Frequency Responsive Demand

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Project Objective

- This project is evaluating the utilization of large numbers of small loads to provide spinning reserve
- The specific scope of this project is comparing the ability of load to provide equivalent primary frequency response that would be available from conventional generation

Utilizing Small Loads for Frequency Responsive Reserves in a Large System Model

- Objectives:
  - Credible analysis of the feasibility of using load as a frequency responsive reserve primarily to offset generator governor action
  - Documented and reproducible base case of the WECC power system using PSLF incorporating frequency responsive loads with a flexible parametric interface
- Questions to address:
  - Can frequency responsive load displace (offset) traditional generator governor response?
  - Can frequency responsive loads address “balancing” of the overall frequency response such that interregional tie-line flows do not change drastically post-contingency?
  - What are the sensitivities to various assumptions?
    - Regionalization of load response
    - Discretization (“lumpiness”) of load response
    - Gain and time constant of independent load controllers

Prior Work

- ORNL has previously investigated demand response for ancillary services (spinning reserve)
- Similar to PNNL LDRD study conducted in the mid 1990s where dynamic load control was investigated to dampen inter-area oscillations in the western power system
- Similar to prior PNNL investigations associated with Grid Friendly™ Appliance Controller deployment
- IEEE Task Force convened approx. 10 years ago (now disbanded) on fast-acting load control for price and system stability

Accomplishments in FY11-12

- Quantified performance improvements on realistic base case with uniformly applied load controls
- Perform and document sensitivities to various parameters
  - "What if" the technology is adopted in the LA basin but not in other parts of the western grid (sensitivity to localization)?
  - "What if" loads respond in big discrete blocks rather than small, smooth increments (sensitivity to discretization)?
  - "What if" one locale (or manufacturer) applies one set of control parameters and another locale (or mfg.) applies a different set of control parameters (sensitivity to gain and/or delay)?
  - Will any of these "what ifs" degrade reliability? Are there any deployment issues we need to watch out for?
- Final Report delivered

Technical Summary

- Over 6000 positive sequence, time domain simulations conducted to assess various sensitivities
- Generic, documented load control model developed and tested
  - Suitable for use by planning engineers for exploratory studies in PSLF simulation environment
  - Flexibility to study various controller parameters and settings
- Autonomous demand response capabilities and vulnerabilities assessed as applied to frequency response

Raw Data Sets for Western US

- Three base cases (different seasons)
- Four contingencies (gen drop contigencies in different areas)
- Approx. 506 sets of parameters for each condition

