Use of Synchrophasors to Detect Control System and Circuit Breaker Reclosing Issues

Pramila Nirbhavane
Senior Grid Operations Engineer

September 26, 2017

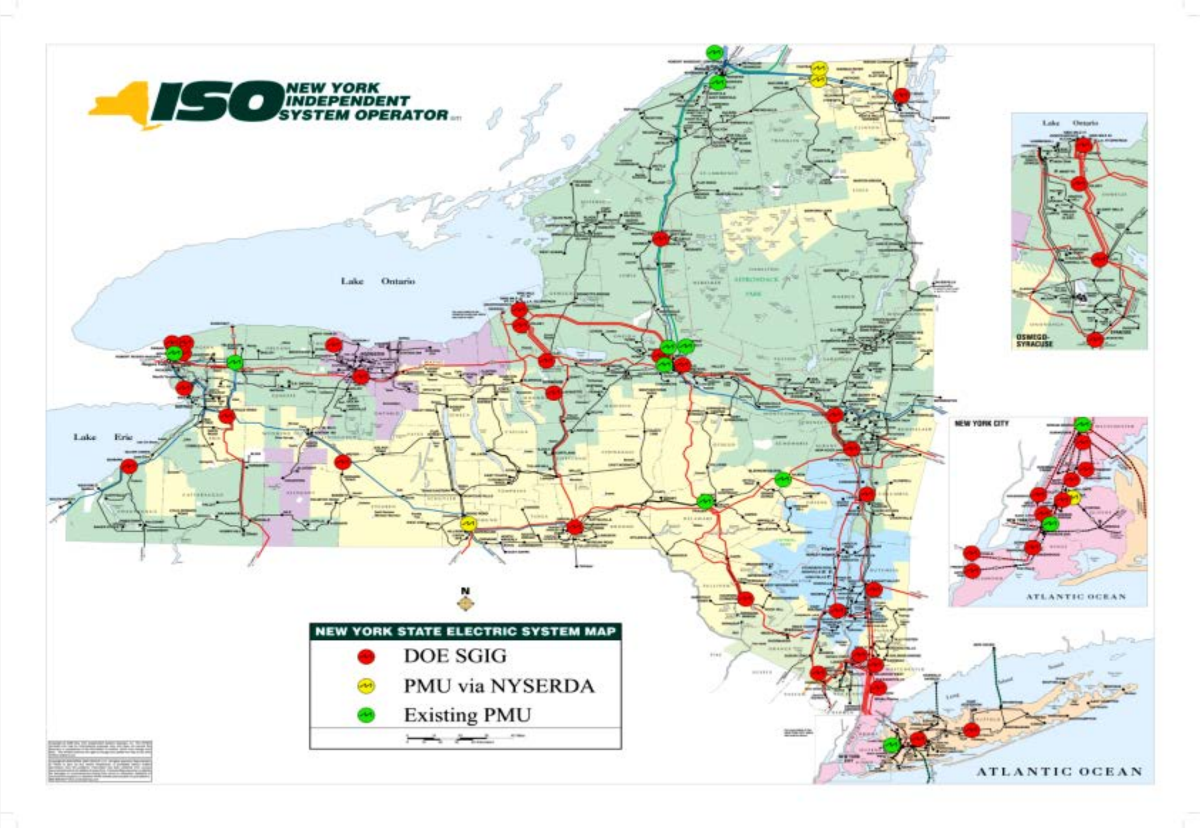
NEW YORK INDEPENDENT SYSTEM OPERATOR

Outline

- PMUs Locations in NYISO
- PMU Applications
- Current Operating Procedures
- Recent Operations Experience
- Data Quality
- Future Work

NEW YORK INDEPENDENT SYSTEM OPERATOR

PMU Locations in NYISO



Synchrophasor Applications in NYISO

- Phasor Enhanced State Estimator
- Phasor Enhanced Voltage Stability Monitor
- Control Room Visualization / Situational Awareness
- Post Event Analysis Capabilities
- TO Portal

Phasor Enhanced State Estimator

- NYISO State Estimator (SE) was augmented to accept Synchrophasor measurements
  - Voltage magnitudes & angles (220+)
  - Current magnitudes & angles (280+)
  - Frequencies (70+)
  - Line flow Mw & Mvar (400+)
- *Selected* points are being used by SE
- Monitor actual values against SE solutions
- Phasor Enhanced State Estimator developed by ABB

