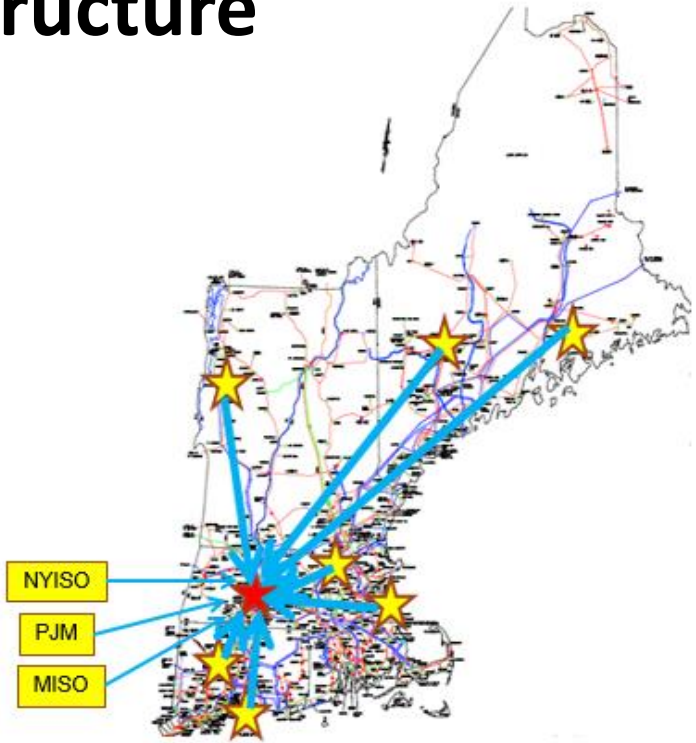
# Experience with Oscillations in ISO New England

Slava Maslennikov

TECHNICAL MANAGER, ADVANCED TECHNOLOGY SOLUTIONS

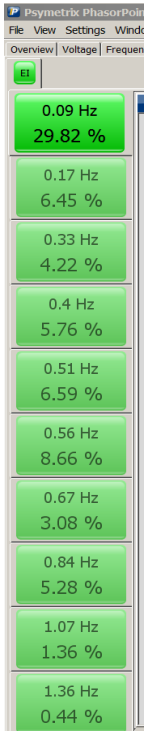
# Measurements: PMU Infrastructure

- ~100 PMUs and constantly growing
- Full observability of 345 kV with some redundancy
- Selected PMU data from NYISO, PJM and MISO; adding TVA, SOCO,SPP
- 30 samples/s
- New: requirement to add PMU at every utility scale IBR installation




**Good system observability for oscillations**

# Detection of Oscillations: PMU processing

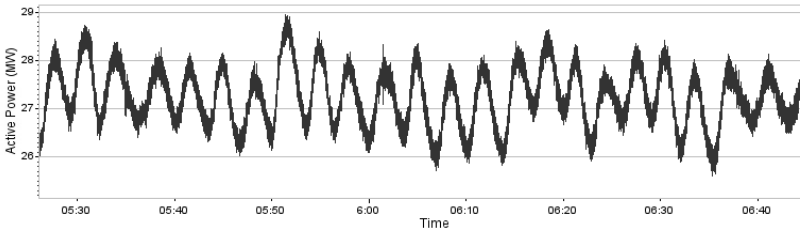



- Front end application continiously processing PMU data
  - Detection of oscillations
  - Characterization (Frequency, Damping, Mode shape)
  - Alarming and Alerting
- Results are updated every 5 seconds
- Reliable detection of oscillation with magnitude larger than white noise and frequency from 0.05Hz up to 4-7Hz.

**High confidence level that all potentially dangerous oscillations within measurement frequency range are detected**

# Observed Oscillations: Statistics since 2013, >1200 events

| Property | Description |
|---|---|
| Frequency | Typical range: 0.05 … 1.5 Hz;<br>Some instances of 0.004 and 8 Hz |
| Damping | 0 … 20 % |
| Magnitude | Up to 150 MW, peak-to-peak<br>Majority of instances <10MW |
| Observability | Local and Wide-spread |
| Duration | From few seconds to hours |




- Natural oscillations
  - Always well damped so far
- Forced Oscillations (FO)
  - **Almost 100% of observed sustained oscillations are FO originating from synchronous generators**
- IBR-based oscillations
  - Practically not detected yet at 10-13% generation from renewables
- 1-2 MW sustained oscillation with period 3-5 min observed in area with multiple wind farms

**So far, FO is the major thread to ISO-NE power system**

# FO is the Thread to Power System

- Potential instability and uncontrolled cascading outages
- Undesirable mechanical vibration in system components.
  - Example: 2009 Disaster at 6400 MW Hydro Power Plant*

- Mitigation is necessary for reliable operation of bulk power system and the key step is finding the Source of FO

**Source of FO = "Bad actor"**

* https://www.powermag.com/investigating-the-sayano-shushenskaya-hydro-power-plant-disaster/

# What Does it Mean “Find the Source”?


Is the Source located in my Control Area?

