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Oscillation Analysis on an Interconnection Scale

Modeling and Experiences

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NASPI November Meeting

RELIABILITY | RESILIENCE | SECURITY




Data Needed for Offline Engineering Tools

Data for Offline Engineering Tools - Event Analysis

- Need for data in offline EA analysis and for Transmission Analysis
  - Blue Cut Fire and Canyon 2 Fire
- Studies performed historically did not cover the large disturbance behavior of IBRs.

Data for Offline Engineering Tools – Event Analysis

- Blue Cut Fire Example

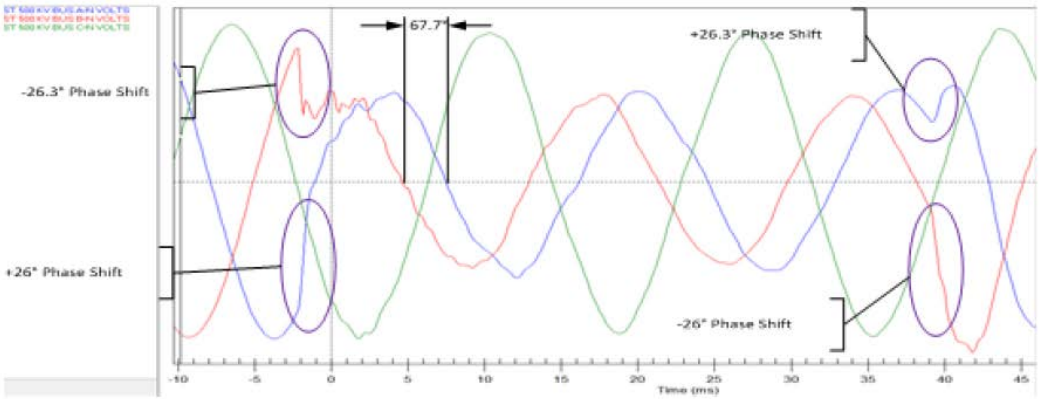


