MontanaTech
THE UNIVERSITY OF MONTANA

Using Synchrophasors for Oscillation Detection & Mitigation

Mode meter use in Western Interconnection

Panel Session on Oscillations

NASPI Work Group Meeting
06/08/2011
Matt Donnelly

Proposed Definitions

Mode: A measure of oscillatory activity or potential activity. A mode can be electromechanical, describing the oscillatory behavior of the system – termed a system mode; or a measure of the system's oscillatory response to a forcing function—termed an input mode.

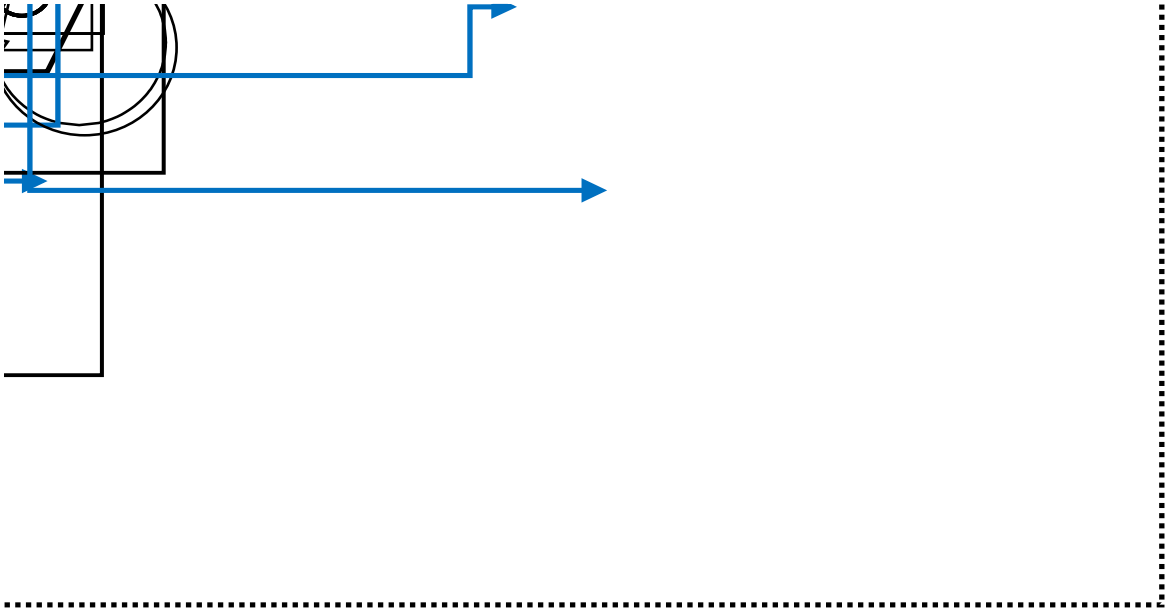
Mode Meter: A tool used to estimate a specific mode's frequency and damping under primarily ambient system conditions.

Oscillation Detector: A tool used to detect unusual oscillatory activity and provide notification to an application, e.g. an alarm processor. An oscillation detector does not attempt to calculate damping or shape of oscillations.

Ringdown Damping Estimator: A tool used to detect an oscillation and, once detected, to estimate the frequency and damping of the predominant modes under primarily transient system conditions.

DESCRIPTION OF WISP-RELATED TOOLS

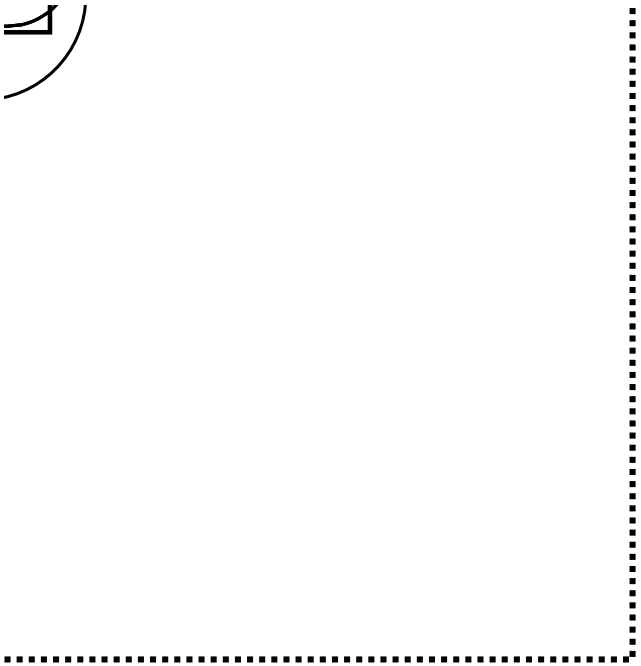
Mode Meter (used during ambient conditions)