Yes

No

My problem, I have to solve it

I cannot mitigate that oscillation

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

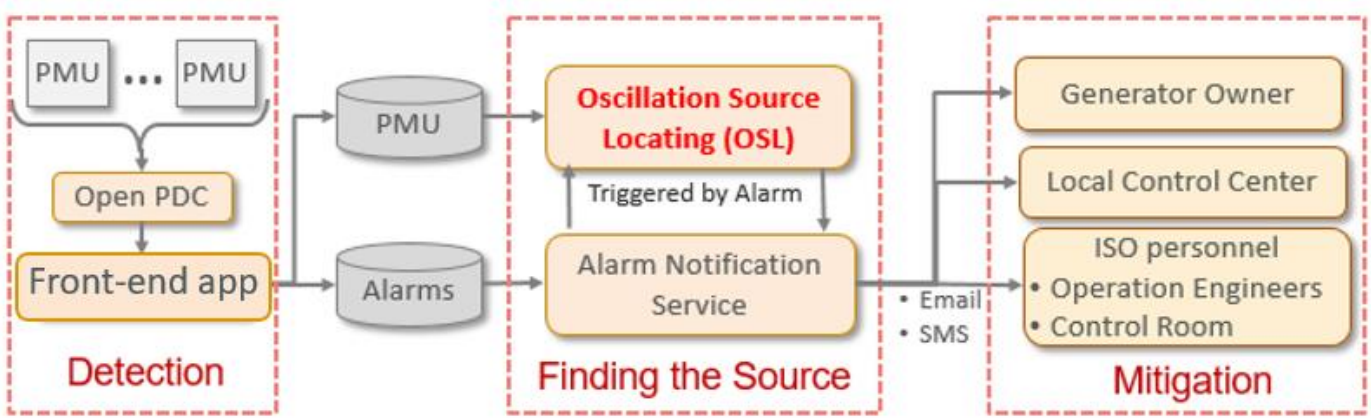
Source: Area, Substation, Unit

Mitigation: Actions applied inside the Control Area

**“Find the Source” means providing actionable information to the Operator**

# On-line Oscillation Management

- Objective
  - Detect significant oscillatory events and generate Alarms/Alerts.
  - Estimate the Source and deliver results to the designated personnel.



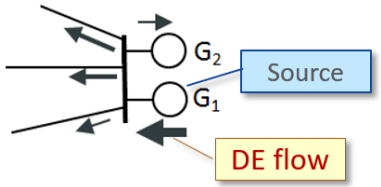

**Fully automated 24/7 process, operational since September 2017**

# Oscillation Source Locating (OSL) Is the Key

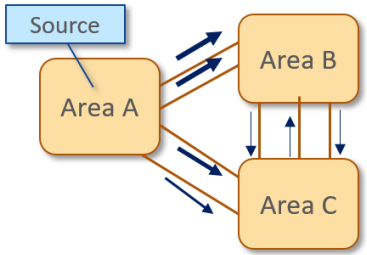
- OSL calculates the flow of Dissipating Energy ($DE$) in any branch monitored by PMU
- Similar to regular MW, *DE* flows from Source to Sink

- Use cases of *DE* pattern:

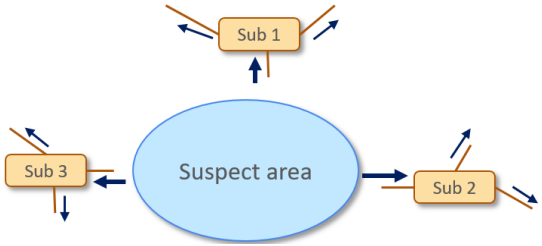
1. PMU at the Point Of Interconnection allows to trace specific power plant or generator




