OE Transmission Reliability Internal Review

Modal Analysis for Grid Operation (MANGO)

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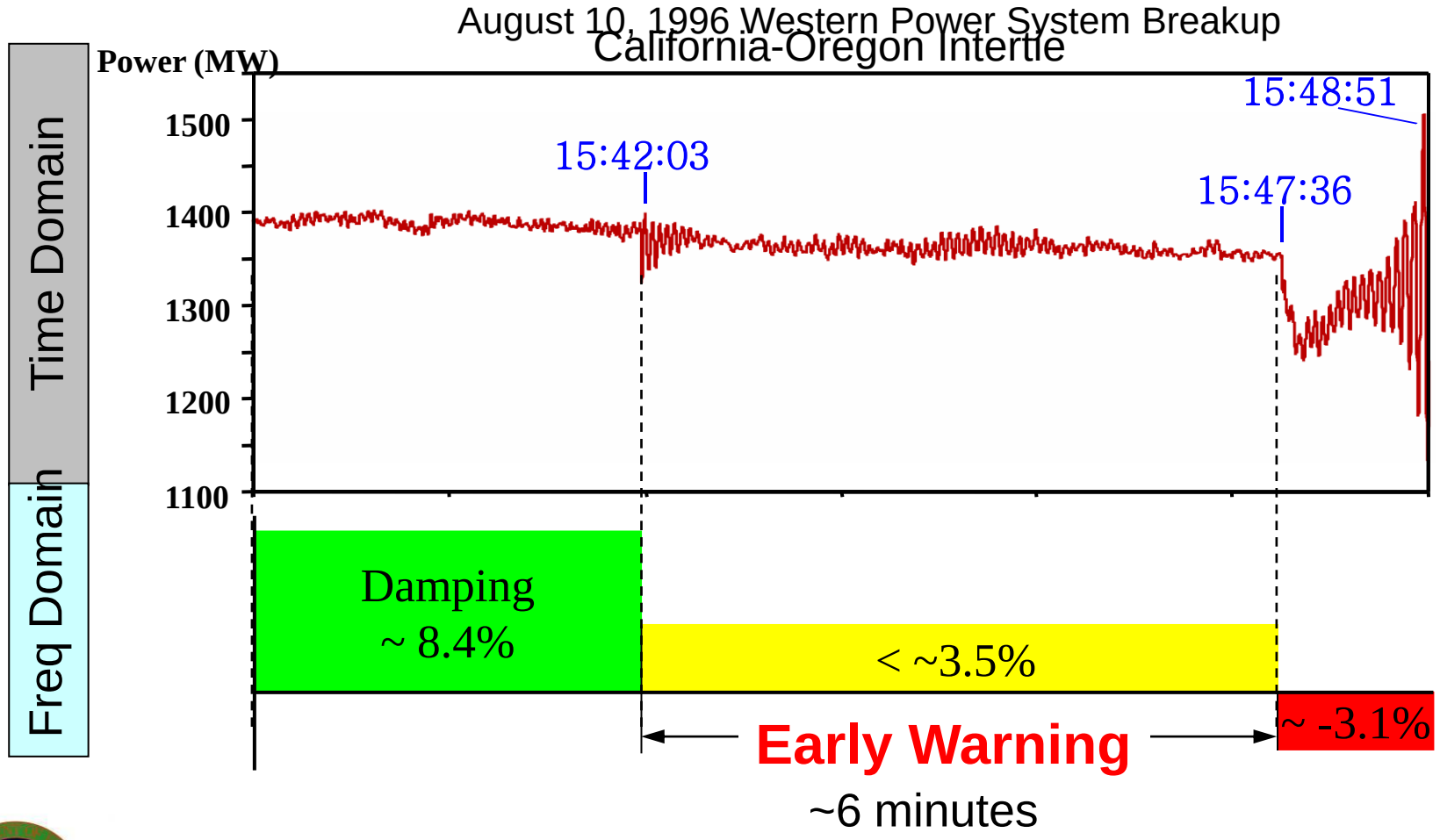
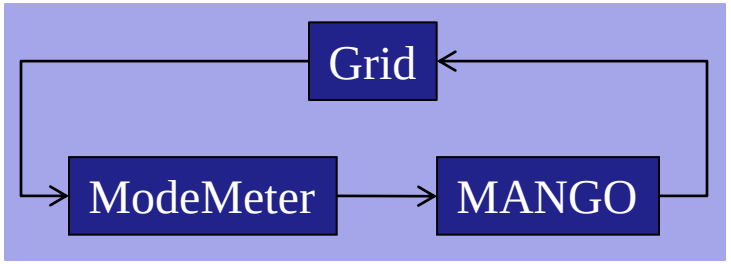
Past Oscillation Event – 1996/08/10