1. Form pseudosignal from combination of several voltage and/or MW signals combined with intent to isolate mode in a single signal.
2. Preprocess pseudosignal by applying filters, bad data detection, resampling, etc.
3. Estimate mode several times using different methods and parameters. Some key methods are Yule Walker and R3LS.
4. Select “best” estimate by choosing result meeting specified accuracy with minimal data.
5. Using “best” mode estimate, calculate mode shape estimate from voltages at many locations .

Spectral Estimation

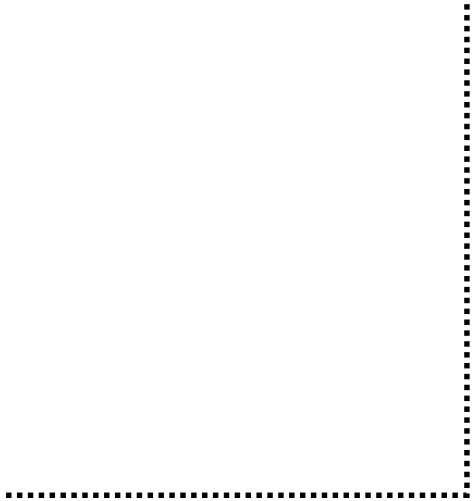
(used during ambient and transient conditions for oscillation detection)



1. Input many synchrophasor signals from many locations.
2. Preprocess signals by applying filters, bad data detection, resampling, etc.
3. Estimate spectra for each signal using one or more methods. One key method is recursive non-parameteric Welch's method (very fast).

Ringdown Damping Estimation

(used during transient conditions, i.e. major disturbances)



1. Input several key synchrophasor signals.
2. Preprocess signals by applying filters, bad data detection, resampling, etc.
3. Estimate frequency and damping of several modes for each signal. One key method is automated Prony analysis.

Summary of WISP Tools

Mode Meter

- Method operates on one “pseudosignal”, but something on the order of 6-10 synchrophasors required to generate pseudosignal
- Designed for ambient conditions, but also works during transient conditions
- Tens-of-minutes of data required
- Delivers estimate of frequency, damping and shape for one mode

Spectral Estimation (oscillation detection)

- Method operates on one synchrophasor, but can have many estimates running simultaneously
- Can be used during ambient or transient conditions
- Tens-of-minutes of data customarily required
- Delivers estimate of modal energy across a broad frequency spectrum

Ringdown Damping Estimation

- Method operates on one or several synchrophasors
- Best during transient conditions
- About ten seconds of data required
- Delivers estimate of frequency and damping for several modes at once