Figure 1: Phase Jump at Fault Location during Blue Cut Fire Disturbance

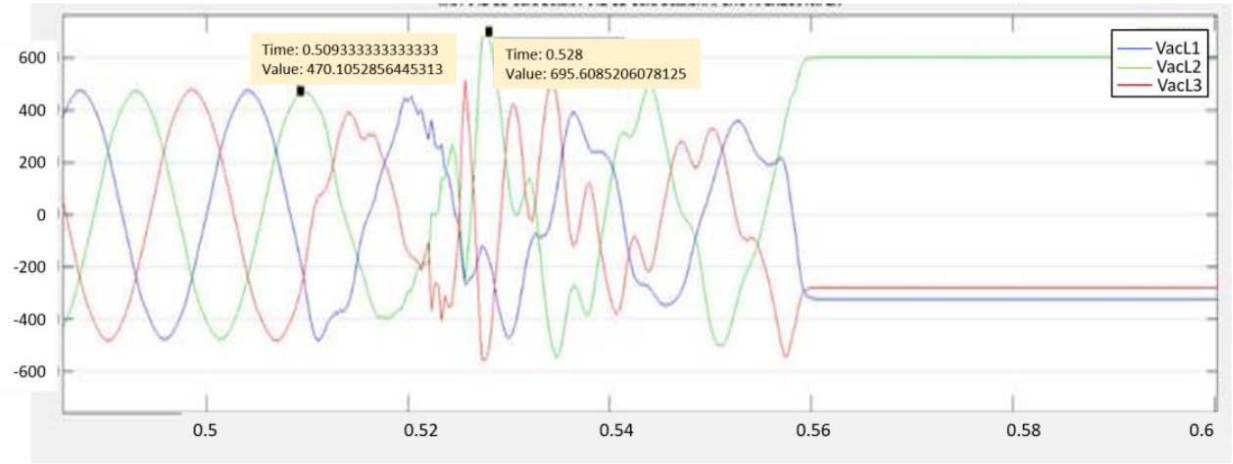


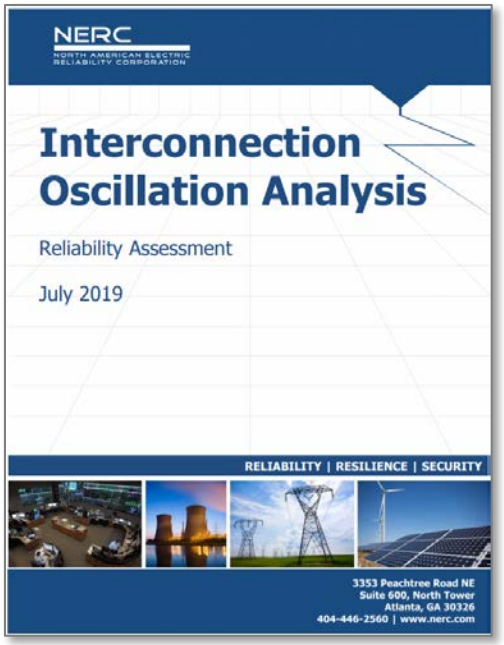
Figure 3: Transient Overvoltage at Inverter Terminals

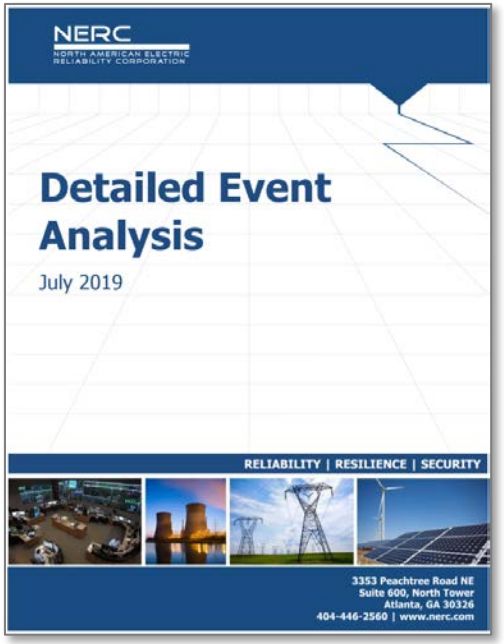
Data for Offline Engineering Tools – More than just EA

- Recommendations on recording:
  - Plant Control Settings and Static Values
  - Plant SCADA Data
  - SER Data
  - DFR Data (at Point of Measurement)
  - DDR Data
  - Inverter fault codes and dynamic recordings

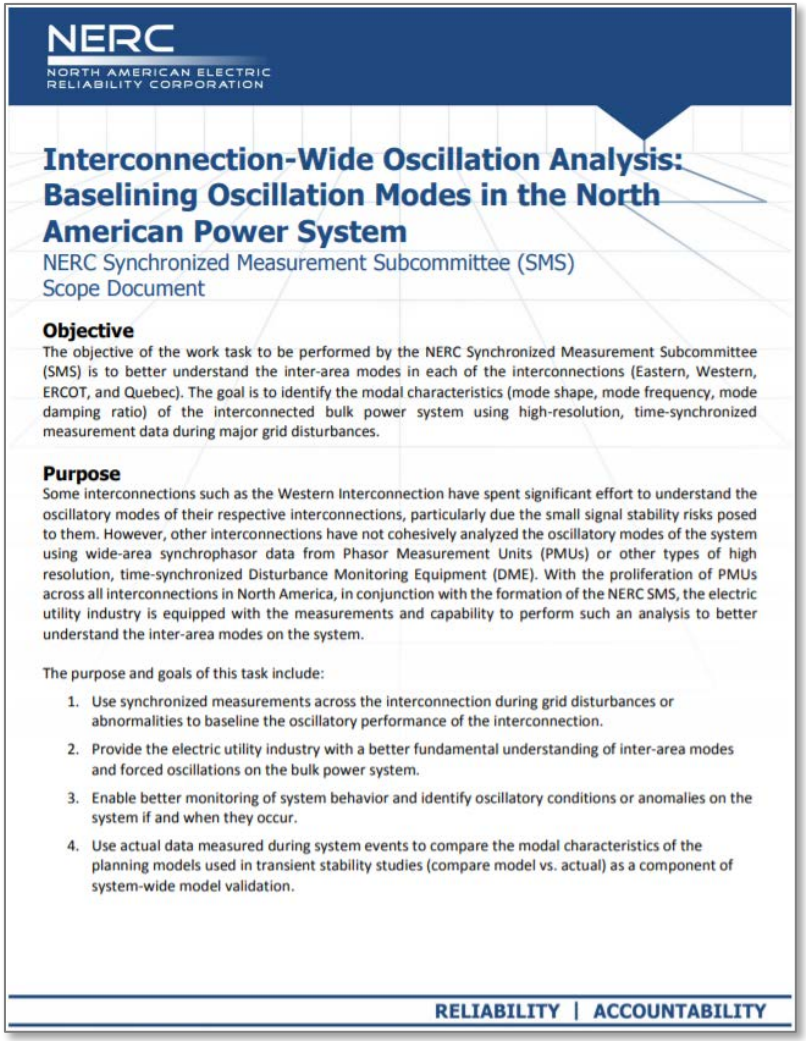
- Many of these can help in the offline oscillation analysis world!

