Oscillation source location and long term dynamic performance baselining study using ISO-NE's synchrophasor data

ISO new england

NASPI Working Group Meeting

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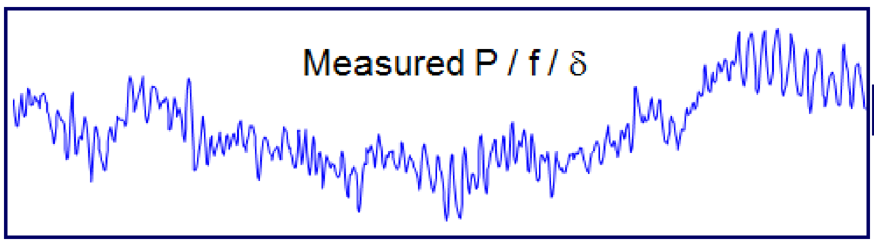
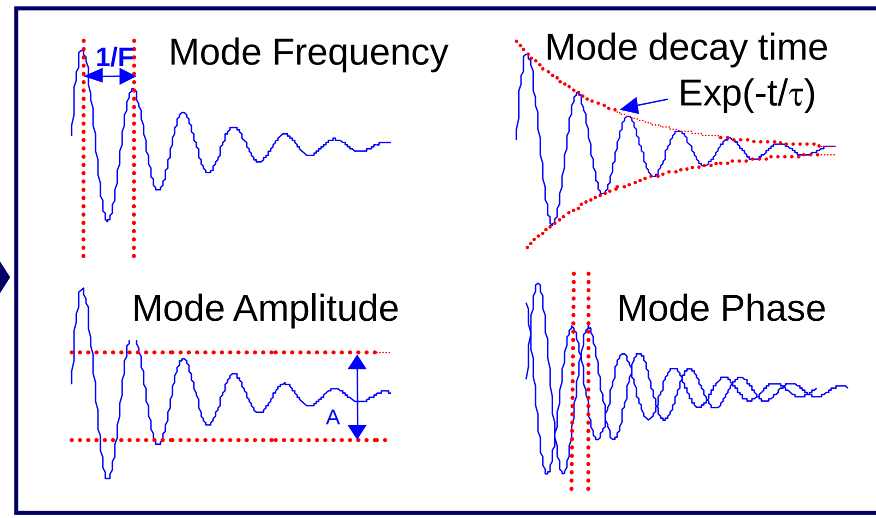
Outline

- Introduction of PhasorPoint oscillation stability monitoring application
- ISO-NE long-term system baselining using PhasorPoint and PhasorAnalytics
- IS-ONE oscillation source identification by PhasorPoint

Oscillation Stability Monitoring (OSM)

