




# Regional Localization of Forced Oscillation Sources in the U.S. Eastern Interconnection

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# Motivation

- Recent wide-area oscillation events highlight a reliability threat requiring improved coordination among Reliability Coordinators (RCs)
- The Eastern Interconnection Situational Awareness Monitoring System (ESAMS) was developed to meet this need
- ESAMS provides near real-time notifications of the region containing a forced oscillation's source


“RCs should consider jointly developing interconnection-wide oscillation detection and source location applications...”



## Eastern Interconnection Oscillation Disturbance

January 11, 2019 Forced Oscillation Event  
December 2019

RELIABILITY | RESILIENCE | SECURITY



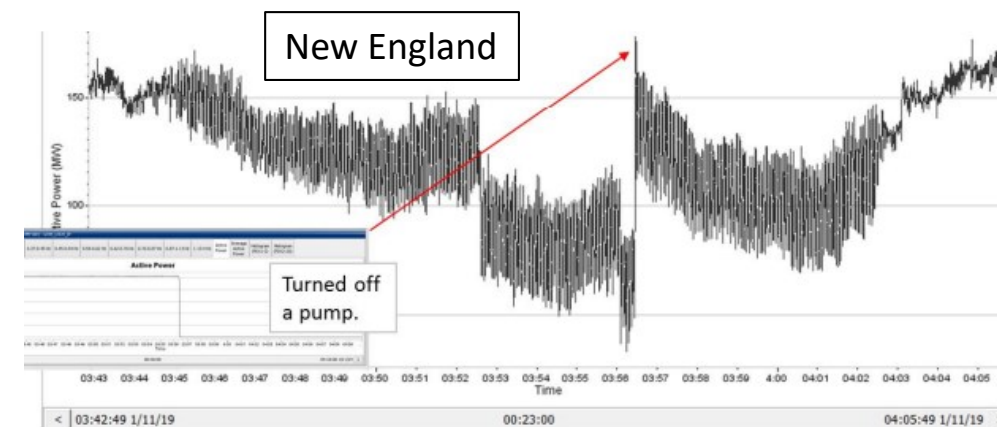
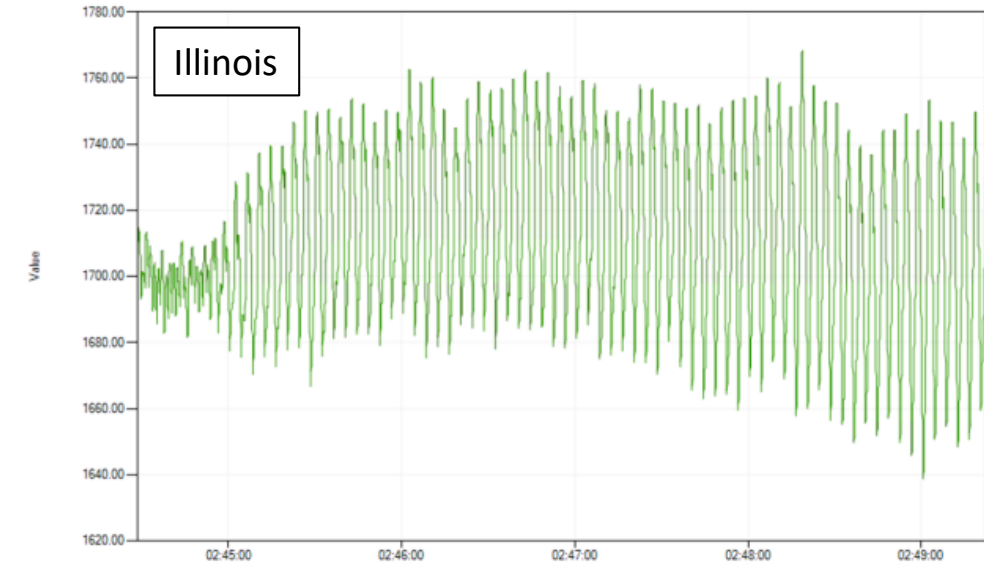
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# Presentation Topics

- Background on Forced Oscillations
- ESAMS Capabilities
  - Detection
  - Regional source localization
  - Confidence assessment
  - Reporting
- Example
- Lessons Learned

