Welcome and Workshop Opening

Ted Reguly, Director
Growth and Technology Integration Department
SDG&E

2017 EPIC Fall Symposium

October 18, 2017

Welcome to the Symposium and San Diego

SDG&E EPIC Program Introduction

2017 Fall EPIC Symposium

Presenter: Frank Goodman

SDG&E EPIC-1 CPUC-Approved Projects

Five projects on advanced distribution automation:

1. Smart Grid Architecture Demonstrations
2. **Visualization and Situational Awareness Demonstrations**
3. **Distributed Control for Smart Grids**
4. Demonstration of Grid Support Functions of DER
5. Smart Distribution Circuit Demonstrations

SDG&E EPIC-2 CPUC-Approved Projects

1. **Modernization of Distribution System and Integration of Distributed Generation and Storage**
2. Data Analytics in Support of Advanced Planning and System Operations
3. Monitoring, Communication, and Control Infrastructure for Power System Modernization
4. System Operations Development and Advancement
5. Integration of Customer Systems into Electric Utility Infrastructure
6. Collaborative Programs in R&D Consortia

Overall Program Status

- All EPIC-1 and EPIC-2 projects are winding down
- Expect final reports to be submitted to CPUC and posted on the SDG&E EPIC website in early 2018
- https://www.sdge.com/epic

Distributed Control Systems for Smart Grids

2017 EPIC Fall Symposium

Presented by: Amin Salmani

Outline

- Project Objectives
- Introduction to Distributed Control Systems
- Project approach
- Schematic of test set-up
- Use cases
- High-level summary of results
- Findings and conclusions

Project Team

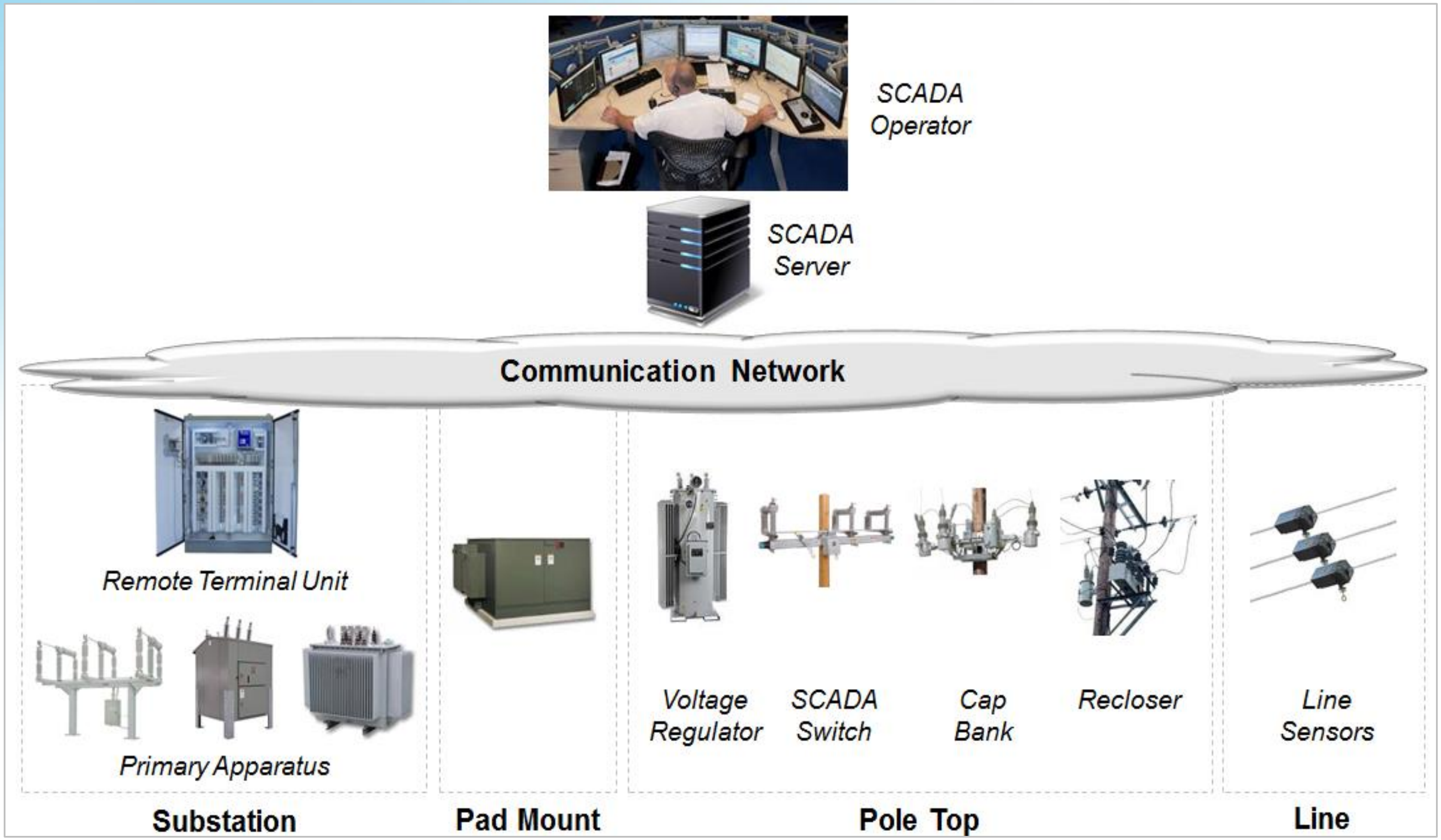
- SDG&E Internal Team
  - Aksel Encinas
  - Frank Goodman
  - Prajwal Raval
  - Amin Salmani
- Contractor: Quanta Technology, LLC.

Project Objectives

- Demonstrate distributed control concepts that fill gaps in traditional control system infrastructure, and are compatible with it.
- Identify preferred **operational responsibilities** and **control characteristics** that can be controlled by a distributed control system infrastructure.
- Develop methods of **communication** and **control coordination** across **multiple resources** to optimize distribution system performance.
- Identify distributed control methods and approaches to control resources that are compatible with other utility control systems such as SCADA/EMS, ADMS, DERMS and DRMS.

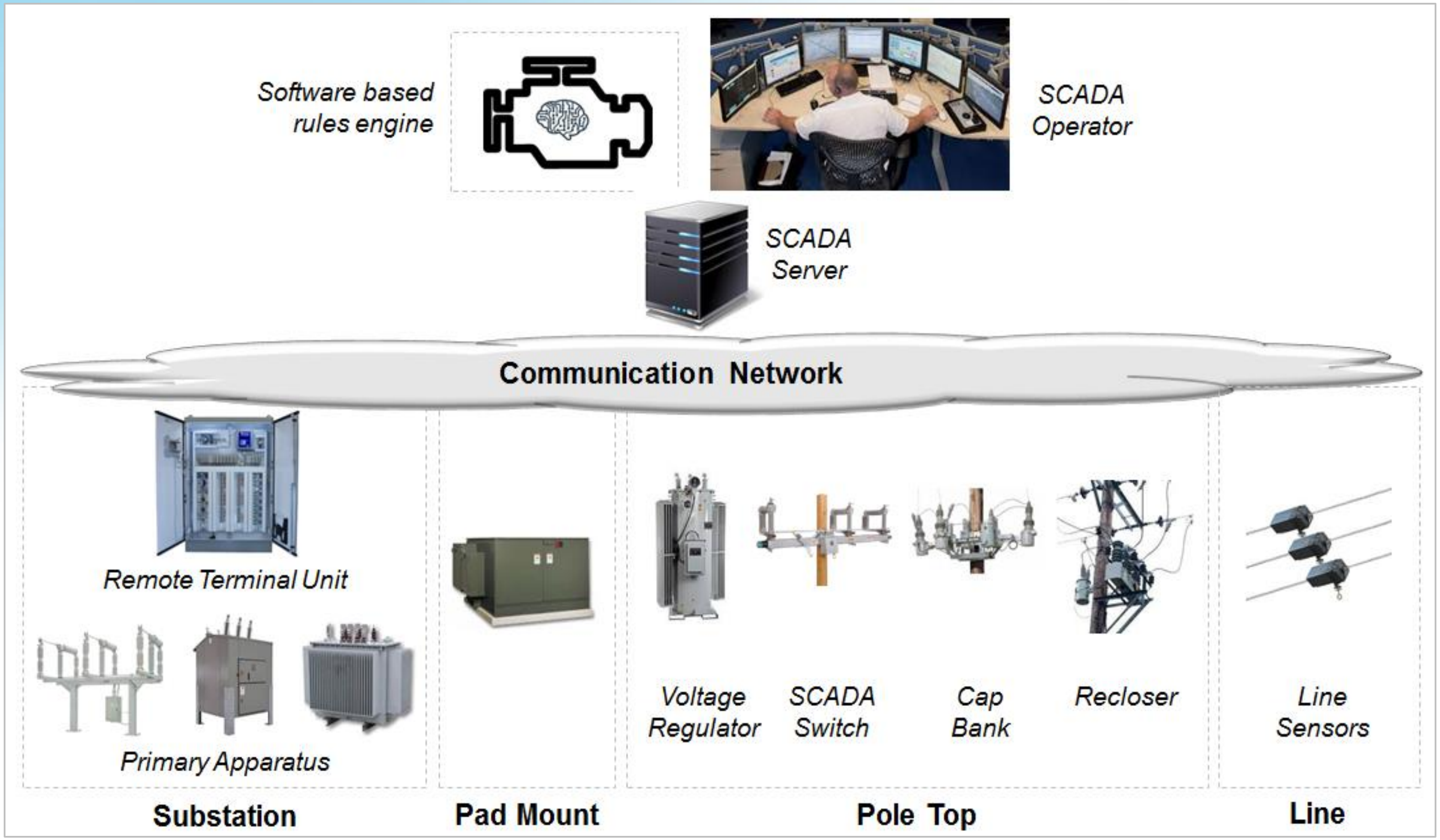
Centralized Control for Distribution Systems

Conventional distribution control systems are centralized in nature.



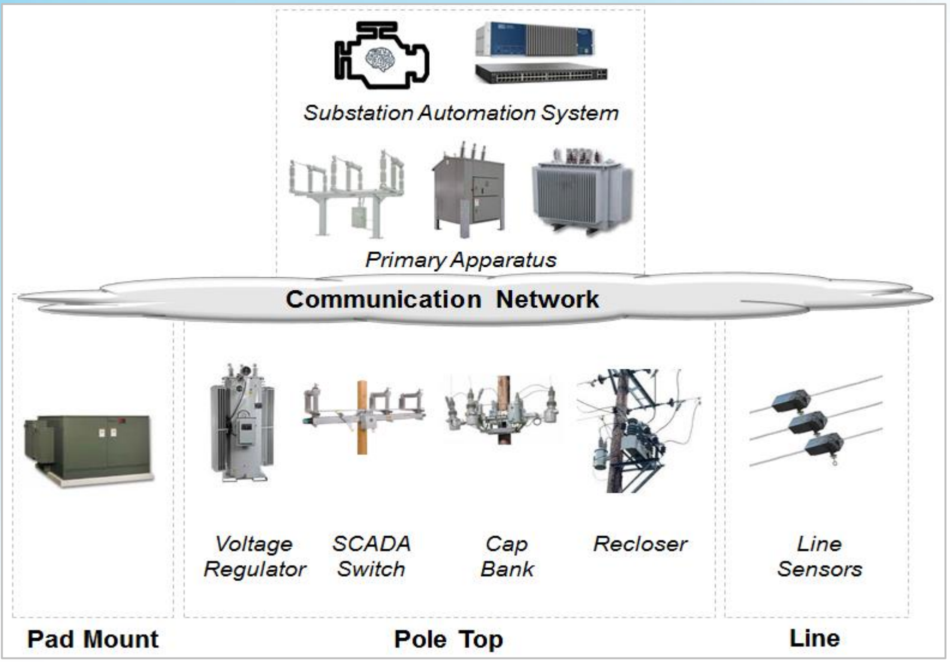
Centralized Control for Distribution Systems

It is possible to improve the speed of response by automating the decision tree and sequence of actions (e.g. Fault Location Isolation and Service Restoration)

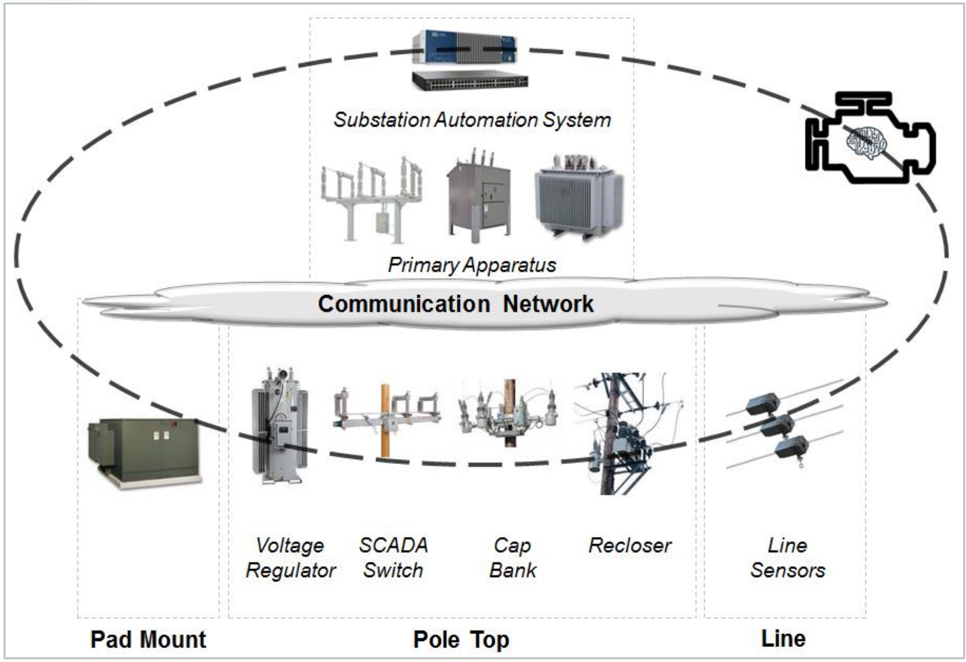


Distributed Control Systems

Distributed/decentralized control design can be either “substation centric” (DCS project) or “peer-to-peer” (Smart Grid Architecture Project)



