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SIMPLE – A Multi-Function Grid Edge Device with PMU and Point-on-Wave Streaming Capability to Support Multiple Advanced Distribution Use-Cases

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Outline

1. Need for Advanced Grid Edge Sensing Platform
2. Distributed Intelligence and Grid Edge Sensing
3. Intelligent Sensor Platform - SIMPLE
4. Applications and Testing of SIMPLE

Need for Advanced Grid Edge Sensing Platform

- Proliferation of DERs and EVs and the need for controlling bi-directional energy flow
- Evolution of the grid and customer expectations
- Focus on reliability, flexibility and resiliency
- Instrumentation outside substations
- Growing number of applications and functions needing accurate and reliable measurement data
  - Grid monitoring, protection, and control
  - Power Quality
  - Optimization
  - System restoration
  - Advanced smart grid applications and analytics

Distributed Intelligence and Grid Edge Sensing

- Computation and intelligence at the edge
  - Increased granularity and visibility
  - Highly Scalable
  - Faster response with decentralized and distributed control
  - Interoperability
  - Peer to peer communication
  - Intelligence at the edge enabled by advanced algorithms and computation
  - Low communication burden
  - Can still coordinate with centralized control system (layered coordination)
- Enables community resilience, security, safety and economy

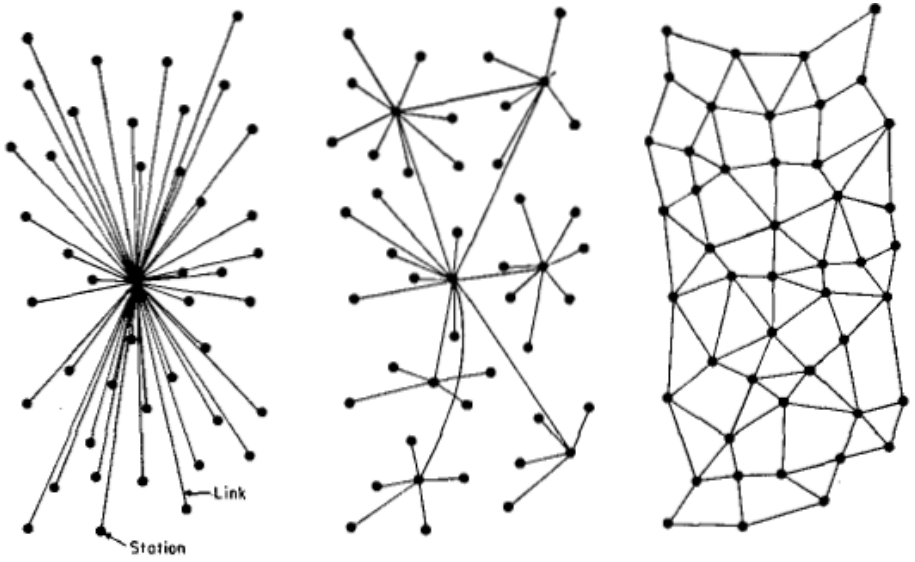


Fig. 1—(a) Centralized. (b) Decentralized. (c) Distributed networks.

