Online Oscillations Analysis at ISO New England

Current status and future needs

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Oscillations Analysis. Why?

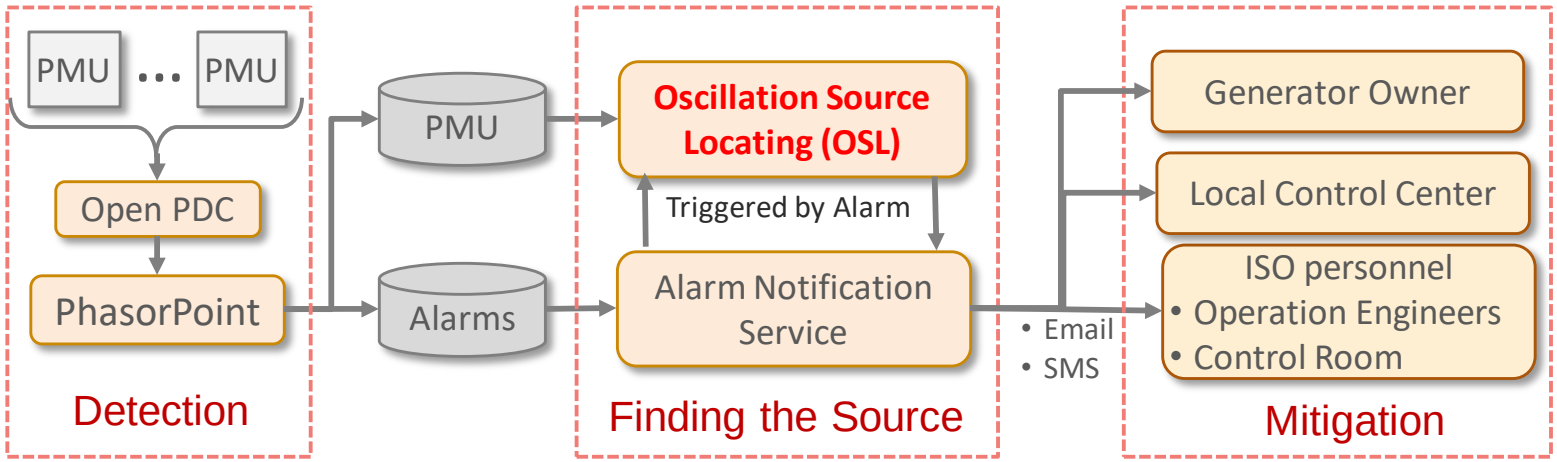
- Oscillations is an inherent property of power systems.
- Sustained oscillations (forced and poorly damped natural) can cause
  - ✓ At large magnitude : Potential uncontrolled cascading outages
  - ✓ For all magnitudes: Undesirable mechanical vibrations in system components

- Objective
  - ✓ Constantly monitor the power system for the presence of sustained oscillations
  - ✓ Systematically mitigate sustained oscillations

Online Oscillations Management

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 process, operational since September 2017.



The content of E-mail with OSL results

- Example of January 11, 2019 event. Email was sent in real-time, during the developing event.

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 summary:

Source: New York ISO

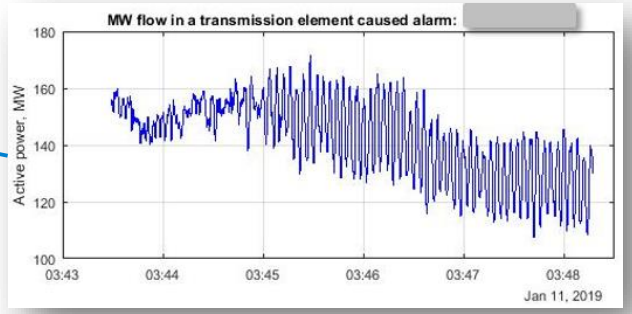
DE* in tabular form

DE	Line	Substation
-1		
0.9941		
-0.9146		
-0.9124		
0.9006		

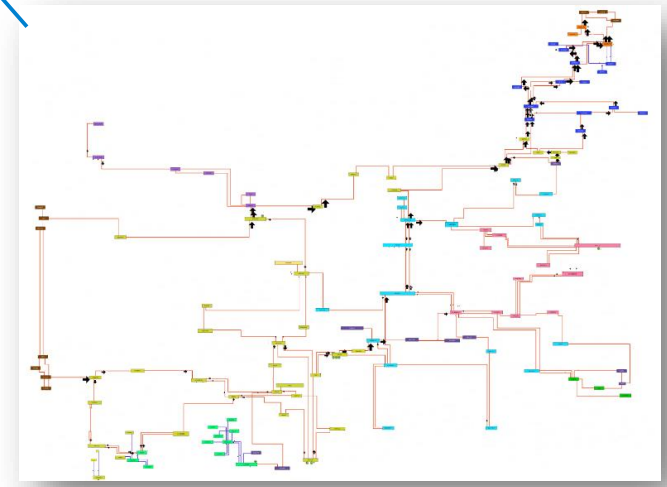
Parameters of oscillations

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



DE* visualization on oneline diagram



* Dissipating Energy (DE)

Statistics

- 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 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

Comments and Future needs

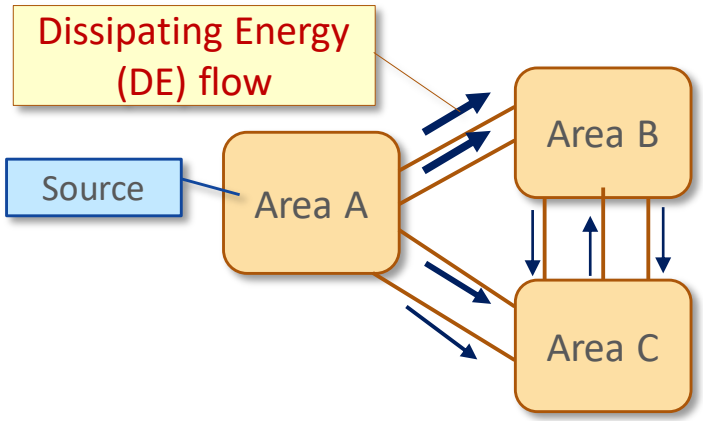
Monitoring should serve Mitigation needs

- Reliable detection of oscillations is generally solved. Details of monitoring should serve the ultimate goal – mitigation.
  - ✓ PMU locations, monitored quantities, thresholds, characterization
- Overwhelming majority of observed oscillations are forced oscillations (FO)
  - ✓ The most efficient mitigation of FO is mitigation the source. Monitoring should serve the task "finding the source".
- Majority of poorly damped natural oscillations such as related to bad PSS and control system tuning could be also efficiently mitigated by using "finding the source" approach
- Special case: poorly damped natural oscillations (inter-area mode) due to large MW transfer over a weak network
  - ✓ Mitigation: reduction of MW transfer
  - ✓ Can this case be mitigated by using "finding the source" approach?

