PMU Status – Exelon Utilities

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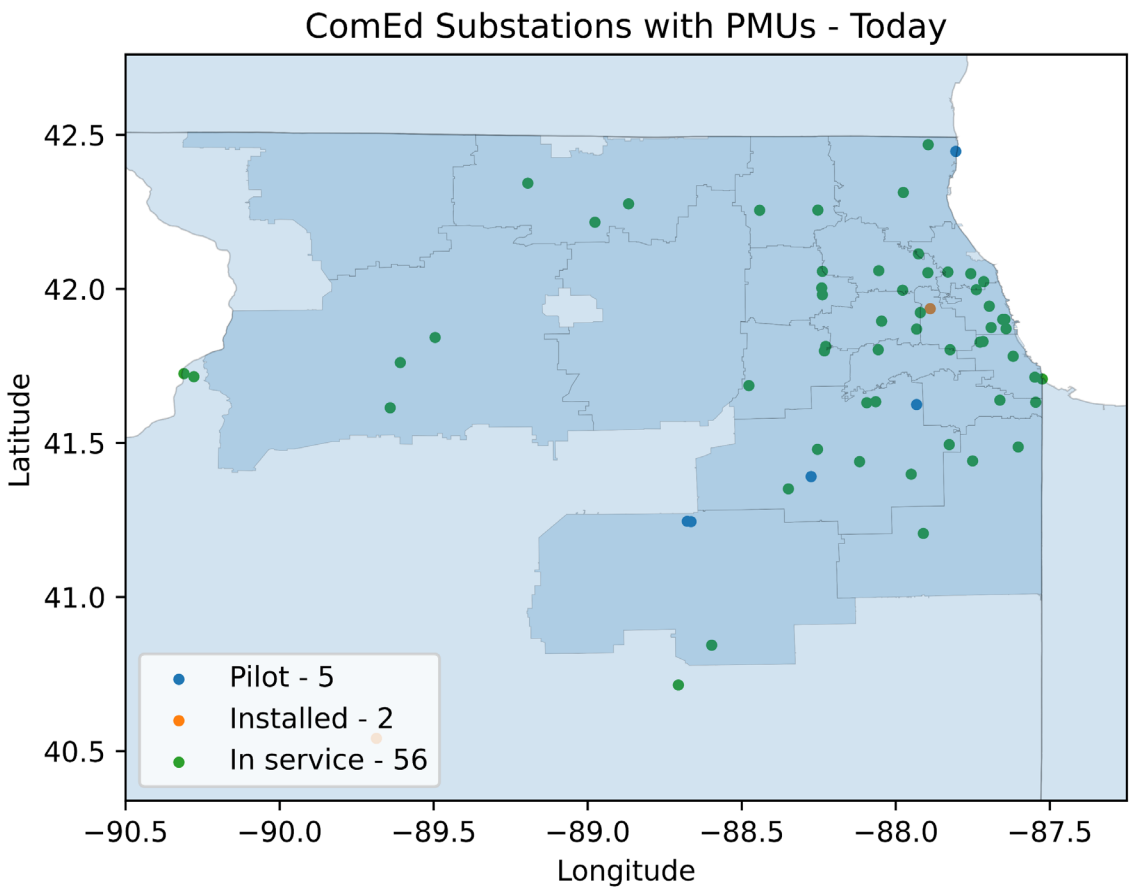
ComEd PMU Installation Status

- 148 PMUs going to PJM
- Prior to build-out starting in 2017:
  - ARRA Pilot Project
  - 7 substations
  - 12 PMUs
- Substation PDCs
  - SEL 3573
  - Moving to SEL 3555 RTAC
- 61 substations
  - 2 PMUs per substation for first installation is typical
  - As many as 6
  - Switching data center to C37.118.2 because of the number of PMUs
- Mixture of methods:
  - Planned installations
  - Opportunistic installations as part of reinforcement projects