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



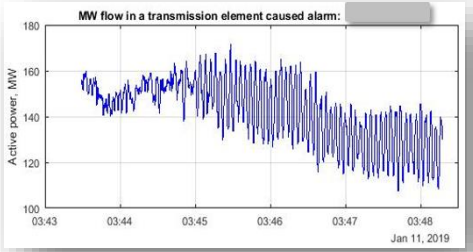

3. Even limited number of PMUs allows greatly localize the suspect area



# Example: January 11, 2019 Event

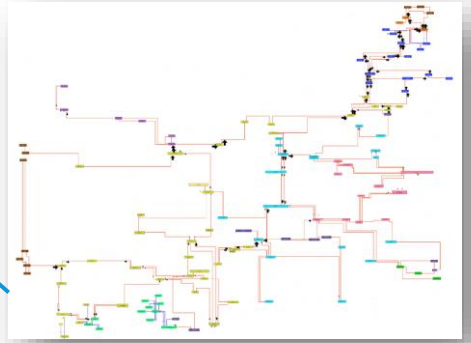
- Near-resonance conditions with inter-area mode around 0.25 Hz have caused the propagation of oscillation across the entire Eastern Interconnection

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



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 %]

**********

Oscillation Source Location (OSL) detection summ

Source: New York ISO

Parameters of oscillations

**Results from DE pattern**

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

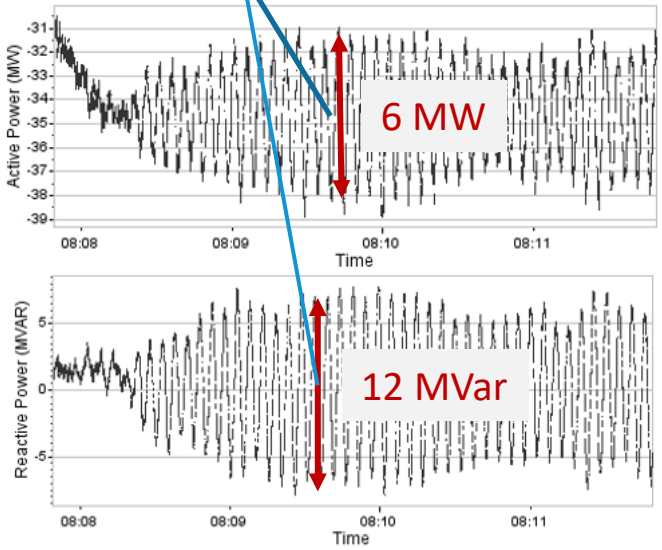
# Dissipating Energy Pattern Recognition (DR-PR)

- A human makes the source identification by looking at DE pattern visualized on oneline diagram.
- A useful feature is an automatic Source identification based on DE pattern


**DR-PR greatly increases selectivity of Source identification for non-observable by PMU areas**

# DE-PR Example: 7/2/2023: 0.2Hz oscillation caused by excitation system

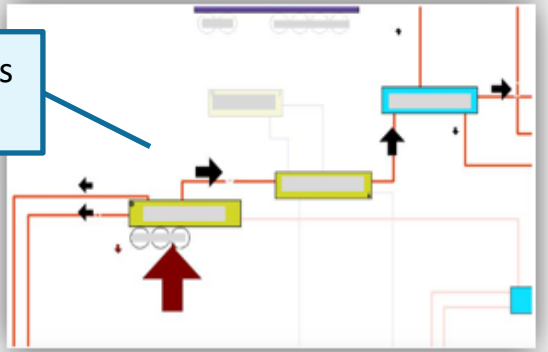
MVar magnitude 2x of MW




OSL Results

The source of oscillation is likely located in: **Voltage control loop**

DE pattern traces the Source



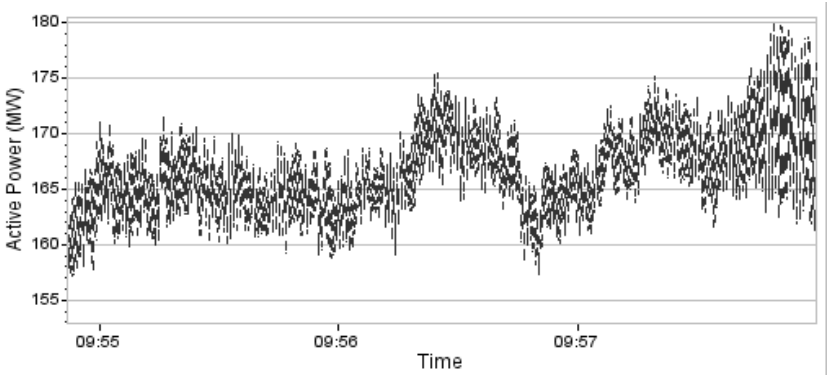
Type of control loop with the Source

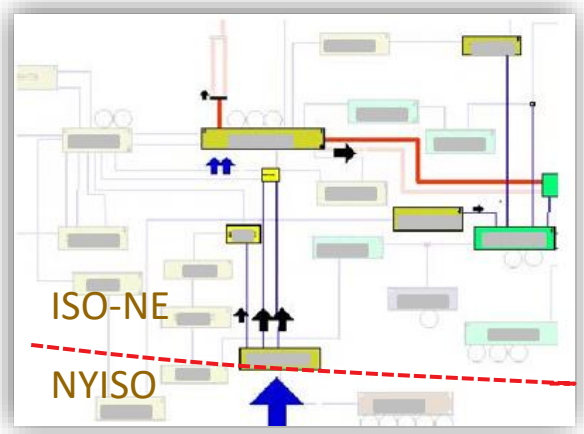
Source: Area=NEPEX (confidence=100%); Station= ; Unit=
Correlation between DE and DEtemplate with the highest rank is: 0.955