= Approx. 6000 simulations

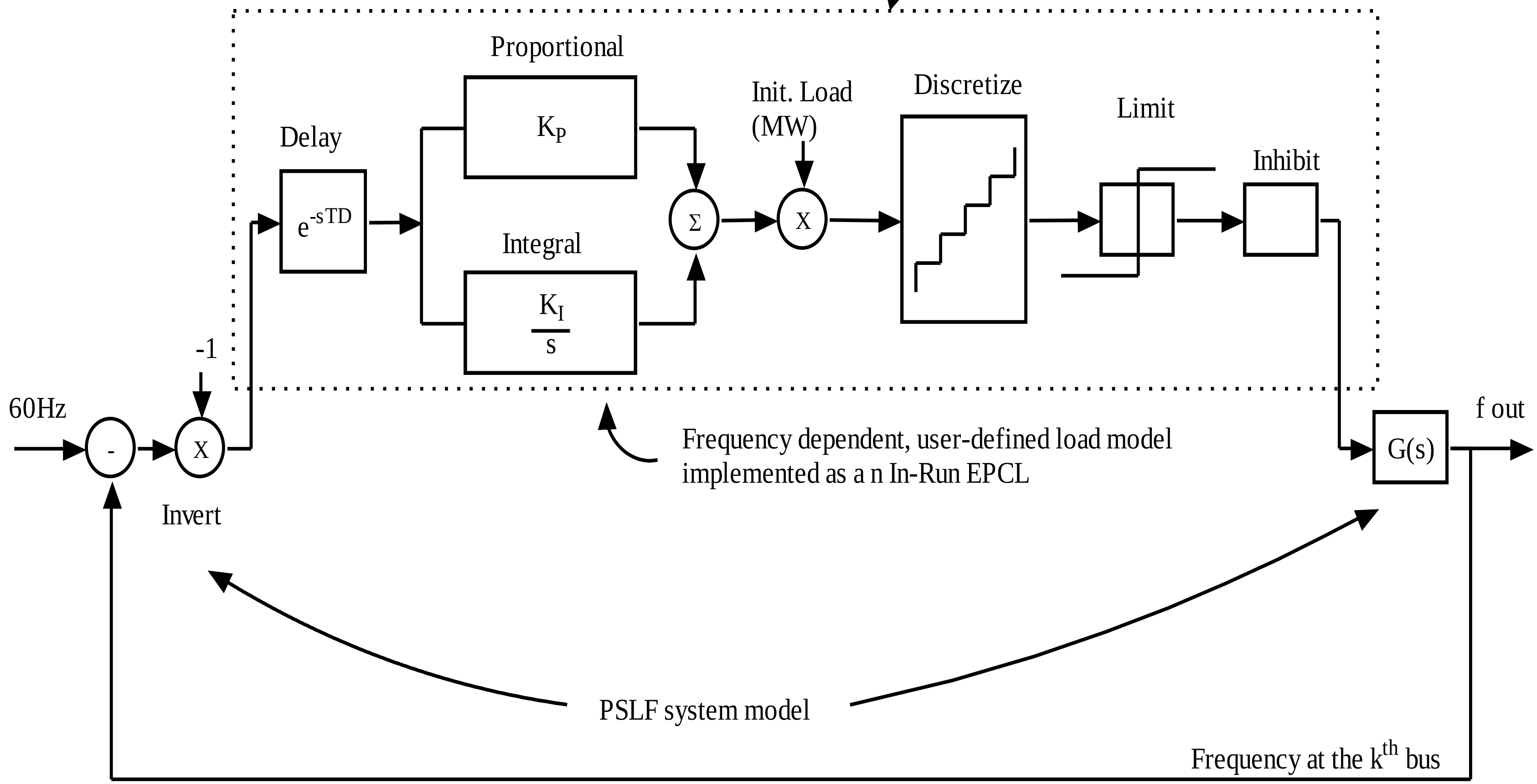
each representing 45 seconds

on a 30,000+ bus system

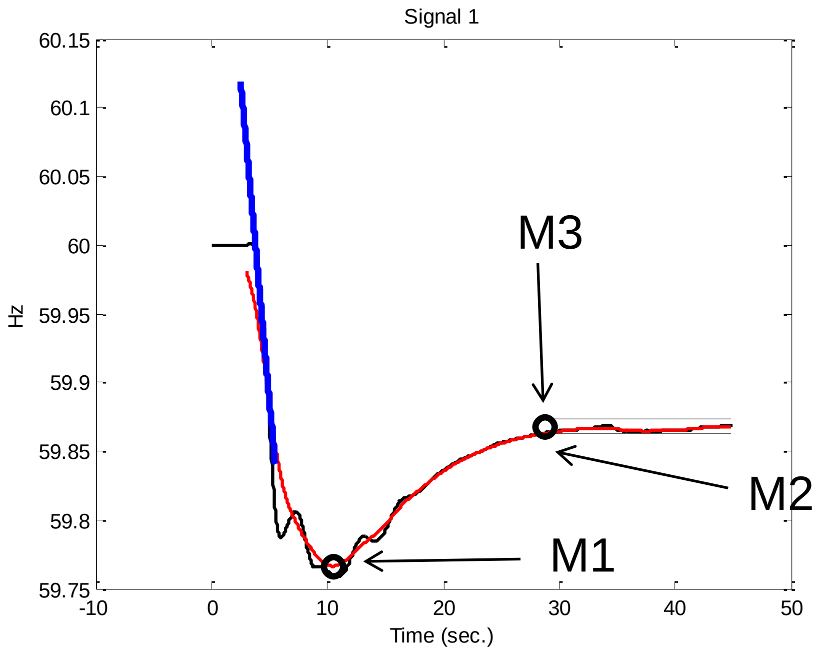
independently controlling 7500+ loads representing 106 GW

Controller model

This controller block executes on each of approximately 8000 load buses at each time step.



