DOE/OE Transmission Reliability Program

Modal Analysis for Grid Operation (MANGO)

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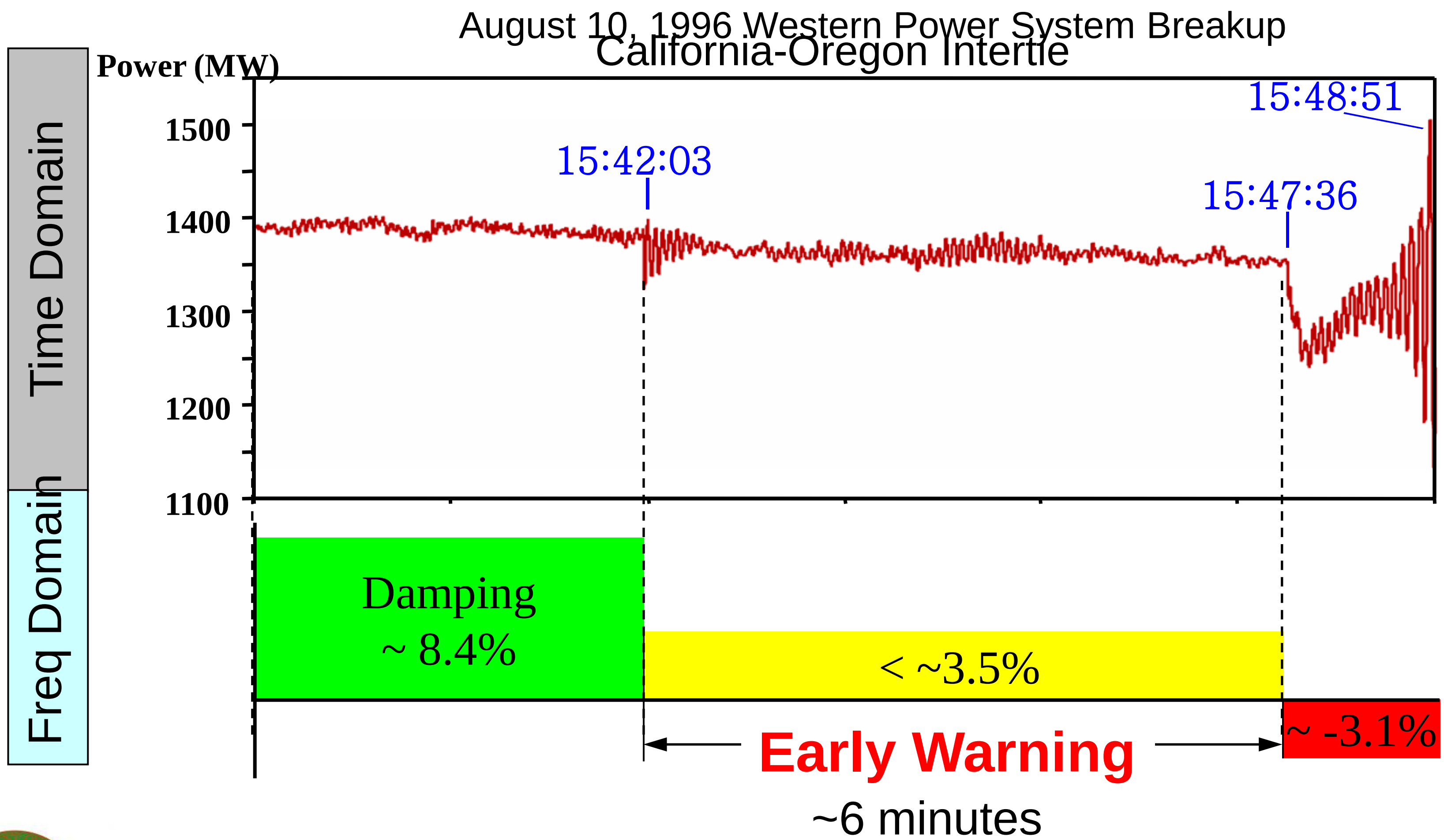
Consortium for Electric Reliability Technology Solutions

