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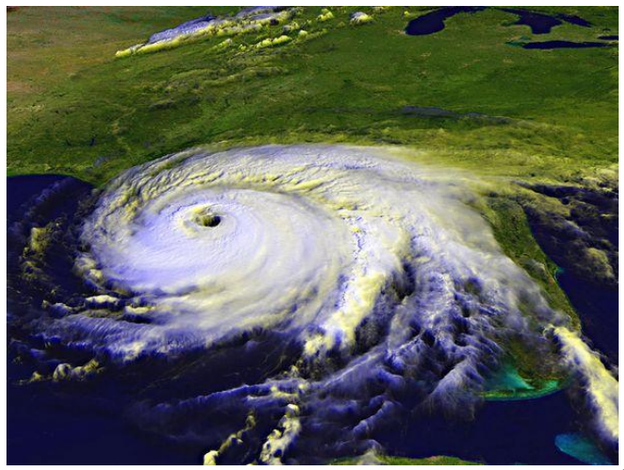

Wide Area Damping Control: Proof of Concept

September 19, 2014

Dave Schoenwald, SNL

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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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

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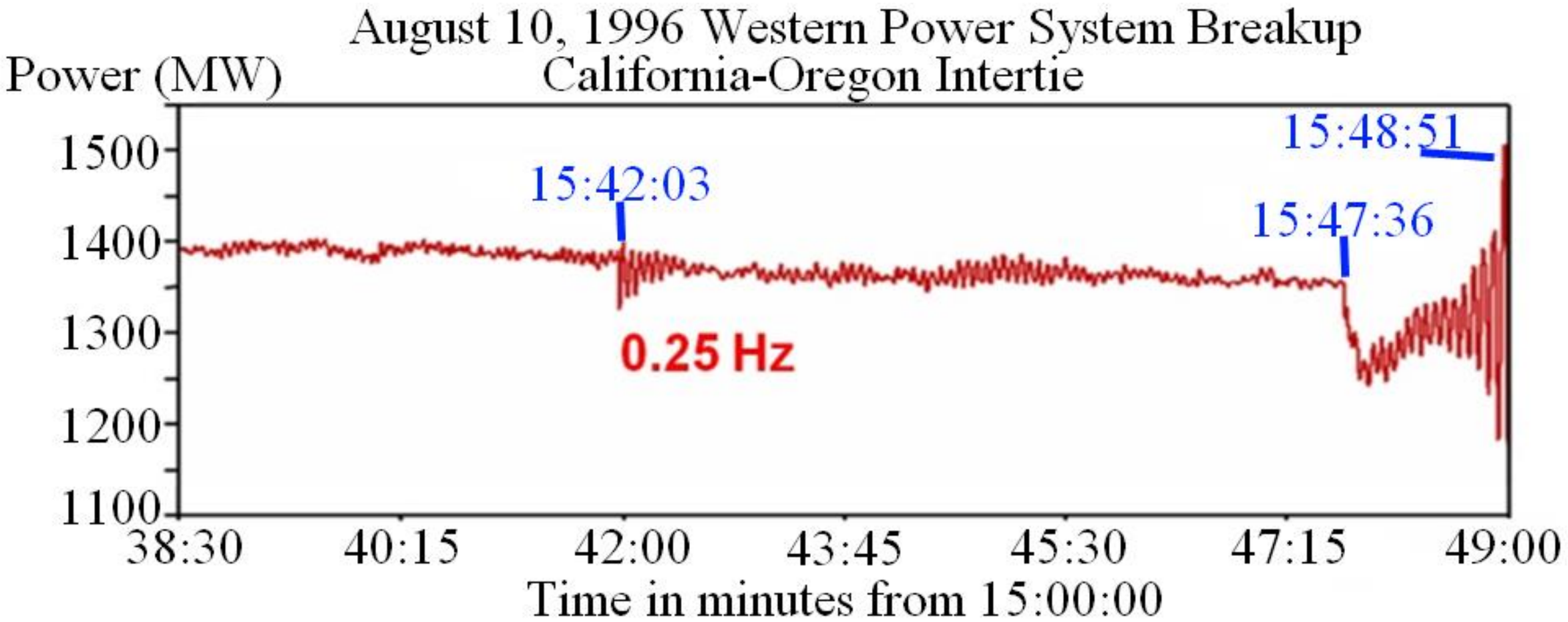
- **Overall Project Goal:**
  - **Significantly increase the TRL** (Technology Readiness Level) of wide area damping control systems such that the **next phase is deployment oriented**
- **Primary Phase I Deliverables:**
  - **Assessment of energy storage** for damping control
    - Coordinated control 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

