

Welcome and Workshop Opening

Ted Reguly, Director

Growth and Technology Integration Department
SDG&E



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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

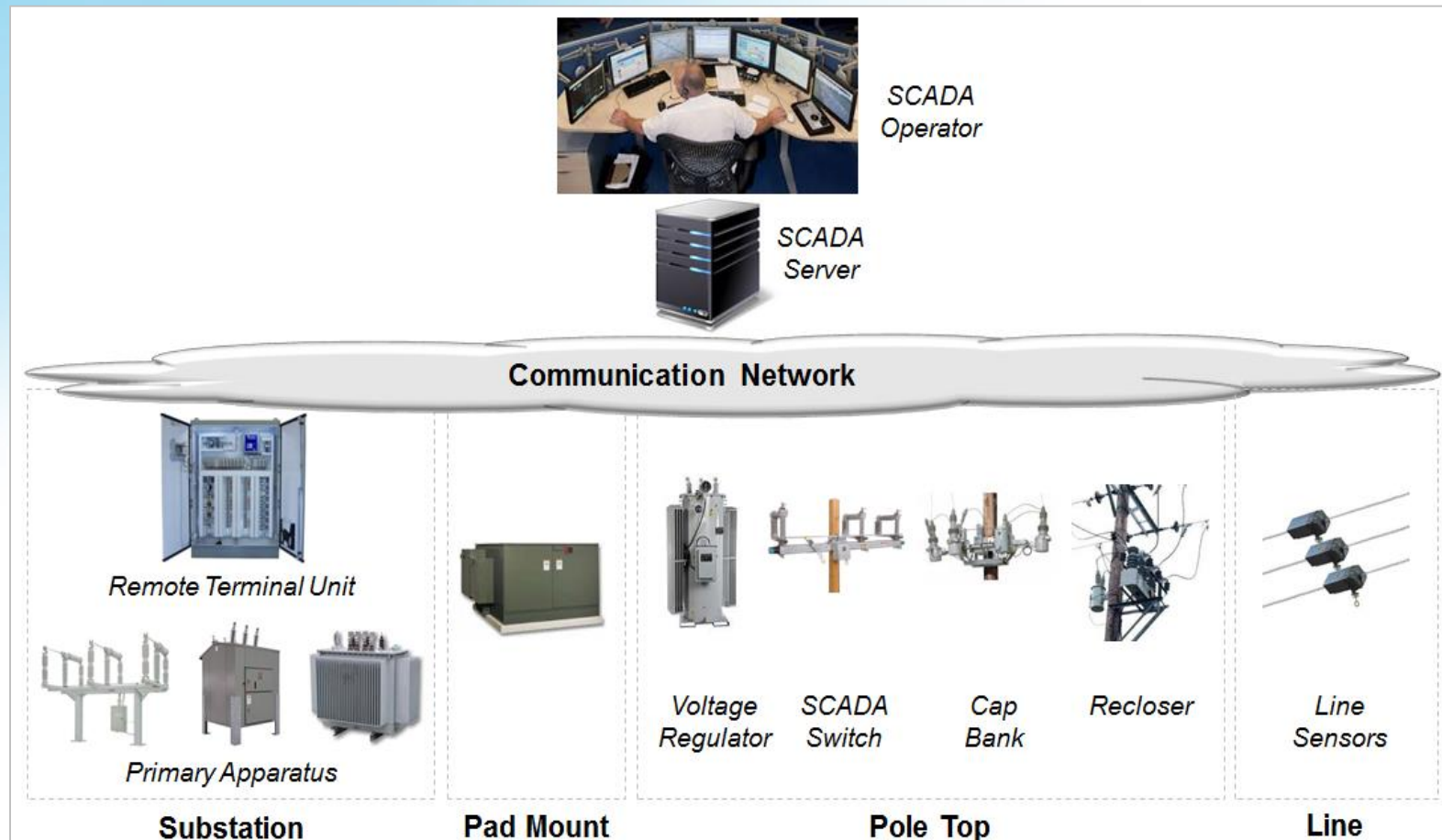
- SDG&E Internal Team
 - Aksel Encinas
 - Frank Goodman
 - Prajwal Raval
 - Amin Salmani
- Contractor: Quanta Technology, LLC.

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.

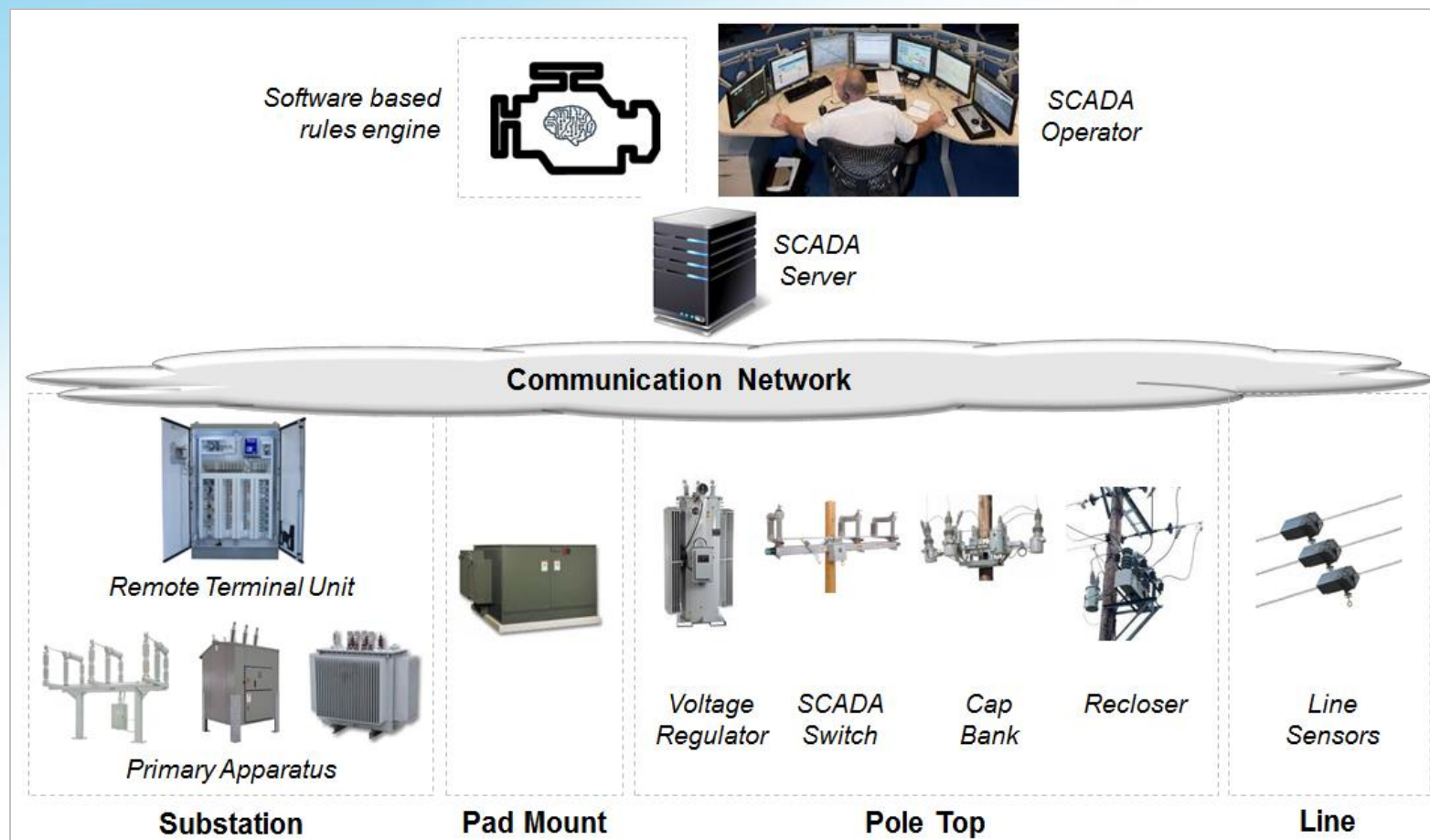
Centralized Control for Distribution Systems

Conventional distribution control systems are centralized in nature.



