DOE Transmission Reliability R&D Program

Eastern Interconnection Situational Awareness Monitoring System (ESAMS) Demonstration Project

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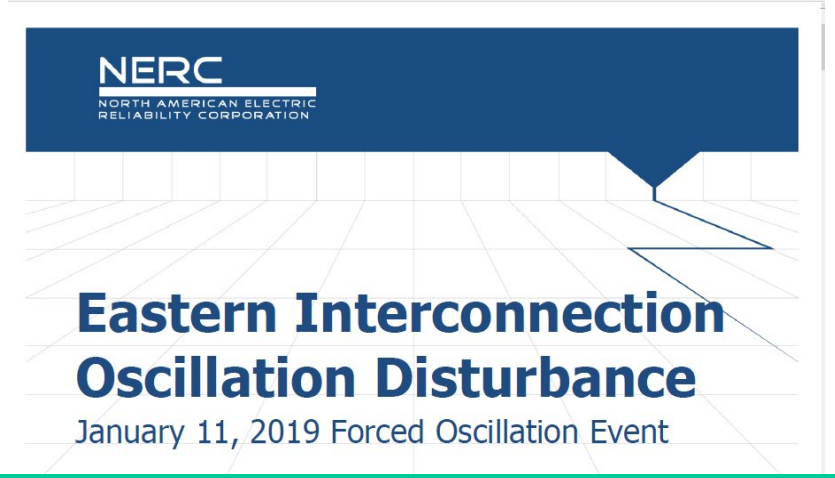
Motivation – January 11, 2019

- Oscillations can affect the behavior of the entire interconnection
- Yet, while operators have *excellent visibility within their footprints…. …. improving visibility outside their footprints is always desirable*



"RCs should improve communication with neighboring RCs in the event of widespread oscillation disturbances on the BPS"

"RCs should consider jointly developing interconnection-wide oscillation detection and source location applications using interconnection-wide PMU and SCADA data."

Project Objectives

Demonstrate an interconnection-wide, high-level, synchrophasor-based monitoring system for the Eastern Interconnection

- ***Provide situational awareness*** *for grid events that can be seen across the Eastern Interconnection – e.g., forced oscillations*
- ***Enhance communications among Reliability Coordinators*** *by providing real-time notifications on the RC footprint that contains the source of a forced oscillation*
- ***Establish a baseline*** *of routine and unusual system behaviors that can only be seen using multiple synchrophasors integrated across the Interconnection*

