California ISO

NERC Oscillation Analysis for Monitoring and Mitigation

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NASPI Workshop on ““Monitoring, Analysis and Mitigation of Oscillations and Inverter Based Resource Impacts”
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About Me

- Aftab Alam - Manager, Operations Planning North, California Independent System Operator (CAISO)

Aftab Alam provides engineering support for outage coordination and planning, real-time grid and market operations for the California ISO and Reliability Coordinator functions for RC West entities. He is also involved in the development of operating procedures and implementation of various real-time assessment applications such as real-time contingency analysis, voltage and transient stability analysis and oscillation monitoring required to provide situational awareness to operators. Prior to joining CAISO in 2011, Aftab was in Transmission Planning at ISO New England since 2007. Aftab completed his PhD and Masters in Electrical Engineering with a focus in Power Systems from Clemson University in 2007 and 2003 respectively. Aftab also serves on the NASPI leadership team and is involved with various working groups focused on system reliability at WECC, NERC and IEEE as a Senior Member.

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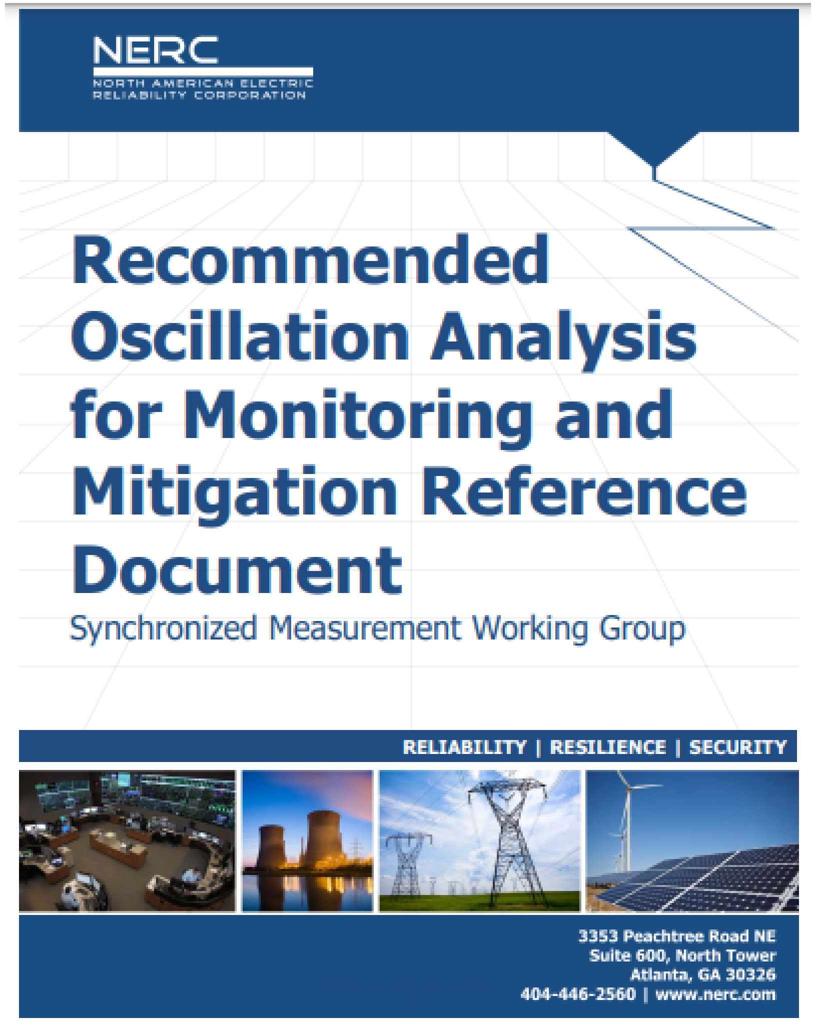
Technical Reference Document on Oscillation Analysis

- Developed by NERC Synchronized Measurement Working Group (SMWG)
- Approved and Published February 2022
- https://www.nerc.com/comm/RSTC_Reliability_Guidelines/Oscillation_Analysis_for_Monitoring_And_Mitigation_TRD.pdf


NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Recommended Oscillation Analysis for Monitoring and Mitigation Reference Document

Synchronized Measurement Working Group

RELIABILITY | RESILIENCE | SECURITY

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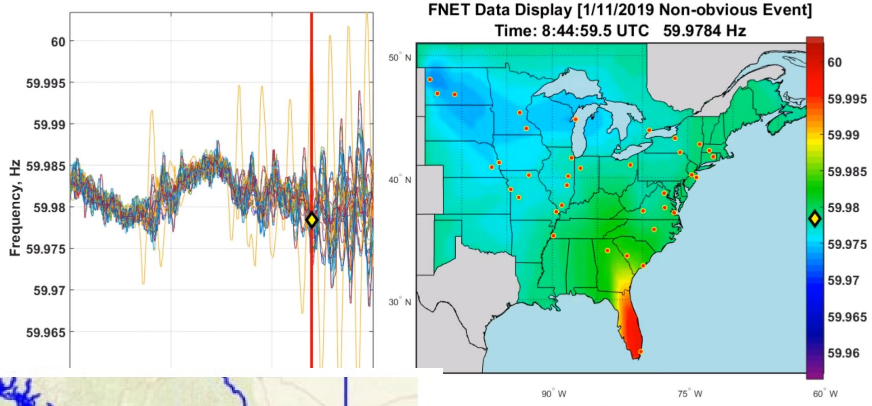
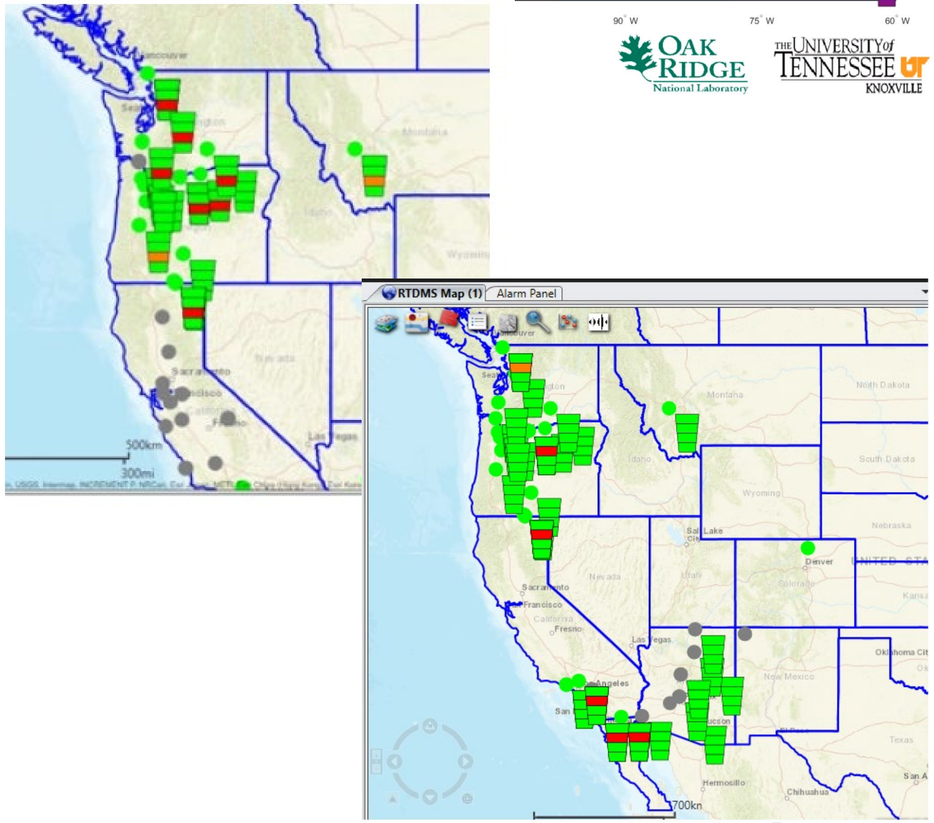
Agenda