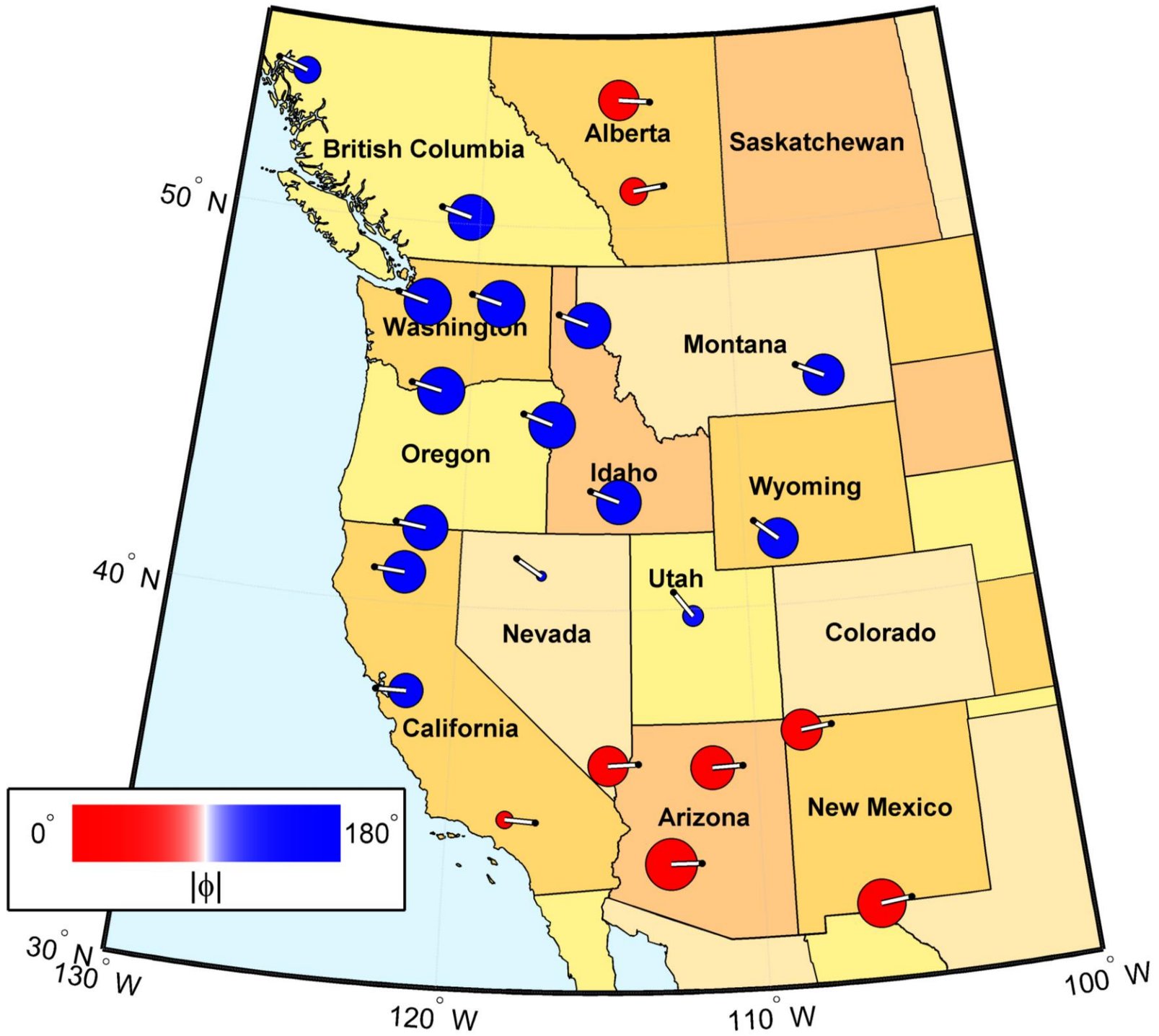
- Large generation and load complexes separated by long transmission lines can develop inter-area oscillations



