - November 2, 2014: Assessment of supervisory control hardware testing

Project Direction/Next Steps

Project is well within budget

FY	Total Project Budget	BPA Budget	Cost Share	BPA Actual	Cost Share Actual
2013	$425K	$125K	$300K	$111K	$292K
2014	$1100K	$500K	$600K	$164K	$48K
2015	$525K	$375K	$150K		

Acknowledgements

- BPA PM: Dr. Jisun Kim
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- Principal Investigators: Dr. Dave Schoenwald & Dr. Ray Byrne (Sandia) and Prof. Dan Trudnowski (Montana Tech)
- Team Members: Ryan Elliott, Dr. Jason Neely, Dakota Roberson (Sandia) and Prof. Matt Donnelly (Montana Tech)
- Project Consultant: Dr. John Undrill

Q&A