WESTERN INTERCONNECTION SUCCESSES

Current Status

Used for 10+ years in offline analysis and planning

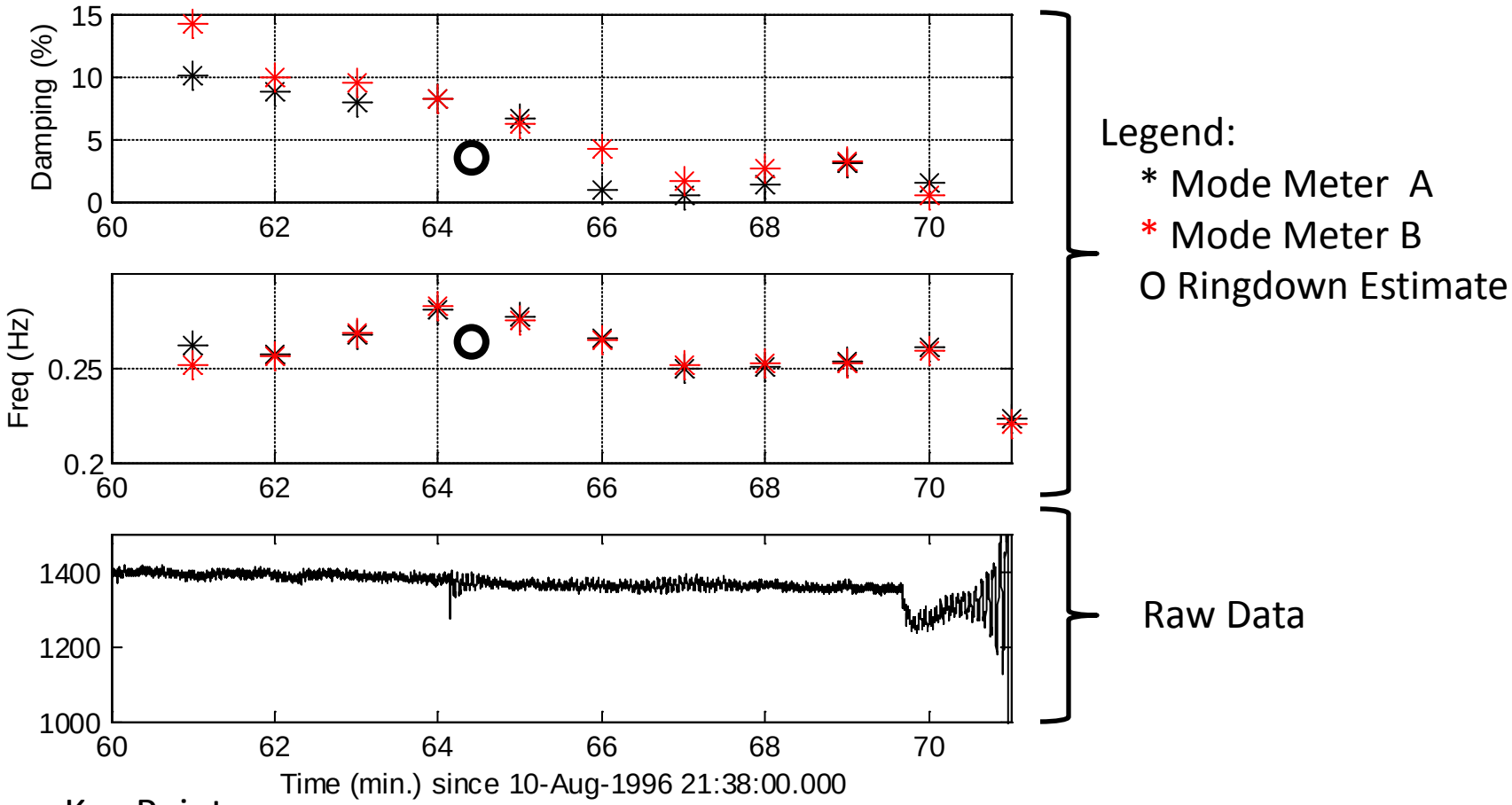
- Analyses using these tools can be found in many WECC reports and studies

Continuous on-line monitoring in BPA lab since May 2010

Currently being used to baseline oscillatory performance in the WI

Being implemented by WECC as part of WISP project and as part of the synchro-phasor programs being initiated within the WI by various transmission operators