1996 breakup caused by low-frequency oscillations

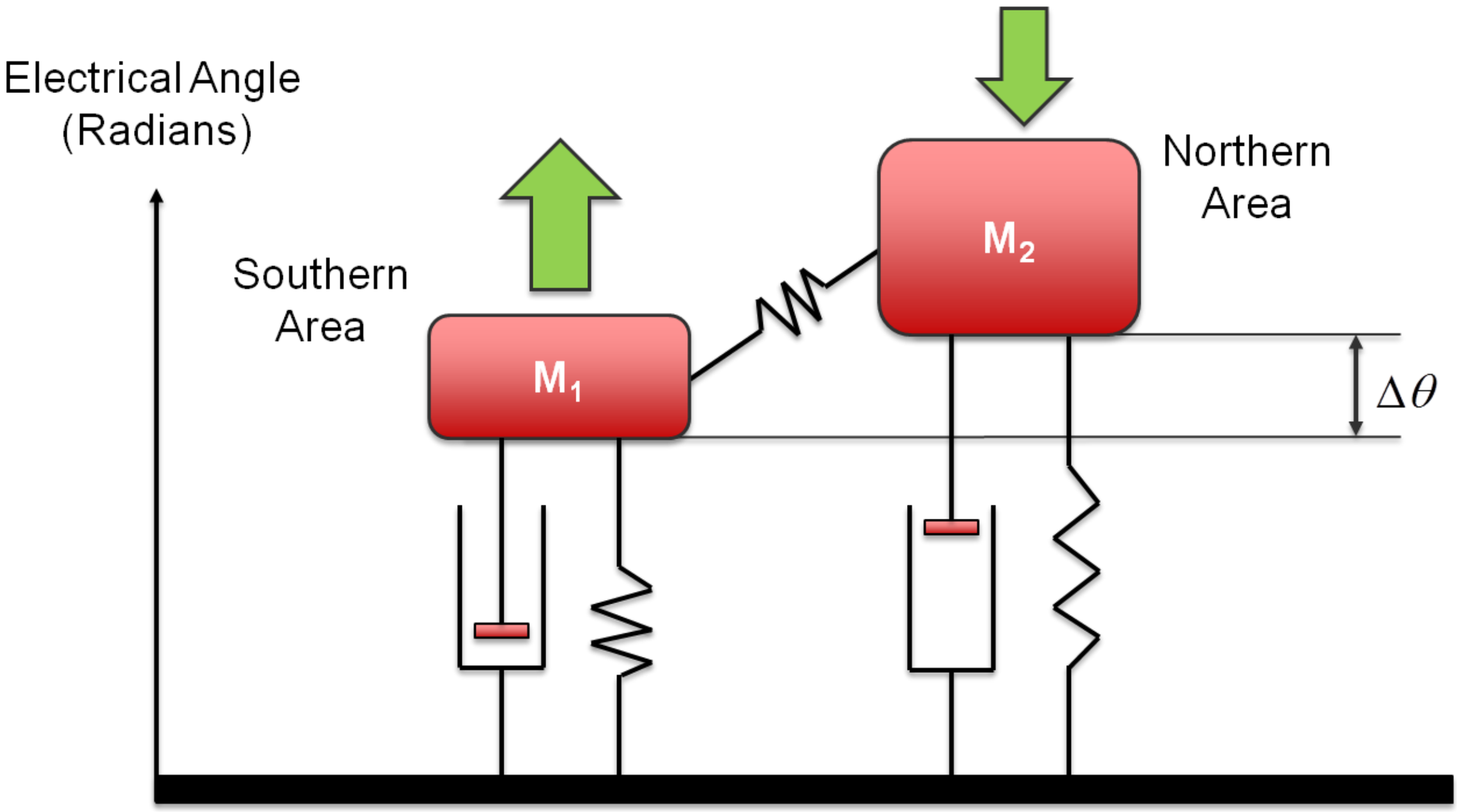
Visualization of Wide Area Oscillations

- 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



