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

Manohar Chamana
Distribution Planning, Smart Grid and Innovation

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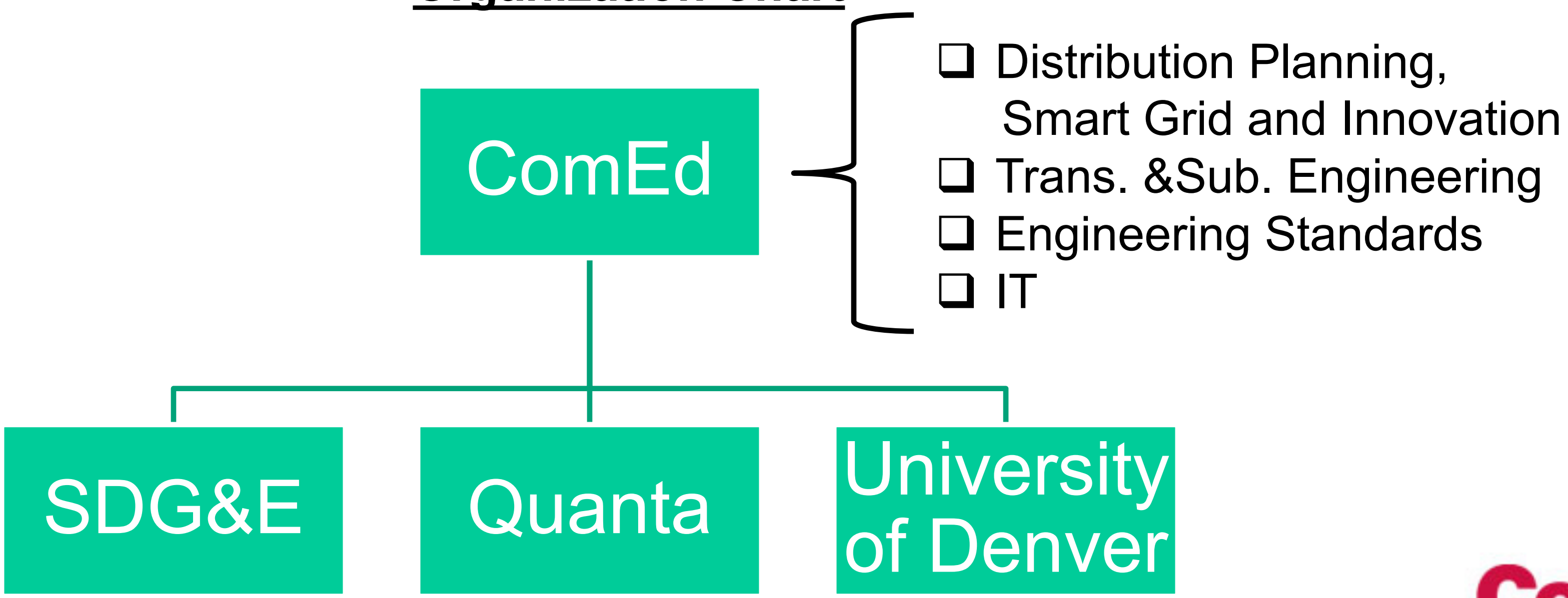
Grant Information

- **SIMPLE** project funded by U.S. Department of Energy's (DoE) Office of Electricity Delivery and Energy Reliability (OE).

- Project won under OE's grid modernization initiative (GMI) to improve Grid Reliability and Resilience through the Expanded Use of Distributed Energy Resources.

- Proposal submitted in November, 2016 and awarded in June, 2017.

Organization Chart



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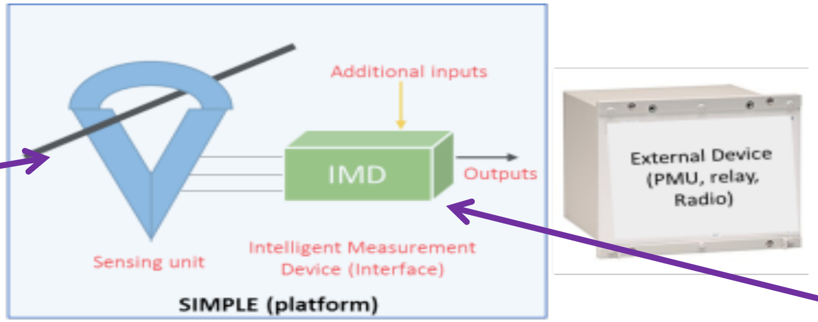
Introduction

What is SIMPLE (Intelligent Sensor Platform)?