Substation-Centric Decentralized Design



Peer-to Peer Based Decentralized Design

Project Steps and Approach

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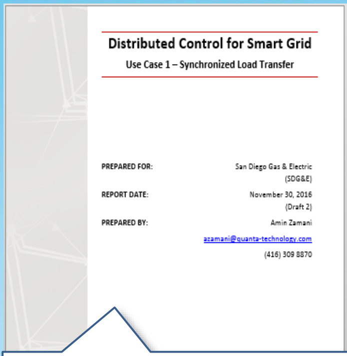
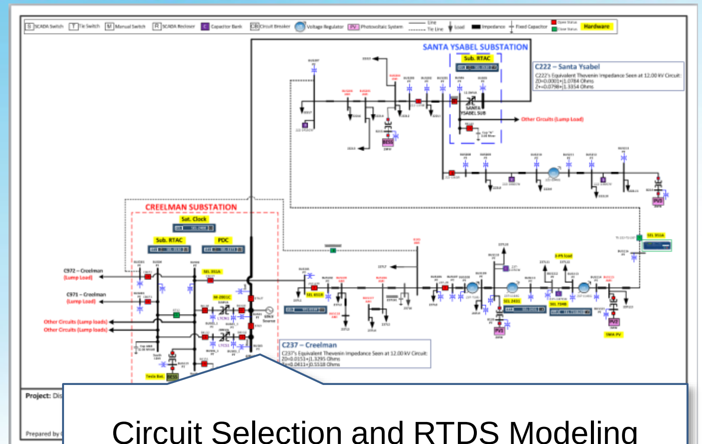
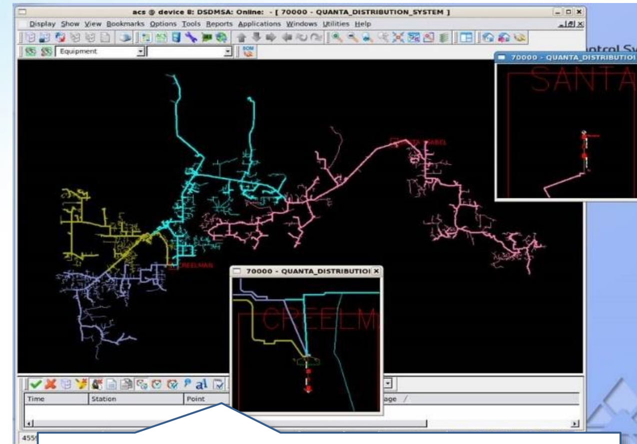


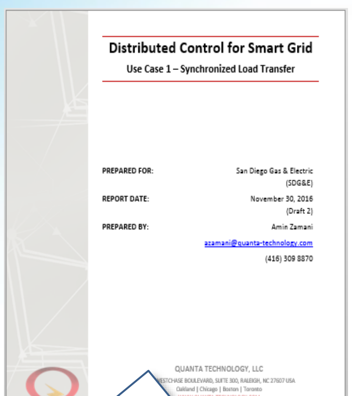
Literature Review of DA Applications



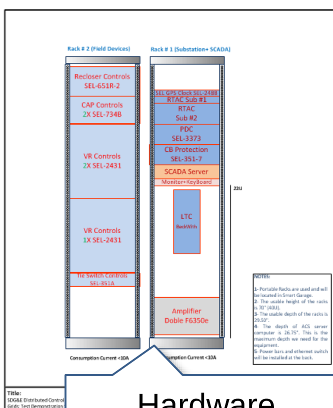
Circuit Selection and RTDS Modeling



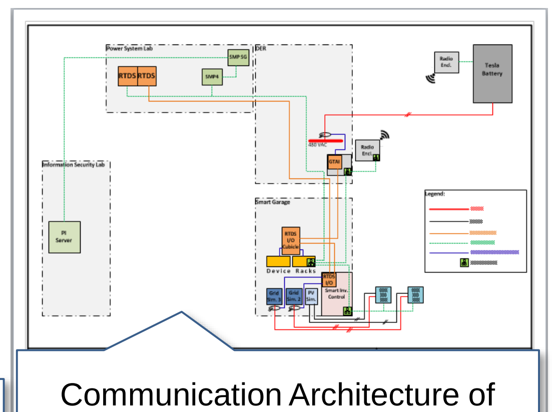
Master Control System Development



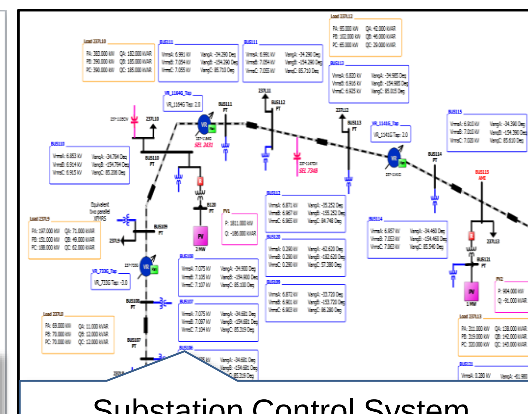
3 x Use Cases docs



Hardware Development



Communication Architecture of Test Platform



Substation Control System Development

Distribution Automation Applications

Distributed Automation (DA) applications utilized to enhance distribution systems:

1. Operation and Control
2. Planning and Assessment
3. DER Integration and Management
4. Monitoring and Diagnostics
5. Protection and Automation

Selected use cases:

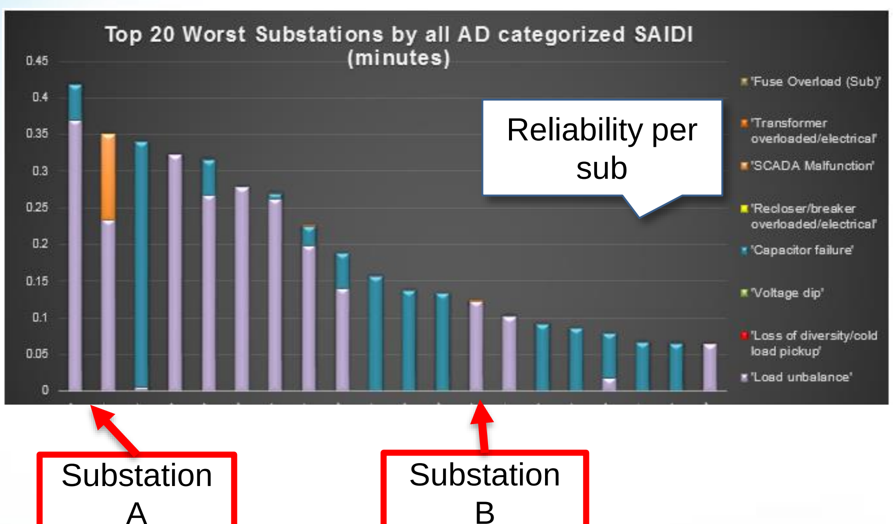
Category 1: Operation & Controls
- Synchronized/Energized Load Transfer (closed-loop operation of circuits)

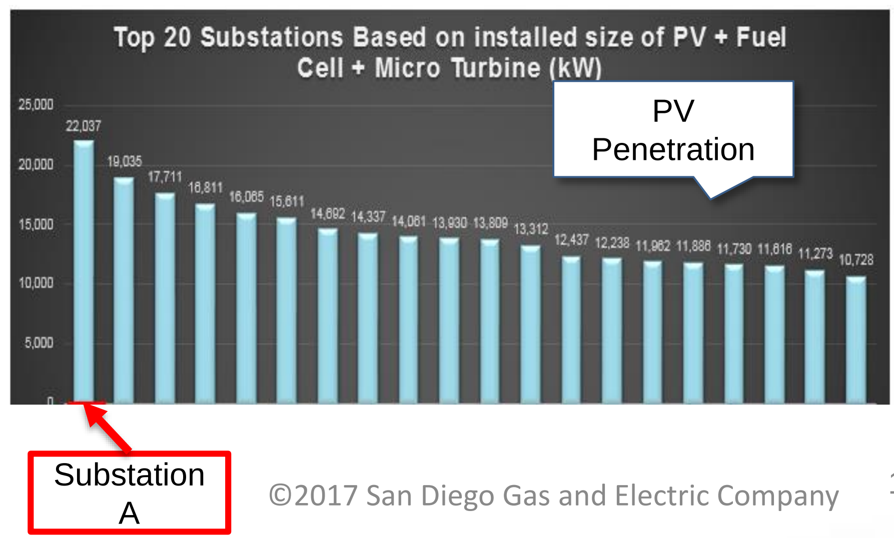
Category 3: DER Integration & Management
- Automatic Resource Control (DER and LTC/VR/Cap control)

Category 5: Protection
- Automated Protection Setting Change

Circuit Selection Criteria

- DER penetration level
- System reliability
- Circuit performance
  - Capacitor failure
  - Load imbalance
- Power quality:
  - Voltage fluctuations
  - Voltage imbalance
- Two circuits from two substations, with a tie between them.





Distributed Control System Test Platform

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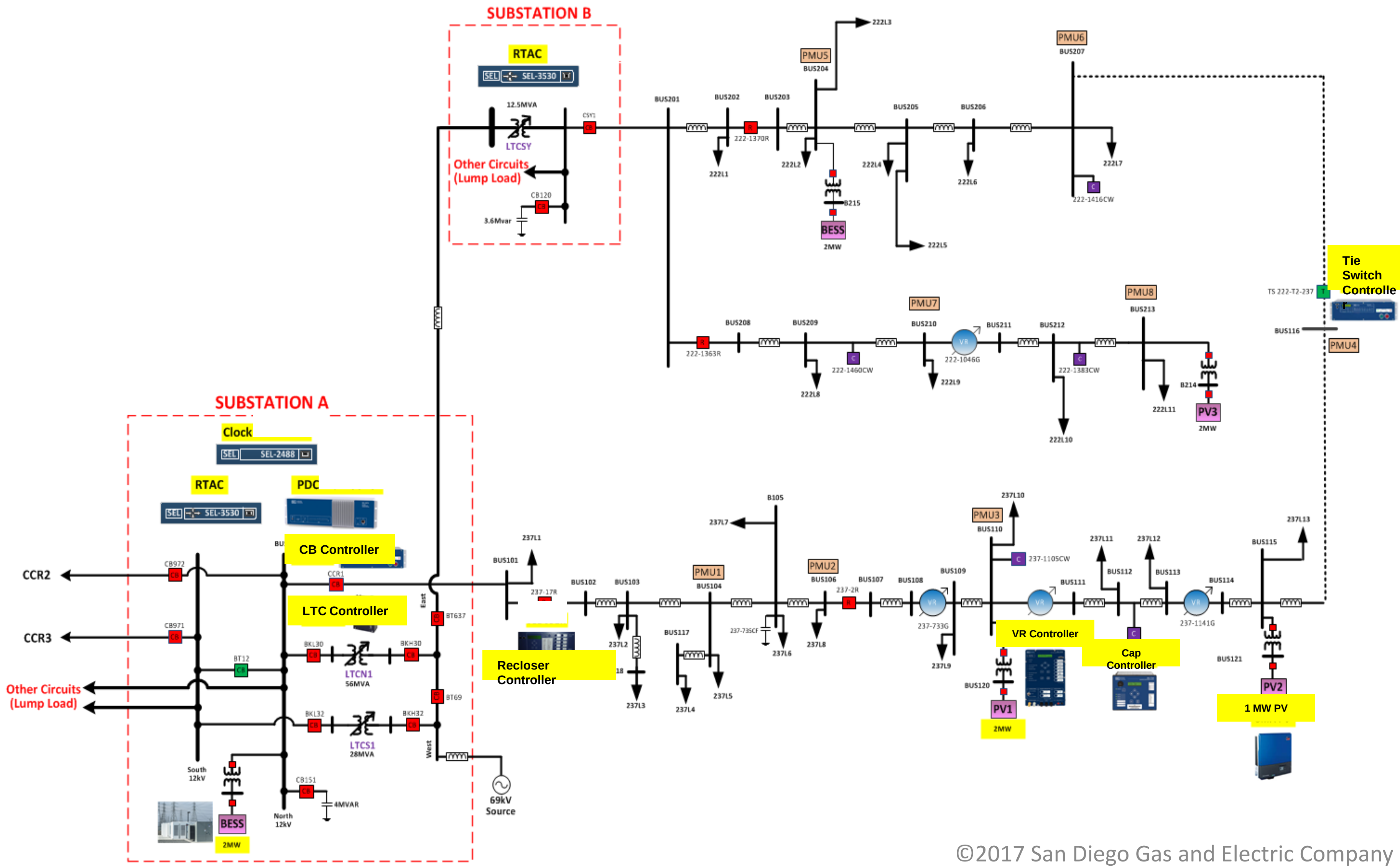
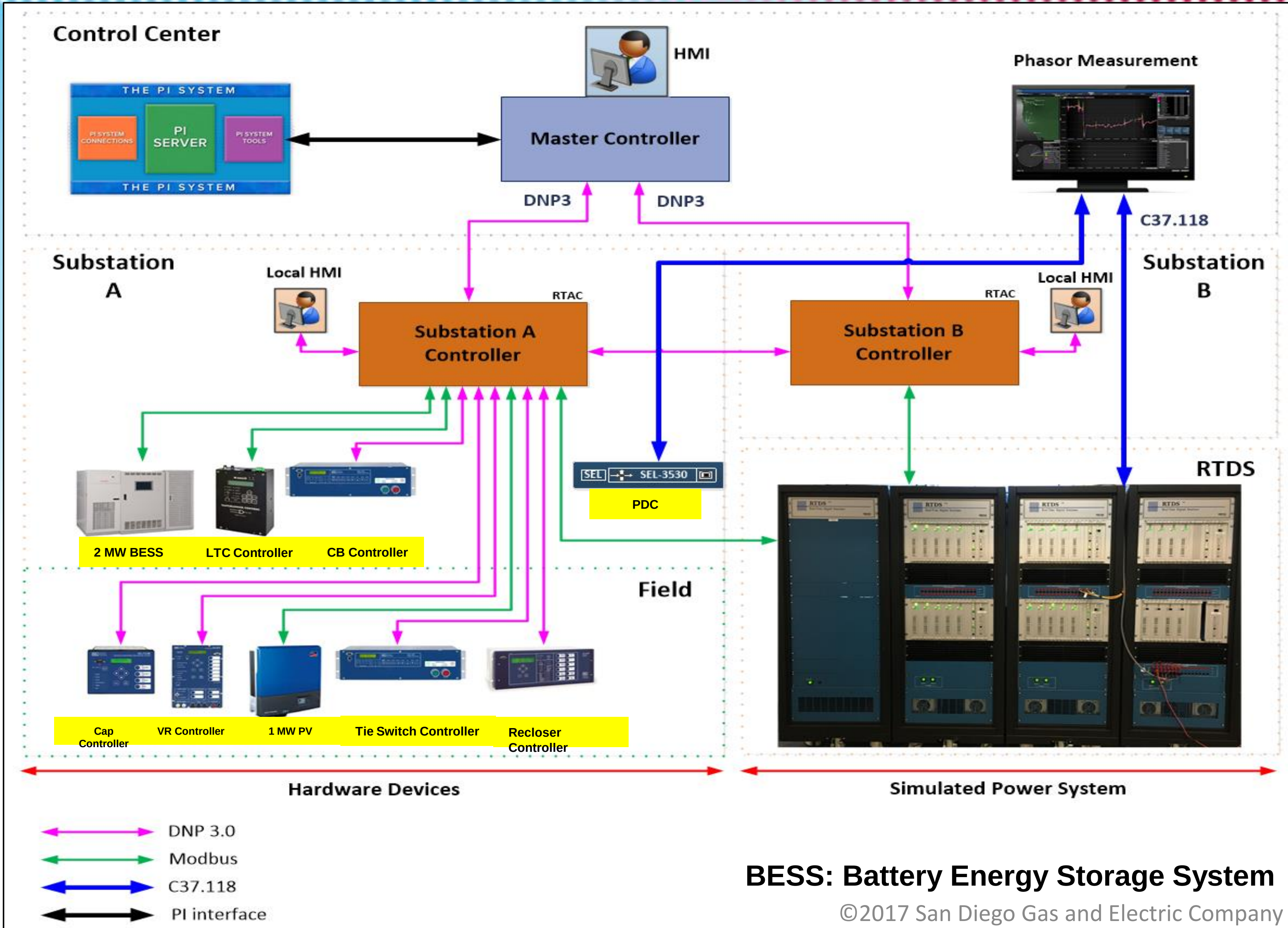