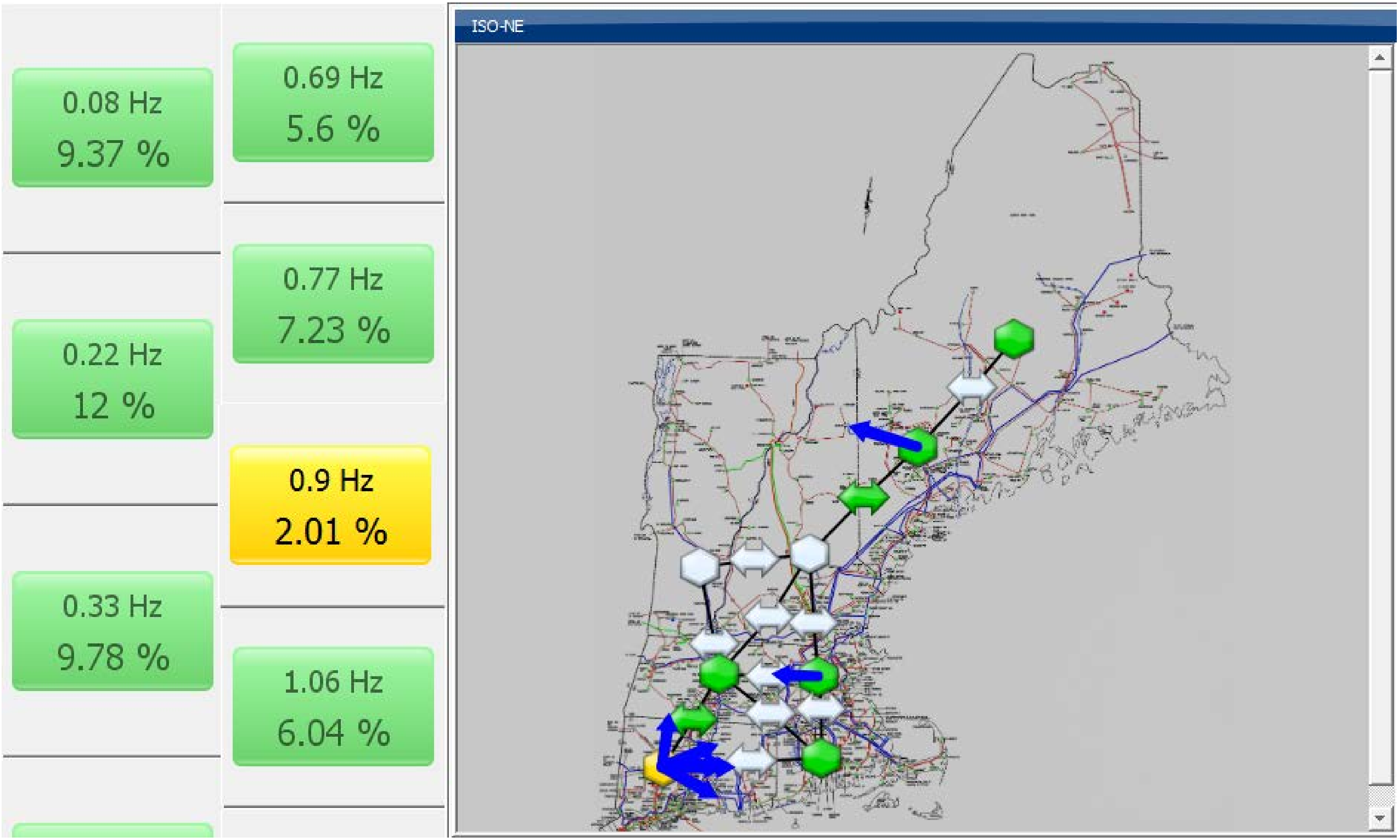
- Extracts frequency, damping, amplitude and phase of the main electromechanical oscillations in the band 0.04 – 4.0 Hz
- Configurable triggering attributes
  - Mode frequency sub-band
  - Mode damping ratio or decaying time
  - Mode amplitude
  - Hysteresis





- Efficiency of OSM depends on settings of triggering attributes

Oscillation Stability Monitoring, cont.



Long-term System Baselining

Long-term oscillation review

- One month PMU data from ISO New England (more than 300 PMU measurements)
- Applied offline oscillation monitoring tool on available and non-redundant measurements

Sub-bands identification

- Histograms (occurrences of modes by oscillation frequency)calculated for frequency and real power measurements
- Oscillation frequency sub-bands detected by studying histograms

Measurements selection

- Finding most observable measurements for each sub-band
- Filter out insensitive measurements for more accurate and pinpointed oscillation detection