Active control has the potential to significantly improve damping of inter-area oscillations

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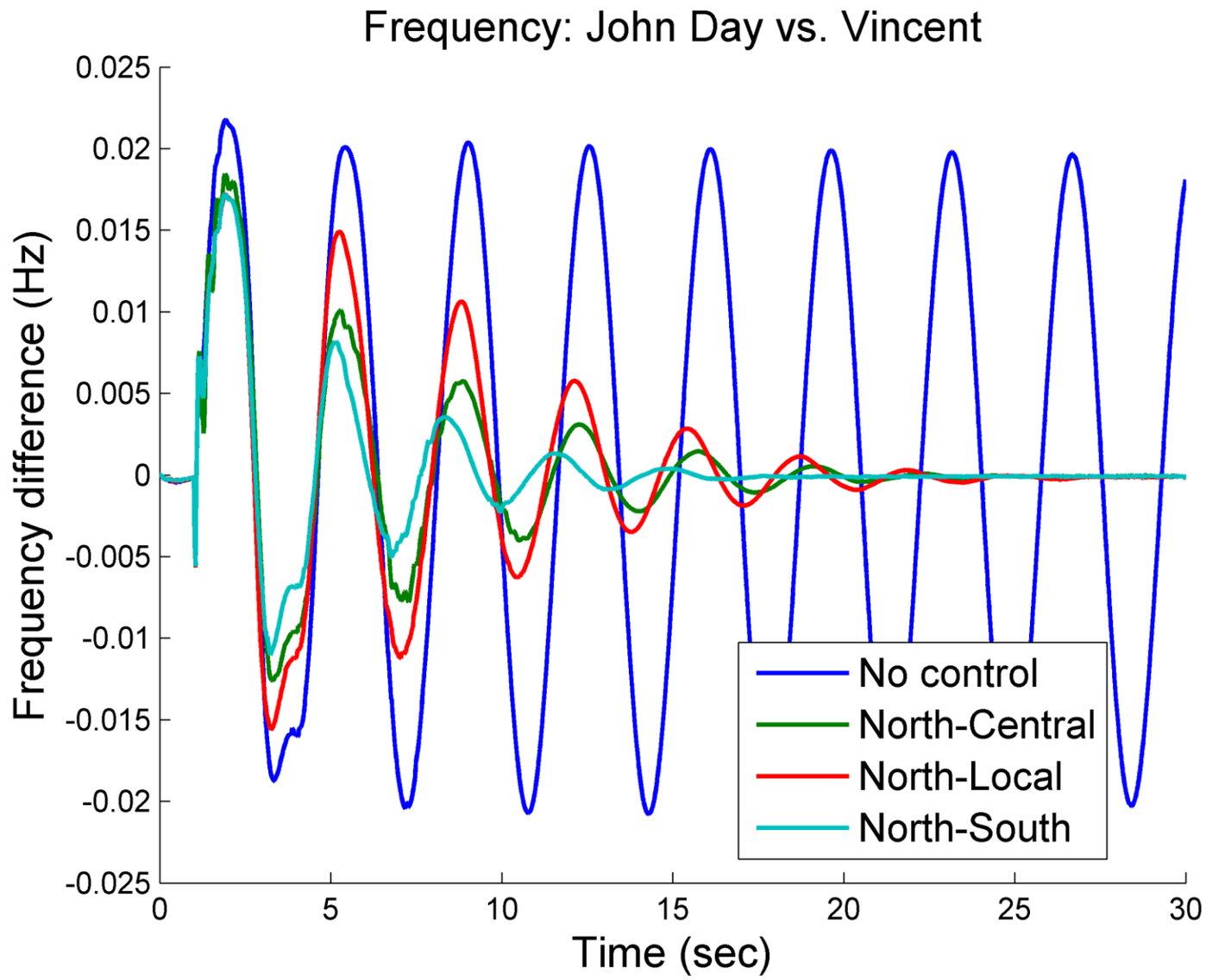
Example: British Columbia - Alberta Separation