Oscillation Benchmarking





Oscillation Benchmarking



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Interconnection-Wide Oscillation Analysis: Baselining Oscillation Modes in the North American Power System

NERC Synchronized Measurement Subcommittee (SMS)
Scope Document

Objective

The objective of the work task to be performed by the NERC Synchronized Measurement Subcommittee (SMS) is to better understand the inter-area modes in each of the interconnections (Eastern, Western, ERCOT, and Quebec). The goal is to identify the modal characteristics (mode shape, mode frequency, mode damping ratio) of the interconnected bulk power system using high-resolution, time-synchronized measurement data during major grid disturbances.

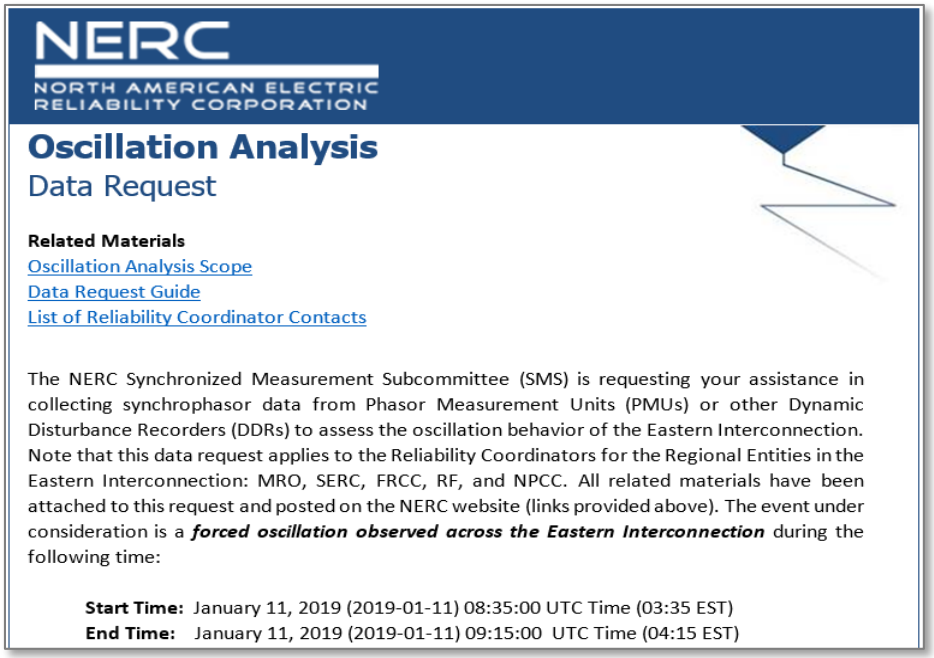
Purpose

Some interconnections such as the Western Interconnection have spent significant effort to understand the oscillatory modes of their respective interconnections, particularly due the small signal stability risks posed to them. However, other interconnections have not cohesively analyzed the oscillatory modes of the system using wide-area synchrophasor data from Phasor Measurement Units (PMUs) or other types of high resolution, time-synchronized Disturbance Monitoring Equipment (DME). With the proliferation of PMUs across all interconnections in North America, in conjunction with the formation of the NERC SMS, the electric utility industry is equipped with the measurements and capability to perform such an analysis to better understand the inter-area modes on the system.