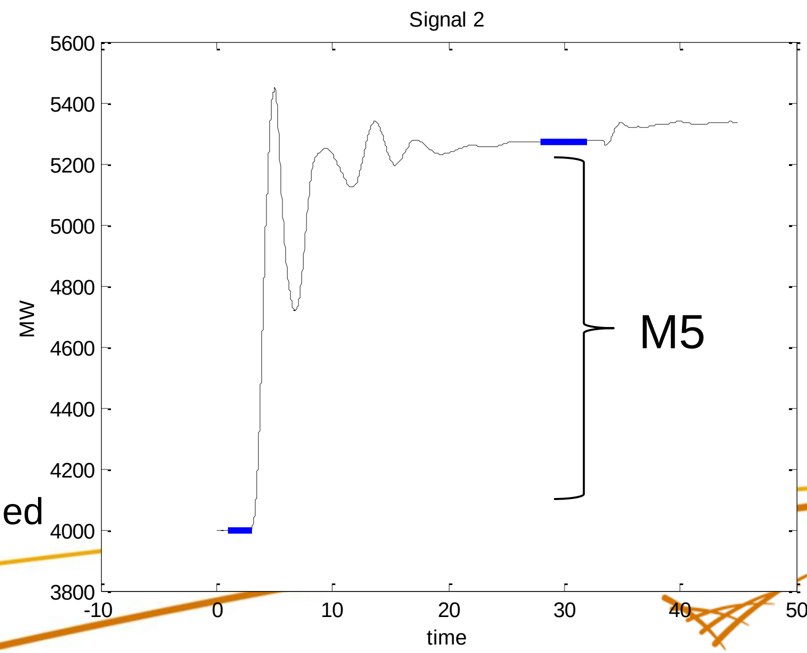
Metrics Used To Evaluate Sensitivities



LBNL Metrics (FERC Report) Used as Basis

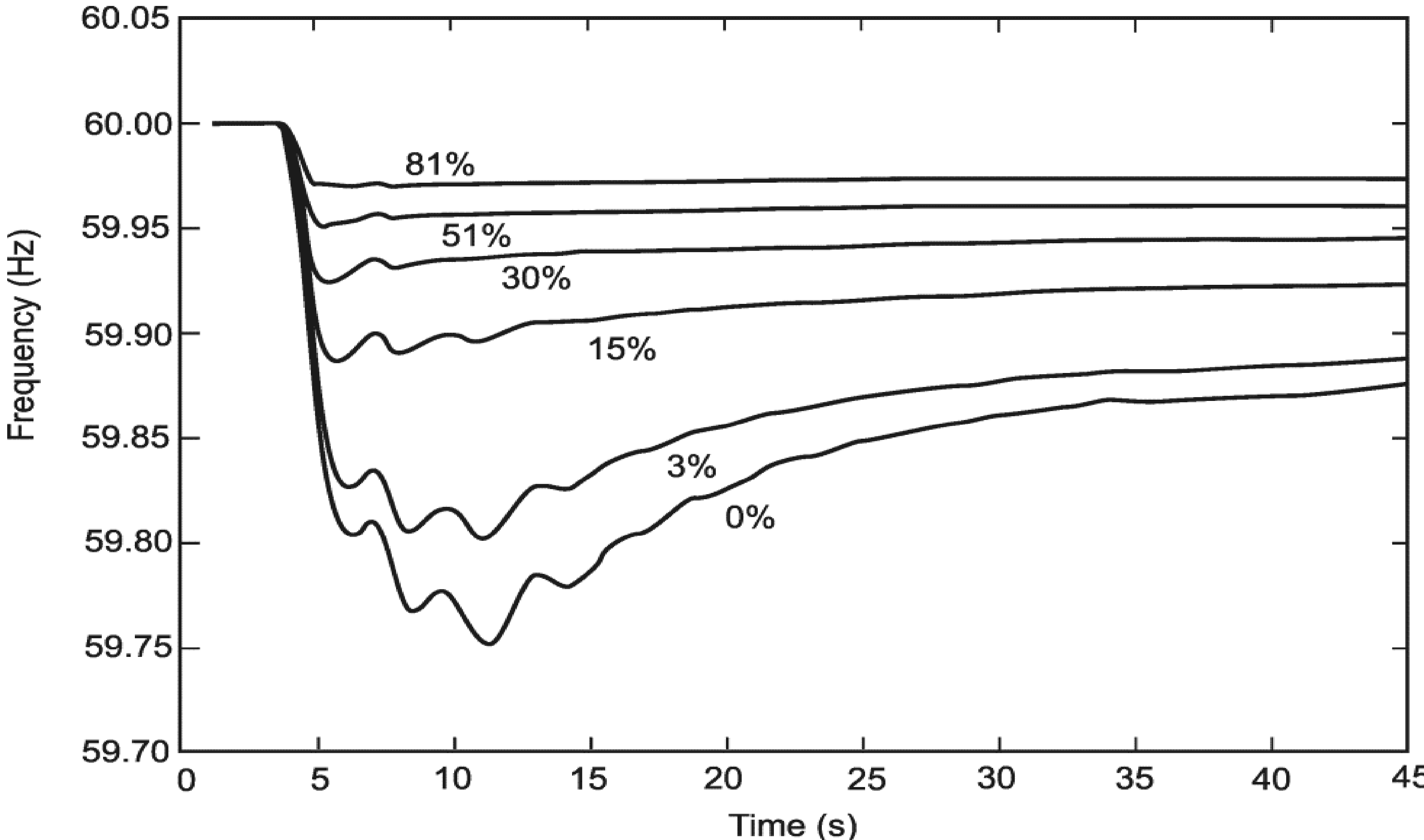
- Frequency Nadir (M1)
- Settling Frequency (M2)
- Time of Settling (M3)
- Nadir-Based Frequency Response (M4)
- Normalized Change in COI Flow (M5)