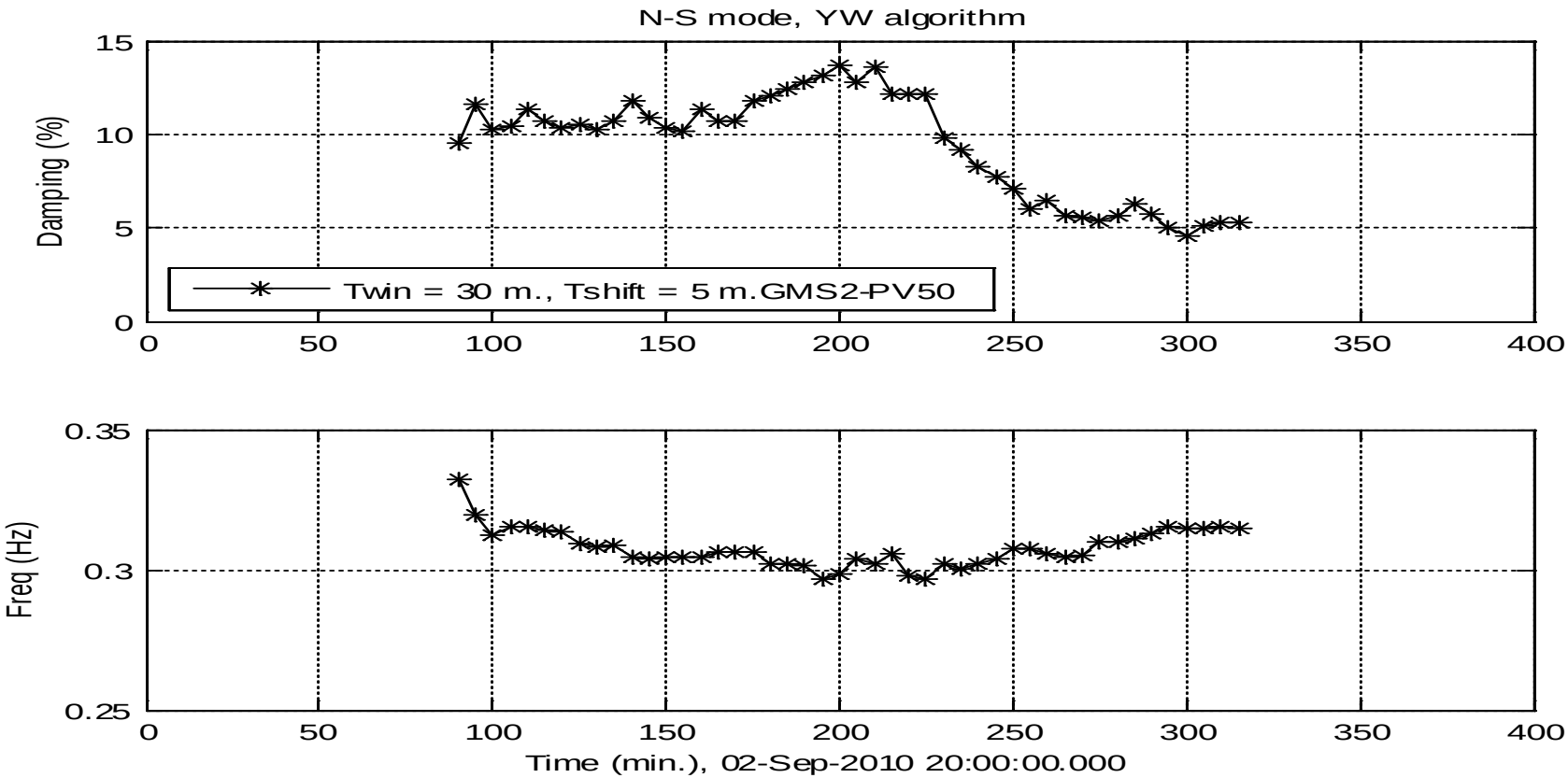
Mode Meter vs. Ringdown Damping Estimation



Key Points:

- Large transient occurs at t=64.1 minutes, picked up by oscillation detector
- Mode meter is providing estimates all the time, but ringdown estimator only during a transient
- Ringdown estimate faster, but requires higher energy signal