# Forced Oscillations

- Forced oscillations are the response of the grid to a periodic disturbance
  - Broken valve on thermal unit
  - Operation of hydro unit in rough zone
  - Wind power plant control
  - HVDC controller
- Under certain circumstances, the oscillation can have widespread impact
- Example: January 11, 2019
  - Steam turbine
  - 200 MW swings at source in Florida
  - Persisted for 18 minutes before plant operator removed unit from service

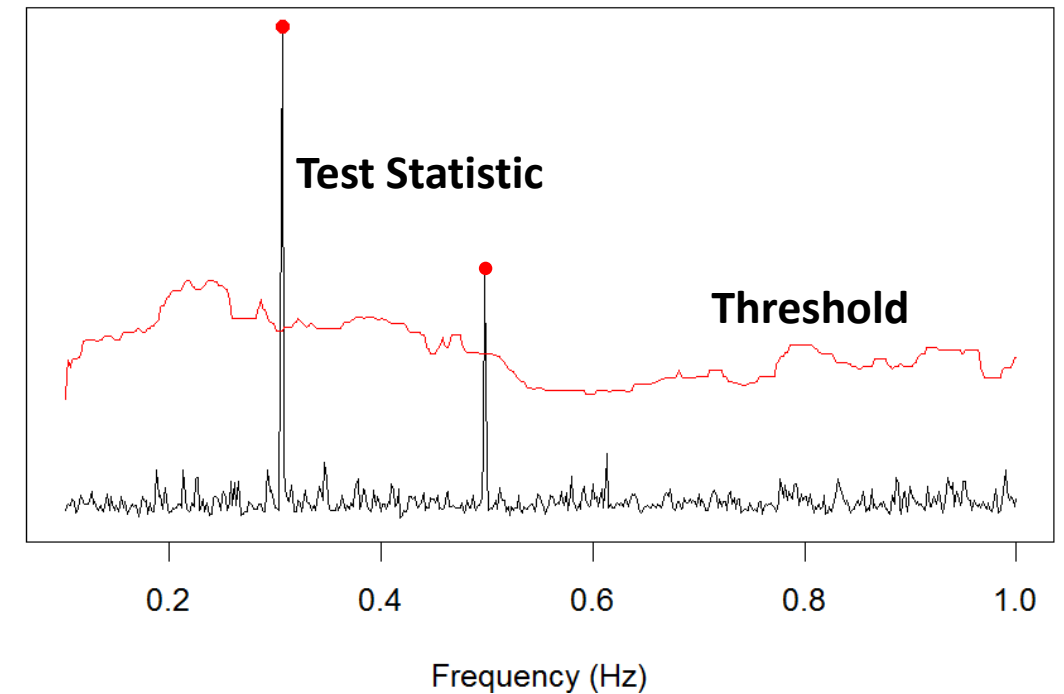


Figures from:  
[https://www.nerc.com/pa/rrm/ea/Documents/January\\_11\\_Oscillation\\_Event\\_Report.pdf](https://www.nerc.com/pa/rrm/ea/Documents/January_11_Oscillation_Event_Report.pdf)

# Oscillation Detection

## Multichannel Periodogram Method

- **Theoretically grounded:** detection threshold is determined by selecting the probability of false alarm
- **No baselining required:** practical for ESAMS with 47 PMUs and no access to historical data
- **Emphasizes wide-area oscillations:** does not duplicate existing ability of RCs to analyze localized oscillations



# Identifying the Oscillation's Source

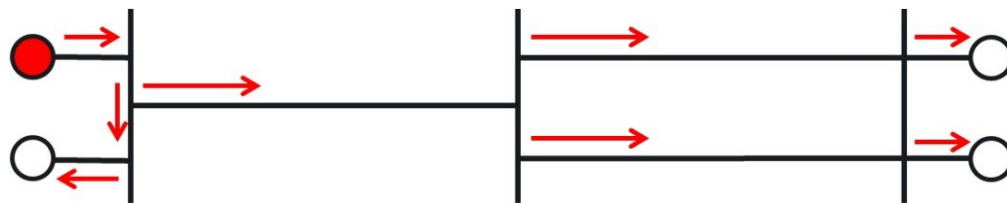
## The dissipating energy flow (DEF) method