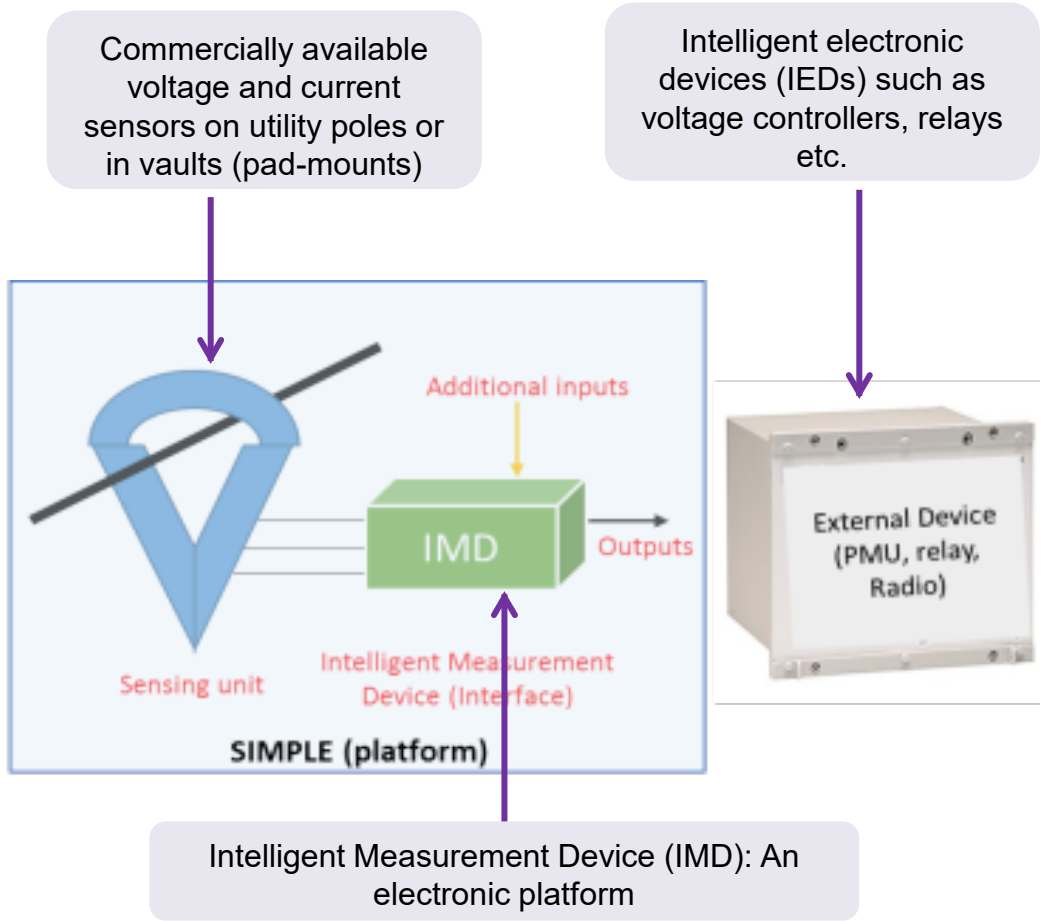
Sources: Duke Energy and OES Analysis

Intelligent Grid-Edge Sensor Platform

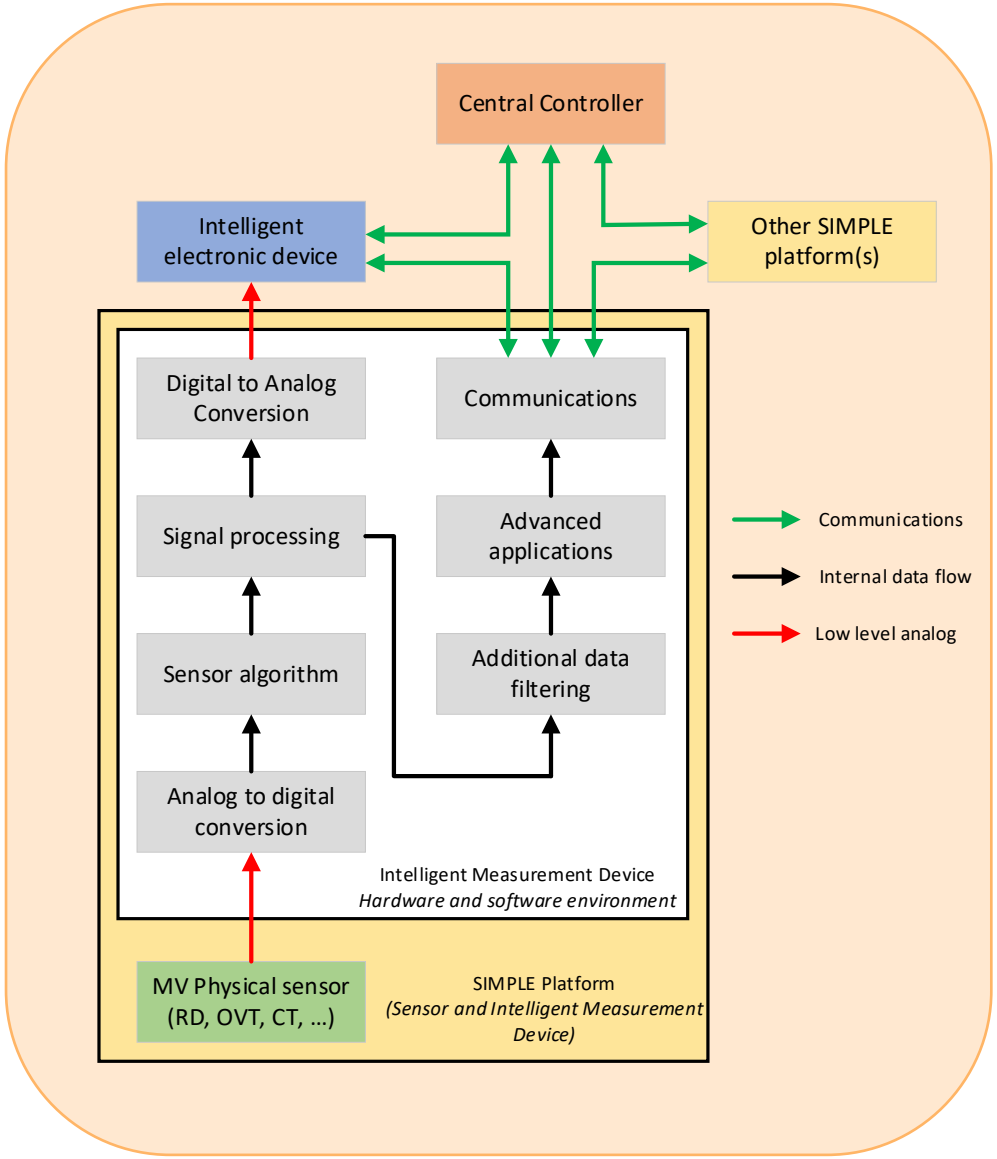