The purpose and goals of this task include:

1. Use synchronized measurements across the interconnection during grid disturbances or abnormalities to baseline the oscillatory performance of the interconnection.
2. Provide the electric utility industry with a better fundamental understanding of inter-area modes and forced oscillations on the bulk power system.
3. Enable better monitoring of system behavior and identify oscillatory conditions or anomalies on the system if and when they occur.
4. Use actual data measured during system events to compare the modal characteristics of the planning models used in transient stability studies (compare model vs. actual) as a component of system-wide model validation.

RELIABILITY | ACCOUNTABILITY



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Oscillation Analysis

Data Request

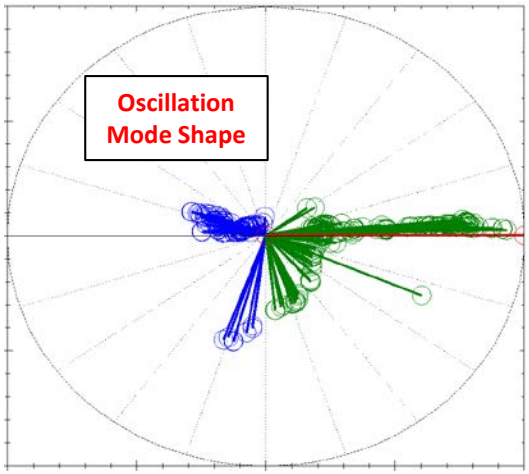
Related Materials

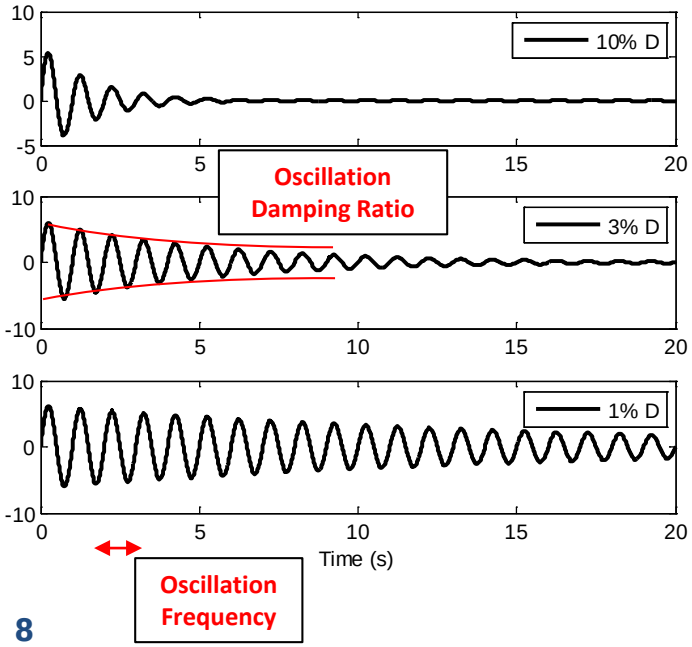
Oscillation Analysis Scope
Data Request Guide
List of Reliability Coordinator Contacts

