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Advanced Technologies for Resilient and Sustainable Grid

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Outline

- ComEd Overview
- Vision of Future Grid
- ComEd Grid Integration and Technology (GrIT) Lab
- Selected Projects
    - DOE SHINES: MicroGrid Controller Development and Testing
    - Distributed Energy Resources Management System (DERMS)
    - DOE ENERGISE: Security Constrained Economic Optimization of DERs
    - Grid-Edge Smart Sensor + Distributed Linear State Estimator (DLSE) R&D
    - Energy Storage Solutions for Targeted Customers
- Community of the Future

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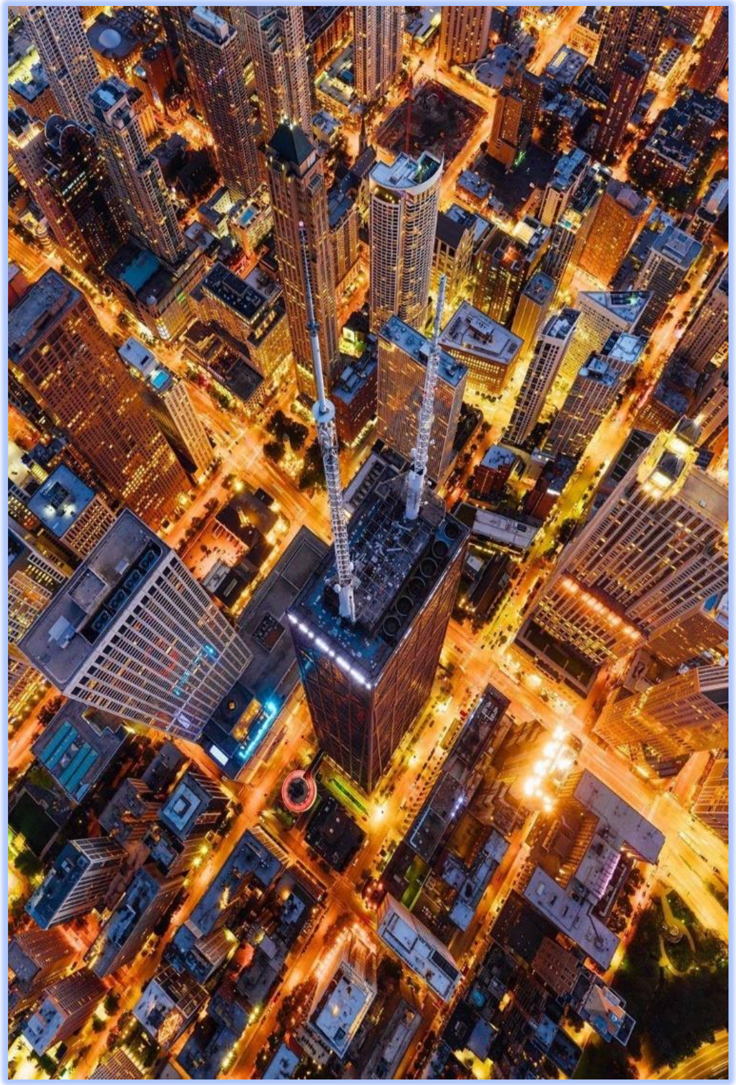
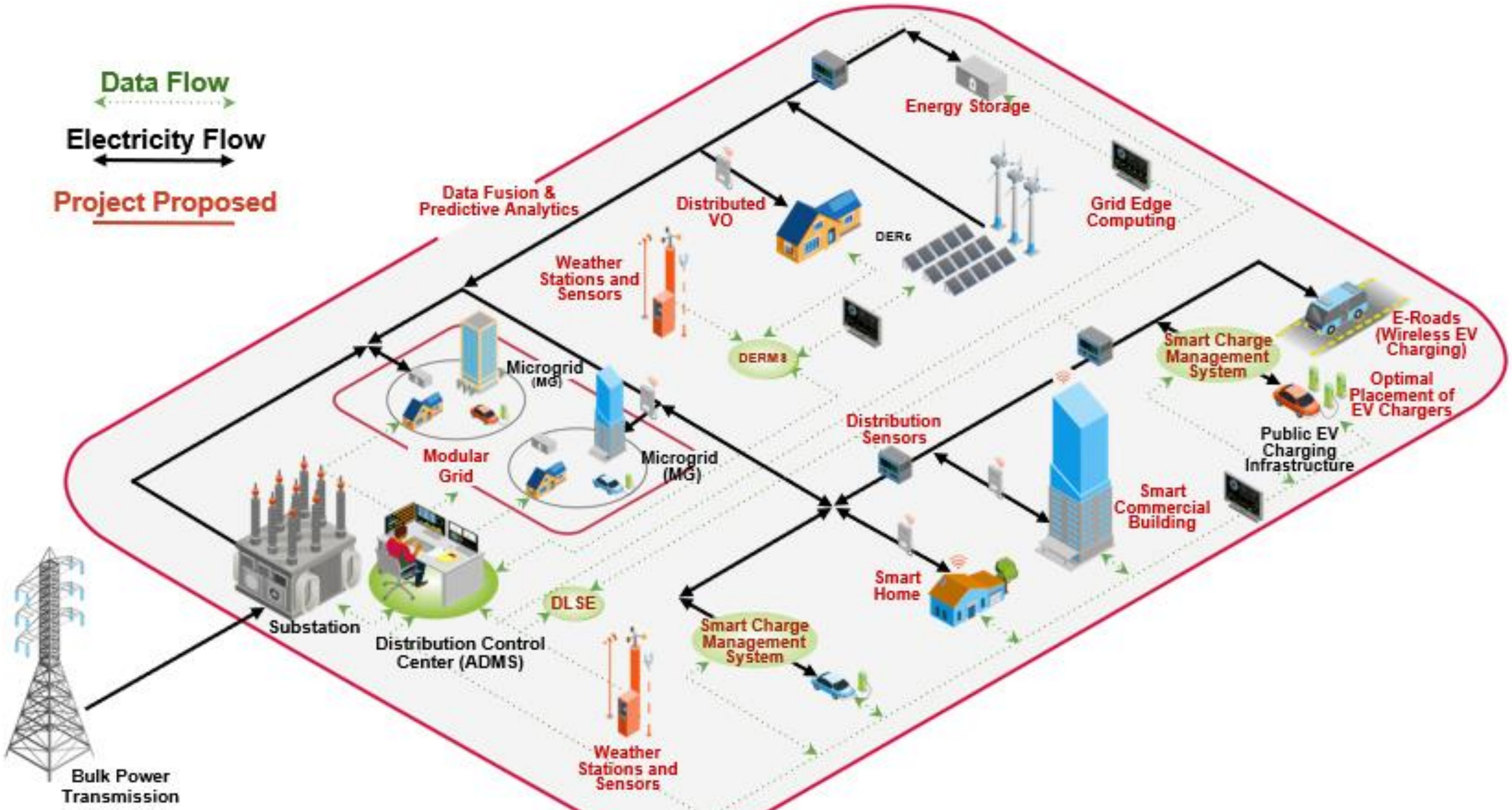
Our Company:
- One of six utilities owned by Exelon. (Exelon also owns generation and energy sales businesses.)
- 6,400 Employees
- Service Territory: 11,428 square miles

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



Vision of Future Grid



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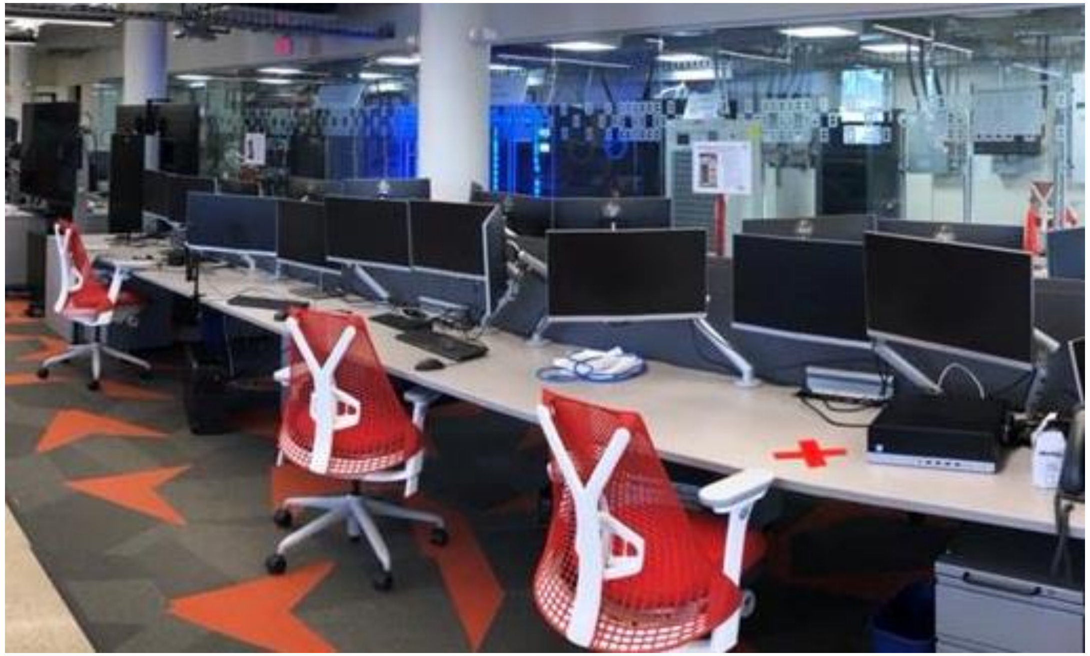
ComEd Grid Integration and Technology (GrIT) Lab