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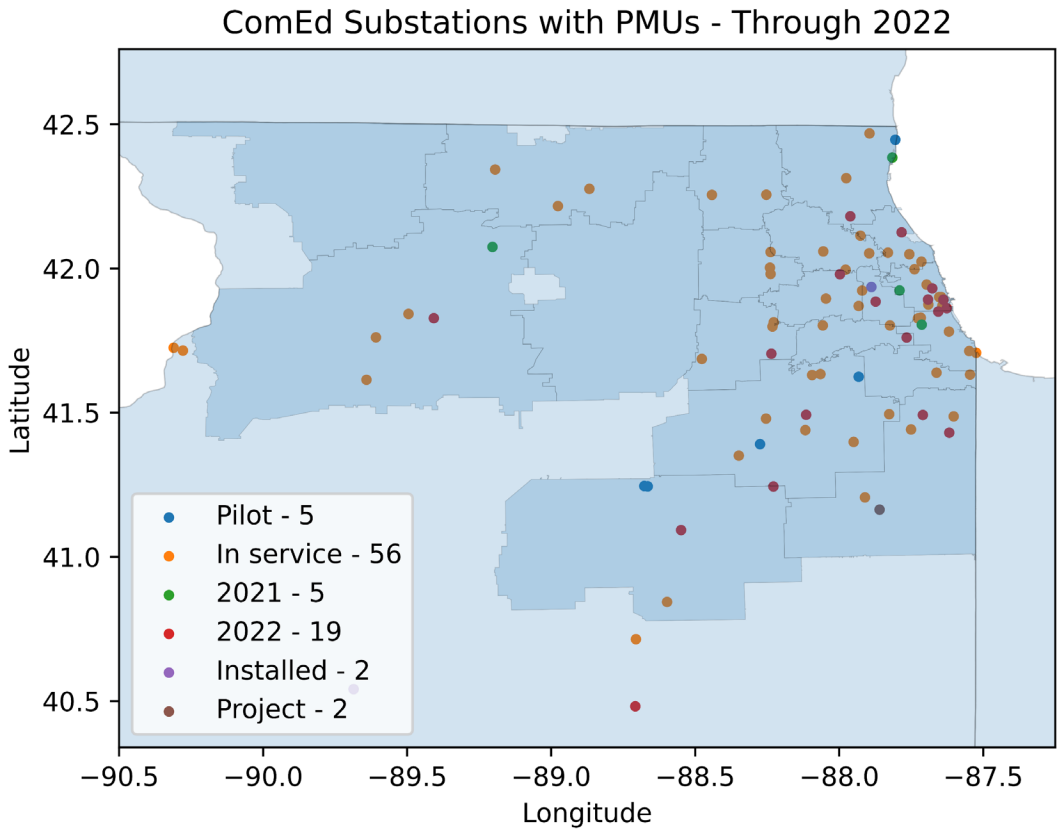
ComEd PMU Installations - Future

- Possibly 200 PMUs going to PJM by the end of 2022
- Almost all 345kV substations will have PMUs
  - Exceptions have insufficient communications or relays
  - Starting to fill in 138kV
- Retrofitting old pilot-project sites
- Station Types
  - All nuclear plants will have PMUs
  - Remaining coal and some gas
  - Starting to pick up wind farms
- LRP funding ends after 2022
  - Need to figure out what to do to clean up a few sites



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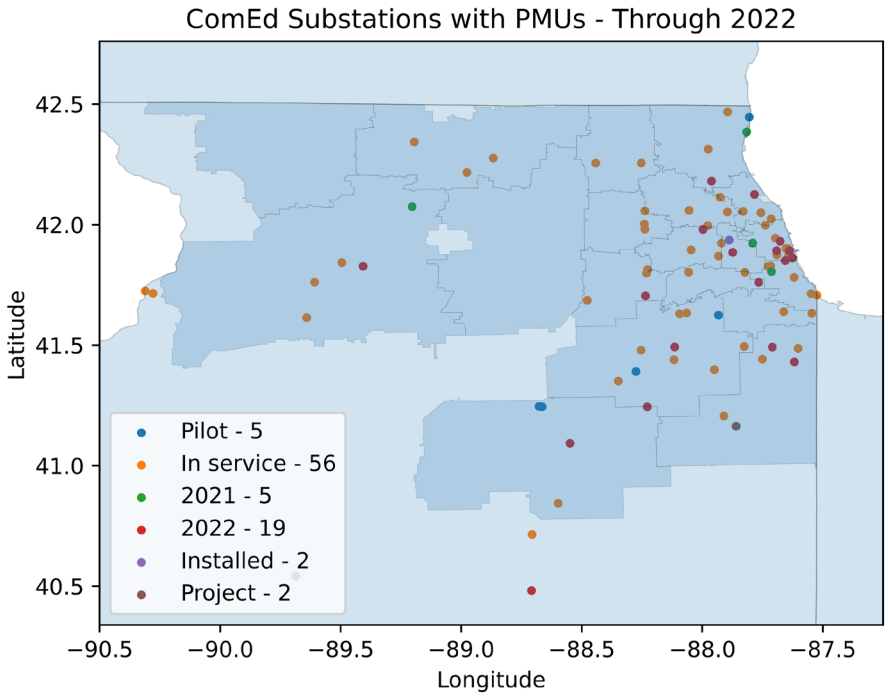
REACTS - ComEd Fiber Build-out

- Communications availability limits where PMUs can be deployed
  - Fiber is always preferred
  - At least one transmission site is WiMax
- ComEd has initiated a 15-year program to install optical fiber across the system
  - Running fiber to substations where the is no fiber today
  - Adding additional circuits to substations that already have it
- We are hoping to leverage the fiber installations to install more PMUs