Past Oscillation Event – 1996/08/10



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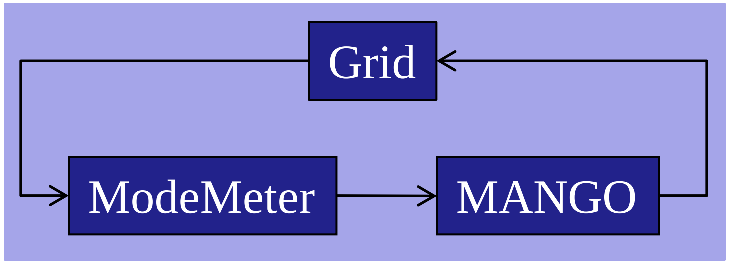
Project Objective

- 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
  - Adjustment of Operator Controllable Variables : operator actions determined with the on-line scenarios
- Objective of this Project:
  - Develop methods to increase damping based on modal analysis results
  - Example output #1: *"Generator A's output needs to be adjusted by X MW to improve damping from Y% to Z%"*
  - Example output #2: "Switch in controllers at Gen A and B to increase damping of south-north modes."



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Work Team

- Project team in the PNNL
  - Zhenyu (Henry) Huang
  - Ning Zhou
  - Jianming Lian
  - Ruisheng Diao
- Collaboration team in the BPA
  - Dmitry Kosterev
  - Ryan Quint

Recent Interactions with BPA

- We sent the BPA team 2 recent MANGO reports for review and the BPA team provided constructive comments and suggestions:
  - Practical considerations and constraints
  - Applicability and values for utilities

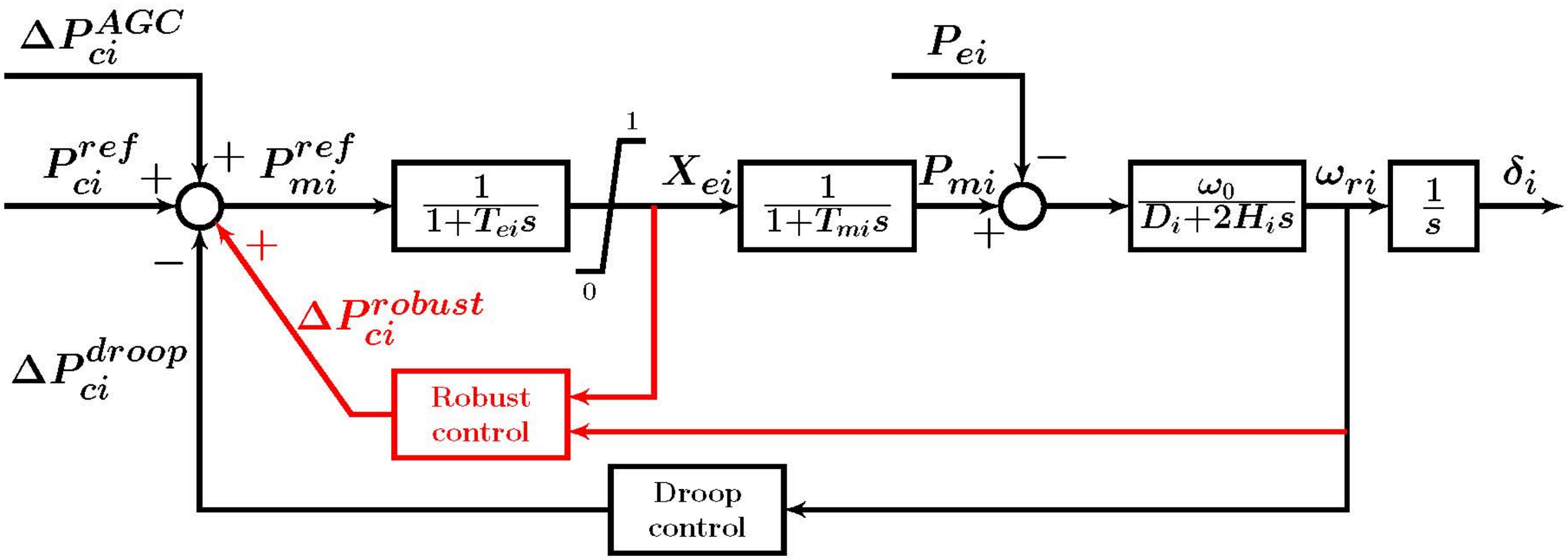
- The BPA's feedback helps the PNNL team clarify the scopes of MANGO:
  - NOT to develop an operating procedure
  - To develop methods and generate insights to assist operating entities develop operating procedures

Outcomes

- Improve communication of MANGO concepts and clarify the goals and scopes MANGO studies.
- Actively seek feedback from operating entities to improve understanding of practical constraints and considerations
- Provide multiple options for consideration and selection