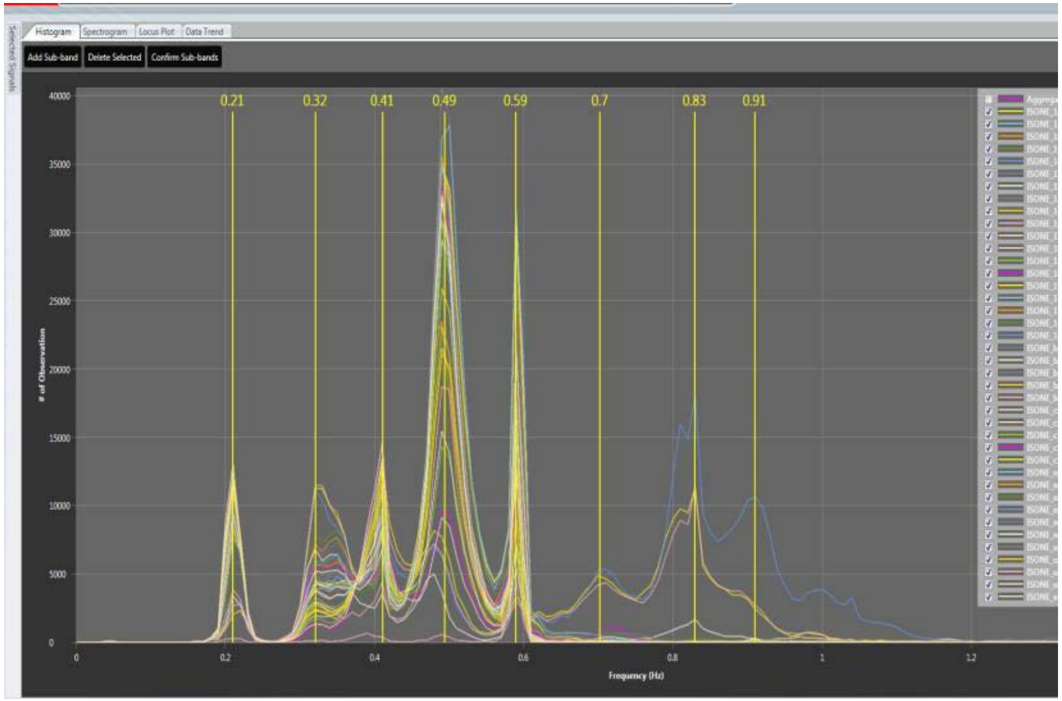
Threshold settings

- Drawing locus plots (damping ratio / oscillation magnitude vs. frequency) for selected measurements
- Configuring alert/alarm settings for PhasorPoint real-time online monitoring stability

Sub-bands Identification

- Finding dominant modes in ISO-New England system
  - Substation frequencies are good candidates
- Determining boundaries between different modes

Filters have been applied to system oscillation modal results to shade out less important PDX results



Measurements Selection

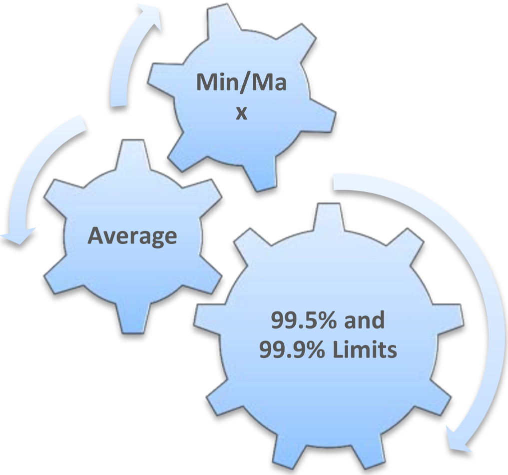
- Only observable locations are suitable for oscillation monitoring.
- Measurements with low observability may affect the accuracy of oscillation results
- Statistics for observability of each dominant modes by each measurement are used for measurement selection.

