Deploying Grid Edge Analytics in Utility Distribution Systems

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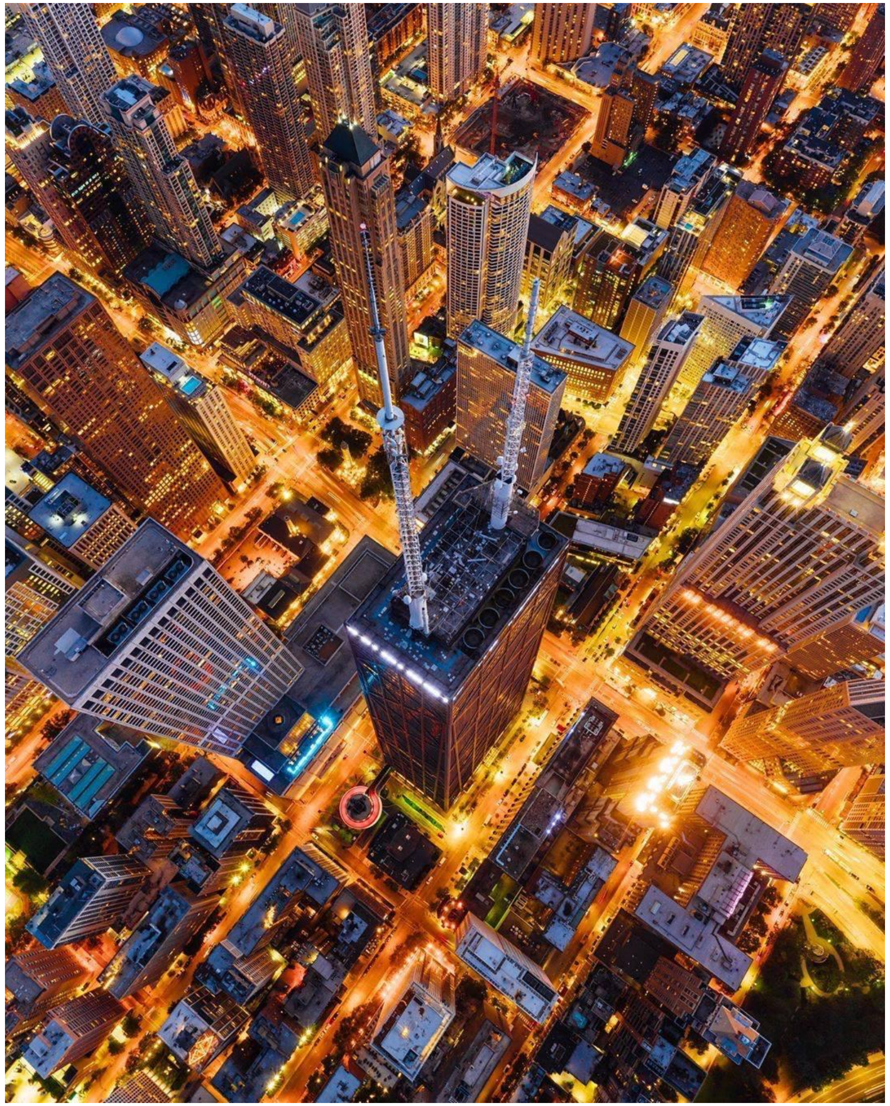
Smart Grid: Emerging Tech

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
- 53% overhead, 43% underground
- 5,800 circuit miles of transmission
- 93% overhead, 7% underground



Outline

Overview

PMU and Distribution Linear State Estimator

Sensors with Intelligent Measurement Platform and Low-Cost Equipment (SIMPLE)

Conclusions

ComEd's PMU road map

ComEd Identified 55 DPMU (Distribution PMU) use cases

These applications are divided into 11 broad categories

- Real-time distribution system monitoring and operation
- PMU Based Fault Location
- Anomaly and Event Detection
- Asset Monitoring
- Load Modelling and Model Validation
- Volt-Var Control and Feeder Monitoring
- DER Integration
- Improved Stability Management
- Advanced Distribution Protection and Control
- Advanced Microgrid application and Operation
- Power Quality assessment and analysis

Identified use cases can be achieved by PMUs because of their time-synchronized high-speed measurement (30 to 120 samples per seconds) or as an alternative measurement source

PMU for Bronzeville Community Microgrid

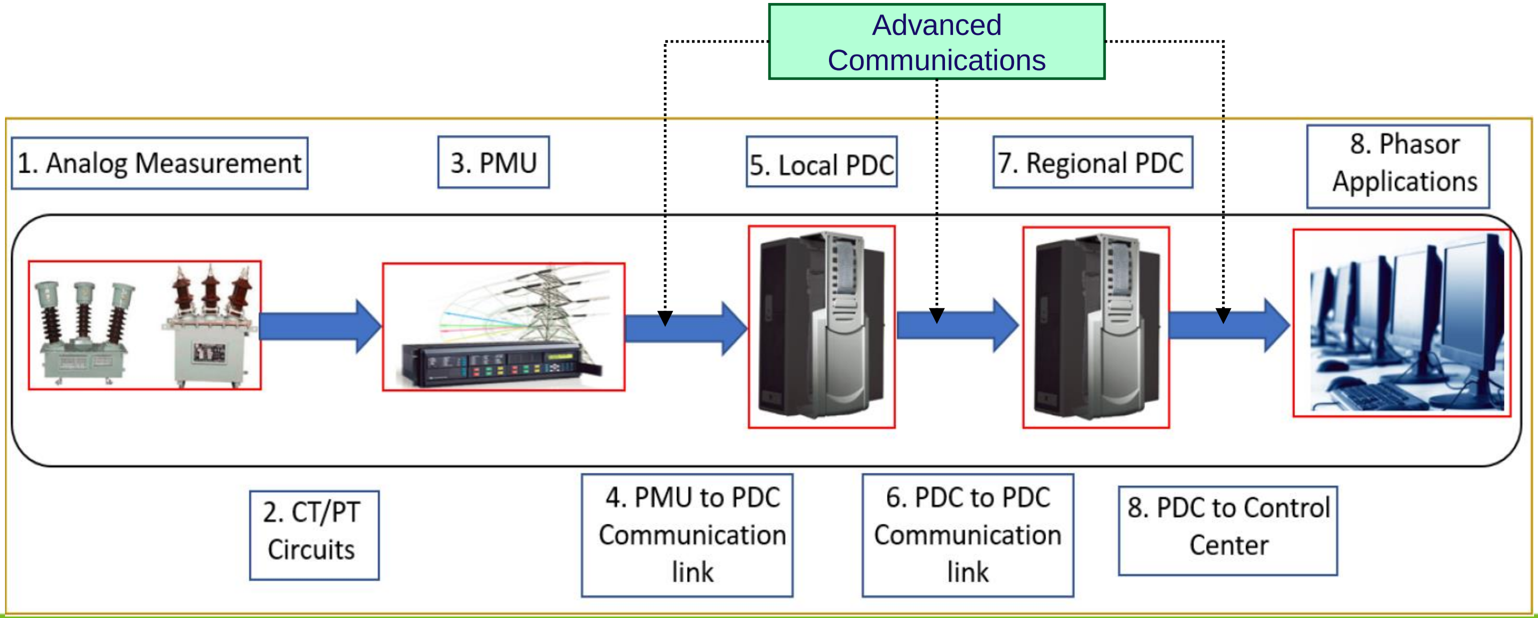
The Bronzeville Community Microgrid enables a green, resilient, sustainable neighborhood for consumers