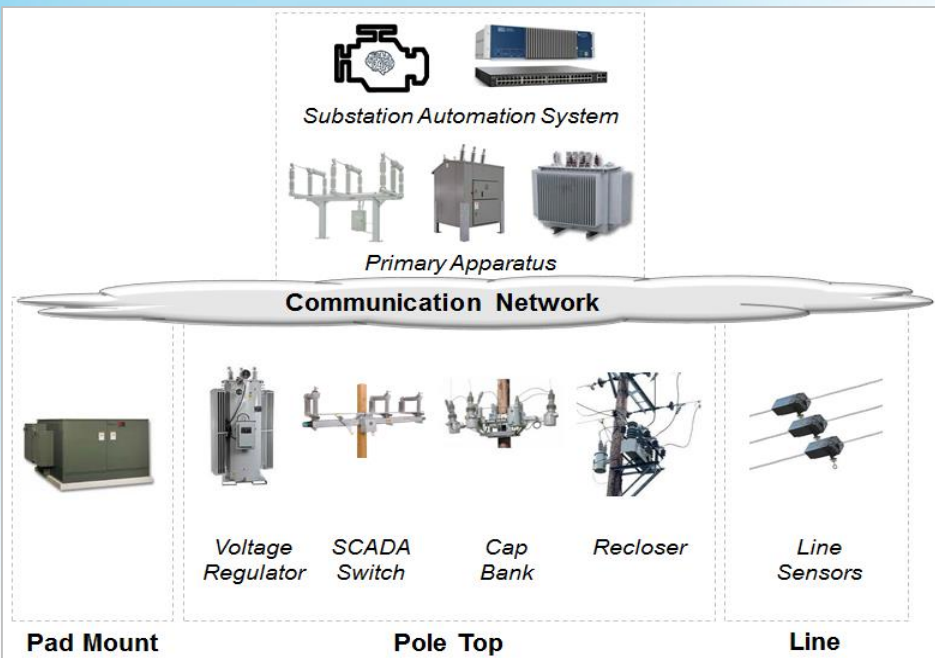
Centralized Control for Distribution Systems

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)

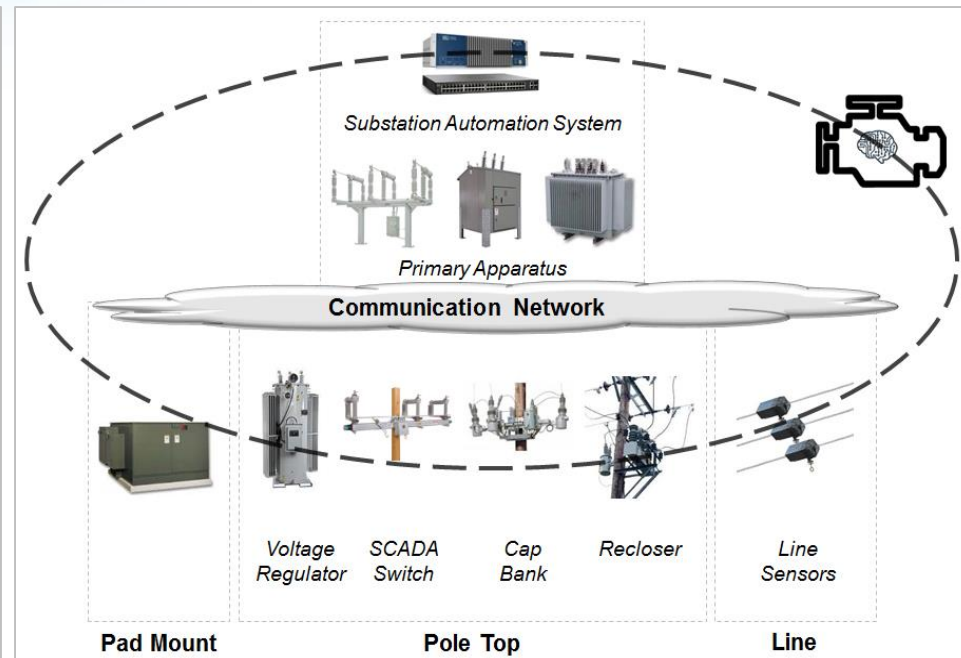


Distributed Control Systems

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

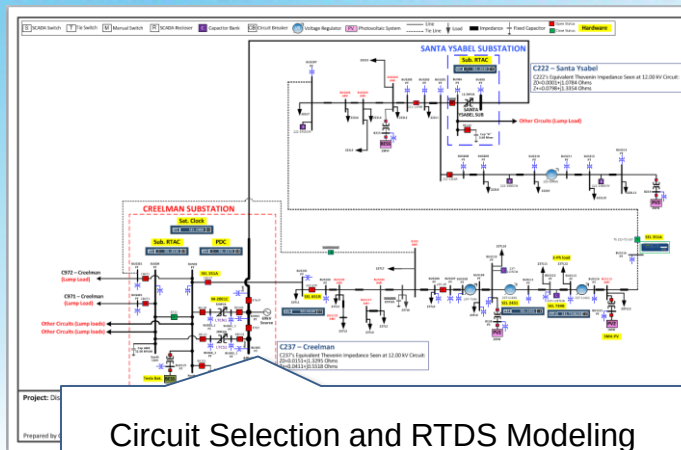
Project Steps and Approach



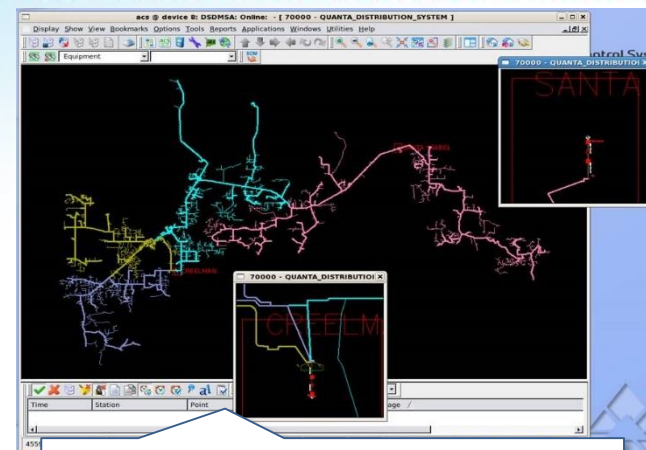
Distributed Control for Smart Grid Use Case 1 – Synchronized Load Transfer

PREPARED FOR: San Diego Gas & Electric (SDGE)
REPORT DATE: November 30, 2016 (Draft 2)
PREPARED BY: Amin Zamani
azamani@quanta-technology.com
(416) 509 8870

Literature Review of DA Applications



Circuit Selection and RTDS Modeling

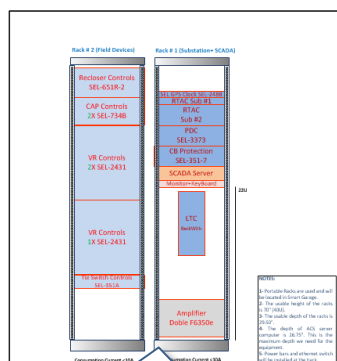


Master Control System Development

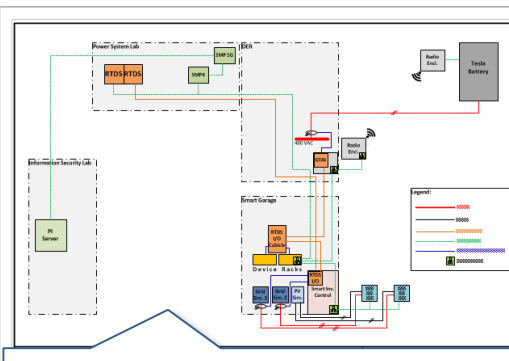
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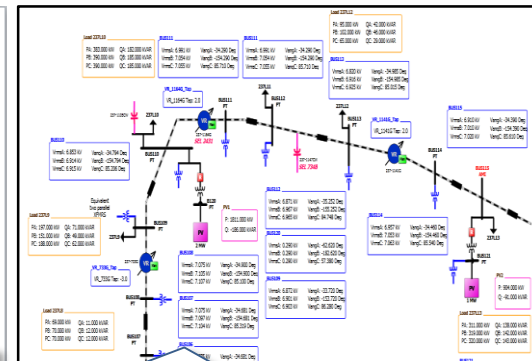
3 x Use Cases docs