Dissipating Energy is not the same as $\frac{d\,\mathrm{Re}(\lambda)}{dP}$

Wide – Area Monitoring

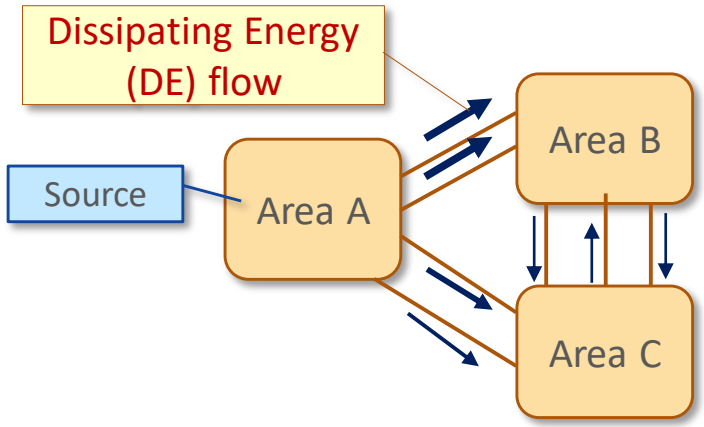
- Objective
  - ✓ Detection and characterization of oscillations
  - ✓ Identification of Area locating the source of oscillations
  - ✓ Notification of utilities on the source location
- Monitoring tie-lines between control Areas by PMU and the use of “OSL-like” tool allows the identification of the source-Area.



- Need to install PMU on all major tie-lines and provide sharing of these measurements online

Wide – Area Oscillation Management

- Assumptions: all entities use “OSL-like” tool for locating the source of oscillations
- Any entity can technically do wide-area monitoring online by having limited PMU data from major tie-lines between Areas in the interconnection
  - ✓ Can be a single designated entity or all entities can implement this function



- Every entity uses all internal PMU for the localization of the source inside of Area
  - ✓ SCADA data can be also used as a supplementary data source
- Expected benefit
  - ✓ Source localization within minutes online. Providing key information for efficient mitigation.
  - ✓ Avoiding attempts of wrong/inefficient mitigation actions in real-time due to insufficient situational awareness

“Natural”/”Forced” Classification

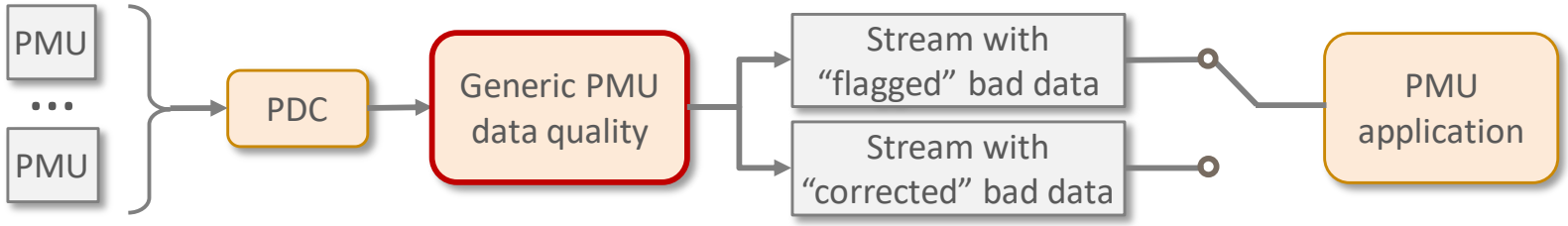
- Oscillations must be classified as Forced or Natural if that is necessary for mitigation. Otherwise, it is not needed for practice.
- All Forced and majority of natural oscillations can me mitigated by “finding the source” approach without the need for classification
- “Poor damped inter-area mode due the large MW transfer over a weak network” is the only case requiring the classification because of known remedial action (reduce MW transfer) developed offline
- Concerns
  - ✓ Safe MW transfer limits related to low-damped natural modes are established in studies and enforced in real-time dispatch to prevent the occurrence of low-damped oscillations
  - ✓ What does it mean if we still observe such oscillations?
    - ❖ Incorrect model? Insufficient study? Shall we trust the model-based mitigation measures?
    - ❖ Is the classification correct? Probably we see something different?
  - ✓ Can we reliably distinguish the case “natural mode” from the case of “FO resonance conditions with natural mode”?