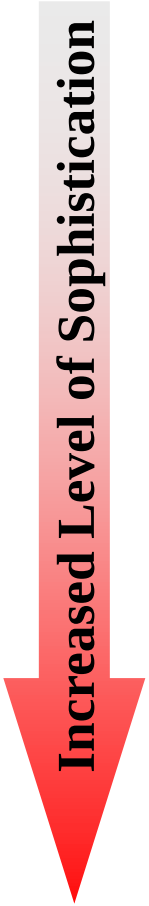


Project Objective

- Ways to Improve Damping
  - Power System Stabilizer (PSS): parameters pre-tuned based on off-line scenarios
  - Reactive Support: locations pre-selected based on off-line scenarios
  - Operating Point Adjustment: operator actions determined with the on-line scenario
- Objective of this Project: Operating Point Adjustment
  - Derive recommended operation actions based on modal analysis results
  - Example output: *"Generator A's output needs to be adjusted by X MW to improve damping from Y% to Z%"*
  - Implement with operators in the loop, linking with current grid operating procedures (e.g. AGC, TLR, BPA Dispatch Standing Order 303)



MANGO Procedure



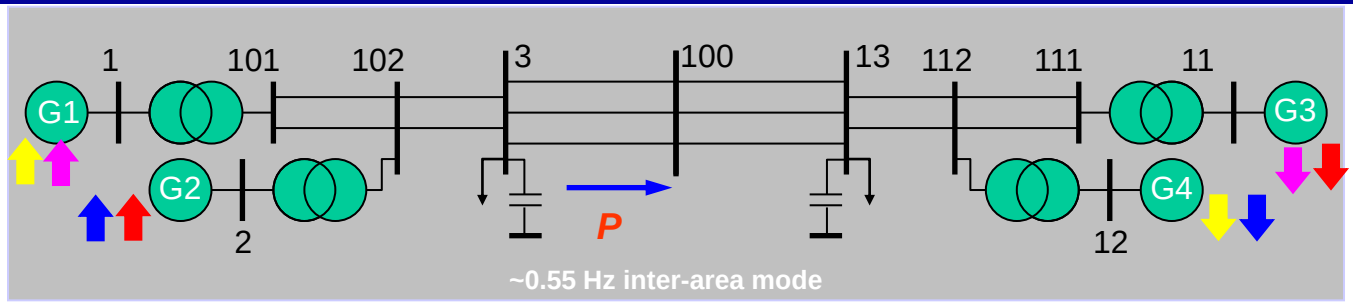
- Identify tie-line P

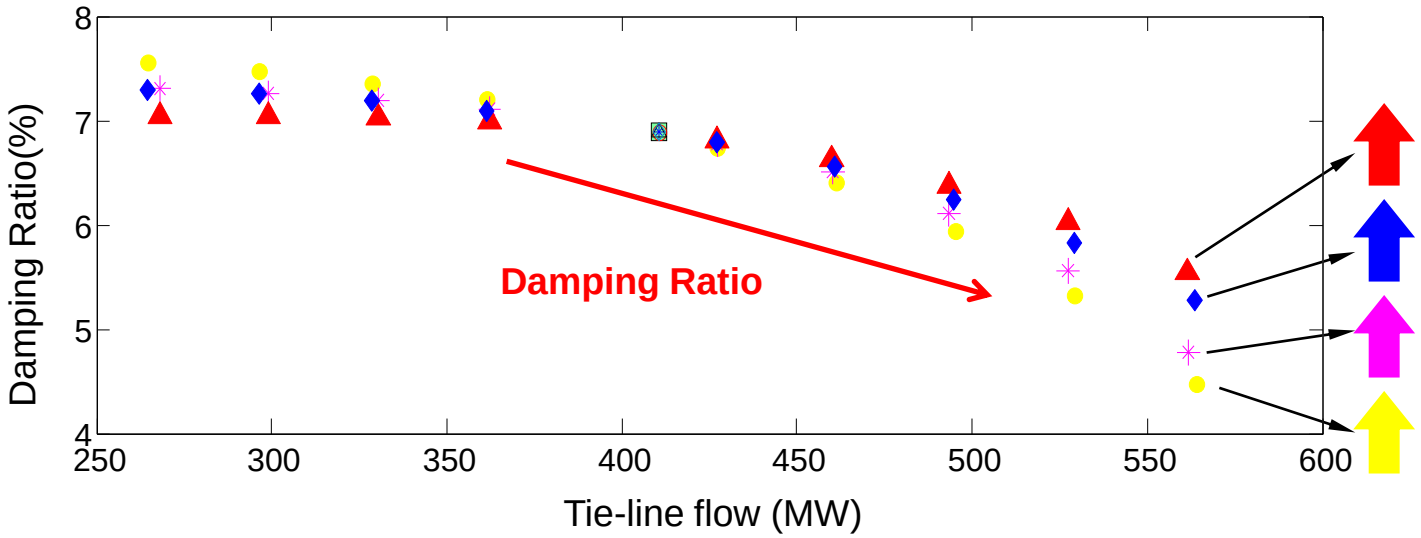
  ➔ qualitative: lower tie-line P
- Identify key generators

  ➔ more effective: decrease P@genX (sending), and increase P@genY (receiving)
- Determine power adjustment ΔP

  ➔ quantitative: decrease ΔP@genX (sending), and increase ΔP@genY (receiving), expect damping ratio increase z%