7 MW aggregate load, serving approximately 1,000 residences, businesses and public institutions

Installation of first utility-operated microgrid cluster powered by DERs including 750 kW solar PV, 500kW/2000kWh battery energy storage, and controllable gas generation

PMUs in BCM area: 25 MicroPMUs and 2 Substation PMUs (currently 2 Substation PMUs and 2 MicroPMUs streaming data)

Total Substation PMUs : 190 deployed



Use Cases of DLSE

- **Increasing levels of DER penetration -** causing bi-directional power flows, which represents the challenge with protection and control, fault location and others
- **Measurement and control** – PV, BESS, DER integration
- **Asset management** – what assets might fail
- **Beneficial electrification** (i.e., electric vehicles) - will result in operational and system planning challenges (what if cloud goes over PV site when EVs are charging; EV charging is a stochastic in nature, so capacity planning for EV adoption and charging patterns will require additional field measurements)
- **ADMS/DERMS** – model integrity, control thousands of devices (including residential), phase identification
- **Transmission operations** – DERs on distribution system have major impact of transmission system operations
- **Power quality** – voltage sags, swells, short term/long term flicker, rapid voltage change (RVC), harmonics (location and direction), system dynamics, oscillatory behavior – PMUs do not power quality level of data, but could/should they (PMU – 60 samples/second vs. PQ – 512 samples/cycle)

Voltage and Current Measurement in the Distribution Grid

- VT and CTs in substations
- Evolved utility customer expectations
- Proliferation of DERs and
  - the need for controlling bi-directional energy flow
- Instrumentation outside substations
- Growing number of applications and functions needing measurement data
  - Grid monitoring, protection, and control
  - Evolving smart grid applications

Challenges

- Cost
  - Value optimization: we need to share
- Installation and Deployment
  - Weight, Size, Safety
- Performance
  - Accuracy and linearity
  - Measurement Bandwidth
  - Stability (over time and environment)
  - Data quality to serve multiple applications concurrently
- Communications
  - Providing data to all applications needing that data
  - Latency
  - Communications bandwidth (data volume and speed)
  - Access along the feeder (outside substations)

Proposed Solution

- A combination of low-cost sensors and advanced intelligent electronics devices (IEDs) as a digital sensor system
  - Manage cost
  - Enable interchangeability
    - Multi sensing technologies
    - Future expansion
  - Provide data correction and compensation locally
  - Address communication needs through local IED
  - Provide multiple outputs (when required) to address various applications at low cost-per-application

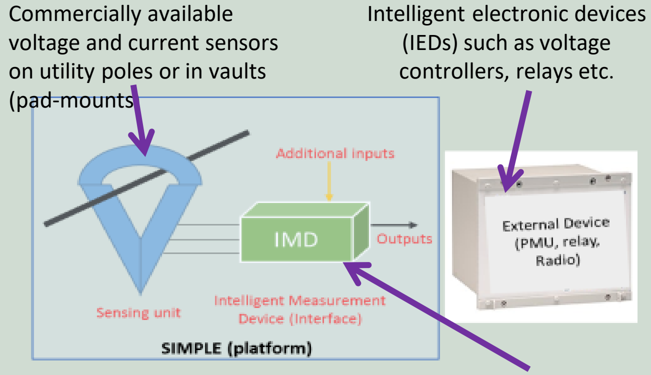
Sensors with Intelligent Measurement Platform and Low-Cost Equipment (SIMPLE)

Objectives

- 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
- Enhancement of existing (commercially available) voltage/current sensors that are used as inputs to Advanced SCADA Devices and Power Quality Measurement units for applications involving distribution PMUs and field power quality analyzers
- Development of performance requirements and functional specifications for voltage/current sensors

Focus

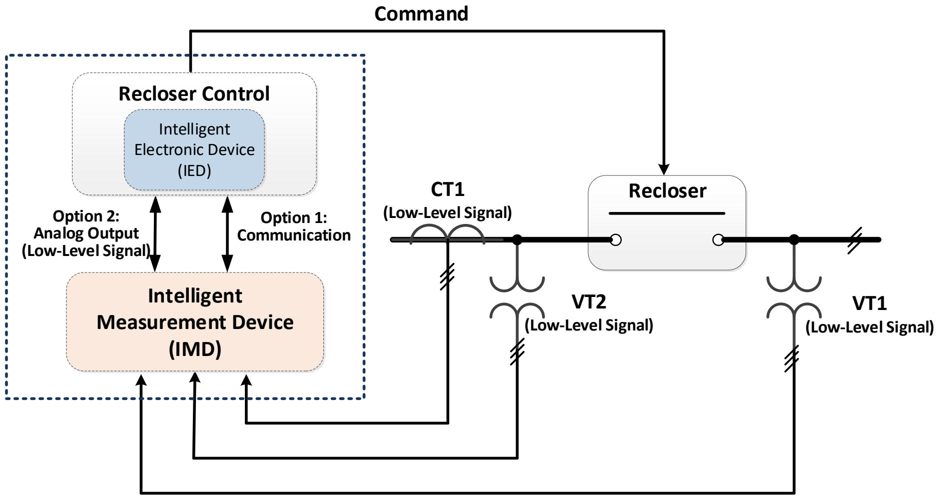
- Develop new prototype system
- Perform high voltage/high current testing
- Perform hardware-in-loop application testing at ComEd's RTDS lab
- Field demonstration within ComEd service territory



Intelligent Measurement Device (IMD): An electronic platform

Sensors with Intelligent Measurement Platform and Low-Cost Equipment (SIMPLE)