S SCADA Switch | T Tie Switch | M Manual Switch | R SCADA Recloser | C Capacitor Bank | CB Circuit Breaker | VR Voltage Regulator | PV Photovoltaic System | Line | Tie Line | Load | Line Impedance | Fixed Capacitor | Open Status | Close Status | Hardware | PMU Simulated PMU

Communication Architecture of DCS Test Platform



BESS: Battery Energy Storage System

Hardware Integration

Substation B RTAC

Substation A RTAC

Substation A PDC

Substation A CB Relay

ACS Control Center

Local HMI

Substation A LTC

I/O Cabinet

Feeder Equipment

Control Center and Substation Equipment

Use Case 1 – Automatic Resource Control

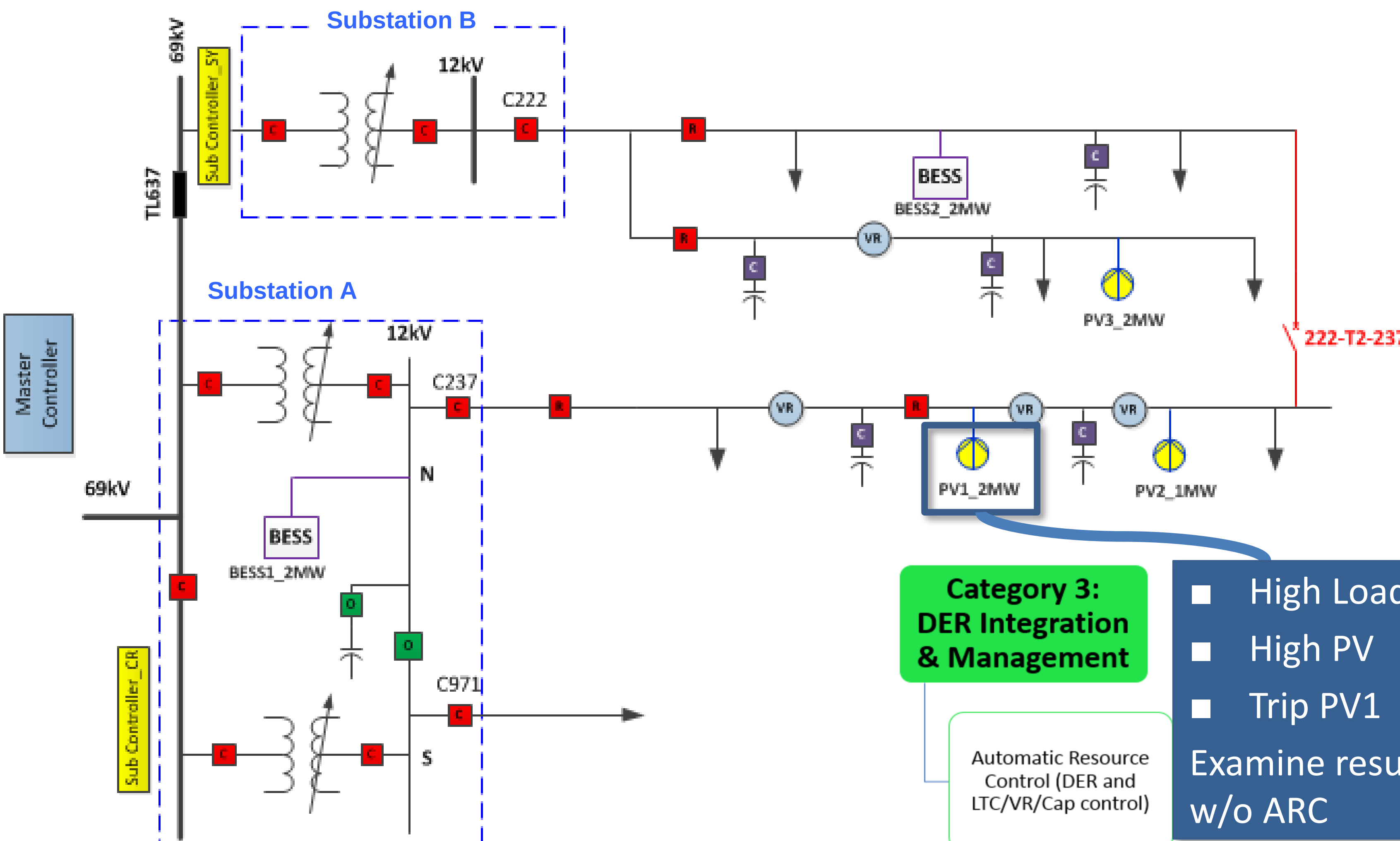
Primary objectives of the Automatic Resource Control (ARC):

- Achieve the optimal combination of **LTC, VR, Cap Bank settings and output power of controllable DERs**
- Improve operating conditions: voltage profile, losses, load balance, overloading conditions
- Prevent excessive reverse power flow from local distributed generation by limiting the maximum DER generation

Control scheme is developed based on a **three-pass iterative approach**:

1. The first pass minimized the VAr losses **by controlling the feeder capacitors**.
2. The second pass flattened the line drop voltage after the impact of the capacitor switching in the first layer was calculated. The second pass controlled the **LTC and voltage regulators**.
3. The third pass applied fine control of the voltage based on the ability of the inverter to affect the voltage at the point of common coupling/injection points.

Use Case 1 – Automatic Resource Control



Category 3: DER Integration & Management

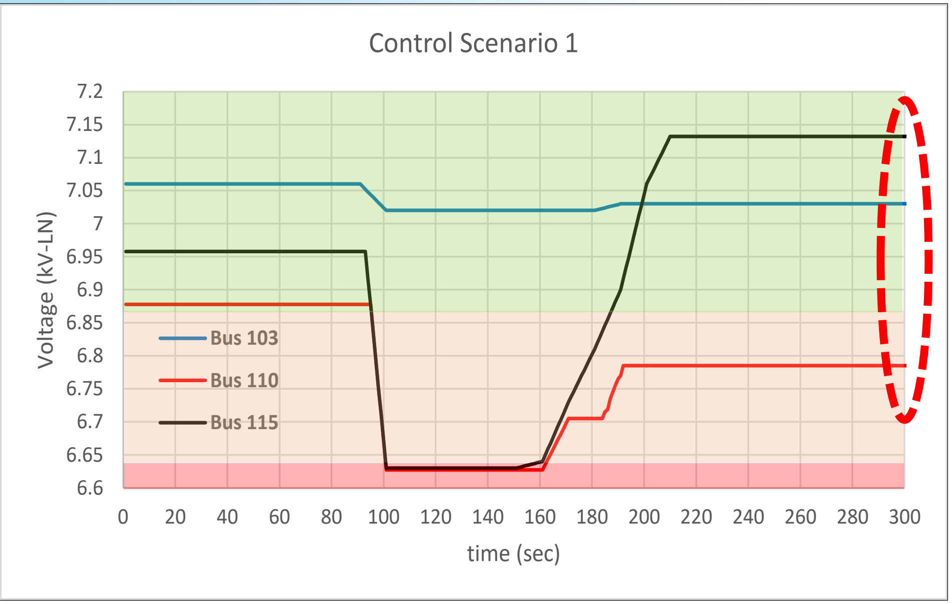
Automatic Resource Control (DER and LTC/VR/Cap control)

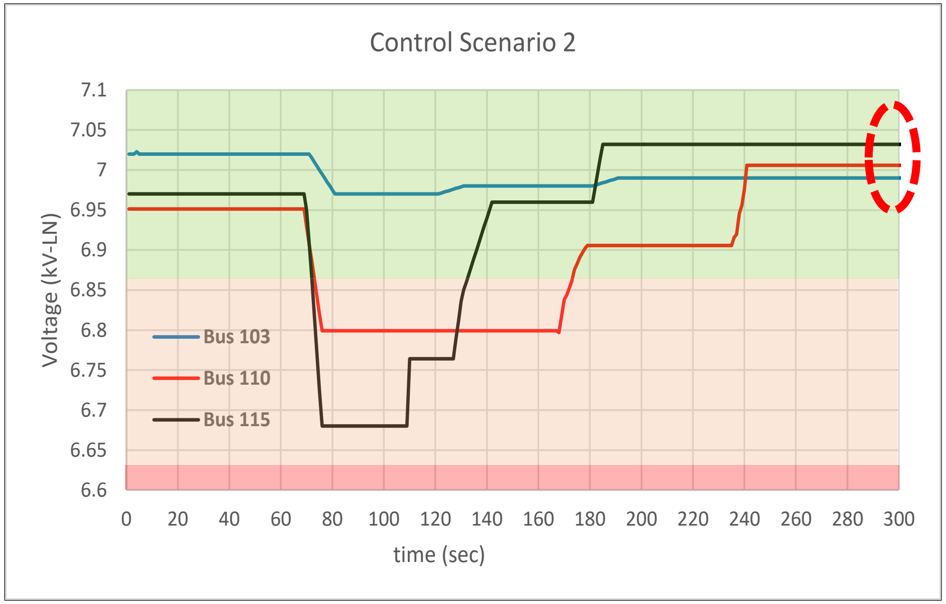
- High Load
- High PV
- Trip PV1

Examine results w and w/o ARC

Use Case 1 – Automatic Resource Control

Case 1	Case 1.10 (PBESS1= PBESS2=0), trip PV 1 after the system gets to the steady state condition.	High load (fix), High PV (fix)	Baseline System 2 (all controllable devices were in Local/Auto mode)
Case 2	Case 1.11 (PBESS1= PBESS2=0), trip PV 1 after the system gets to the steady state condition.	High load (fix), High PV (fix)	Master controller was responsible to take actions via ARC/IVVC algorithm.