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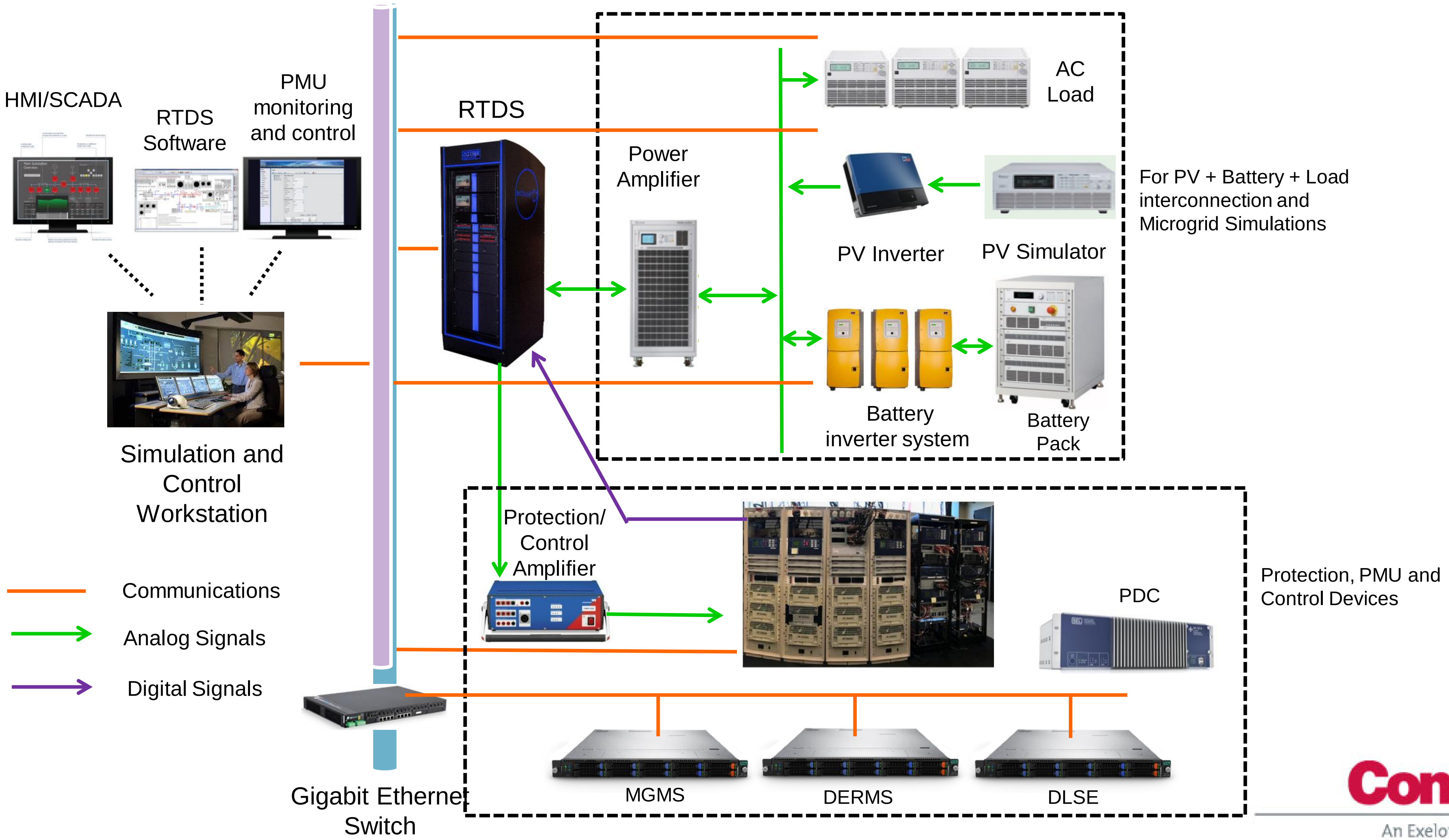
ComEd Grid Integration and Technology (GrIT) Lab Architecture



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Demonstrating Cutting-Edge Technologies Funded by DOE

SHINES

- Awarded $4M to support the use of solar PV, Battery Energy Storage System, smart inverters and microgrid master controller to demonstrate microgrid integrated solar storage technology (MISST)

SIMPLE

- Awarded $1.5M to develop sensor platform with advanced features to support distributed energy resource (DER) penetration: Sensors with Intelligent Measurement Platform and Low-Cost Equipment (SIMPLE)

XFC EV

- Partnership with Virginia Tech to develop and test a cyber-secure extreme-fast charging (XFC) station for electric vehicle (EV) within the Bronzeville area
- 350kW XFC charger will be tested in ComEd lab

MUD EV

- Partnership with the Center for Sustainable Energy (CSE) to install EV charging stations serving multi-unit dwellings (MUD) and curbside charging needs in Bronzeville
- Will support the development of best practices for this type of program

Blockchain Technology

- Develop and test a blockchain-secured transactive energy and demand response platform
- Partnership with BEM Controls & Virginia Tech (VT)

FAST DERMS

- Develop and demonstrate a federated architecture – FAST-DERMS with management of both utility-scale and small-scale DERs
- For reliable, resilient, and secure distribution and transmission grid services

CITADELS

- Enable networked microgrids (NMG), and their component DERs, to operate distributedly using collaborative autonomy concepts implemented in an OpenFMB (Open Field Message Bus) architecture.

ENERGISE

- Demonstrate cost-effective integration of behind the meter PV by utilizing Battery Energy Storage and DER real time management system

BTM DER-AMI Integration

- Risk-informed Hierarchical Control of Behind-the-Meter (BTM) DERs with AMI Data Integration
- Helping advance integration, monitoring and control of increasing number of DER assets in electric power grid

Microgrid Master Controller

Completed (2018)

- Develop, design and test the microgrid master controller (MMC) capable of managing clustered microgrids.

SECURE

- A de-centralized Autonomous Control System (DAC) for Resilient Community Microgrids – The technology will be tested in ComEd lab
- Partnership with EPRI, NREL, GridScape, Yashaw Solectria Solar, ComEd, PG&E, Xcel, SCE

Hybrid State Estimation

- Partnership with Northeastern University to develop Graph-Learning-Assisted State Estimation method by utilizing the diverse set of existing data sources (SCADA, AMI, PMU, smart inverter, weather data) to improve system-wide situational awareness

Cyber Resilience Project

- In partnership with VT, GE Corp Research, use block-chain-based distributed control architecture to coordinate multiple hybrid solar PV plants to provide grid reliability and resilience services to cyberattacks

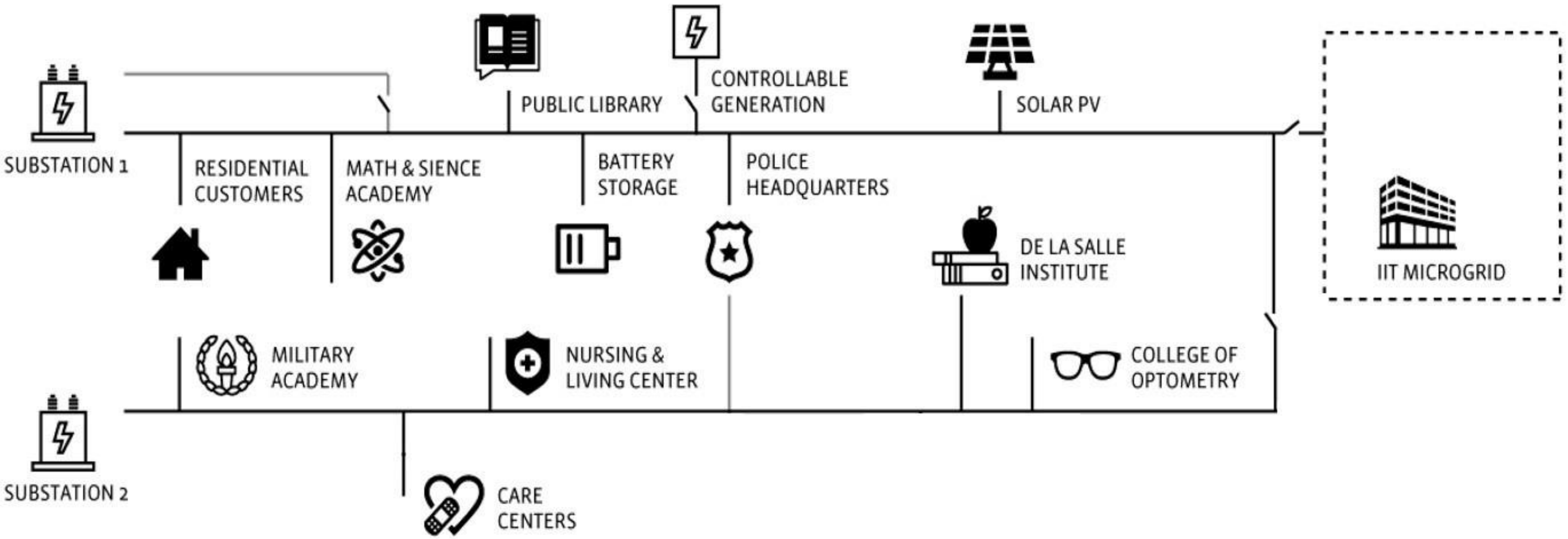
ABSCoRES*

- Partnership with Lehigh University, MIT, ANL and Siemens, to develop coherent asset and risk management framework in power systems with application of the method utilized by banking scoring and rating
- This is ARPA-e supported project

NOTE: *Participating in an advisory role with no budget commitment from ComEd

Bronzeville Community Microgrid

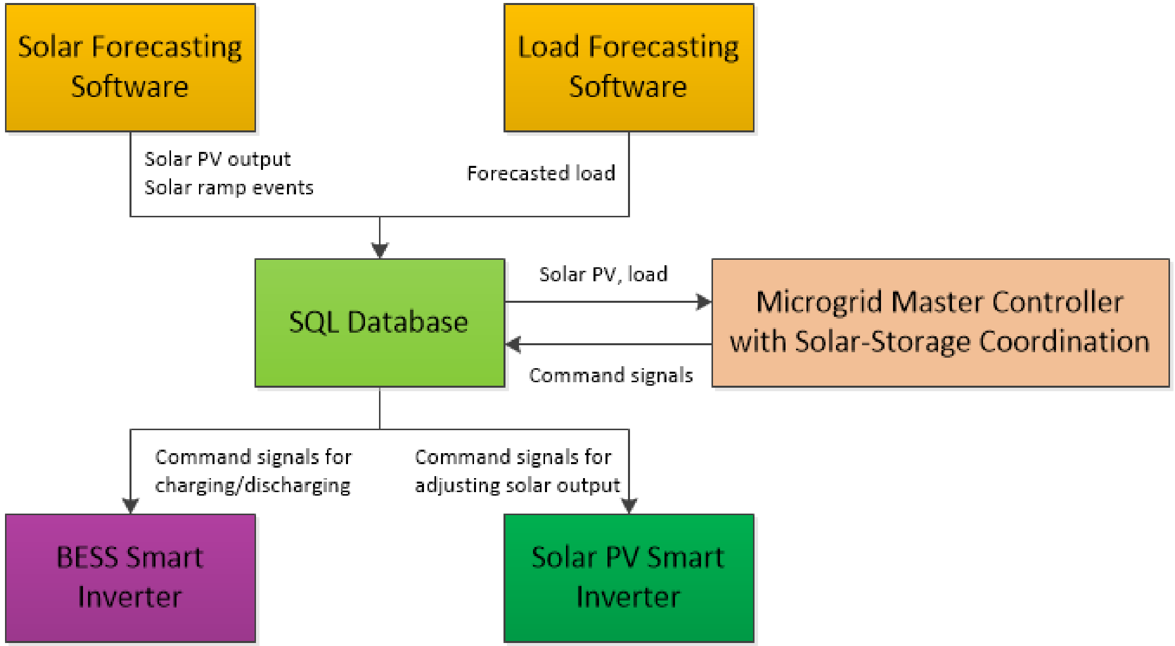
- 7 MW aggregate load, serving residences, businesses and public institutions
- Phase I – 2.5 MW load, solar PV and Battery Energy Storage System, mobile diesel generation for testing
- Phase II – Sufficient controllable generation to meet load
- Demonstration of first utility-operated microgrid cluster
- U.S. Department of Energy grants awarded to ComEd develop and demonstrate technologies to improve reliability, resilience and sustainability



ILLINOIS INSTITUTE OF TECHNOLOGY · UNIVERSITY of DENVER · NREL Transforming ENERGY · Argonne NATIONAL LABORATORY · QUANTA TECHNOLOGY · SIEMENS · NuGrid