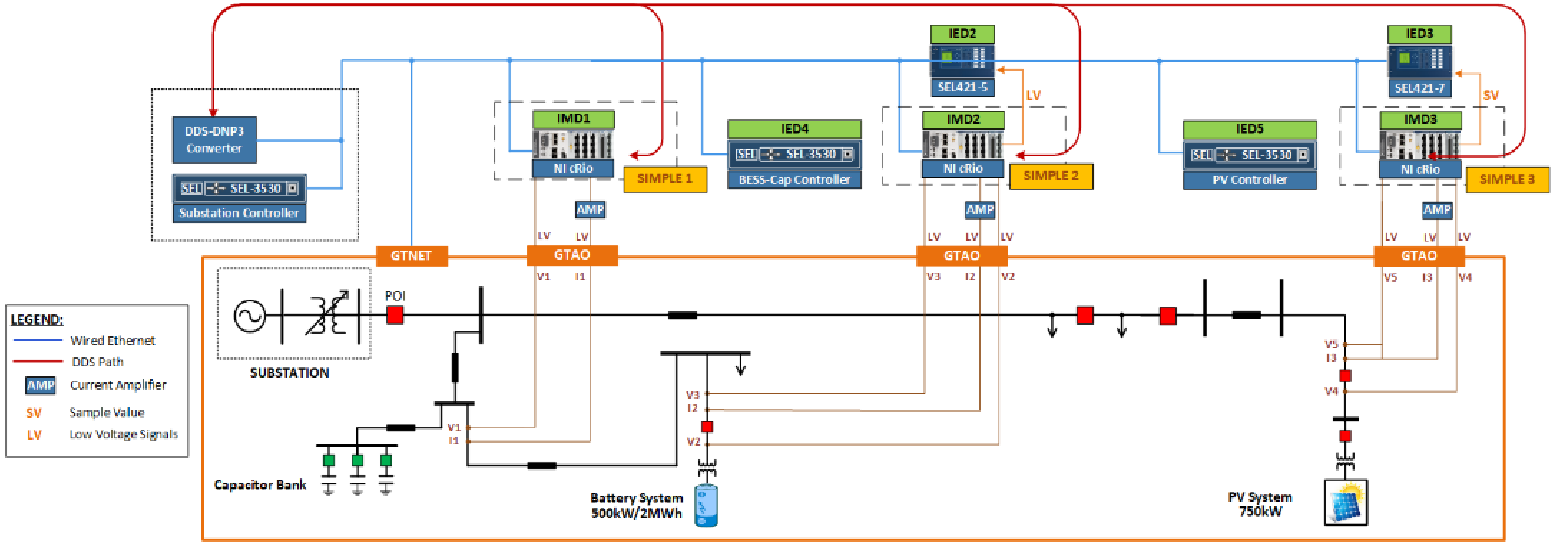
- The Intelligent sensor system is a platform designed to address the major gaps –accuracy, lack of intelligence and flexibility for integration- in utilizing low-voltage measurement sensors (both voltage and current sensors) in power distribution systems with high penetration of distributed energy resources (DERs)
- A medium-voltage intelligent measurement platform that provides post-processing of raw measurements received from commercially-available voltage/current sensors to enhance accuracy and bandwidth of monitoring system
- Platform integrates into a Data Distribution Service (DDS) messaging bus for distributed control and interoperability



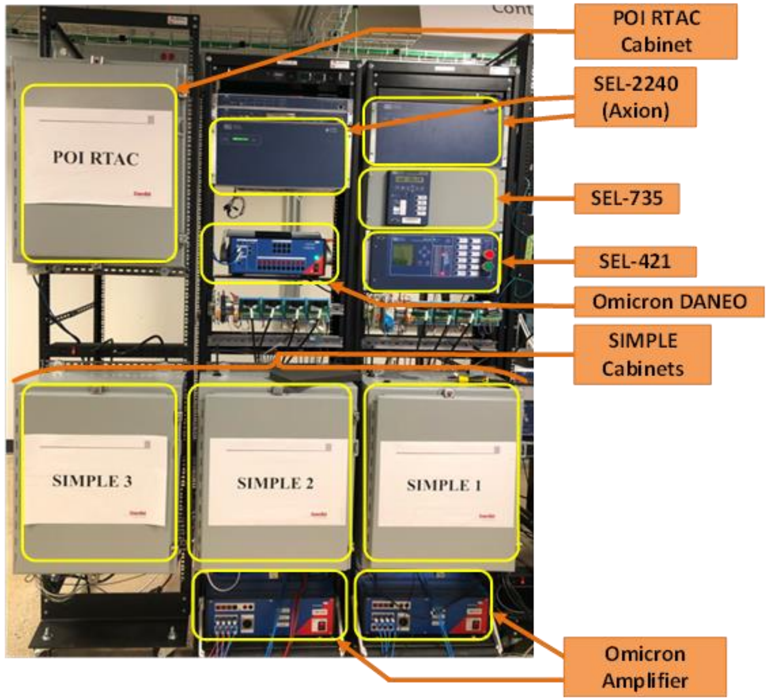
SIMPLE conceptual implementation in a recloser application using sensors and low-level signals

SIMPLE: Use Cases and HIL Lab Test Setup

- Use Case 1: Distribution Circuit Monitoring (DCM)
  a) Monitoring voltage and power flow across the distribution system
  b) Obtain data for root-cause analysis, maintenance, and pre-event analysis
- Use Case 2: Automatic Resource Control (ARC)
  a) Manage operation of DERs with feeder-level devices to improve feeder voltage profile
  b) Coordinated dispatch of DERs to manage feeder power flow



HIL Testbed schematic

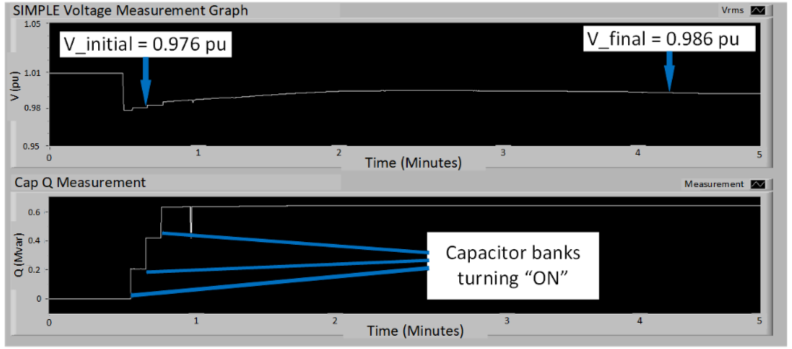


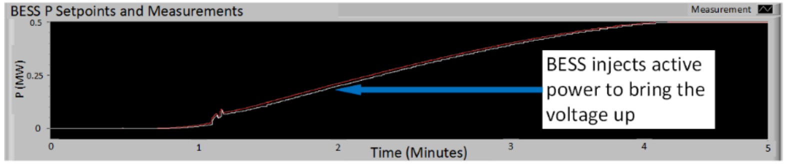
HIL laboratory test setup

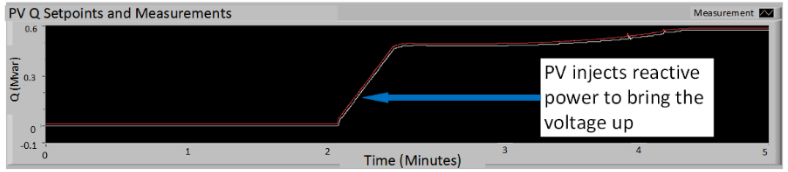
HIL Test Results – Application Tests (Automatic Resource Control)

- SIMPLE coordinates the controllable distribution assets to achieve voltage control and power flow control objectives.

