ComEd PMU Deployment – Lessons Learned (We will figure this out, eventually)

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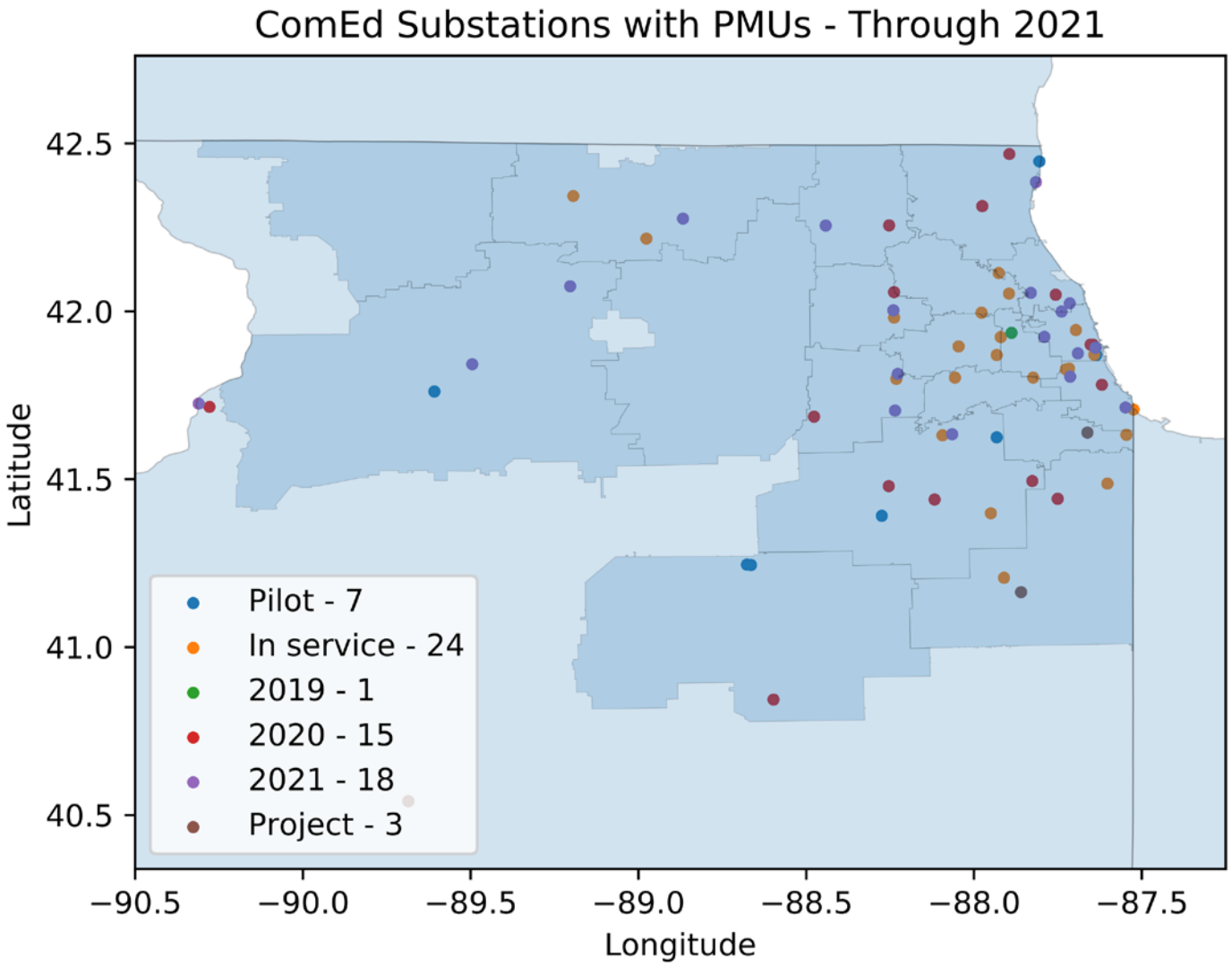
Go Big or Go Home!

- Budgeted projects starting in 2017/2018 through 2022
- By the end of this process:
  - We will have PMUs at almost all 345kV substations and many 138kV substations
  - Additional substations and PMUs to be implemented during reinforcement projects
    - Already seeing benefits from this
    - New substation coming in later this year. Every line will have a PMU
- To date:
  - 86 transmission PMUs
  - 100+ distribution PMUs
- **Will have 100+ transmission PMUs installed by the end of the year**

2021 Build-out



Exelon

How We Did This

Solid design up front

- When it came time to implement the data center work, everyone knew what to do
  - Design for expandability
    - Initial sizing is for 500-1000 PMUs – additional PDCs can be added as necessary
  - Take future CIP requirements into account
    - The system is segmented so that the necessary parts can be updated to meet CIP requirements without affecting other parts

- When we go into a substation, we make it PMU ready
  - Standalone cabinet containing a substation PDC and whatever else equipment is necessary
    - The cabinet design is standardized across the company
    - All substations are upgraded to an SEL 2488 clock if necessary
      - Higher resolution
    - Two or more PMUs will be added when a substation is upgraded
  - Substations are upgraded during reinforcement projects if possible
    - During new construction or substation rebuilds, PMUs are installed on all lines and whatever other equipment makes sense

- PMU capability is enabled during relay firmware upgrades
  - Doing this eliminates future line outages

Standardization

Design

- Substation design is standardized
  - Substation modifications have to be approved for NERC compliance
    - A standard design makes this easy
    - Upgrading a substation for future CIP considerations should not require removing or replacing equipment
  - Dedicated cabinet/panel for PDC and associated equipment
    - Upgradable for CIP
  - Upgrade clock if necessary

Process

- The process for bringing a substation online is also standardized
  - IT requires a 2-week burn-in period for new networking equipment
    - Only necessary if we are adding firewalls or routers
  - A 2-hour conference call is scheduled for after the burn-in is complete
    - All relevant groups are on the phone or available when the new PDC is brought online
    - Most issues are configuration errors – having everyone there makes it easy to resolve configuration problems
    - Sometimes the conference call lasts only 5 or 10 minutes

Be Standard – But Not Too Standard

We currently specify SEL 3573 PDCs in substations

- Deployment without a substation PDC not currently necessary
  - We probably could if there was a need
- Investigating how to use SEL 3555 as substation PDC
  - We already have a lot of them deployed already
    - Substantial cost savings from not having to deploy a new device
    - Avoid PMU-specific cabinet where possible
    - Not as user friendly for field configuration of PMU data
  - Conducting opportunistic testing to see if we can do this reliably

When not everything works…

Standardization eliminates some of the variables, making it easier to diagnose some problems

- Artificial network limits
  - Bandwidth limits on routers accidently left in place
  - We know about this but it still happens
    - We start data to first data center – everything ok
    - We start data to second data center – second data center works but first one quits
    - Shut everything down immediately!
- Misconfigured PDCs (other than IP addresses or IDs)
  - New PMUs were not added to the output streams in the substation PDCs
  - Field engineers are becoming more and more familiar with the equipment
    - Misconfigurations happen less often
    - Office engineering staff needs to be able to talk field engineers through configuration issues
      - Never underestimate the value of cell phone video
  - Planned visit to present PMUs to field engineers cancelled due to COVID-19