Online Oscillations Analysis at ISO New England

Current Status and Future Needs with Respect to IBR

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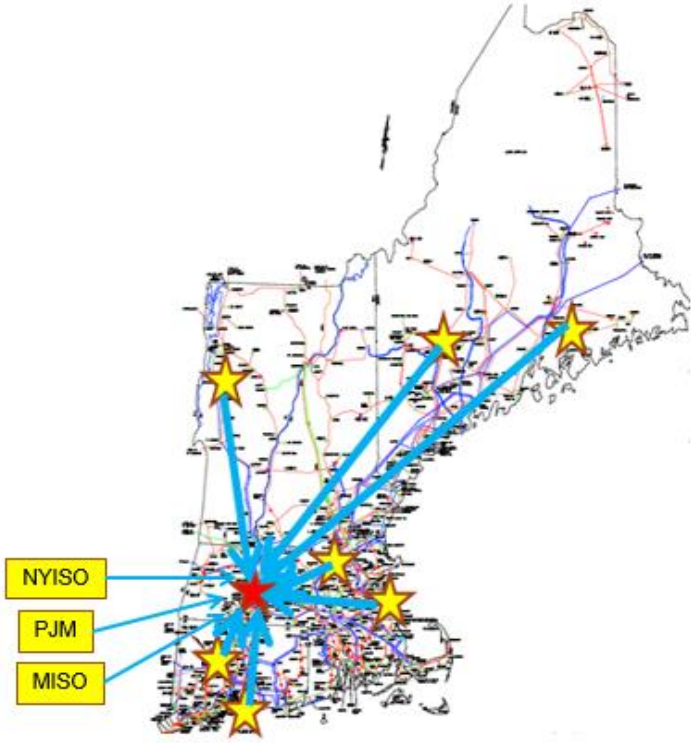
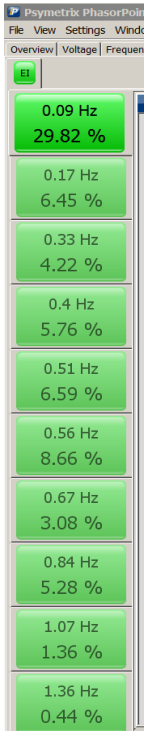
PMU Infrastructure at ISO New England

- ~100 PMUs and constantly growing
- Full observability of 345 kV with some redundancy
- Selected PMU data from NYISO, PJM and MISO
- 30 samples/s
- Operational since 2013
- Adding selected PMU data from TVA, SOCO, SPP



Detection of Oscillations



- PhasorPoint (GE application) automatically detects oscillations
  - Detection
  - Characterization (Frequency, Damping, Mode shape)
  - Alarming and Alerting
- Results are updated every 5 seconds
- Reliable detection of oscillations with magnitude larger than white noise

High confidence level that all potentially dangerous oscillations are detected and nothing important is missed

Observed Oscillations

Property	Description
Frequency	0.05 … 2 Hz; some instances of 8 Hz
Damping	0 … 20 %
Magnitude	Up to 150 MW, peak-to-peak
Observability	Local and Wide-spread
Duration	From few seconds to hours

- Natural oscillations: practically always well damped
  - Right design of system components
  - Right tuning of controls
  - Conservative limits for operating conditions
- Forced Oscillations (FO): operational task which cannot be solved in planning
  - Almost 100% of observed sustained oscillations are FO originating from generators

Forced Oscillations (FO)

- Caused by periodic injection of energy into the power system
  - Faulty equipment or control systems
  - Abnormal operating conditions
  - Inadequate control design/tuning
  - Cycling load
- Properties
  - Sustained and exist as long as the forced signal exist
  - The only effective mitigation is the removal of forced signal
  - A possibility of resonance with interarea mode and spreading across the system

Why We Are Concerned with Forced Oscillations?

- Represent a threat for power systems
  - Potential instability and uncontrolled cascading outages
  - Undesirable mechanical vibration in system components
- The presence of FO is an indicator of existing issues
  - Poorly tuned control systems
  - Equipment or control system failure
  - Abnormal operating conditions
- Mitigation is necessary for reliable operation of bulk power system and the key step is finding the Source of FO

What Does it Mean “Find the Source”?

Is the Source located in my Control Area?

Yes

My problem, I have to solve it

Which substation is the suspect?
Which specific unit is the suspect?