SIMPLE (Sensors with Intelligent Measurement Platform and Low-cost Equipment)

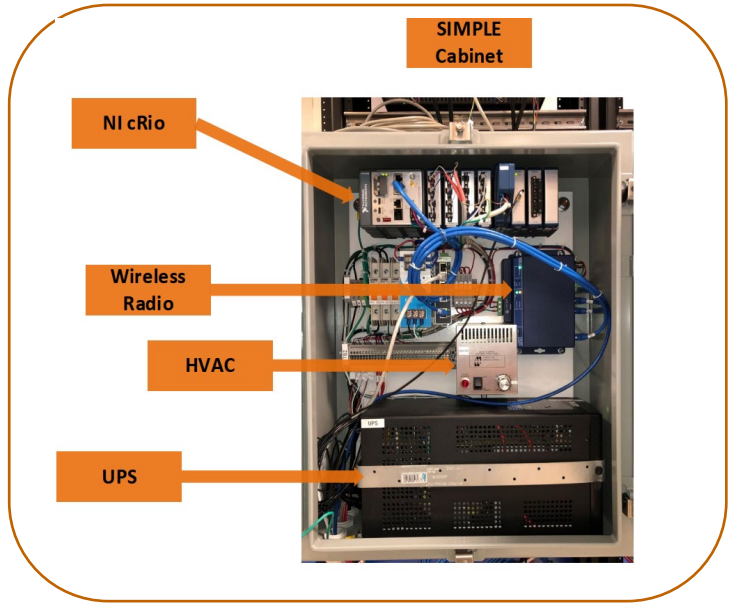
A combination of low-cost sensors and advanced intelligent measurement devices (IMDs)