Hardware Development



Communication Architecture of Test Platform



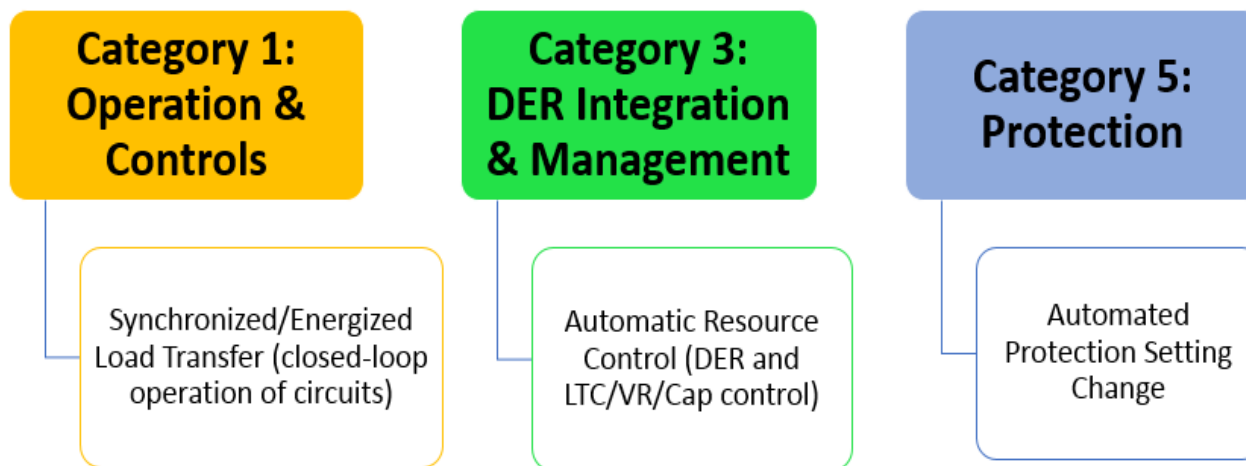
Substation Control System Development

Distribution Automation Applications

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

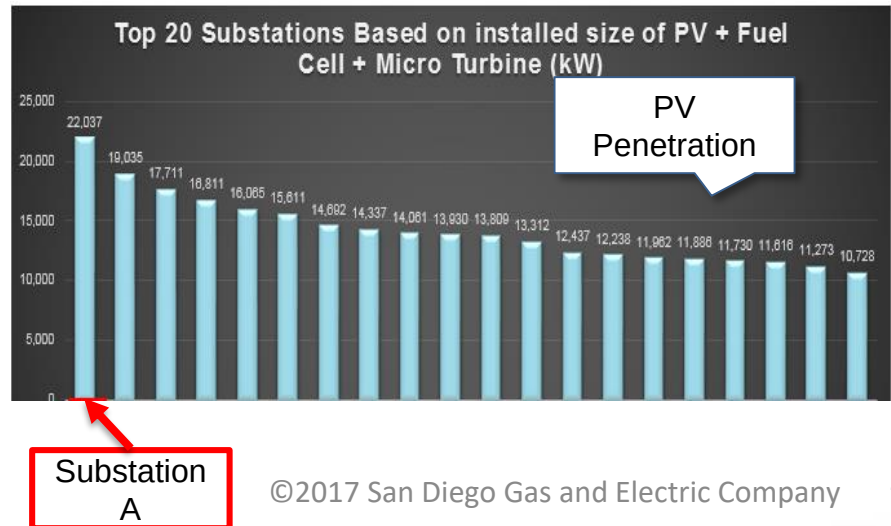
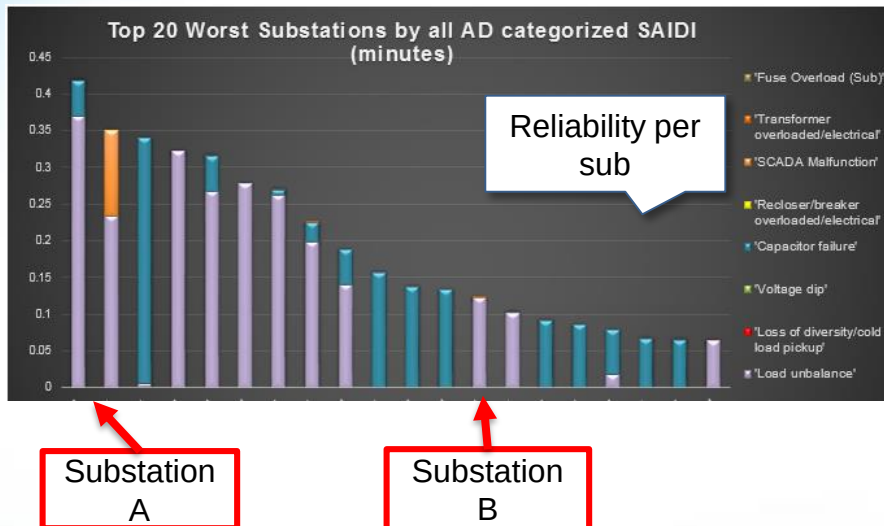
1. Operation and Control
2. Planning and Assessment
3. DER Integration and Management
4. Monitoring and Diagnostics
5. Protection and Automation

Selected use cases:



Circuit Selection Criteria

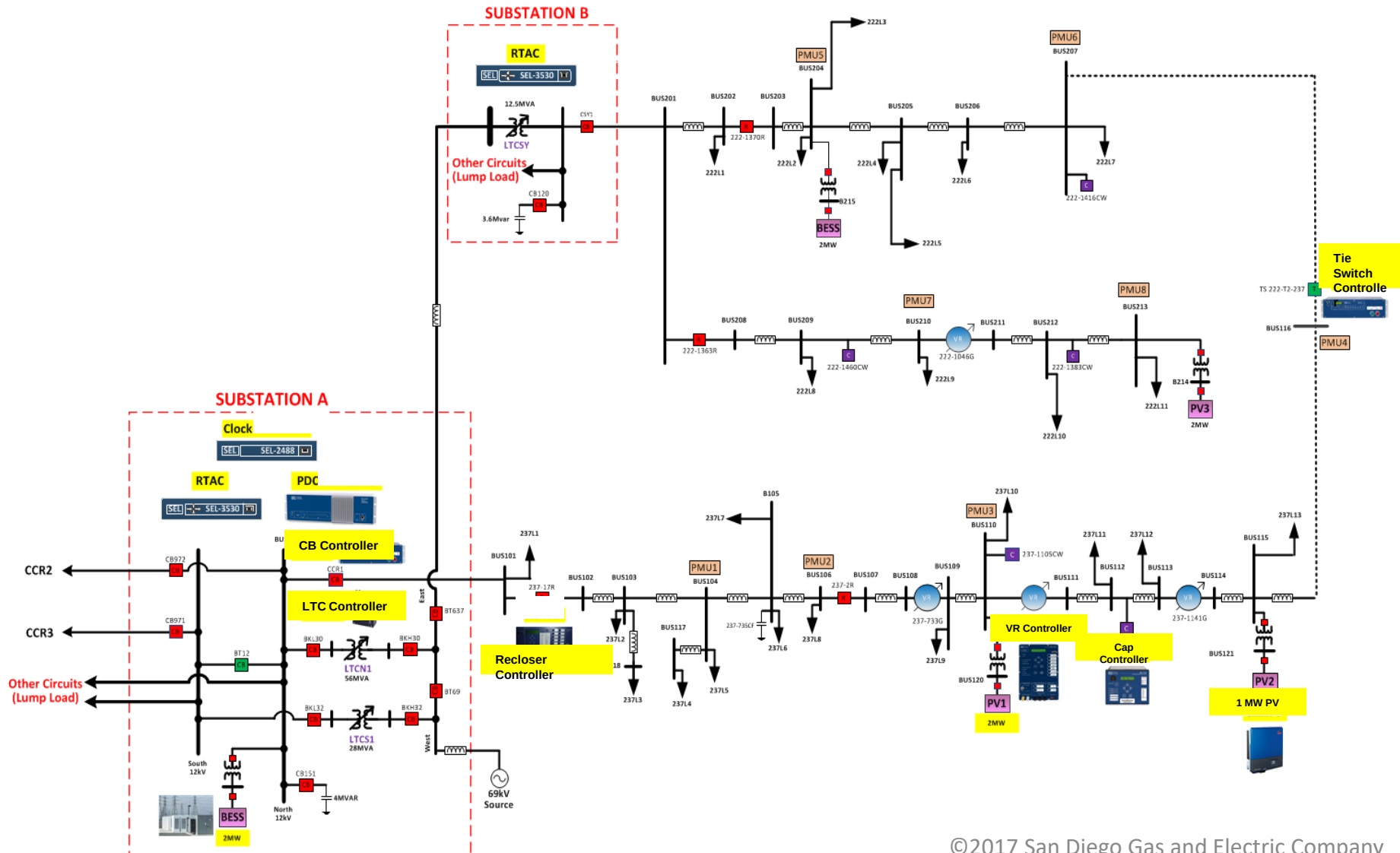
- DER penetration level
- System reliability
- Circuit performance
 - Capacitor failure
 - Load imbalance
- Power quality:
 - Voltage fluctuations
 - Voltage imbalance
- Two circuits from two substations, with a tie between them.



Distributed Control System Test Platform

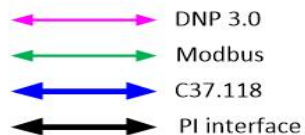
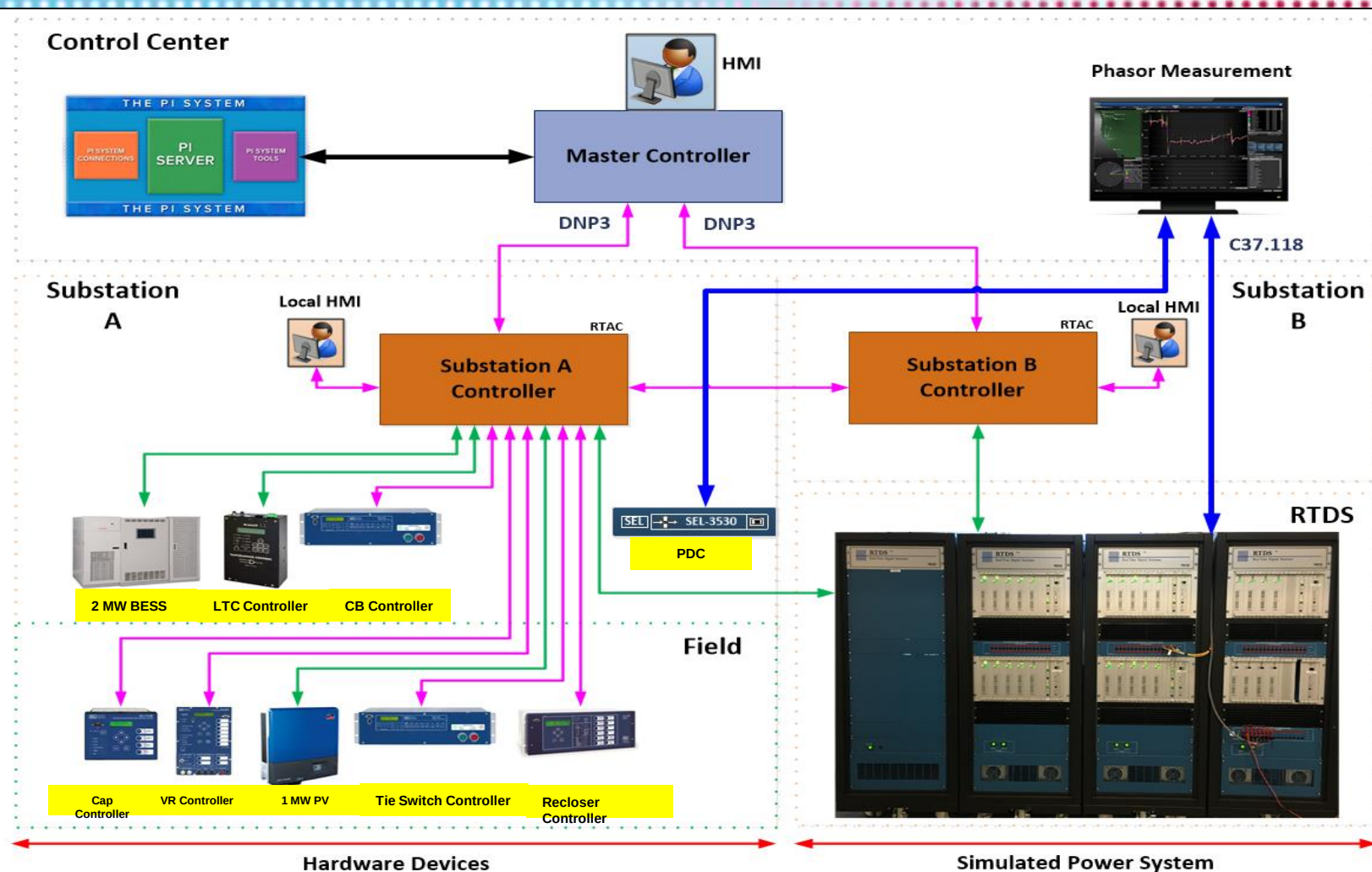