- Background and Motivation
- Summary of the main sections
- Review of the key findings and recommendations
- Questions and Answers

Background and Motivation

- Recent oscillation events, have highlighted the **need for increased monitoring and consistency** in the monitoring of oscillation disturbances.
- Some of the key recommendations from prior event analyses included the need for Reliability Coordinators (RCs) and TOPs to have real-time oscillation detection tools in place to identify when oscillations are occurring and determine if the oscillations are limited locally within their footprint or are more widespread.
- Equally important is to be able to distinguish between forced oscillations, poorly damped natural system modes, or scenarios where forced oscillations may be propagating across a wider area due to resonance conditions.
- The NERC Synchronized Measurement Working Group (SMWG) was also requested to develop guidance on oscillation analysis methods to encourage consistency in the system quantities that are monitored for oscillation events and the respective thresholds for alarms.
- **The detection and alarming of oscillations and their classification in a consistent manner is critical in ensuring coordinated mitigation of both local and widespread oscillation disturbances in BPS.**





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Chapter 1: Inter-Area Electromechanical Oscillations

- Inter-area electromechanical oscillations are often referred to as natural oscillations because they arise from the dynamics inherent to any power system.

- A system's inter-area modes of oscillation govern the periodic exchange of energy between generators in different parts of the system.

- Natural oscillations can take on different forms depending on how the system's dynamics are excited: ambient oscillations resulting from continuous perturbation by random load changes and ringdown oscillations caused by an impulsive disturbance, such as a generator tripping off-line

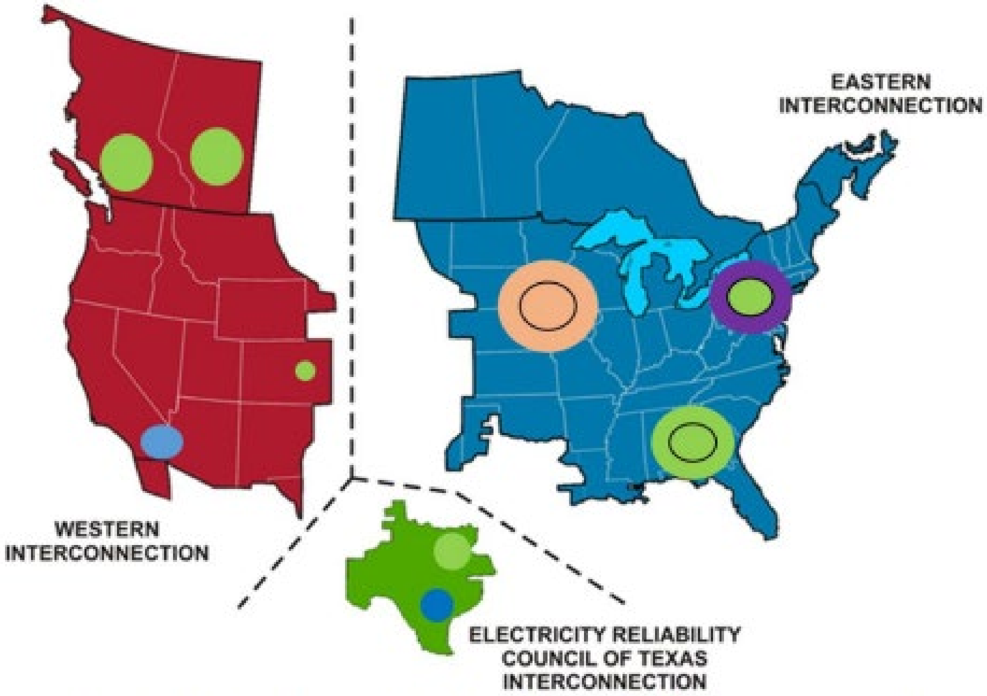


Figure 3.1 Dominant Mode 1 Geographic Representation

Chapter 1: Inter-Area Electromechanical Oscillations

Section 1.1

Data and Model based methods

- Methods to determine inter-area modes of significance

Section 1.2

Model based methods

- Determining mitigation actions for modes of significance.