- 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

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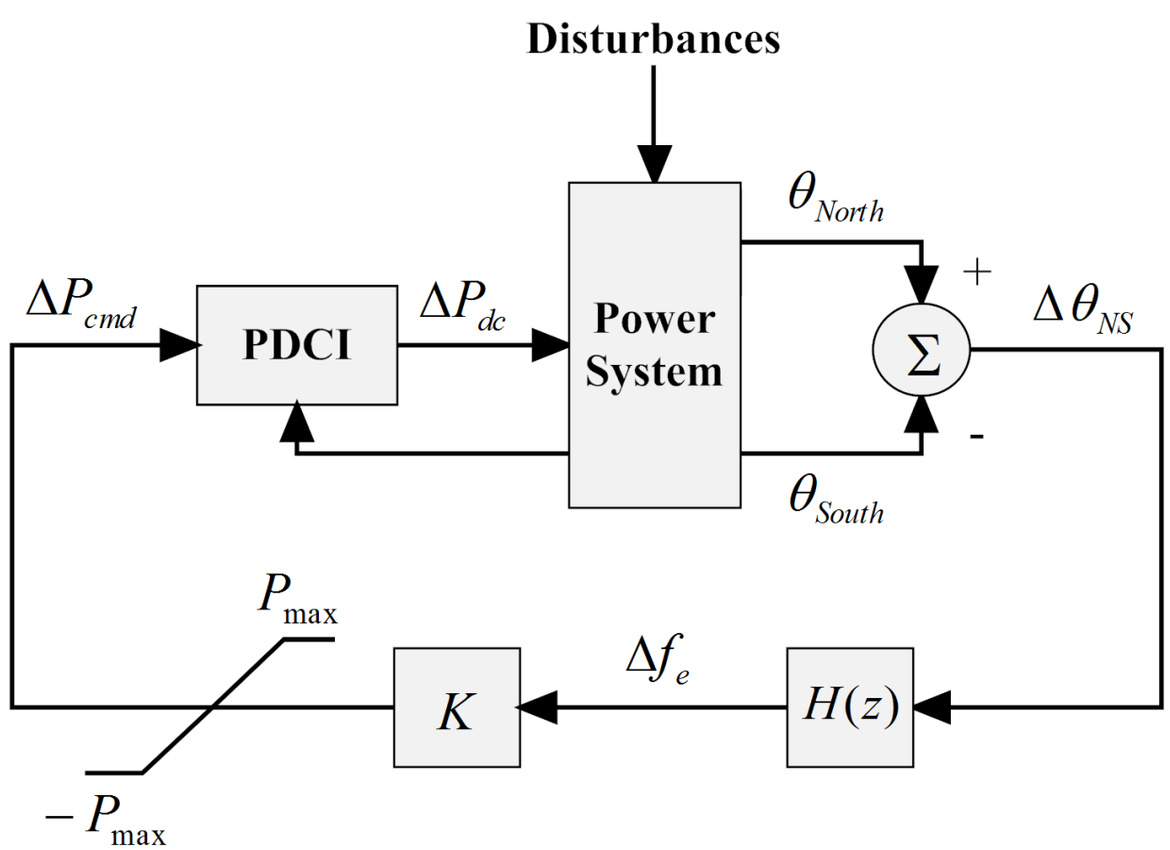
- **Improved system reliability**
- **Additional contingency in a stressed system condition**
- **Economic benefits**
  - Avoidance of costs from an oscillation-induced system breakup
    - 1996 outage costs: > $1B overall impact
  - Reduced need for new transmission capacity
    - Capital cost savings 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