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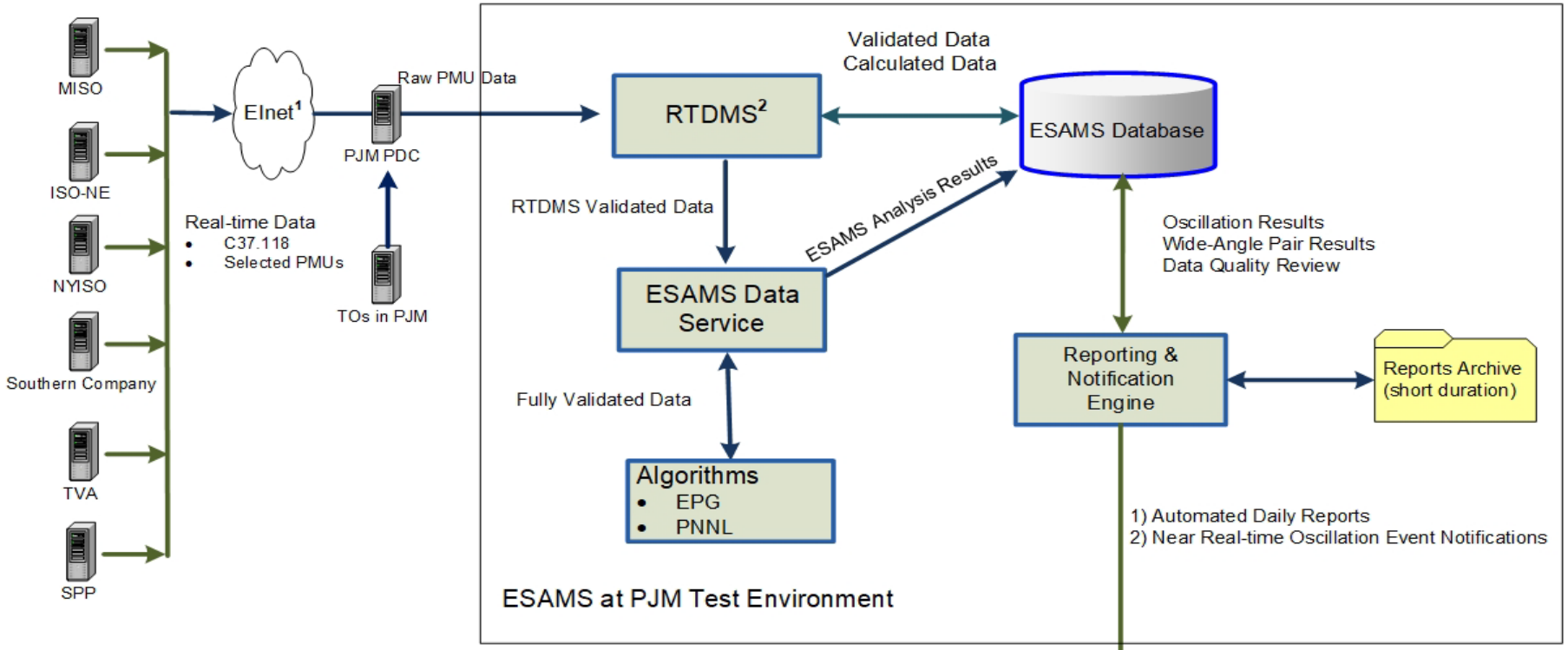
System Architecture for the Prototype System