- New prototype to be built with commercially available sensors interfaced with an electronic platform (e.g. National Instruments' Compact RIO platform) for performance compensation/correction.
- To be housed within a NEMA enclosure.
- Output modules interfaced to communications and external hardware running the applications.

Commercially available voltage and current sensors on utility poles or in vaults (pad-mounts)



Intelligent electronic devices (IEDs) such as voltage controllers, relays etc.

Electronic platform, such as National Instruments' compact RIO

Motivation

- Gaps in existing technology: Low voltage & current measurements accuracy, Insufficient bandwidth and narrow harmonic range, Lack of intelligence & integration flexibility within the modern smart grid.

Expected Benefits

- Convert analog measurements at multiple locations to digital signals using **filtering** and **digital signal processing** techniques locally.
- Make **localized decisions** with high granular data by distributed sensors located close to DER and distribution equipment of interest.
- Achieve **greater observability** of the distribution system when the deployed in multiple locations along distribution feeders, including service transformers.
- Adding standard communication protocols (IEC 61850, DNP3, IEC37-118, Modbus, etc.) to enable better integration and eliminates the need for **protocol convergence**.
- **Lower cost** solution compared to existing technology.

Technology Applications

- SIMPLE primary purpose:

  Control applications, such as **voltage regulation and frequency support**, by **DER** including storage, with or without smart inverters.

- In addition, SIMPLE would be well suited for:
  - **Voltage sensing** for conservation voltage reduction (CVR)/voltage and volt-ampere-reactive (VAR) optimization (VVO).
  - **Fault detection and location**, such as advanced applications of employing faulted circuit indicators (FCIs) for load profile monitoring beyond their present use for fault, voltage, and current indication.
  - Distribution system **state estimation** and electrical distribution network **topology processing**.

Key Project Milestones

Milestone	Description
Project planning complete	Project Management Plan (PMP), Data Management Plan (DMP), Cybersecurity and Interoperability plans completed and delivered
System specification approval	Acceptance of Functional Specification (or equivalent) for sensor by ComEd
System design completion	Complete the design and development of SIMPLE prototype
Prototype delivery	Prototype system delivered to laboratory
High Voltage Testing Complete	High voltage testing completed at the HV Lab
RTDS Testing Complete	Low voltage testing completed at the ComEd Grid of the Future Lab
System design Acceptance	Acceptance of Field Demonstration Plan by ComEd
Demonstration system installed	Installation of Field Demonstration within ComEd Service Territory
Demonstration Complete	Completion of Field Demonstration

SIMPLE Development Plan

Develop a modular electronic platform:

- ❑ Input modules: Sensing elements, time synchronization input signals, control and status indication signals.
- ❑ Output modules: Communications and interface of the sensor system to the hardware running the applications.

Approach:

- ❑ Utilize National Instruments’ Compact RIO platform (controller), to leverage the available tools for interface, interoperability, and security control implementation.

Process:

- ❑ Review voltage and current sensing solutions for overall **cost-performance** efficiency.
- ❑ Review, select, and acquire I/O modules for the SIMPLE system to be **interface** with the distribution system monitoring and control applications.
- ❑ Perform basic **integration/functionality tests** to make sure all parts of the SIMPLE system work together.
- ❑ Develop specifications for a **portable accuracy testing** system that provides NIST-traceable calibration.

SIMPLE System

Optical or resistive divider medium-voltage sensing head

Electronic module (Intelligent Measurement Device - IMD)