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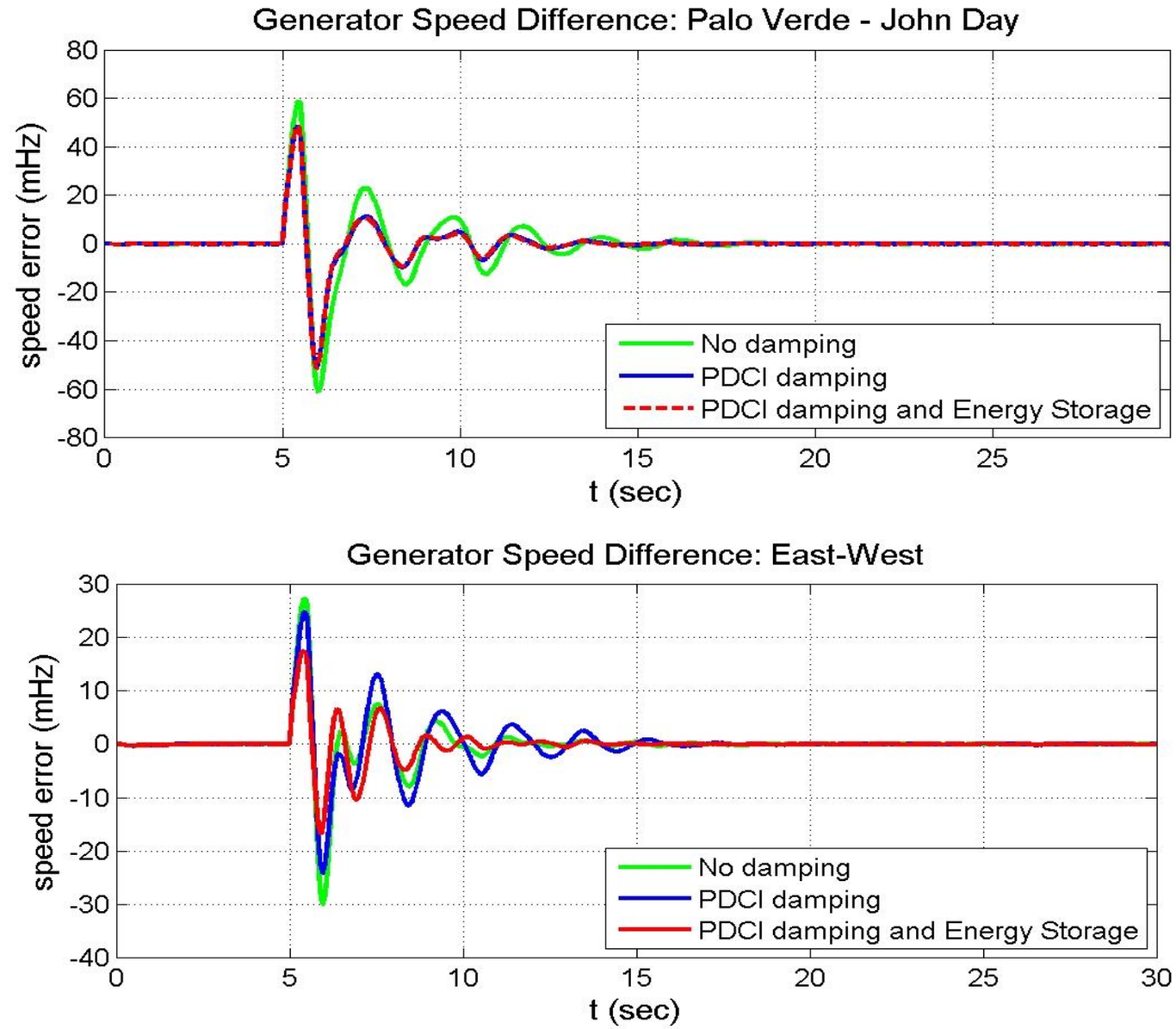