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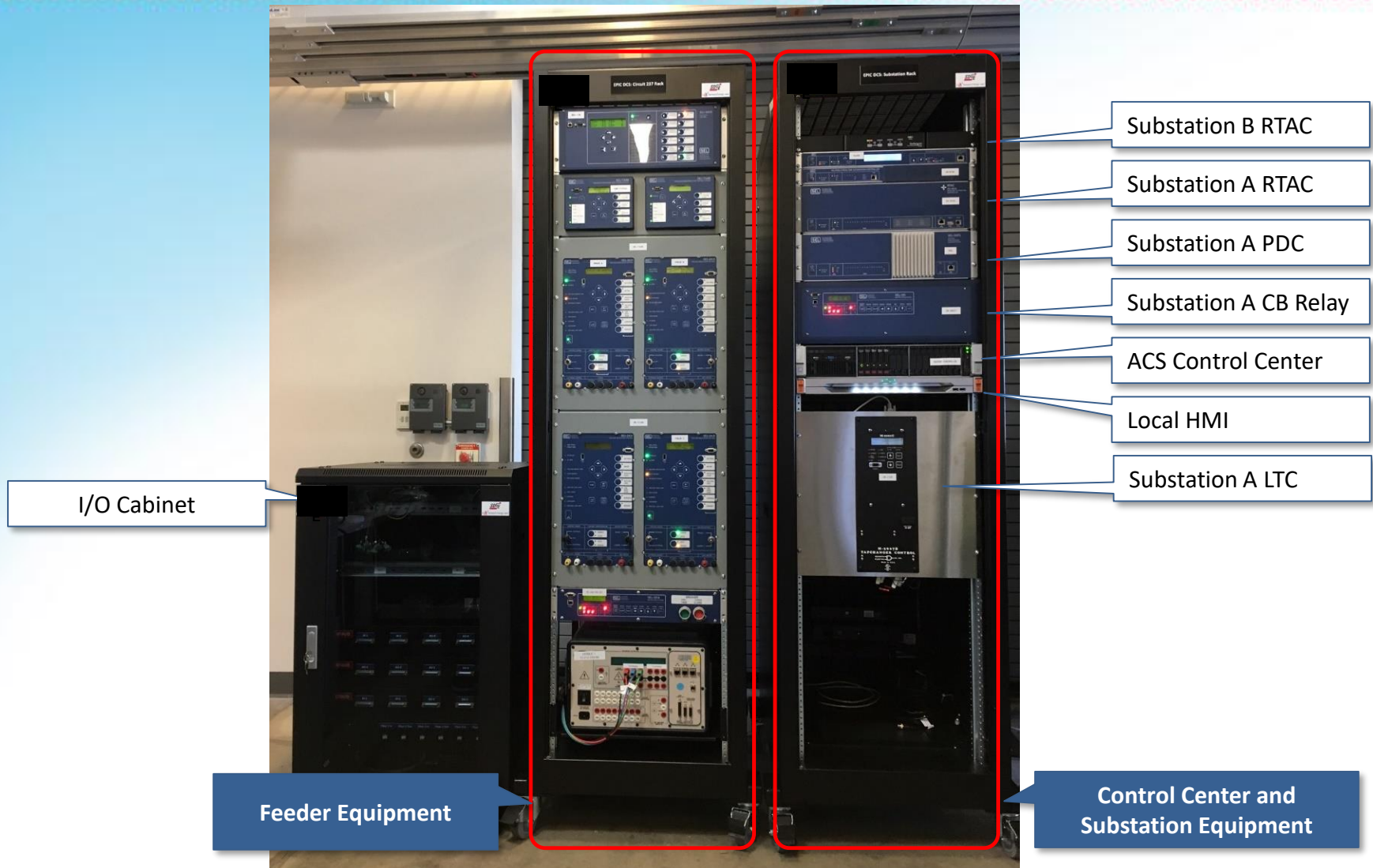
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Communication Architecture of DCS Test Platform



BESS: Battery Energy Storage System

Hardware Integration



Use Case 1 – Automatic Resource Control

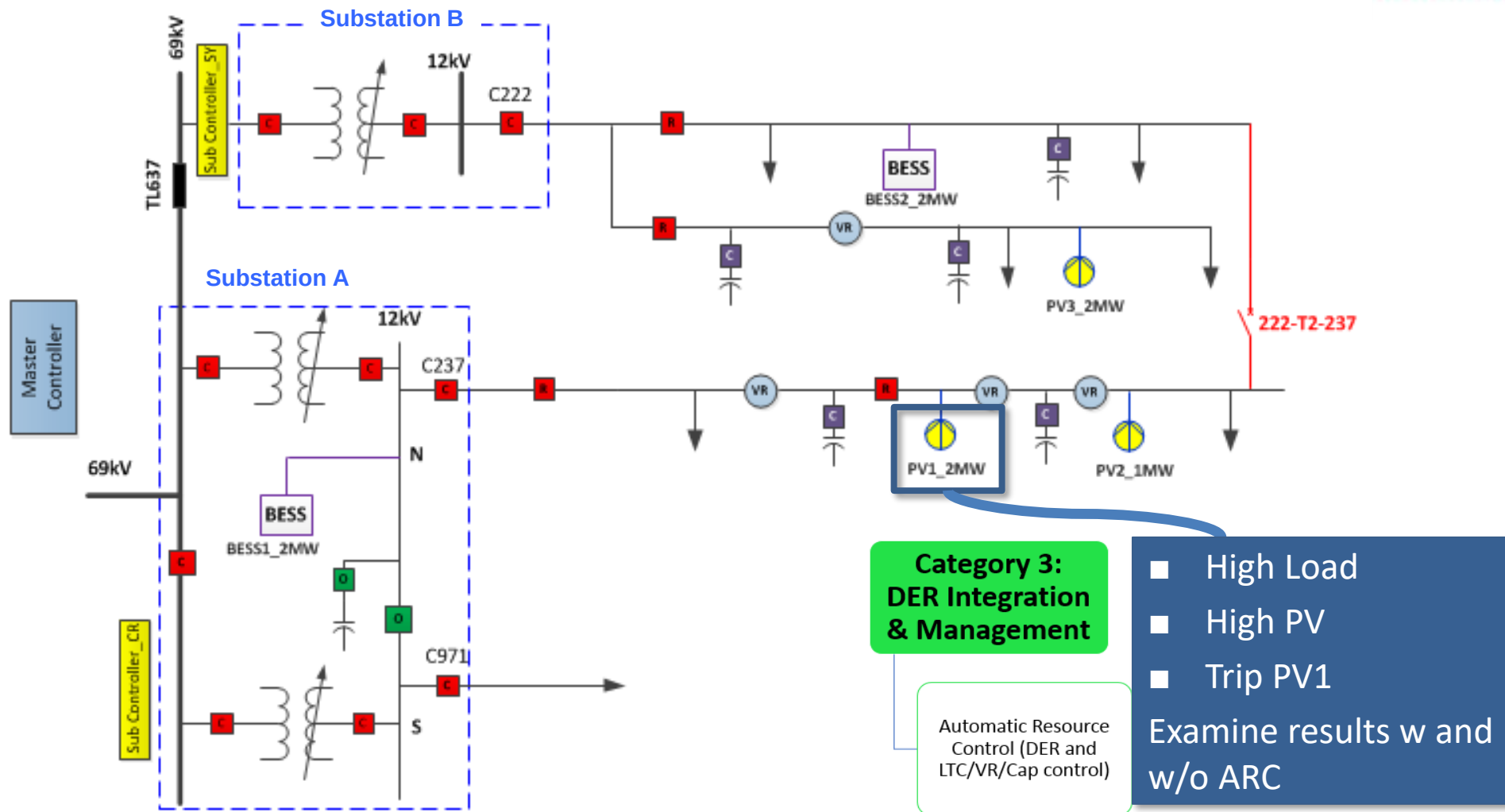
Primary objectives of the Automatic Resource Control (ARC):