NEW YORK INDEPENDENT SYSTEM OPERATOR

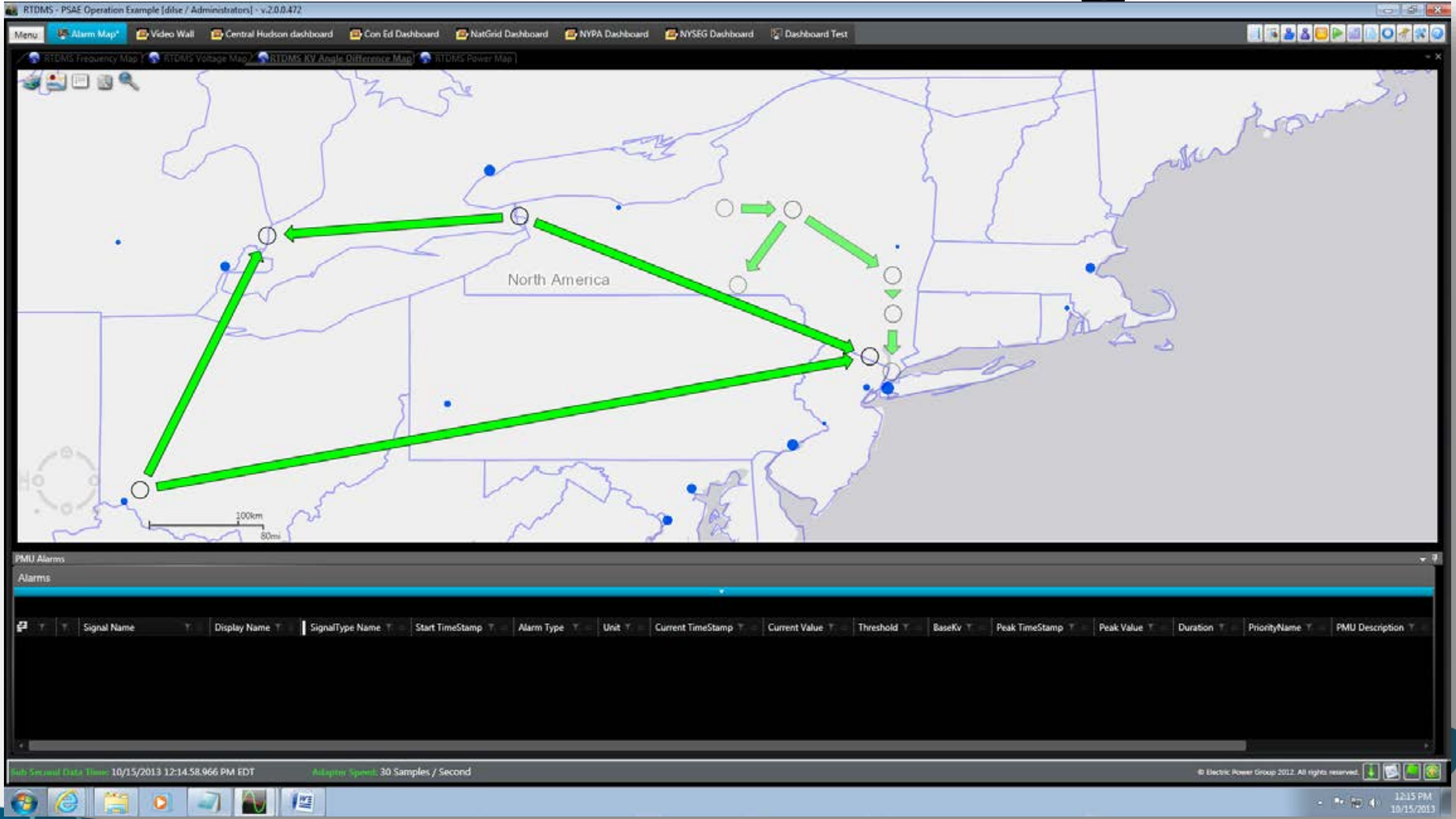
Visualization & Situational Awareness

- Synchrophasor dashboard organized by seven New York State electrical regions and four external neighboring ISO/RTO regions

- *PMUs grouped by defined regions to reflect the expected coherent generation response*
- *Visualization is part of NYISO control room video wall*

NEW YORK INDEPENDENT SYSTEM OPERATOR

Wide Area Monitoring



NEW YORK INDEPENDENT SYSTEM OPERATOR

Operations Control Center Dashboard

Post Event Analysis Capabilities

- **Synchrophasor Grid Dynamics Analyzer capability for after the fact review of system events**
  - Frequency response
  - Transient voltage recovery
  - Modal analysis
  - Ringdown analysis
  - System Stress analysis
  - Validation of system component models
  - Analysis of Unusual System Operating Events