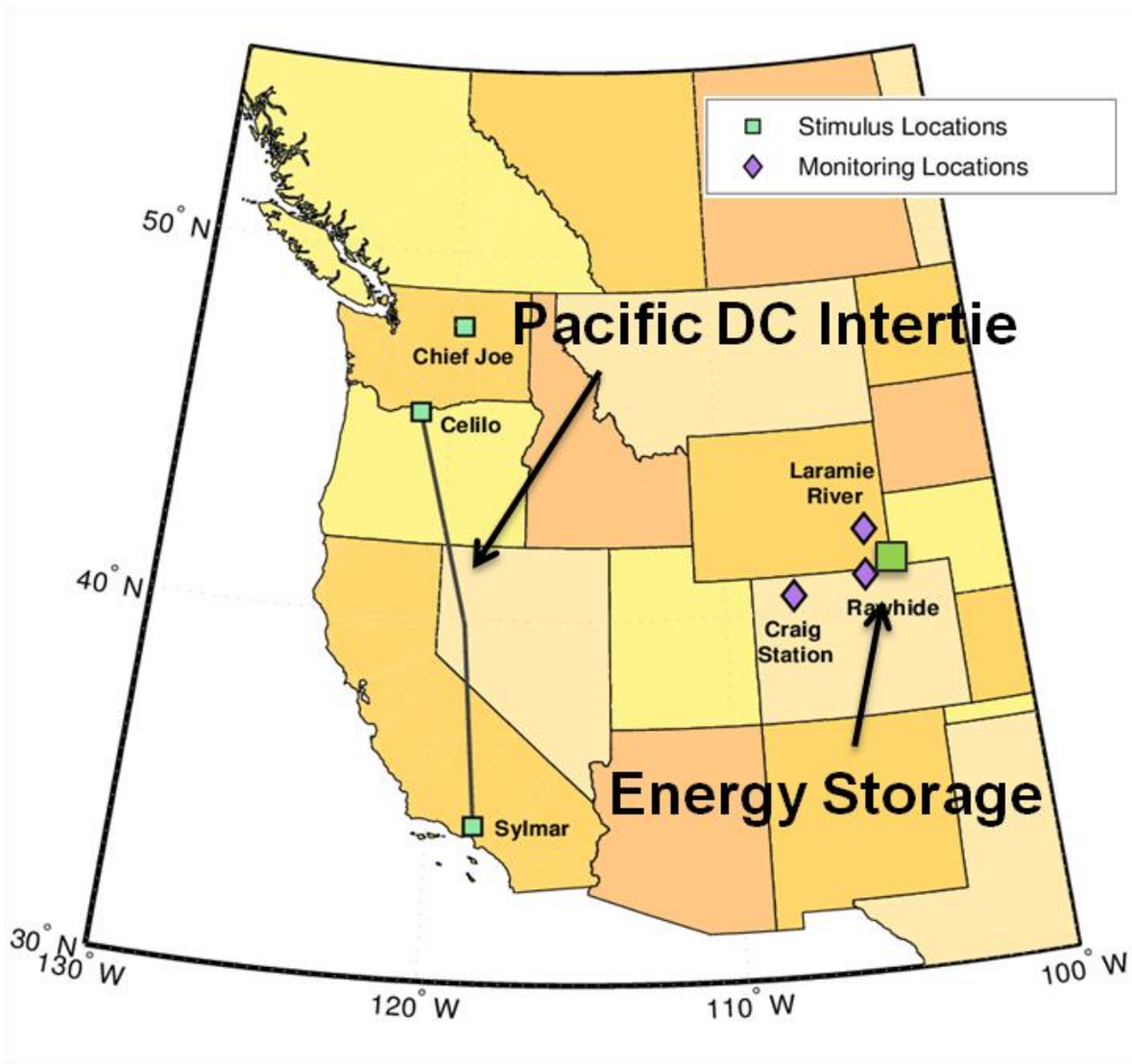
Addition of energy storage improves damping of East-West A mode