- 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



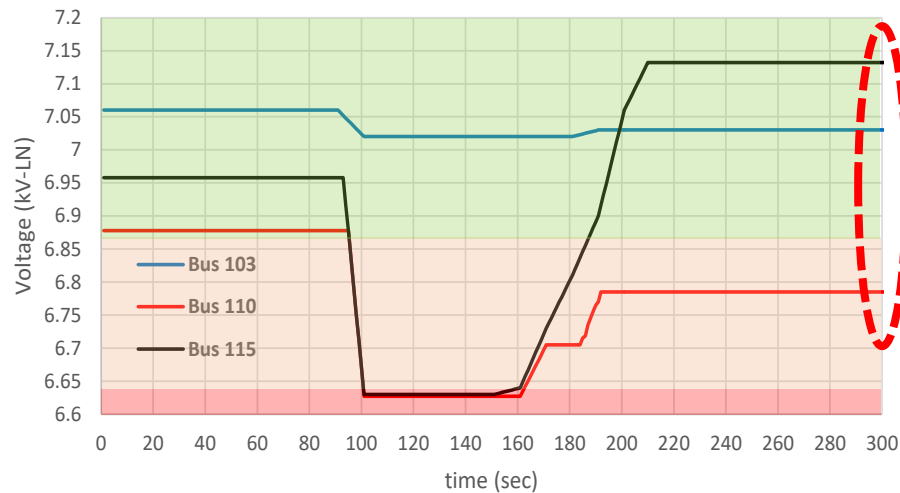
Use Case 1 – Automatic Resource Control



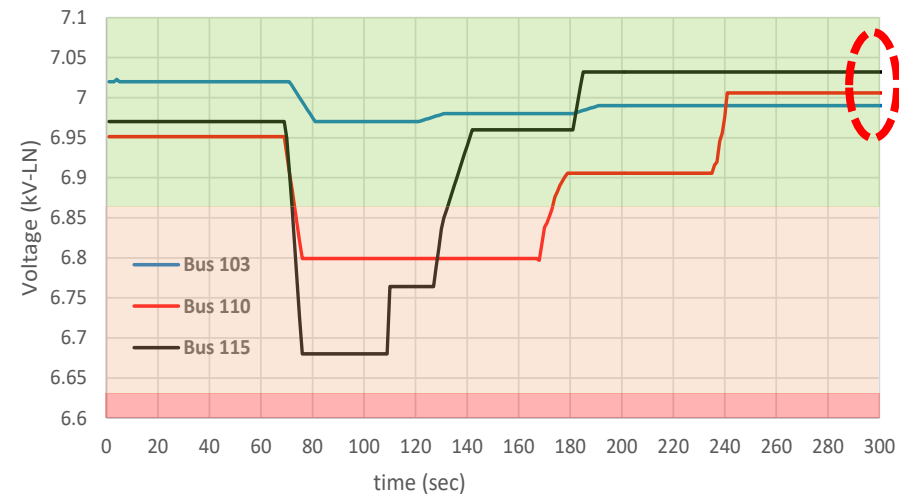
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Case 1	Case 1.10 (PBESS1= PBESS2=0), trip PV 1 after the system gets to the steady state condition.	High load (fix), High PV (fix)	Baseline System 2 (all controllable devices were in Local/Auto mode)
Case 2	Case 1.11 (PBESS1= PBESS2=0), trip PV 1 after 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.

Control Scenario 1



Control Scenario 2



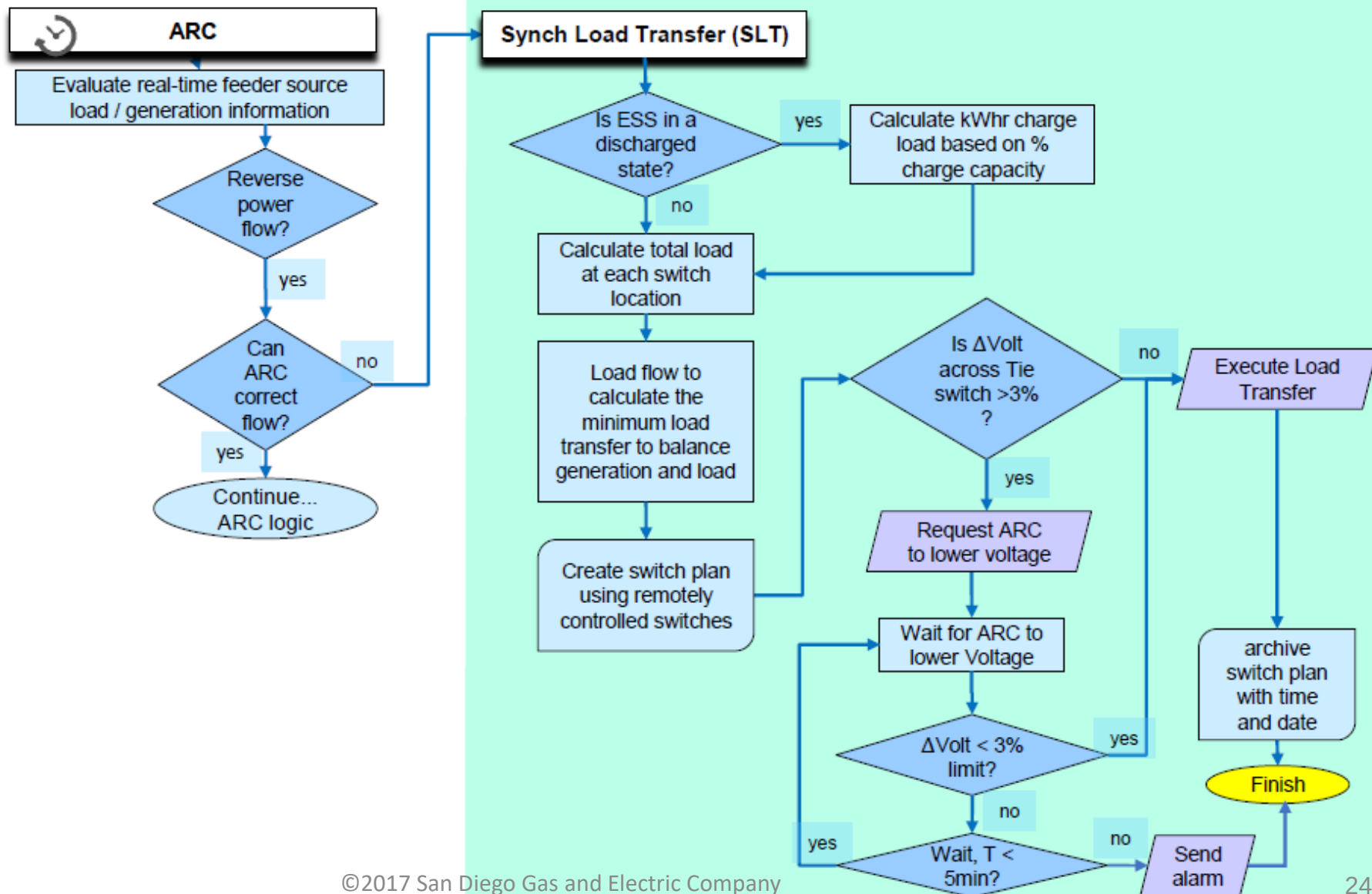
IVVC: Integrated Volt-Var Control

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.