Section 1.3

Correlation / Spectral Analysis

Monitoring setup

- Monitoring, Selection of quantities and thresholds for monitoring of modes

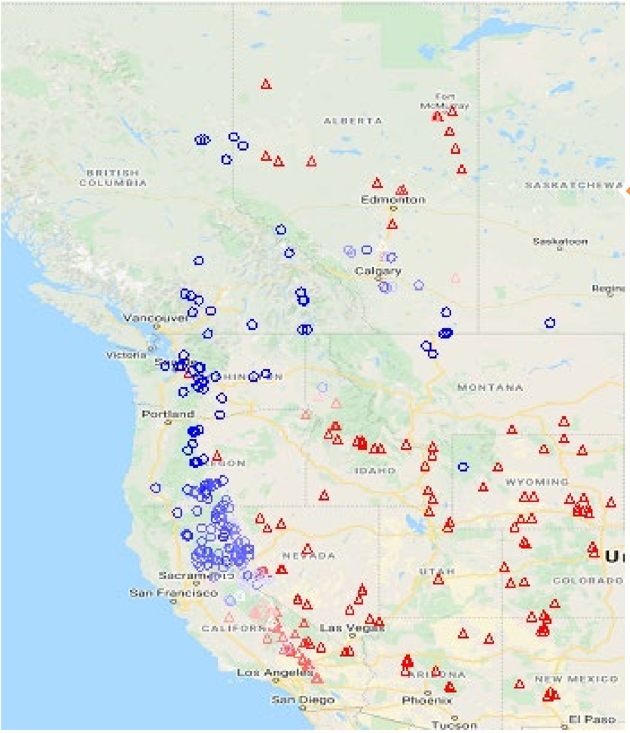
Section 1.1: Interconnection Wide Analysis to Determine Significant Modes

- Ringdown Methods
- Ambient Methods
- Eigenvalue Analysis Method

Table 1.2: Methods for Modal Analysis			
Data Type	**Ringdown Methods**	**Ambient Methods**	**Eigenvalue Analysis**
Synchrophasor Data (Ambient Data)		X	
Synchrophasor Data (Post-Disturbance Data)	X		
Powerflow Base-Cases (Offline Planning Models or Real-Time State Estimator Snapshots) with associated dynamic data	X		X

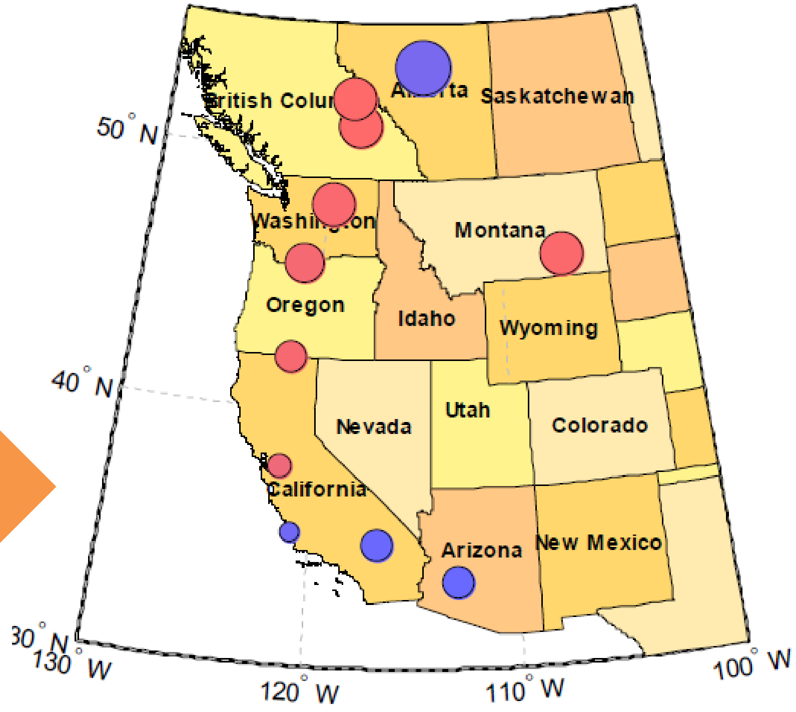
Section 1.2: Determination of Mitigation Actions