Three Node Damping Control Scheme: Improved Controllability of E-W Mode

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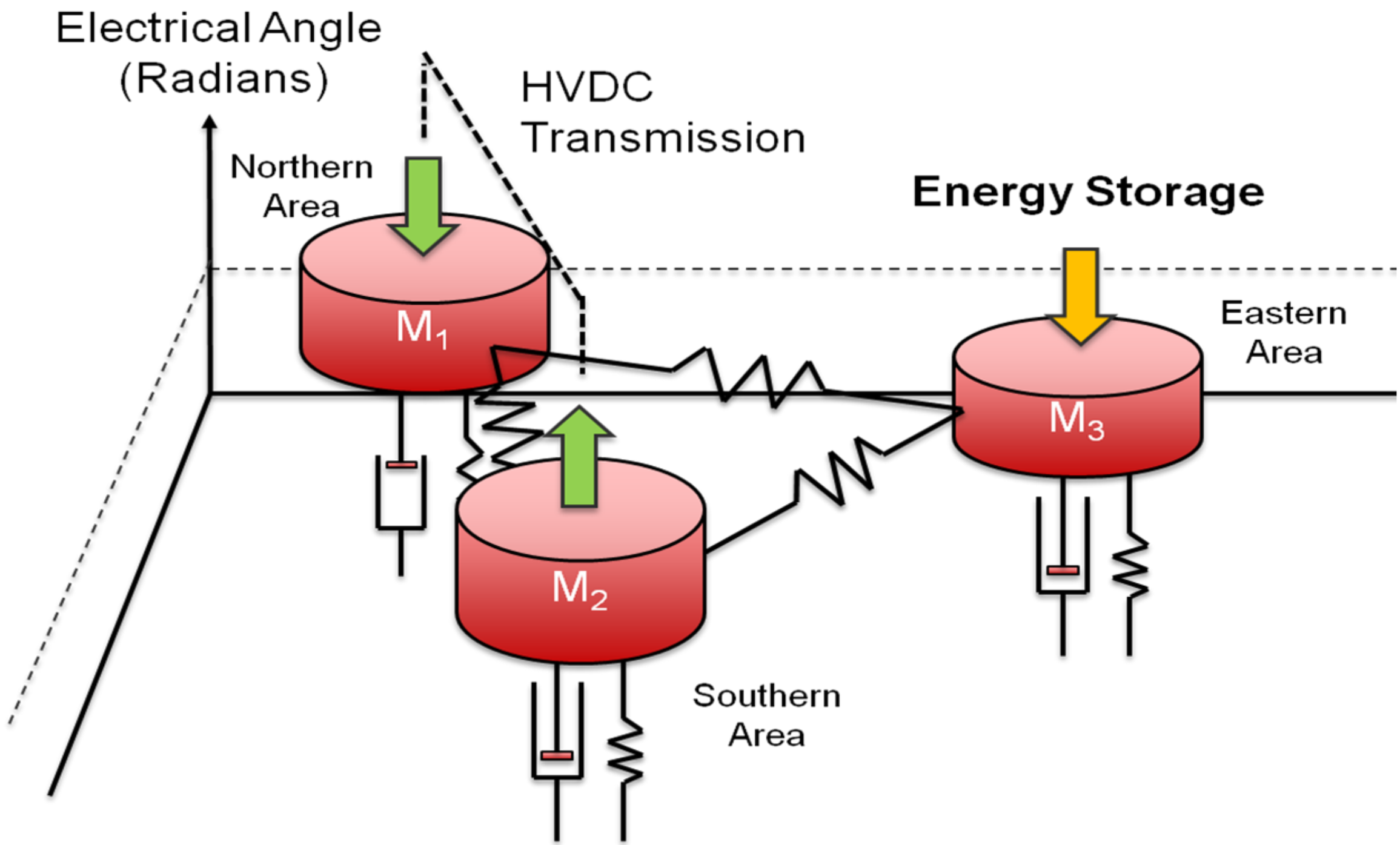

Project Accomplishments: FY13 - FY14

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- **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

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- 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)

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Questions?

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