Importance of Baselining



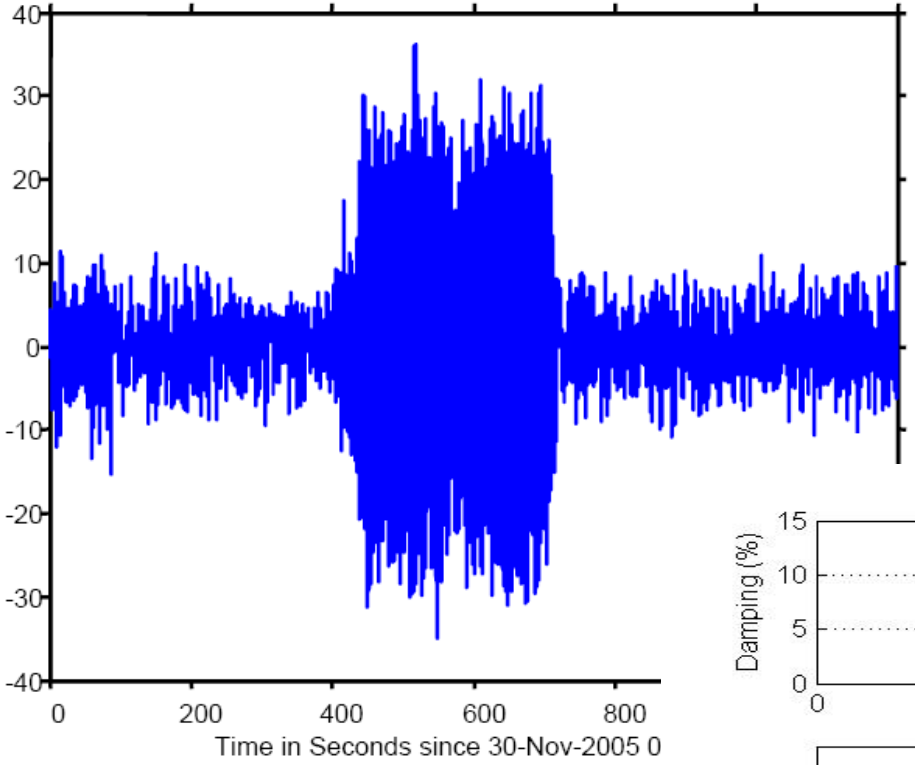
Key Points:

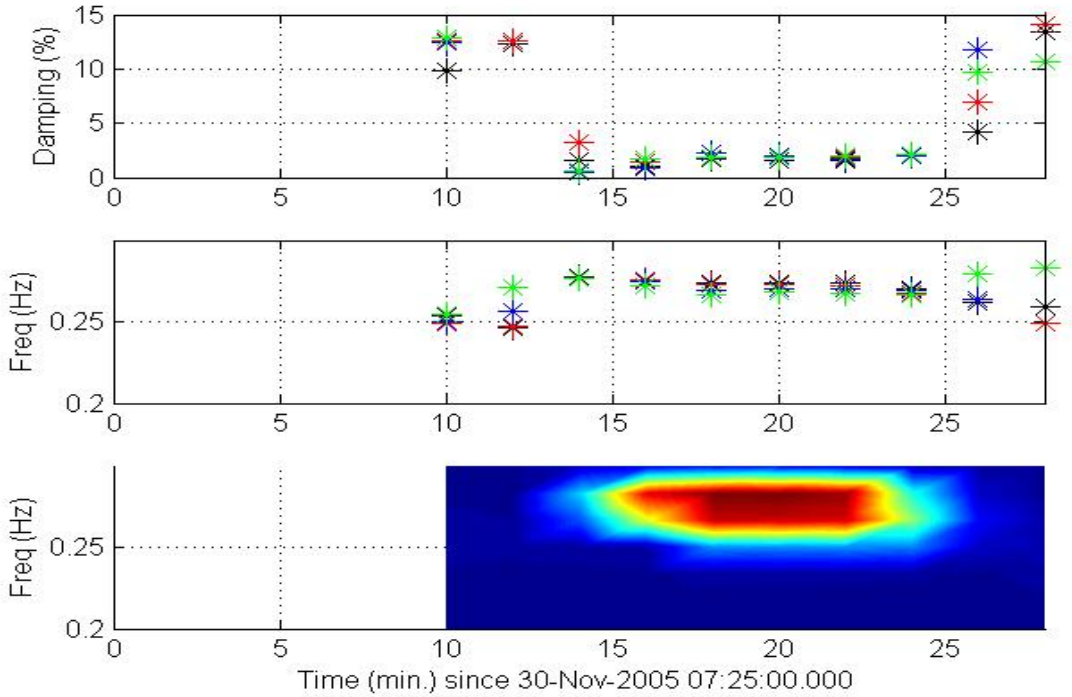
- Having a baseline of modal information will help answer questions like, “Have we seen this before? Is this expected behavior for these system conditions?”

