NEW YORK
STATE OF
OPPORTUNITY.
NY Power Authority

Real Time Application for PMU Wide Area Monitoring, Alarming and Analytics

Atena Darvishi, Research and Technology Development Dept.

September 23, 2021

Overview

- Project Introduction, and Background
- Project Details
- Application overview
- Value and Benefits

Project Introduction, and Background

Introduction: DOE funded ($1,293,095) collaborative project with EPG (Electric Power Group) and BPA (Bonneville Power Administration) to develop real time applications using PMU data

Motivation: Improve limitation of real time observability and analytics in the grid specially during contingencies and stressed conditions, and Develop real time assessment of phase angle and voltage stability margins

2003 North Eastern blackout costs US at least $4 billion[1]

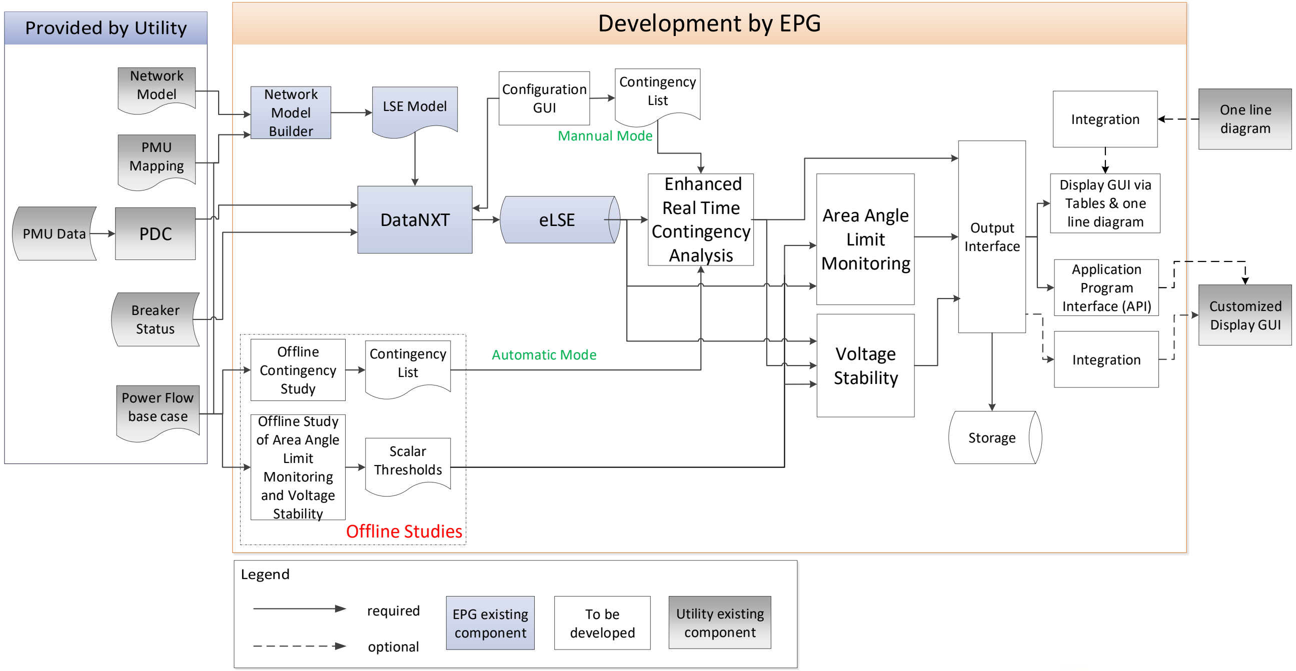
Objectives: Provide operators with intelligence and alerts on grid conditions, contingencies, phase angle limits and voltage margins

[1] https://www.energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf

Project Details: System Modules and Functionalities

The project developed four following functions:

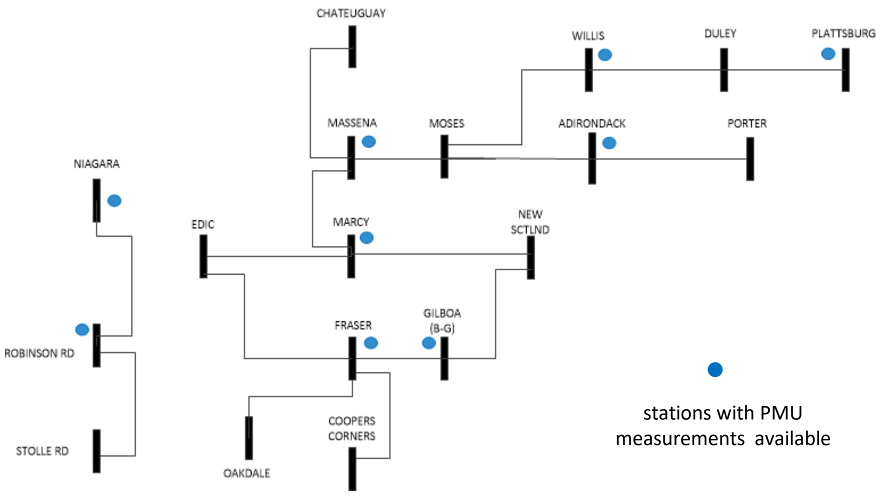
- Enhanced PMU monitoring and analytics
- Enhanced Real Time Contingency Analysis (ERTCA)
- Area angle limit monitoring
- Voltage stability



Project Details: NYPA PMU Observable Area

Directly Observable Station: Using linear state estimation, a directly observable station is one which has at least one voltage pmu measurement available.

Indirectly Observable Station: An indirectly observable station is the one for which at least one voltage pmu measurement present on an adjacent station and one current measurement is present on the links connecting the two.



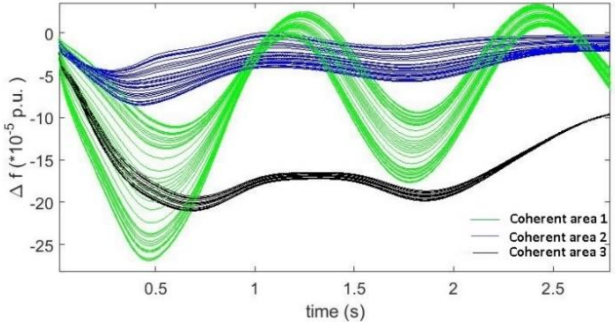
The stations with blue circles in the figure are directly observable.

Project Details: RTCA Function

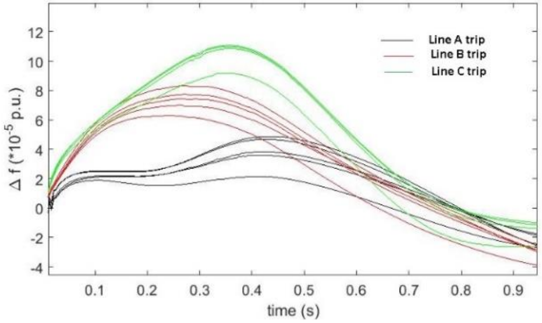
RTCA provide information to characterize steady state conditions in real-time and under contingencies. Contingencies can be based on critical contingency list, N-1 based on current condition, N-k special condition, user-defined, or triggered by system events (e.g., network topology change).

- Tests what can happen next based on the current system
  - ✓ Uses a pre-made list of contingencies such as line outages, transformer failure, RAS actions, etc.
  - ✓ Checks for low voltage or excessive power flow caused by the outage
- Uses a solved case from the LSE
  - ✓ Set of system voltages and currents consistent with model
- Applies each contingency, checks for violations
  - ✓ Check power flow and bus voltage limits
  - ✓ Rank and list violations
  - ✓ Send alerts based on violation level
- Manual operation allows testing user specified cases
  - ✓ Special conditions, pre-study before switching