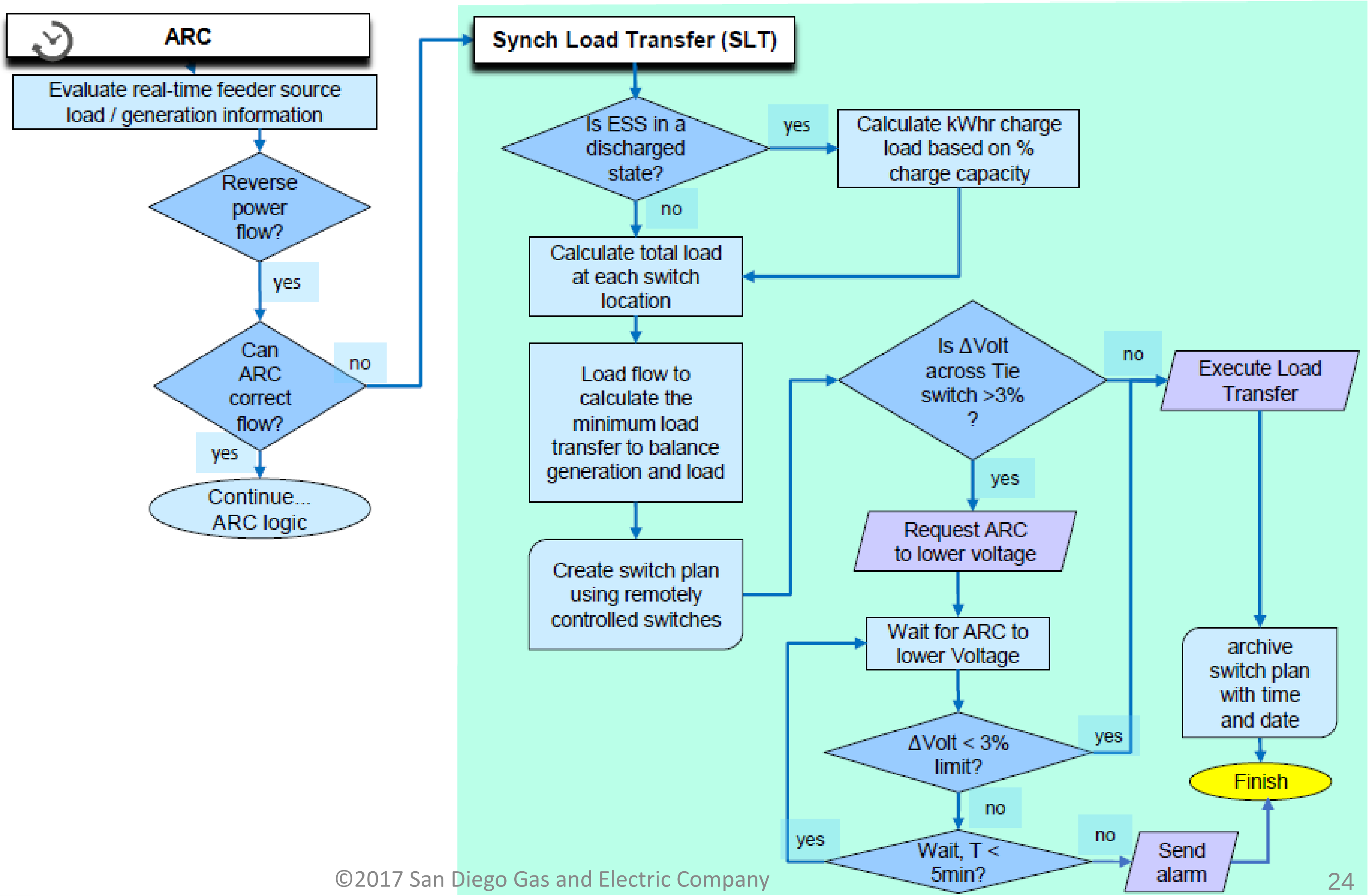
IVVC: Integrated Volt-Var Control

High-Level Summary of Results

- ***Scenario 1:*** No remote control of distribution system resources, all working autonomously and in isolation.
- ***Scenario 2:*** Distribution system resources were intelligently controlled by a **Master Controller** able to monitor and control the resources in both substations
- ***Scenario 3:*** Distribution system resources were intelligently controlled by the **Substation Controllers** for each substation, autonomously and in isolation from each other.

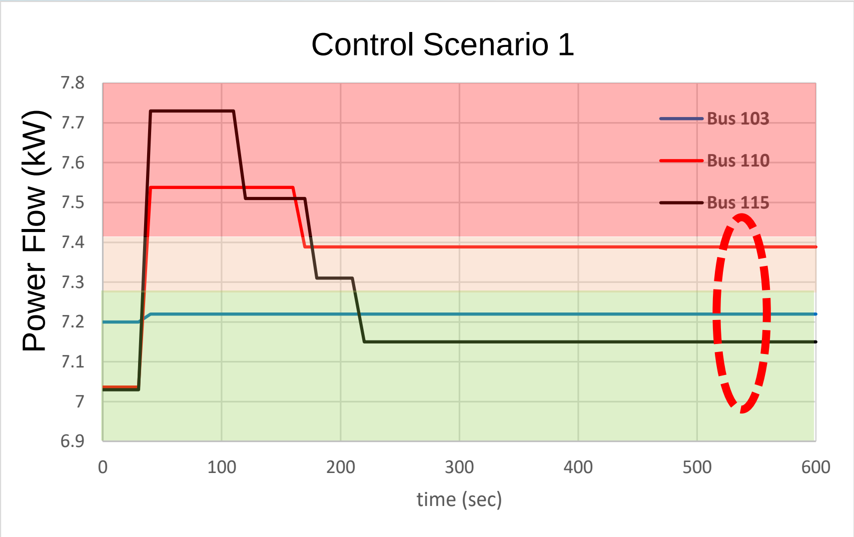
Parameter	Scenario 1 Result	Delta between Scenarios 1 and 2	Delta between Scenarios 1 and 3
Maximum voltage magnitude (rms)	8.04 kV (1.16pu)	7% less	5% less
Maximum out-of-range value with respect to maximum allowable voltage (rms)	765.4 V (0.11pu)	78% less	48% less
Out-of-range duration (seconds)	115 seconds	78% less	30% less
Power Loss	1.04MW	26% less	17% less
Active Power (DER Involvement/Contribution)	31.8 kW	4% less	3% less
Asset Operations	52 operations	35% less	6% more

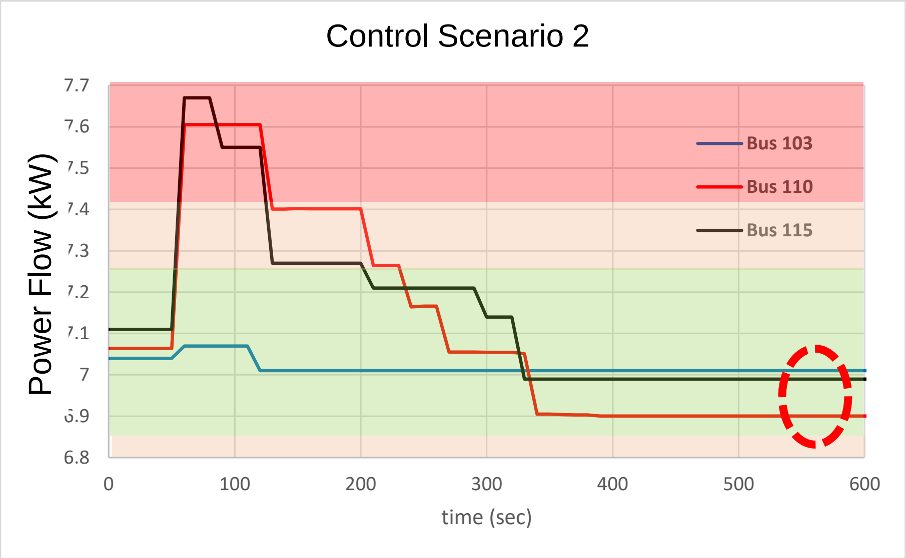
Use Case 2 – Synchronized Load Transfer

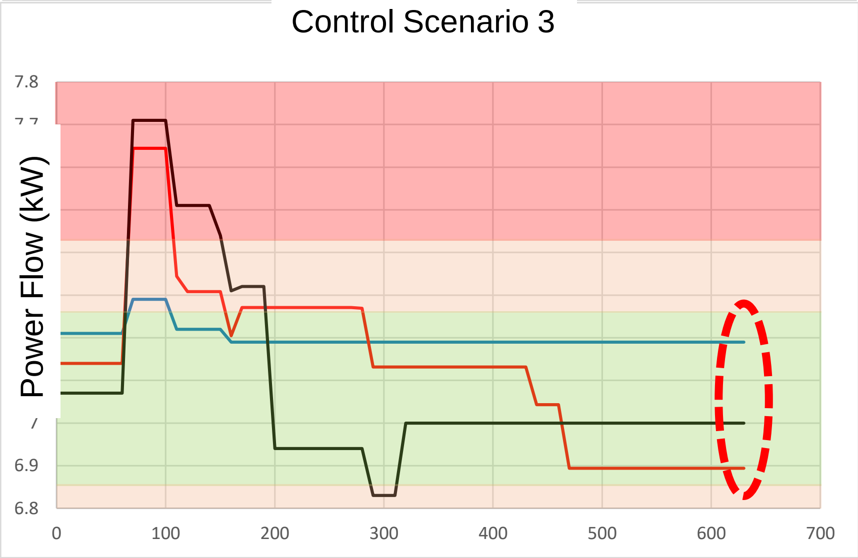


Use Case 2 – Synchronized Load Transfer

Case 1	Low load, High PV, **PV3 tripped**	**Baseline System** 2 (all controllable devices were in Local/Auto mode)
Case 2		**Master controller** was responsible to take actions through SLT/IVVC algorithm.
Case 3		**Sub controller** was responsible to take actions via communication loss permission







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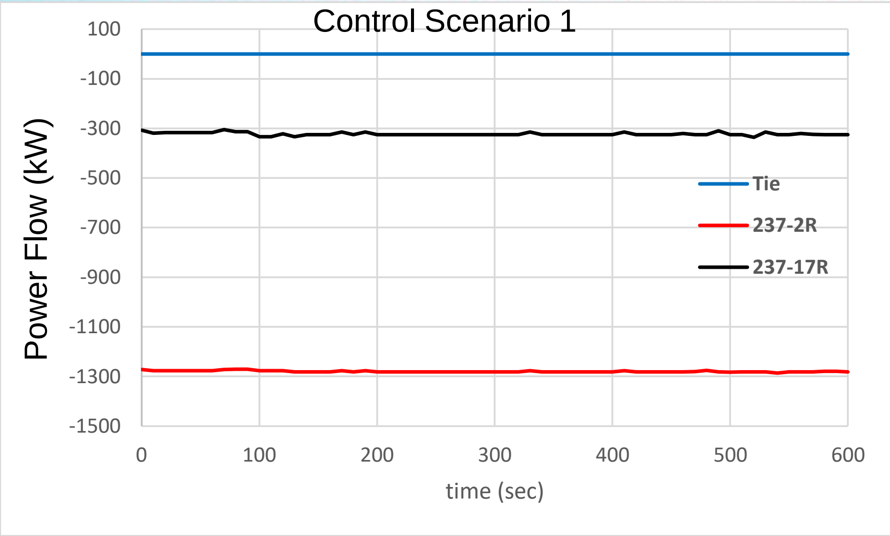

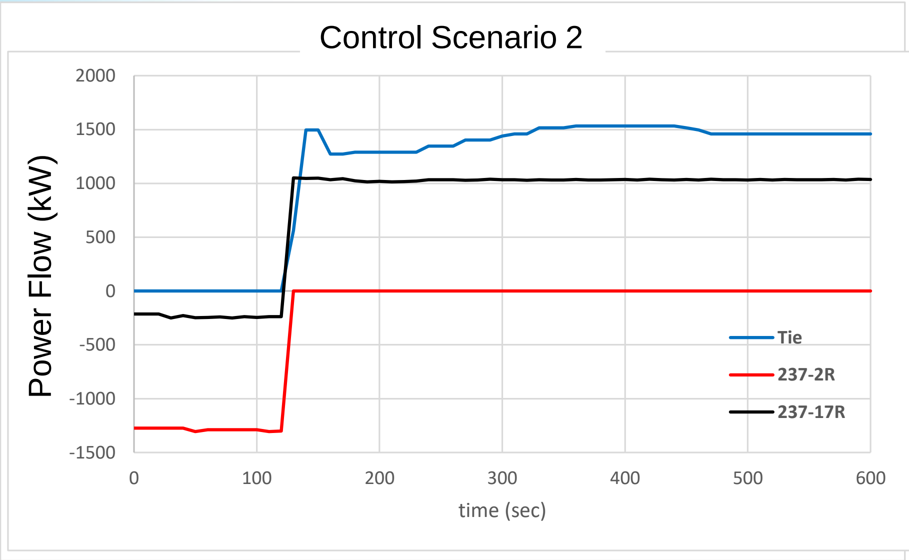

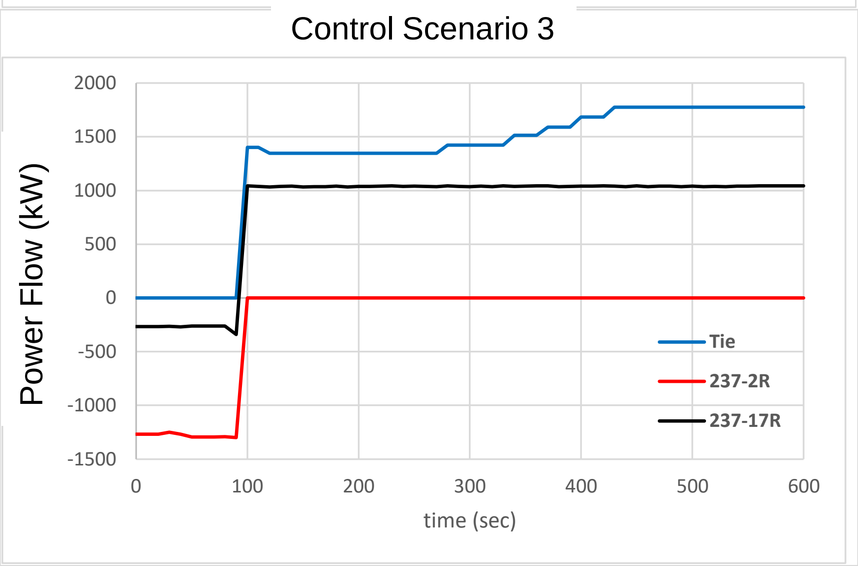

Project Findings

Intelligent control of distribution system resources was able to achieve the following benefits when compared to a conventional approach:

- Increase the utilization and contribution of DERs
- Reduce and even prevent unintentional reverse power flow
- Produce a flatter voltage profile over the length of a circuit
- Bring voltage profiles back inside the accepted range after a system event
- Reduce system power loss
- Improve the power factor of a circuit
- Reduce the number of operations of controllable assets like capacitor banks, voltage regulators and LTC
- Dynamically adjust protection settings to increase system reliability

Q&A

For questions or interest in this project please contact:

- EPIC Program Manager
  Frank Goodman
  fgoodman@semprautilities.com

- Project Technical Lead
  Molham Kayali
  mkayali@seucontractor.com

Modernization of Distribution System & Integration of Distributed Generation and Storage

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2017 EPIC Fall Symposium

Presented by: Molham Kayali

Outline

- Project objective
- IEC61850 design process and engineering implementation
- Using IEC61850 to do substation protection use cases
    - IEC61850 line differential protection use case
- IEC61850 & vendors interoperability
- Results and findings
- Q&A

Project Team

- SDG&E Internal Team
  - Frank Goodman
  - Molham Kayali
  - Zoltan Kertay
  - Iman Mazhari
  - Alfonso Orozco
  - Kirsten Petersen
  - Prajwal Raval
- Contractor: POWER Engineers, Inc.