Technical Approaches

- Decentralized robust control:



Governor dynamics:

$$\dot{X}_{ei} = -\frac{1}{T_{ei}}X_{ei} + \frac{1}{T_{ei}}P_{mi}^{ref}$$

$$0 \leq X_{ei} \leq 1$$

Turbine dynamics:

$$\dot{P}_{mi} = -\frac{1}{T_{mi}}P_{mi} + \frac{K_{mi}}{T_{mi}}X_{ei}$$

Rotor dynamics:

$$\dot{\delta}_i = \omega_{ri},$$

$$\dot{\omega}_{ri} = -\frac{D_i}{2H_i}\omega_{ri} + \frac{\omega_o}{2H_i}\left(P_{mi} - P_{ei}\right)$$

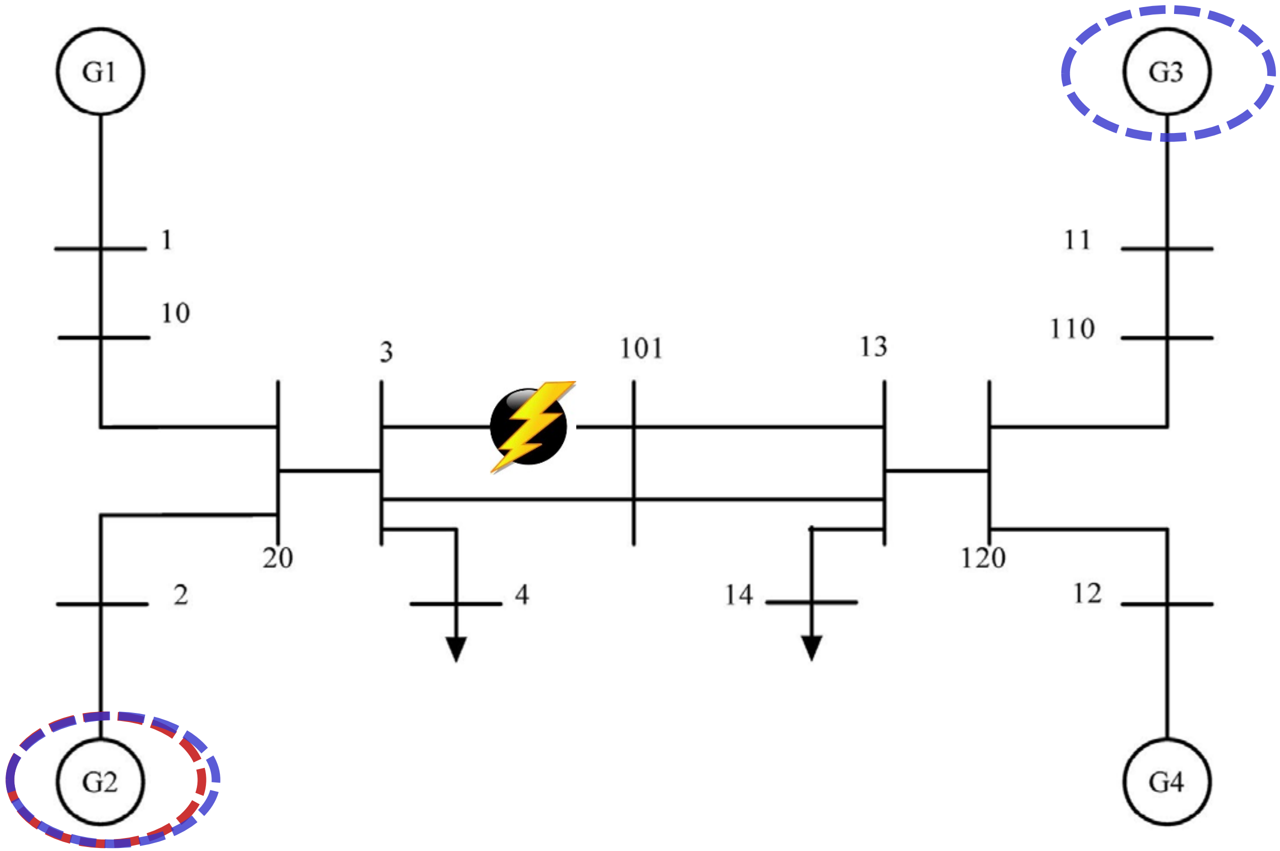
Controller Design

- **Objective:** Maximize the tolerance of disturbance
- **Constraints:** Stability of the system
- **Approach:** Linear matrix inequalities (LMI) method
- **Properties:** Each controller works properly whether other controllers are on-line or off-line.