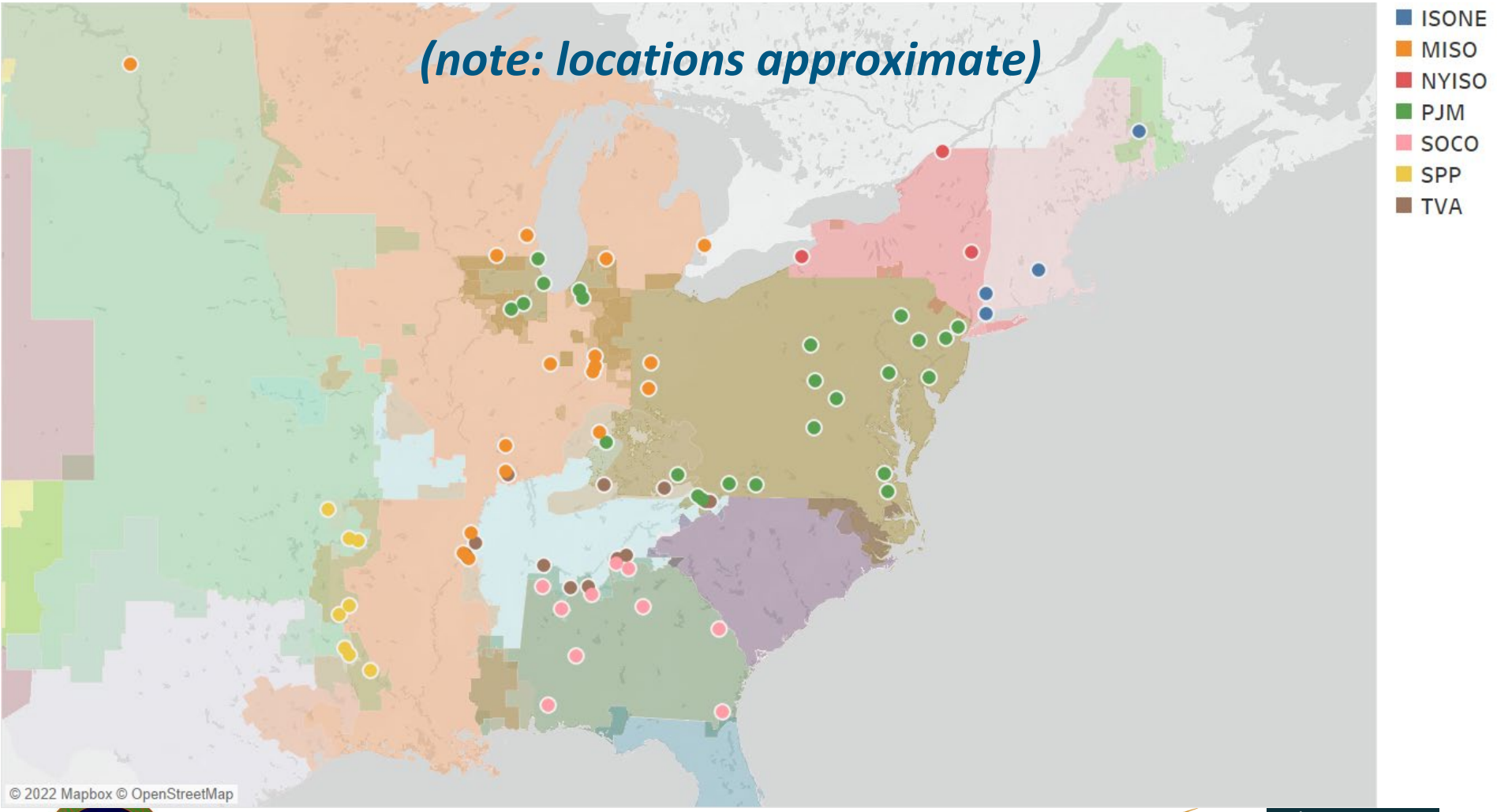


Eastern Interconnection Situational Awareness Monitoring System (ESAMS) System Architecture

[1]EInet – Eastern Interconnection Data Sharing Network
[2]RTDMS – Real-Time Dynamics Monitoring System

MISO, ISO-NE, NYISO,
PJM, Southern, TVA, SPP

PMU Signals Currently Streaming into ESAMS



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ESAMS Applications – Daily Summary Report

Focus of today's Presentation

Summary (Eastern Standard Time, 24-Hour Format)

Event Type	Event Time (EST)	Additional Information
Interconnection Oscillatory Behavior & Phenomenon		
Forced Oscillation Detection & Source Location	09:16-10:04 *Time for event with highest energy*	**1 forced oscillation event(s) detected** Key info for event with highest energy: • Signal: [redacted] • Type: Real Power • Frequency: 1.175 Hz • Value: 8.042 MW
Dominant Natural Oscillation Baselining		Daily Report on Natural Oscillations
Ringdown Detection	18:59-18:59 *Time for event with the earliest event time*	**1 ringdown event detected** List of angle pair(s) for event with the earliest time: [redacted]
Wide Area Phase Angles		
Rapid Step Changes	05:09 *Time for event with the most angle pairs participating*	**3 events with rapid step changes detected** Key info for event with the most angle pairs participating: • Number of Angle Pairs participating: 3 • Most sensitive angle pair during the event: [redacted]
Very Large Angles Compared to Recent Observations	00:00-00:01 *Time for event with the longest time under stress*	**2 events with large angles detected** Angle Pair with the longest event time: • Angle Pair: [redacted]
Atypical Combinations of Rapid Step Changes and Large Angles	00:03 *Time for event with the most angle pairs participating*	**5 Atypical Combinations detected** List of angle pair(s) contributed most to the event with the most angle pairs participating: [redacted]
PMU Data Quality		Daily Report on PMU Data Quality