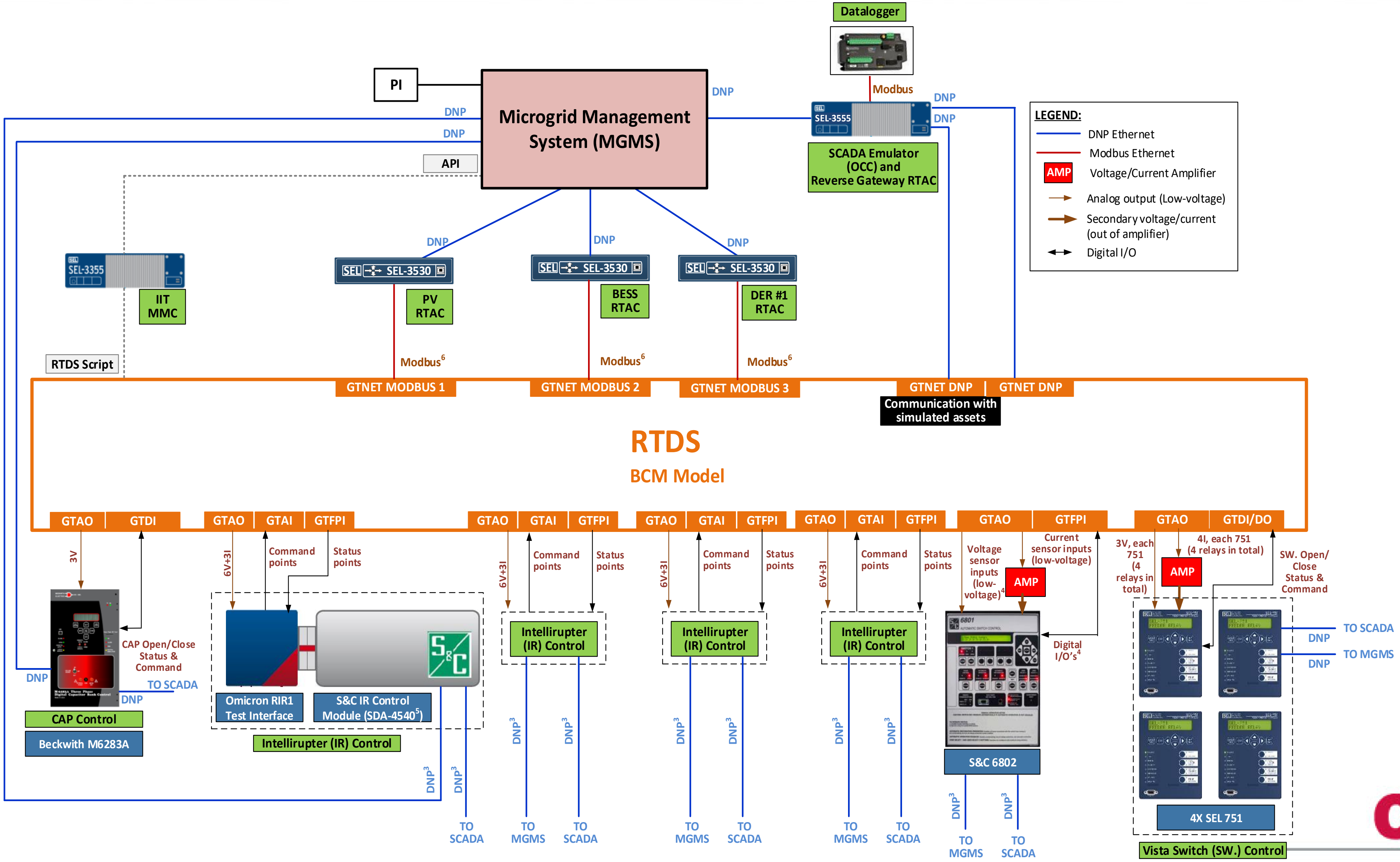
Microgrid Integrated Solar Storage Technology (MISST) Project

- $8 million DOE SHINES project. Development and demonstration of integrated, scalable, and cost-effective technologies for solar PV that incorporate energy storage in a microgrid
- Enhanced microgrid controller with solar-storage control was tested with the BCM model



Solar-storage controller high-level architecture

Microgrid Controller HIL Testbed Setup



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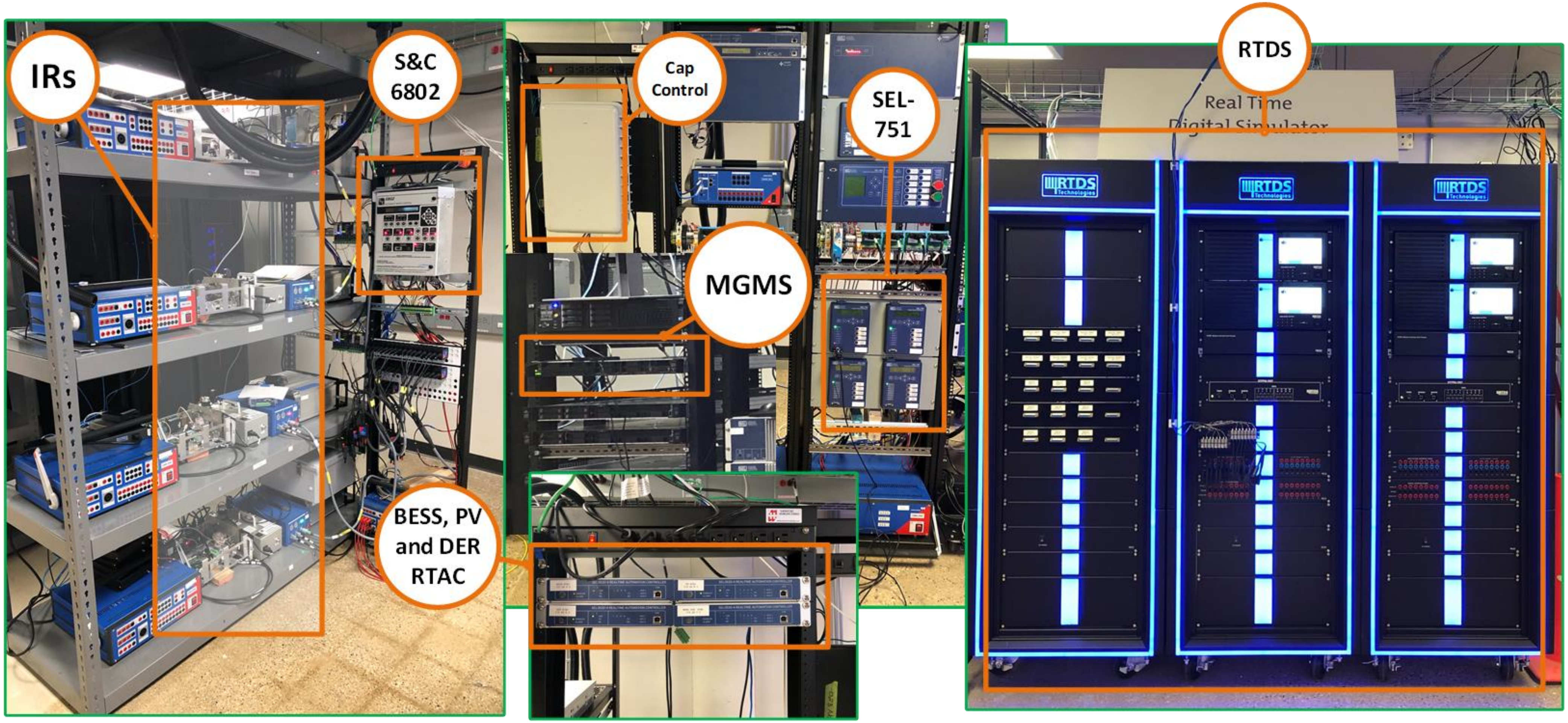
Microgrid Controller HIL Testbed

- A comprehensive lab setup has been designed and implemented for Microgrid Controller validation



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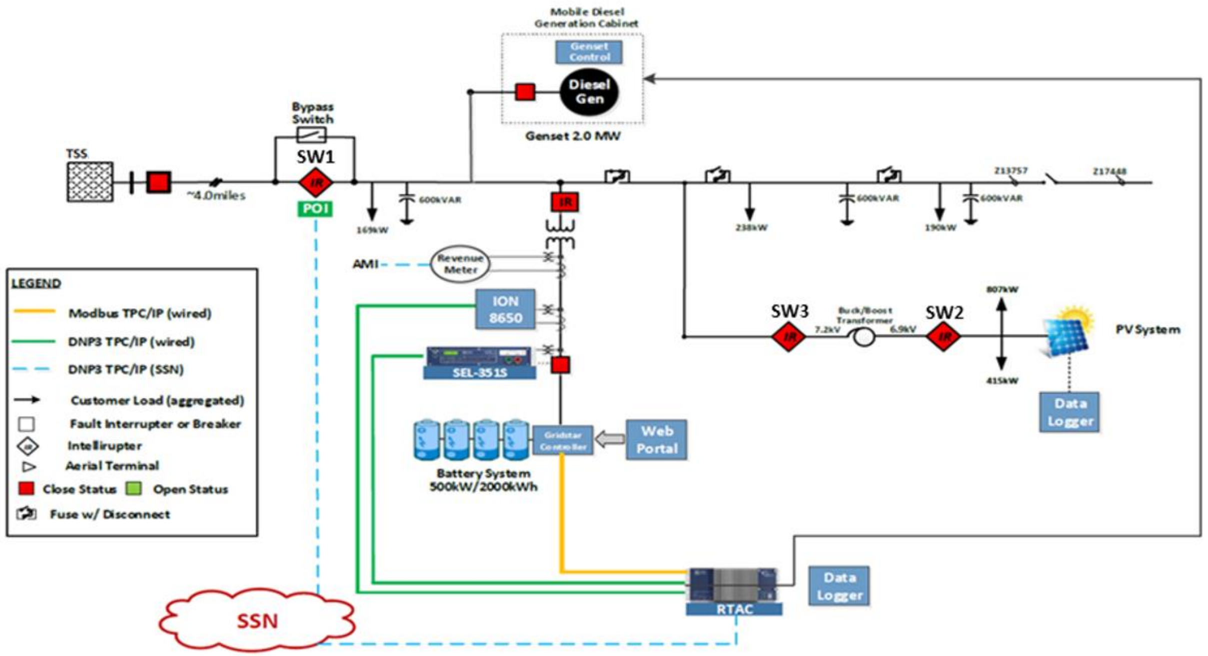
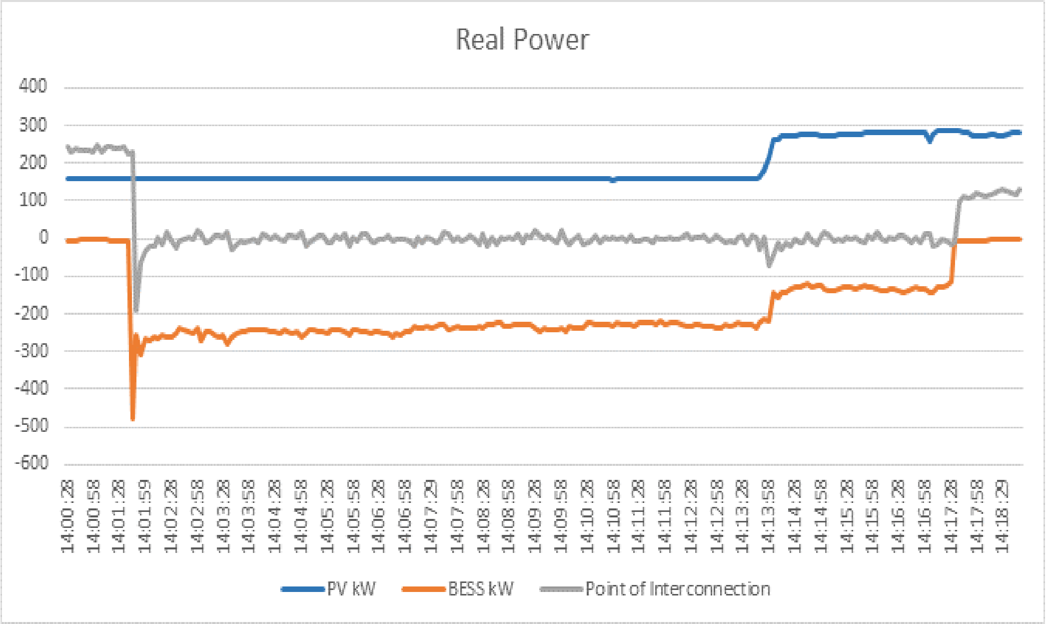
Demonstrating Resilience through Islanding Capability