M4 = MW of Gen Lost/M1



Sensitivity to Mx =
((Mx,withControl – Mx,noControl)/Mx,noControl)/MWcontrolled

Gain Sensitivities



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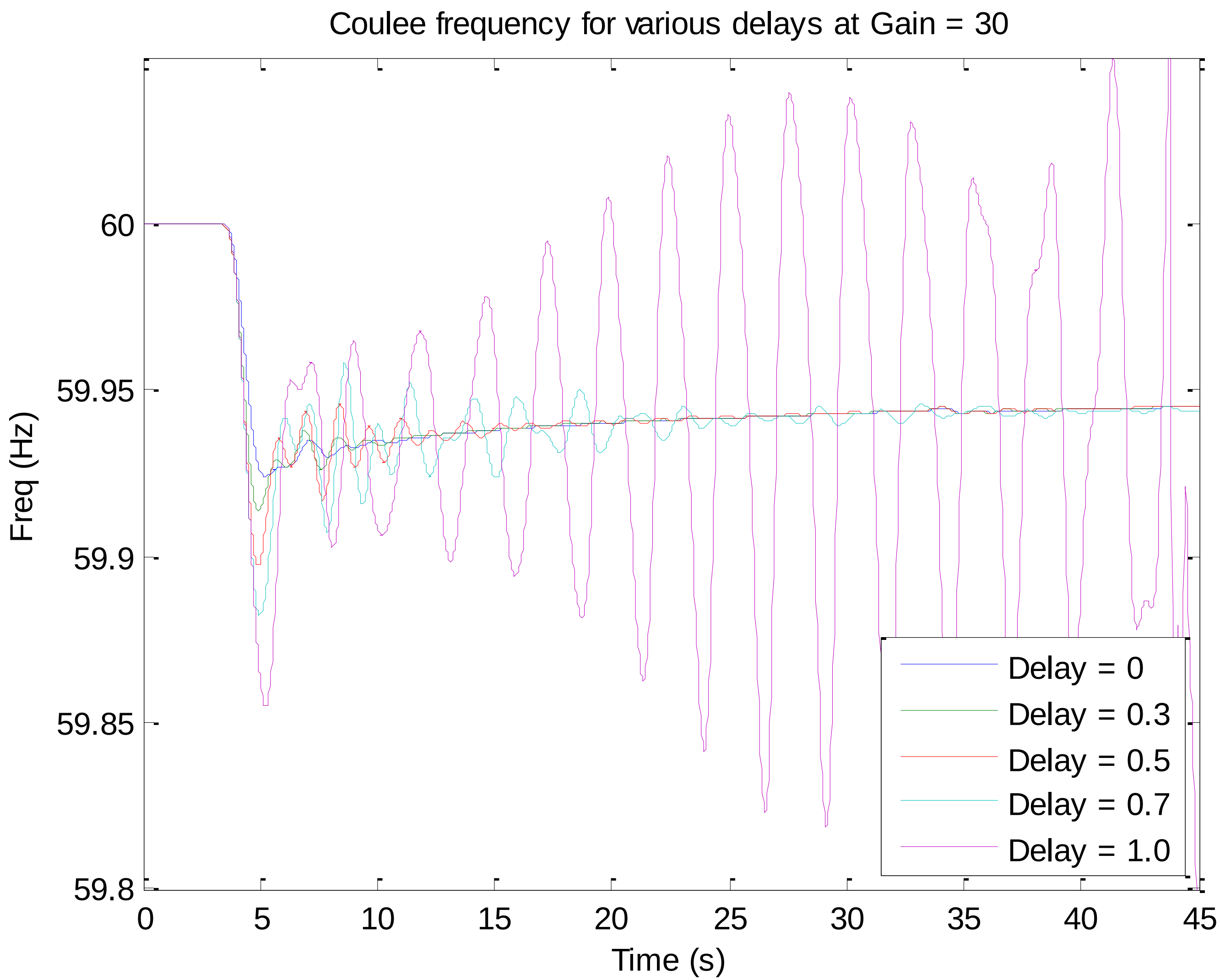
Delay Sensitivities