On December 8, 2021, ESAMS detected a forced oscillation that lasted 36 minutes

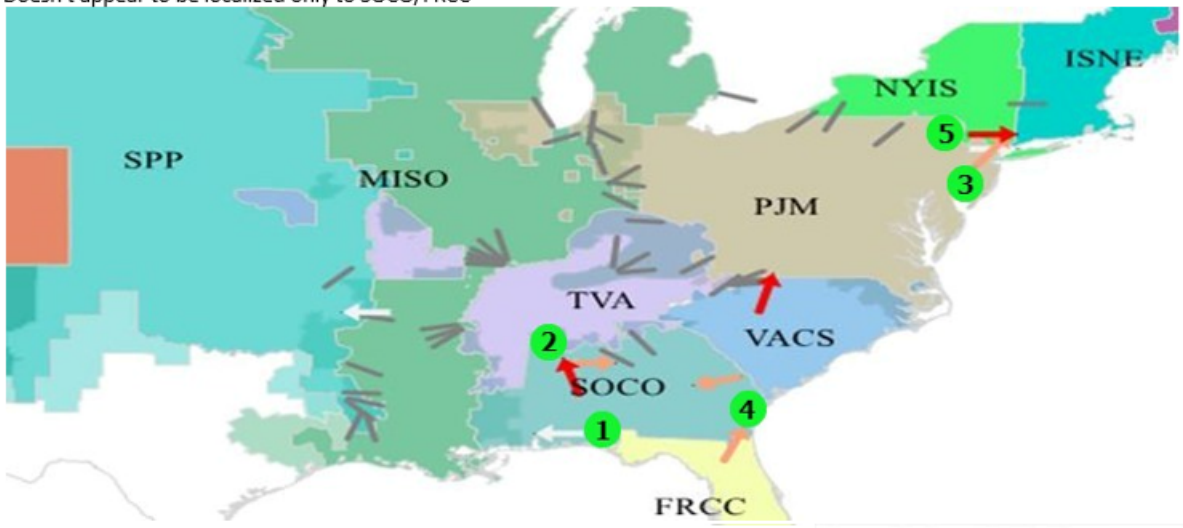
ESAMS identified SOCO/FRCC as the likely source

Following additional internal investigation, SOCO reported peak-to-peak was 85 MW

The oscillation was observable across the Eastern Interconnect: 17 MW peak-to-peak at ISNE/NYIS interface

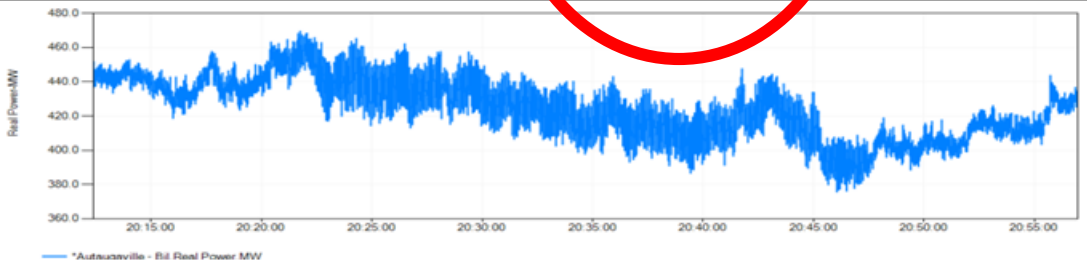
Forced Oscillation observed for 12/08/2021

Forced Oscillation event was detected by signa[redacted], 12/08/2021 20:11 ET - 12/08/2021 20:47 ET,
RC Region with Highest net oscillation energy export: SOCO/FRCC **Confidence Level:** Low
Doesn't appear to be localized only to SOCO/FRCC



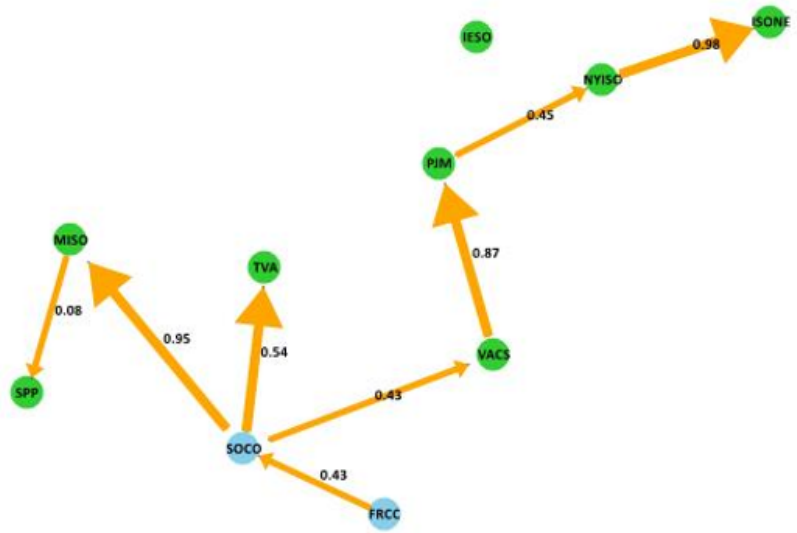
Time (EST): 20:11: - 20:[redacted]7; Frequency: 0.17 Hz; Oscillation Type: Inter-area Oscillations