- Calculate the oscillation's energy using PMU data

$$W = \int_0^T P_f(t)\Omega_f(t)dt + \int_0^T Q_f(t)U'_f(t)dt$$

*P*: Active power  
*Ω*: Frequency  
*Q*: Reactive power  
*U*: Voltage magnitude

- Trace the flow of energy back to the source

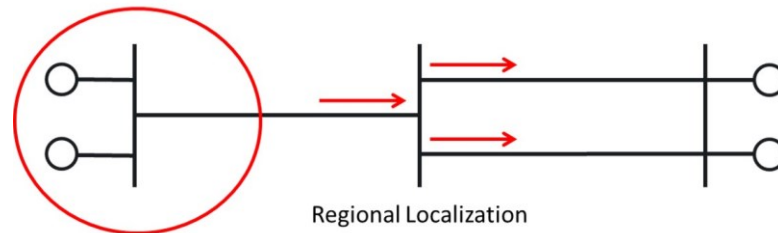


- Excellent tool for system operators, but impractical at interconnection scale

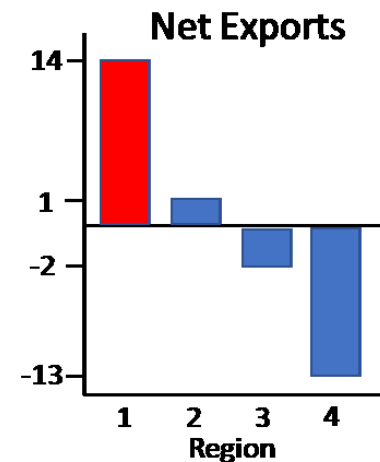
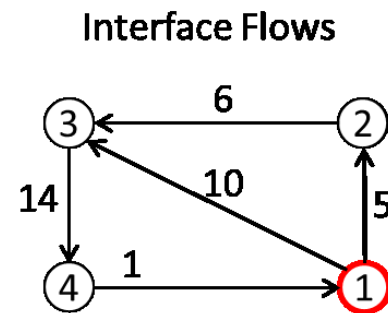
# Identifying the Source Region

## Generalization of the DEF method

- Calculate energy flowing between regions



- The region with the highest net export is identified as the source



# Assigning Confidence

- In practical systems, data quality/availability must be considered
- Though the source location method is robust, poor data availability can hinder performance
- Real-time notifications needed a confidence score