Forced Oscillations

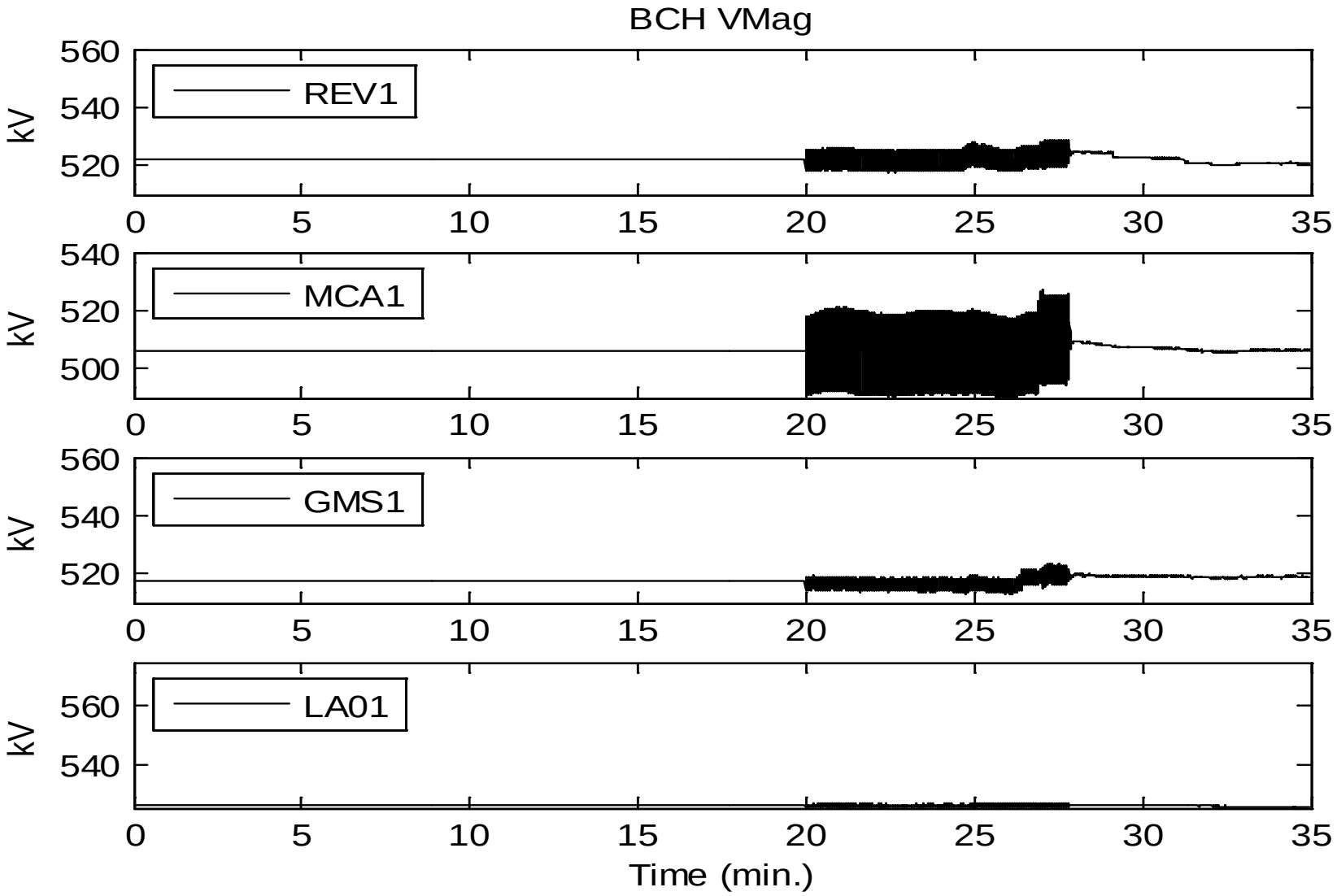
- Response of system to an apparatus in a limit cycle
  - e.g. generator controller
- NOT A SYSTEM INSTABILITY
- Forced oscillations very common (16 events in 2008/9 operating season in WECC).
- Can be very severe: November 30, 2005.