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PMU DNA

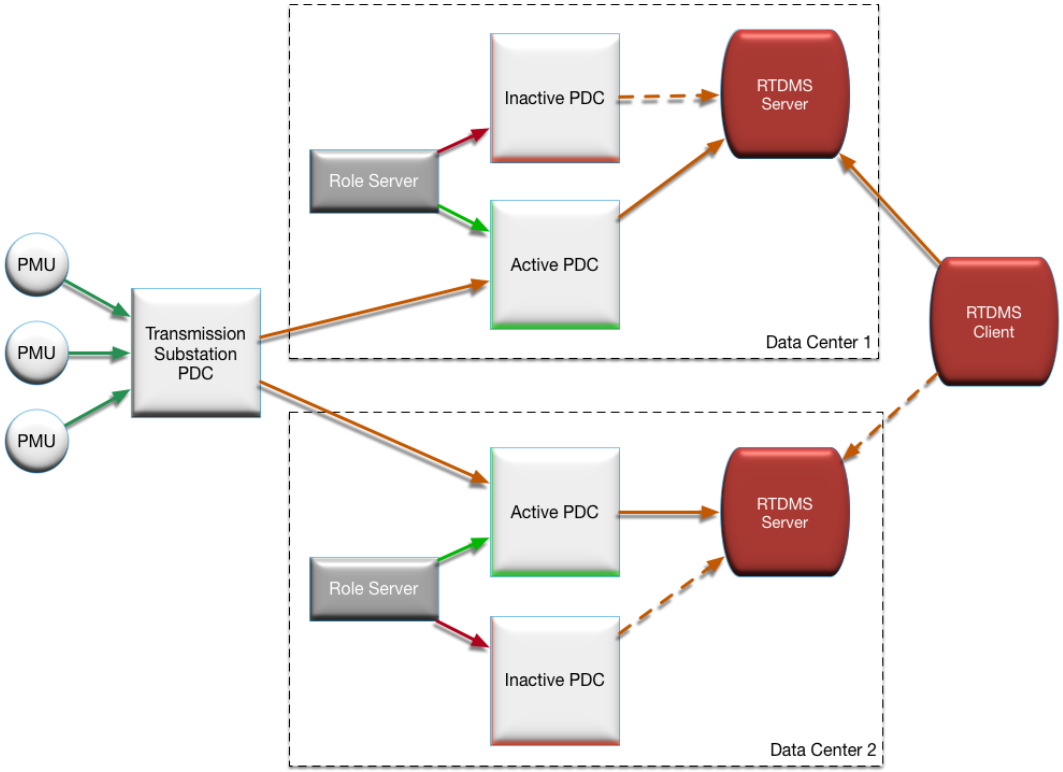
- We are inserting PMU DNA into the company
- Transmission Reinforcement Projects
  - ComEd Transmission Planning uses a checklist when developing project diagrams for reinforcement projects
  - PMU installations are now on the checklist with standard notes
    - Relays associated with upgrades get turned into PMUs
    - If the substation needs a PDC, it gets one if the cost of the project allows for it
  - Learning: It is important to word the notes on the project diagrams correctly
    - Project managers have been installing cabinets and then walking away without establishing the network connections
- Remote ends
  - It is often necessary to take a line out of service when updating relay firmware or updating settings
  - We have so many substations upgraded now with PDC cabinets that we are having to take more care to make sure that we do both ends of each line
    - For example, if a substation is getting a PDC and two or more PMUs, then the remote ends of the lines also get PMUs if a PDC has been installed.

Usage

- Post-event Analysis
  - Verification of correct relay operation
    - Was there really a fault?
  - Oscillation Analysis
    - Midwest 0.72 Hz oscillation originates within ComEd
  - New EMS is capable of consuming PMU data
  - Planned
    - Load modeling and support of DER integration
  - Future LSE
  - Control room implementation
  - Situational awareness during loss of SCADA
- EPRI Supplemental Project
  - "Data-Driven Real-time State Estimator Using Machine Learning for Transmission Systems"
    - Basically, how do you make a state estimator when you don't have complete coverage of the system?
  - What is the best way to combine SCADA and PMU data and get a functional linear state estimator

Data Center Design – Quick Summary

- Redundant data centers
- Substation PDCs send data to both data centers
- Redundancy for PDCs, historian, and application servers