NEW YORK INDEPENDENT SYSTEM OPERATOR

Recent Operations Experience

- Operators leveraging synchrophasor capability
  - Faster sampling rate of PMU data (30 samples/second) provides more insight than review of traditional SCADA data
  - Power swing/oscillation investigations (Use Case -1 and Use Case-2)
    - Control system issues typically cause in higher frequency oscillations that can only be observed from PMU data
    - Frequency of oscillations can provide insight into root cause of issue being investigated (e.g. local plant control system issue or inter-area issue due to opposing coherent generation groups)
  - Transmission line reclosing failure (Use Case-3)
    - Phase angle difference for the line protection relay was too wide, auto-reclosing of the lines failed and line was unable to be manually restored by manual supervisory control

NEW YORK INDEPENDENT SYSTEM OPERATOR

Use Case 1: HVDC Interconnection

Observation from SCADA data:

- Energizing a 200MVar cap bank resulted in the power output from a major HVDC interconnection to drop from 1500MW to 1000MW

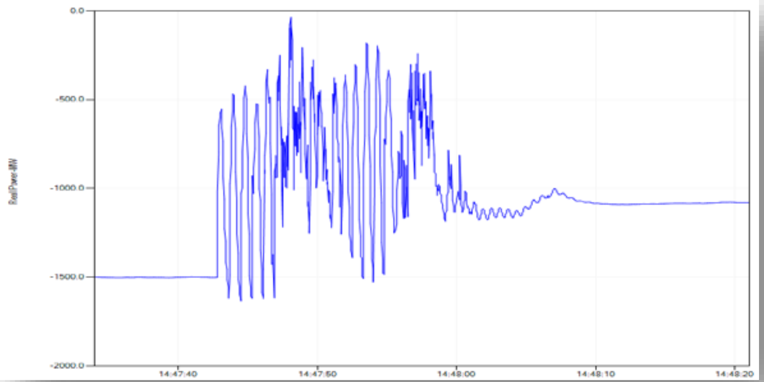
Observation from PMU data:

- Unexpected 1 Hz power swings of up to 1000MW
- Voltage swings in excess of 10% nominal voltage

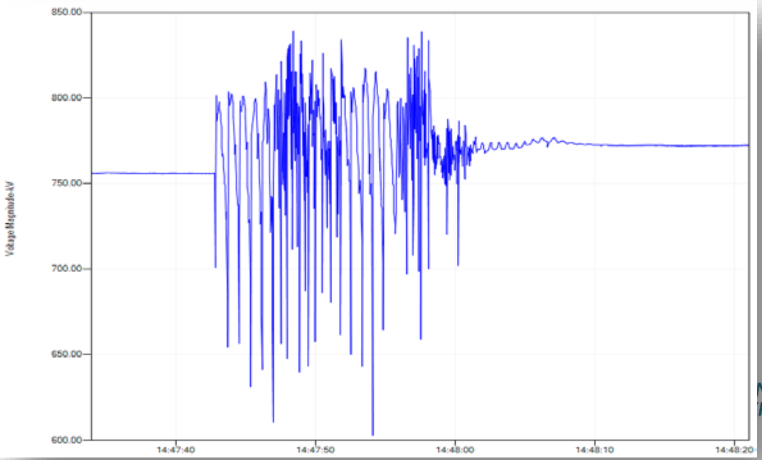
Actions Taken:

- HVDC Interconnection capability derated based on unexpected power swings
- Transmission Owner, facility owner, and the NYISO reviewed EMS and PMU data
- Certain HVDC controls were found to not be operating as expected
- HVDC controls were modified accordingly and successfully field tested
- HVDC interconnection restored to full capability in about two weeks

Power Flow Oscillations



Voltage Oscillations



Use Case 2: Wind Turbine Generation

Observation from SCADA data

- A 200MW wind plant rapidly reduced output a number of times until ordered off-line

