SDG&E's EPIC Demonstration Projects on Emerging Communication Standards

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Outline

- IEC 61850 Adoption Status and Need for Demonstrations in North America
- Electric Program Investment Charge (EPIC) Program
- Architecture Demonstrations Project
- Open Field Message Bus Demonstration
- Substation Network Demonstration

IEC 61850 Adoption Status

- IEC spreading to medium voltage assets globally outside of North America
  - Central regulatory entities and large nationalized utilities
  - Rapid adoption in Latin America projected (new large substations); manpower has been aligned
- Slow adoption in North America
  - State and regional regulatory processes
  - Largely a retrofit market
- Vendors have been slow to implement the IEC 61850 DER object models
- More demonstration work needed broadly in the industry

What is EPIC?

- **EPIC = Electric Program Investment Charge**
  - Statewide program administered by SDG&E, SCE, PG&E, and California Energy Commission
  - Program organized in 3 triennial cycles, spanning the period 2012 2020
- **Major SDG&E EPIC Project Activity Areas**
  - Advanced power system automation
  - Data analytics, visualization, and situational awareness capabilities
  - Integration of distributed energy resources
  - System operations development and advancement

Attribution: SDG&E EPIC Team Members for Communications-Related Demonstrations

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SDG&E EPIC-Funded* Communication Standards-Related Projects

- Smart Grid Architecture Demonstrations
  - Focus: Communications standards for integration of feeder equipment and DER into networked automation
- Monitoring, Communication, and Control Infrastructure for Power System Modernization
  - Focus: Open Field Message Bus
- Modernization of Distribution System and Integration of Distributed Generation and Storage
  - Focus: IEC 61850 in substation network

*EPIC = Electric Program Investment Charge, a statewide initiative

Architecture Demonstration Project Objective

- Perform pilot demonstrations of key candidate prototype building blocks of the SDG&E smart grid architecture to determine their suitability for commercial adoption
- Objective demonstrated in two phases:
  - Phase 1 – Update SDG&E Distribution Systems Operational Architecture
  - Phase 2 – Demonstrate IEC 61850 for Substation and Feeder Automation, including DER control using IEC 61850

Overall Scope of Architecture Project

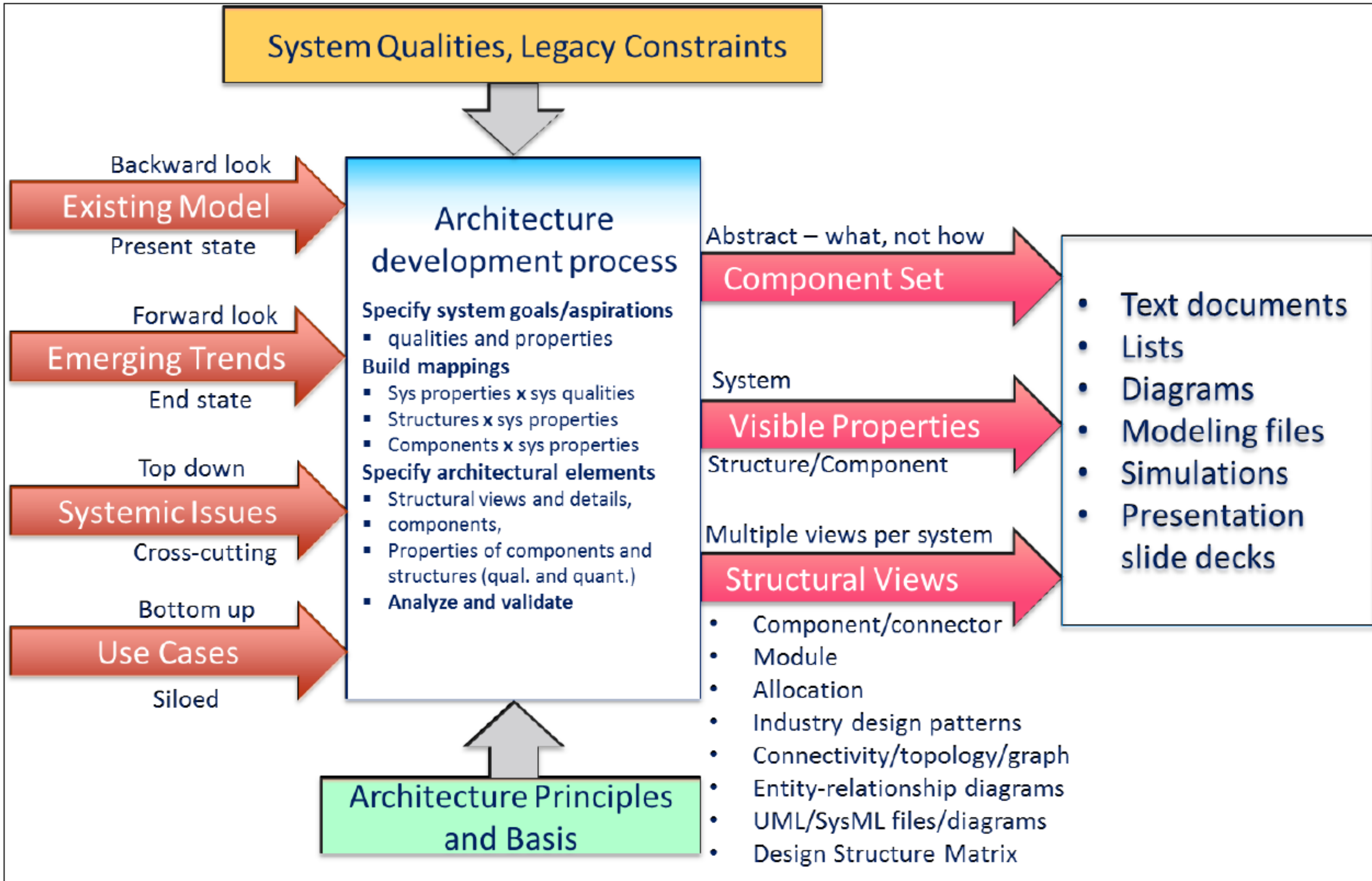
Phase 1…Architecture Development

- As-is architecture baseline analysis
- Review of the next generation of architecture principles
- Evaluate different standards and protocols
- Recommend future architecture for SDG&E