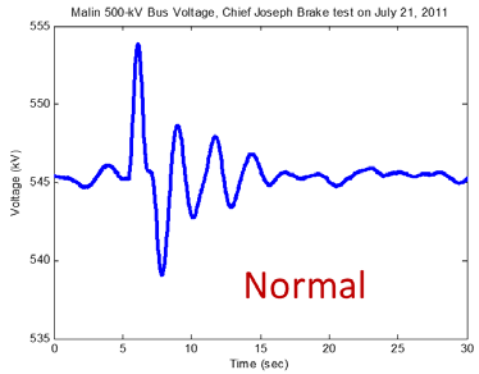
The NERC Synchronized Measurement Subcommittee (SMS) is requesting your assistance in collecting synchrophasor data from Phasor Measurement Units (PMUs) or other Dynamic Disturbance Recorders (DDRs) to assess the oscillation behavior of the Eastern Interconnection. Note that this data request applies to the Reliability Coordinators for the Regional Entities in the Eastern Interconnection: MRO, SERC, FRCC, RF, and NPCC. All related materials have been attached to this request and posted on the NERC website (links provided above). The event under consideration is a ***forced oscillation observed across the Eastern Interconnection*** during the following time:

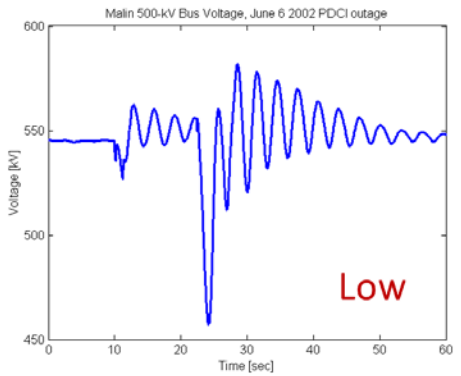
Start Time: January 11, 2019 (2019-01-11) 08:35:00 UTC Time (03:35 EST)
End Time: January 11, 2019 (2019-01-11) 09:15:00 UTC Time (04:15 EST)