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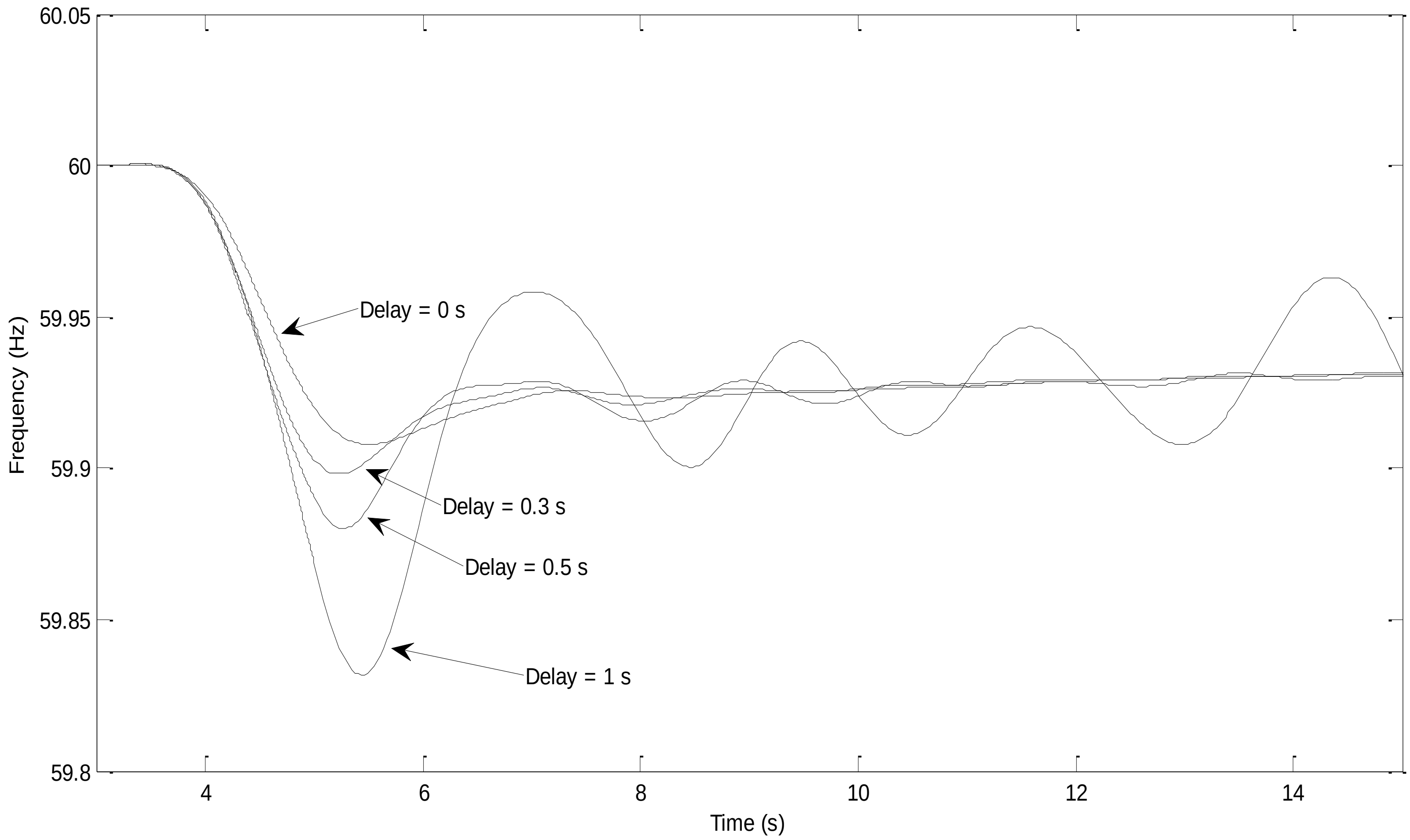
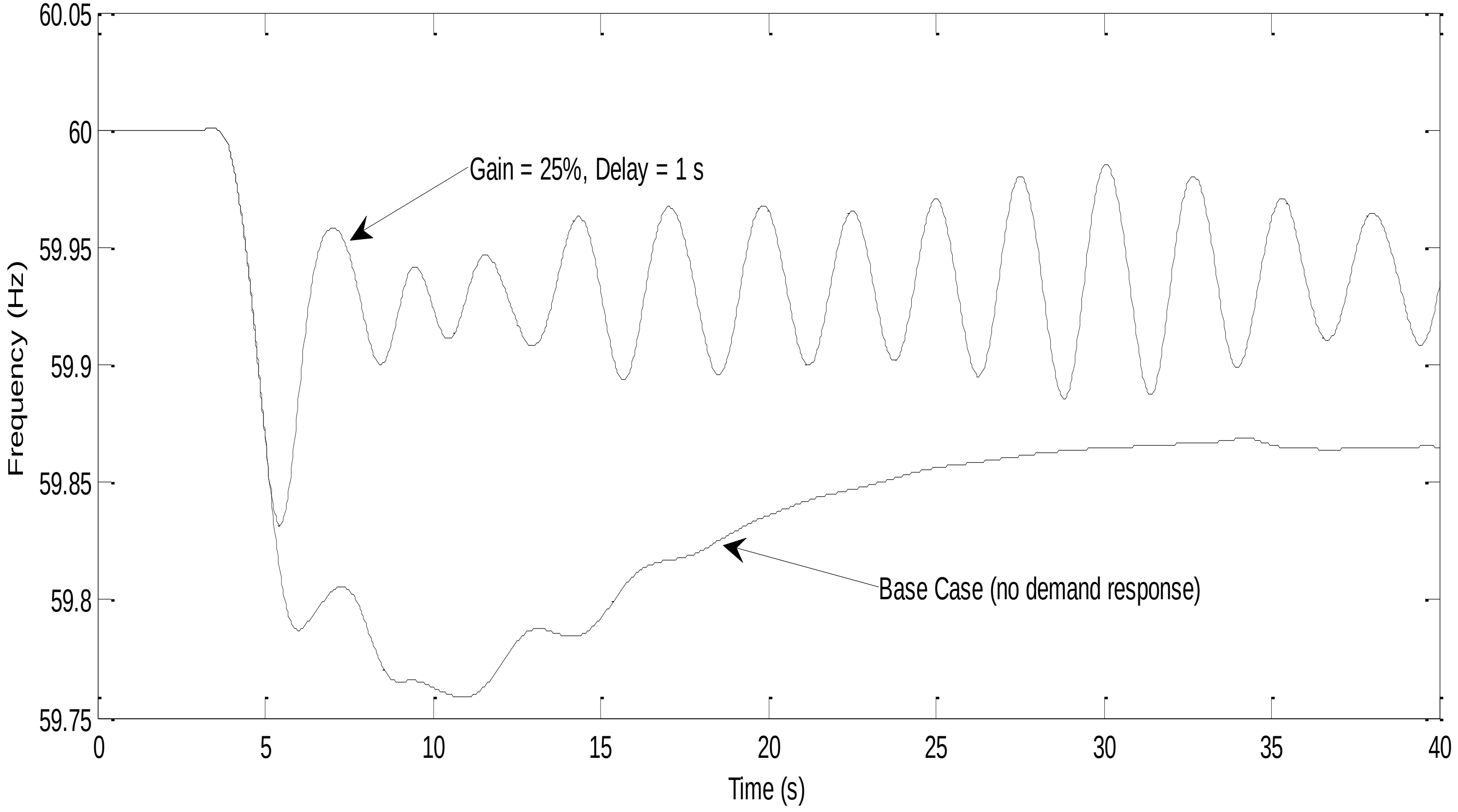
Various Delays Showing Instability