## Data Availability

- System data availability
- Source region data availability

## Network Flow

- Import from other regions
- Number of other regions with net export

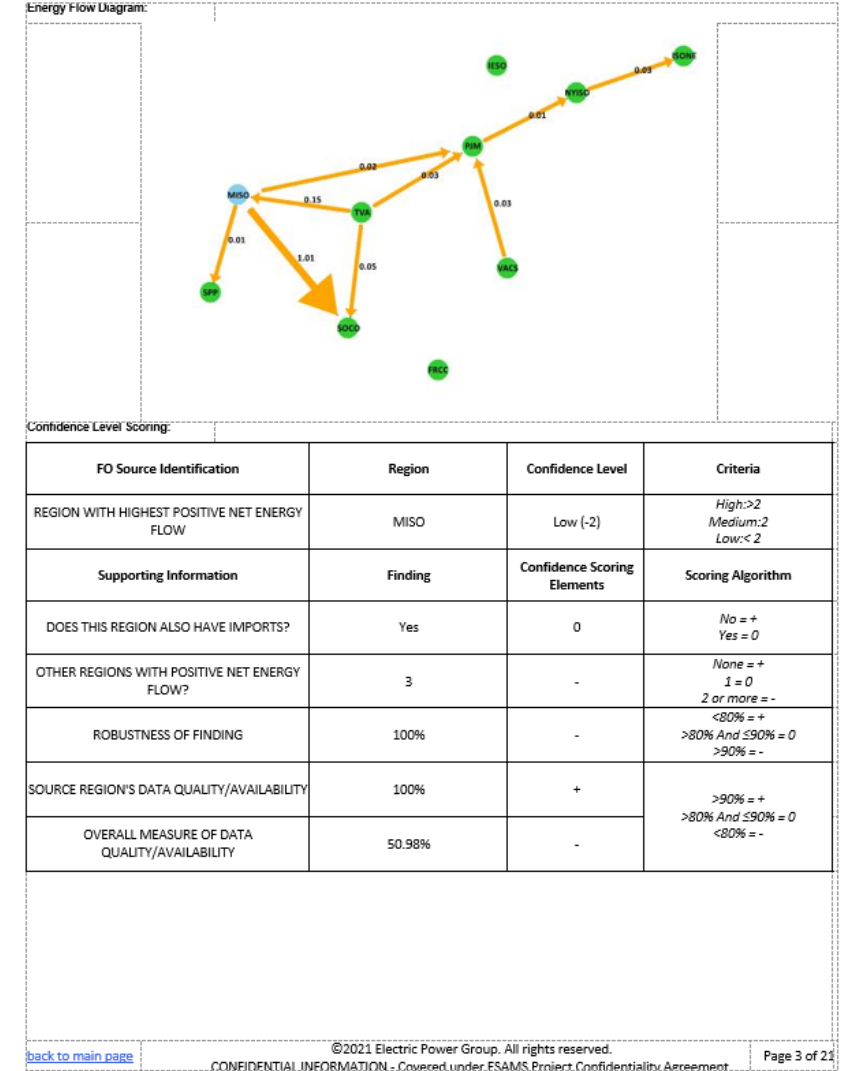
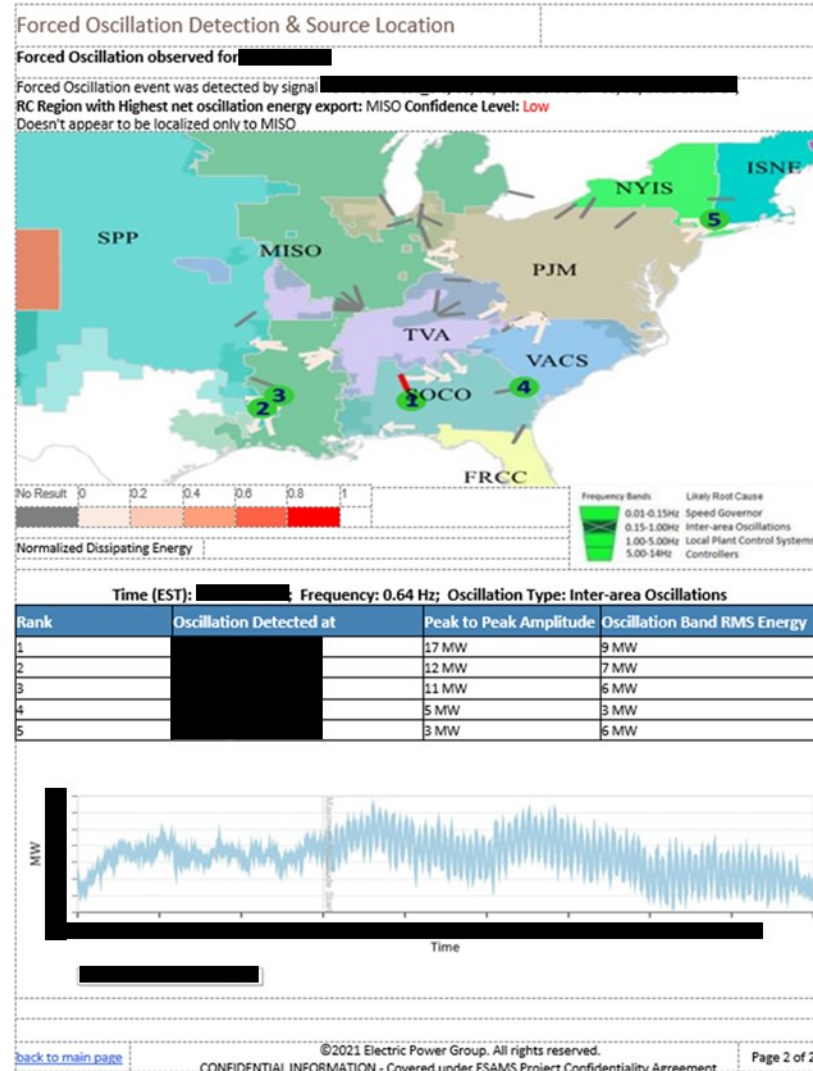
## Robustness