Modular IMD design

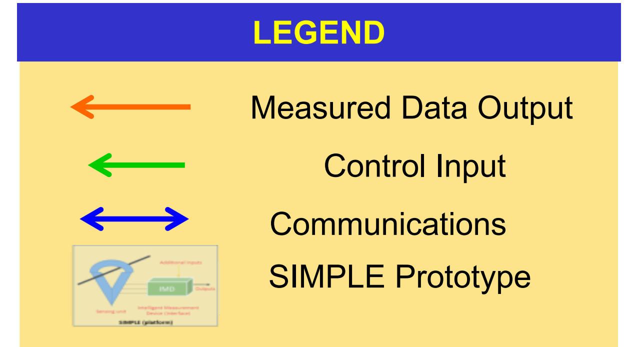
Input module for optical voltage sensor

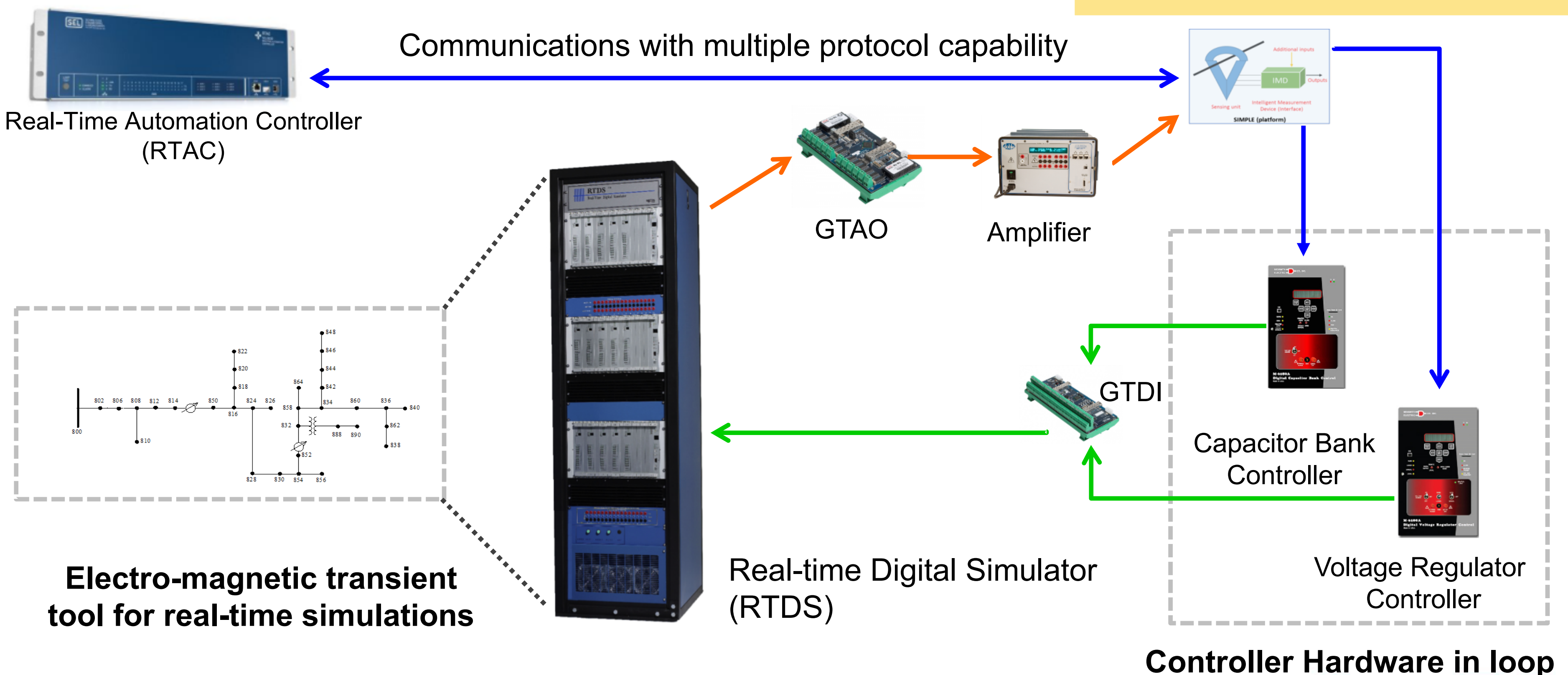
Module to backplane (chassis) connections

Hardware-in-the-Loop Testing

RTDS hardware in the loop (HiL) Testing, covering:
- ❑ Modeling and simulation of a selected feeder.
- ❑ Test controls and communication functionalities.
- ❑ Interface validation and verifications for the interface functionality.

Example of a Volt/VAR Control (VVC) Use Case Testing:
a) Step change of load or DG in the selected feeder, to create a disturbance.
b) Real-Time Automation Controller (RTAC) detects a voltage violation.
c) RTAC sends control signals to the HiL to maintain selected voltage.