- Eigenvalue Analysis with Powerflow Base Cases
- Ringdown Analysis with Powerflow Base Cases



Model

Model-less



Section 1.2: Determination of Mitigation Actions

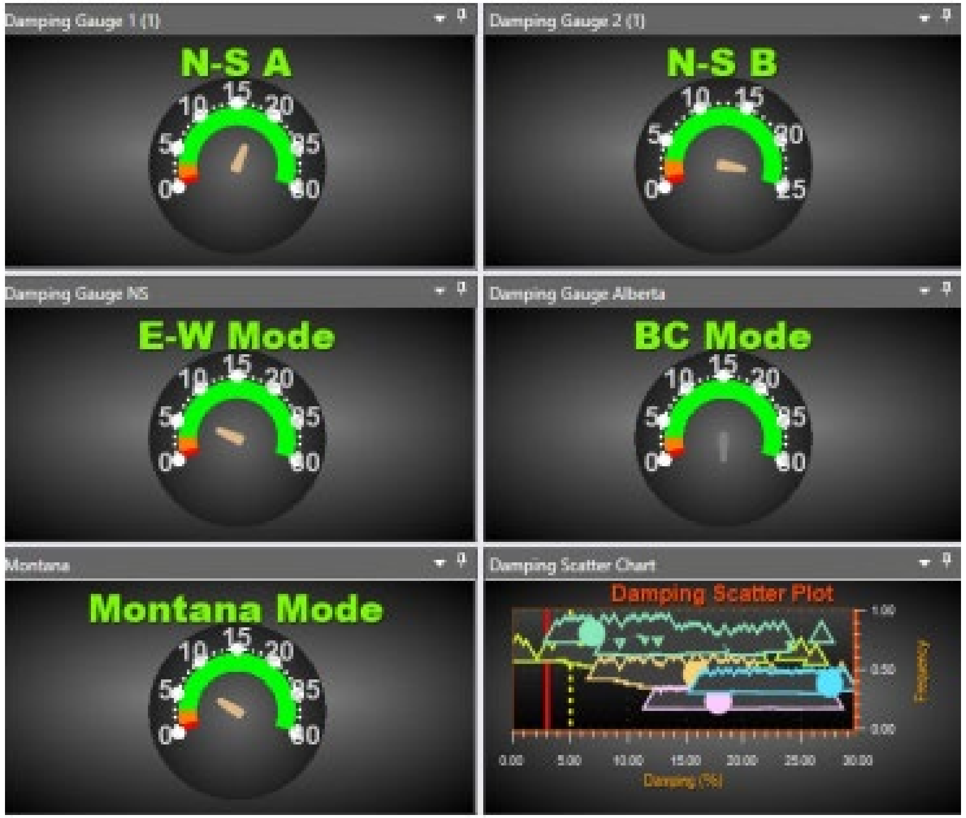
- Eigenvalue Analysis and Ringdown analysis based methods can be applied to both offline powerflow cases used for transmission and operational planning purposes and with real-time powerflow cases that utilize the state estimation solution and realtime conditions.

- The model-based approach to determining the mitigation actions provides some advantages:
  - Real-time validation of the provided mitigation approaches in operating guidelines provided to operators when used with real-time powerflow cases and the associated dynamic data.
  - Can test different strategies such as varying transfers along major transmission corridors, varying topology conditions, such as status of transmission lines or series capacitors or generation redispatch.
  - Can test the impact of contingencies on the damping of the significant modes. This can provide situational awareness to operators of the impact of contingencies when the damping of the monitored modes is below the critical levels for a sustained period.

Section 1.3: Monitored Quantities Informed by Analysis

- Monitoring the modes of significance requires determining which synchrophasor data that should be utilized in tools to monitor the modes. Various quantities can be used, such as voltage angle pairs, voltages, or flows. It is important for system operators to monitor modes in a consistent manner.