Tie-line Flow Adjustment: A Simple Multi-Machine Case

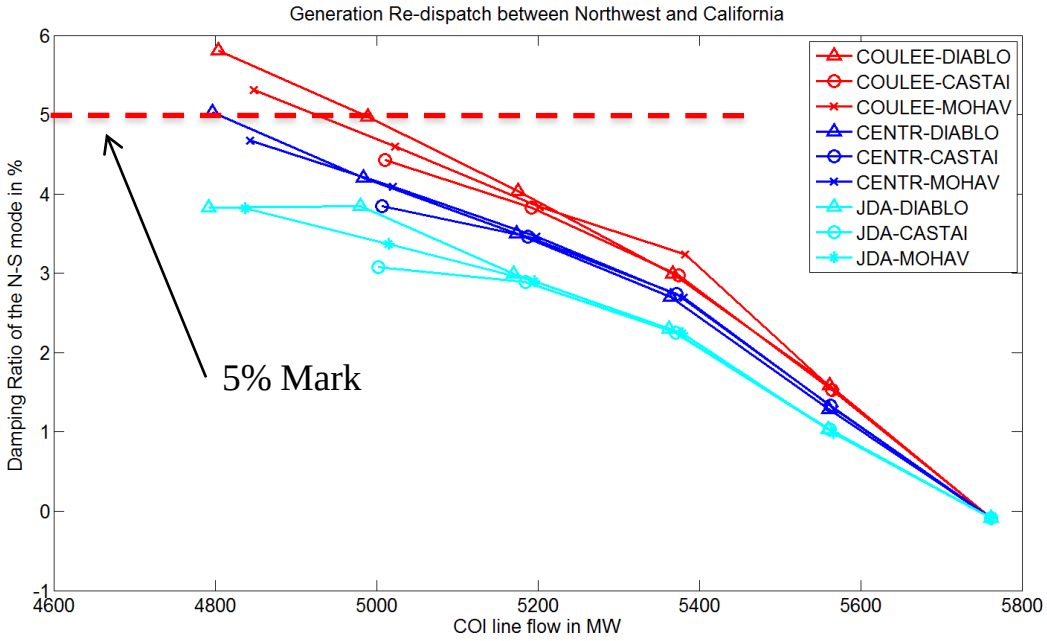


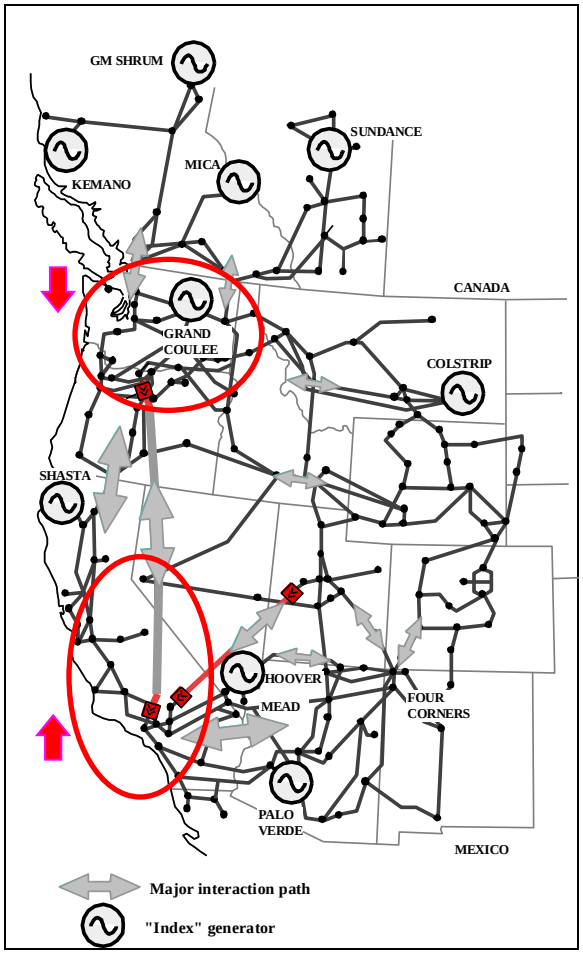


- Reducing tie-line transfer is effective in improving modal damping
- Locational effect is apparent

Tie-line Flow Adjustment: WECC Case

- Tie-line Effect on North-South Mode
  - COI tie-line
  - Northwest vs. California