Rank	Oscillation Detected at	Peak to Peak Amplitude	Oscillation Band RMS Energy
1	[redacted]	24.6 MW	8.7 MW
2	[redacted]	18.5 MW	6.5 MW
3	[redacted]	16.8 MW	5.9 MW
4	[redacted]	12.6 MW	4.4 MW
5	[redacted]	12.1 MW	4.3 MW



ESAMS assigns a confidence score to the information used to support identification of the RC footprint that is the source of a forced oscillation

Energy Flow Diagram:

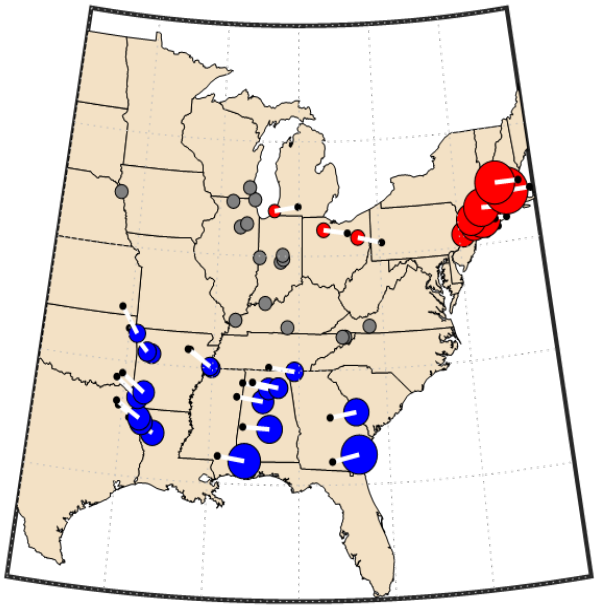


Confidence Level Scoring:

FO Source Identification	Region	Confidence Level	Criteria
REGION WITH HIGHEST POSITIVE NET ENERGY FLOW	SOCO/FRCC	Low (1)	*High:>2* *Medium:2* *Low:< 2*
Supporting Information	**Finding**	**Confidence Scoring Elements**	**Scoring Algorithm**
DOES THIS REGION ALSO HAVE IMPORTS?	Yes	0	*No = +* *Yes = 0*
OTHER REGIONS WITH POSITIVE NET ENERGY FLOW?	3	-	*None = +* *1 = 0* *2 or more = -*
ROBUSTNESS OF FINDING	86%	0	*<80% = +* *>80% And ≤90% = 0* *>90% = -*
SOURCE REGION'S DATA QUALITY/AVAILABILITY	71.4%	+	*>90% = +* *>80% And ≤90% = 0* *<80% = -*
OVERALL MEASURE OF DATA QUALITY/AVAILABILITY	40%	+	