Project Objectives and Focus

Project Objective

This project will demonstrate distribution system infrastructure modernization solutions, including advances in distribution system design to enable use of new technologies, such as power electronic components, new protection systems, distributed generation and alternative storage technologies.

Focus:

- Pre-commercial demonstration of International Electrotechnical Commission (IEC) 61850 standard application to a substation mockup in a laboratory
- Specific emphasis on Generic Object Oriented Substation Event (GOOSE) and Sample Value (SV) messages
- Study the pros and cons of using this standard in a predefined set of use cases
- Study vendor interoperability for some of the available IEC61850 products
- Make recommendations regarding commercial adoption

Project Approach

1. Developed project plan
2. Added engineering services contractor to team
3. Developed concept of operations
4. Designed system and competitively procured equipment and materials
5. Set up test system in laboratory
6. Performed factory acceptance test and system acceptance test

Project Approach

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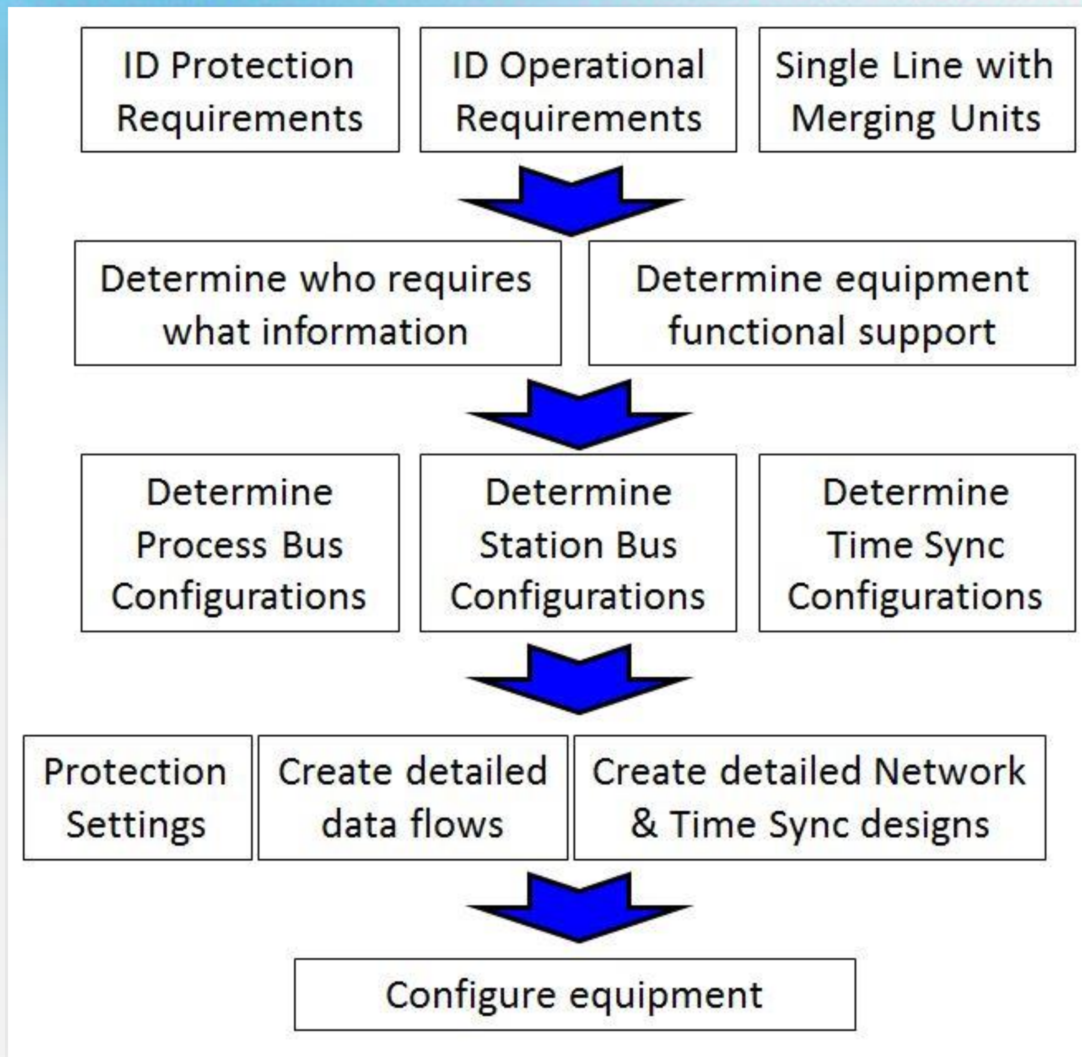
7
- Performed pre-commercial demonstration (ran use cases)

8
- Analyzed data

9
- Developed findings, conclusions, and recommendations

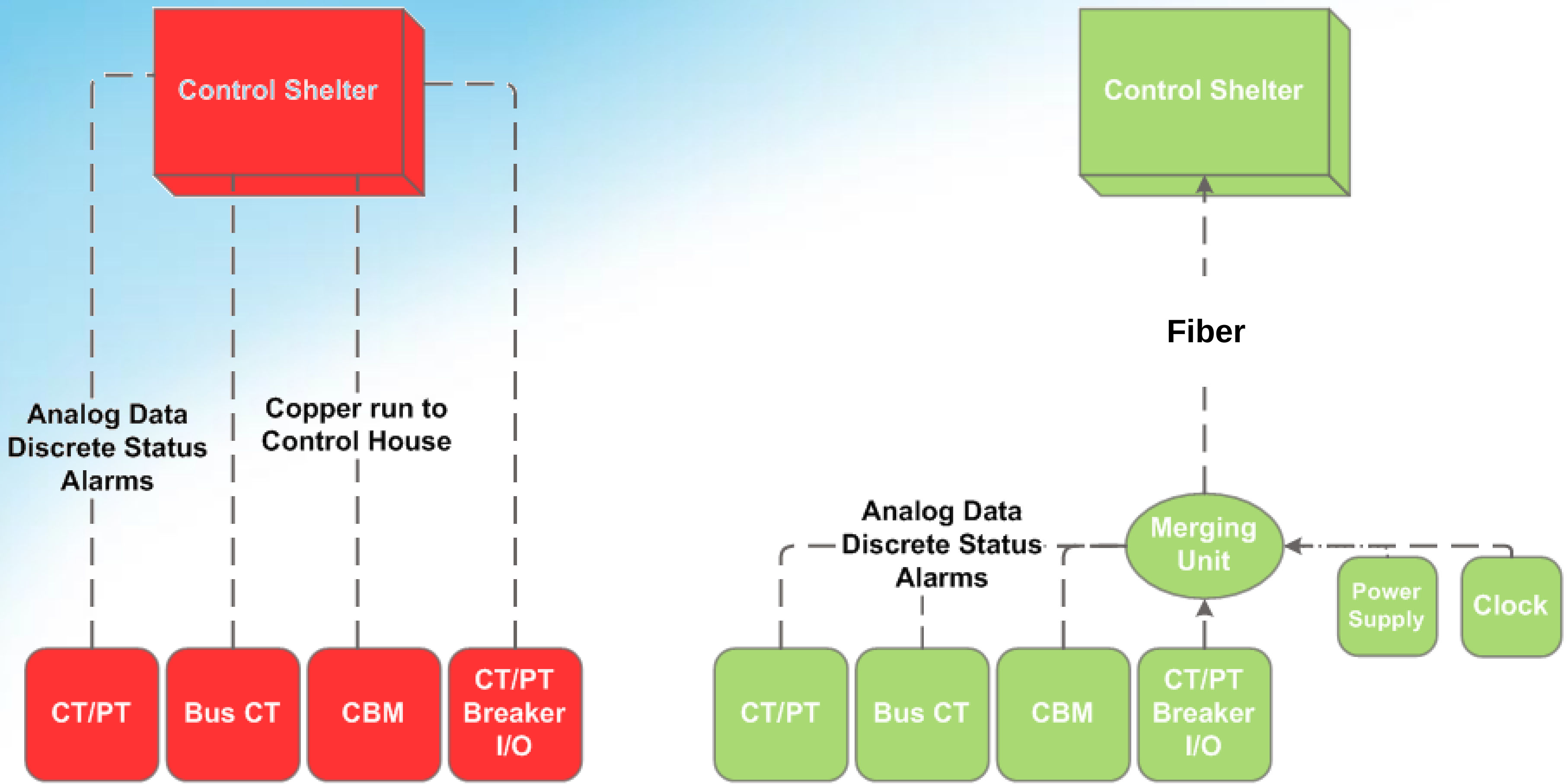
10
- Prepared comprehensive final report (including tech transfer plan)

Design Process



- ID: Identification

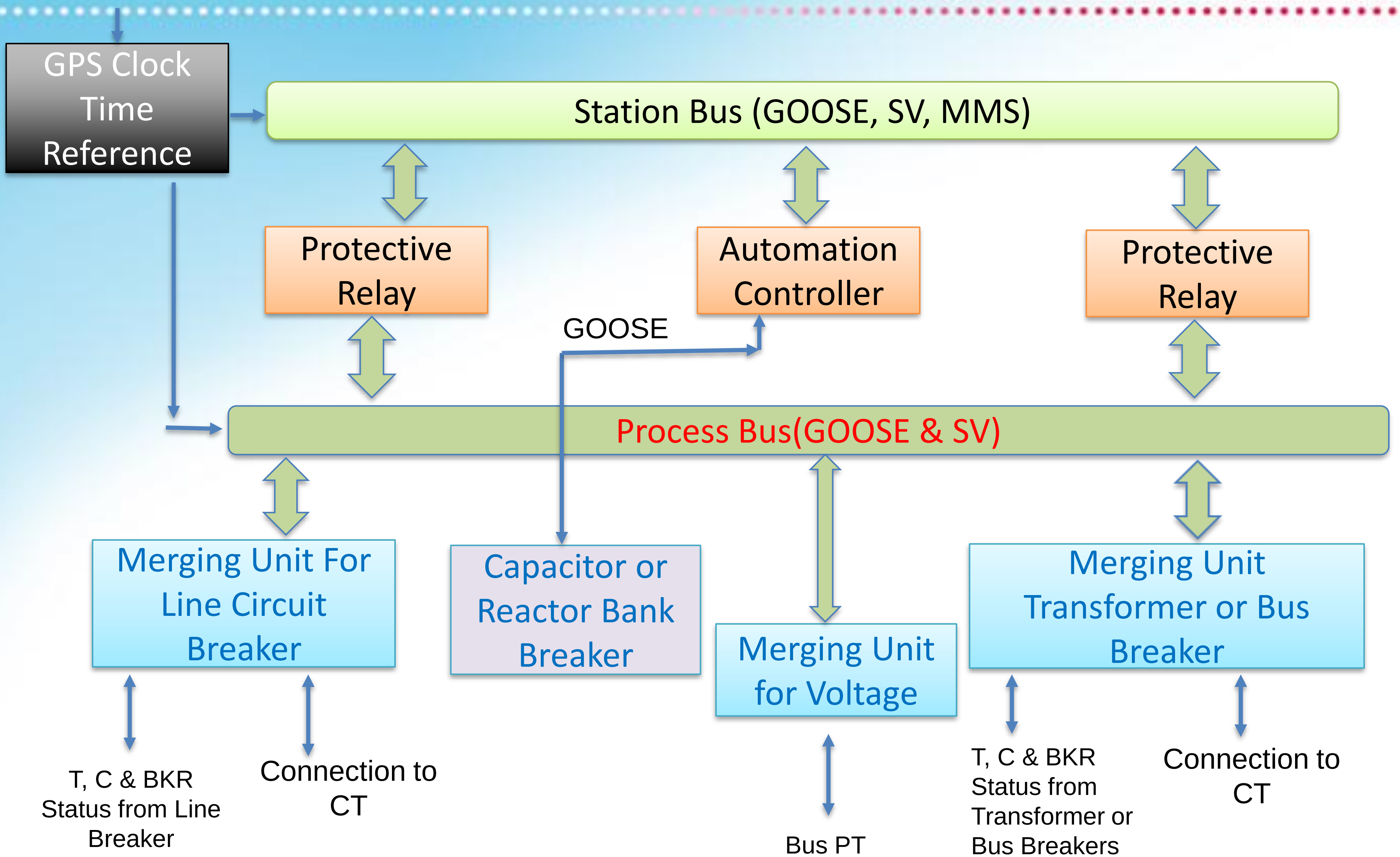
Comparison of Legacy and IEC 61850 System