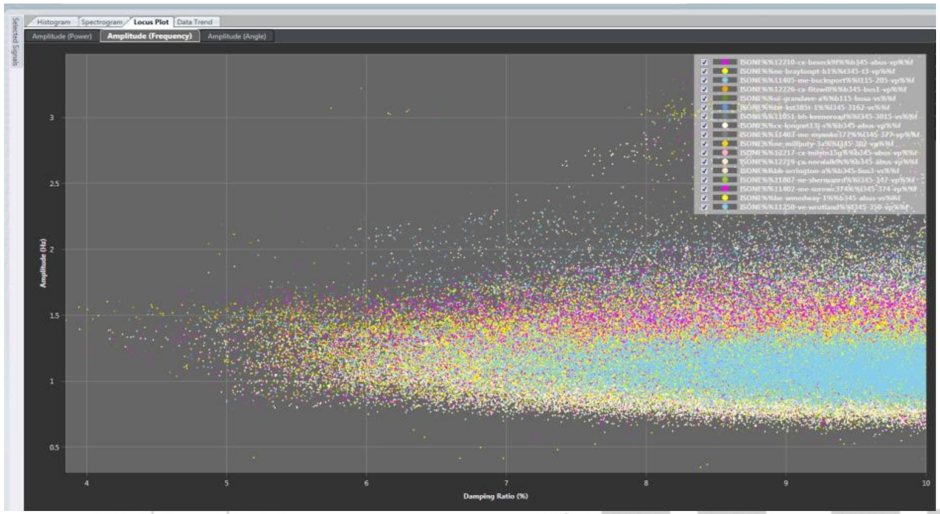
Threshold Settings

- Low damping ratio (smaller than 3%) is considered to be dangerous to system operation
- Too many alerts / alarms can overwhelm system operators
- Dead bands are suggested to avoid false alarming

Threshold Settings

- Two ways to determine alert / alarm thresholds
  - Statistical Results
    - Especially, the 99.5% and 99.9% limits could tell user at where do outliers show up
  - Locus Plot
    - Shows damping ratio vs. magnitude
    - Overview of modal results
    - Highlights outliers immediately

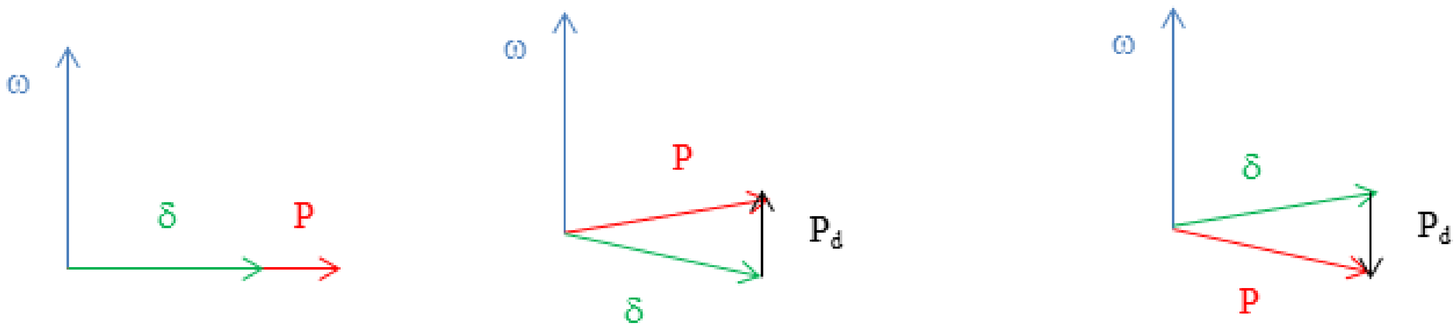




Threshold Setting Results

		SB1 0.04-0.15	SB2 0.15-0.28	SB3 0.28-0.37	SB4 0.37-0.45	SB5 0.45-0.54	SB6 0.54-0.62	SB7 0.62-0.76	SB8 0.76-0.87
Damping Ratio (%)	Alert	2.5	5	4	3	1.5	1.1	2.5	2.5
	Alarm	2	4	3.5	2.5	1	1	2	2
	Dead Band	10	10	10	10	10	10	10	10
Amplitude Frequency (mHz)	Alert	2.5	2.5	3.5	2	3	1.1	5.5	2.5
	Alarm	3	3	4	2.5	4	1.2	6	3
	Dead Band	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Amplitude Active Power (MW)	Alert	7	3.5	6.5	5	1	3.5	4.5	3.5
	Alarm	8	7	7	5.5	1.2	4.5	5	4
	Dead Band	1	1	1	1	1	1	1	1