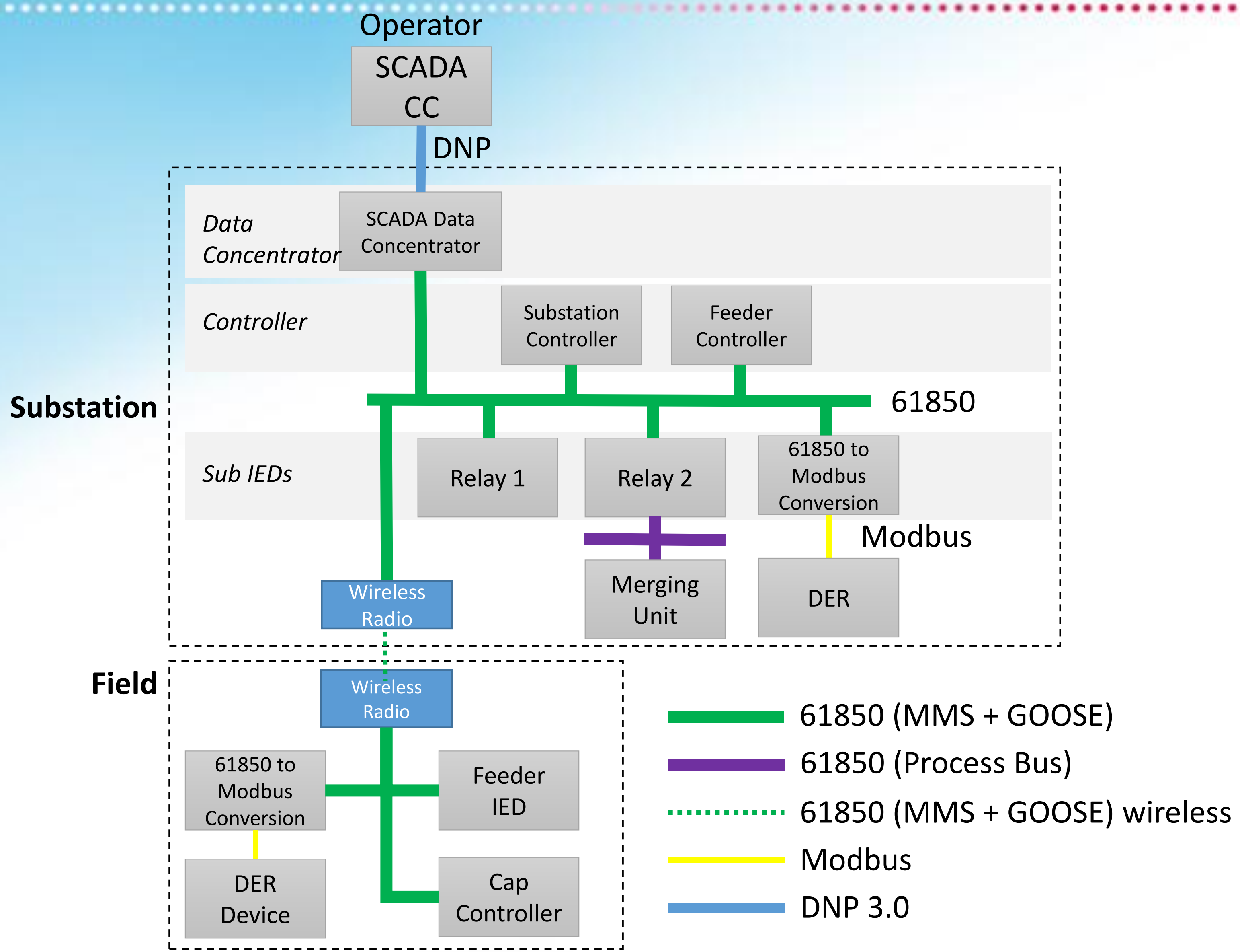
Phase 2…Architecture Demonstration

- Conduct pre-commercial demonstration of IEC 61850 on test system

Review Next-Generation Architecture Principles

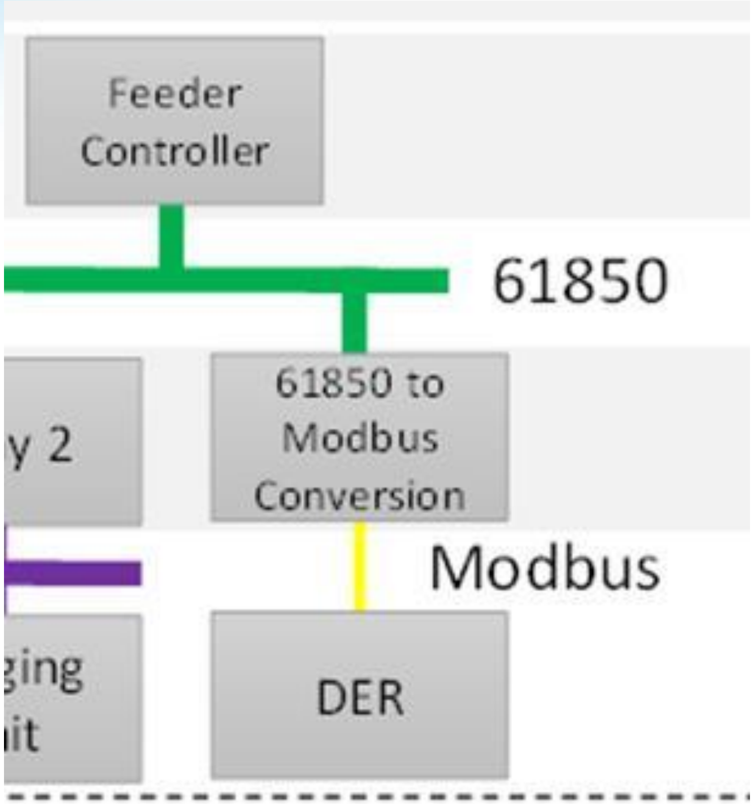


SDG&E ITF IEC 61850 Test Setup



Use of IEC 61850 for DER Integration

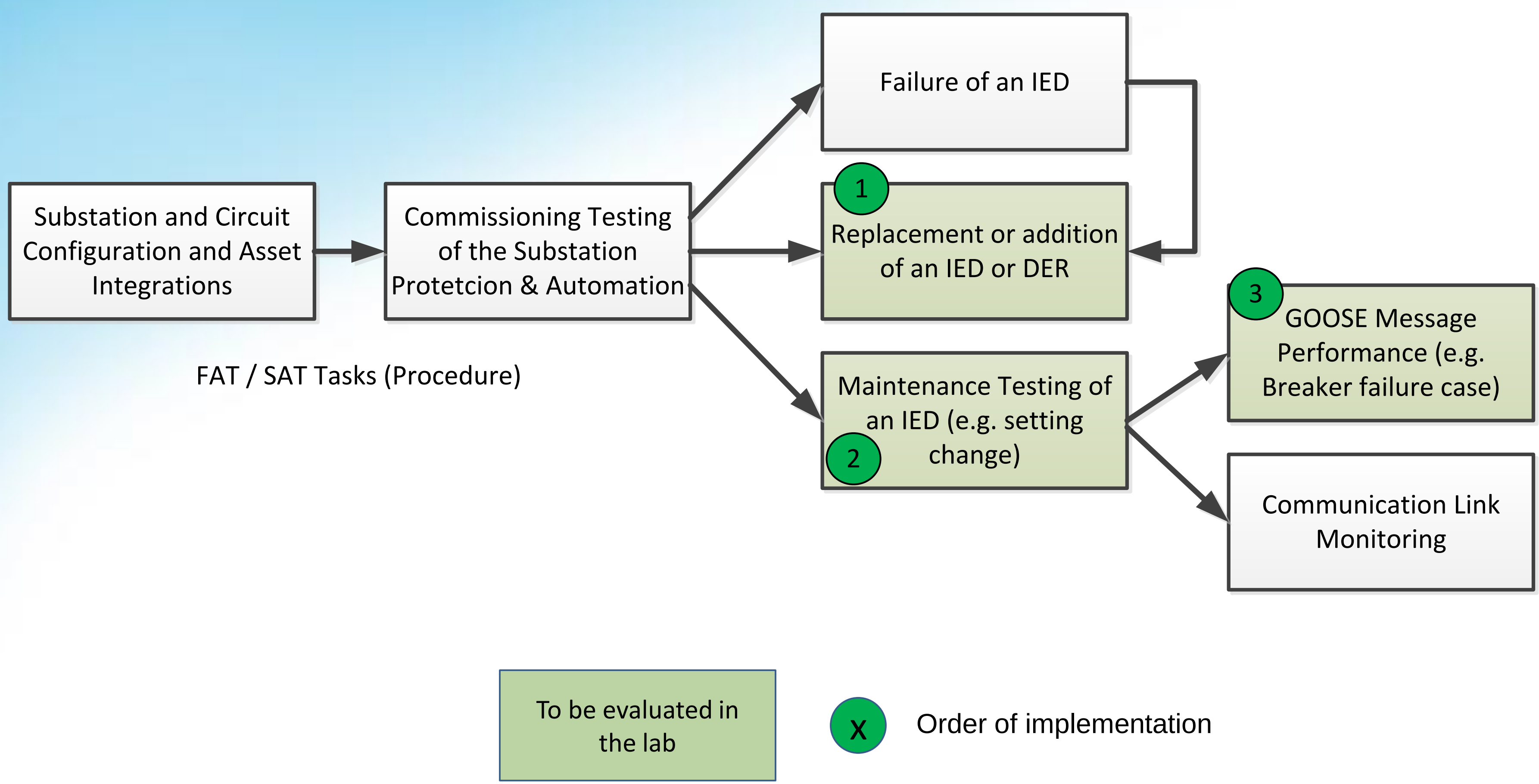
- DERs with nascent IEC 61850 unavailable in the market
- Workaround by integrating actual DER device (battery) onto the 61850 network using protocol converters (Modbus to IEC 61850)