Observation from PMU data

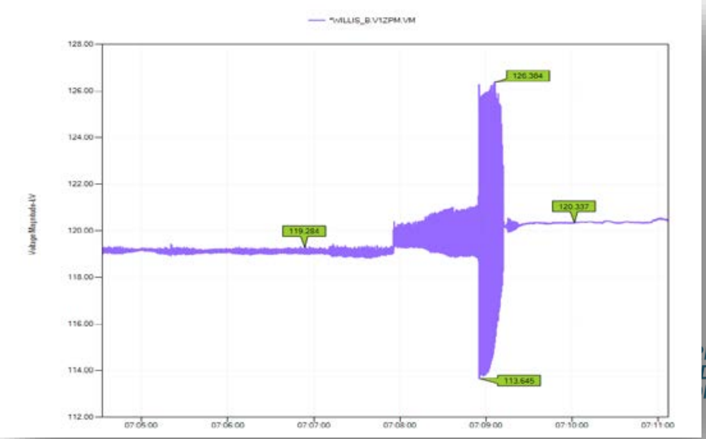
- Unexpected high frequency voltage swings of about 10% nominal voltage
- Repeated high frequency power oscillations preceding each reduction in wind plant power output

Actions Taken:

- Wind plant directed off-line until performance issue identified and remediated
- Wind plant controls originally designed for connect to both 230 kV and 115 kV systems
- Wind plant connected only to 115 kV system when performance issue occurred
- Wind plant controls modified accordingly to accommodate weaker short circuit strength systems conditions
- Wind plant allowed to return to operation in about 24 hours

Power Flow Oscillations

Voltage Oscillations



Use Case 3: Line Reclosing Failure

Synchronizing

When closing a circuit breaker between two energized parts of the power system, it is crucial to match the three different aspects of the voltage across the circuit breaker:

- Voltage magnitudes across the circuit breaker
- Phase angle difference between the voltages across the circuit breaker
- Frequency of Voltages across the circuit breaker

NEW YORK INDEPENDENT SYSTEM OPERATOR

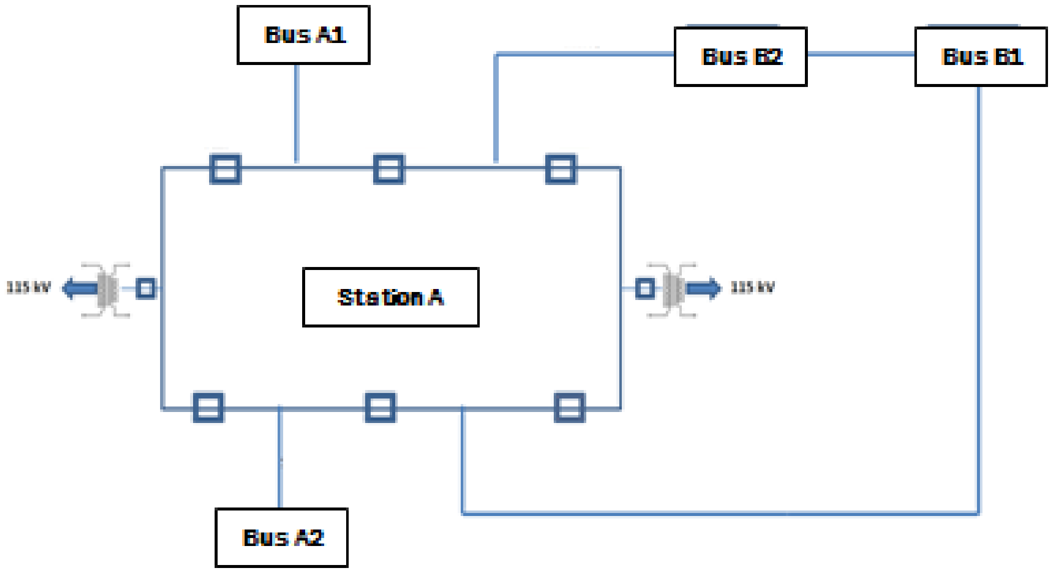
Use Case 3: Line Reclosing Failure

Circuit breakers with Sync Check Relays

- Sync-Check relays **are designed to permit the breaker closure only after** the specified phase angle conditions have been verified and the condition is satisfied for a specified time period.
- This relay **monitors the voltages on both sides of a circuit breaker** and determines that proper phase angle and voltage exist prior to allowing the breaker to be closed
- The allowable **limits will vary with the location** on the power system.
- Synch-check relays **typically do not provide indication** of the voltage magnitude, frequency or phase angle. A synch-check relay decides internally whether its conditions for closing are satisfied.
- The synch-check relay **will either allow or prevent closing depending on its settings.** A typical synch-check relay may allow closing if the voltage angle across the breaker is less than 30°