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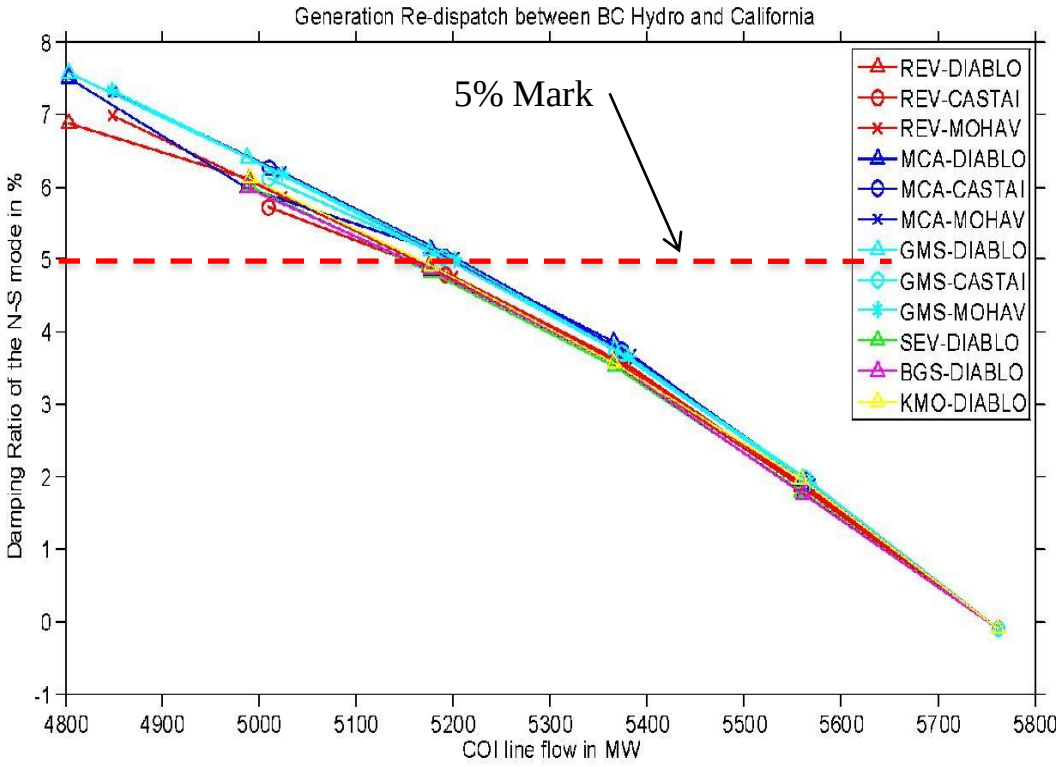
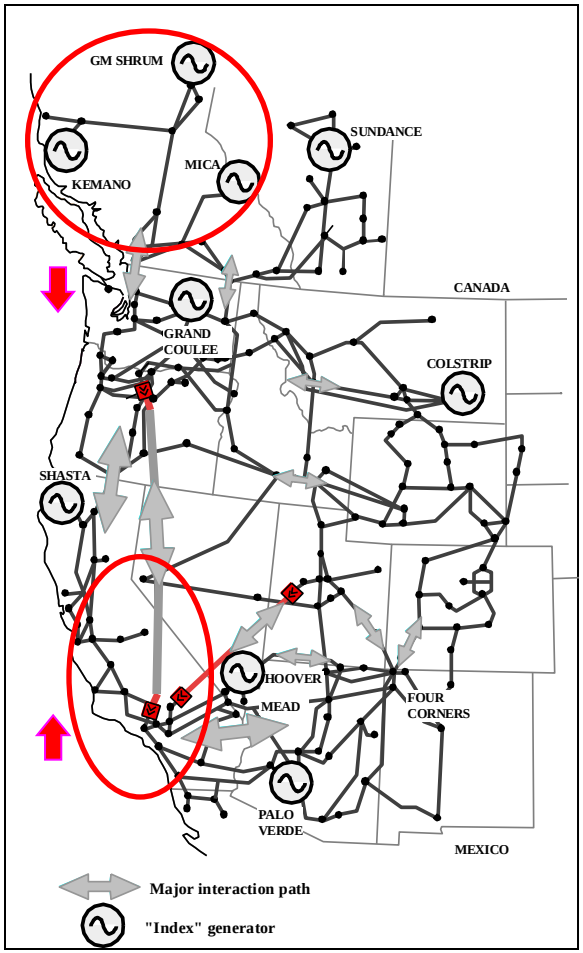
Tie-line Flow Adjustment: WECC Case

- Tie-line Effect on North-South Mode
  - COI tie-line
  - BC Hydro vs. California