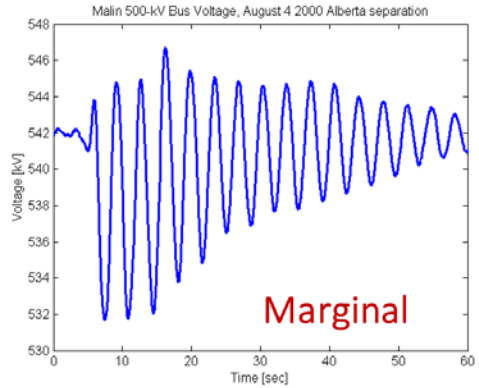
Oscillation Fundamentals

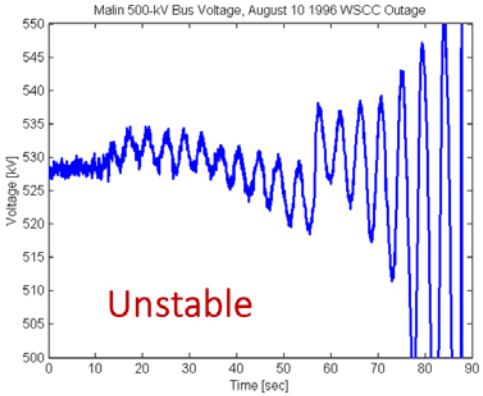










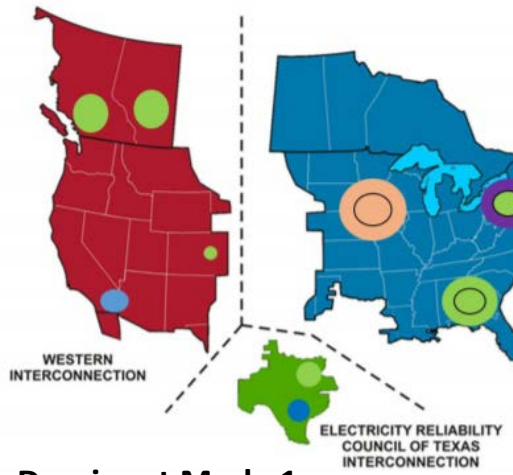


Source: Montana Tech

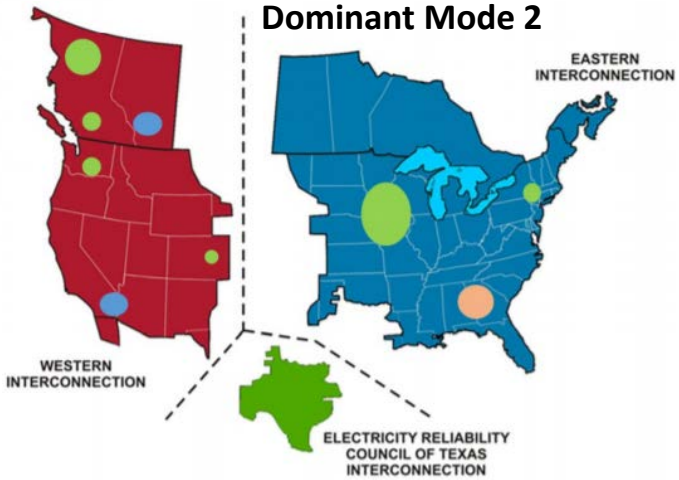
Oscillation Analysis Events

Table I.1: Analysis Reporting Algorithm and Data Source per Event			
Interconnection	**Event Number**	**Chosen Algorithm**	**Chosen Data Source (All relative)**
Eastern	Event 1: 2016-02-01	ERA	Bus Frequencies
	Event 2: 2016-04-15	Matrix Pencil	First Derivative of Voltage Phase Angle
	Event 3: 2016-06-17	FSSI/FFDD	Bus Frequencies
	Event 4: 2016-11-27	FSSI/FFDD	Bus Frequencies
	Event 5: 2017-01-12	HTLS	Bus Voltage Phase Angle
	Event 6: 2017-02-14	Matrix Pencil	Bus Voltage Phase Angle
	Event 7: 2017-03-16	HTLS	Bus Frequencies
Texas	Event 1: 2016-01-27	ERA	Bus Voltage Phase Angle
	Event 2: 2016-04-18	Prony	Bus Voltage Phase Angle
	Event 3: 2016-07-10	HTLS	Bus Voltage Phase Angle
	Event 4: 2016-10-23	HTLS	Bus Voltage Phase Angle
	Event 5: 2017-03-10	ERA	Bus Voltage Phase Angle
Western	Event 1: 2016-01-21	HTLS	Bus Frequencies
	Event 2: 2016-01-27	HTLS	Bus Frequencies
	Event 3: 2016-09-08	HTLS	Bus Frequencies
	Event 4: 2016-09-21	Prony	First Derivative of Voltage Phase Angle
	Event 5: 2017-01-20	HTLS	Bus Frequencies
	Event 6: 2017-03-09	HTLS	Bus Frequencies
	Event 7: 2017-05-10	HTLS	Bus Frequencies

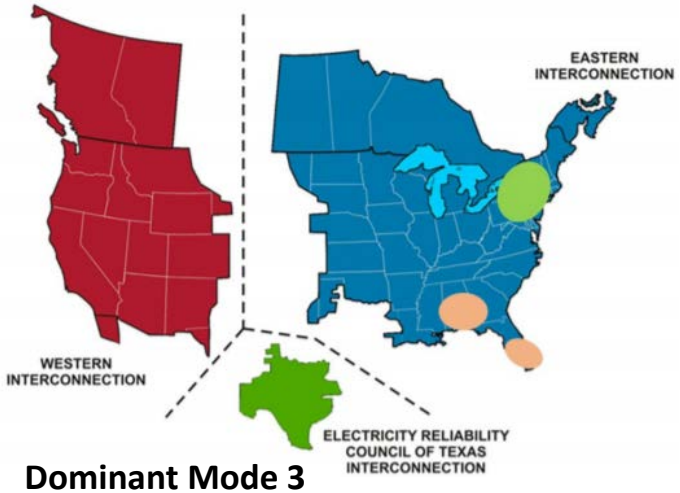
Overview of System Modes



Dominant Mode 1



Dominant Mode 2



Dominant Mode 3

Interconnection	Mode Name	Mode Frequency Range (Hz)	Mode Average Damping Ratio (%)
Eastern	NE–S	0.16–0.22	9.70
	NW–S	0.29–0.32	16.45
	NE–NW–S	0.23–0.24	12.80
Texas	N–SE	0.62–0.73	9.26
Western	NS Mode A	0.37–0.42	12.71
	NS Mode B	0.24–0.27	13.525

