Synchrophasor Measurements at Distribution Systems

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ComEd
An Exelon Company

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Outline

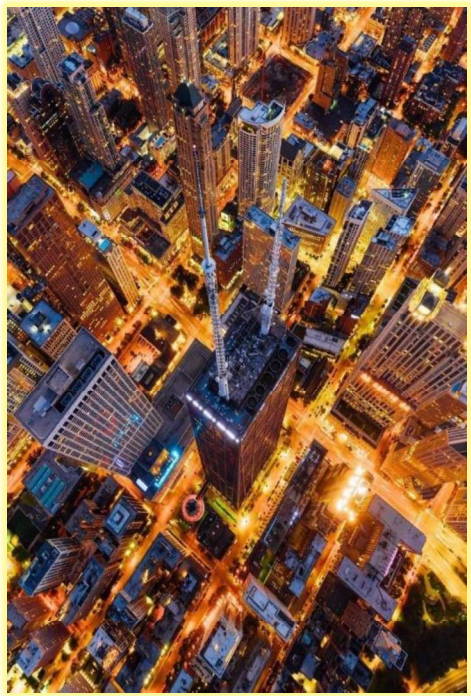
- ComEd Overview
- ComEd PMU History
- Distribution PMU Deployment
- Applications
- Roadmap and Next Steps

ComEd, An Exelon Company

Our Company:
- One of six utilities owned by Exelon. (Exelon also owns generation and energy sales businesses.)
- 6,400 Employees
- Service Territory: 11,428 square miles

Our Customers:
- 4 million customers in northern Illinois, including the City of Chicago

Our Grid:
- Peak Load: 23,753 MW (7/20/2011)
- 553,800 distribution transformers
- 66,200 circuit miles of primary distribution
- 52% overhead, 48% underground
- 5,800 circuit miles of transmission
- 93% overhead, 7% underground



ComEd PMU History

In 2015, ComEd initiated development of a road map and strategy for wide-scale operational use of Phasor Measurement Units (PMUs) in its transmission and distribution system.

In this roadmap, many distribution functions/applications were identified for PMUs in the following five categories:

Distributed Energy Resource (DER) Integration	Distribution System Operations	Wide-Area Monitoring, Protection, Automation and Control (WAMPAC)	Asset Management and Reliability	Planning and Analysis

There were also several benefits and deployment challenges identified and qualitatively compared for the distribution applications.

Key Distribution Synchrophasor Functions

- Pilots focused on demonstrating key synchrophasor capabilities at various levels of complexity
  - Microgrid operation
  - Distribution state estimation
  - Voltage and current profile monitoring
  - Real-time system operations (limited scope)
  - DER monitoring (Solar PV and Energy Storage)
  - Condition monitoring and asset management
  - Smart inverter monitoring and control
  - Incipient fault and failure detection
  - Root-cause and post-mortem analysis
  - Monitoring of critical infrastructure and large customers

Where it Began: 2018 Pilot Installations

- ComEd targeted installation of distribution PMUs, PDCs (Phasor Data Concentrators), and other associated equipment at 7 key locations:
  - Substations feeding ComEd's ICC-approved microgrid
  - Substation serving a 10MW solar farm in Southeast Chicago
  - Substations feeding Chicago's two international airports
- Synchrophasor data is collected by substation PDCs and sent to a central PDC and synchrophasor data management system.
- In addition to the above pilots, the project team has installed a Proof-of-Concept (PoC) synchrophasor data system in a laboratory environment for troubleshooting and demonstration purposes.