- Successfully tested and demonstrated islanding ability on portion of the BCM feeder using BESS, PV and mobile generator



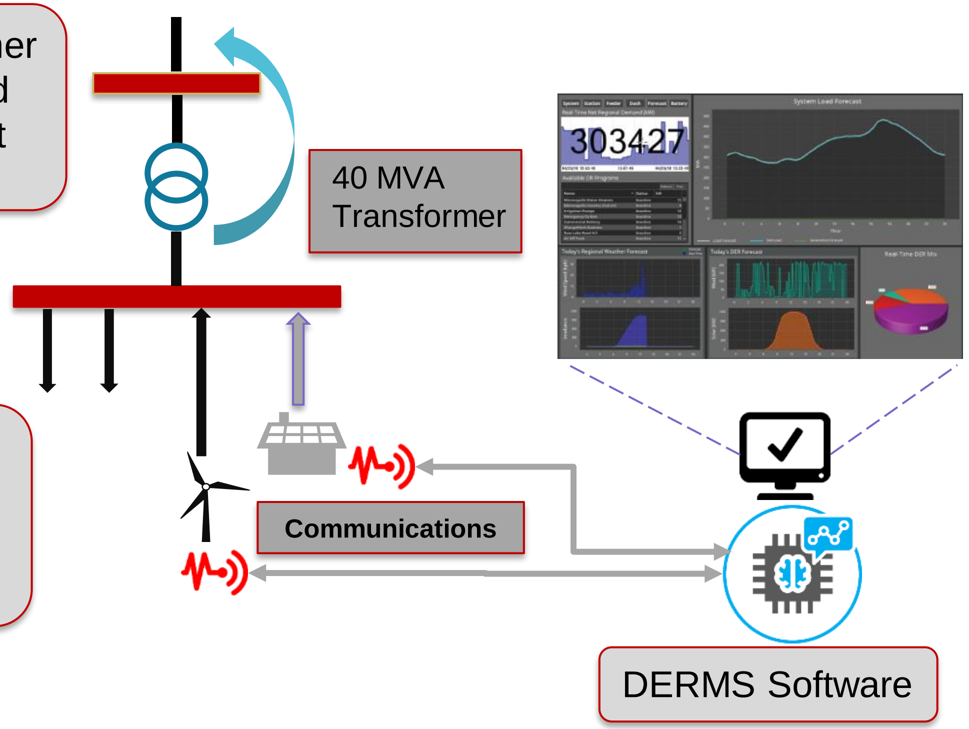


Schematic diagram of the test system

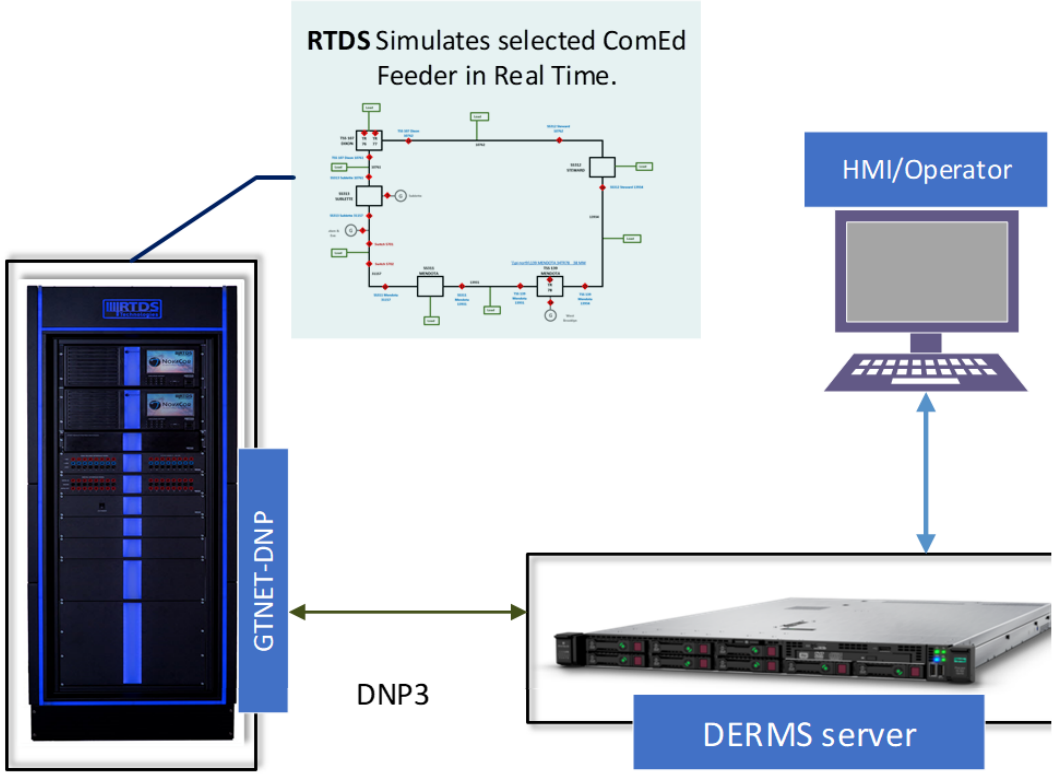
DERMS for Renewable Integration

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 solutions 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

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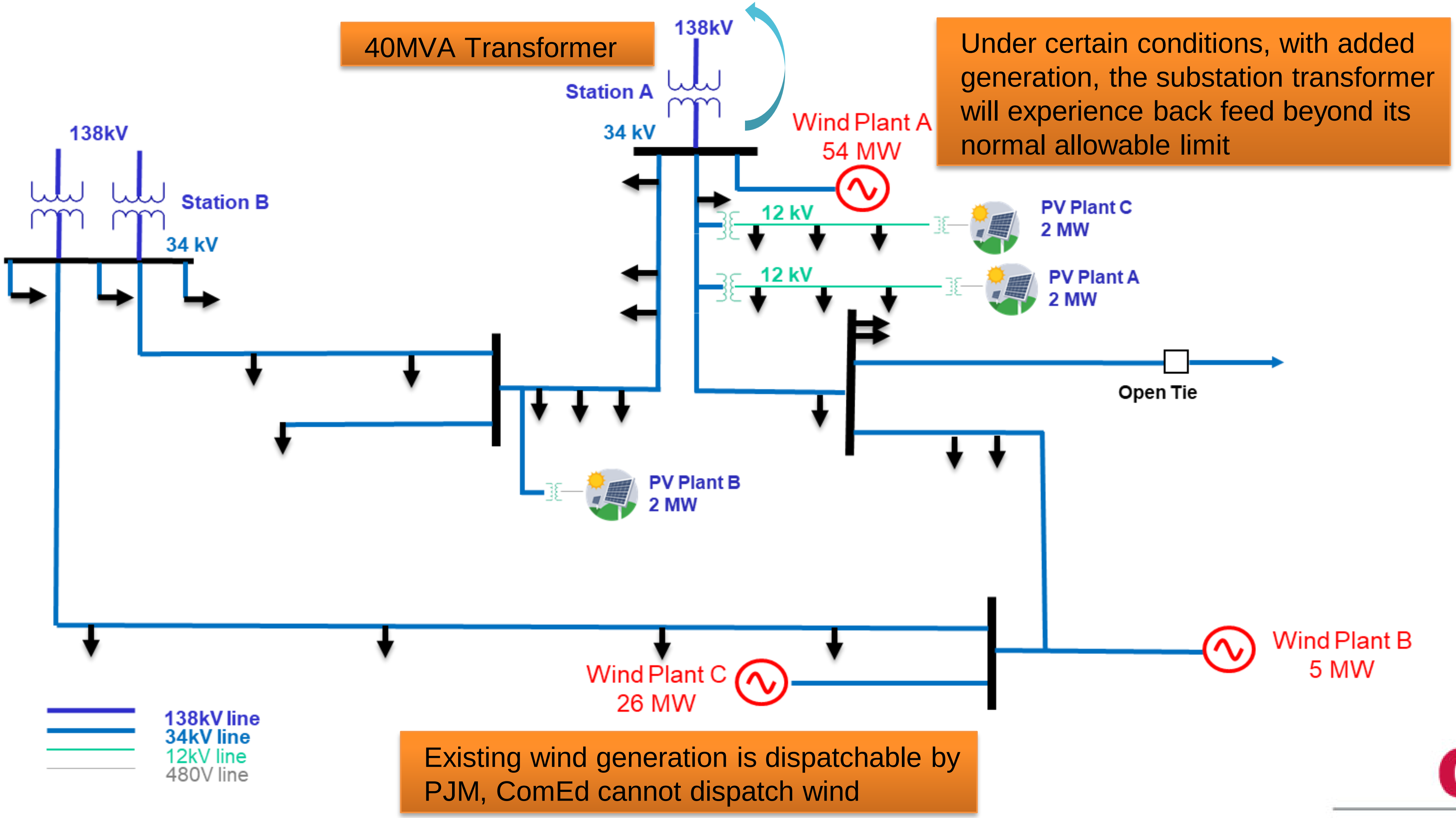
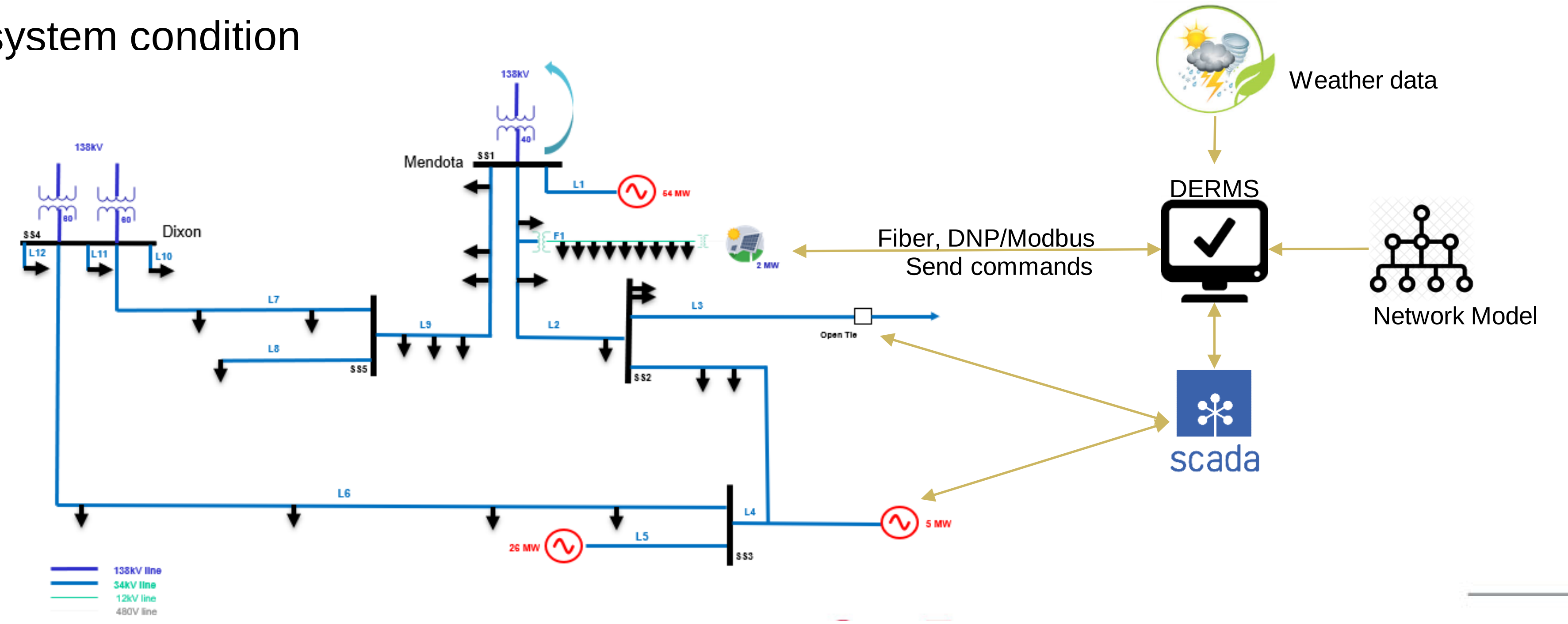
Mendota Substation Issue with Added Solar Gen