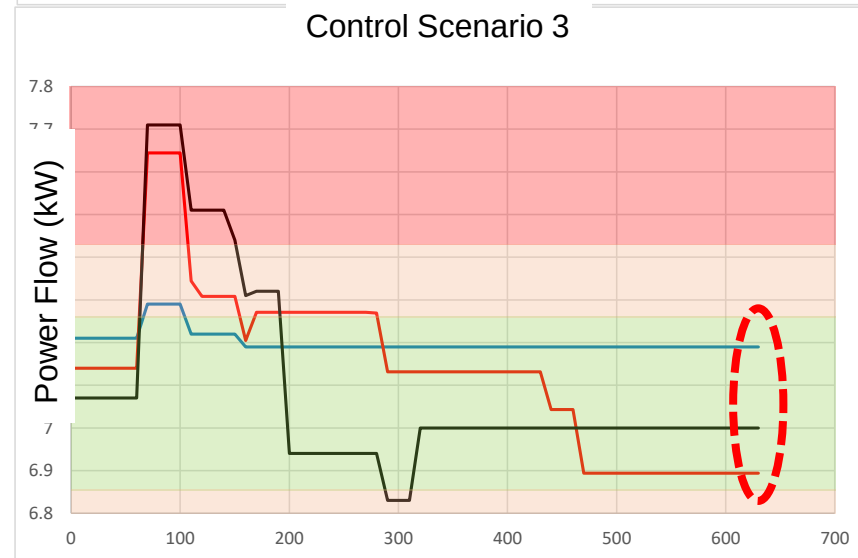
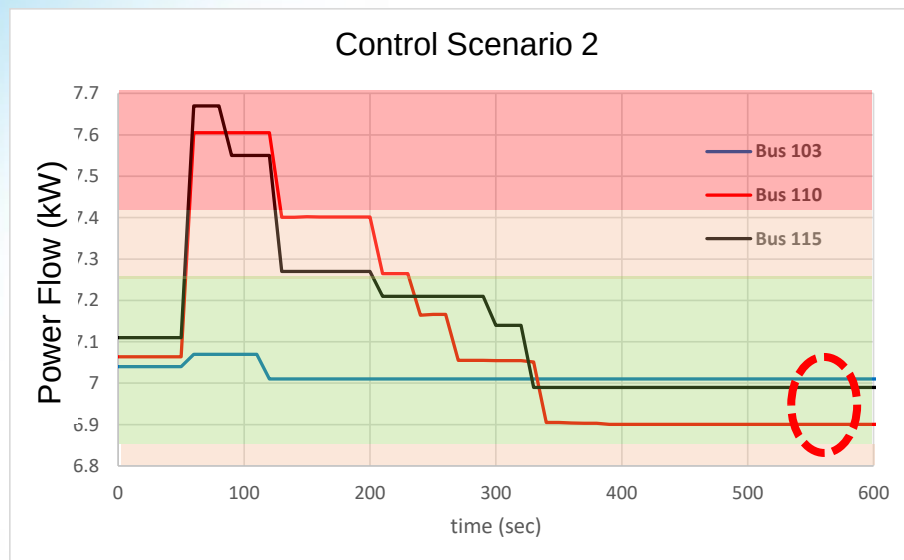
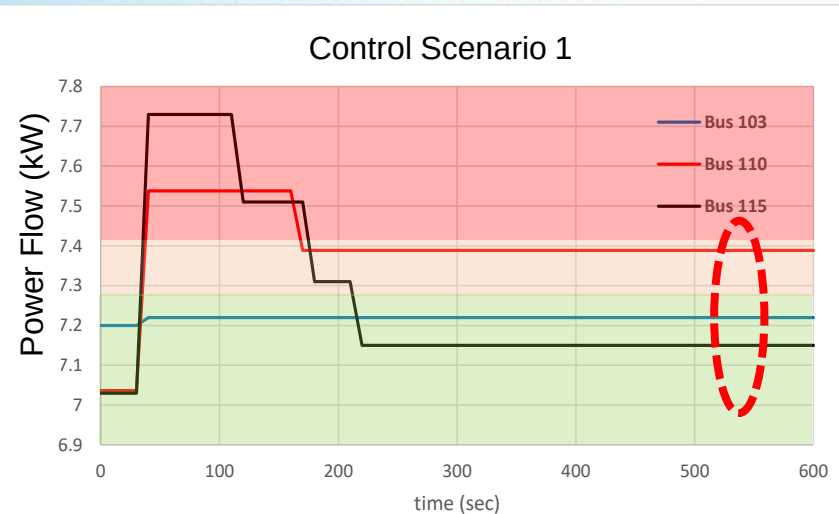
Parameter	Scenario 1 Result	Delta between Scenarios 1 and 2	Delta between Scenarios 1 and 3
<u>Maximum</u> voltage magnitude (rms)	8.04 kV (1.16pu)	7% less	5% less
<u>Maximum</u> out-of-range value with respect to maximum allowable voltage (rms)	765.4 V (0.11pu)	78% less	48% less
Out-of-range duration (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

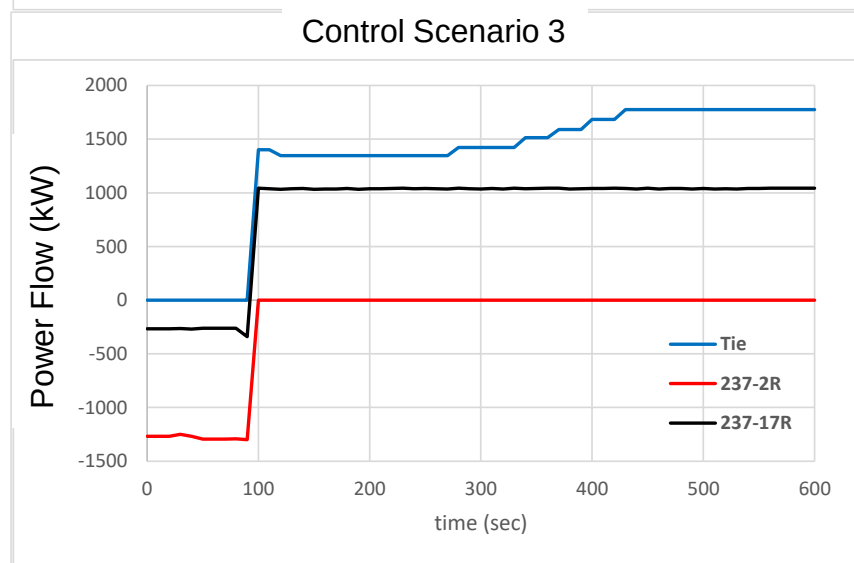
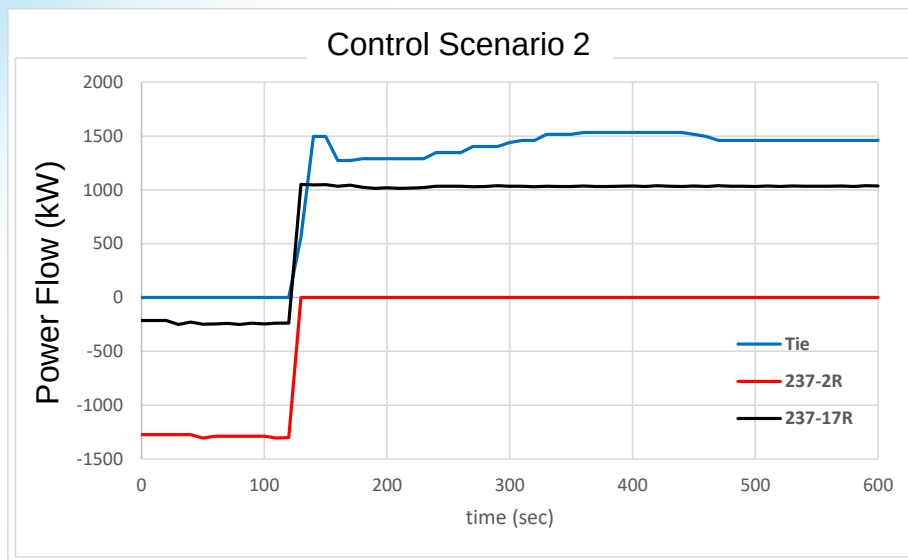
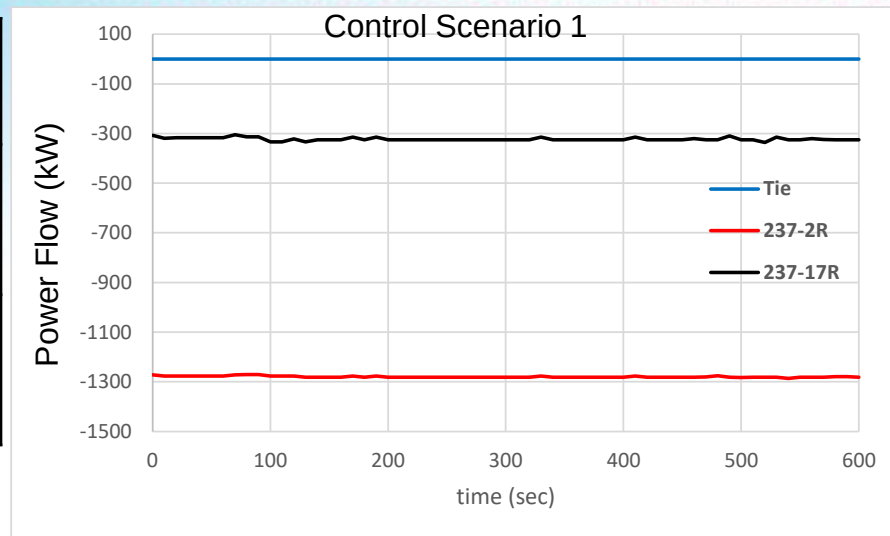


Use Case 2 – Synchronized Load Transfer



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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



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

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

7

- Performed pre-commercial demonstration (ran use cases)