Mitigation Actions applied inside the Control Area

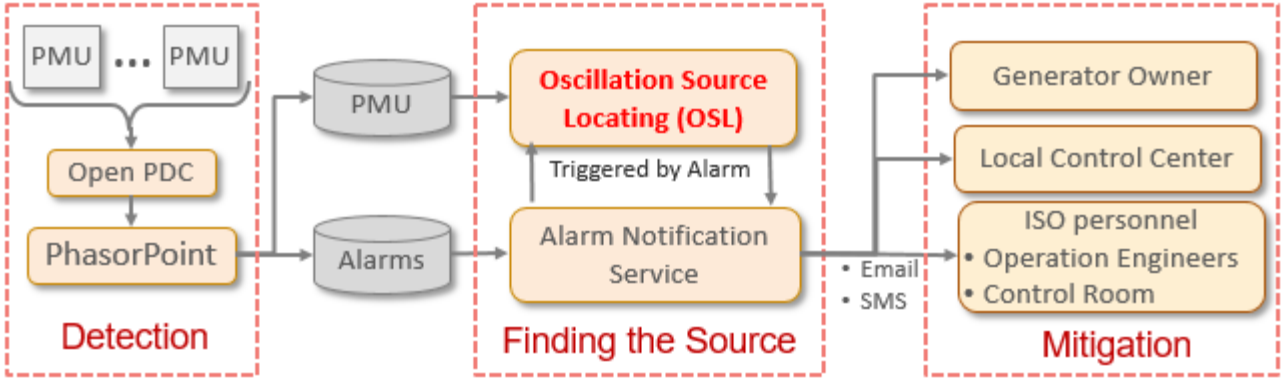
No

I cannot mitigate that oscillation by actions within my Control Area

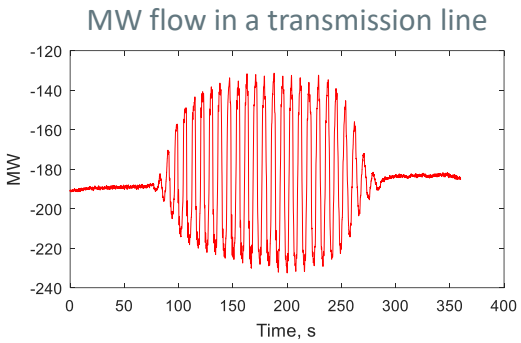
“Find the Source” means providing the **Actionable Information** to the Operator

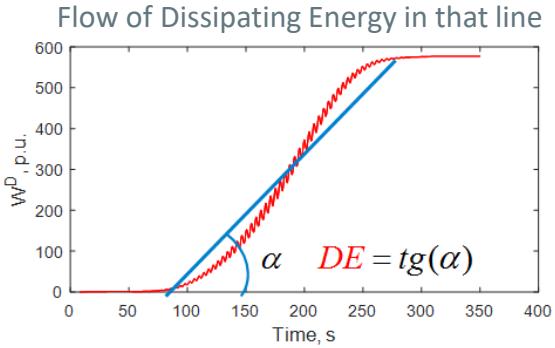
Oscillation Management at ISO-NE

- Objective
  - Detect all significant oscillatory events and generate Alarms/Alerts.
  - Estimate the Source of oscillations for every oscillatory Alarm (and Alert) and deliver results to the designated personnel.
- Fully automated 24/7 process, operational since September 2017



Oscillation Source Locating (OSL) Is the Key





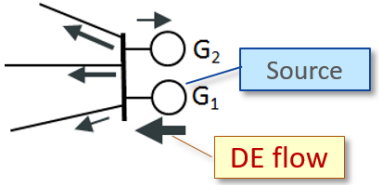
- Dissipating Energy Flow method calculates the flow of Dissipating Energy (DE) for any branch *ij* monitored by PMU at bus i.