$$P_{mi}^{ref} = \Delta P_{ci}^{droop} + \boxed{\Delta P_{ci}^{robust}} + \Delta P_{ci}^{AGC} + P_{ci}^{ref}$$

$$\Delta P_{ci}^{robust} = K(X_{ei}, \omega_{ri})$$

Case #1: Two Area Model



Increase tie line impedance increased by 10% and disable the PSS to reduce the damping

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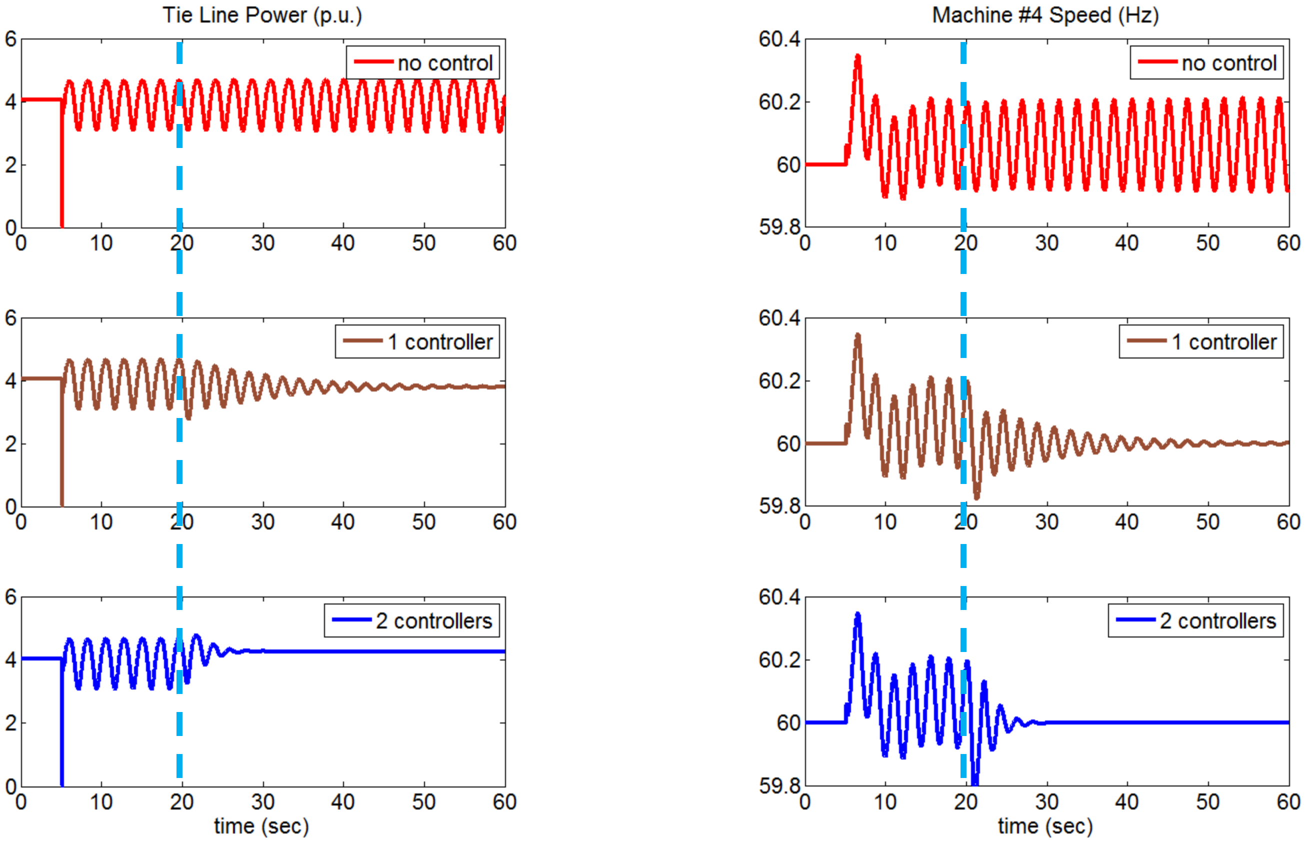
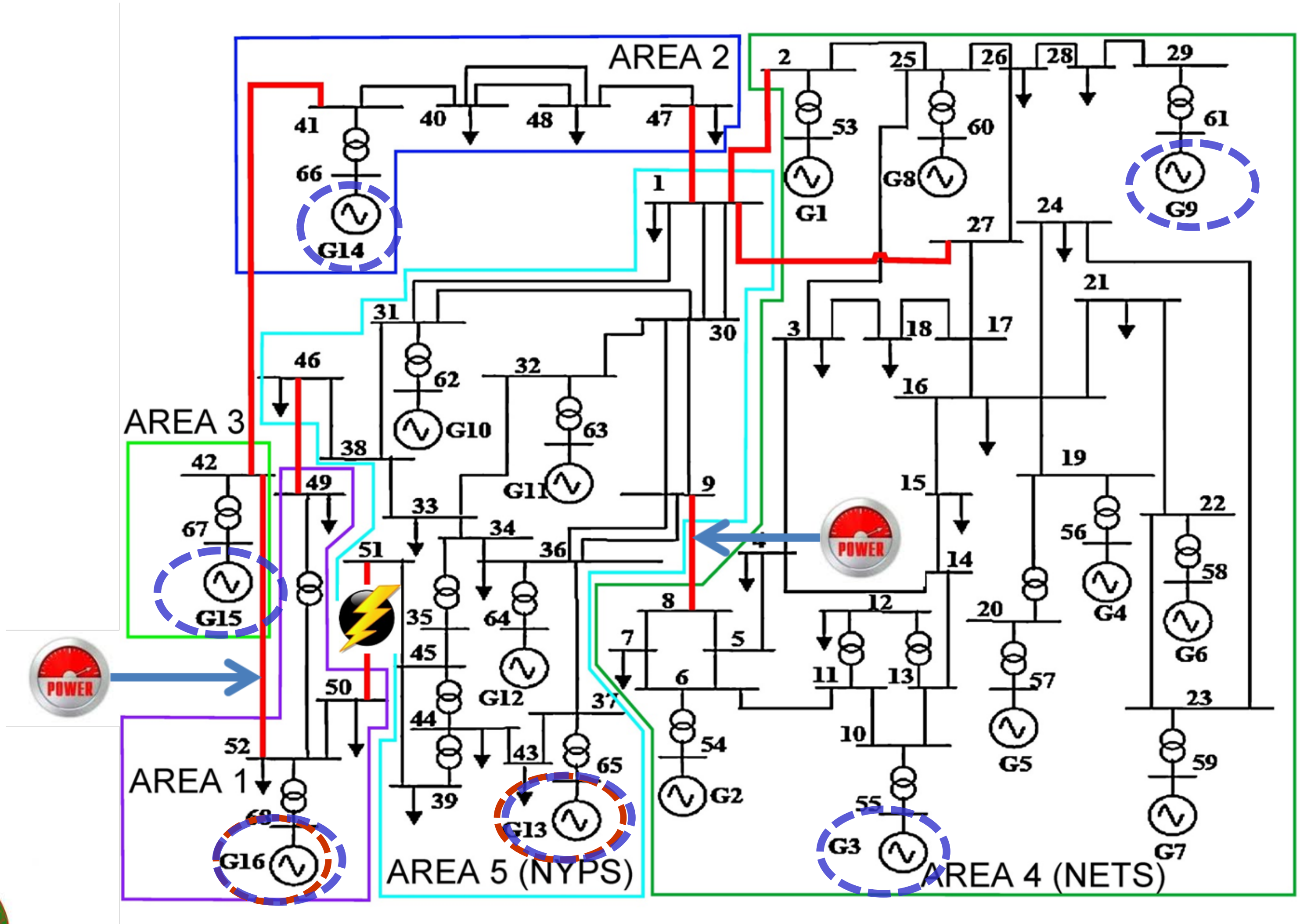
Effectiveness of the Control