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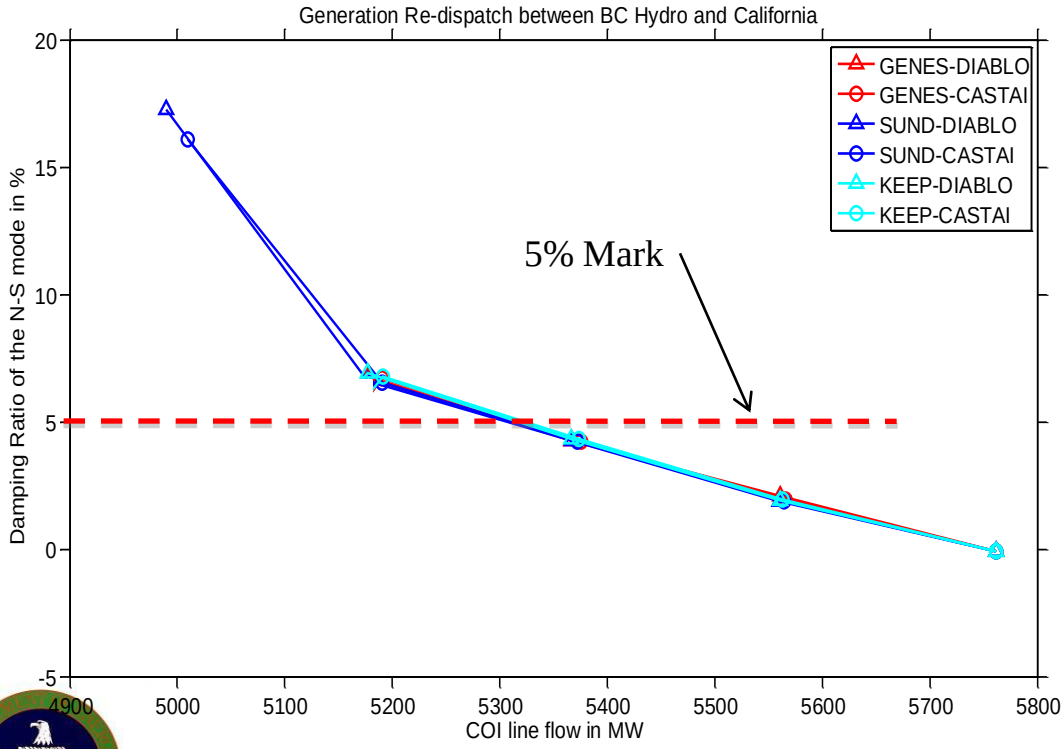
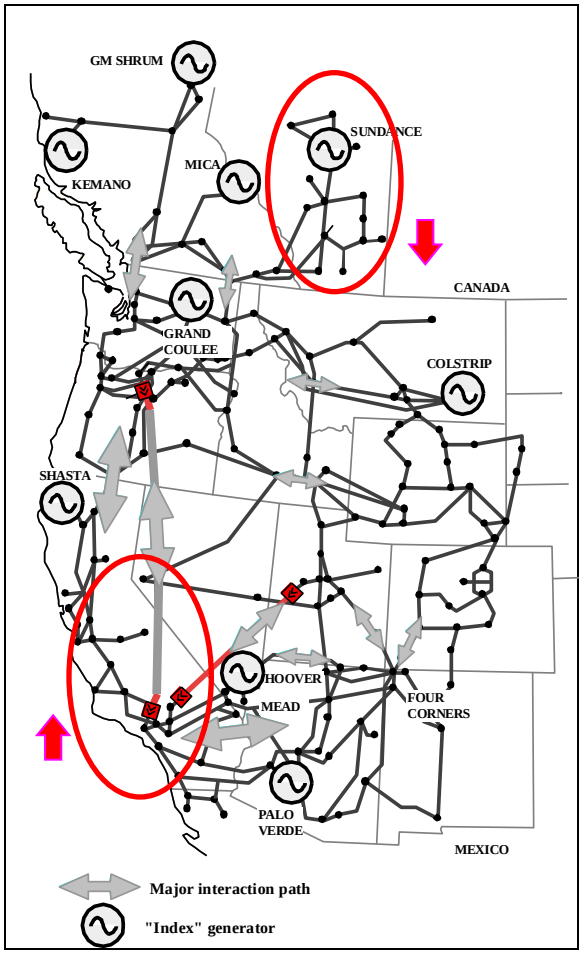
Tie-line Flow Adjustment: WECC Case

- Tie-line Effect on North-South Mode
  - COI tie-line
  - Alberta vs. California