PMU Input: I_{ij}, V_i, f_i ⇒ $W_{ij}^{D}(t) = \int \left(\Delta P_{ij} \mathrm{d}\Delta\theta_i + \Delta Q_{ij} \mathrm{d}\Delta \ln V_i \right)$ ⇒ $W_{ij}^{D}(t) \approx DE_{ij} \cdot t$

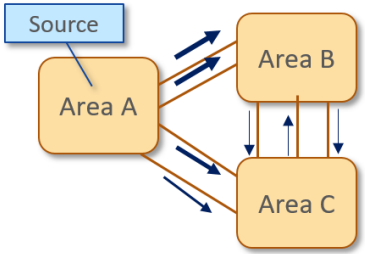
  - DE coefficient can be viewed as a regular MW flow in terms of Source-Sink for a flow of the transient energy: flows from Source to Sink
  - The direction and the value of DE in multiple branches allow tracing the source of oscillations

Interpretation of DE Pattern

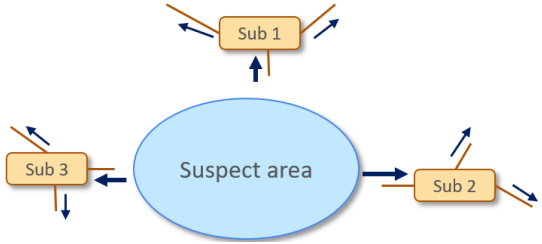
- PMU measurement at the Point Of Interconnection allows to trace specific power plant or generator



- PMU measurements in tie-lines between control areas allow to identify which area contains the source



- Even limited system observability by PMU allows greatly localize the suspect area



Example: Notification Email on Oscillatory Event

- Oscillation caused by testing AVR at a generator within ISO-NE

Reply Reply All Forward

Mon 6/6/2022 12:53 PM

PMU.alarms.DoNotReply@iso-ne.com

WARNING - PhasorPoint Alarms Notification

To

DE20220606_125029.csv 5 KB | P_DE20220606_125029.jpg 30 KB | DE20220606_125029.jpg 753 KB

Computer: [BATP]; PhasorPoint has issued 1 oscillation Alarms for the 30 seconds interval.

---------- Alarm ----------

PMU data Timestamp: [2022-06-06 12:50:29.967]

Substation/measurement: [3_IP]

Mode Frequency: [1.074 Hz]

Mode Peak-to-Peak Amplitude: [12.8 MW]

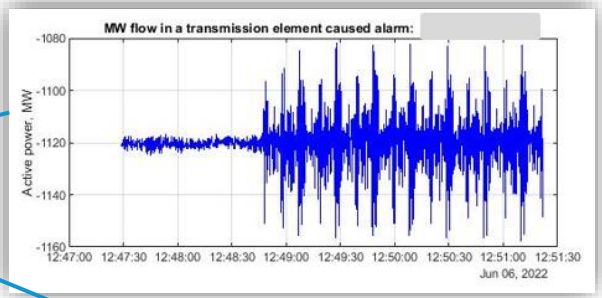
Mode Damping Ratio: [0.6 %]

Parameters of oscillations

--- Oscillation Source Location (OSL) detection summary ---

Source: , unit

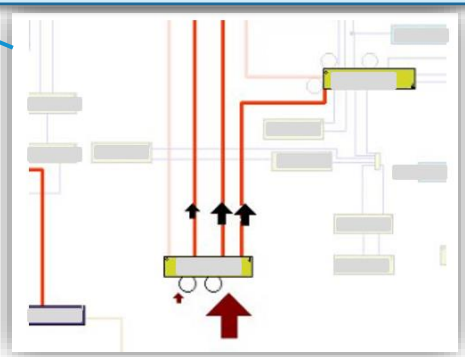
Results of DE pattern recognition



DE* in tabular form

DE	ID	Substation
-1		
0.4541		
0.4279		
0.2892		
-0.1931		
-0.1729		

DE* visualization on oneline diagram



* Dissipating Energy (DE)

Example: January 11, 2019 Event

- Near-resonance conditions with inter-area mode around 0.25 Hz have caused the propagation of oscillation across entire Eastern Interconnection

DoNotReply@iso-ne.com

WARNING - PhasorPoint Alarms Notification

DE20190111_034649.csv 5 KB | P_DE20190111_034649.jpg 25 KB | DE20190 1 MB

---------- Alarm ----------

PMU data Timestamp: [2019-01-11 03:46:49.967]

Detected Substation: [Long Mountain (13J)]

Detected Measurement: [1 IP]

Mode Frequency: [0.249 Hz]

Mode RMS Amplitude: [12.2 MW]

Mode Damping Ratio: [1.2 %]