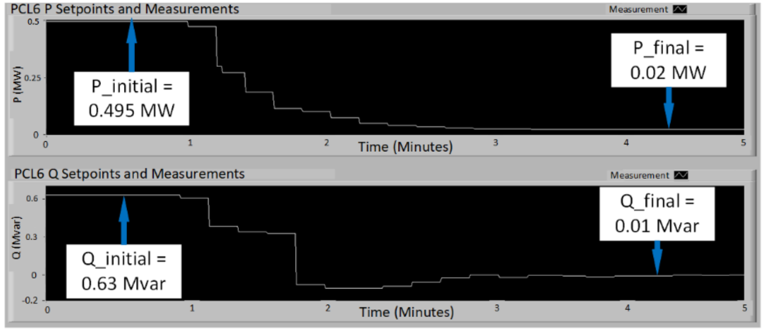
Management of DER Operation to Improve Voltage Profile

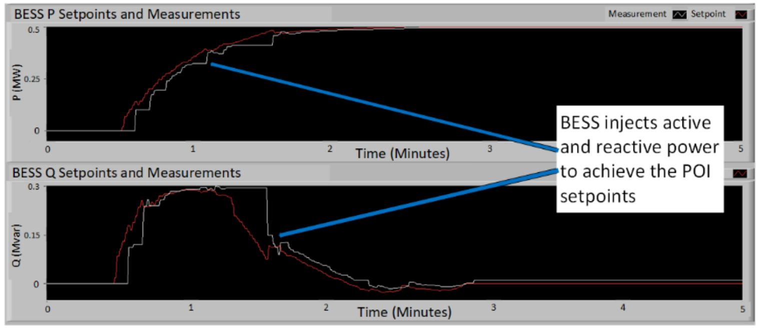


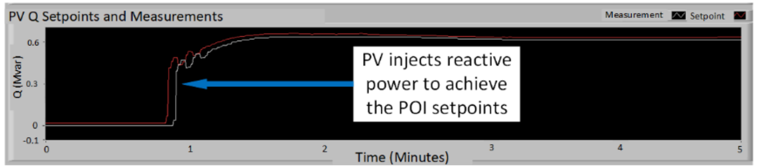




Coordinated Dispatch of DERs to Manage Power Flow



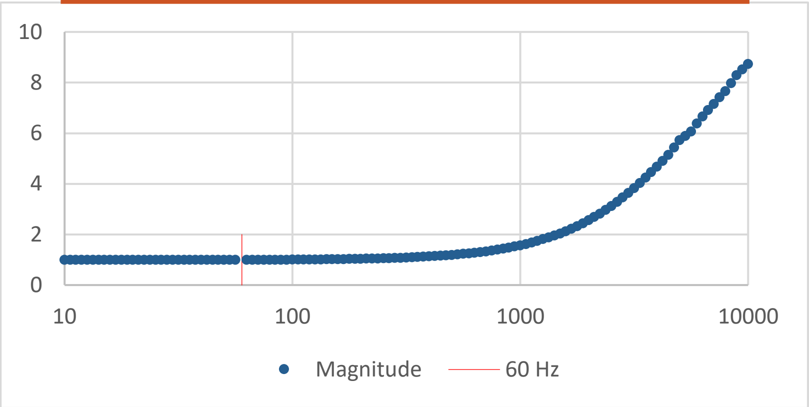


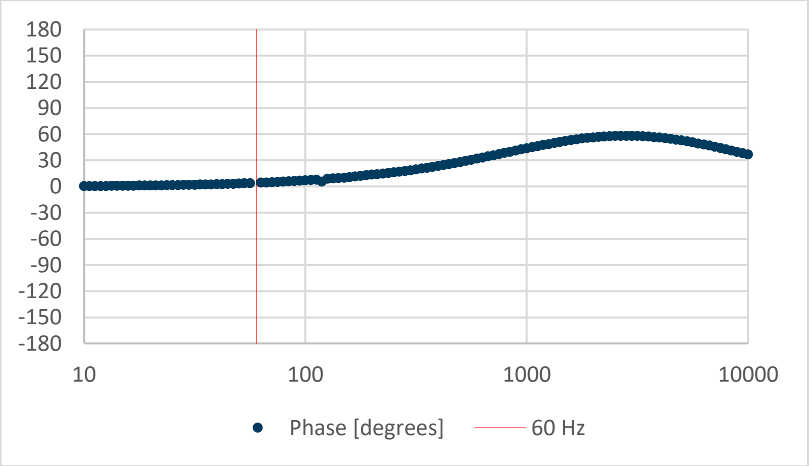


Sensor Characterization and Compensation – Voltage Sensor

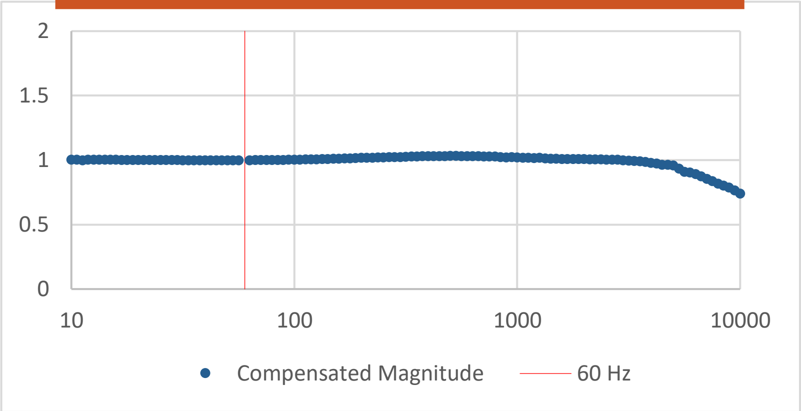
- Frequency Response of a Lindsey 9E650 (Voltage Sensor) Combined Sensor with Compensation is compared with Response of Uncompensated Sensor