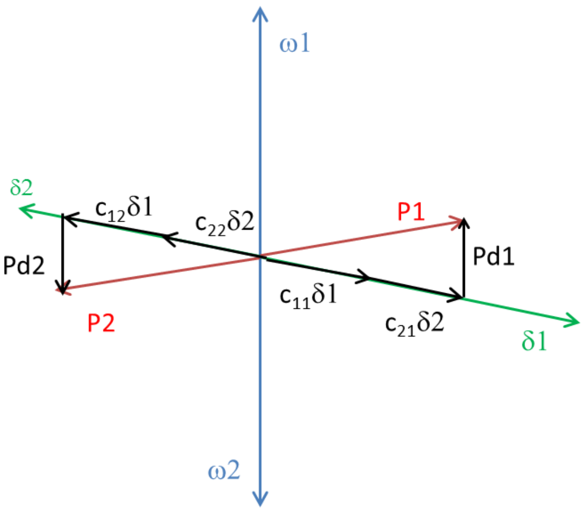
Oscillation Phase Relations for a Single Machine



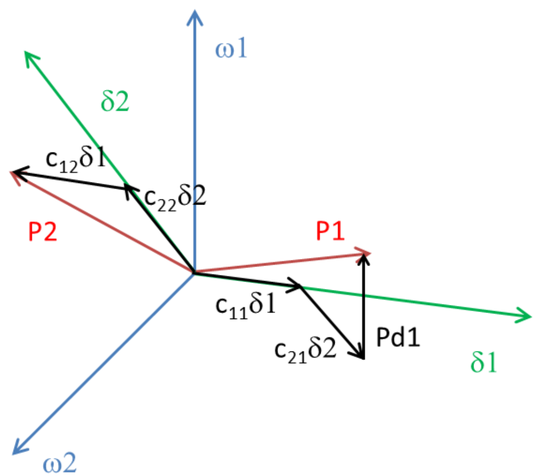
(a) Undamped (b) Positive Damping (c) Negative Damping

- P and δ lag ω by about 90°, determined by damping.
  E.g. damping ratio 20%, angle lags 90°+12° and power lag speed by 90°-12°
- Power (P) in phase with speed (ω) produces positive damping.
- Power out of phase with speed produces negative damping.