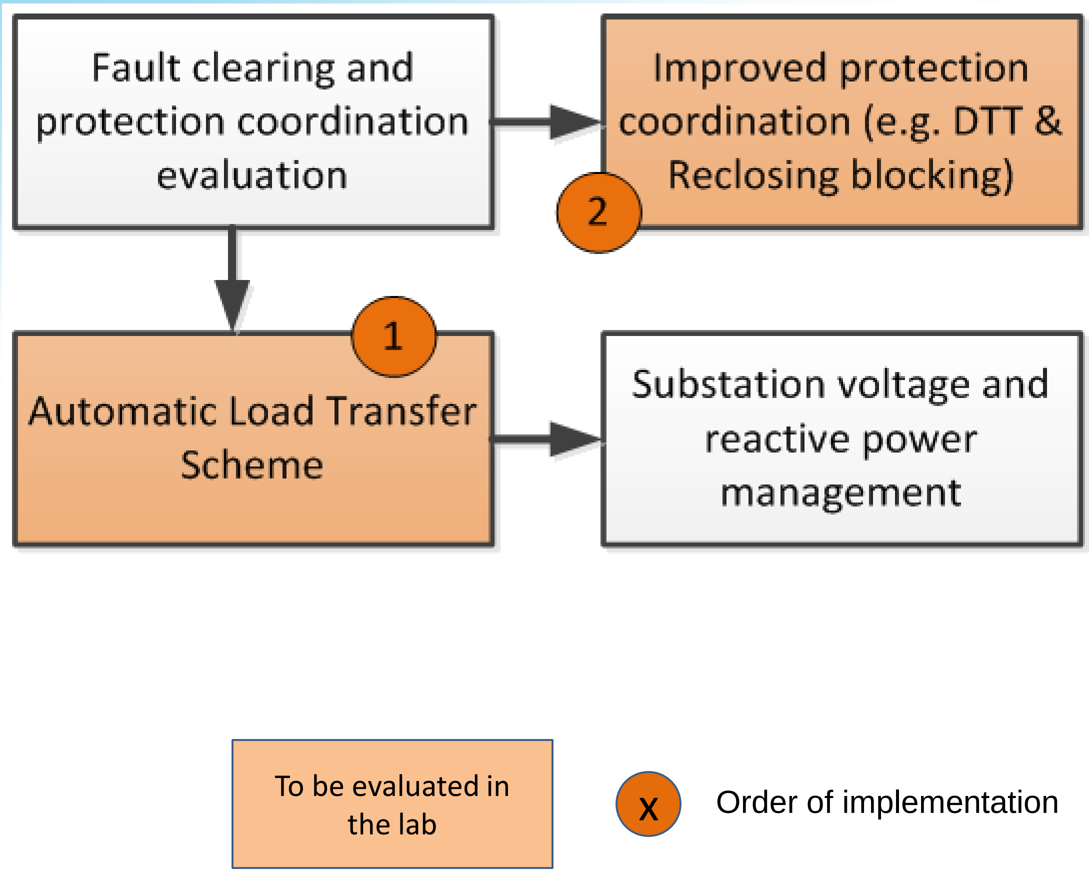
Use Cases

- Non Functional
  - Replacement or addition of an IED or DER
  - Maintenance testing of an IED
  - GOOSE message performance
- Substation Automation
  - Improved protection coordination
  - Automatic load transfer scheme
- Feeder Automation and DER Integration
  - DER control
  - DER grid support
  - Emergency load management with DER