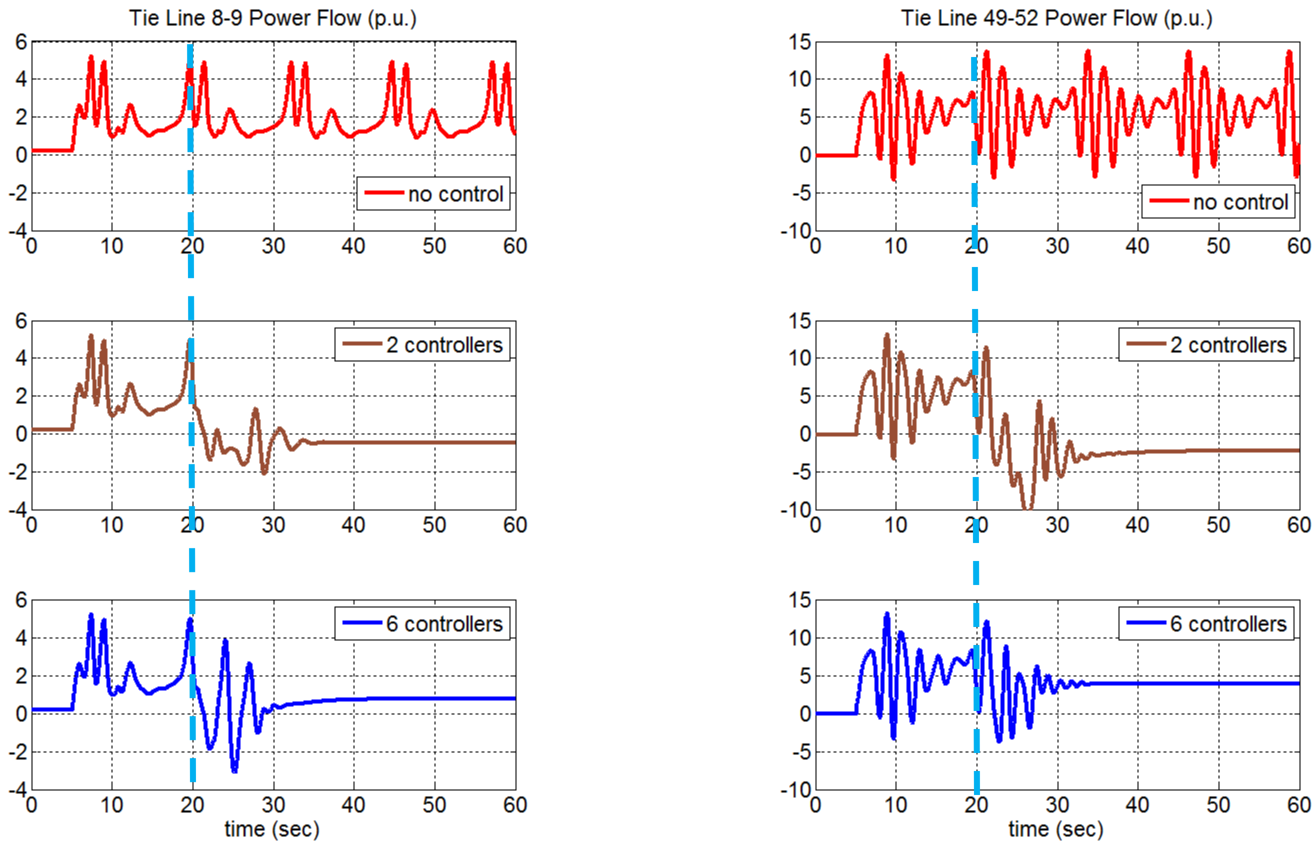


The controllers are activated at 20th second

Case #2: The 16 Machine Model



Effectiveness of the Control



The controllers are activated at 20th second

Summary

- The distributed controllers can improve damping
- When low damping is observed, operators may engage the controllers to improve damping
- The effectiveness increases when the number of controllers increases
- The effectiveness depends on the locations of the controllers and the mode shapes

Major Technical Accomplishment

- Applied a decentralized robust control method to increase the damping when a low damping is observed.
- Worked with BPA in reviewing past MANGO reports to generate insights on practical considerations and constraints.

RD&D CYCLE:
2. Modeling/simulation

Deliverables and Schedules Under FY 13 Funding

- Develop and implement control algorithms to increase the modal damping by coordinating multiple critical controllable variables. (09/30/2013, 30%)
- Build up a demo using an industrial model to reveal the values of MANGO control in power system operations. (03/31/2014, 10%)

Risk Factors & Mitigation Approaches

- Major risks: Practical constraints may limit the applicability of MANGO controls.
  - Work with industry experts to understand the practical constraints
  - Develop multiple optional control strategies

Follow on work for FY14

- Develop multiple strategies for implementing MANGO control
- Study the scalability of MANGO control

Questions or Comments?

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