Legacy Analog System

IEC 61850 Compliant System

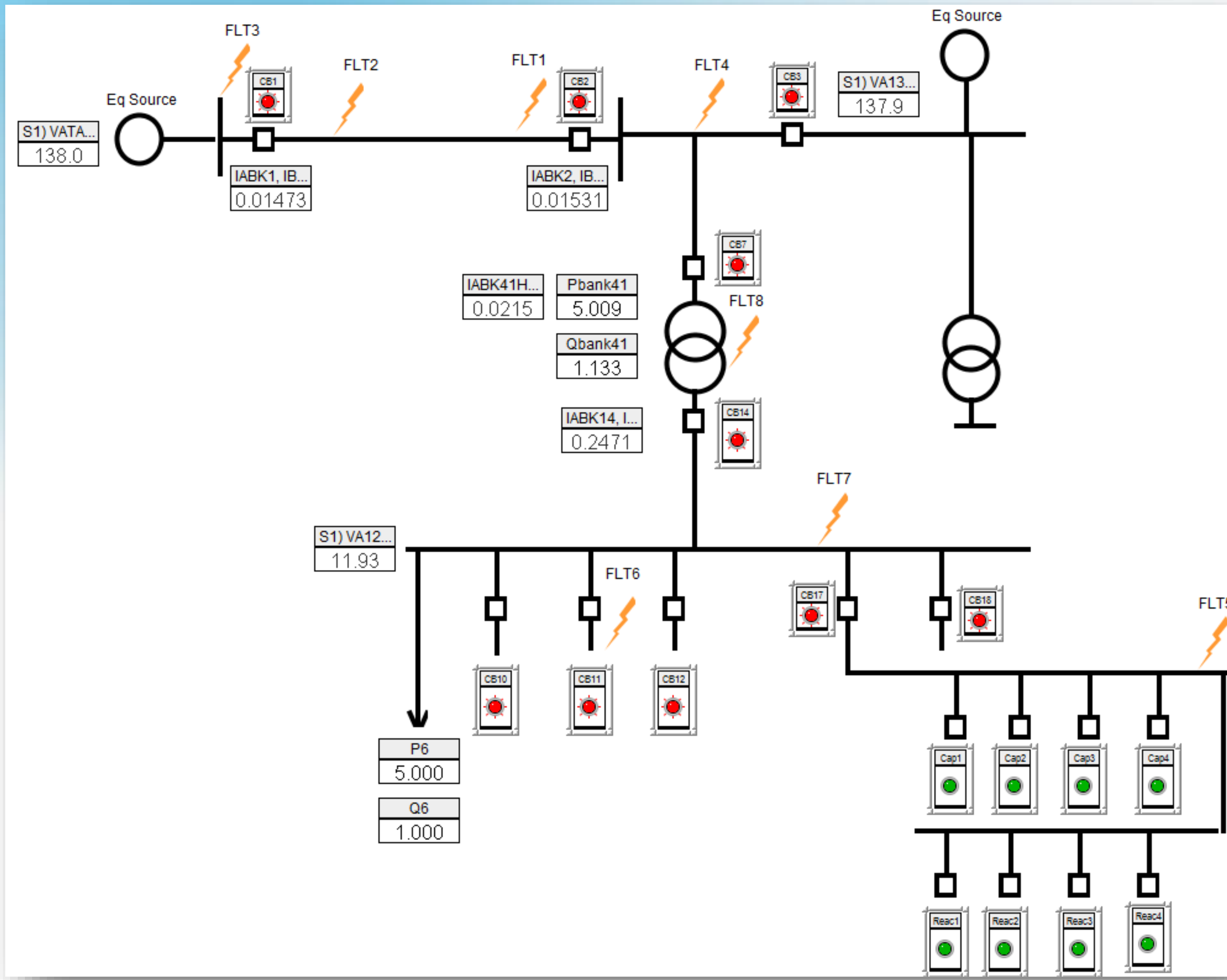
Simplified Conceptual Diagram for IEC-61850 Substation Project



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)

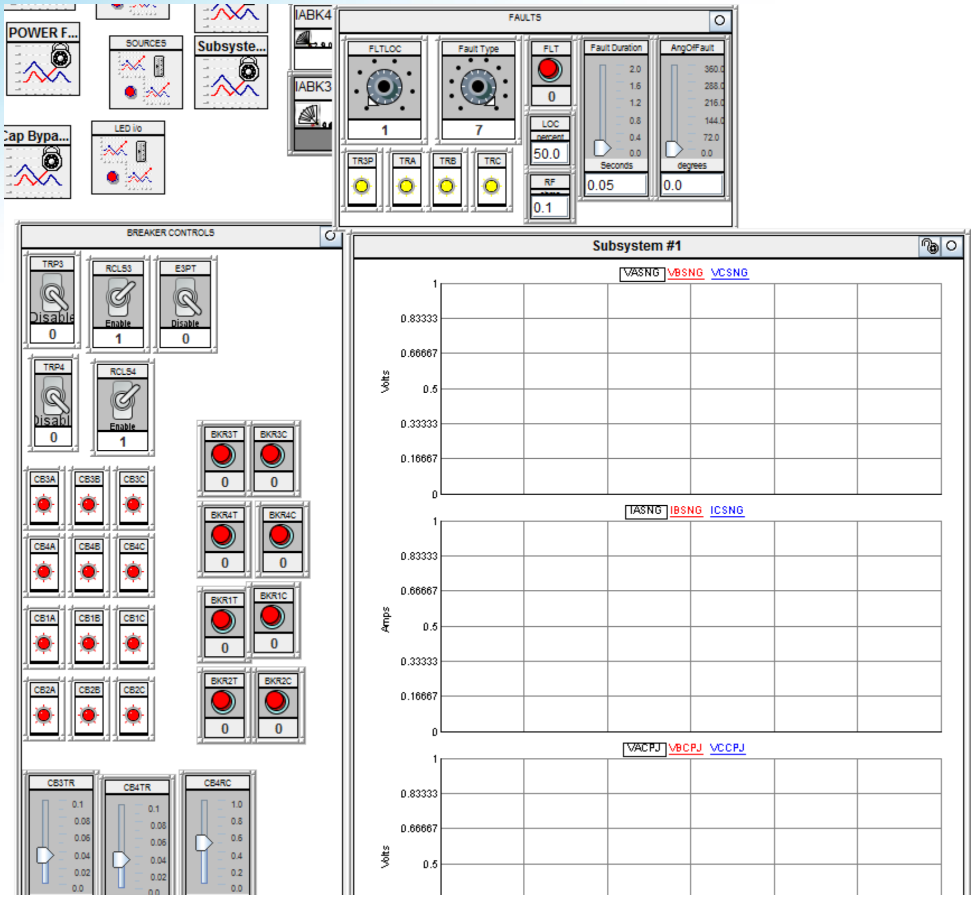
RTDS Model



FLT3
FLT2
FLT1
FLT4
Eq Source
Eq Source
S1) VATA...
138.0
CB1
CB2
CB3
S1) VA13...
137.9
IABK1, IB...
0.01473
IABK2, IB...
0.01531
CB7
IABK41H...
0.0215
Pbank41
5.009
FLT8
Qbank41
1.133
IABK14, I...
0.2471
CB14
FLT7
S1) VA12...
11.93
FLT6
CB17
CB18
FLT5
CB10
CB11
CB12
P6
5.000
Q6
1.000
Cap1
Cap2
Cap3
Cap4
Reac1
Reac2
Reac3
Reac4

RTDS Human Machine Interface (HMI)

- An HMI was designed for the RTDS runtime
  - display the generated currents, voltages, breaker status, VAR flow
- Used to monitor the currents and voltages being output to the amplifiers
- Merging units and relays will control simulation breakers via digital inputs
- Capacitor and reactor bank controllers will control reactive components in the simulation via digital inputs.



Sample Use Case Results for a Protection Scheme

The line differential protection use case is intended to simulate primary line differential protection on a 69 or 138 kV sub-transmission circuit that interconnects a typical 12 kV distribution substation to the SDG&E grid.

- **Performance Tests**
- Simulate a 3LG fault close-in to the local 87L by COMTRADE playback injection
- Record the following:
  - Download event records from the relays at each line end
  - Fault Initiation Time: 9:52:00.532 PM
  - Local Relay 87L Trip Initiation Time: 9:52:00.543 PM
  - Remote Relay 87L Trip Initiation Time: 9:52:00.543 PM
  - Local Relay 52a Open Detected Time: 9:52:00.565 PM
  - Comments: True sub-cycle relay operation

IEC61850 & Vendors Interoperability

Test the interoperability of merging units with relays for IEC61850

- *Are vendor solutions configurable?*
  - *Yes*
- *Are solutions compatible with devices made by other vendors?*
  - *Yes*

IEC61850 GOOSE/SV Edition 1&2

Use Case Finding

- **SV**: Time synchronization “SmpSynch”=true

True=1 for edition2 LE subscriber 1 is not synchronized

- **GOOSE**: Edition 2 changed “test field” to a “simulation field”.
- **SCL file schemes**:

Edition1/2 support.

Some you have to select it.

Key Findings

- IEC61850 can do all the standard protection schemes in SDG&E substations.
- IEC61850 can do peer to peer communication, which enables increased functionality and allows more flexible control and automation operations.
- IEC61850 enables faster communications than achievable in conventional substations.
- IEC61850 is easier to configure, and can substantially reduce the amount of hard wiring that is needed.

Key Findings

- Maintenance is easier, faster and less expensive.
- More operational activity can be done remotely.
- IEC61850 is an open industry standard (non-proprietary)
  - Different vendors can utilize IEC61850 and do multi-vendor networks.
- IEC61850 hardware equipment cost is currently more expensive but can achieve higher functionality than conventional substations.
- IEC61850 enables increased distributed control compared to current centralized substations.
- The project results support a recommendation that SDG&E pursue commercial adoption of the IEC61850 substation standard.

Q&A

For questions or interest in this project please contact:

- EPIC Program Manager
  Frank Goodman
  fgoodman@semprautilities.com

- Project Technical Lead
  Molham Kayali
  mkayali@seucontractor.com

EPIC Visualization & Situational Awareness Demonstrations Project

2017 EPIC Fall Symposium

Presented by: Aksel Encinas
Subbu Sankaran

Outline

- Project Objective
- Project Team
- Review Visualization & Situational Awareness Use Cases
- Results and Findings
- Q&A.

Project Objective and Focus

- Project objective:
  - Pre-commercial demonstration to explore how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances grid monitoring and situational awareness.
  - Examine how data currently unexploited and separately processed can be integrated and visually presented for strategic use by system operators.
- Focus:
  - Demonstrate prospective components and subsystems for SDG&E’s Visualization and Situational Awareness Systems designed to address a data tsunami produced by SCADA, PMU and Smart Meters and formulate recommendations on which options should be commercially adopted.

Project Team

- Internal SDG&E Project Team

    1. Gayatri Alapati
    2. Brian Bardic
    3. Jungyoon Chung
    4. Casey Cook
    5. Srihari Darapaneni
    6. Susmita Duncan
    7. Aksel Encinas
    8. Frank Goodman
    9. David Hawkins
    10. Molham Kayali
    11. Kyle Kewley
    12. Mark Liwanag
    13. Iman Mazhari
    14. Timothy McDermott
    15. Bao P Nguyen
    16. Subbu Sankaran
    17. Mark Stiefel
    18. Chris Surbey

- Contractors

    1. Quanta Technology, LLC
    2. Avineon, Inc.

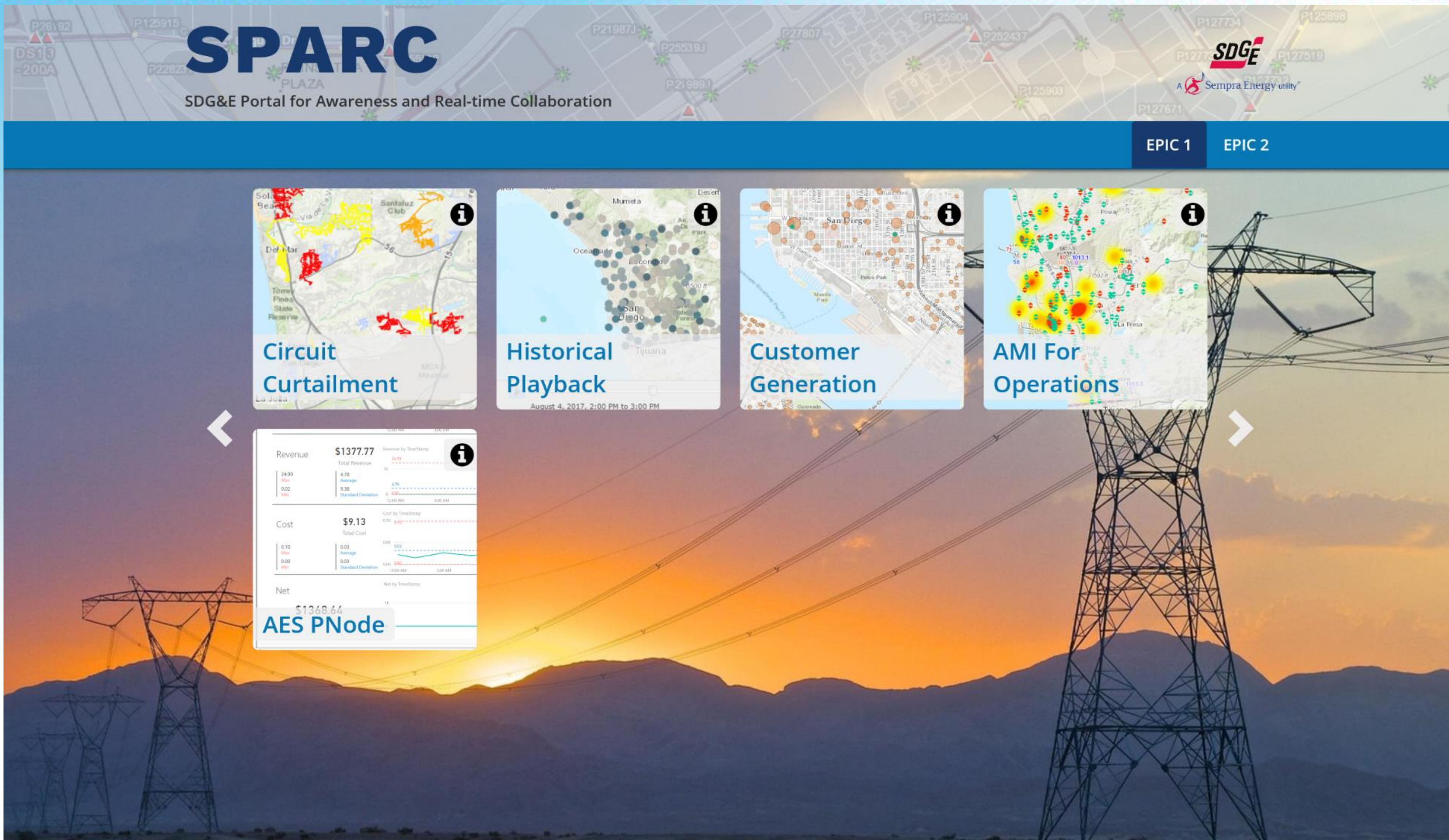
- SDG&E Business Units

    1. Electric Distribution Operations
    2. Emergency Operation Center
    3. Electric T&D Engineering
    4. T&D System Planning
    5. Distributed Energy Resources
    6. Kearny Maintenance & Ops

Selected Use Cases for Pre-Commercial Demonstrations

1. Visualization of electric transmission outages.
2. Visualization of electric load curtailment.
3. Self-service electric GIS reporting interface.
4. Historical playback.
5. Real time system visualization dashboards based on distribution SCADA and AMI data.
6. Incorporate a representation of customer-owned energy resources.
7. Imagery management.
8. Visualization modernization infrastructure.