A Three-Tier Approach

Substation Level PMU

- 12kV and 34kV feeder relays
- Transformer relays
  - Situational awareness of feeder heads and medium voltage busses

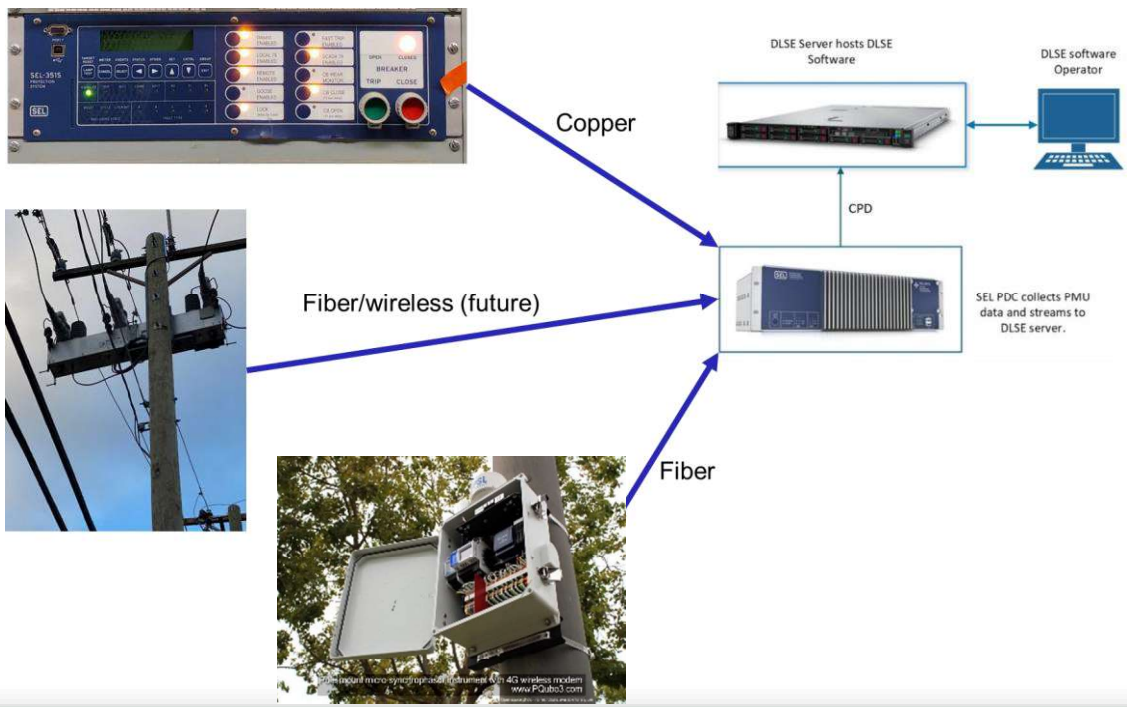
Feeder Main-Stem PMU

- Distribution automation devices (in-development)

Feeder Edge PMU

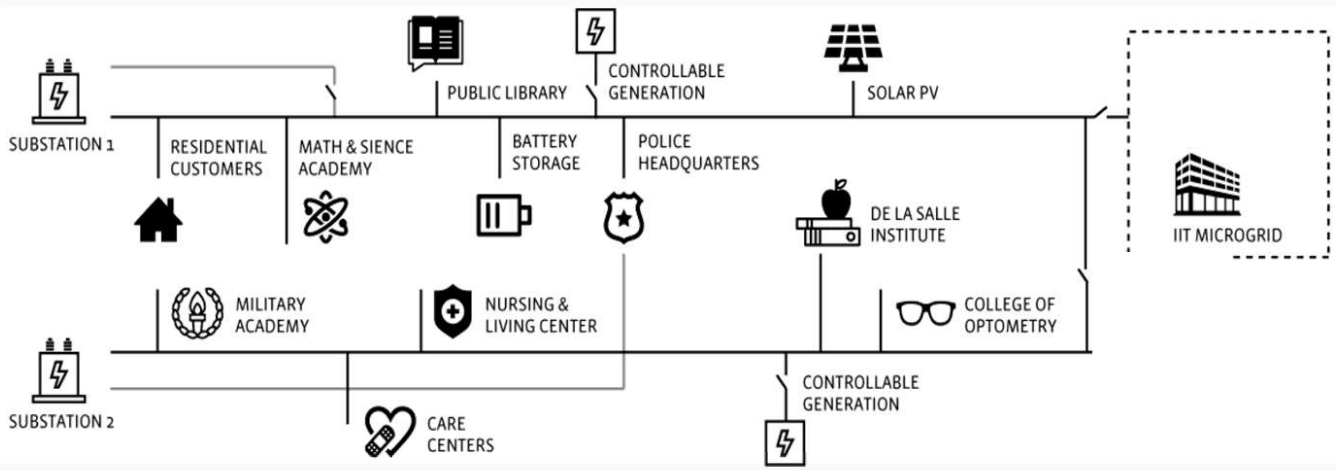
- Standalone microPMU
- Distributed generation