8

- Analyzed data

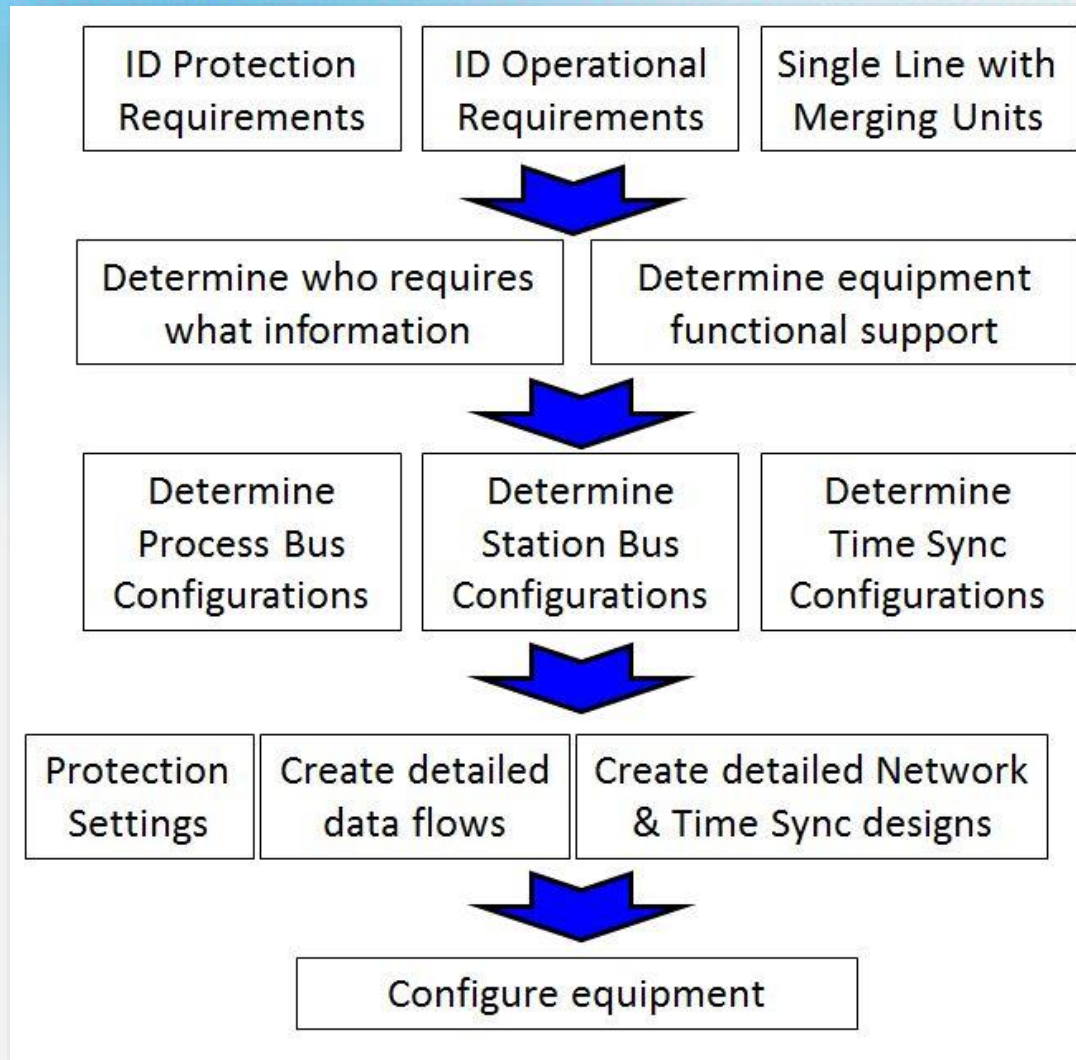
9

- Developed findings, conclusions, and recommendations

10

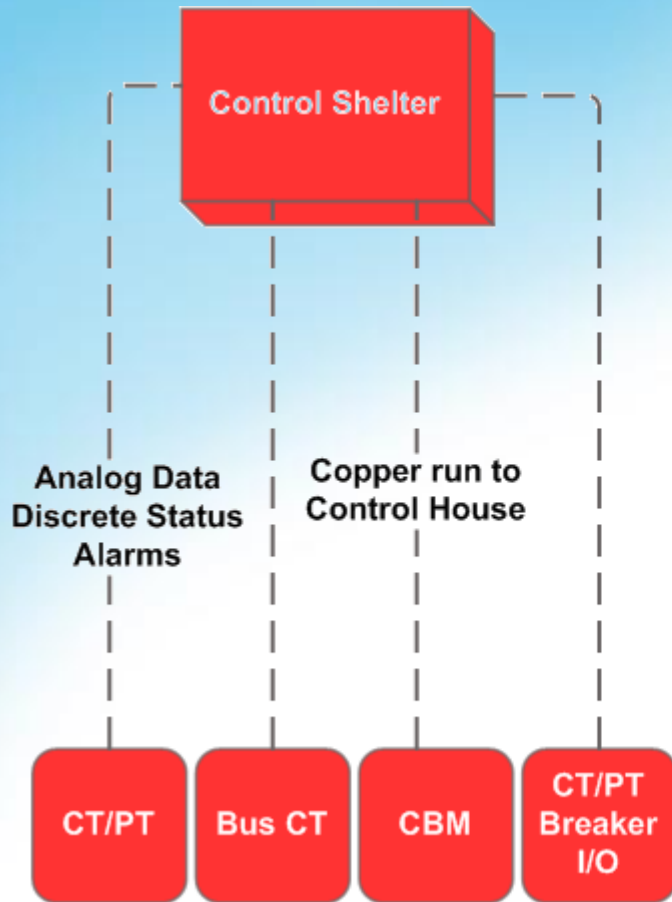
- Prepared comprehensive final report (including tech transfer plan)