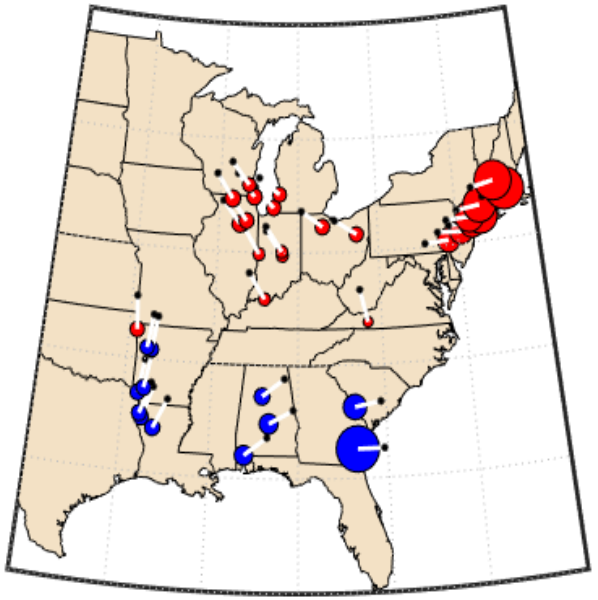
Forced Oscillation Shape

NE-S mode shape



30 mins data window, Nov 2021, source:[1]

FO shape (December 8, 2021)



Data window: 20:15-20:45 ET, Dec 8, 2021

The forced oscillation shape on Dec 8 conforms to the NE-S mode shape

[1] J. Follum, "Continuous tracking of two oscillatory modes in the Eastern Interconnection", presented at SMWG Meeting, Nov 2021. PNNL-SA-168514

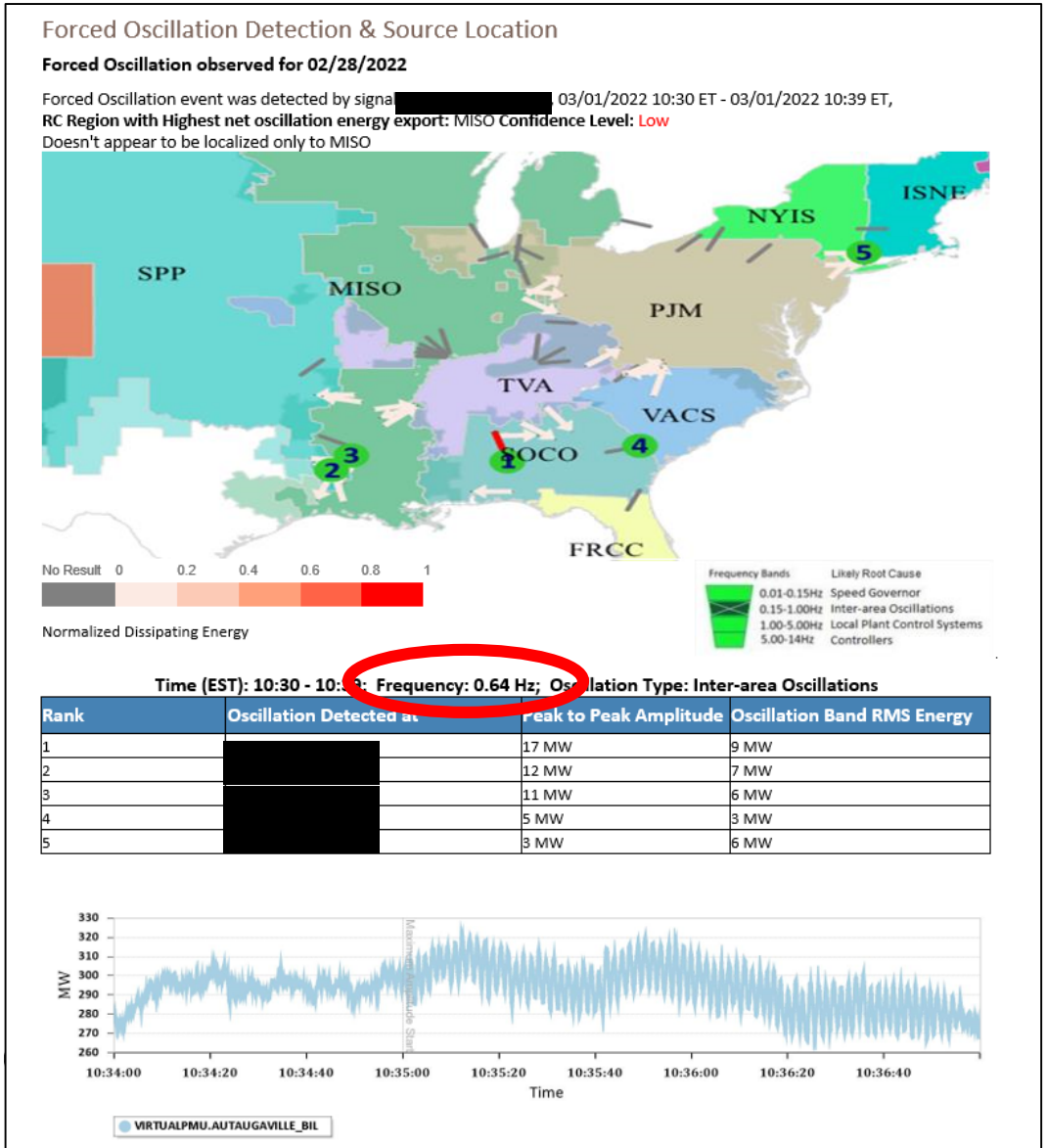
Forced Oscillations Detected by ESAMS (June 2021 – January 2022)