- Existing conditions don't allow new DER interconnection without system upgrade
- However, there are lots of new DER development interests due to large area of land in Mendota area



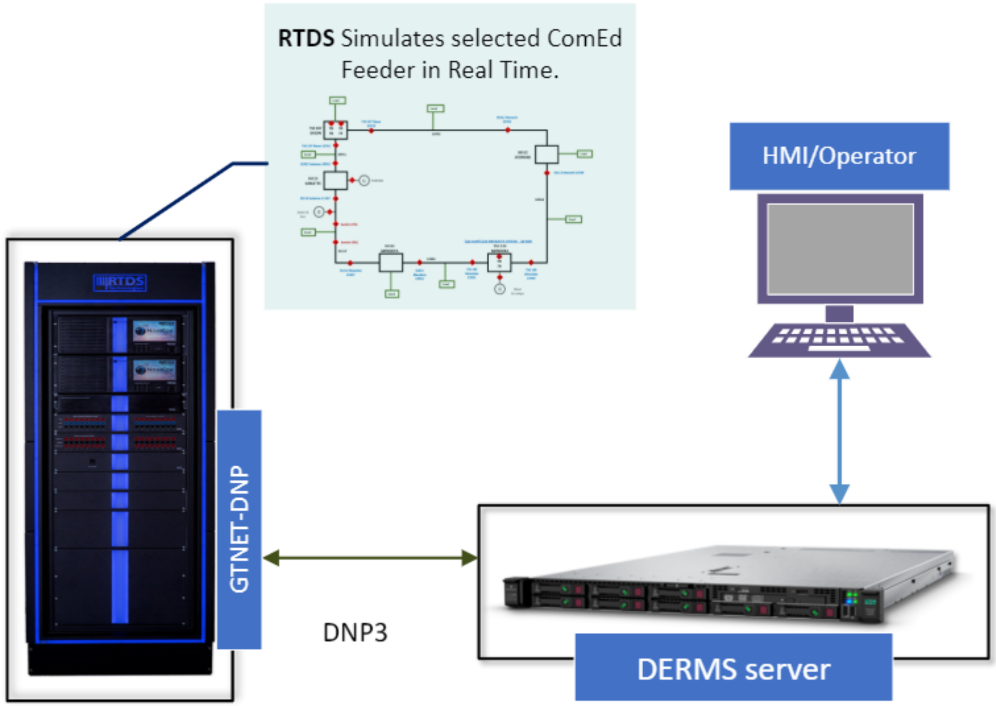
DERMS Implementation Overview

- Deploy DERMS in a central server environment for future scalability
- Fiber connection available at Mendota substation, needs to extend fiber to solar site
- Real-time DNP/Modbus connection to smart inverters at solar site
- Real-time SCADA data integration for wind farms monitoring
- CYME model and breaker/switch status integration for system topology
- Integrate weather data and build generation forecasting model for wind and solar
- Send commands to solar based on the following to avoid Mendota transformer overloading
  - Scheduled dispatch based on forecast
  - Real time system condition



Software Deployment – Testing

- RTDS Simulation Testing
  - Hardware-in-the-loop (HIL) test bed using RTDS and the DERMS server.
  - The objective is to test connectivity with the lab system and DERMS' functionality under different scenarios. This includes different network topologies, and different solar, wind and load profiles to simulate multiple management/release sequences.
- QAS and Prod Testing
  - In QAS, test communications with all SCADA points, verification that the alarms are triggered correctly, test all modules of the DERMS software are working properly. Once in QAS DERMS works as expected, use the same configuration for PROD.



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DERMS Management Strategy

- Rule-based Pre-defined Logic
  - Depends on user to provide the rules and contribution factors
  - Easy to implement and calculate
  - May not be the “optimal” result

- Optimal Power Flow (OPF)
  - Network-model-based numerical analysis
  - Compute-intensive
  - Accurate result

DERMS Management Strategy – Rule-Based

Activate Managemen

- 15-minute rolling average reverse MVA > target + deadband a.k.a. threshold 1 (e.g., 40 MVA)

Calculate Error

- Error = 15-minute rolling average MVA – target (e.g., 39.75 MVA)
- Apply power factor to convert error from MVA to MW

Curtail PV Generation

- Curtail PVs in the same priority group using contribution factors and gains
- Curtail PVs in next priority group if PVs in high priority group are fully curtailed

Notify User

- Issue the setpoints
- If all the PVs are curtailed and average MVA > threshold 2 (47MVA), notify operator to communicate with PJM to curtail wind farm generation

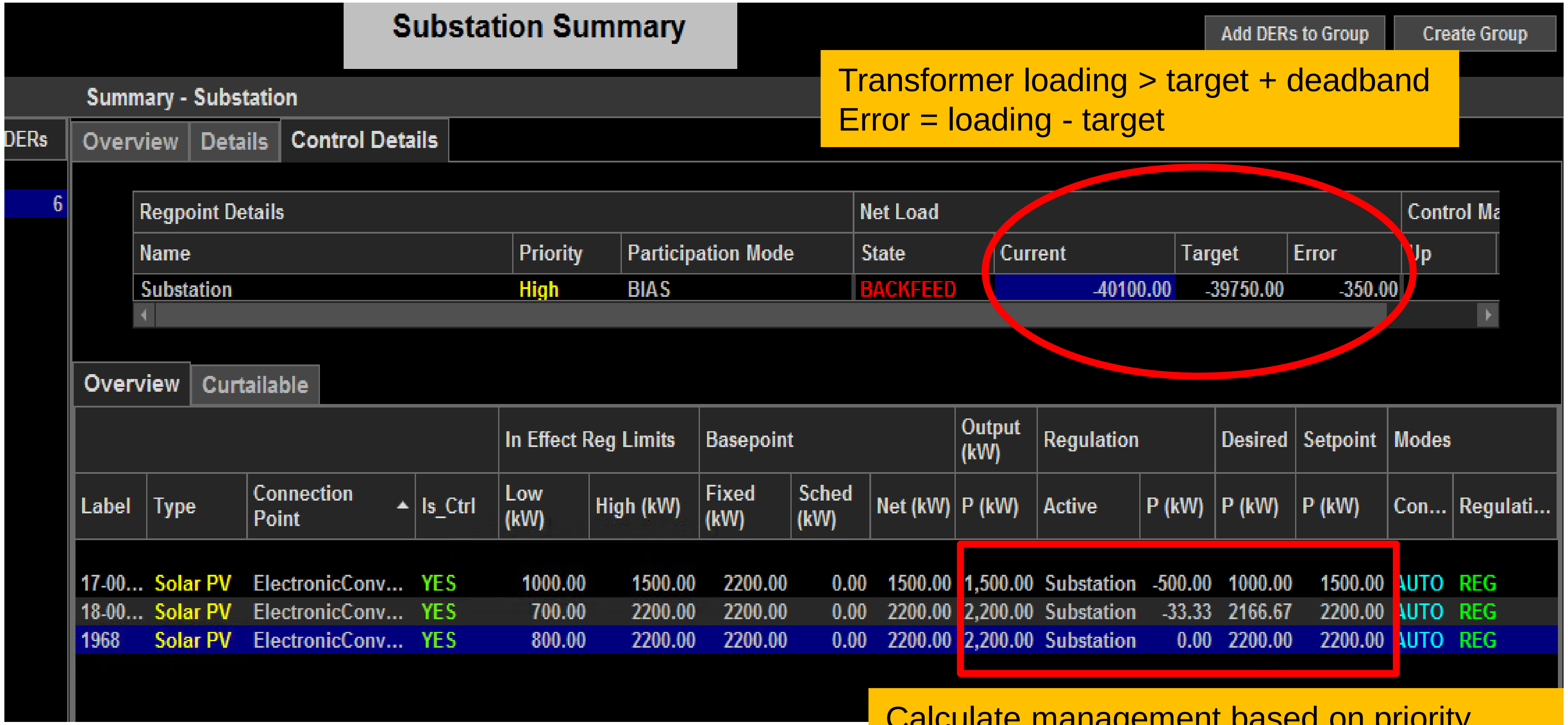
Start Releas

- 15-minute rolling average MVA < target

Release Managemen

- In the reverse priority order, last in first out (LIFO)

Example: PV Management



Transformer loading > target + deadband
Error = loading - target

Calculate management based on priority, gain, and contribution factor

Site	Priority	Gain	Contribution Factor	Error Distribution	Management	Desired P
PV1	1	1.5	1	-333.33	-500	1000
PV2	2	2	1	-16.67	-33.33	2166.67
PV3	3	1	1	0	0	2200

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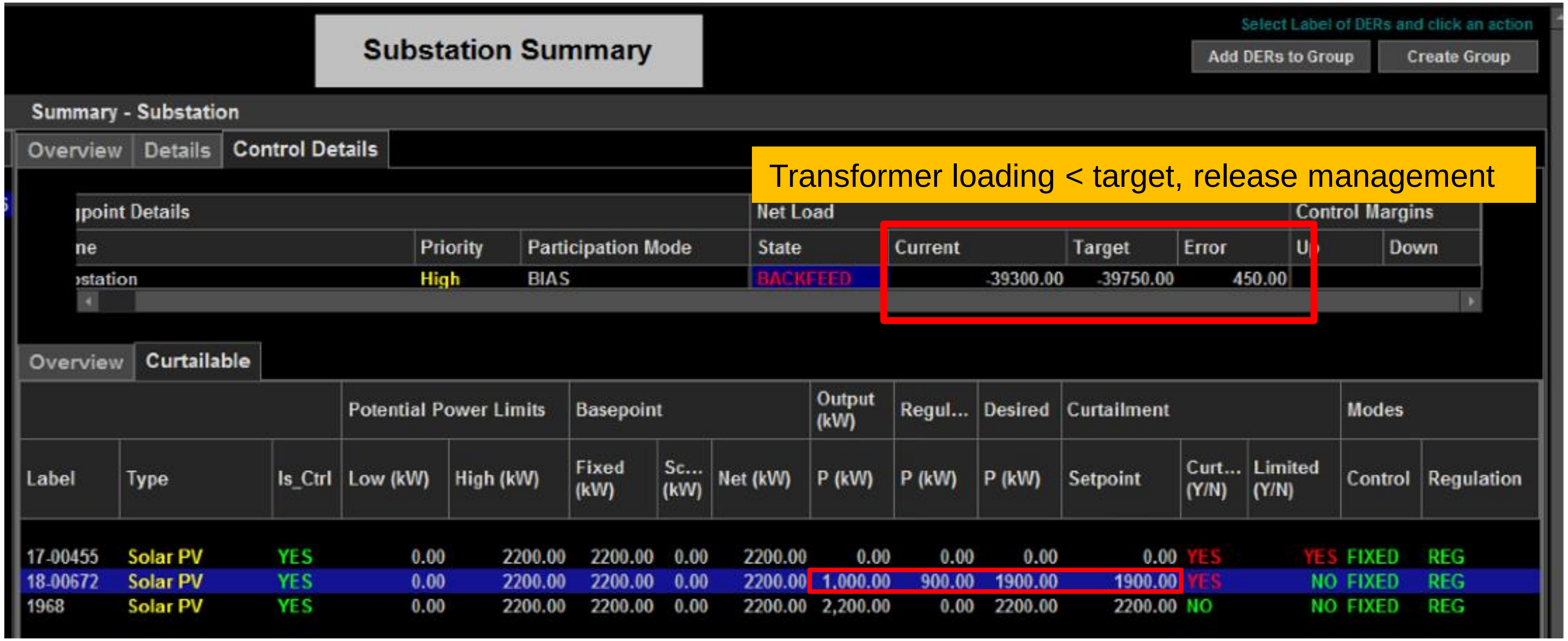
Example: PV Management Release