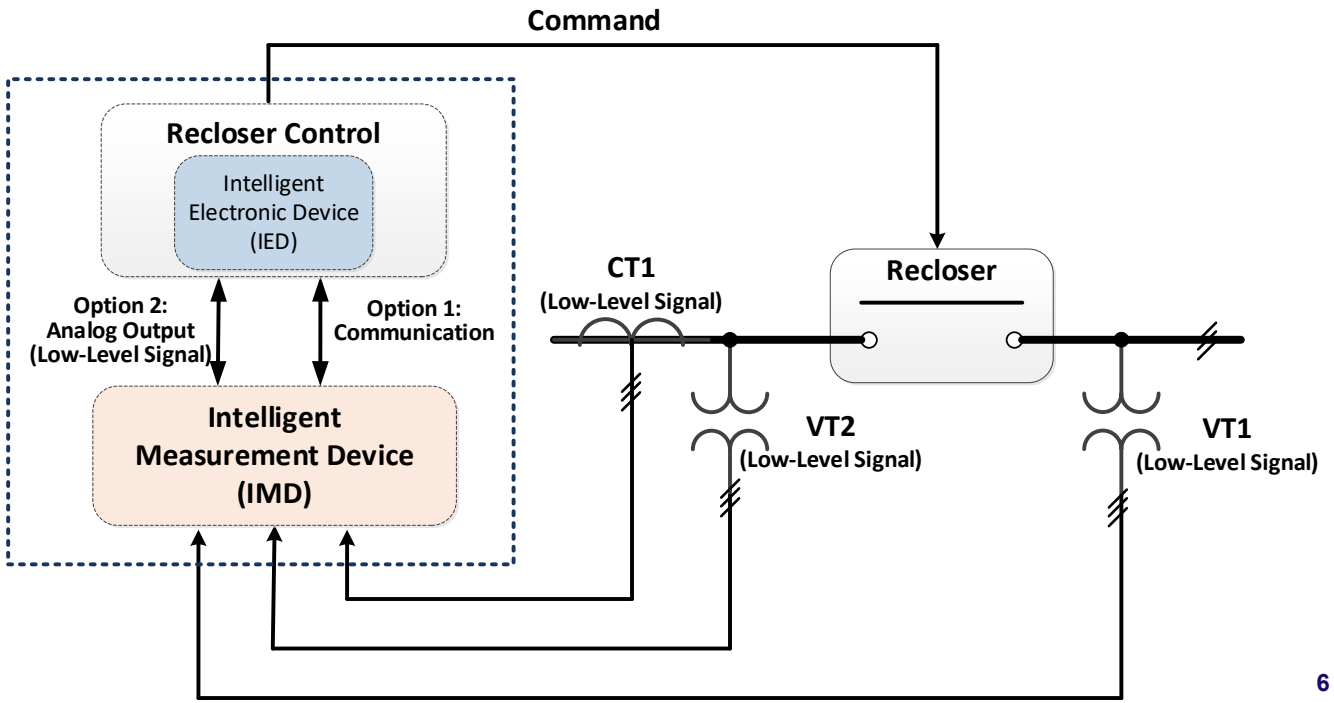
- Manage cost via value stacking
- Enable interchangeability
  - Multi sensing technologies
  - Future expansion
- Provide data correction and compensation locally
- Host advanced smart grid application such as data analysis, optimization and control
- Address communication needs through local IED
- Provide multiple outputs to address various applications at low cost-per-application