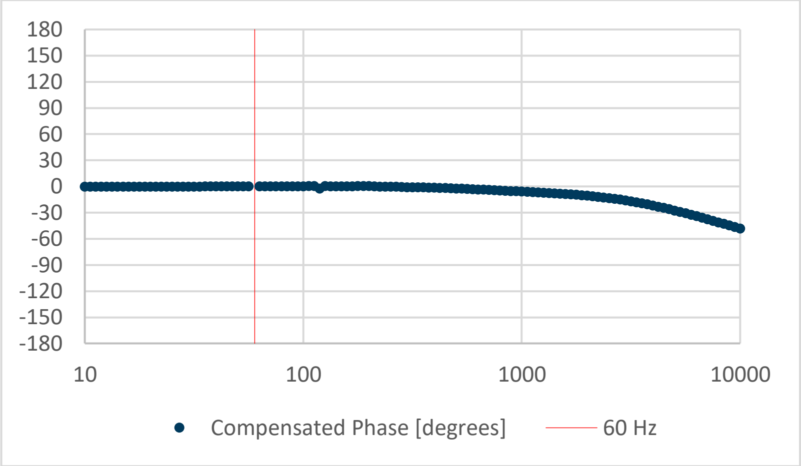
Uncompensated Response





Compensated Response

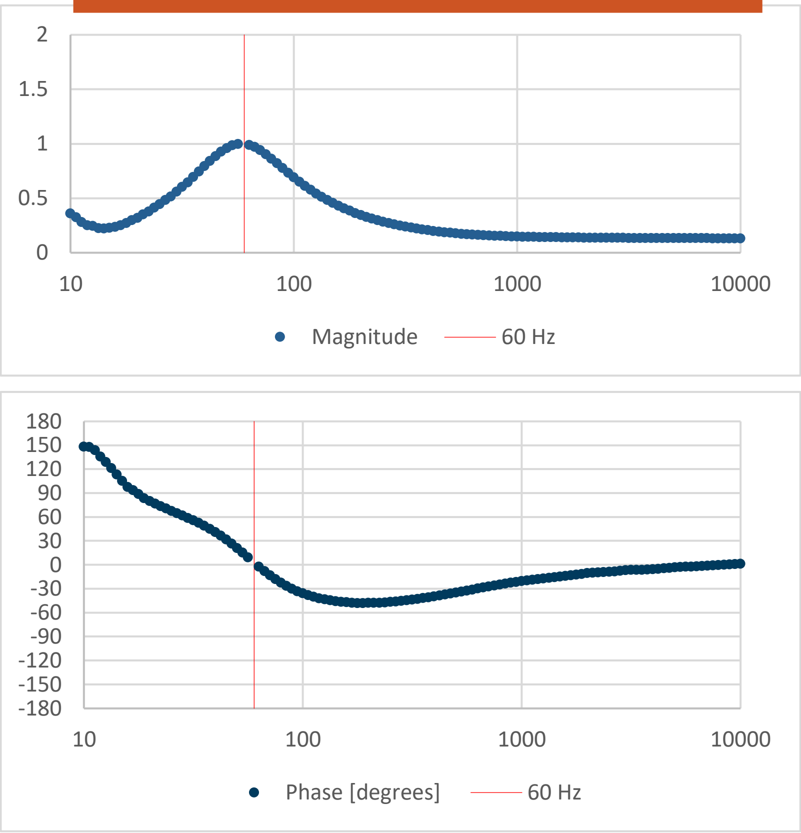




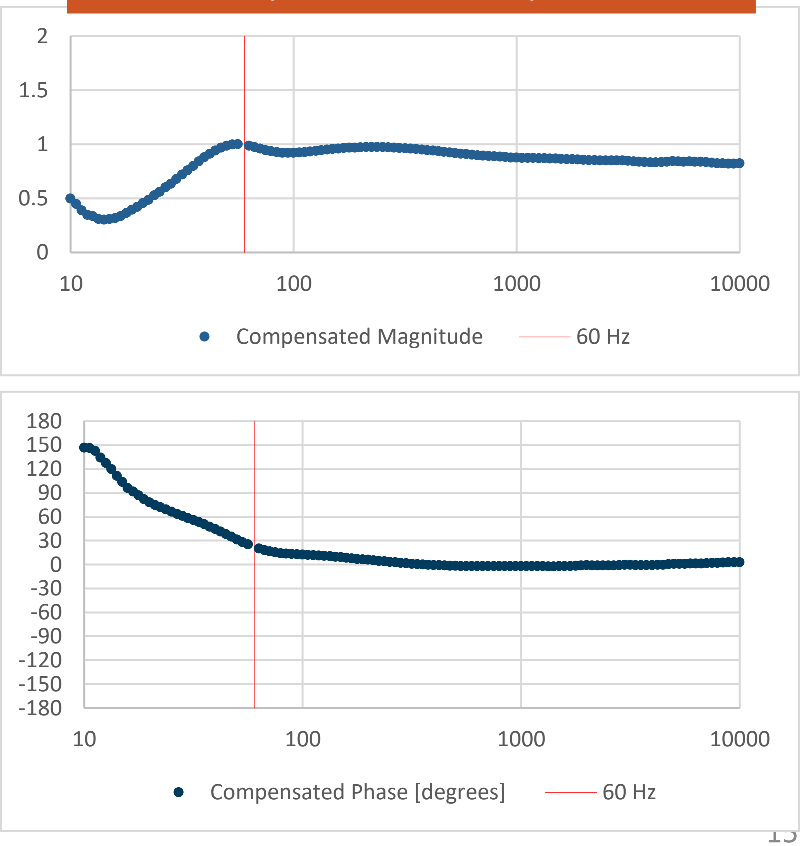
Sensor Characterization and Compensation – Current Sensor

Frequency Response of a Lindsey 9E650 (Current Sensor) Combined Sensor with Compensation is compared with Response of Uncompensated Sensor