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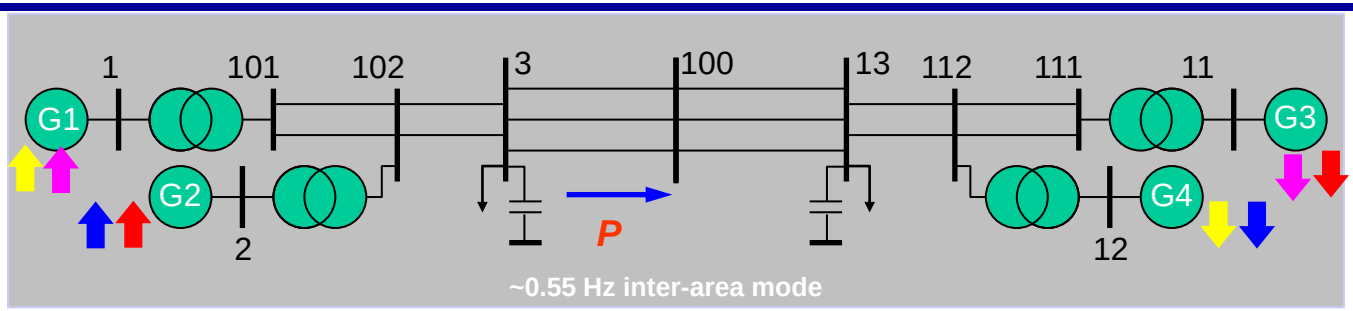
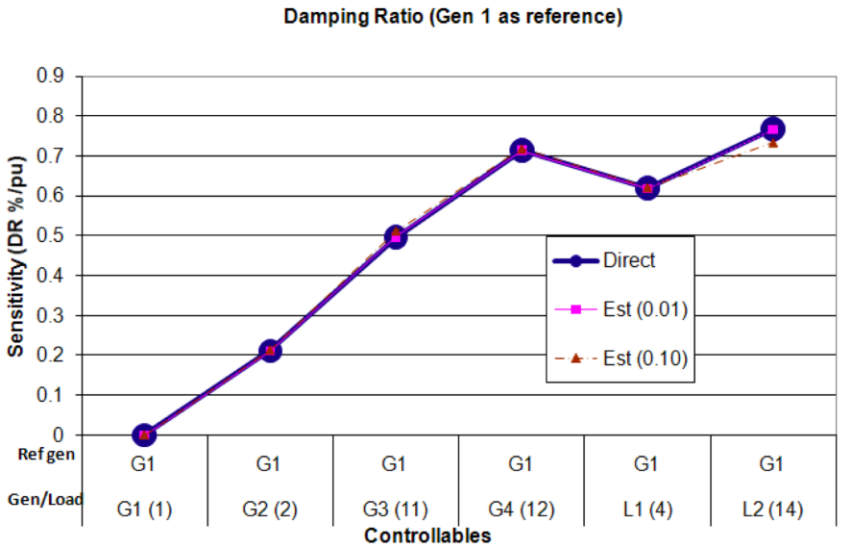
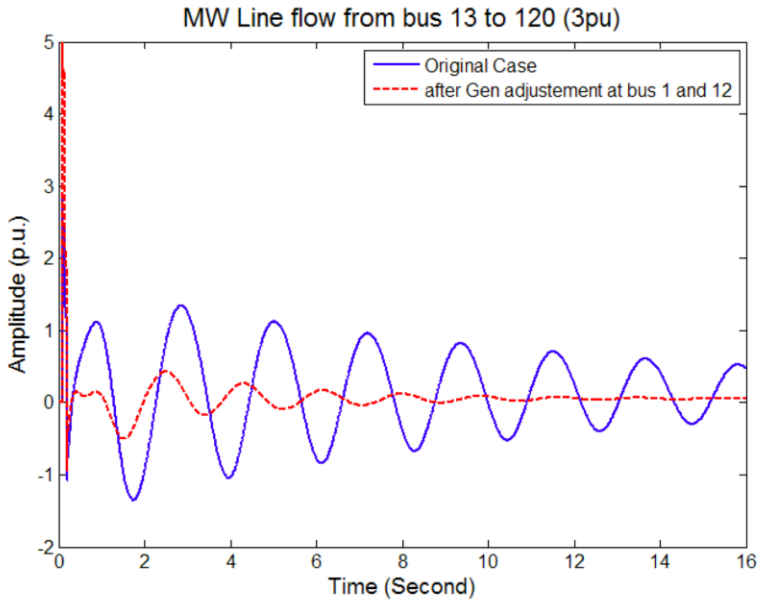
Relative Modal Sensitivity Estimation: A Multi-Machine System