- This section provides guidance on:
  - Which quantities can be selected.
  - Thresholds for Damping and Energy
  - Monitoring Mode Shape
  - Monitoring System Conditions



Chapter 2: Forced Oscillations

- Methods to detect forced oscillations

Section 2.1

Various Methods

Section 2.2

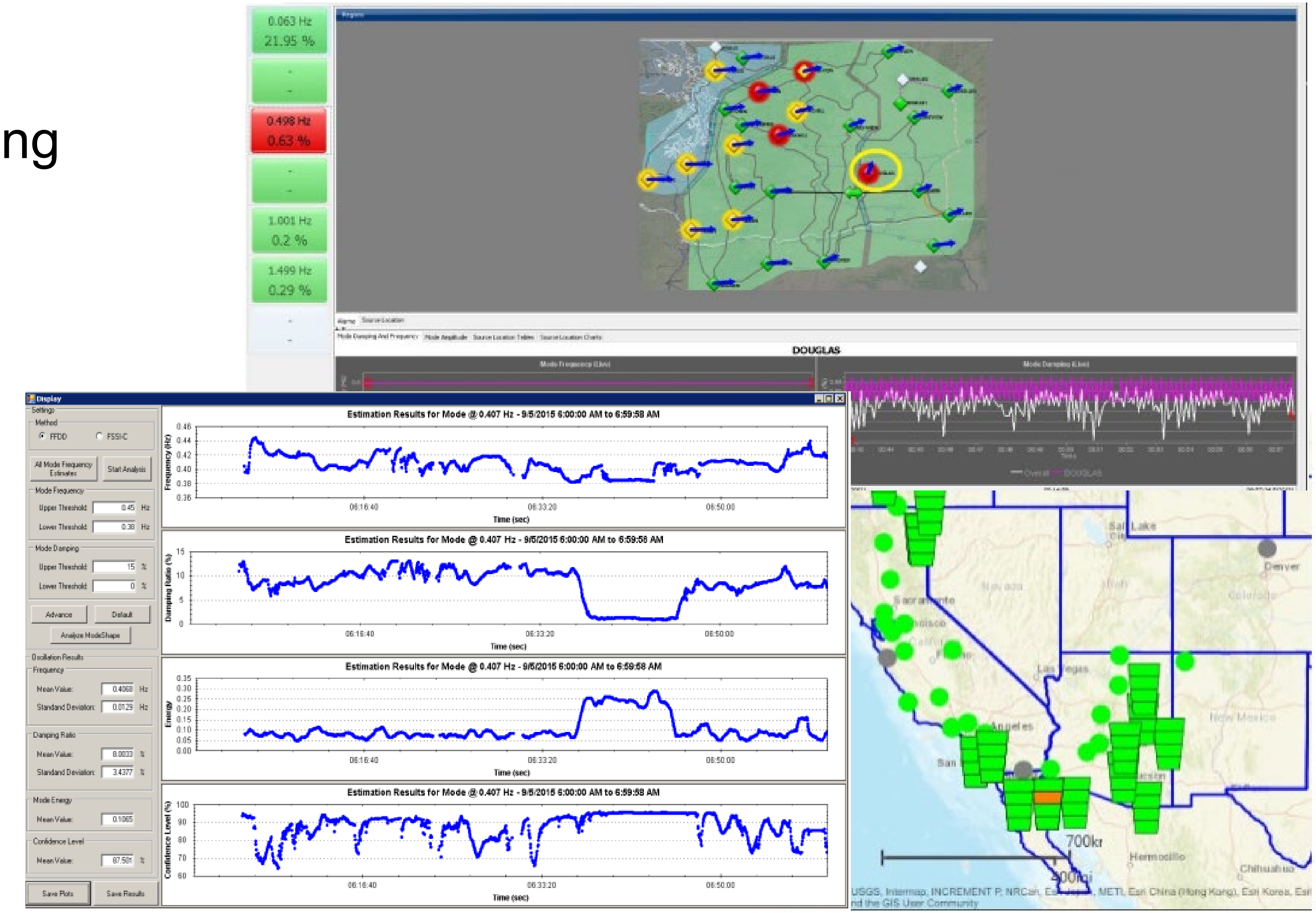
Local Area

Wide Area (DE and SCADA based methods)