Oscillation Benchmarking

Table 2.2 Dominant Mode Comparison					
	Dominant Mode 1 Simulated	Dominant Mode 2 Simulated	Dominant Mode 3 Simulated	Dominant Mode 1 Actual	Dominant Mode 2 Actual
Frequency (Hz)	0.32	0.71	0.53	0.32	0.17
Damping Ratio (%)	17.8	6.4	6.7	20	13
Relative Energy (%)	44	37	12	79	16

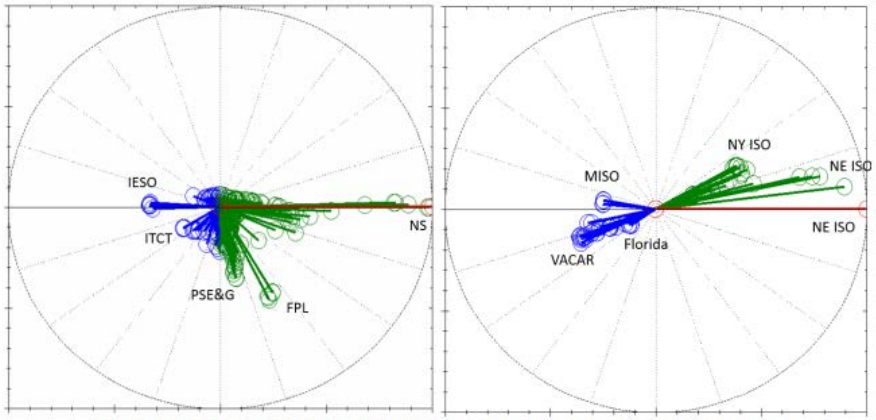


Figure 2.2 Simulated (left) versus Physical (right) Dominant Mode Shape 1

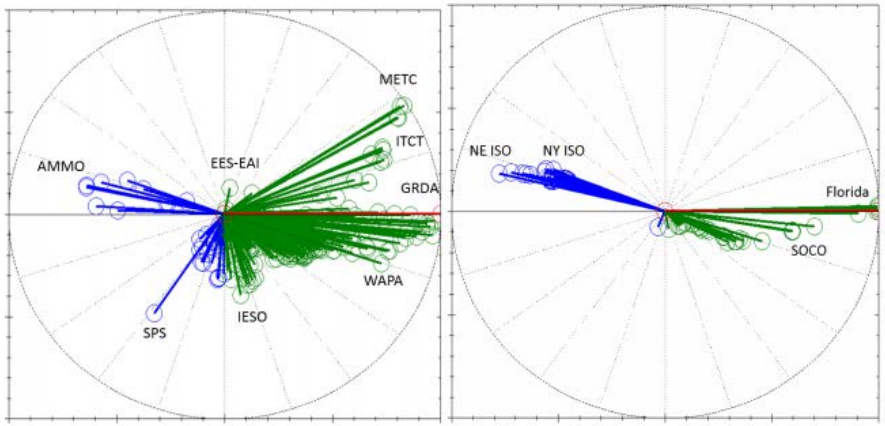
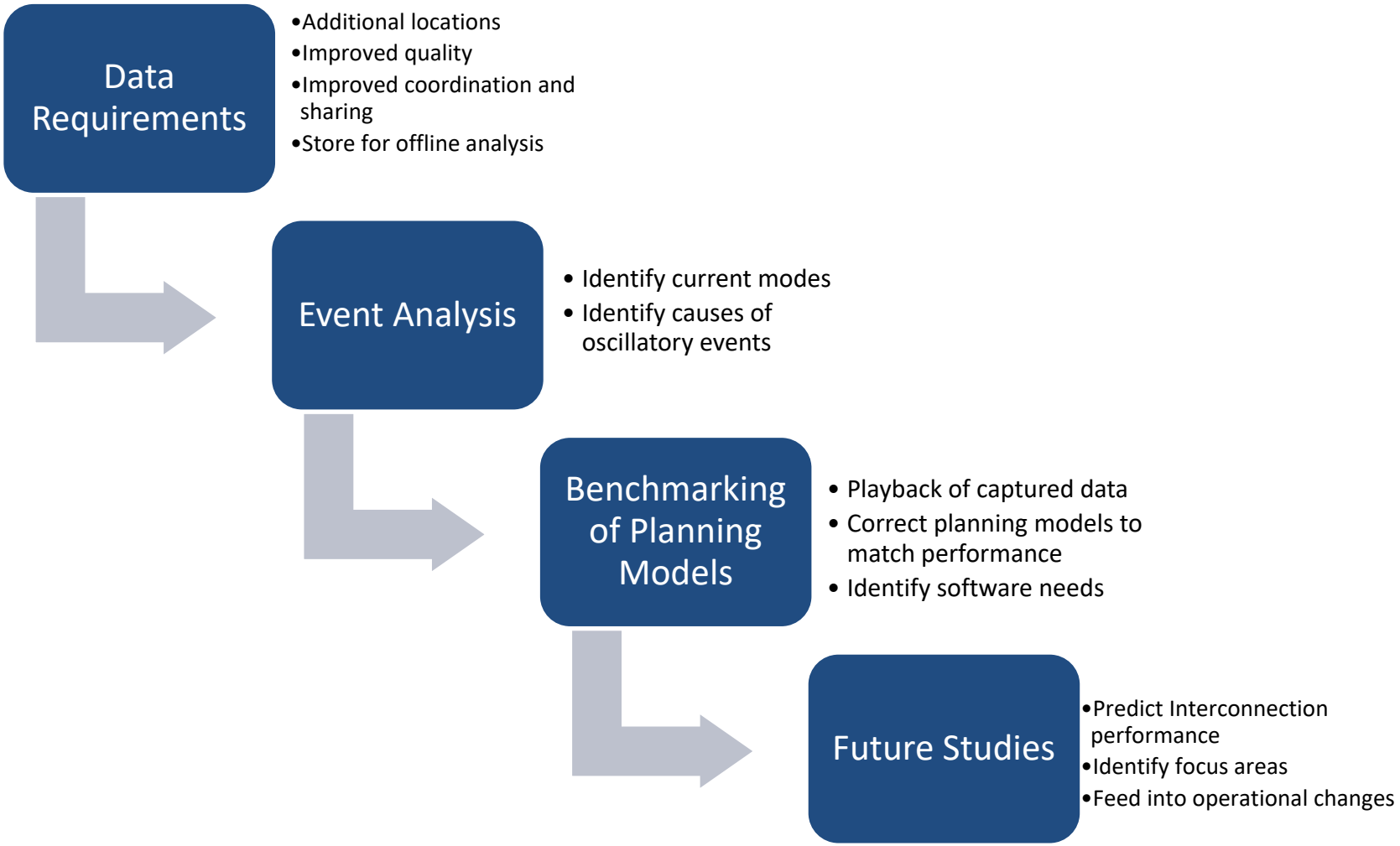


Figure 2.3 Simulated (left) versus Physical (right) Dominant Mode Shape 2

Planning Studies on Changing Oscillations



Planning Studies on Changing Oscillations

Primary:

- Continued detailed oscillation studies *(TP, PC, RC)*
- Standardized data formats *(Industry)*
- System operator training and support *(RC, TOP)*

Secondary:

- Simulation software improvements – oscillation benchmarking (*Vendors*)
- Improved visibility of inter-area oscillations *(TO, PC, RC)*

Interconnection	Recommendation
WI	• Improve understanding of east–west modes (Montana and Colorado participation)
TI	• Increase PMU coverage from northwestern region
EI	• Perform studies to better understand widespread system modes (near 0.25 Hz) • Track the 0.78 Hz forced oscillation source; monitor mode shapes around 0.67 to 0.8 Hz • Understand why these shapes do not extend to New York/Canada or Florida regions

Questions and Answers