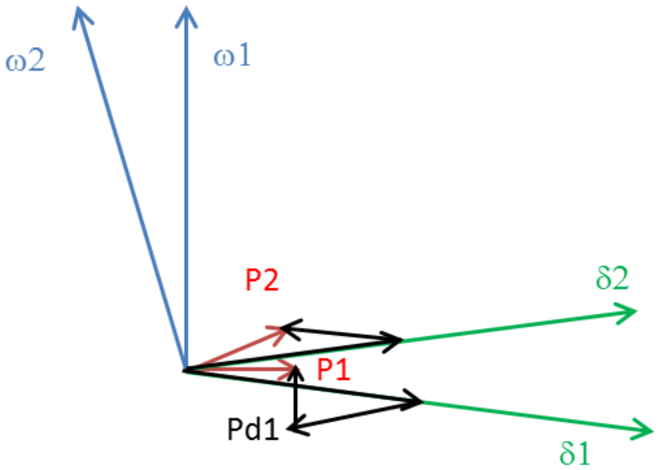
A two machine example



Equal Damping Contributions



More Damping Contribution from Generator 1

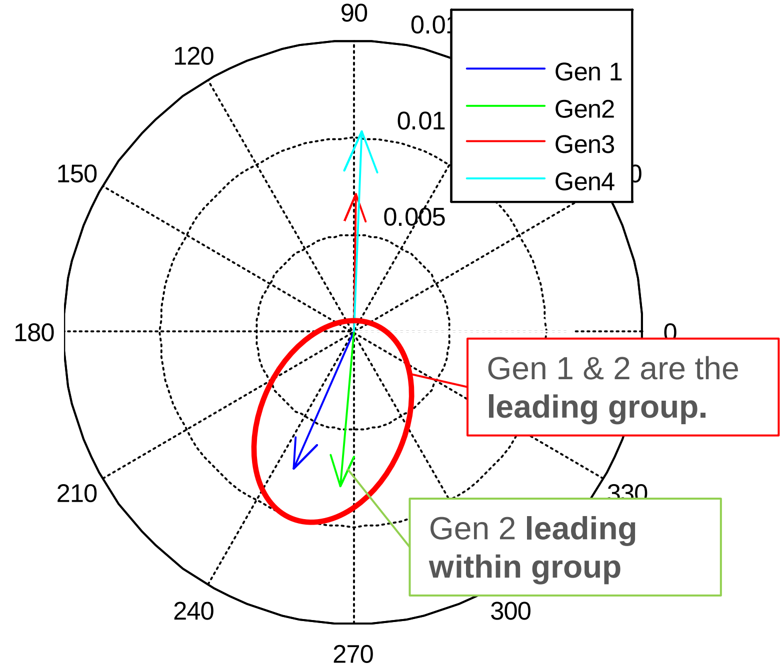


More Damping Contribution from Generator 1

The Lagging generator contributes more damping than the leading generator – Leading generator is “source”

Identifying Sources of Oscillations

- *Leading phase indicates less damping contribution.*
- *The "source" is the location with the lowest damping contribution (possibly negative).*
- *To find the source of an oscillation:*
  1. Divide into opposing groups. The group leading by less than 180° is the group containing the source.
  2. Find the most leading location within the leading group.