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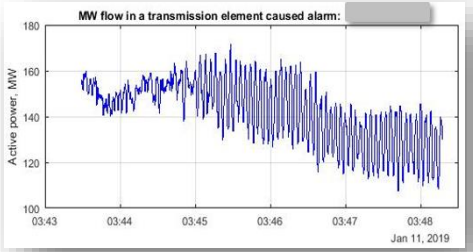
Oscillation Source Location (OSL) detection summ

Source: New York ISO

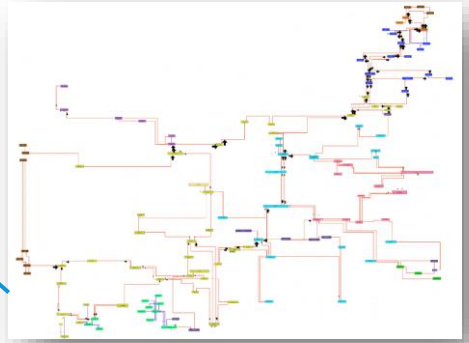
Parameters of oscillations

NYISO – ISO-NE tie line flow



- Email was sent in real-time, during the developing event
- Source is 1000+ miles away from ISO-NE

DE visualization on oneline diagram



Results of DE pattern recognition

- PMU only from ISO-NE footprint are used
- That allows to identify that the Source:
  - ✓ Is located outside and
  - ✓ In NYISO direction

Statistics of Oscillation Management Operation

- Since 2017, automatically processed 1200+ oscillatory Alerts and Alarms generated by the PhasorPoint application.
- Correctly identified the source (generator and area) for all instances of oscillations with known sources inside and outside of ISO-NE.

- **Existing Online Oscillation Management satisfies today's operational needs for online detection of oscillations and efficient mitigation**
  - The process works in the background and automatically provides key analytical information for operations when it is needed without the need for human to monitor raw PMU data

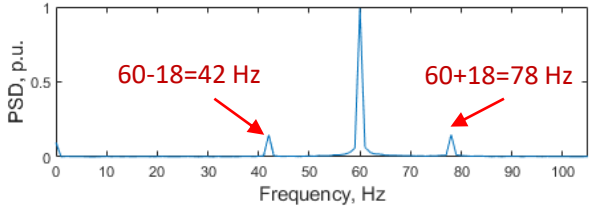
Important Implementation Details

- The process is robust and efficient for majority of practical situations
- Can handle actual oscillatory events: variable magnitude, frequency and short duration of oscillation
  - Researches typically assume idealized stationary, infinite oscillation process
- Dealing with actual PMU data
  - Bad data, missing samples, outliers, noise
  - Necessary PMU data filtering and de-trending
- Ability to identify and filter out false Phasorpoint alarms
  - Phasorpoint could generates false oscillatory alarm caused by bad PMU data

Future needs

Change in Operating Landscape

- Appearance of sub- and super-synchronous IBR-based oscillations (SSO) with frequencies > 2-4Hz
  - Sub-synchronous resonance (SSR)
  - Sub-synchronous control interaction (SSCI)



- Mitigation of SSO is mainly addressed at the planning stage
  - Proper EMT-type of modeling
  - Understand the root-cause of SSO, develop proper component design/tuning and establish operating limits
- Likely reduction of FO instances due to reduction the number of mechanical systems and related equipment failures

Challenges related to IBRs

- Finding specific IBR and control parameter(s) negatively contributing to the damping of SSO in simulation environment and in actual operation
  - FO will still exist and that is operational task
- Existing source locating methods could be insufficient
  - Strong control from multiple IBRs, HVDC and FACTS devices can negatively impact results the source localization
  - Possible more severe negative impact network/load resistance on efficiency of existing energy-based OSL methods
- Lack of high-speed synchronized measurements to track SSO
  - Existing PMUs with 30 samples/s rate are good for < 8-12 Hz due to internal filtering

Areas for R & D

- The need in data-driven methods for locating the source of SSO by using synthetic PMU (simulated EMT-type data) and actual PMU measurements
  - Robust for actual measurements (missing samples, bad data, outliers, noise)
- Compliment traditional PMU with high-sampling rate synchronized measurements
  - At least 200 samples per second
- Energy-based method locating the source of SSO with proper implementation could be efficient
  - Use of instantaneous Voltage/Current quantities instead of phasors
  - Accounting for both sub- and super-synchronous components of SSO
  - Extended energy formulation by adding path-dependent components

Questions?

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