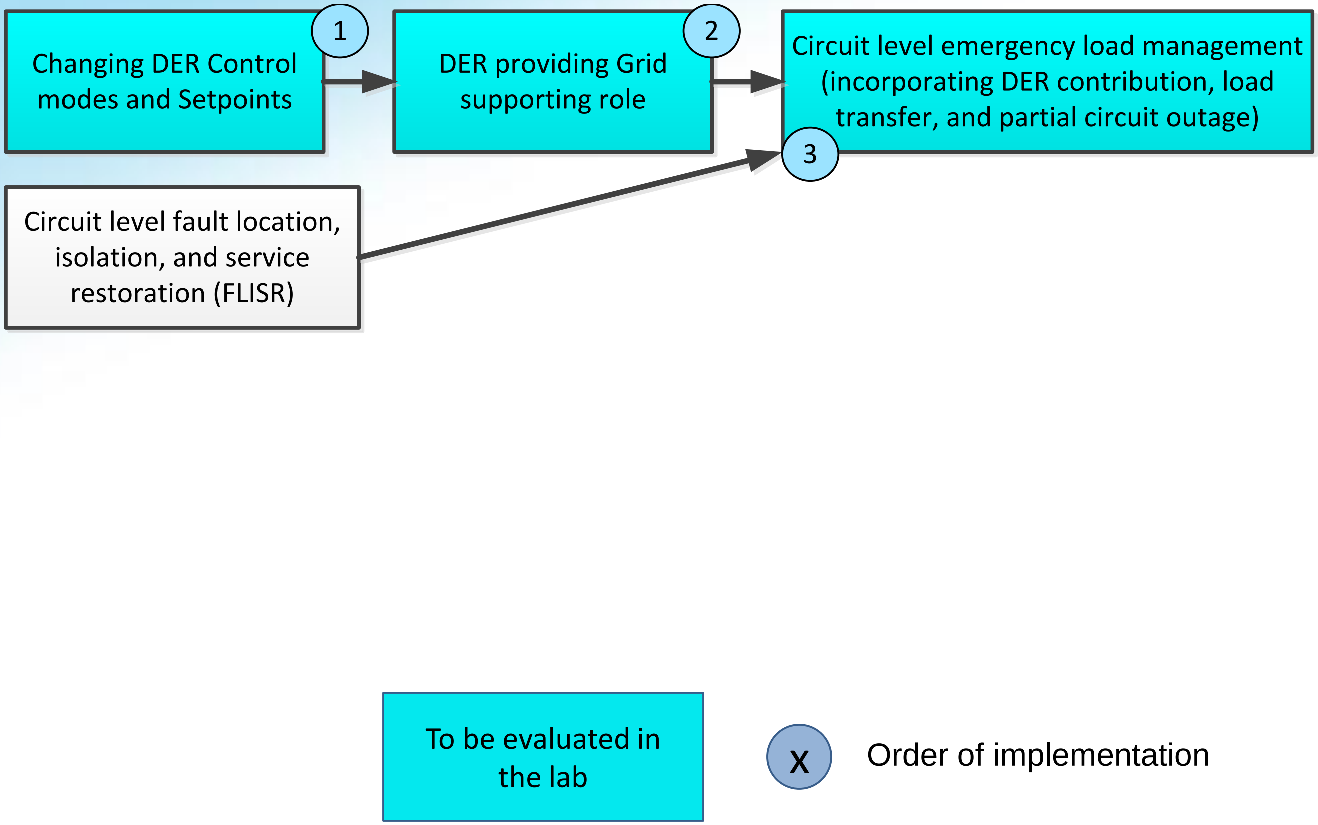
Use Cases – Non Functional



Use Cases – Substation

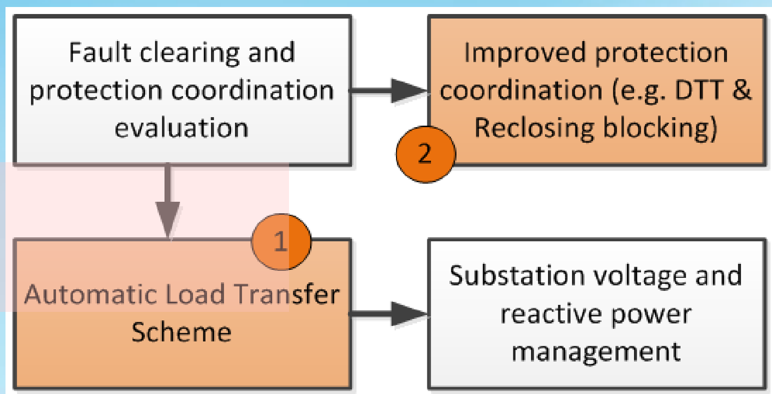


Use Cases – Feeder and DER

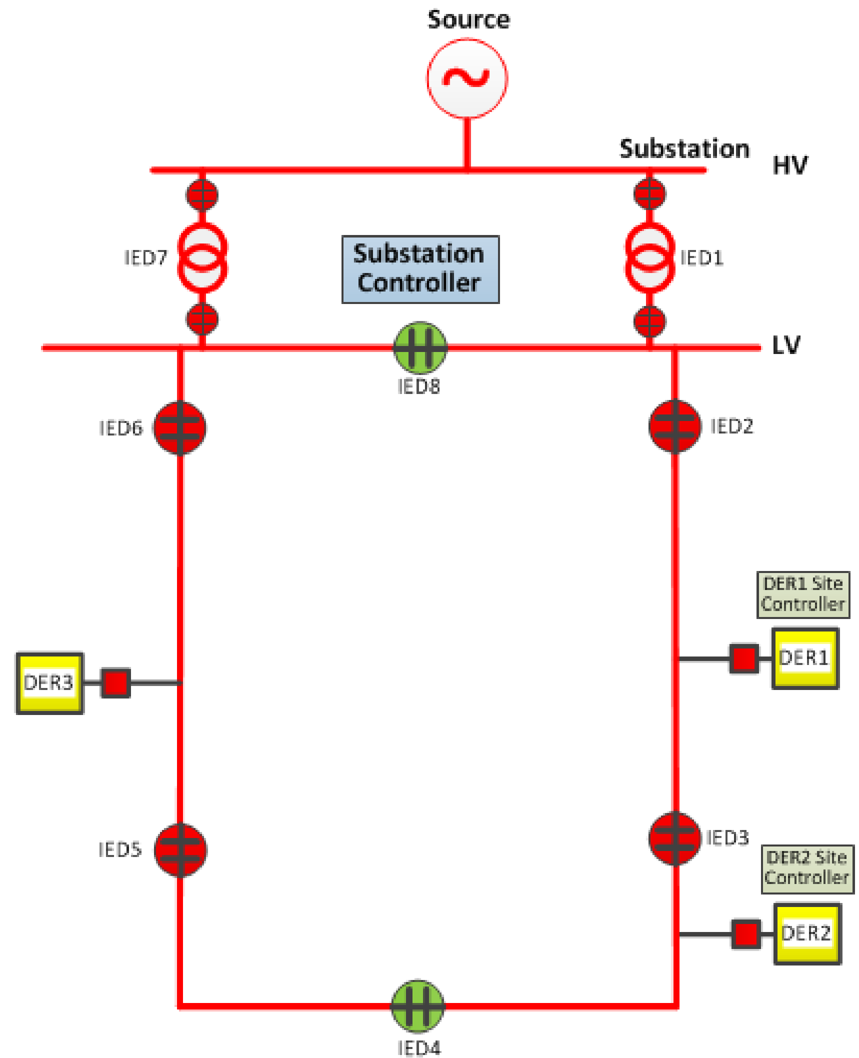


Automation of Operator Actions

Usage in Substation Automation

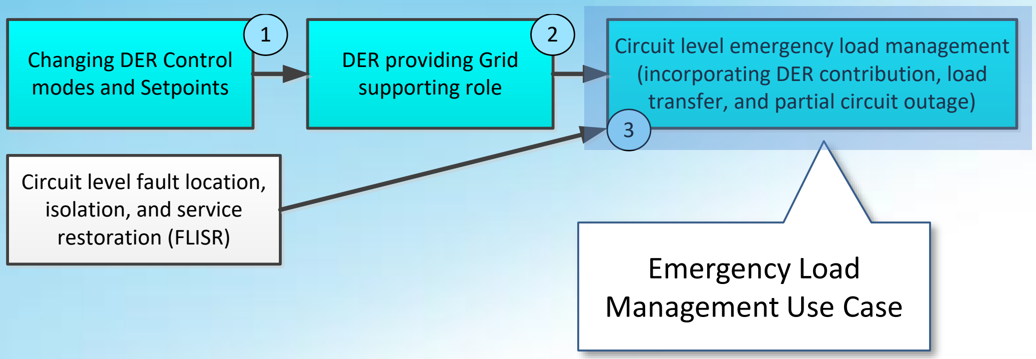


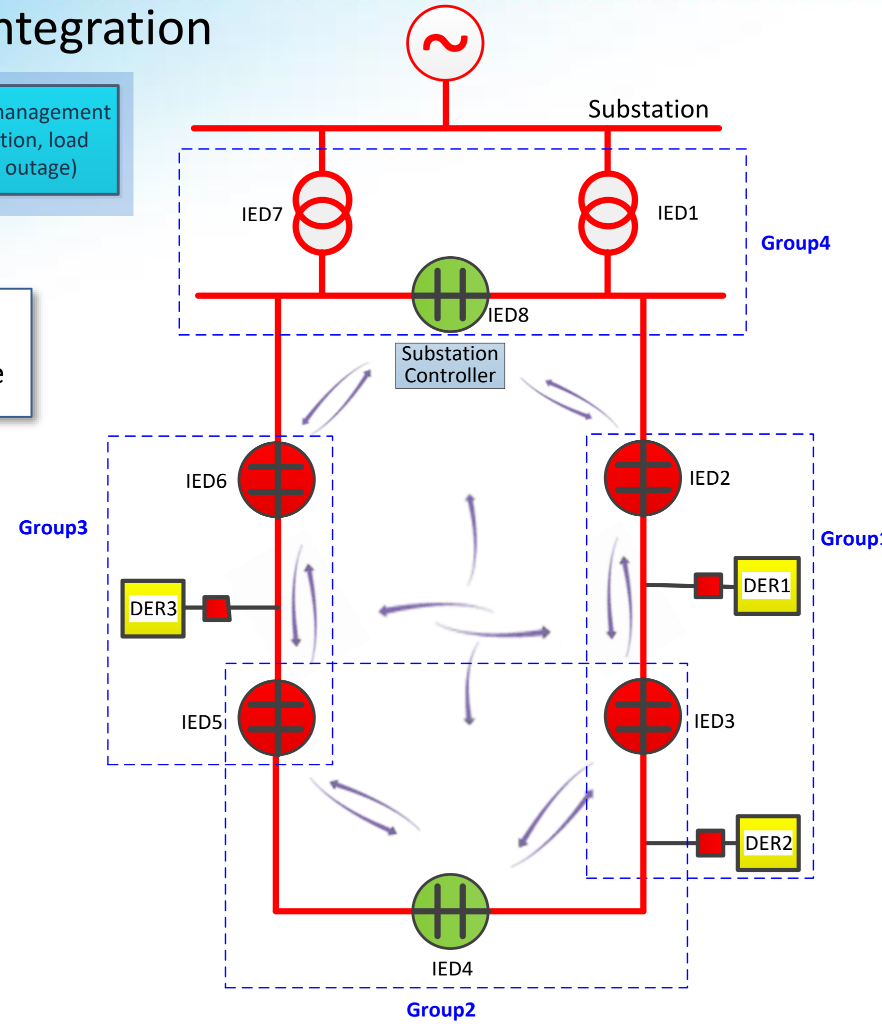
Automatic Load Transfer Use Case



Peer-to-Peer Communication

Usage in Feeder Automation and DER Integration





Use Cases – Feeder / DER (1/2)

1. **Change in DER control modes**
   - Remotely change control mode of a feeder-connected DER for enhanced operation of distribution system via IEC-61850 communications.
   - Settings include ideal or block mode, reactive power control methods of inverters (Q versus pf) or droop control modes.
2. **Emergency load management**
   - Surgical load shedding and DER control. Utilize DERs in order to:
     – Reduce the needs for disconnecting large amount of customers, based on the generation contribution from DERs
     – Perform partial load shedding, to restore some loads through alternative power sources
     – Rotate the scheduled outages more frequently as the need for load reduction changes.

Use Cases – Feeder / DER (2/2)

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3. **Grid support using DER**
   - Evaluate advanced inverter functionalities to facilitate grid integration and high penetration by utilizing DER control features to provide support to distribution system
     – Utilization of DER to correct feeder power factor and/or to improve feeder voltage through management of the reactive power flow.
     – Coordinated use of DER ride-through capabilities to enhance system performance under network faults and/or transient disturbances.
4. **Enhanced protection coordination for substation**
   - Enhance overcurrent protection coordination among conventional protective devices, particularly with high penetration of DER
     – Improved anti-islanding protection of DER
     – Improved reclosing/relaying operation
     – Enhanced operation of feeder protection

Use Cases – Substation (1/2)

- **Lifecycle Asset Provisioning**