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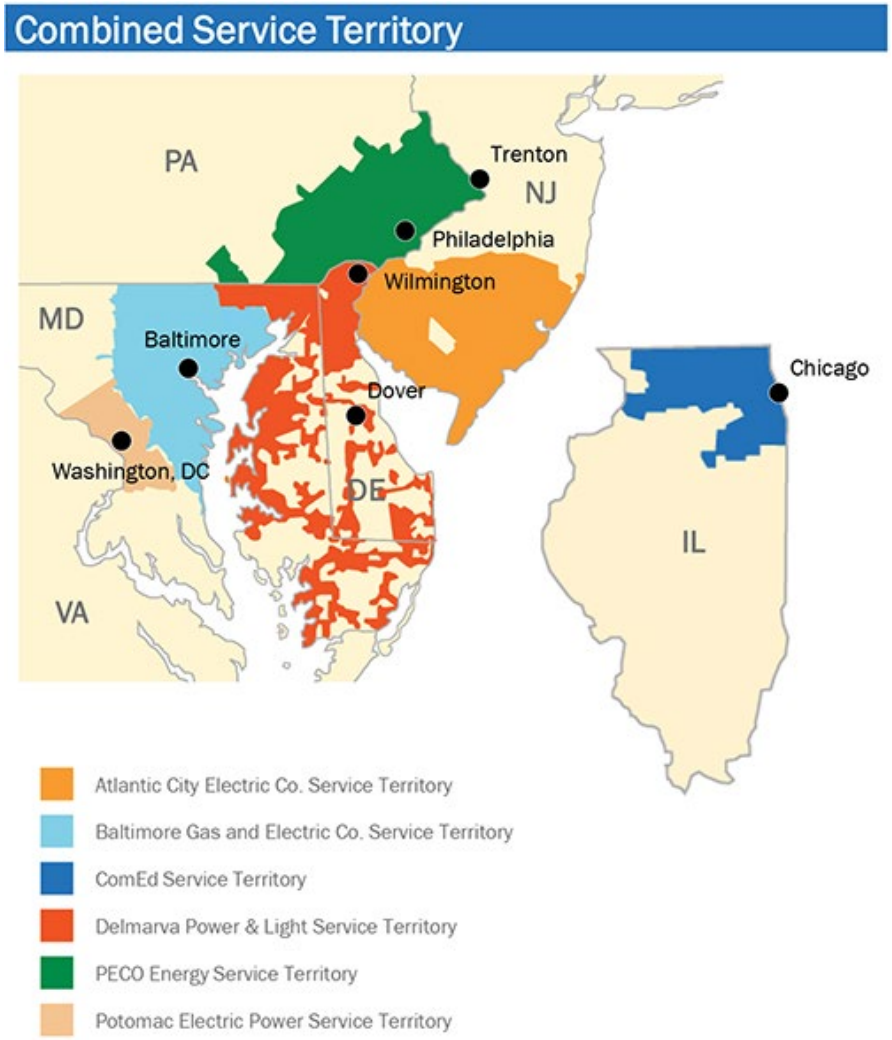
Exelon Mid-Atlantic Utilities

- Exelon's mid-Atlantic utilities
  - PECO (Philadelphia)
  - BGE (Baltimore)
  - Pepco
    - Delmarva
    - Atlantic City Electric
- All of Exelon's mid-Atlantic PMUs are from the ARRA days
- It's time to fix that



Mid-Atlantic PMU Development

- If you think it is fun getting one utility to buy in, try five
- Primary points of interest
  - **PJM's new requirements** have been a big help to get things moving
  - Situational awareness during loss of SCADA
    - Ultimate plan is for an LSE
- Data center design in mid-Atlantic will be identical to ComEd's
- Improvements due to lessons learned
- The mid-Atlantic utilities now share data and control centers for EMS and SCADA
  - Two data centers
  - PMU data from each utility will go to the two mid-Atlantic data centers

Mid-Atlantic Development – In Progress

- Working with IT to develop placeholders and funding estimates for data center implementation in the mid-Atlantic
  - Part of larger effort to identify future needs for Transmission Operations
  - Essentially identical to ComEd but will implement lessons learned
- Work needed for communications assessment in the mid-Atlantic
  - How do we get PMU data from substations to new control centers?
  - How do differing practices at the OpCos impact the implementation of PMUs in the substations
  - There will be some differences in how CIP requirements will be handled
- Working to identify mid-Atlantic SMEs
- Mid-Atlantic data-center installation in 2025 for full effort
  - Working on a “boot strap” installation in the meantime

Additional Integration

- Will start training mid-Atlantic SMEs on the applications installed at ComEd
- Expect to see more Exelon people at SMWG and NASPI meetings
  - Be nice to them!
- Data sharing between Midwest (ComEd) and mid-Atlantic utilities
  - This might be an application for STTP
- Integration with OSI Monarch EMS
  - Sending PMU data has been tested
    - Issues with interpretation of C37.118 standard – working on it
- We will be on the hook for control-room deployment
  - 202x'ish?

The End

Any Questions?