Site	Priority	Gain	Contribution Factor	Error Distribution	Release	Desired P
PV1	1	1.5	1	0	0	0
PV2	2	2	1	450	900	1900
PV3	3	1	1	0	0	2200

DERMS Management Strategy – OPF

- Optimal Power Flow (OPF) dispatches DER generation without exceeding loading limits of the generation and distribution assets or violating bus voltage limits.
  - Objective functions: minimize generation cost, control actions, etc.
  - Constraints: power flow constraints, distribution asset flow limits, DER generation limits, bus voltage limits, etc.
- Non-linear non-convex problems and computationally intensive
- Solved through iterative techniques with Newton-Raphson being the most common power flow algorithm.

$$objective\ function:\ \min f(x,t)$$

$$subject\ to:\ g(x,t) = 0;$$

$$h(x,t) \leq 0;$$

$$where:\ x - state\ variables;$$

$$t - control\ variables;$$

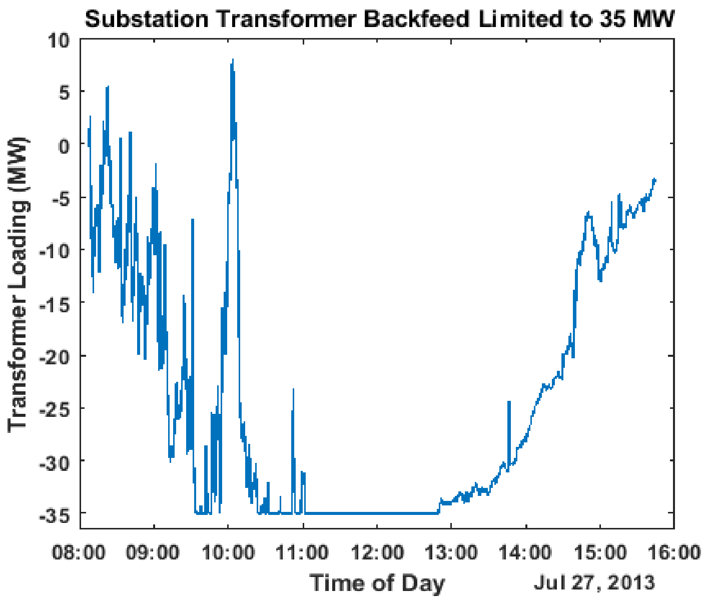
$$f(x,t) - objective\ function;$$

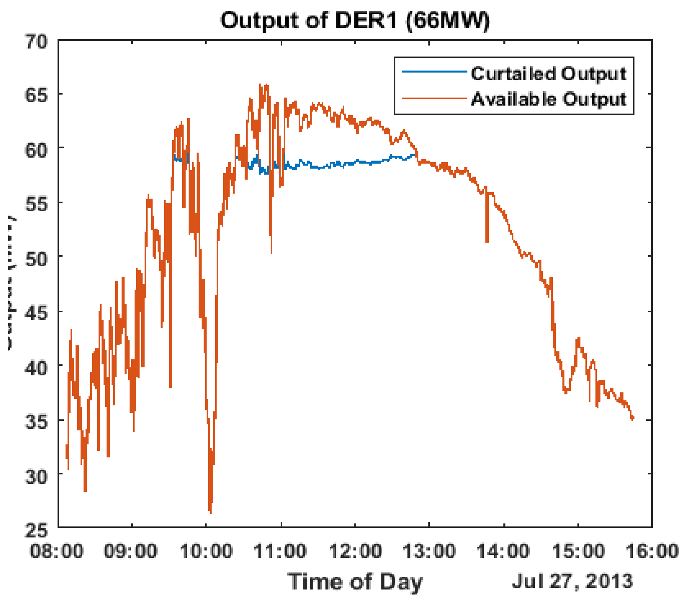
$$g(x,t), h(x,t) - constraints;$$

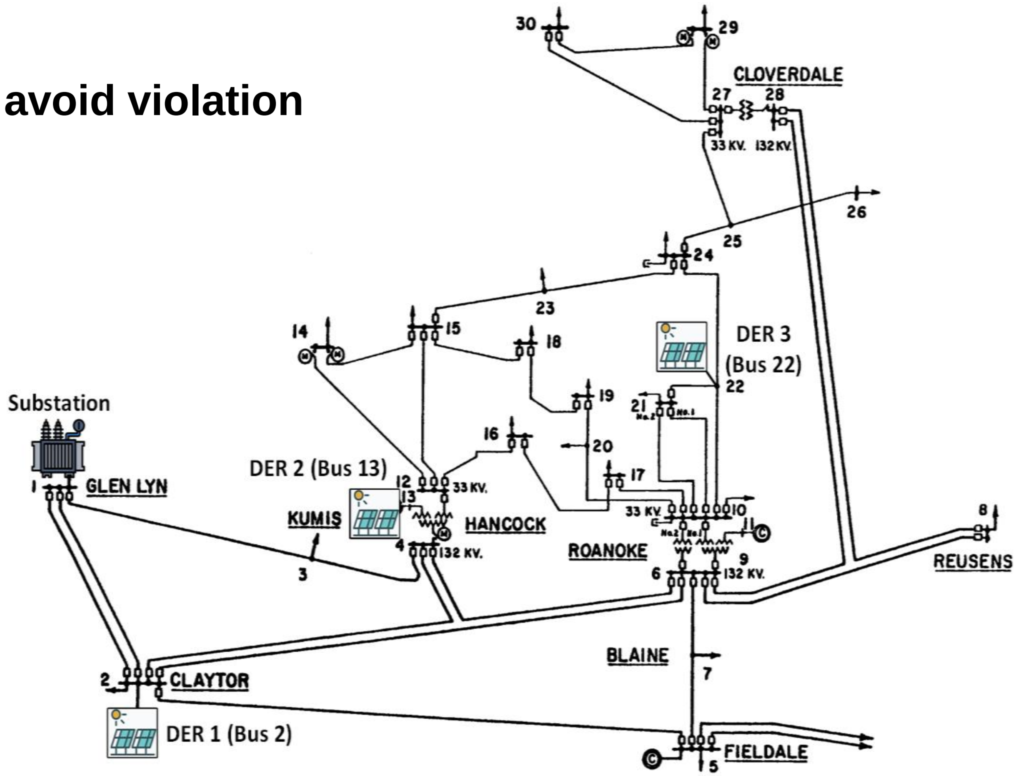
Example: OPF

A modified IEEE 30 bus system is used here to demonstrate OPF functionality

- Maximum DER Generation: DER1 = 66 MW, DER2 = 15 MW, DER3 = 5 MW
- Minimum DER Generation: DER1 = 40 MW, DER2 = 5 MW, DER3 = 2 MW
- **Transformer back-feed limit: (-)35 MW**
- **24-hour simulation shows management between 10:30 to 12:30 to avoid violation**







Description	Max. DER1 Management	Max. DER2 Management	Max. DER3 Management
Priority level: DER3>DER2>DER1 (most) Cost fcn: −500P1 – 1000P2- 10000P3	8.36 MW (12.66%)	0	0