- Number of measurements result is dependent upon

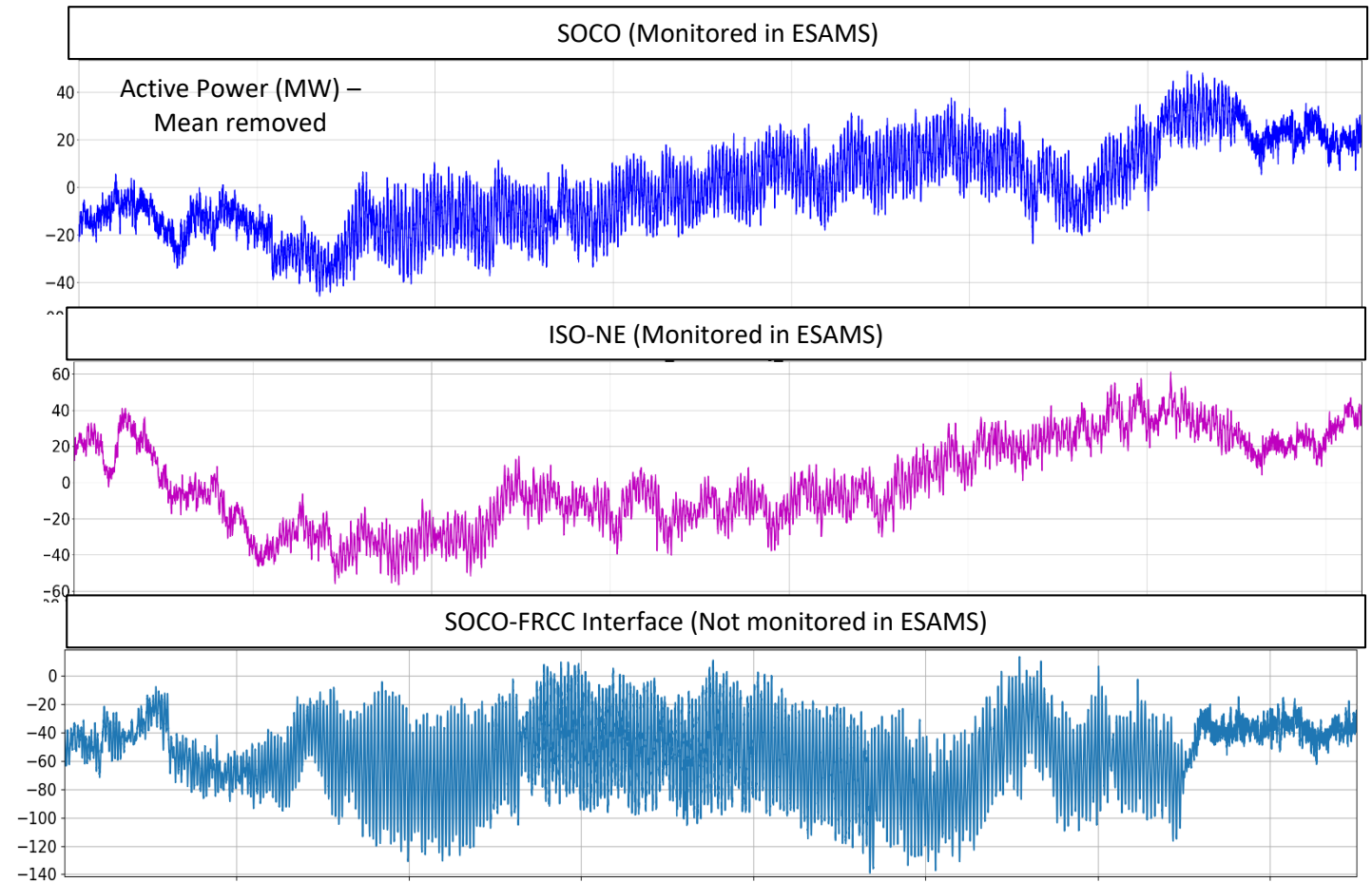
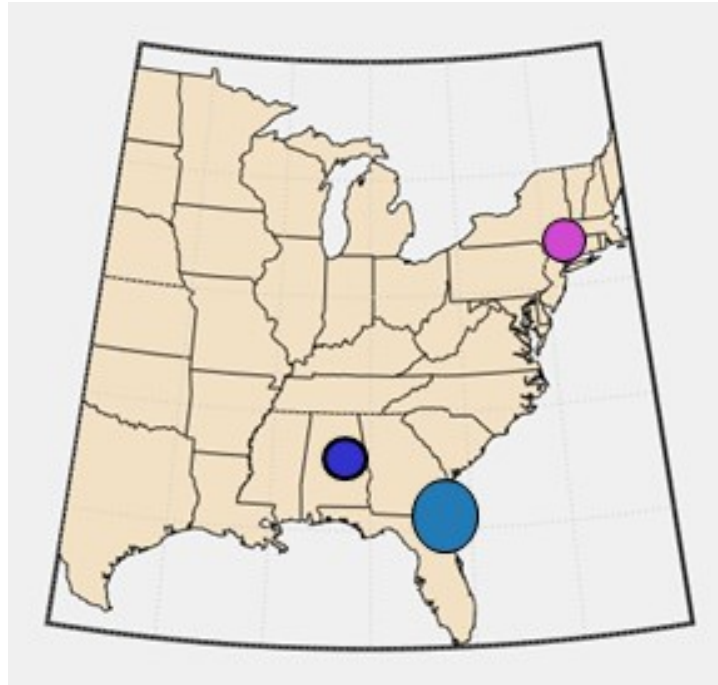