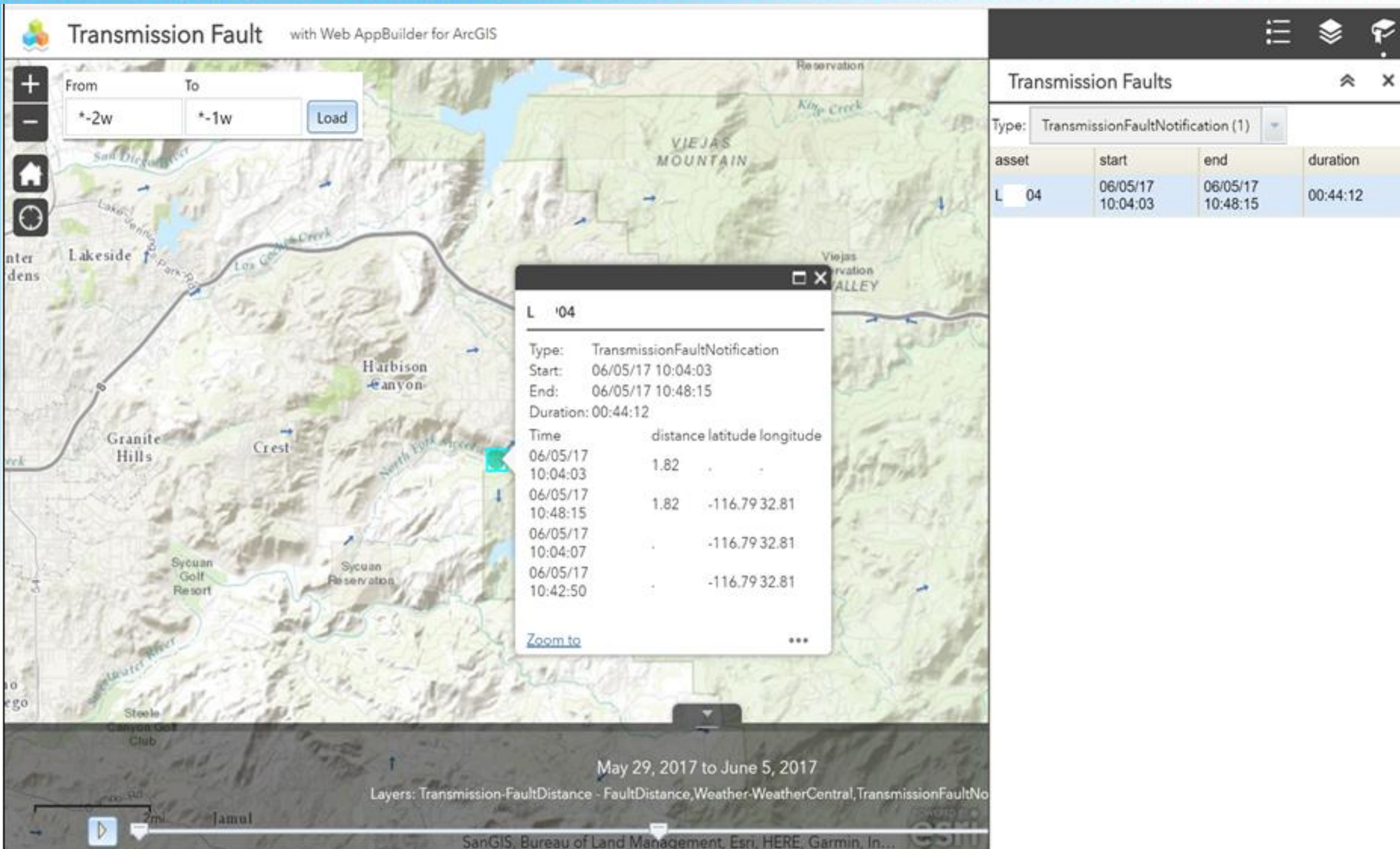
Homepage - Sample Use Cases for Pre-Commercial Demonstrations



Use Case 1: Visualization of Electric Transmission Outages

- Objective
  - Display electric transmission fault location details on a geospatial map
- Approach
  - Use linear distance to a fault computed by relays and stored in PI Data Historian, and *ArcGIS linear referencing Geoprocessing service* to compute Lat/Long of the fault location; use PI Esri Integrator to publish fault distance template to ArcGIS Portal, and to update it with the lat/long computed by Geoprocessing service (and stored in PI)
- Output
  - ArcGIS portal maps showing electrical circuits with fault indicators
  - Formatted email with embedded hyperlink to ArcGIS Portal map
  - Relay-computed fault distance converted to lat/long and stored in PI

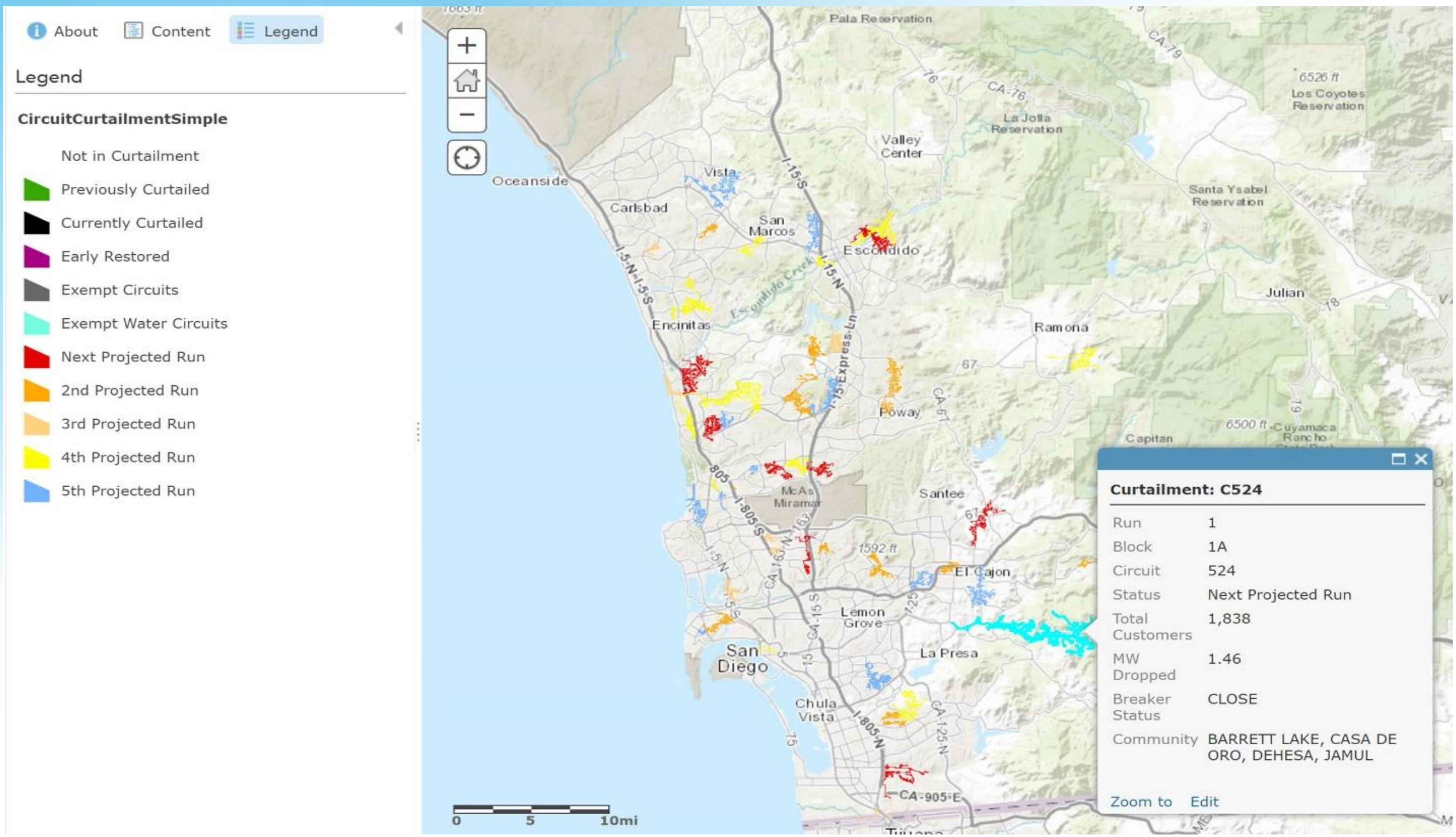
Use Case 1: Visualization of Electric Transmission Outages - Example



Use Case 2: Visualization of Electric Load Curtailment

- Objective:
  - Develop a program that has the ability to visualize the load curtailment or demand response.
- Approach:
  - Develop and ArcGIS portal map application.
  - Create distribution circuit spatial layer to display the curtailment information.
- Output:
  - Color coding, displaying circuit information via circuit on the map near real time.

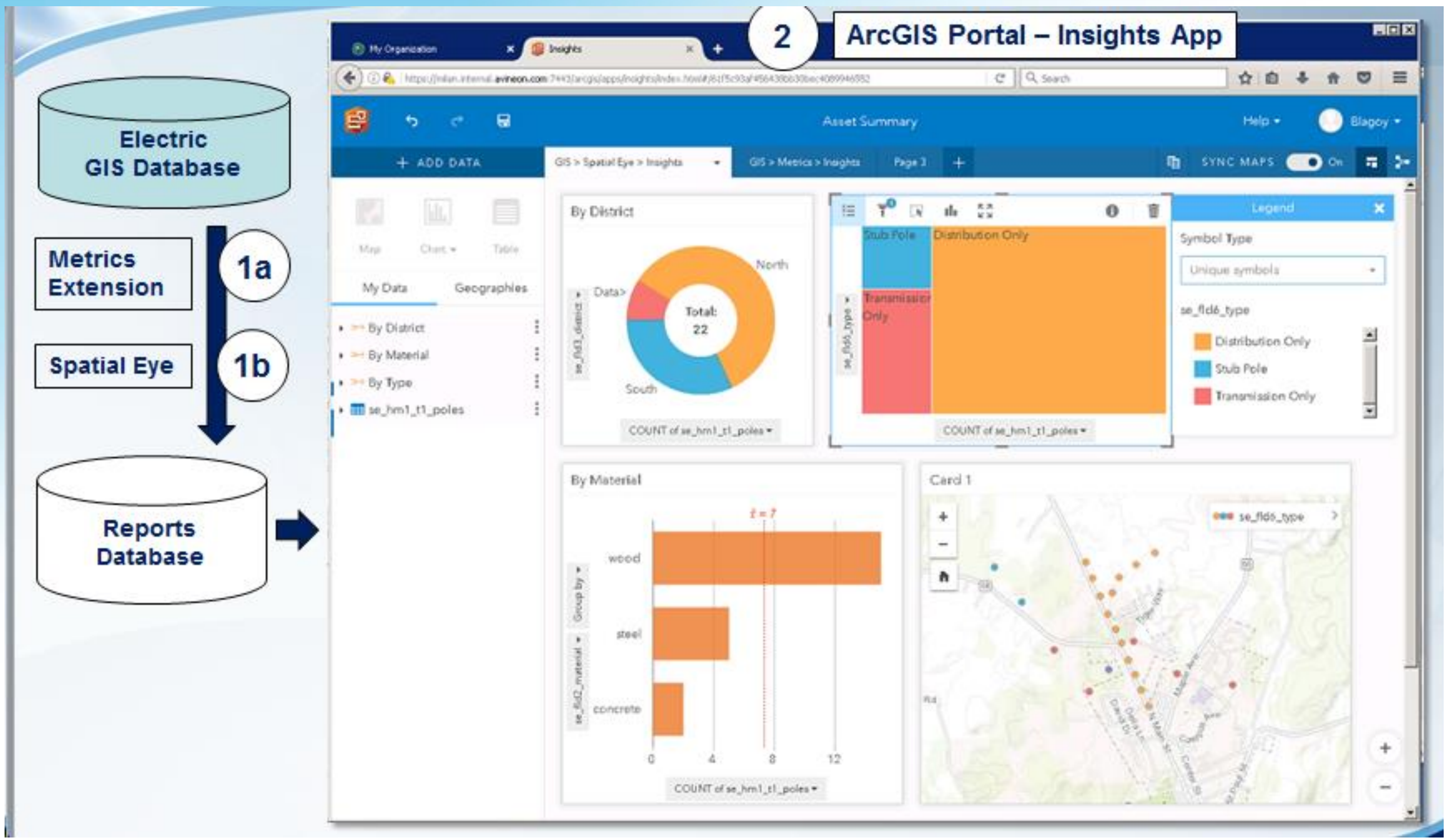
Use Case 2: Visualization of Electric Load Curtailment - Example



Use Case 3: Self-Service Electric GIS Reporting Interface

- Objective:
  - To evaluate options for a self-services electric GIS reporting tool. Demonstrate a flexible, intuitive "self-service" reporting application using the electric GIS and/or other databases.
  - Focus is on providing functionality to explore data and ease of use while achieving higher performance.
- Approach:
  - Develop use cases based on current GIS report requirements. Include the ability to create reports via user input such as lists of all wood poles over a certain length within a high risk fire area.
  - The execution of such requests would typically consist of selecting features, attributes, polygons and electric networks (circuits) from rules based on valid domains.
- Output:
  - An intuitive user interface providing electric GIS users ability to generate a variety of GIS reports based on any combination of the following four parameters:
    - Features, e.g., wood poles.
    - Attributes, e.g., characteristics like length of poles.
    - Polygons, e.g., high risk fire area.
    - Networks, e.g., by circuit.