  - Demonstration of engineering process to:
    - Create IEC 61850 system configuration files including
      - MMS mapping and HMI integration
      - Peer to peer (GOOSE) communication between IEDs
      - Sample values assignments (process bus)
    - Facilitate documentation method of a system design and implementation,
    - Update and reconfigure an existing system easily,
    - Add, remove, or replace components (IED/DER)
- **Goose Performance/Breaker Failure**
  - Evaluate performance of GOOSE-message-based breaker failure scheme, in connection with copper-wired implementation. Main criteria are speed and reliability.

Use Cases – Substation (2/2)

- **Field Testing and Maintenance of IED**
  - Investigate isolation and re-routing mechanism for GOOSE and process bus links provided by IEC61850:
    - How can the IED read process bus data provided by a test set versus actual merging unit information during maintenance test?
    - What is the impact if the GOOSE link to a device is interrupted during maintenance test?
  - Apply and verify test mode and simulation features as defined in latest IEC61850 standard.
- **Automatic Load Switch**
  - Implement automatic transfer scheme using IEC 61850 GOOSE messages based on SDG&E standard practices.
  - Circuit breaker positions, voltage phasor measurements, fault indications and synchronizing condition information transmitted via IEC61850 and processed by substation automation controller.

Data Analysis

- Detailed analysis of data from demonstration
  - Functions of control strategy
  - Effects on distribution control system
  - Benefits, costs, challenges, and impacts on distribution system
  - Impacts on operational practices (reliability, electrical losses, service quality)
- Analysis of metrics based on comparison of processed data with and without IEC 61850
  - Power factor, voltage, frequency, harmonics;
  - Electrical efficiency (i.e., electrical loss reduction);
  - System reliability
  - Conservation voltage reduction targets, etc.

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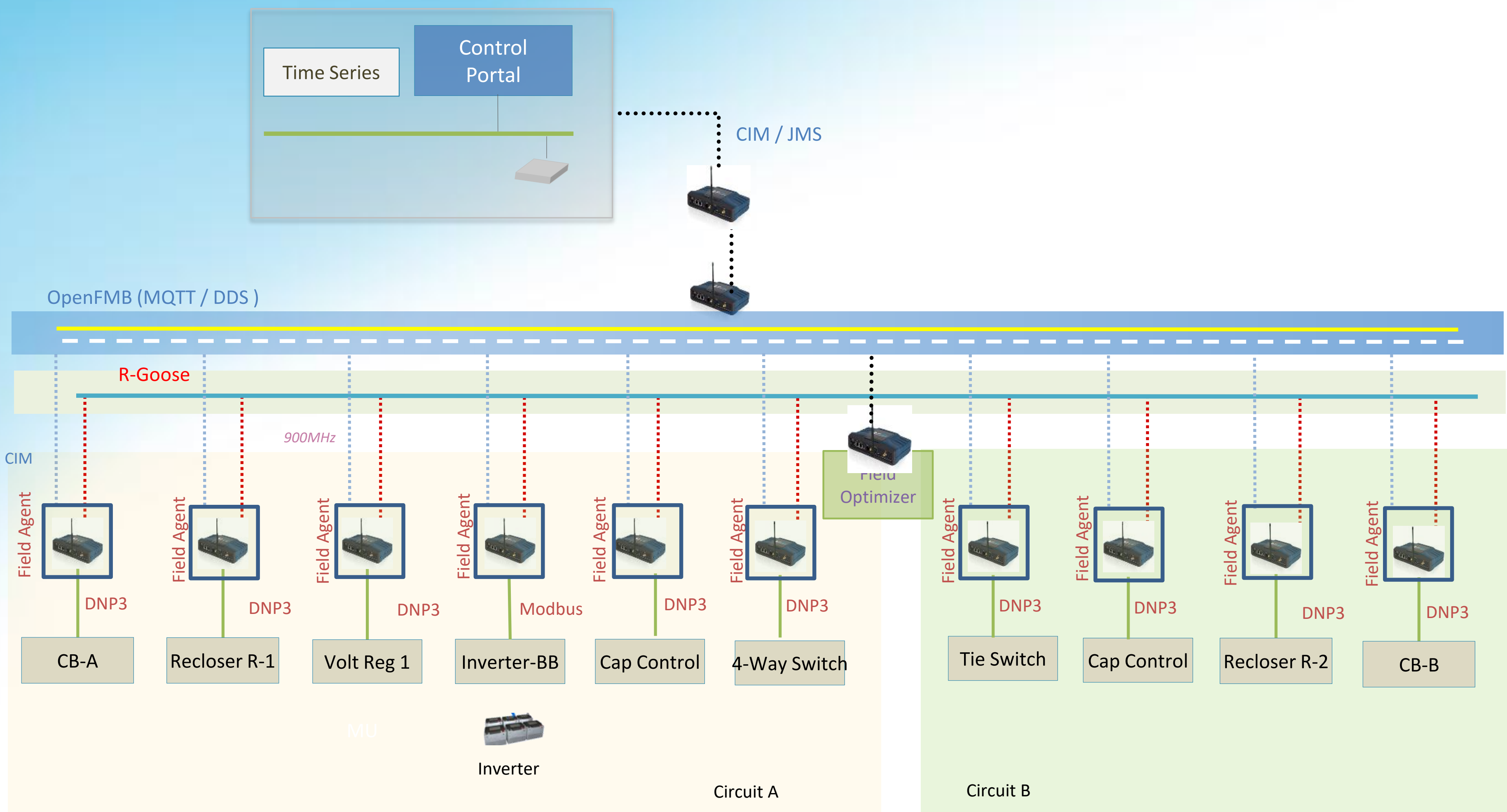
OpenFMB Demonstration Project