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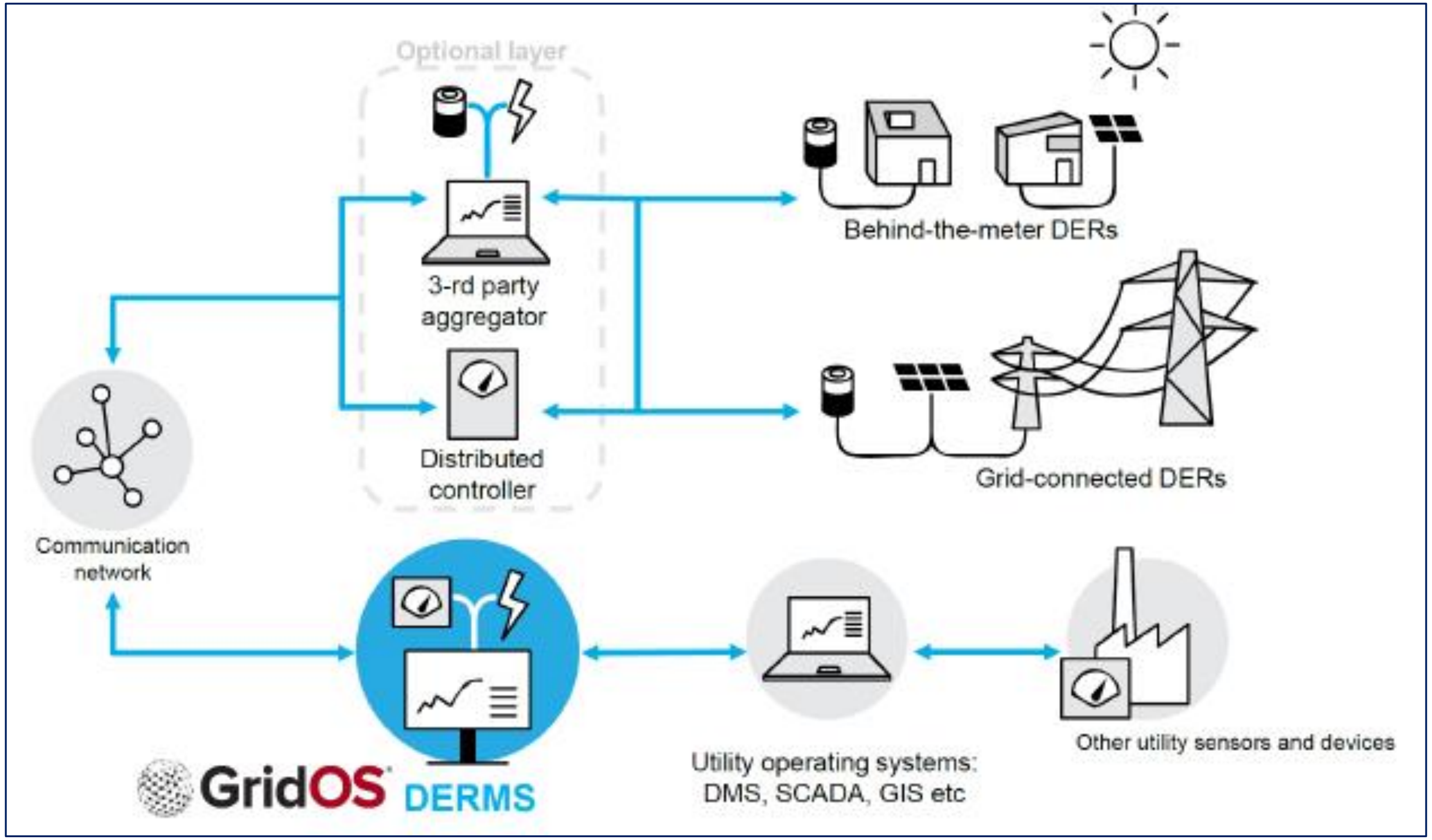
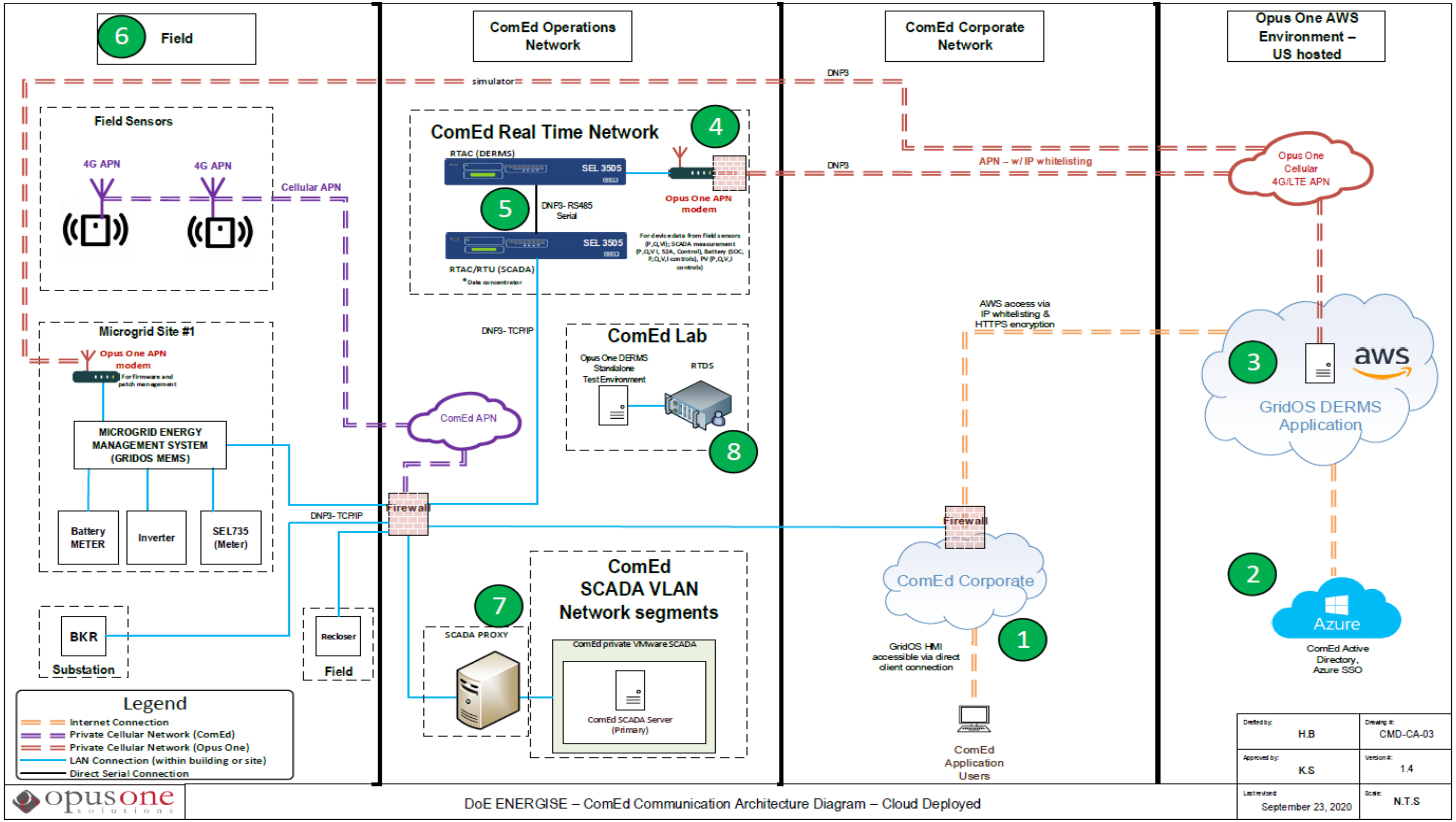
Security Constrained Economic Optimization of PV and Other Distributed Assets (DOE ENERGISE)

- A 3-year $6.5 million project with $3.2 Million DOE grant (partners: Opus One, ComEd);
- Development and demonstration of integrated, scalable, and cost-effective technologies for behind-the-meter (BTM) solar PV that incorporate energy storage in a microgrid
- ComEd to provide test bed for new technology deployment with existing or planned PV



Cloud-deployed DERMS System



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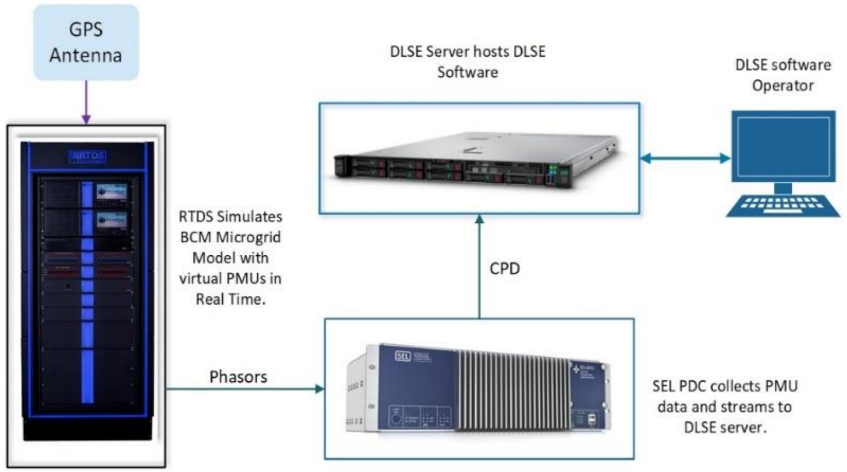
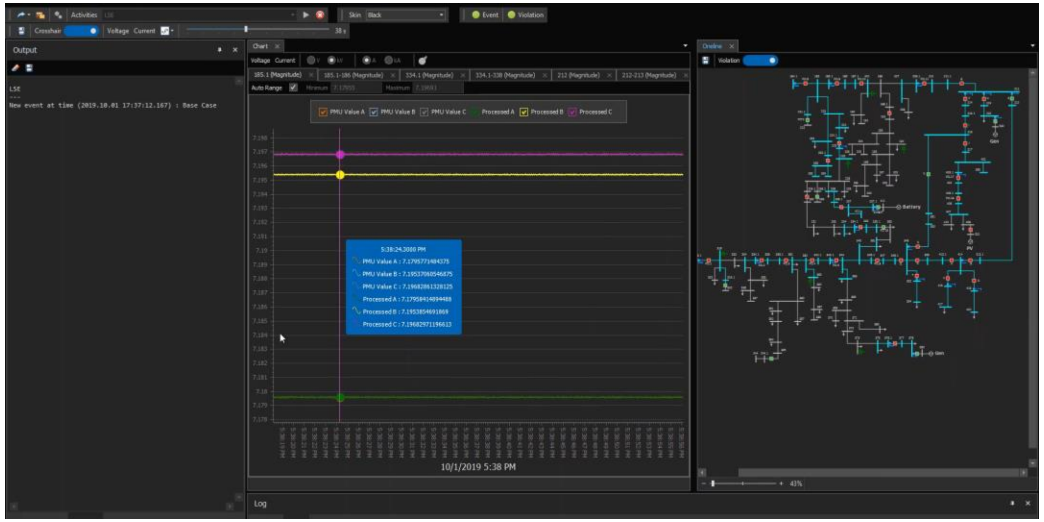
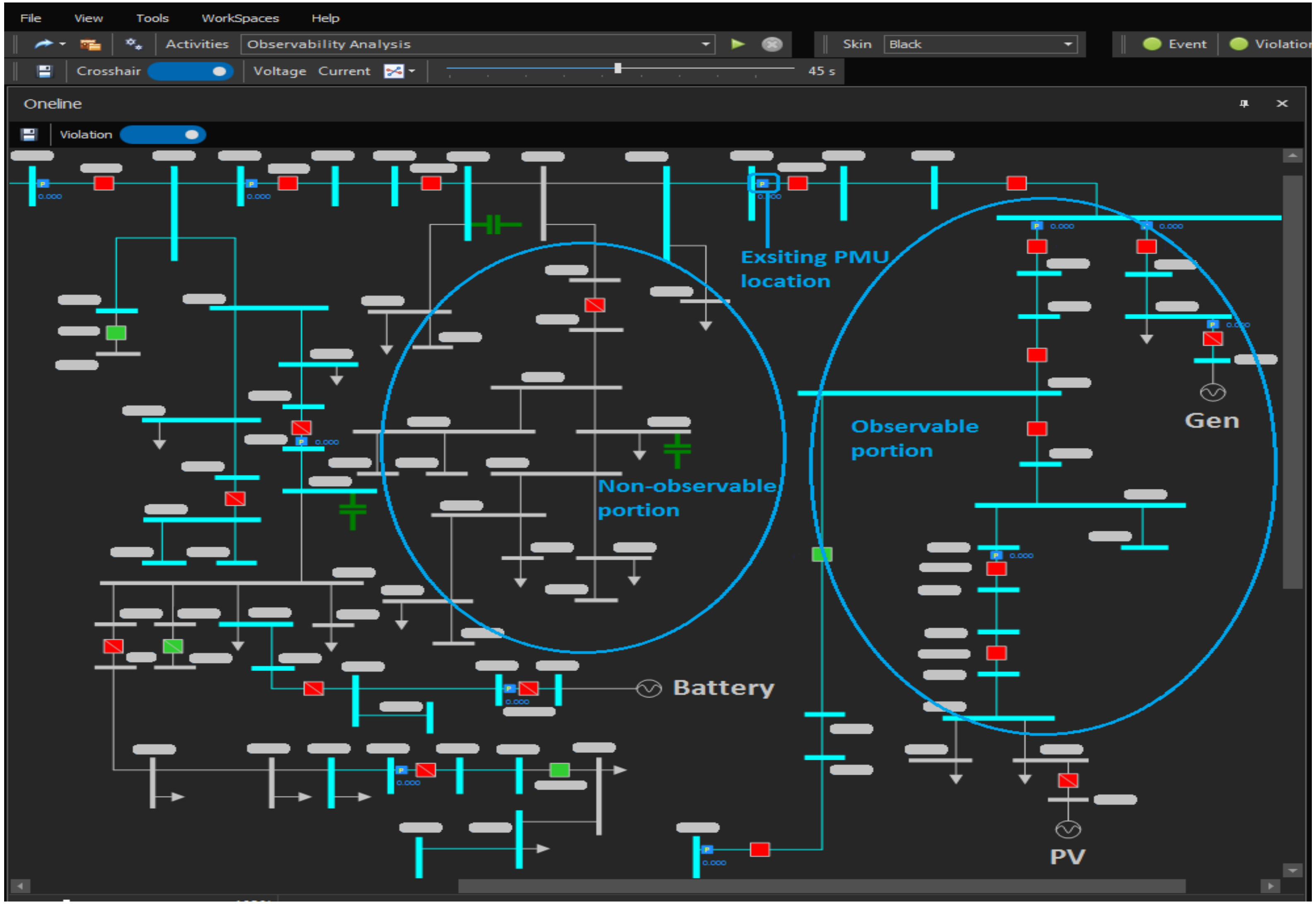
Distribution PMU and Application for Situation Awareness