- Methods to determine source of forced oscillation

Section 2.1: Forced Oscillation Detection Methods

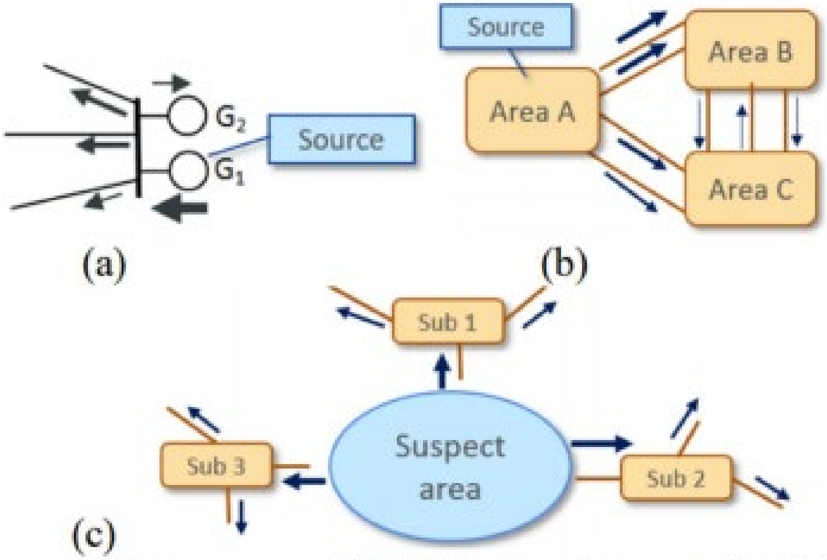
- Energy Bands Monitoring Approach
- Fast frequency domain decomposition
- Mode Frequency Band Monitoring Method



Section 2.2: Determination of Oscillation Source

- Local Forced Oscillations: Gives the impacted RC and TOP a starting point to coordinate to determine the source

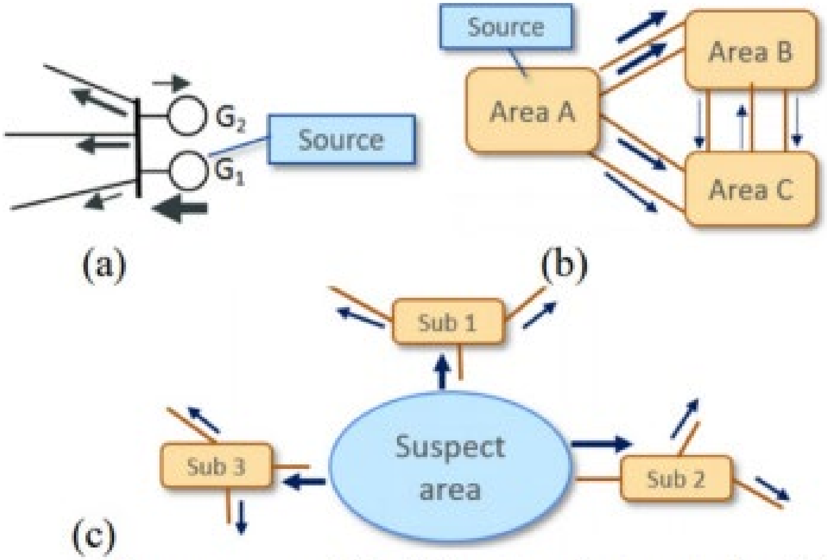
- Forced Oscillations Impacting a Wide Area:
  - Dissipating Energy Method: The method is based on tracing the flow of transient dissipating energy through the power system network



The use cases of the DE pattern interpretation (a) PMU monitors POI of a power plant, (b) PMU monitor tie-lines between areas, (c) localization of suspect area non-observable by PMUs

Section 2.2: Determination of Oscillation Source

- Forced Oscillations Impacting a Wide Area:
  - Source Location Using the Phase of Oscillation: The method is based on tracing the flow of transient dissipating energy through the power system network
  - Other Oscillation Source Location Methods recognized in recent IEEE Source Location Contest