Uncompensated Response

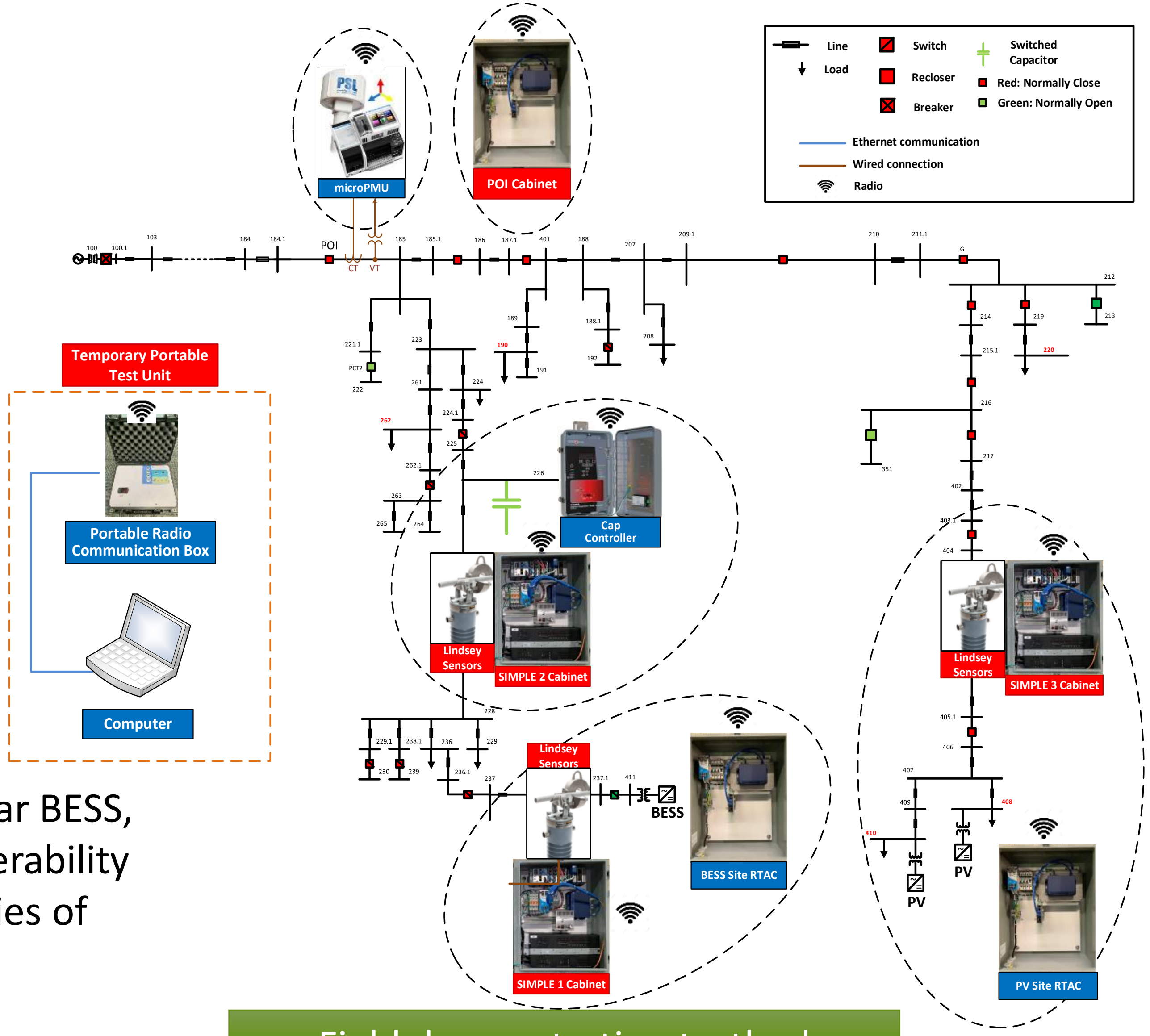


Compensated Response



SIMPLE: Field Demonstration Use Cases

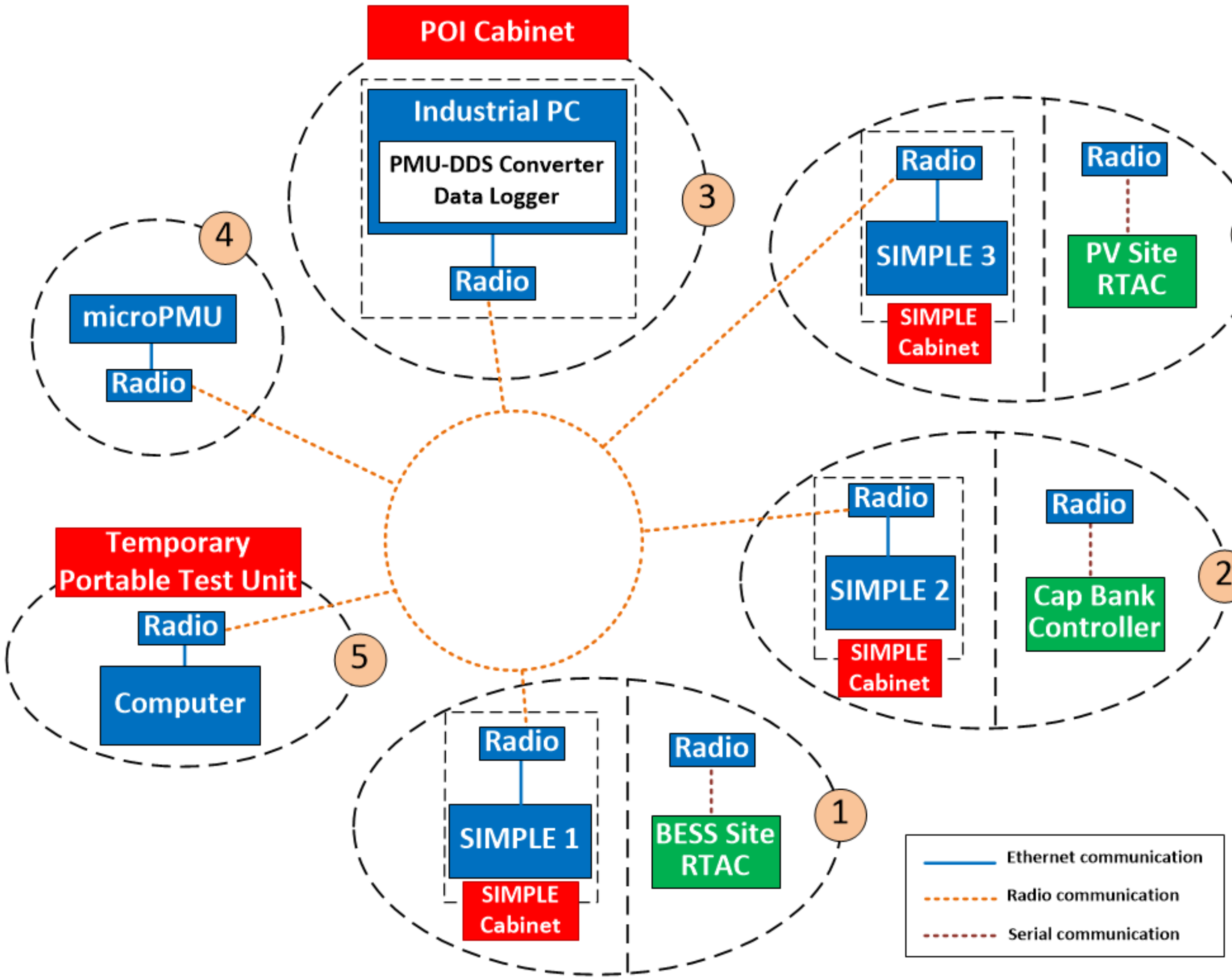
- Use Case 1: Distribution Circuit Monitoring (DCM)
  - a) Monitoring voltage and power flow across the distribution system
  - b) Obtain data for root-cause analysis, maintenance, and pre-event analysis
- Use Case 2: Automatic Resource Control (ARC)
  - a) Manage operation of DERs with feeder-level devices to improve feeder voltage profile
  - b) Coordinated dispatch of DERs to manage feeder power flow



- The three SIMPLE devices are strategically placed near BESS, PV and a capacitor bank to demonstrate the interoperability and coordinated monitoring and control functionalities of this newly developed technology.