SIMPLE Architecture and Prototype



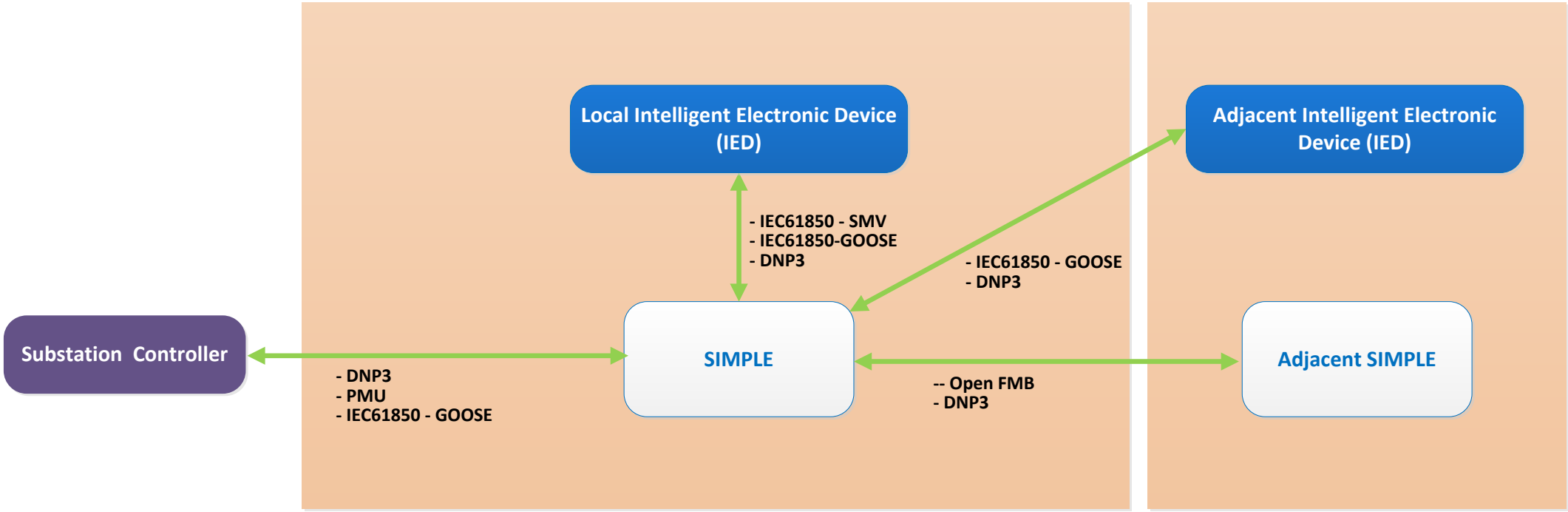




Enabling Interoperability

The key protocols and associated devices are:

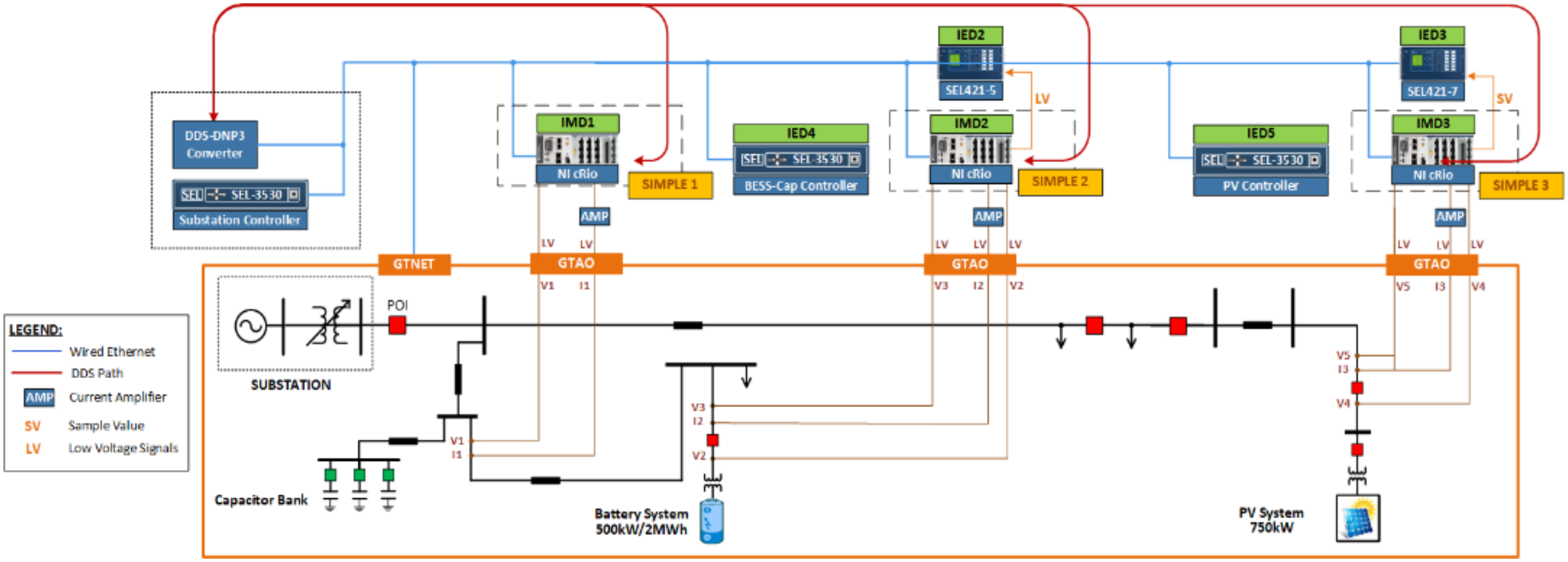
- Substation Controller or HMI: DNP3, PMU and GOOSE
- Local/adjacent IED devices for distribution apparatus such as capacitor bank, load tap changer, voltage regulator: DNP3 and GOOSE, LEA
- Any IED associated with DERs: DNP3 and GOOSE
- Adjacent SIMPLE devices and other grid edge devices: OpenFMB (DDS) and DNP3