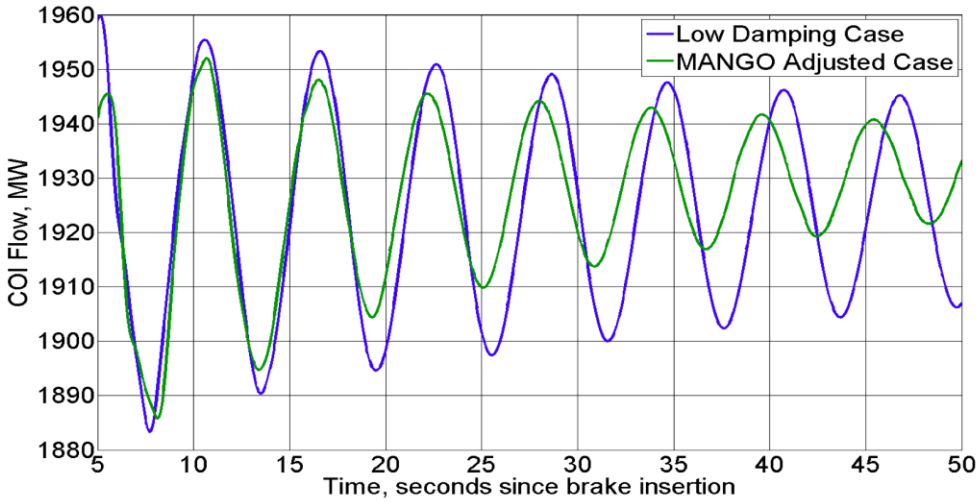


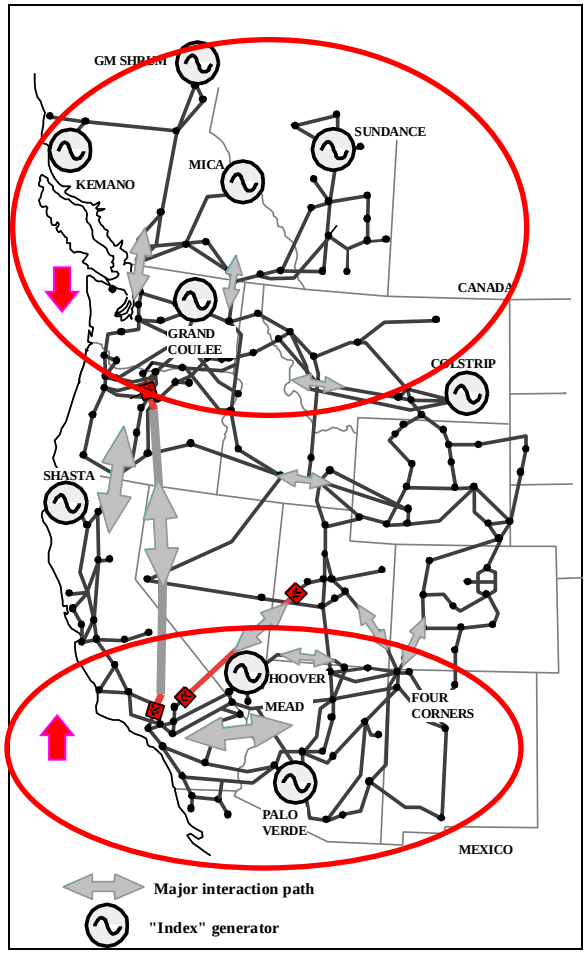




Relative Modal Sensitivity Estimation: The WECC case

- Most effective adjustment: Alberta + PG&E
  - Consistent with simulation studies
  - 300 MW adjustment improves damping from 2% to 5%





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Topology Impact and Locational Effect

- Topology impact:
  - Topology with respect to major line tripping.
  - Topology affects the relationship between damping and tie-line flow. MANGO procedure should include topology information.
- Locational effect:
  - Bus pairs with arbitrary MW injections, e.g. +200MW in north , -200MW in south.
  - Bus pairs with the longest electrical distance have the most impact on damping.

Technical Report:

Z Huang, N Zhou, FK Tuffner, R Diao, DJ Trudnowski, Y Chen, JF Fuller, S Jin, JF Hauer, and JE Dagle, "Modal Analysis for Grid Operation (MANGO): Use of Modal Sensitivity for Damping Improvement through Generation Adjustment", Prepared for the US Department of Energy, Pacific Northwest National Laboratory, Richland, WA, 2012.

Summary

- Modes can be controlled by operating point adjustment.
- MANGO works for damping improvement
  - Relative modal sensitivity concept was proposed
  - Its real-time estimation was mathematically formulated as an estimation problem using real-time measurements.
- Testing with simulated measurements demonstrated good performance of the MANGO method.

FY12 Plan

- Demonstrate relative modal sensitivity estimation with phasor measurements.
- Identify implementation issues with the practical environment.

Risk Factors:

- Availability of phasor measurements.
- Access to phasor measurements.

Questions/Comments