Comparison to Baseline to Damand Response with Kp=25%, Delay=1s



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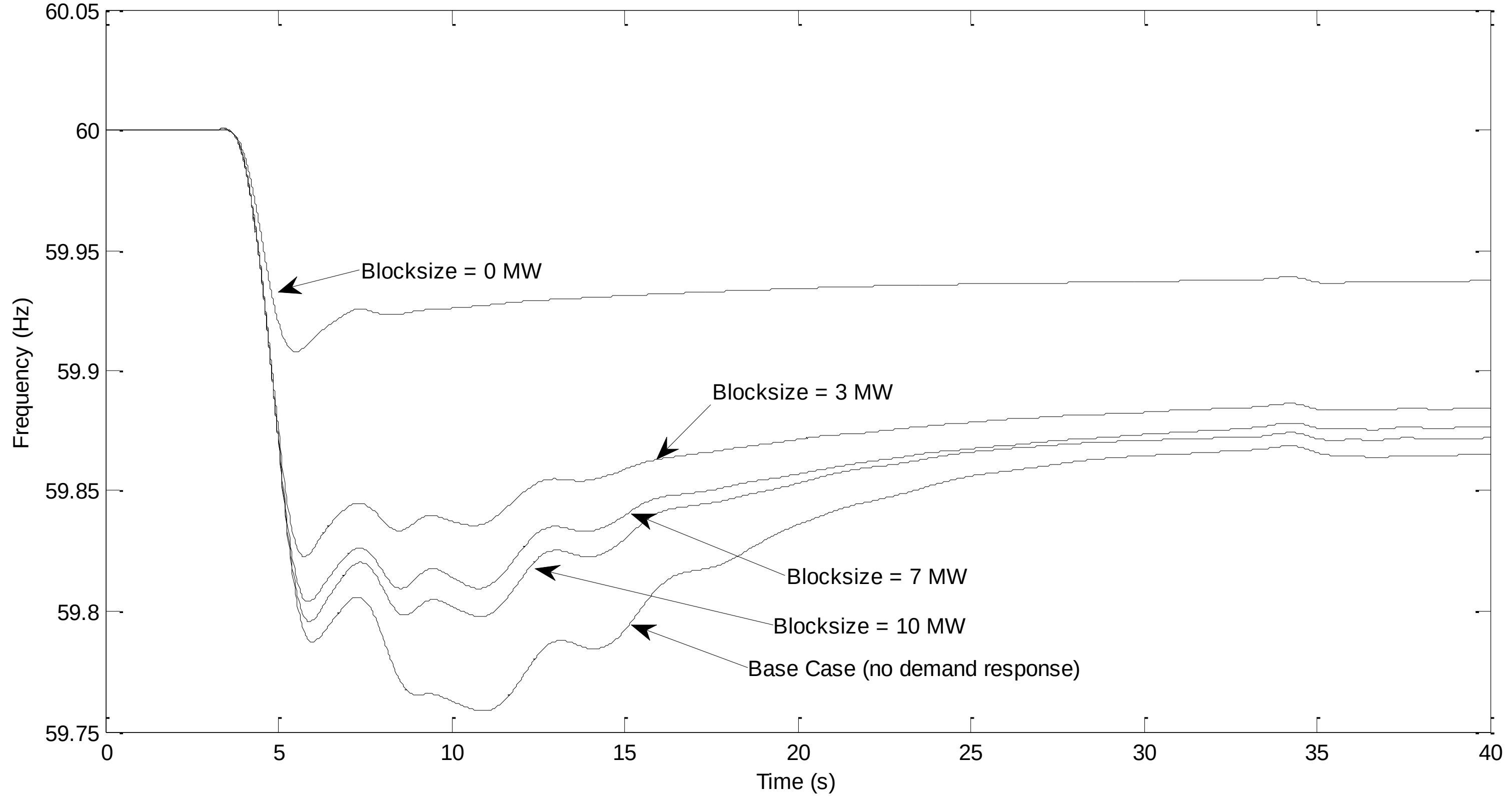