The use cases of the DE pattern interpretation (a) PMU monitors POI of a power plant, (b) PMU monitor tie-lines between areas, (c) localization of suspect area non-observable by PMUs

Chapter 3: Forced Oscillations Causing Inter-Area Oscillations

- Conditions that lead to resonance phenomenon

Section 3.1

Main conditions

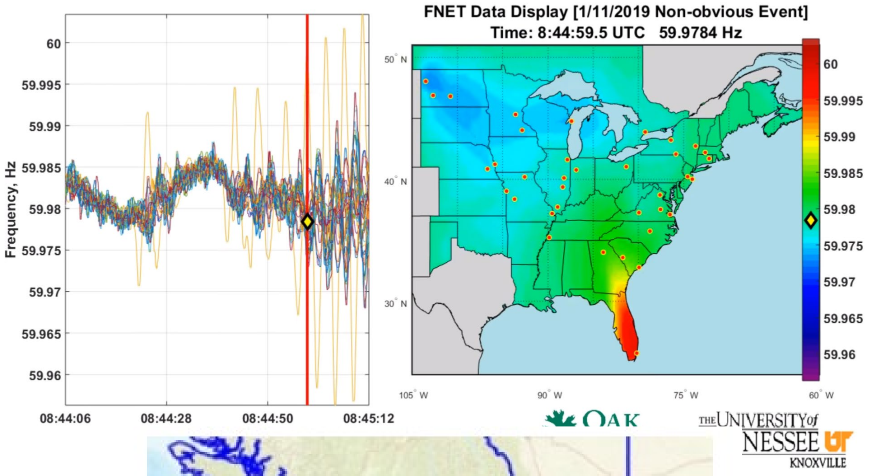
Section 3.2

Model based method example

- Methods to determine impact of forced oscillation that causes resonance

Section 3.1: Conditions that Lead to this Phenomenon

- A forced oscillation whose frequency is the same or very close to the frequency of an inter-area mode can lead to resonance that can potentially cause amplification of the oscillation across an Interconnection.
- Three major conditions are necessary for the resonance effect to be high
  - The forced oscillation frequency should be at or near a system mode frequency.
  - The system mode should be poorly damped.
  - The source is near a strong participation location of that system mode, such as the distant ends of the system mode. The distant end locations are the strongest participants in the system mode.
- See NASPI Webinar on Impacts of Forced Oscillations: https://www.naspi.org/node/951



Section 3.2: Testing Possible Mitigations

- Using model based approaches to simulate forced oscillations in dynamic simulations to validate the impact of forced oscillations and determining mitigation strategies.

Chapter 4: Guidelines for Addressing Wide-Area Oscillations

Determining if an oscillation is Forced or Natural

Source Determination / Coordination / Operator Actions

Key Findings and Recommendations

- For monitoring of inter-area or natural oscillations, various methods exist that can utilize ambient or post-disturbance data to determine the system modes that are significant. These assessments are recommended to be done annually or based on significant changes in the system. After identifying the significant modes, additional analyses can be performed to determine the locations where the modes are observable and the respective thresholds for alarming or operator action based on damping and the energy of the modes. In addition, analyses using powerflow cases and the associated dynamic models can be utilized to validate the modeling of the observed significant modes and to determine what mitigation actions might be effective in improving the damping of those modes.

- Forced oscillations can be detected using various methods that utilize thresholds established by prior analyses to differentiate between sustained forced oscillations and normal ambient changes in system conditions. Once the forced oscillations are detected, various methods exist to determine the locations from where the forced oscillations originate.

Key Findings and Recommendations

- Under certain conditions, forced oscillations can propagate across an Interconnection due to resonance with a natural system mode. Mitigation of such wide spread oscillations can require a combination of mitigation actions ranging from locating and eliminating the source of the oscillation to taking actions to reduce the impacts across the system by improving the damping of the impacted system mode.

- Mitigation of local and widespread oscillation disturbances and their impact requires effective tools and coordination between RCs and TOPs to determine the type of oscillation and the appropriate mitigation actions

Questions and Answers

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