Field demonstration testbed

SIMPLE: Communication Interface and Field Installation

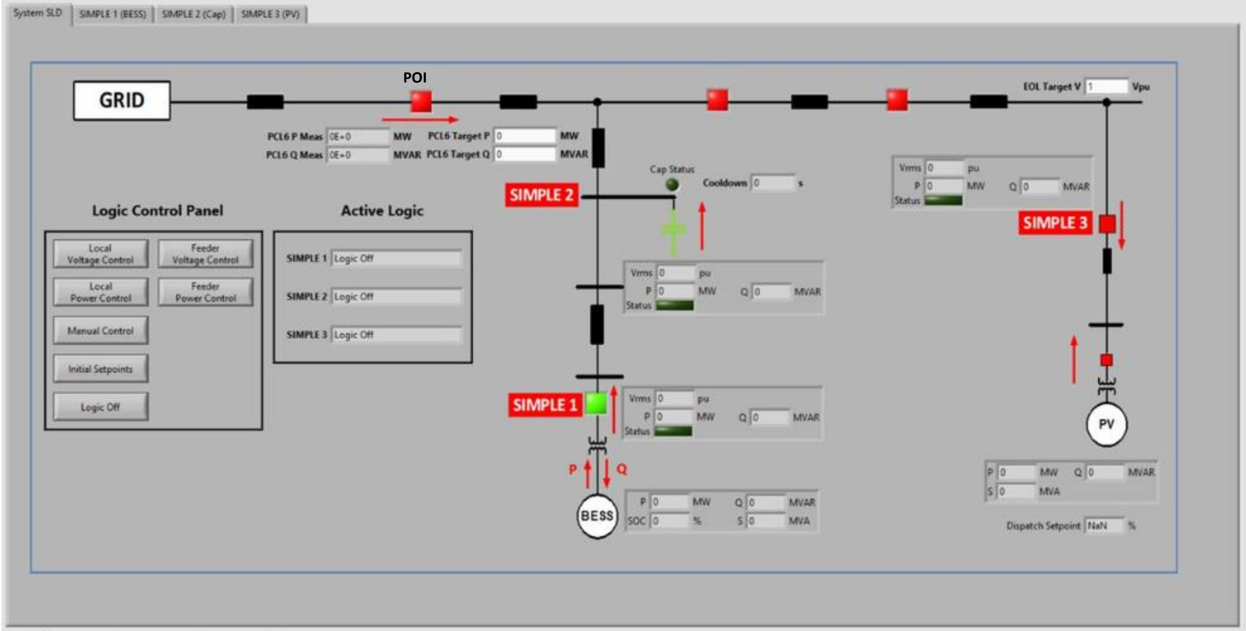


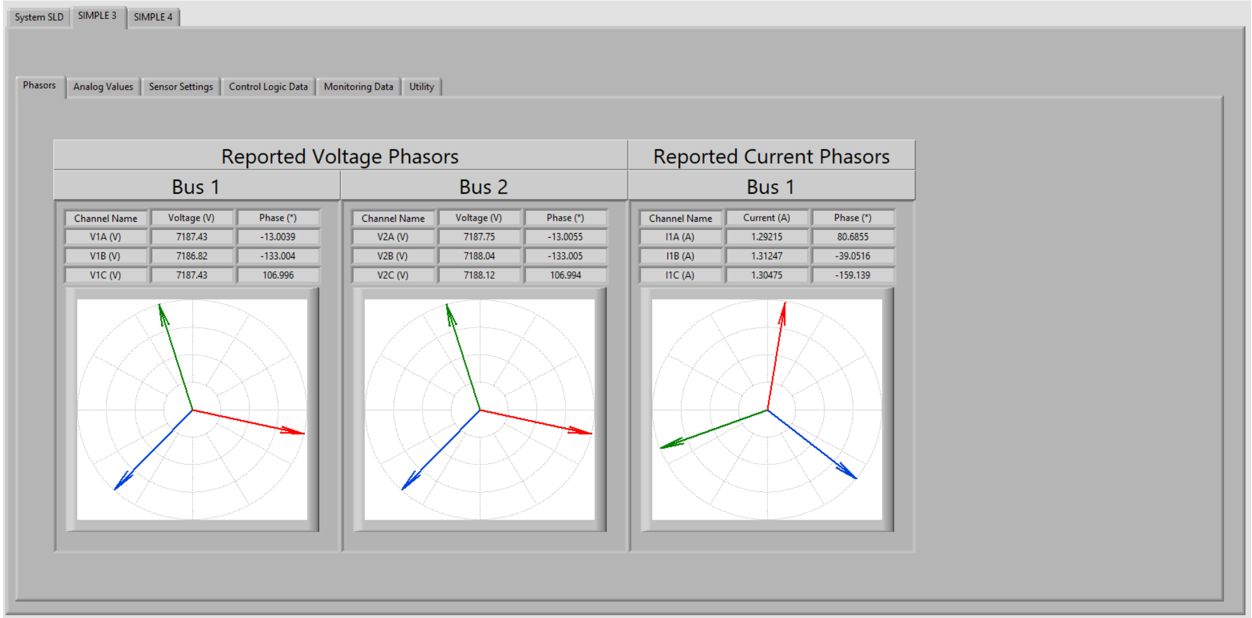
SIMPLE 1, SIMPLE 3 and the POI cabinet

SIMPLE 2 and MVCAL Cabinet

SIMPLE Remote Interface

- Remote interface was designed to facilitate monitoring of the feeder and to initiate desired control modes based selected application





- Snapshot of the SIMPLE platform remote interface – system SLD and logic control panel