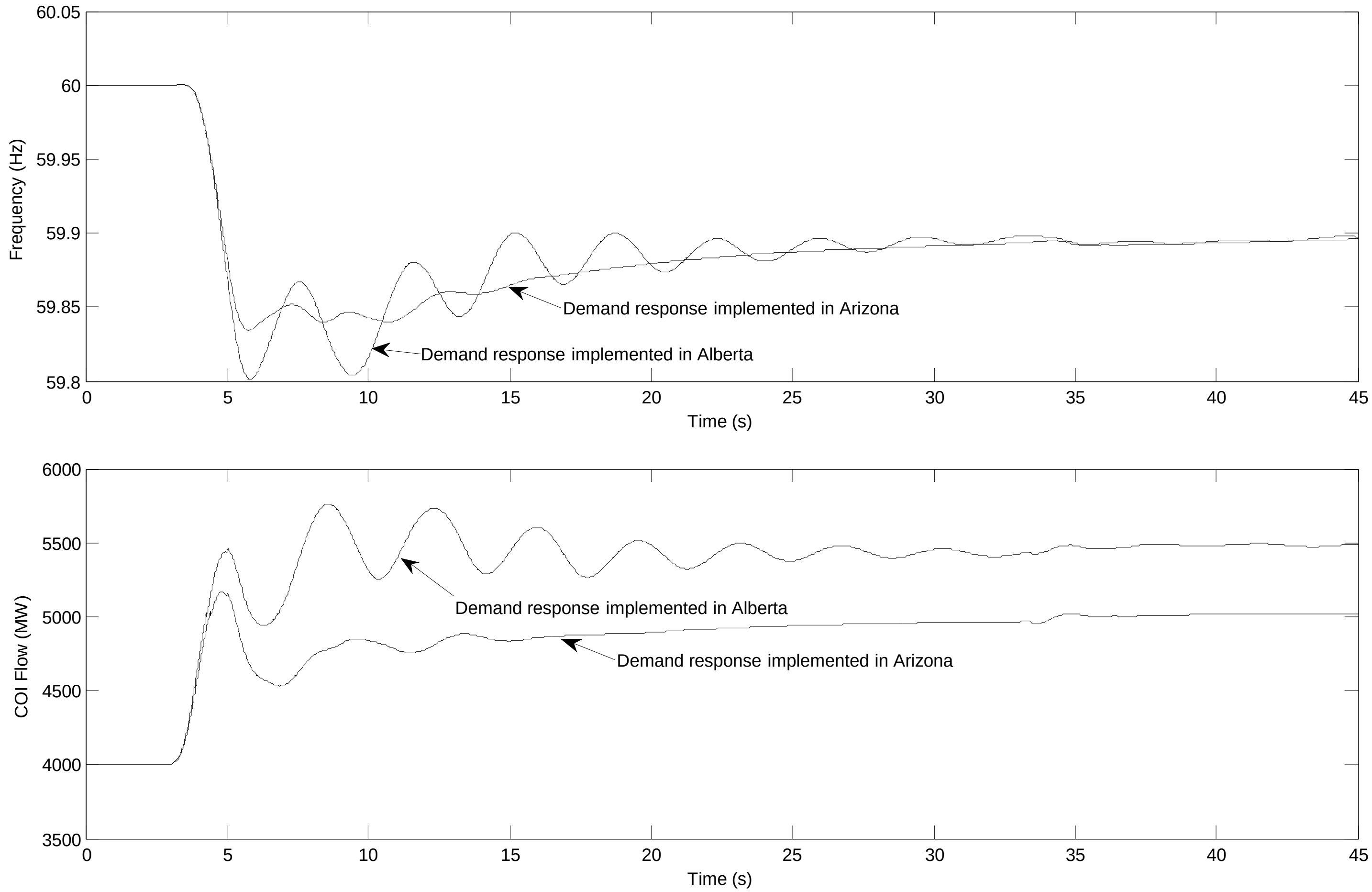
Sensitivity to Block Size:
Various Sizes of Demand Response Blocks for Kp=25%