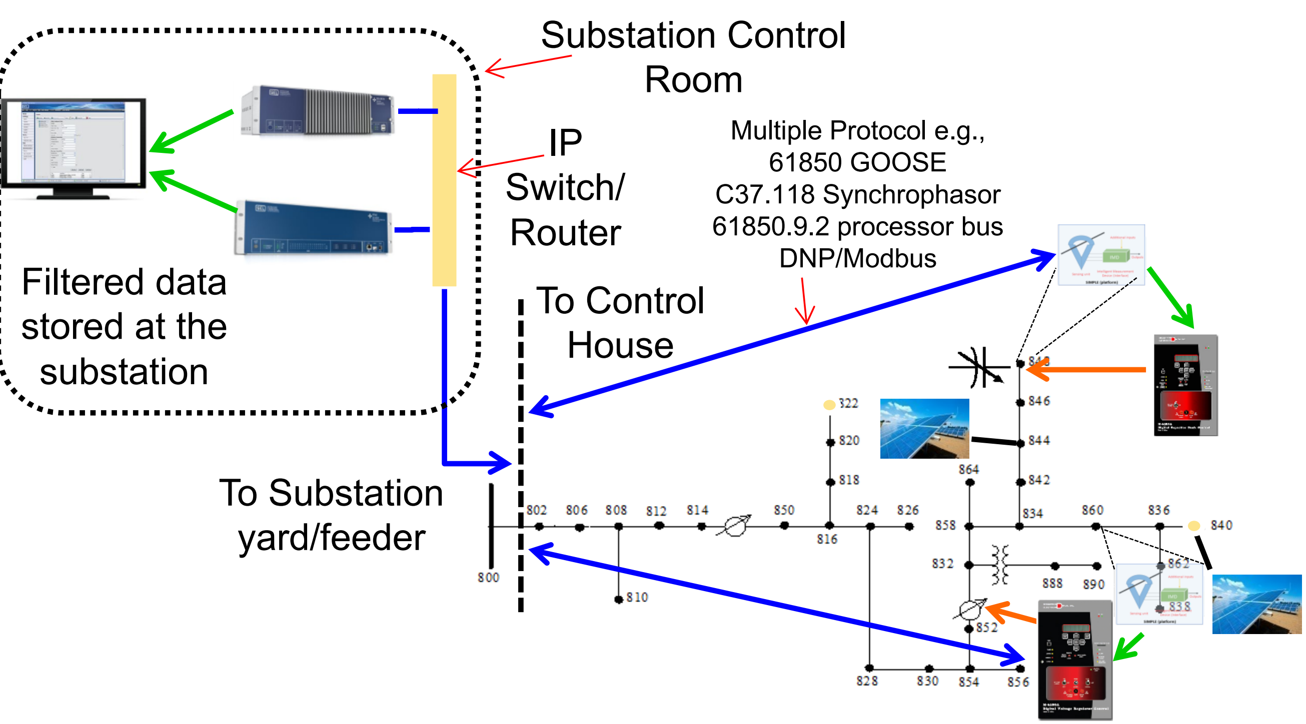


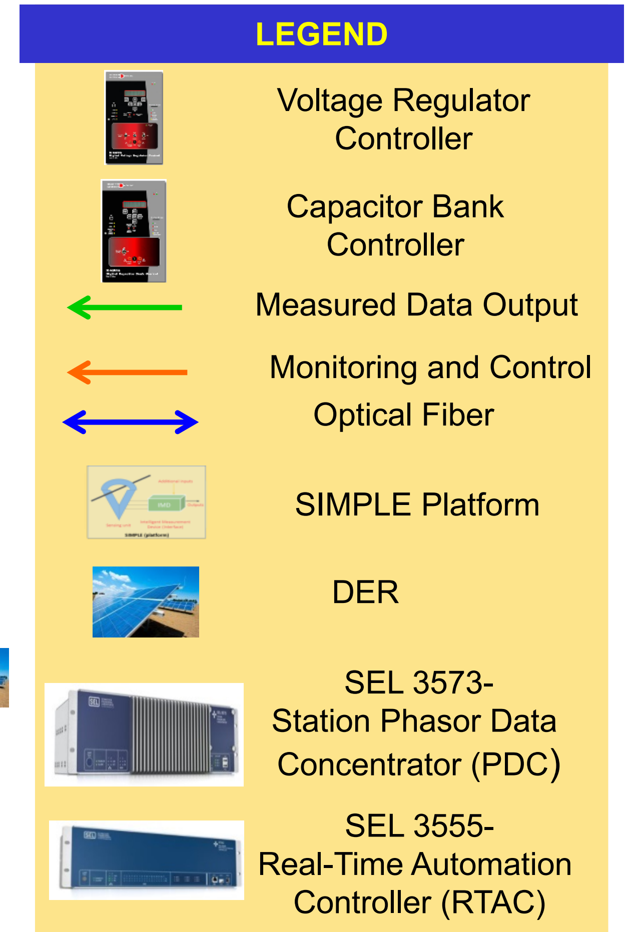
Field Demonstration

- Substation and distribution **feeder selection** process
- SIMPLE **location** selection process
- **Use cases** to be tested, including key electric variables (magnitude and phase angles of voltages and currents, and active and reactive power flows, voltage sags/swells, flicker, Total Harmonic Distortion (THD), etc.) to be measured, collected and analyzed for operation under both radial and primary loop topologies
    - DER and feeder monitoring under radial operation
    - DER and feeder monitoring under loop operation
- Collection, processing, validation, and analysis methods, and results analysis approach.
- Applicable city and county **permits** (environmental, construction, etc.) and approval process
- Project and **risk** management plans
- Detailed **engineering designs** of distribution substation and feeder enhancements
- **Construction** plan for implementation of required substation and feeder upgrades
- Plan for **installation**, testing and commissioning of SIMPLE prototypes
- **Operations** plan for testing and implementation of use cases
- Interoperability and cybersecurity plans

Example of Field Demonstration Architecture

- ❑ Location: A site with DER interconnections, Preferred Location: IIT microgrid in Bronzeville.
- ❑ Install SIMPLE prototypes at 2 locations closer to voltage controllers.
- ❑ Two centralized monitoring and controllers to be installed within substation.
- ❑ Bi-directional communications with two SIMPLE prototypes to perform Volt/VAR operation (VVO), location monitoring and possible control on a selected ComEd feeder.





Questions?

Email: manohar.chamana@comed.com

Thank You!

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APPENDIX

Sensor Attribute

Sensor Attribute	Units	Performance Target	Current Value	Comments
Estimated Capital Cost	$/sensor	$12,000	$30,000	This is cost per 3-phase system (3-phase voltage sensor OR 3-phase current sensor)
Estimated Installation Cost	$/sensor	$4,500	$35,000	Assumes MV bucket truck at $3,000/day Technician hours at $125/hr ($1000/day) Outage time valued at $250/hr (very conservatively) Planning time is excluded (assumed being the same); additional cost of interface