Measurements, Thresholds

- Use of MW flow for monitoring is preferable over other quantities.
- A good practice would be to find the source of all oscillations with magnitude higher than white noise.
- Use of fixed MW threshold to distinguish “dangerous” oscillations could be unpractical
  - ✓ Small local magnitude within Area can cause much bigger magnitude far away in the resonance conditions
  - ✓ Small magnitude can be indicator of equipment failure or the existence of abnormal operating conditions
- Periodically revised thresholds could be a preferable practice
  - ✓ Increase threshold for known issue to avoid multiple alarms. Example: hydro units in a rough zone. Mitigation: fast ramping through the rough zone.
- Two-level Alert/Alarm thresholds
  - ✓ Alarm for severe oscillations requiring mitigation online
  - ✓ Alert for other oscillations tolerating offline mitigation
  - ✓ Today, scientifically justifiable Alarm/Alert thresholds are not established

PMU quality, Standardization

- Multiple PMU data issues, not captured by the status flag, can impact the performance of an application using PMU.
- Today, an efficient PMU application has to have “PMU-data quality handling” module. There is no other choice; inefficient approach.
- A desired approach: Generic PMU data quality module (based on LSE, low-rank properties, etc.)



- Need to have a standardized signs of PMU current measurements consistent with commonly used P and Q signs notation
  - ✓ Positive MW means the power flows from the bus
  - ✓ Deviation from common practice leads to misinterpretation of results

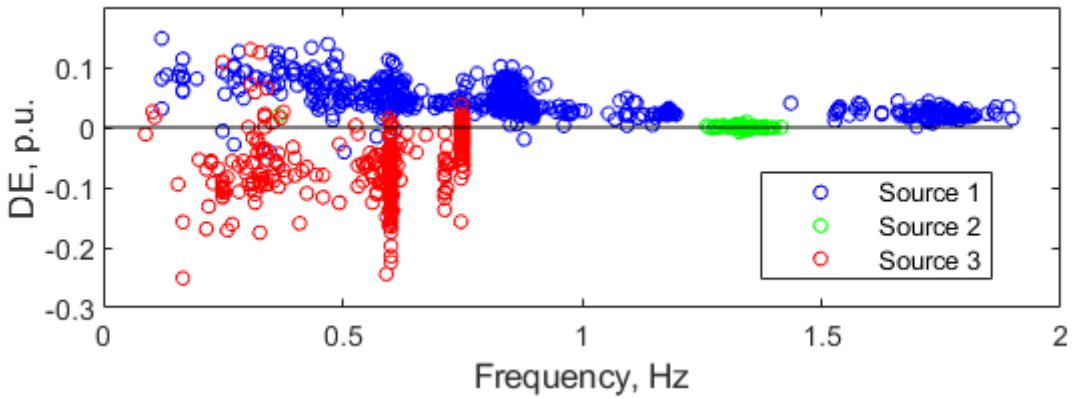
Oscillations at High Penetration of Inverter-Based Generation (IBG)

- High penetration of IBG, but below 100%, will not principally change the structure of oscillations in bulk systems but create new phenomena
- What to expect?
  - ✓ Existing structure of oscillations and related issues continue to exist
  - ✓ Reduced number of local and inter-area modes and change in modes' parameters
  - ✓ Possibility of relatively localized high-frequency oscillations, 10…1000 Hz. These oscillations cannot be monitored by traditional PMUs at 30 fps. Monitoring by "point on the waive" measurements with limited need in data exchange?
  - ✓ High-frequency oscillations are likely to be localized without creating system-wide effect. Such oscillations will be largely depended on IBG controls.
  - ✓ Likely emergence of new sources of forced oscillations (in traditional electromechanical frequency range) such as IBGs, microgrids

Use of Dissipating Energy (DE) for "finding the source"

- The energy-based method has known deficiency: network resistance and load with characteristics different from P,Q=const can produce/consume DE obfuscating the DE pattern and complicate the source localization.
- Statistical results from ISO-NE by using 1200+ actual oscillatory events demonstrates that such obfuscation is not critically impacting DE pattern.
- The DE flow method can be used for practical needs of the source localization

DE value of a load in Boston area for 1242 oscillatory events



Questions