Range of the two previously identified major oscillatory modes for the Eastern Interconnection

Oscillation Frequencies (Hz)	Count of Forced Oscillation Events	Largest Amplitude
0.13	1	6 MW
0.18	5	25 MW
0.2	2	8 MW
0.24	1	7 MW
0.31	1	6 MW
0.34	7	14 MW
0.36	3	12 MW
0.45	1	10 MW
0.57	1	9 MW
0.66	1	7 MW
0.72	26	11 MW
0.83	12	10 MW
1.17	1	8 MW
1.43	4	3.4 MW
1.72	1	4.2 MW
	Total = 67	

Real-time Notifications were Enabled in January 2022

First real-time notification sent at ~10:30 EDT on March 1, 2022 following detection of a forced oscillation with peak-to-peak amplitude greater than 10 MW



Forced Oscillation Detection & Source Location

Forced Oscillation observed for 02/28/2022

Forced Oscillation event was detected by signa[redacted] 03/01/2022 10:30 ET - 03/01/2022 10:39 ET,
RC Region with Highest net oscillation energy export: MISO **Confidence Level:** Low
Doesn't appear to be localized only to MISO

Time (EST): 10:30 - 10:[redacted]; Frequency: 0.64 Hz; Oscillation Type: Inter-area Oscillations

Rank	Oscillation Detected at	Peak to Peak Amplitude	Oscillation Band RMS Energy
1	[redacted]	17 MW	9 MW
2		12 MW	7 MW
3		11 MW	6 MW
4		5 MW	3 MW
5		3 MW	6 MW

ESAMS Industry Partners

PJM *– DEMONSTRATION HOST*– Christopher Callaghan, Hamed Golestani, David Hislop (formerly, Shaun Murphy, Subbarao Eedupuganti, Eric Hsia, and Ryan Nice)

ISO-NE – Frankie Zhang, Slava Maslennikov, Xiaochuan Luo

MISO – Keith Mitchell

NYISO – Emily Fernandez, Shubhrajit Bhattacharajee

Southern Co – Clifton Black, Shih-Min Hsu, James Viikinsalo, Chris Wakefield, Mark Newman, Michael Breuhl, John Pope

SPP – Cody Parker, William Holden, Jennifer Sorrell, Daniel Baker

TVA – Tim Fritch, Gary Kobet, Phillip Crittenden, Jonathan Sides

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Summary of feedback provided by ESAMS Industry Partners

- ***Real-time notification of forced oscillation RC footprint location was successfully demonstrated***
- ***The RCIS may be an appropriate vehicle for distributing real-time forced oscillation notifications***
- ***ESAMS is a needed extension and complement to (not duplication of) our in-house synchrophasor analysis capabilities***
- ***NERC SMWG would like to track oscillation information provided by ESAMS***
- ***The wide-area phase angle section is of interest, but in need of further development***
- ***EIDSN is a means for maintaining these capabilities***

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ESAMS Next Steps

- Project final report in preparation
- Project team will complete SMWG oscillation templates
- Project outreach scheduled
  - NERC SMWG April 28/29
  - NERC RTOS May 3
- EIDSN Advisory Committee will make a decision regarding adoption this Summer/Fall



Thank You

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