Architecture



Bronzeville Community Microgrid (BCM) Situational Awareness and Control

- The Bronzeville Community Microgrid enables a green, resilient, sustainable neighborhood for consumers.
- 7 MW aggregate load, serving approximately 1,000 residences, businesses and public institutions
- Installation of first utility-operated microgrid cluster powered by DER including solar PV and energy storage
- Demonstration of advanced technologies supported by six grants from the Department of Energy
- These technologies have been developed with partnerships with universities, vendors, and national labs



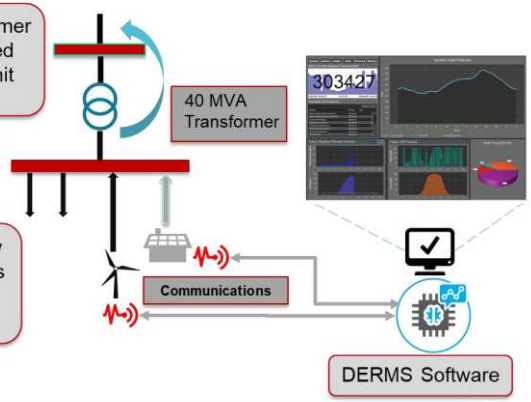
Distribution Linear State Estimator (DLSE)

- Three-phase DLSE platform has been developed to leverage the PMU data that provides
  - observability analysis,
  - optimal PMU placement,
  - bad-data detection,
  - monitoring the microgrid and microgrid controller,
  - alarming, archiving and visualization for situational awareness
- Tested and demonstrated in ComEd's GrIT lab using RTDS that simulates virtual PMUs modeled within BCM
- Developing the ability to identify switching and other events in the microgrid

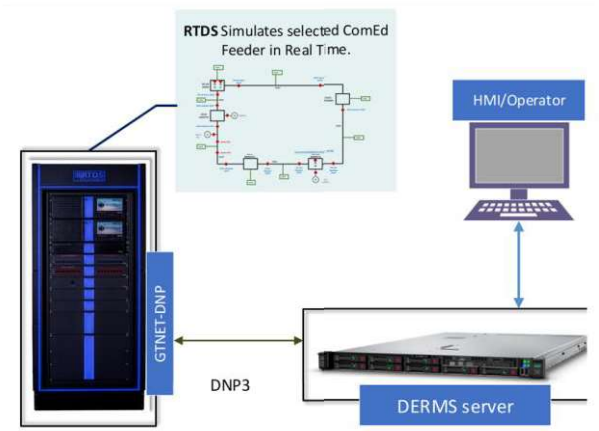
DERMS for Renewable Integration

ComEd is deploying DERMS as a non wire alternative (NWA) to mitigate the overloading of substation transformer due to higher level of PV integration. DERMS monitors transformer loading, DER output, system conditions, and will send signals to manage DERs if any system violations occur.

The substation transformer will experience back feed beyond its allowable limit with added PV



High-speed, low-latency reliable communications is needed for DERMS operation.