Snapshot of the SIMPLE platform remote interface – PMU readings

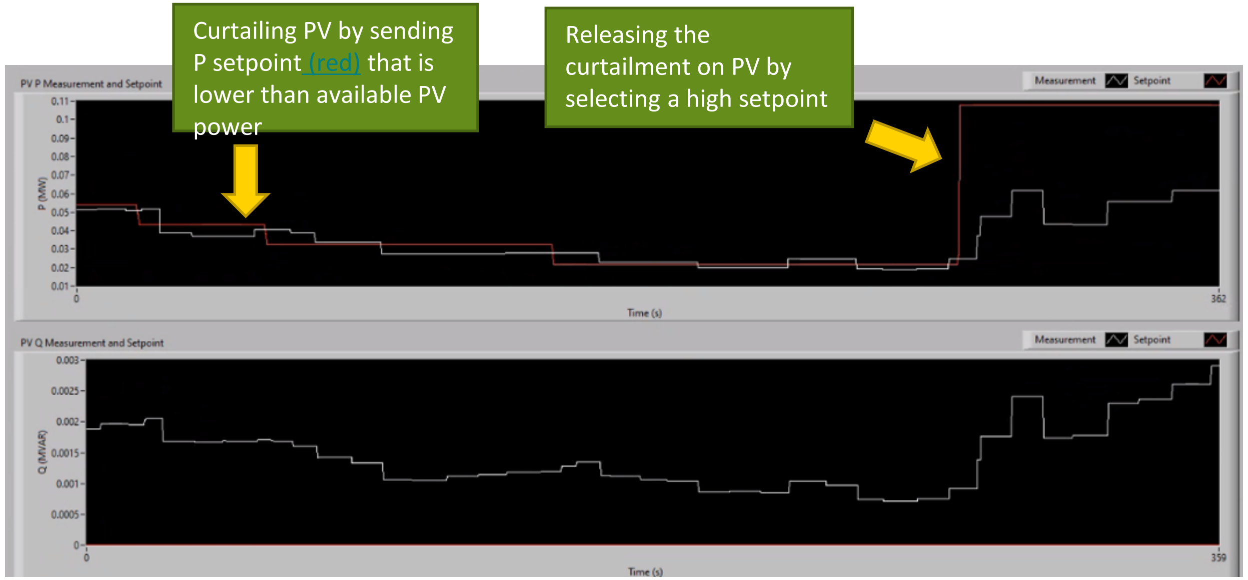
Field Test Cases: Communication Test and Application Test

The communication tests focus on verifying the device-to-device communication and serves as a preparatory step for performing application tests. The applications tests focus on application of SIMPLE for monitoring and control.

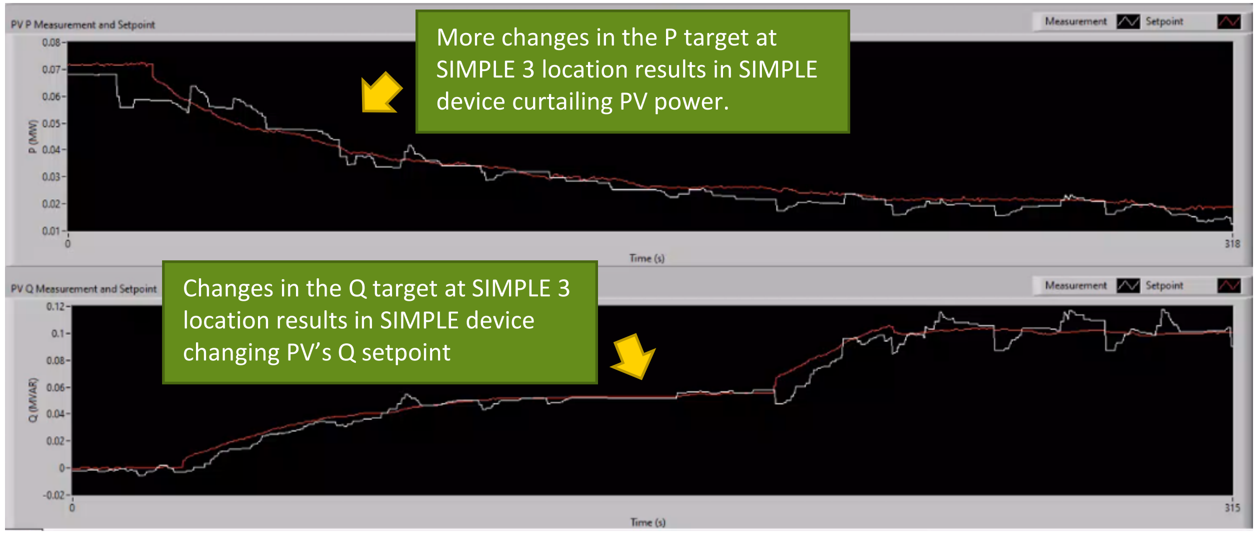
Test Case #	Radio Communication Test	Objective
1	Capacitor radio test	Verify capacitor controller's radio is functioning correctly and can receive/transmit data from the portable unit via DNP3 over radio
2	BESS RTAC radio test	Verify BESS RTAC's radio is functioning correctly and can receive/transmit data from the portable unit via DNP3 over radio
3	PV RTAC radio test	Verify PV RTAC's radio is functioning correctly and can receive/transmit data from the portable unit via DNP3 over radio
4	MicroPMU radio test	Verify radio communication between portable unit running PMU connection tester software and PSL MicroPMU
5	POI cabinet radio test	Verify radio communication between portable unit and the industrial PC (inside POI cabinet) with remote desktop connection
6	SIMPLE 1, 2 & 3 radio tests	Verify communication between the remote interface (i.e. HMI running on the portable unit) and SIMPLE 1, 2 & 3
7	DDS network communication test	Verify the DDS network where the devices communicate with each other through monitoring and control using the HMI running on the portable unit

Application Test Category	Application Test Description	Application Test Objective
1-a	Monitor voltage and power flow across the distribution system	Verify the ability of the SIMPLEs to monitor the voltage and power flow at their point of connection and to generate reports and alarms if required
1-b	Obtain data for root-cause analysis, maintenance, and pre-event analysis	Verify the ability of the SIMPLE devices to obtain data used for root-cause analysis, maintenance, and pre-event analysis, such as device loadings, capacitor switching, etc.
2-a	Local dispatch of each DER or distribution asset to manage local power flow	Evaluate the ability of each SIMPLE in managing the operation of its adjacent DER or distribution asset to manage local power flow
2-b	Coordinate dispatch of DERs and distribution assets to manage power flow	Evaluate the ability of the SIMPLE devices to do coordinated dispatch of DERs and distribution assets to manage feeder power flow
2-c	Local control of each DER or distribution asset to regulate local voltage	Evaluate the ability of each SIMPLE in managing the operation of its adjacent DER or distribution asset to regulate local voltage
2-d	Coordinated control of DERs and distribution assets to regulate feeder voltage	Evaluate the coordinated control of SIMPLE devices in managing the operation of DERs and distribution assets to regulate feeder voltage

Field Test : Manual Control of BESS and PV



Field Test : Local Dispatch of BESS to Manage Local Power Flow



Summary/Conclusion

PMU Applications and Roadmap at ComEd

An intelligent digital sensor platform has been designed that facilitates enhanced performance and improved accuracy and bandwidth with digital voltage and current measurement

The platform serves as an interoperable solution with sensor correction and digital compensation, and can also host advanced grid monitoring and control applications

The characterization and correction of sensor data using digital platform has been validated in both laboratory and field environment

Future development plan for distributed intelligence

Questions ?

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