Project Details: Contingency Analysis using Deep Learning



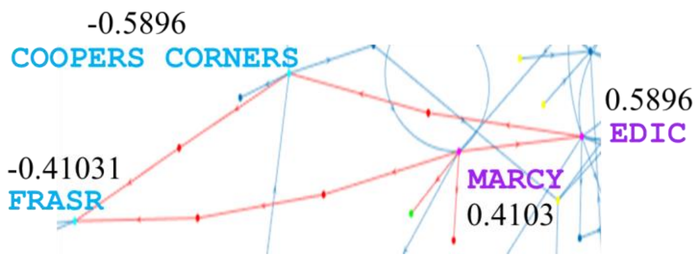
Multiple generation loss scenarios was performed in three coherent areas, western, central-northern and central-southern areas. Principal Component Analysis (PCA) was used to estimate these coherent areas in the NYS grid. The frequency deviations from PMU bus at the Marcy substation are recorded after these generation loss and is used for deep learning training. As it can be seen in the figure at left, the Marcy bus frequency behavior for different generation loss in the same coherent area is similar (same color). Hence it is intuitive to classify the generation loss scenario based on the coherent area.

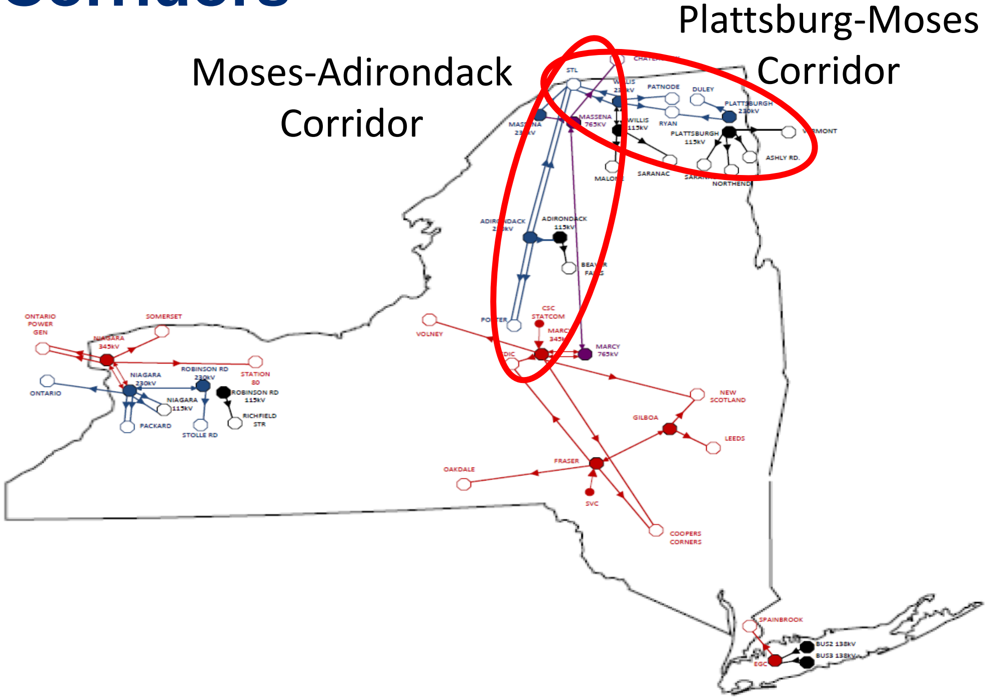


Multiple line outage scenarios was performed in central-east interface with different stress levels. In this case, the system was stressed using increasing power-flow between central-east interface. The frequency deviations from PMU bus at the Marcy substation are recorded after these line outages and is used for deep learning training. As it can be seen in the figure at right, the Marcy bus frequency behavior for the same line in different stress level is similar (same color). Hence it is intuitive to classify the line outages in different stress level.

NEW YORK STATE OF OPPORTUNITY. NY Power Authority

Voltage Stability and Area Angle limits for NYPA Corridors





Trip of two transmission lines remarked
by purple dashed lines:

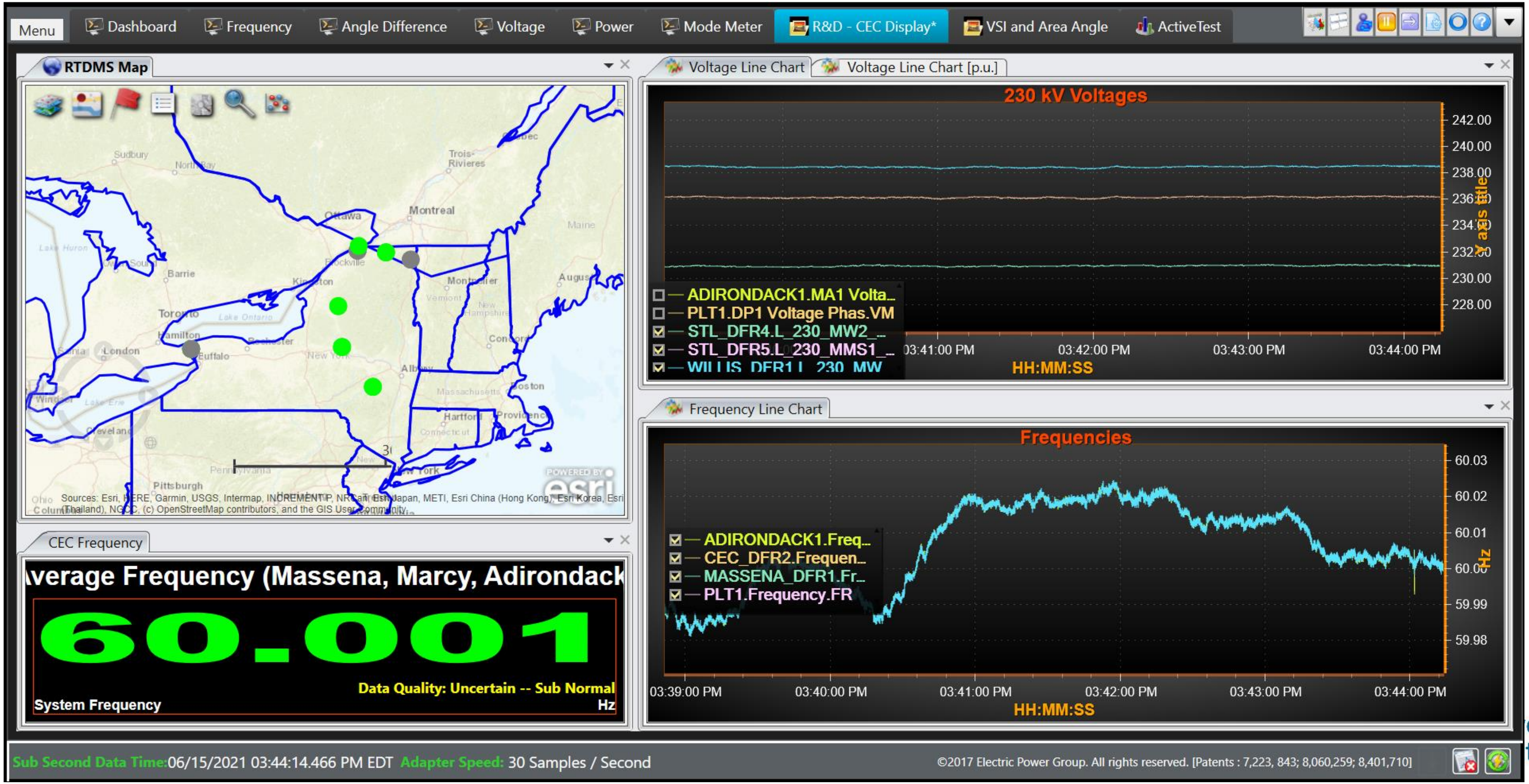
Before tripping the two lines (normal status) :
area angle = 13.75 degree

After tripping the two lines:
area angle = 28.14 degree > emergency threshold

For more info on the method please see the paper below:
Threshold-based monitoring of multiple outages with PMU measurements of area angle
(2015 IEEE Transactions on Power Systems)

NEW YORK STATE OF OPPORTUNITY. NY Power Authority

Snapshot of R&D-CEC display



Summary of Benefits

- Monitoring and Analytics of grid states in real time (less than one second) in steady state and stress conditions.
- Provide real time information about impending grid problems to system operators.
- Fast detection of line outages and stressed conditions.
- Test ability to survive the next contingency (NERC N-1 criteria requirement).
- Fast determination of proximity of the system state to voltage collapse conditions.
- Backup for EMS for grid monitoring and security violation and contingency assessment.