Sensitivity to Location: Effect of Localization on Frequency Response



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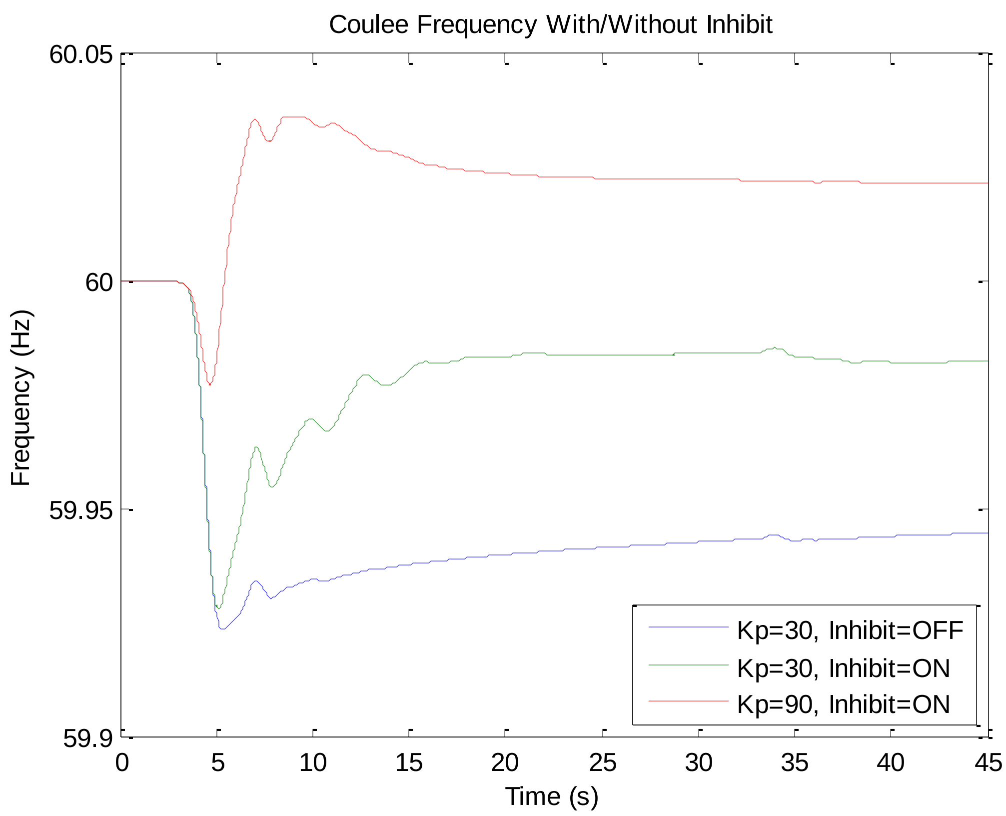
"Inhibit" the Restoration of Load



Key Findings

- Autonomous demand response can provide substantial benefit by responding to under-frequency events in the interconnected power system
- This study demonstrates the characteristics of frequency response delivered by autonomous demand response are analogous to generator governor action
- Very few conditions associated with autonomous demand response have the potential to degrade reliability
  - Two areas of concern identified:
    - Excessive time delay
    - High penetration of autonomous demand response concentrated in one region of an interconnected grid
- Additional work is needed to verify the findings of this study

Proposed Activities for FY13

- Broader stakeholder engagement with WECC planning community
- Investigate future WECC base cases (large renewable penetration)
- Evaluate possible implementation strategies
- Research new control methodologies
- Other areas of technical investigation
  - Voltage effects of demand response, particularly when the controller manipulates both real and reactive load
  - Investigate how classical governors might be modified to accommodate increased autonomous demand response
  - Determine if there is an optimal penetration level when the incremental benefit of adding additional demand response provides a declining benefit

Risk factors affecting timely completion of planned activities as well as movement through RD&D cycle

- Key researchers involved in other tasks that have diverted time and attention to other priorities
- Being resolved through the completion of these other activities as well as bringing additional resources onto the project team