Forced Oscillation, Example #1



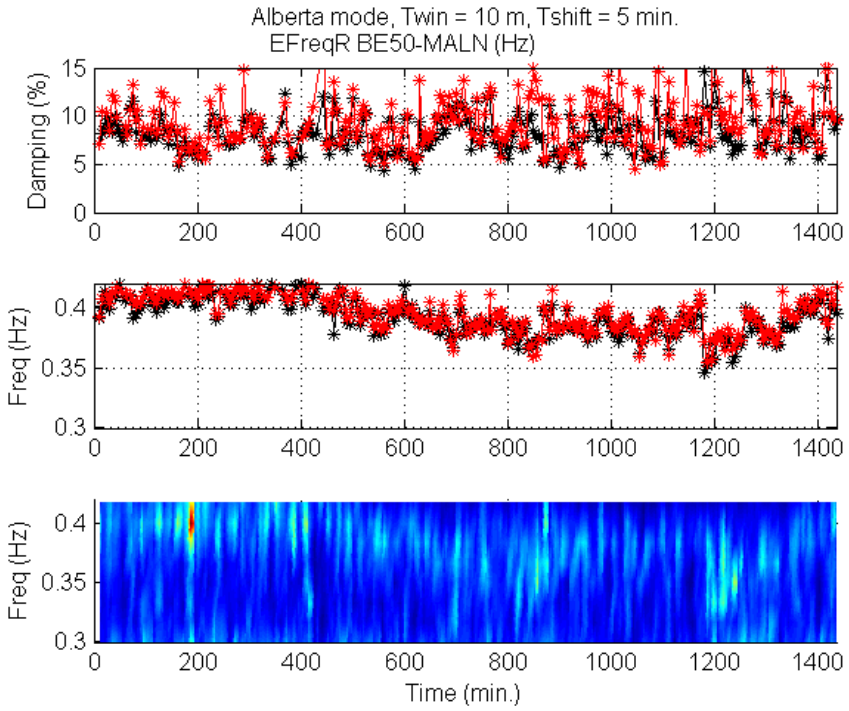


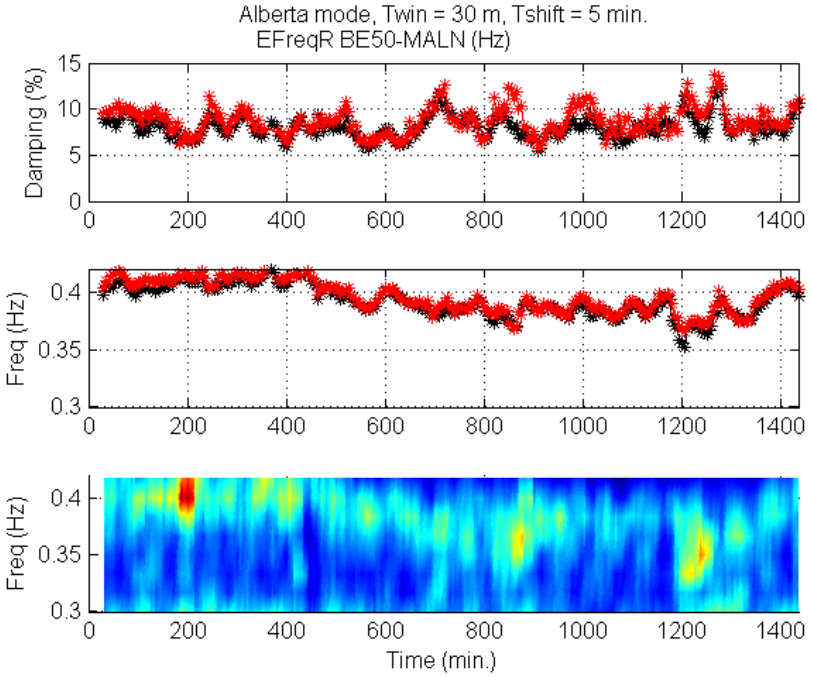
Forced Oscillation, Example #2



Mode-meter Performance vs. Window Size

June 1, 2008





Key Points:

- Smaller window size means faster response, but greater standard deviation of estimates