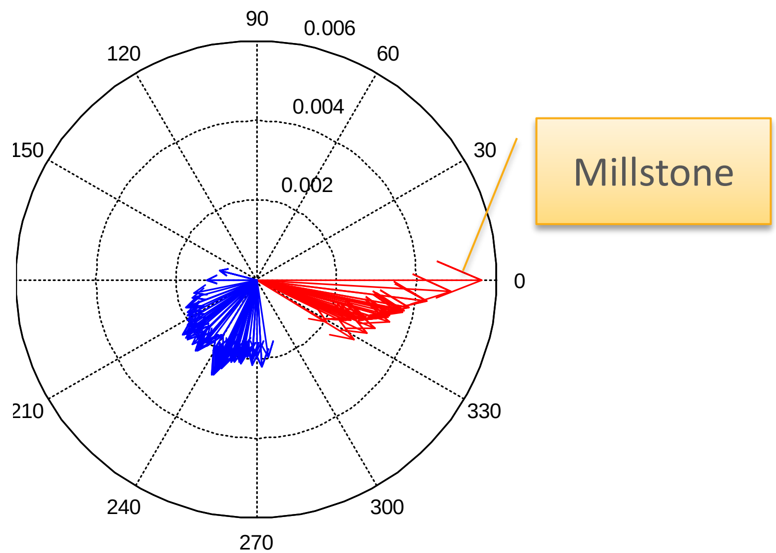


Gen 2 is the Source

Simulation Cases

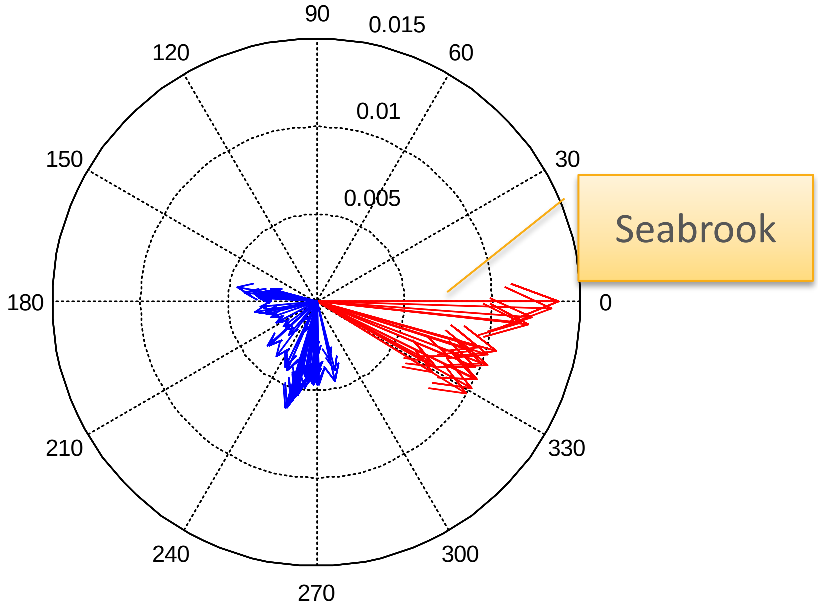
- Cases 1-5 are based on simulation in entire Eastern Interconnection with detail modeling of generators, excitation systems, governors and PSSs. Number of buses is > 50K and the number of generators > 5K.
- Only Voltage Angle measurements from NE were used to identify sources of oscillations.

- Case 1: Inside NE
- 1 Hz sinewave injection at *Millstone* unit 3 Exciter Vref.
- *Millstone* has the most leading phase within the leading group