Specific unit is identified

# DE-PR Example: Tracing the source outside of ISO-NE

- March 2024: multiple instances of ~1.2Hz oscillations originating outside of ISO-NE footprint




~~~ DE pattern recognition results
CDEF method: Source: Area=NYPP (confidence=100%); localized within substations: [redacted]

**DR-PR allows to trace the source within non-observed by PMU area**
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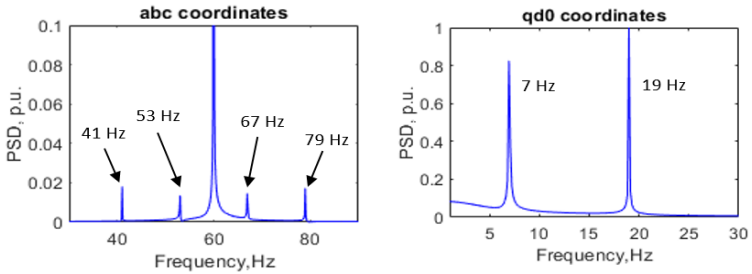
# Statistics of Performance

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

- **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

# Future Needs: Challenges Related to IBRs

- Emergence of sub- and super-synchronous oscillations (SSO) with frequencies > 2-4Hz
- Existing source locating methods could be insufficient
  - Strong control interaction could be challenging




- Lack of high-speed synchronized measurements to track SSO
  - Existing PMUs with 30 samples/s rate are good for < 4-8 Hz

# Which IBR is “bad actor”?

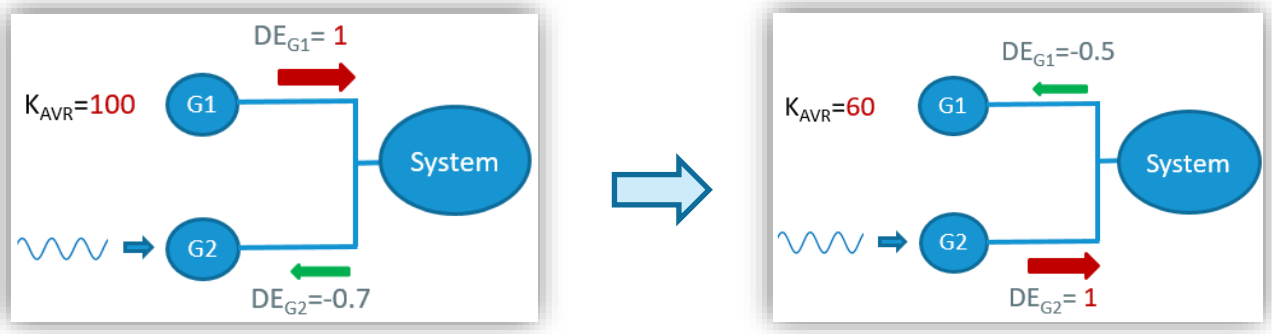
- Need to find specific IBR negatively contributing to the damping of SSO in simulation environment and in actual operation
  - The main focus on natural oscillations, but FO will still exist

| Type of oscillation | The Source is… | Mitigation |
|---|---|---|
| Forced | “Bad actor” | Remove “bad actor” |
| Natural without strong control interaction | “Bad actor” | Modify “ bad actor” parameters or remove it |
| Natural with strong control interaction | Within interacting units | **Is the most contributing unit best for mitigation?** |

**More research is needed**

# Control interaction: “Bad actor” and Efficient Mitigation

- G2 contains periodic injection of energy into the Excitation (Actual Source of FO) and AVR of G1 produces negative damping as a reaction to oscillation (Larger Contributor)
  - G1 is deemed as the Source (Source of DE = Negative contributor to damping)
- Mitigation
  - Step 1: Reduce AVR gain at G1 → Now, G2 is identified as the Source
  - Step 2: eliminate the Source




**“Largest contributor to negative damping” = “Best for mitigation” ??**

# Questions?

Slava Maslennikov, Ph.D.
smaslennikov@iso-ne.com