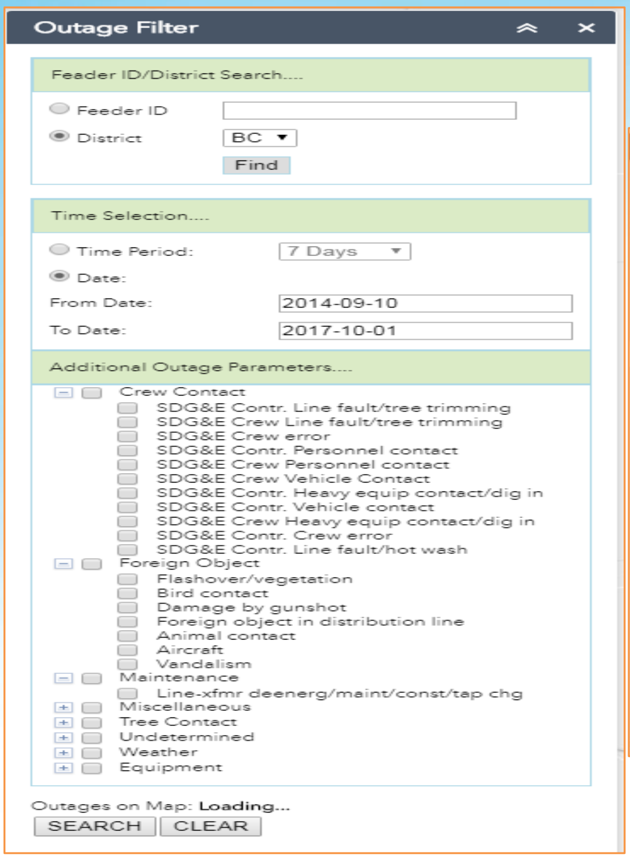
Use Case 3: Self-Service Electric GIS Reporting Interface - Example

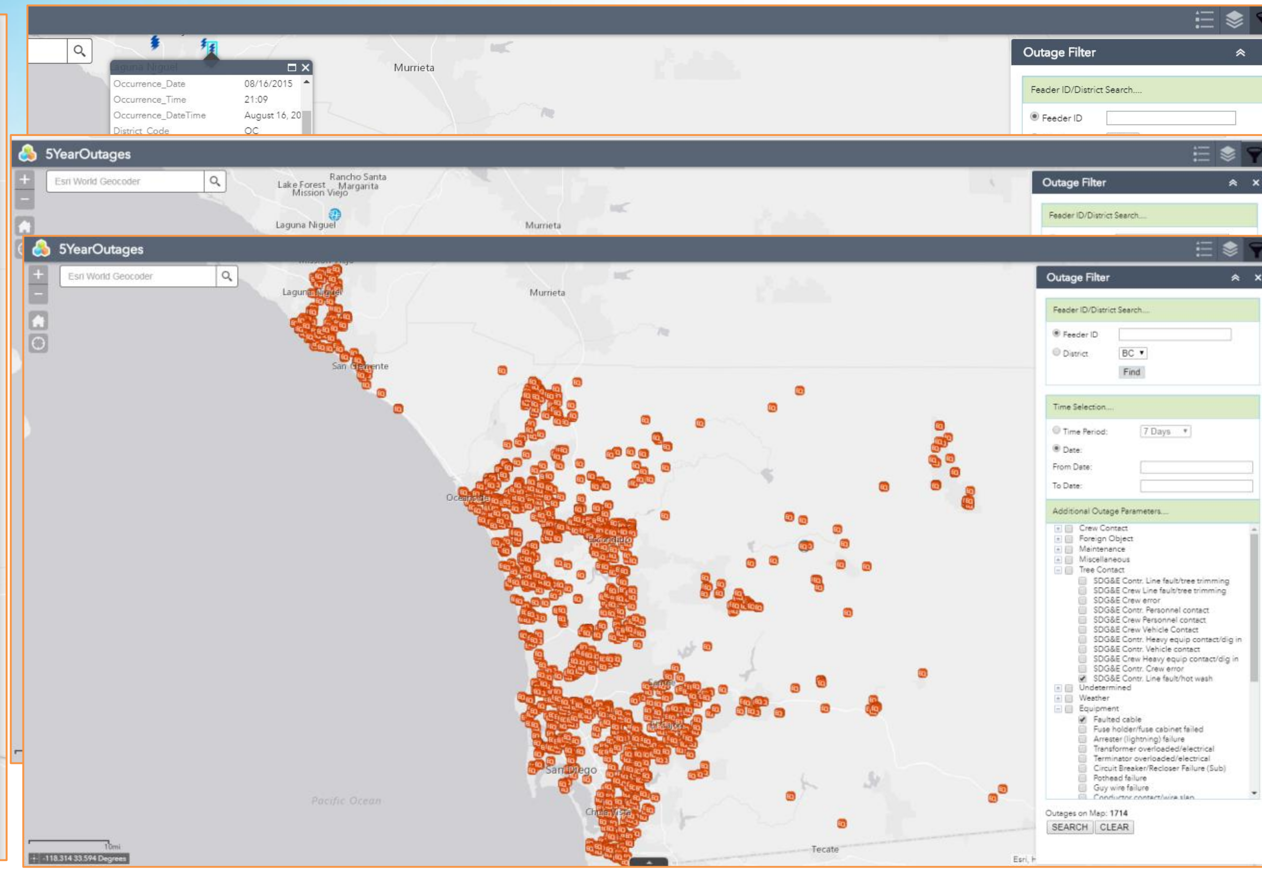


Use Case 4: Historical Outage and Events Playback

- Objective
  - Develop an ability to playback historical data via geospatial maps to get more information about the context for system outages.
- Approach
  - Outage management system polled for outage data
  - Web App Builder for ArcGIS used to develop a custom application to define map features
  - Operational data about outages in PI Data Historian
  - PI ESRI Integrator used to update feature data on a map
- Output
  - An interactive map with a time-enabled layer to view weekly and daily outages playback.

Use Case 4: Historical Playback Example

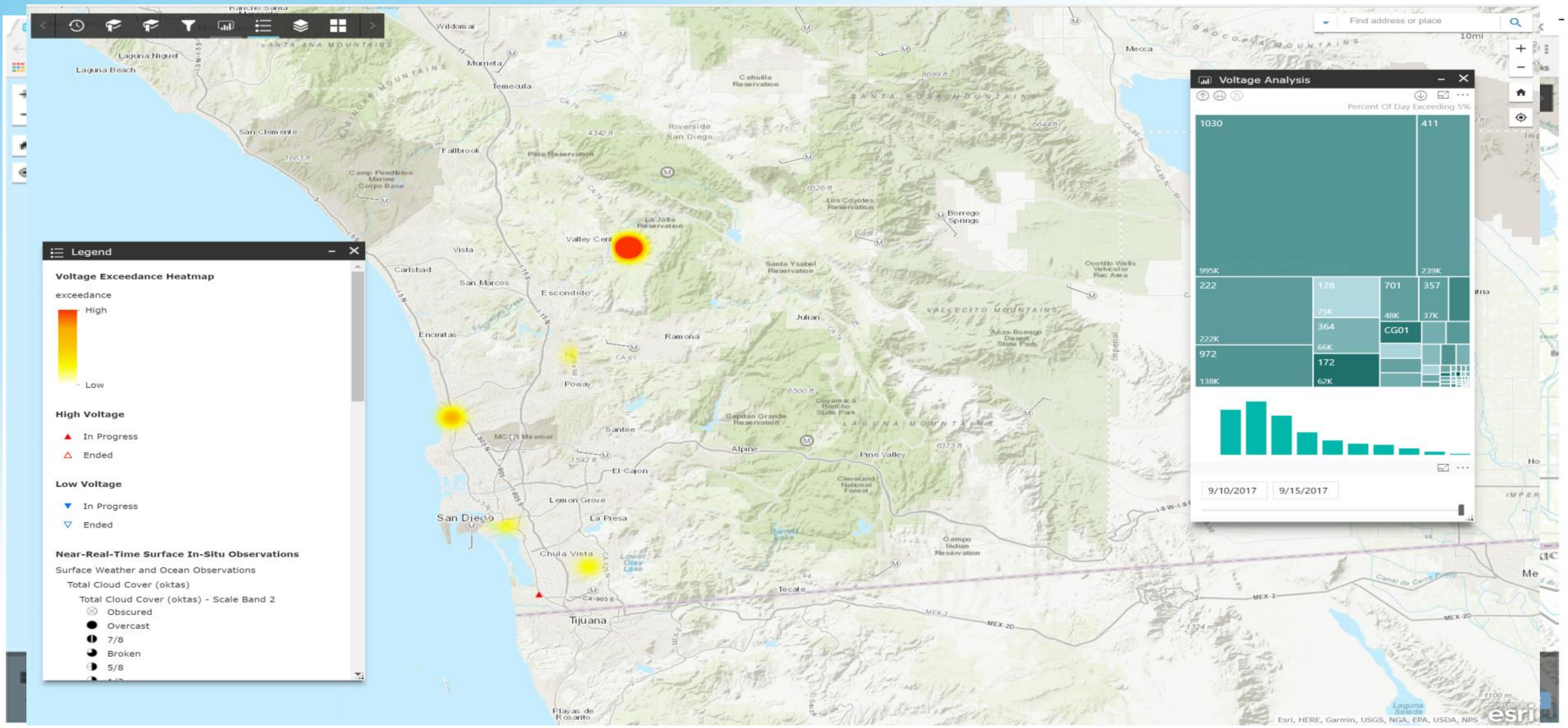




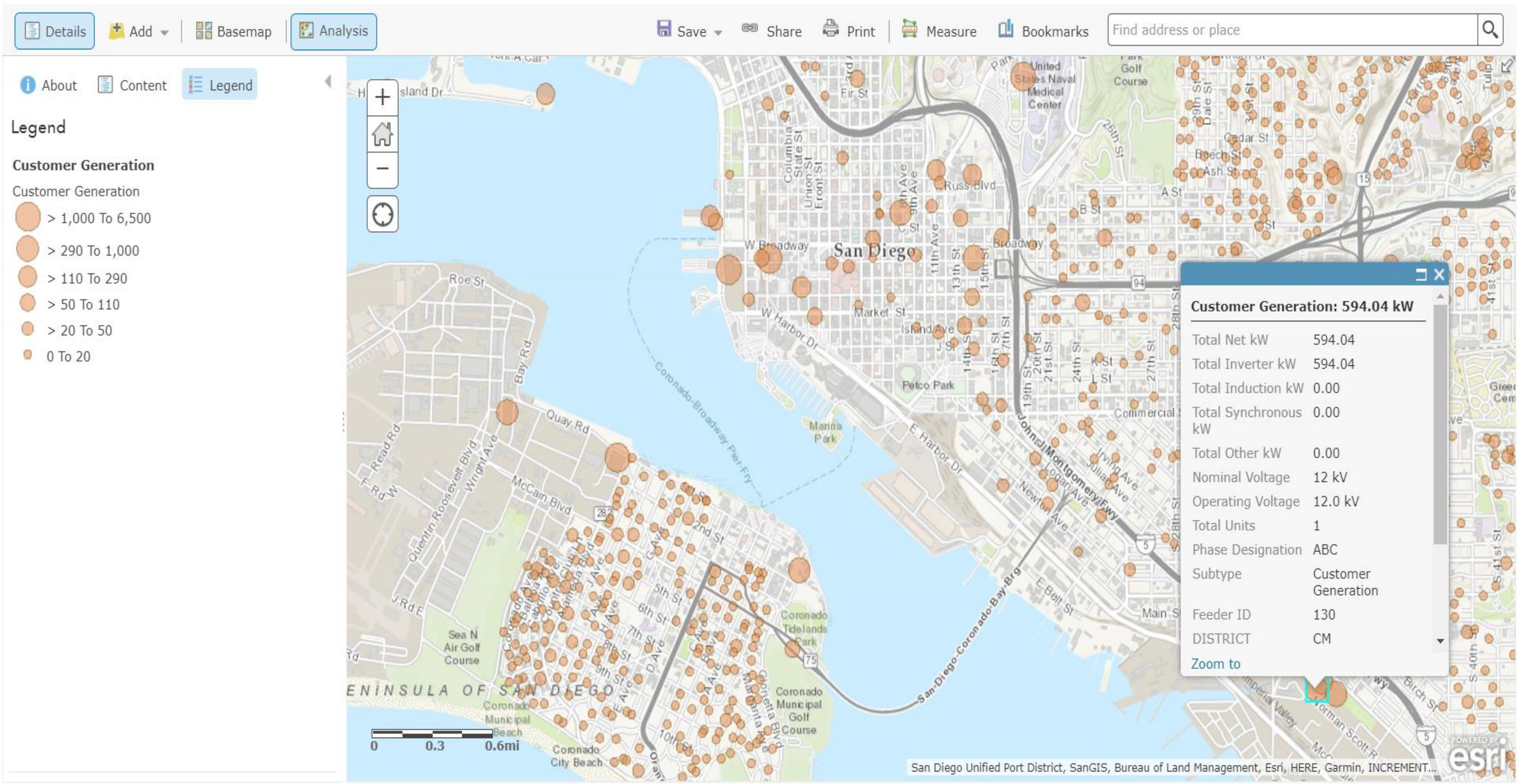
Use Case 5: AMI for Operations

- <u>Objective</u>
  - Overlay AMI and SCADA voltage data onto a GIS map with circuit topology, and create a heat map that shows voltage swells and swags on the GIS map.
- <u>Approach</u>
  - PI Event Frames feature captures voltage exceedance events
  - Power BI used to aggregate events by circuit, transformer, substation
  - Web App Builder for ArcGIS used to integrate Power BI data with GIS maps
  - Maps posted on ArcGIS Portal

Use Case 5: AMI for Operations



Use Case 6: Representation of Customer-Owned Energy Resources



Use Case 6: Incorporate a Representation of Customer-Owned Energy Resources

SDGE
A Sempra Energy utility®

Battery System Pricing Dashboard for monitoring price and other attributes over time.

Visualization & Situational Awareness Demonstrations Project

Findings:

- Determined how data currently unexploited and separately processed at SDG&E can be integrated and visually presented for strategic use by system operators, and demonstrated how data collected from sensors and devices can be processed, combined, and presented to system operators in a way that enhances grid monitoring and situational awareness.
- Illustrated how data commonly used to support diverse business needs at SDG&E can be combined with geospatial data to significantly enhance insights and situational awareness.
- Gained valuable experience that can be reused to speed up future developments in the area of situational awareness and integration of real-time and geospatial data, and defined a framework for further explorations to enable more effective use of GIS technologies.

Q&A

For questions or interest in this project please contact:

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