SIMPLE: Applications

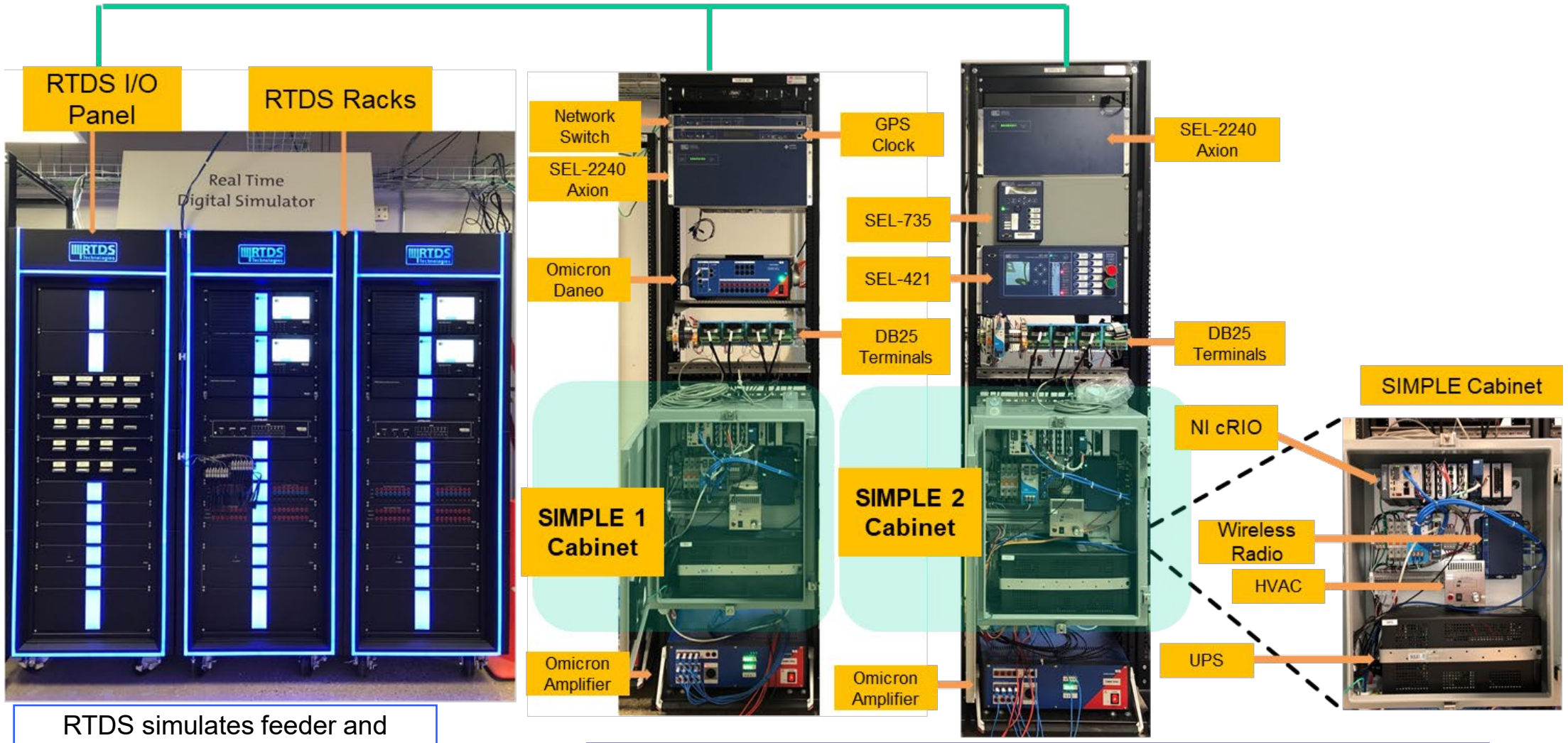
Distribution Circuit Monitoring (DCM)	Synchro phasor Measurement
	Power Quality Monitoring
	Monitoring voltage and power flow across the distribution system
	Obtain data for root-cause analysis, maintenance, and pre-event analysis
Automatic Resource Control (ARC)	Protection and Automation
	Fault Location Identification and System Restoration
	Coordinated control of DERs and Voltage Control devices
	Coordinated dispatch of DERs
	Microgrid Control