- Objective: Demonstrate advanced monitoring, communication and control infrastructure needed to operate an increasing complex power system infrastructure.
- Focus: Pre-commercial demonstration of Open Field Message Bus
- Scope: Hardware-in-the-loop demonstration in laboratory with real-time digital simulator

OpenFMB Project Use Cases

- Non Functional
  - Asset provisioning and integration with OpenFMB
  - Information sharing between devices and backend systems
  - Inter-network communication using OpenFMB
  - Management services
- Functional
  - Volt/VAr
    - Traditional man in the middle
    - Peer to peer
    - Inter-network VAr control
  - DER control using OpenFMB
  - Feeder re-configuration using OpenFMB

OpenFMB Project Test Setup



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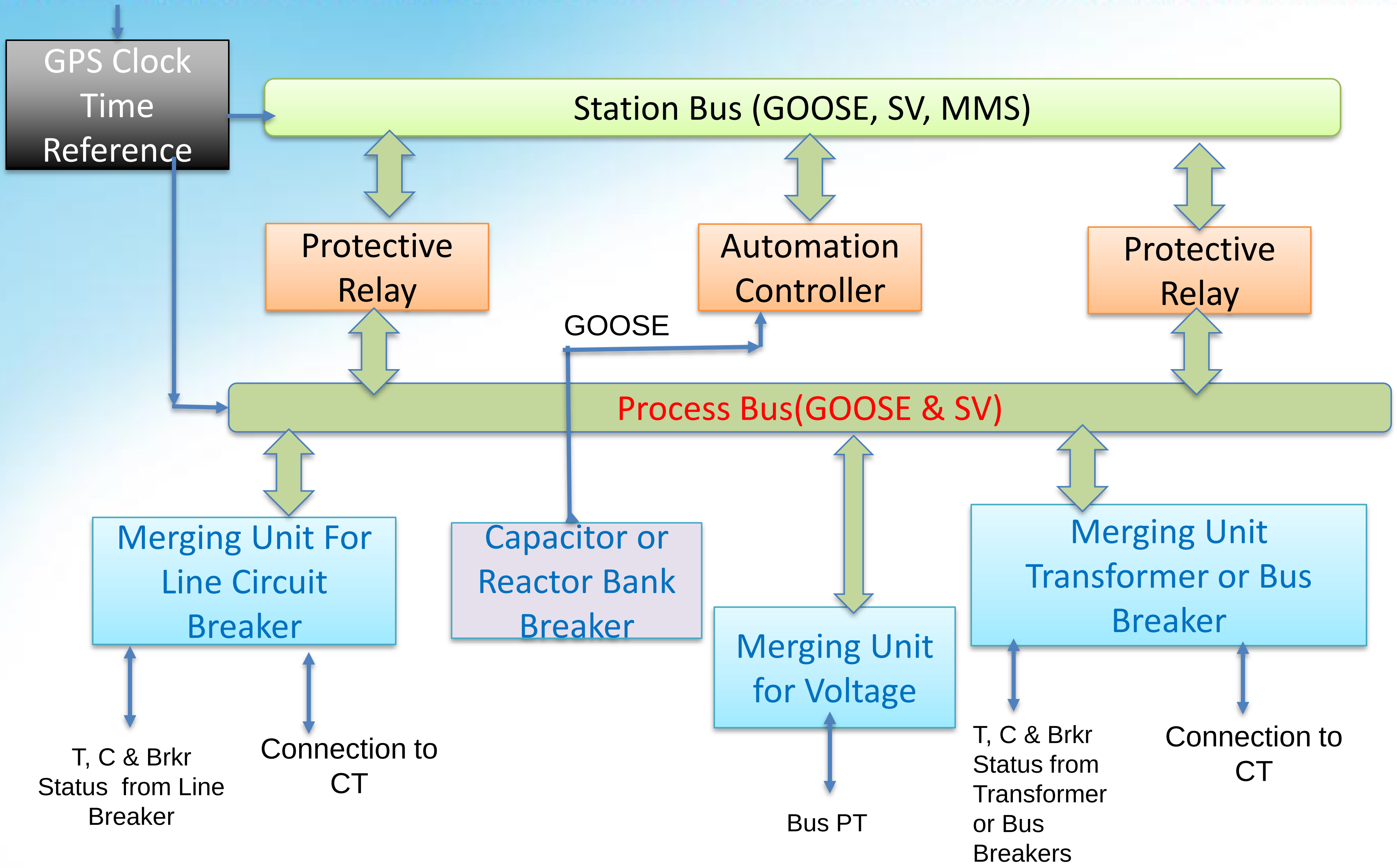
Substation Network Project Objectives

- Pre-commercial demonstration of distribution system modernization solutions, with main focus on new substation protection, control and monitoring.
  - Develop knowledge of IEC 61850 to aid in decision making on whether SDG&E should pursue IEC 61850 on a commercial basis and what the requirements would be.
  - Pilot IEC 61850 interoperability of infrastructure within a substation.