NEW YORK INDEPENDENT SYSTEM OPERATOR

Use Case 3: Line Reclosing Failure



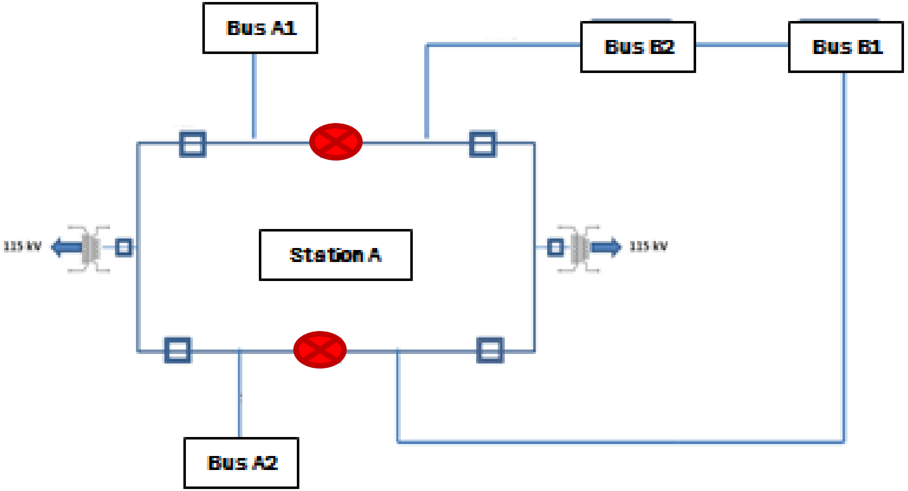
Single Line Breaker Diagram for Station A

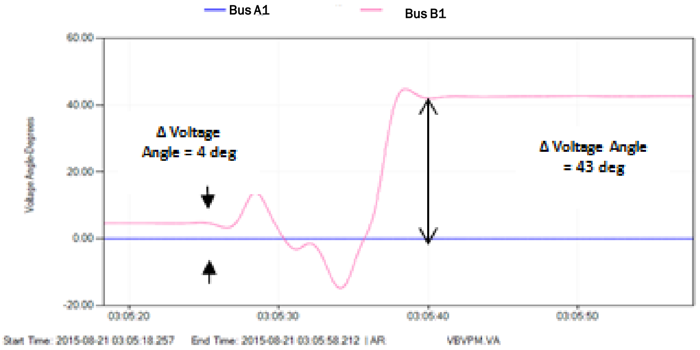
Use Case 3: Line Reclosing Failure contd..

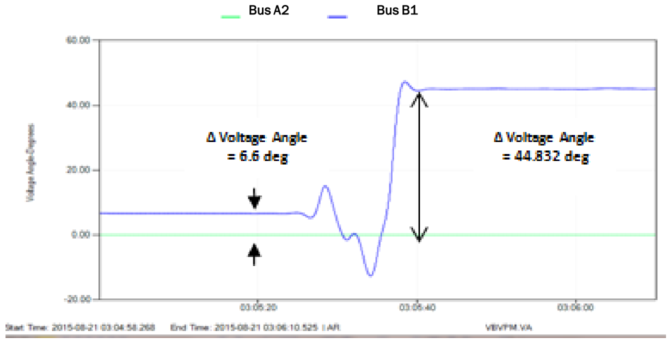
Observations from PMU data

Voltage Angle Difference across the Breakers

Single Line Breaker Diagram for Station A







Performance Review

- **Critical factors for successful PMU utilization:**
  - Data quality
  - Availability
- **NYISO conducts monthly evaluation of data quality of NYCA PMU measurements**
- **PMU Data Quality is categorized into two :**
  - Bad Samples (Error Samples)
  - Good Samples

Performance Review

- Overall Distribution of Bad Samples :
  - Drop Error
  - Data Invalid
  - Synch Error
  - Time Error
  - Transmission Error

Future Areas of Work

- Be able to more quickly identify events in real-time using the Operations Control Center Dashboard (and rely less on after-the-fact post-event analysis)
- Identify the likely cause of the event in real-time by correlating the frequency of the event to typical known sources of oscillation frequency ranges:
  - Control Mode Oscillations – 1-5Hz range
  - Local Plant Mode Oscillations – 1-2 Hz range
  - Inter-Area Power Swing Oscillations – less than 1Hz range
- Be able to "replay" actual events to test Operations Control Center dashboard capabilities

NEW YORK INDEPENDENT SYSTEM OPERATOR

The Mission of the New York Independent System Operator, in collaboration with its stakeholders, is to serve the public interest and provide benefits to consumers by:

- Maintaining and enhancing regional reliability
- Operating open, fair and competitive wholesale electricity markets
- Planning the power system for the future
- Providing factual information to policy makers, stakeholders and investors in the power system

www.nyiso.com

NEW YORK INDEPENDENT SYSTEM OPERATOR