- Traditional method requires significant upgrades including one substation transformer and 138kV line extensions
- DERMS provides an alternative solution to customers by monitoring and managing the DER in real time, which could avoid costs of about $30M
- For this pilot, it will need to curtail only up to 5% of total energy per year based on the analysis using annual historical data and solar forecast, for the 6 MW of solar scenario

Observability Analysis for DER Rich Area

- Mendota / Dixon 34 kV loop, with addition of some 12 kV portions with Solar PV
- Includes 3 windfarms and 3 solar PVs
- Model reduction/refinement from CYME to DLSE complete – more than 300 nodes
- PMU placement complete and single-line-diagram (SLD) was created – 39 PMUs
  - Ten additional operating modes and topologies considered for full observability

Key Customer Monitoring: Airport Observability Analysis Study

- Chicago Airport area consists of critical customers
- ComEd has carried out observability analysis and PMU placement study to assess the PMU infrastructure required for complete observability of key customers in the area
- Airport area consists of Networked and Radial circuits
- The 6 feeders which supply the core airport 480 V bus (in “Networked” configuration) from two substations
- The 19 feeders arranged in radial configuration (the “Radial” circuit) feeding areas around the airport
- 6 Networked feeders require 72 PMUs for complete observability in base case operation
- 19 Radial feeders require 98 PMUs for the complete observability in base case operation

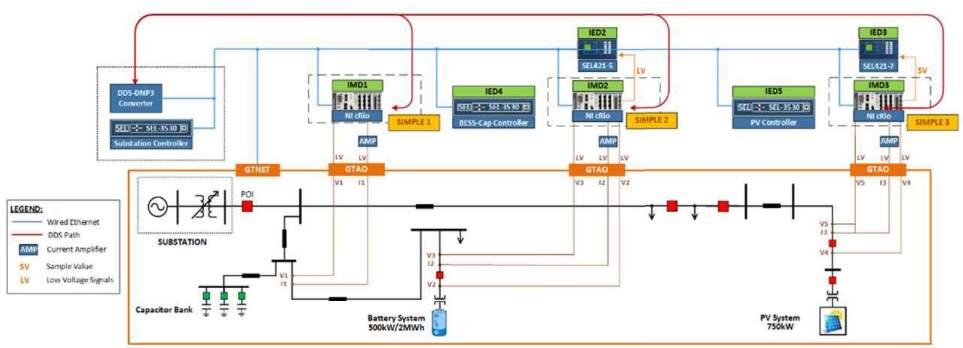
SIMPLE (Sensors with Intelligent Measurement and Low-cost Equipment)

Budget: $2.7M DOE Project

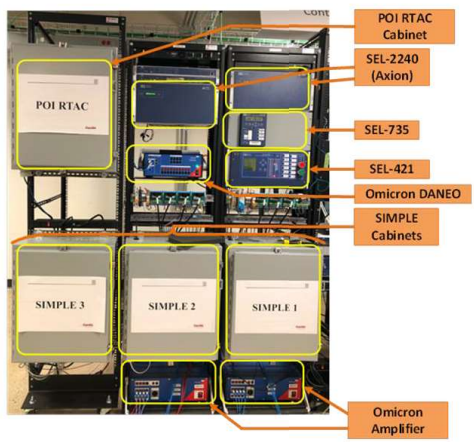
Objective: Development and introduction of voltage/current sensors with enhanced characteristics (accuracy, bandwidth and harmonic range) and high measurement granularity for medium voltage distribution system monitoring, DER monitoring, protection, and controls

Use Cases:

1. Distribution Circuit Monitoring (DCM)
2. Automatic Resource Control (ARC)



HIL Testbed schematic



HIL laboratory test setup

Roadmap and Next Steps

- Leverage point-on-wave data
  - Predictive modeling
  - Pre-event detection
- 5-year programmatic strategy
- Stream C37.118 data from capable DA devices
- Three-tiered approach
  - Substation
  - Distribution main-stem
  - Feeder edge
- DLSE Field Deployment
- Grid Analytics Platform Pilot