# Reporting

- Daily reports summarized previous day's events
- Real-time notifications for oscillations larger than 10 MW



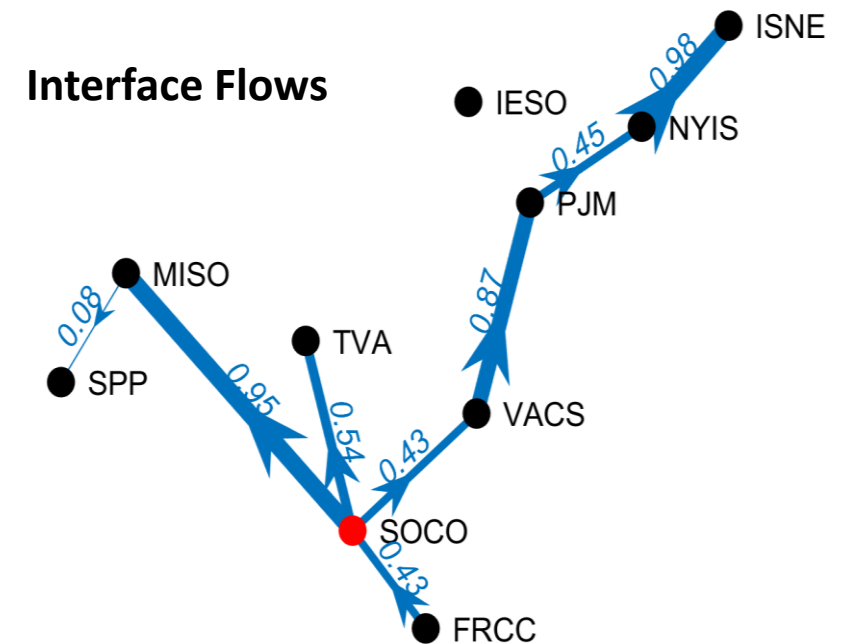
# December 8 Forced Oscillation



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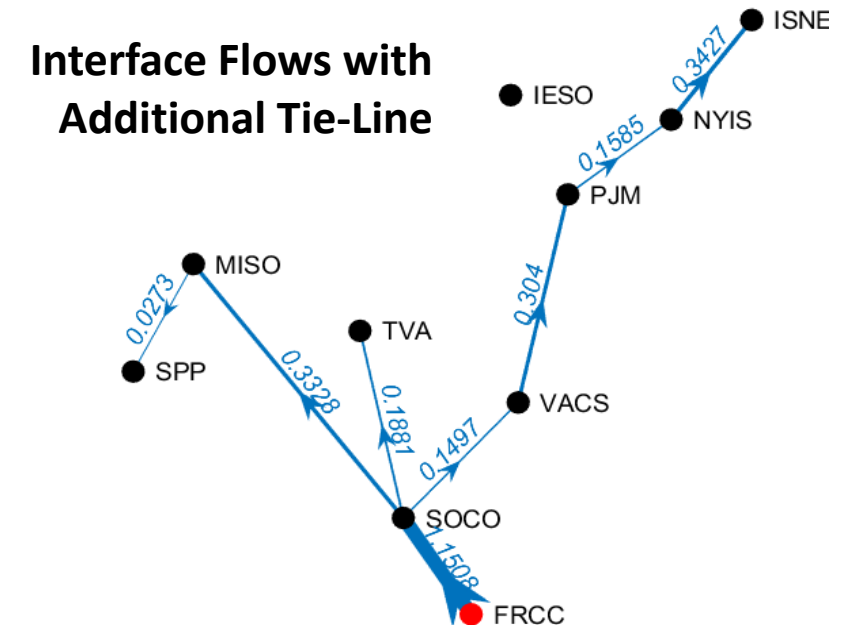
## Initial Results

- Detected at  $\sim 0.17$  Hz
- Present for multiple hours
- Seen across Eastern Interconnection
- Max amplitudes observed :
  - Southern Company (SOCO): 25 MW, 4 MVar
  - New England: 18 MW, 3 MVar
- ESAMS identified SOCO as the source region with low confidence



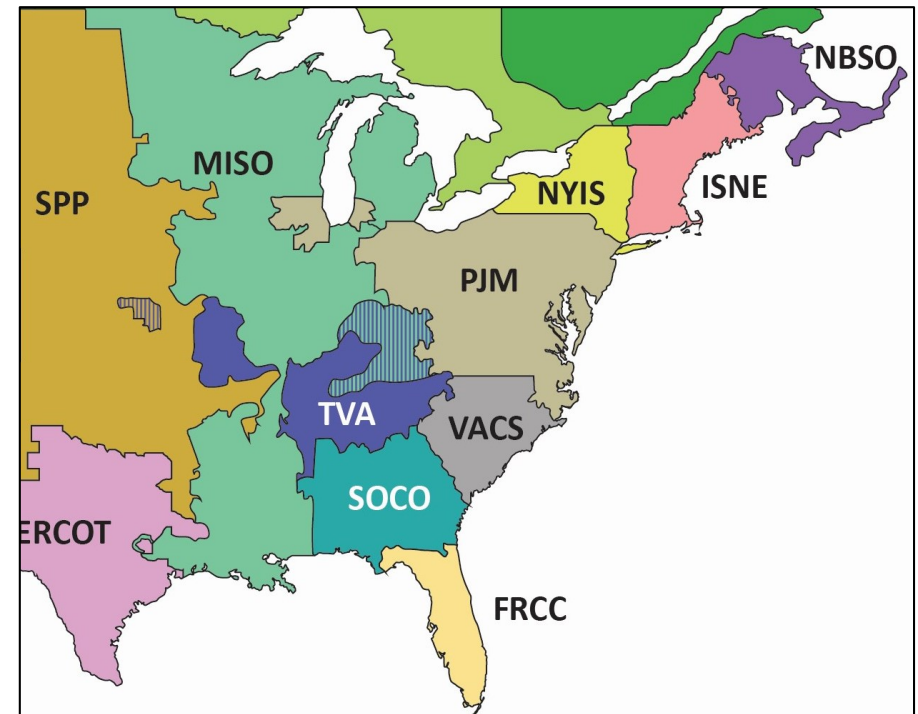
# December 8 Forced Oscillation Follow-Up

- SOCO found that the highest amplitude was  $\sim 85$  MW and 8 MVAR at a 500 kV line **not being monitored in ESAMS.**
- With additional tie-line, analysis indicates the source was in the Florida Reliability Coordinating Council footprint



# Lessons Learned

- Regional localization is possible in the online environment
- Regional boundaries are complex
  - Multiple voltage levels
  - Organizations with disjointed footprints
  - Contiguous footprints with multiple operating areas
- Tie-lines are not monitored as consistently as expected
- Robustness to data quality imperative
- Varying perspectives on notifications (amplitude, duration, observability)





# Thank You

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Thank you to Shuchismita  
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