Hardware-in-Loop Lab Test Schematic



HIL Testbed schematic

HIL Lab Test Setup at GrIT Lab



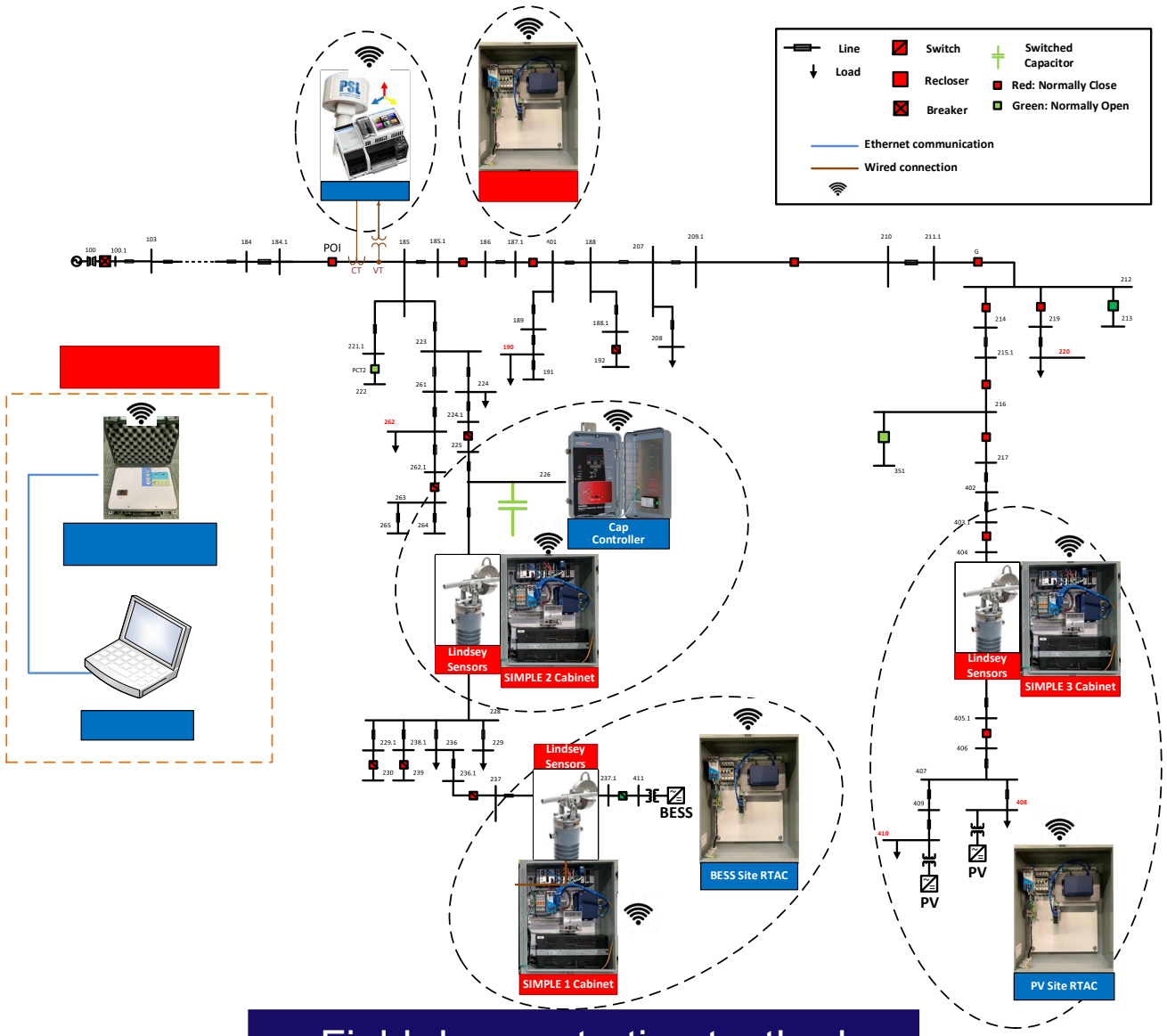
RTDS simulates feeder and interacts with SIMPLE and other IEDs in real time via I/O interface

SIMPLE units and IEDs receive and/or send signals to simulated RTDS model

Type Tests and Outcomes

Test No.	Test Name	Test Outcome
1	Medium voltage accuracy and bandwidth tests	Tests were performed in medium voltage facility, including entire SIMPLE system (passive sensors and IMD) to characterize and verify accuracy of sensor system both at power frequency (60Hz) and over frequency range up to 6 kHz
2	Low Voltage (LV) validation testing	Validation test results were obtained by comparing analog outputs vs analog inputs
3	Sampled Value (SV) verification testing	Comparative test results were obtained using DANEO 400 as subscriber to published SV
4	PMU testing	Comparative measurements were obtained using SEL AXION as the PMU reference device
5	PQ verification testing	Comparative measurements were obtained using SEL 735 as PQ reference device
6	DDS (Data distribution service) and DNP communication verification testing	Data exchange verification for following comm. links was performed: • DDS comm. between POI RTAC and SIMPLEs • DNP comm. between SIMPLEs and IEDs (both hardware and simulated IEDs)

SIMPLE Field Demonstration



Field demonstration testbed

SIMPLE 1, SIMPLE 3 and the POI cabinet

SIMPLE 2 and MVCAL Cabinet

Field Test Cases

Communication Test and Application Test

Communication tests focus on verifying device-to-device communication and serves as a preparatory step for performing application tests. 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 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 HMI running on 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

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Thank you

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