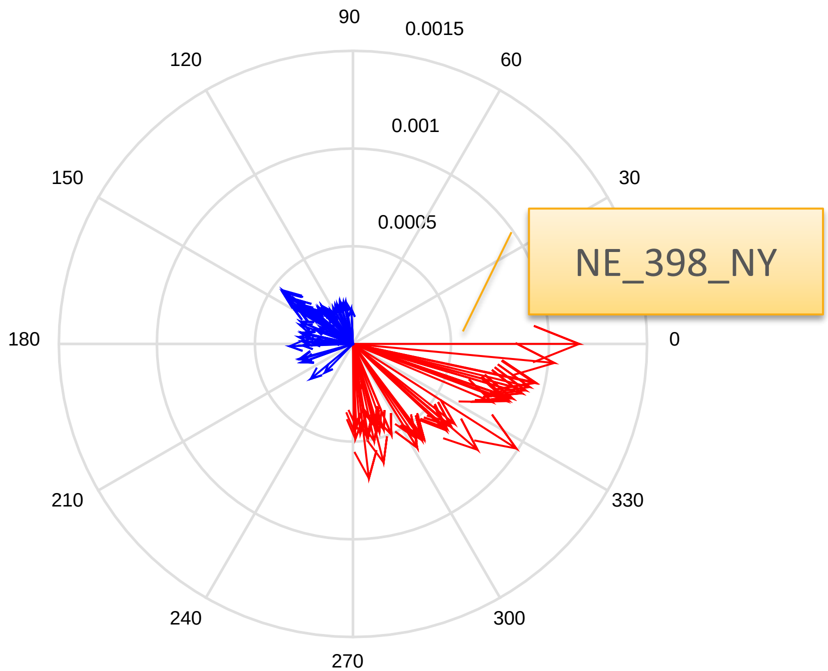


Simulation Cases Continued

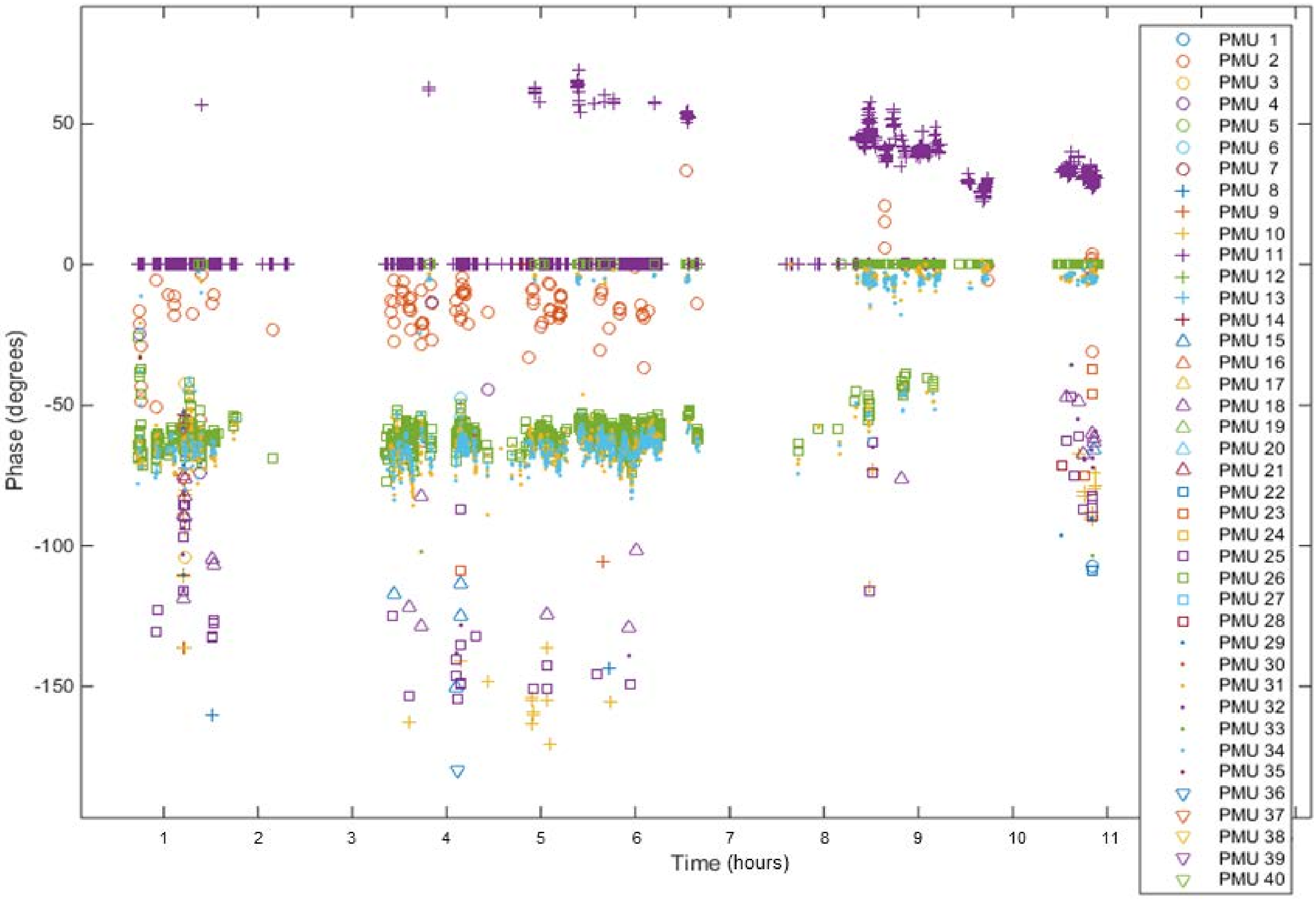
- Case 4: Inside NE: Negative Damping
- Reversed *Seabrook* PSS and created negative damping.
- *Seabrook* has the most leading phase within the leading group.



- Case 5: Outside NE: 1.11 Hz
- 1.11 Hz sin wave was injected on exciter at TMI 1 GEN (204659) at RFC. A resonating 1.11 Hz oscillation at NE was observed with two opposing groups.
- Most leading phase within the leading group, is at the connection to New York (outside NE).



Real Data Example



- A 1.3 Hz mode with poor damping.
- PMU 11 has the most leading phase and is consistently identified as the source.
- The mode damping can be correlated to the output of generators near this PMU.

Questions