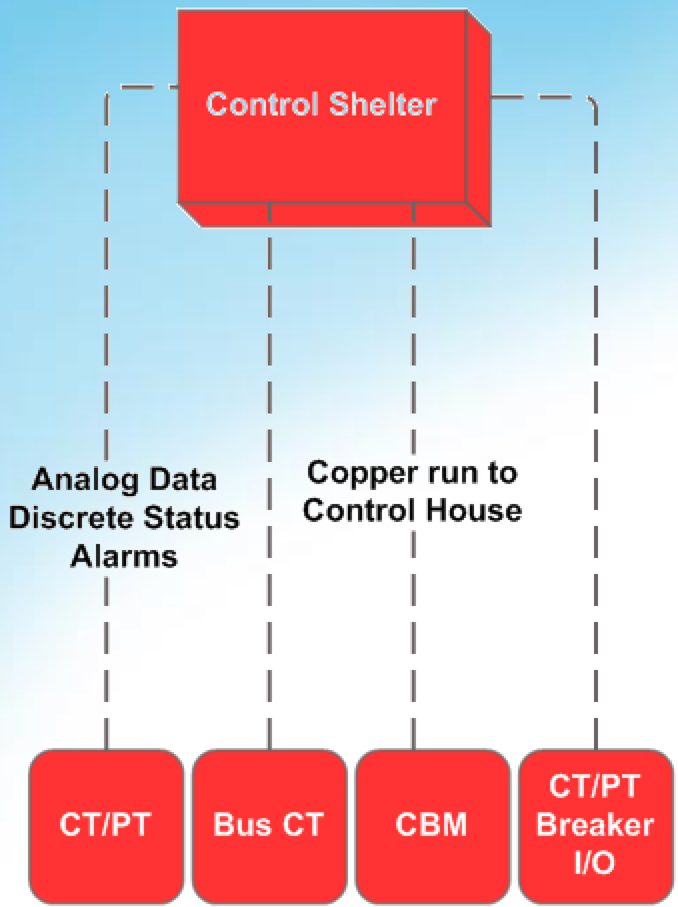
Substation Network Project Approach

- Conduct pilot mock-up and pre-commercial demonstration of an IEC 61850-conformant substation network
- Assess the pros, cons, and benefits of using IEC 61850 by examining a variety of use cases
- Typical 69/12 kV SDG&E substation
  - GOOSE (Generic Object Oriented Substation Event)
  - SV (Sampled Value)
  - Relays and merging units
  - Substation Configuration Language (SCL)
- Replace copper wiring with Ethernet

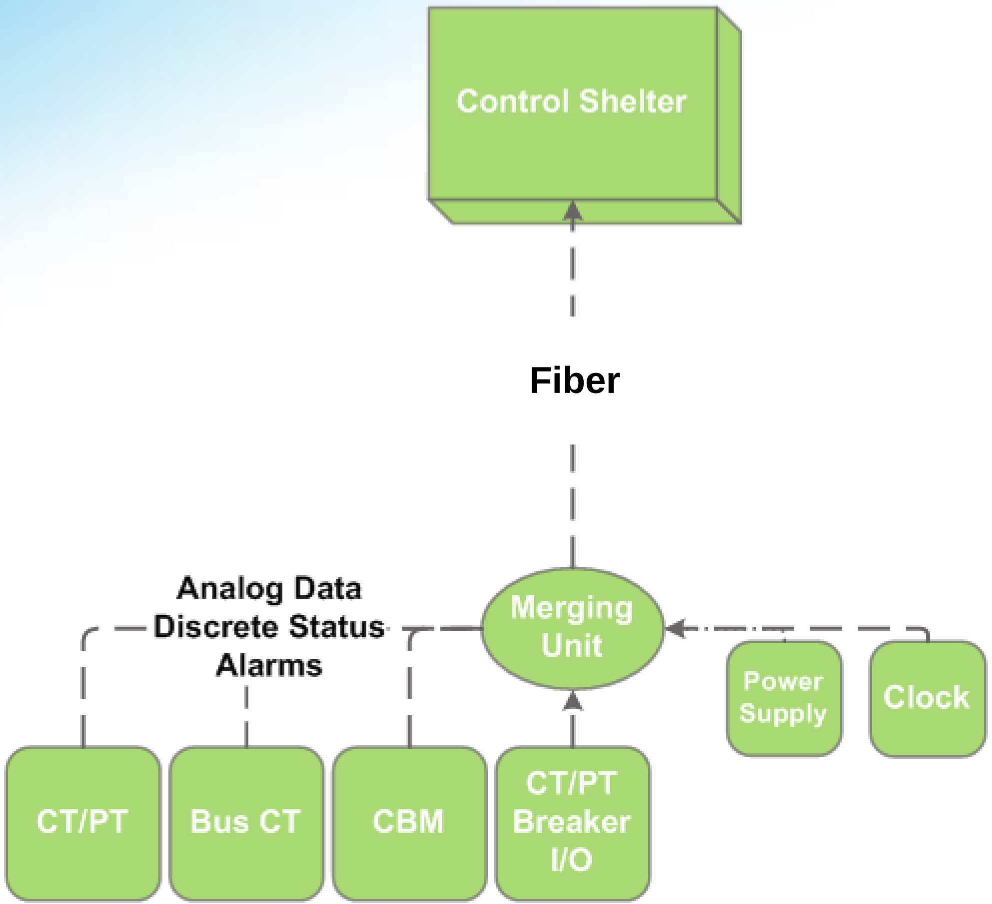
Simplified Conceptual Diagram for Substation Network Project



Comparison of Legacy and IEC 61850 System



Legacy Analog System



IEC 61850 Compliant System

Use Cases for Substation Network Project

- Line Protection
  - Differential Protection(87L) (SV, GOOSE)
  - Distance Protection(21) (SV, GOOSE)
  - Over-Current Protection(50/51) (SV, GOOSE)
  - Under-Frequency (81U) (SV, GOOSE)
- Transformer Protection
  - Differential Protection(87T) (SV, GOOSE)
  - Over-Current Protection (50/51) (SV, GOOSE)
- Bus Protection
  - High Impedance Differential Protection(87Z) (SV, GOOSE)
  - Over-Current Differential Protection(Partial Diff) (SV, GOOSE)
  - Differential Protection (87B) (SV, GOOSE)
  - Over-Current Protection (50/51) (SV, GOOSE)
- Capacitor Bank and Reactor Bank Automation (GOOSE , MMS)

Advantages of IEC 61850 Substation

- Interoperability of different vendor products
- Standardized naming conventions
- Plug-and-play capable
- Ethernet substation
- Wiring reduction
- Re-use existing conduits
- Semantic model
- Shared information
- Flexibility
- Engineering process

Other Related EPIC Projects

- Demonstration of IEEE 2030.5 (SEP 2.0) Standard
- Visualization and Situational Awareness Demonstrations

IEEE 2030.5 Demonstration Project

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- Objective
  - Run tests on SIWG protocol (data and services) mapping of IEC 61850 object models for DER grid support
  - SIWG protocol is IEEE 2030.5 (also known as SEP 2.0)

California SIWG Functions

- High/Low Voltage Ride Through
- High/Low Frequency Ride Through
- Ramp Rate
- On/Off
- Fixed Power Factor
- Volt-VAr Control
- Real Power Output Control