- Phasor Measurement Units (PMU)
  - PMUS on the distribution system provide real time monitoring and enhanced visibility for operation and analysis
  - Deploying distribution PMUs at substations and in BCM to enhance monitoring and the situation awareness of the distribution grid, and to enable efficient integration of Distributed Energy Resources (DER)
- 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, 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





DLSE Result – Observability Analysis & Visualization



D-PMU ROSE considers a power system network to be observable for a given network topology if voltage vector at each node can be calculated based on the PMU measurements

Blue – nodes and branches that are observable with planned PMU installations (for current network topology)

Black – non-observable nodes and branches

Planned PMU installations

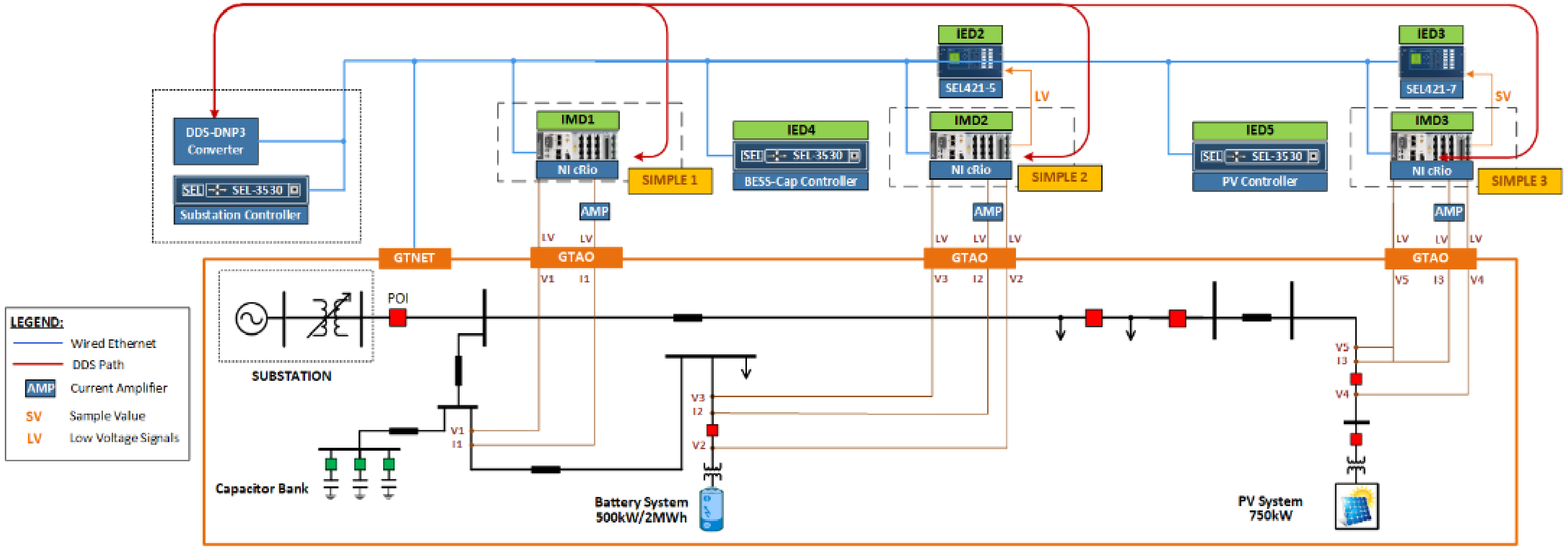
SIMPLE (Sensors with Intelligent Measurement and Low-cost Equipment)

Budget: $2.7M DOE Project

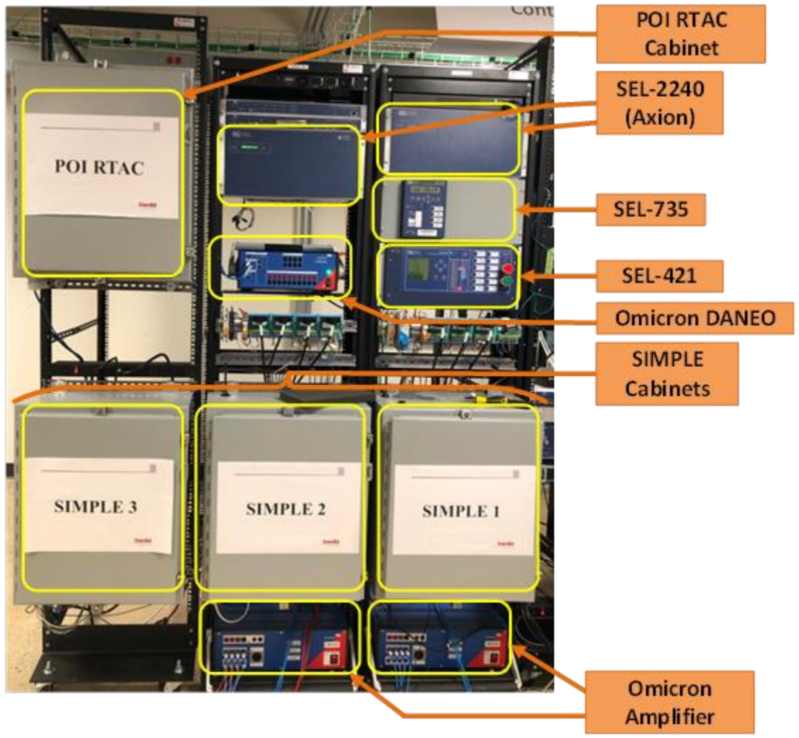
Objective: Development and introduction of voltage/current sensors with enhanced characteristics (accuracy, bandwidth and harmonic range) and high measurement granularity for medium voltage distribution system monitoring, DER monitoring, protection, and controls

Use Cases:

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



HIL Testbed schematic



HIL laboratory test setup

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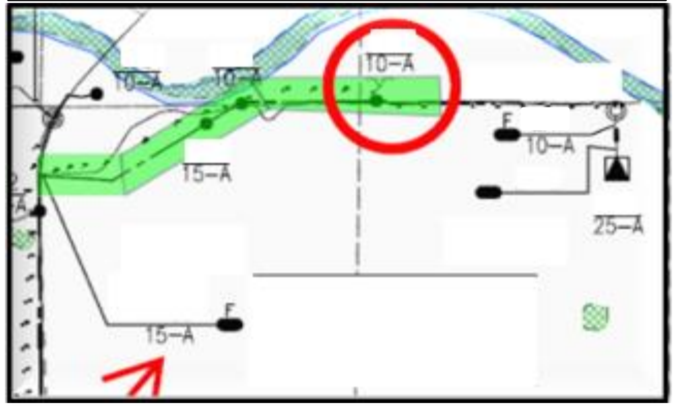
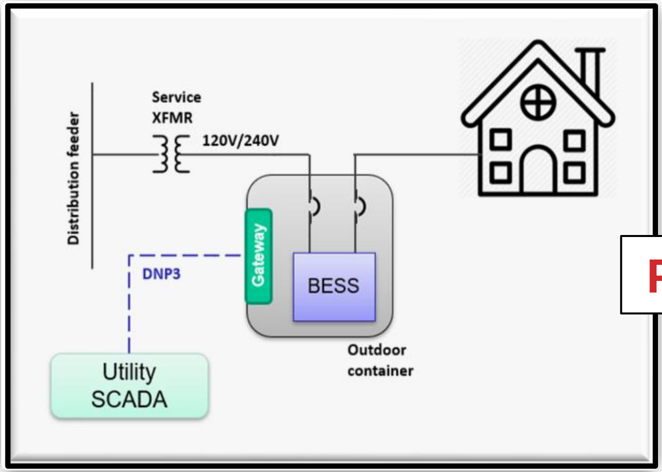
Improving Reliability and Resilience of Targeted Customers

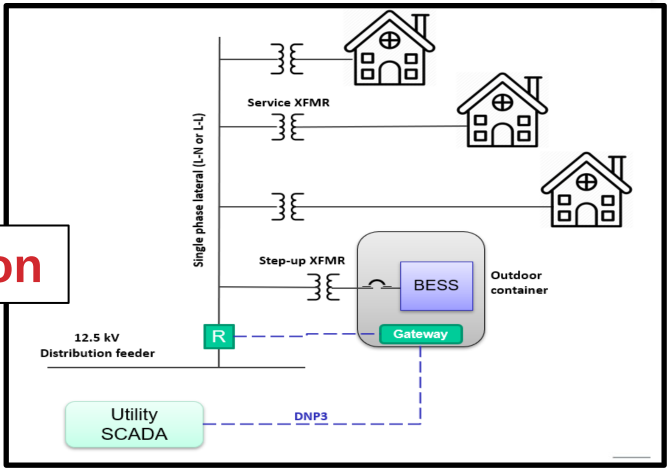
- Battery energy storage system (BESS) solutions to reduce outages for customers facing it greater than a threshold hour per year. (These customers are towards the service end of ComEd's territory which limits options for traditional upgrade such as, alternative taps)
- Identified secondary side solution at 120V service transformer (one BESS serving single customer)
- Identified primary side solution at 7.2kV single phase (one BESS serving multiple customer)

Secondary side use case





Primary side use case



Proposed solution

A ‘Smart Community’ – Connected, Green, and Resilient

Community of the Future Program demonstrates the range of ComEd’s smart grid engineering innovation and technology, deepens our relationships with the communities we serve, and broadens our impact on the landscape of northern Illinois.

Connectedness relates to the information flow of communication technologies, and how these innovations can be leveraged to support the development of a smart community. Connected projects illustrate the interoperability of smart technology for widespread, effective usage in a smart, connected community. They also improve energy costs, grid reliability, and communications capacity and increase infrastructure resilience.

A Green community prioritizes protecting the environment by using clean energy technologies, reducing carbon emissions and particulate matter. Green projects help community members meet their needs while sustaining their neighborhoods and the world.

A Resilient community is one that leverages an advanced grid to manage daily stresses and respond to disruptive events. This includes everything from developing best practices on how to leverage advanced technologies to providing advanced STEM education to develop new technologies.

Community Innovation in Practice

The Community of the Future is a place where ComEd partners with local communities to create a 'smart community' – connected, green, and resilient – in which the smart grid and a host of other technologies and related services are f ully leveraged to enhance the everyday lives of community members.

EV Charging infrastructure installations funded by the DoE to increase EV penetration in the community

Smart Kiosks: Partnered with Interactive Kiosk Experience (IKE) to install and pilot (3) "life-sized" interactive kiosks

STEM Programs: Over 15 virtual and in -person programs to create a pipeline for the workforce of the future

ARIS Lights: Partnered with CHA, CPD, CPS, and ARIS Wind to install solar/wind/battery powered lighting units

Bronzeville Film Festival: Platform to present short documentary films created by Bronzeville high school and college students

Bronzeville Renaissance Mural: an (AR) enhanced mural; visualization tool to support ComEd's planned smart city projects.

Thank you!

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