Calibration	hours/sensor	2 hr	16 hr	per 3-phase system; + additional interface and comm part
Calibration	$/sensor	$1,125	$10,000	Today, there is a need for an outage, test equipment, and several hours for testing. The low-cost sensor can be calibrated live with the signal already on the line.
Calibration Frequency	time between calibration events (e.g. months)	5 yr	1 yr	
Calibration Longevity	duration for which unit stays calibrated (e.g. months)	5 yr	2 yr	
Maintenance	hours/sensor	minimal	TBD	
Maintenance	$/sensor	minimal	TBD	With dedicated electronics, continuous monitoring of the sensor is included. We expect no additional maintenance beyond the 5-year calibration effort
Maintenance Cycle	time between maintenance events (e.g. months)	10	5 yr	
Life Expectancy	(e.g. years)	20 yr	10 yr	20 years or more for the primary sensing elements, 10 to 15 years for the electronics,
Peripheral equipment cost	$/application	10,000	50,000	Interface to IED, Communication setup, Settings, etc.

Technical Specs

Technical Specs	Units	Target Value	Current Value	Comments
Power Consumption	Watts	20W	120W	sensor and the interface board
Measurement Range	(e.g. x Volts - y Volts, x °F - y °F, x Amperes - y Amperes)	2 kV - 35 kV	15kV	
Limit of Detection		SNR > 30 dB	SNR=20 dB	
Response Time	(ms, ms etc.)	50 μs	20 ms	Sensor only; add 20 ms for the communication delay in the interface
Accuracy	% Full Scale	< 1%	5%	we are limited to sensor accuracy of commercial devices
Resolution	(e.g. mV)	16 bits	Not applicable	Today, sensor and the interface board are separate; we will combine them to enhance accuracy in digital environment
Drift		0.1%/yr	1%/hr	
Environmental	(e.g. temperature rage, humidity, et.c)	-20C to +45C	15C to 25C	
Case	UL rating			
Tamper Proof Packaging	Security Measurements	Yes	Not Available	Will plan for tamper-proofing similar to revenue meters
Other				Other Project Dependent Technical Specs

Ease of Deployment

Ease of Deployment	Units	Performance Target	Current Value	Comments
Labor Required	hours/sensor	<8hr	48	-Today at least 3 people for two full day (significant commissioning/integration effort at site -Target 2 people for 4 hours max.
Cost	$/sensor	$ 1,000	$ 6,000	mostly labor at $125/hr used
Hot Stick Capability		Yes	No	The light, safe sensors can targeted to be installed live with lot-stick