Red: cannot be changed over Modbus
Green: can be changed over Modbus

Use cases in green font were tested

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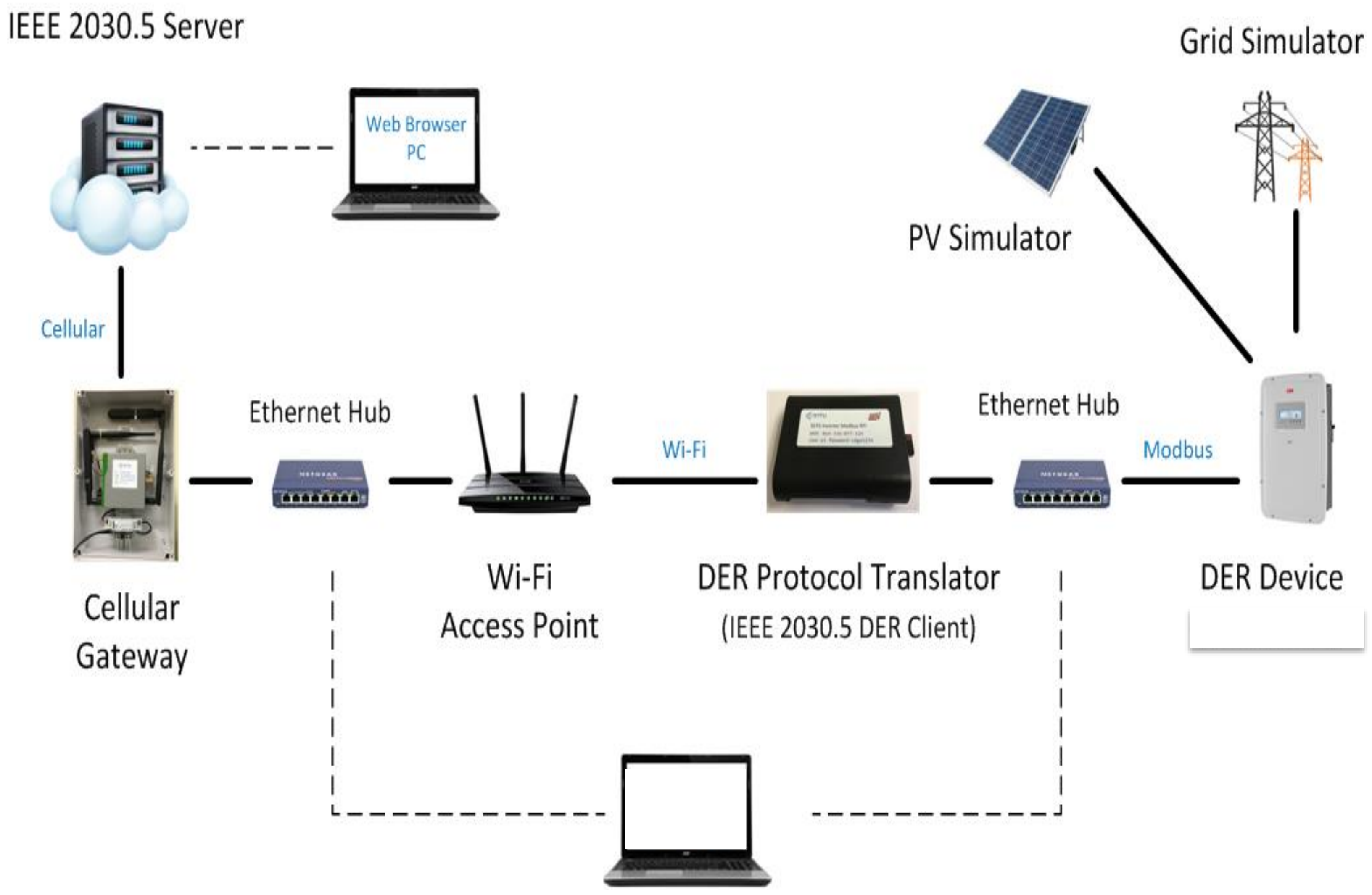
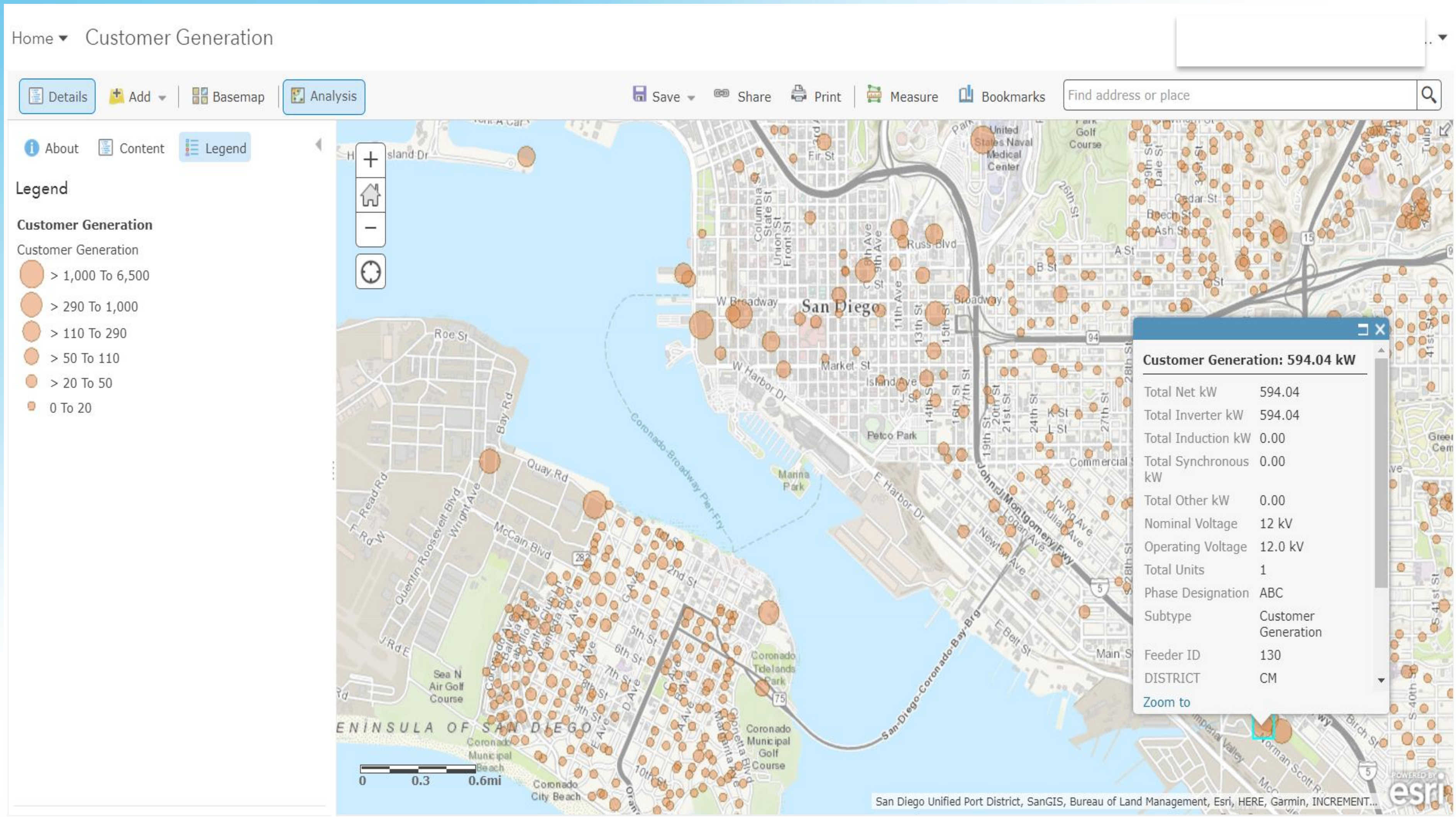
IEEE 2030.5 Test Setup



Visualization Project Output Example: Customer-Owned Energy Resources



Overall Status of Demonstration Work

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- SDG&E's EPIC demonstrations are completed or near completion
- Final reports to be filed to posted on the SDG&E EPIC web site@ www.sdge.com/epic in early 2018
- Much additional demonstration work, broadly in the industry, needs to be performed and shared with others to help accelerate adoption of IEC 61850 in North America

Questions and Discussion

Thank you for your time