Design Process

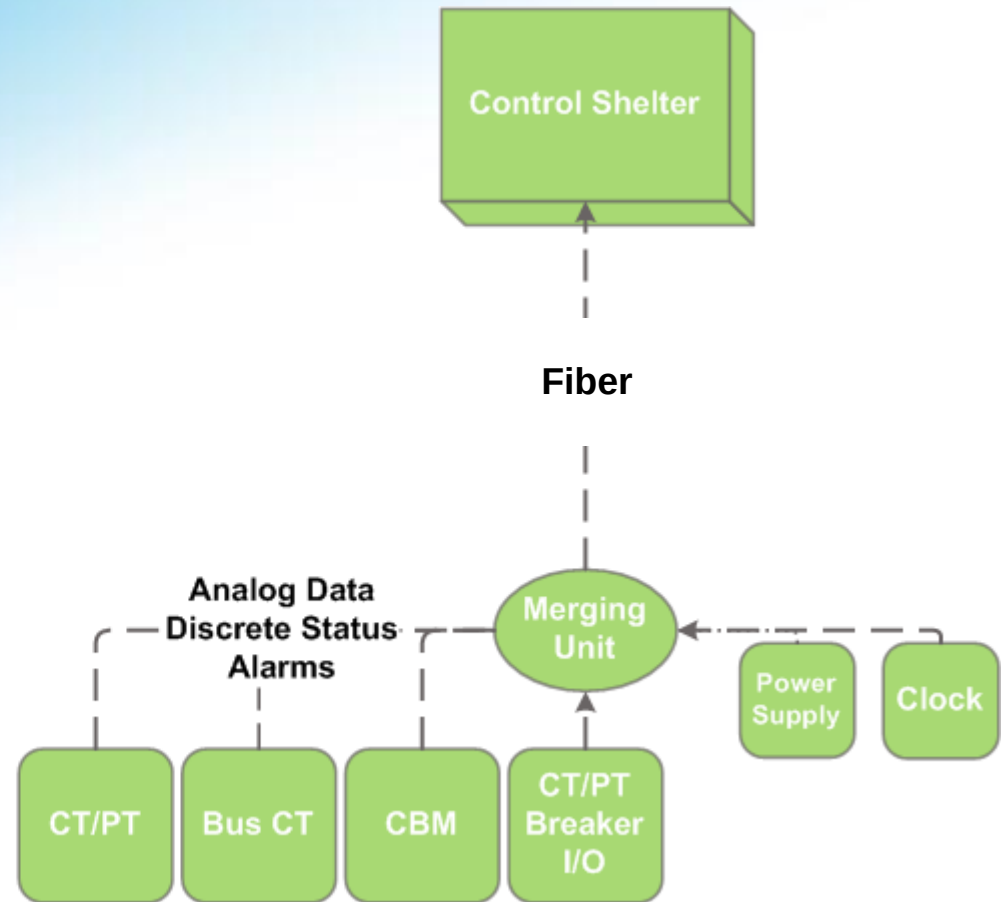


- ID: Identification

Comparison of Legacy and IEC 61850 System

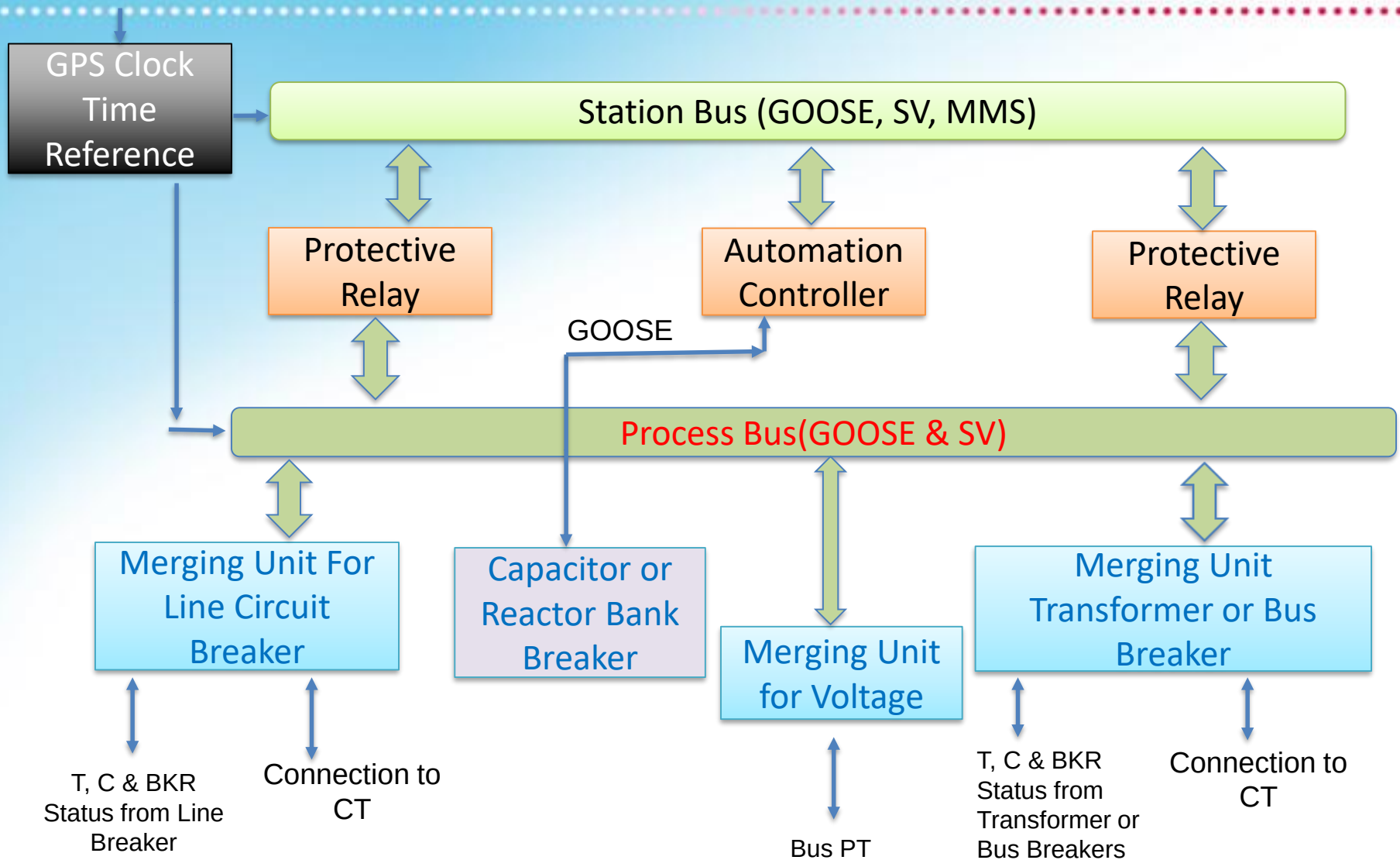


Legacy Analog System



IEC 61850 Compliant System

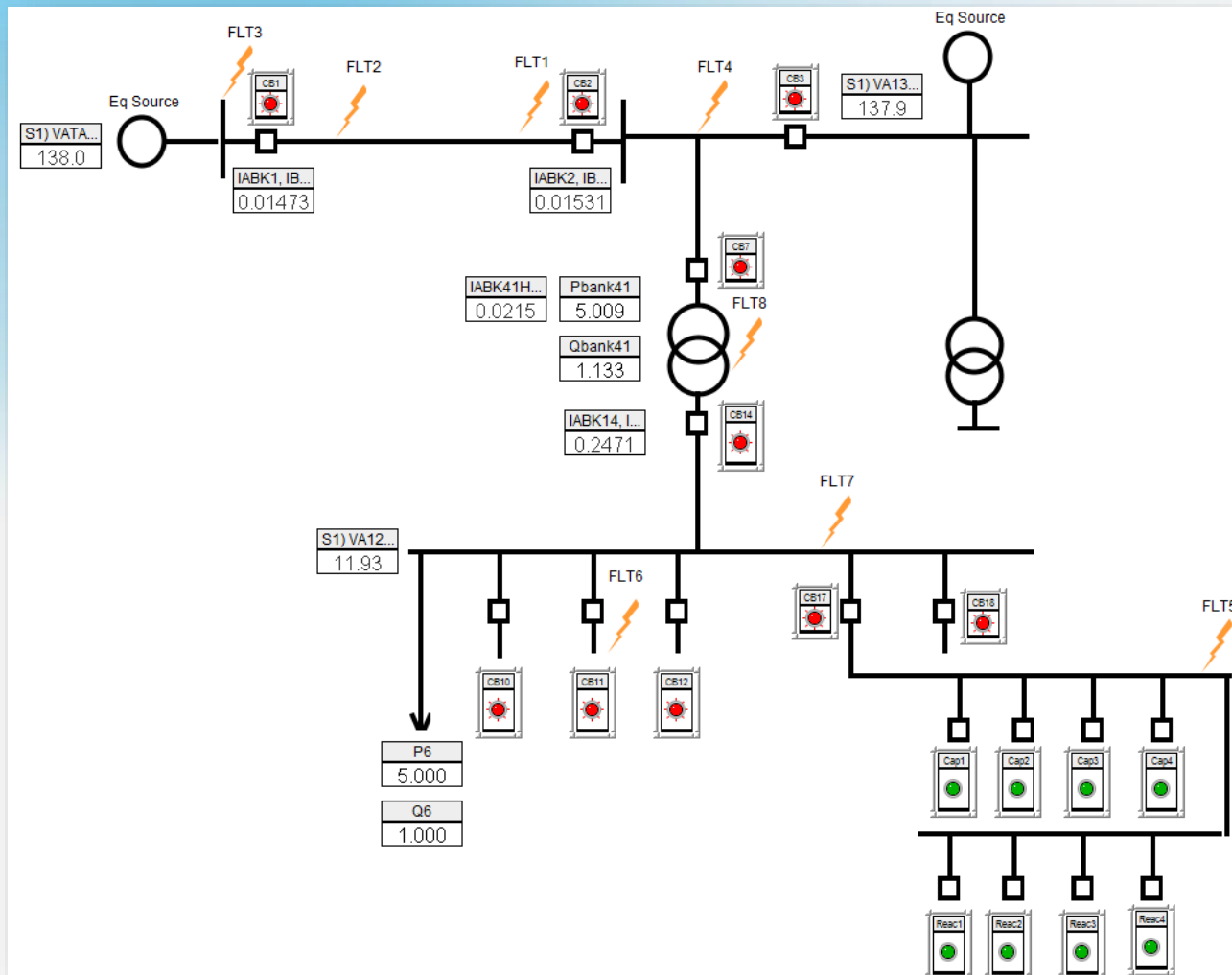
Simplified Conceptual Diagram for IEC-61850 Substation Project



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



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-
- The screenshot displays the IABK3 software interface, which is divided into several functional areas:
- Top Left:** A series of small utility icons including "POWER F...", "SOURCES", "Subsyste...", "cap Bypa...", and "LED I/O".
 - Top Center:** A "FAULTS" panel with a "FAULTS" title bar. It contains two circular gauges labeled "1" and "7", a "PLT" indicator with a red light, a "LOC" indicator with a value of "50.0", and an "RF" indicator with a value of "0.1". To the right are two vertical sliders for "Fault Duration" (set to "0.05" seconds) and "AngOfFault" (set to "0.0" degrees).
 - Top Right:** A "Subsystem #1" monitor window. It contains three vertically stacked plots:
 - Top plot: Labeled "VASNG", "VBSNG", and "VCSNG". The y-axis is "Volts" ranging from 0 to 1.0.
 - Middle plot: Labeled "IASNG", "IBSNG", and "ICSNG". The y-axis is "Amps" ranging from 0 to 1.0.
 - Bottom plot: Labeled "VACPJ", "VBCPJ", and "VCCPJ". The y-axis is "Volts" ranging from 0 to 1.0.
 - Bottom Left:** A "BREAKER CONTROLS" panel. It includes a grid of breaker status indicators (TRP3, RCL33, ESP3, TRP4, RCL4, etc.) with "Disable" and "Enable" buttons. Below this is a grid of breaker status indicators (CB3A, CB3B, CB3C, etc.) with "Disable" and "Enable" buttons. At the bottom are three vertical sliders for "CB3TR", "CB4TR", and "CB4C".

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
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- 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



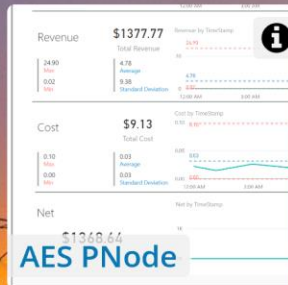
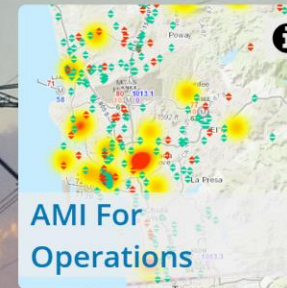
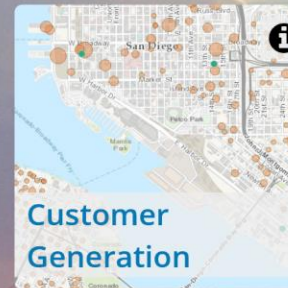
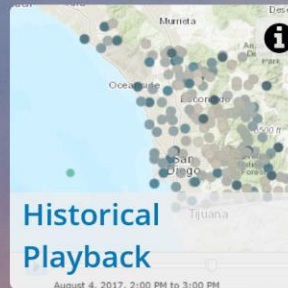
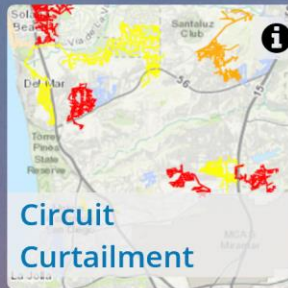
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SPARC

SDG&E Portal for Awareness and Real-time Collaboration

EPIC 1

EPIC 2



Use Case 1: Visualization of Electric Transmission Outages

➤ Objective

- Display electric transmission fault location details on a geospatial map

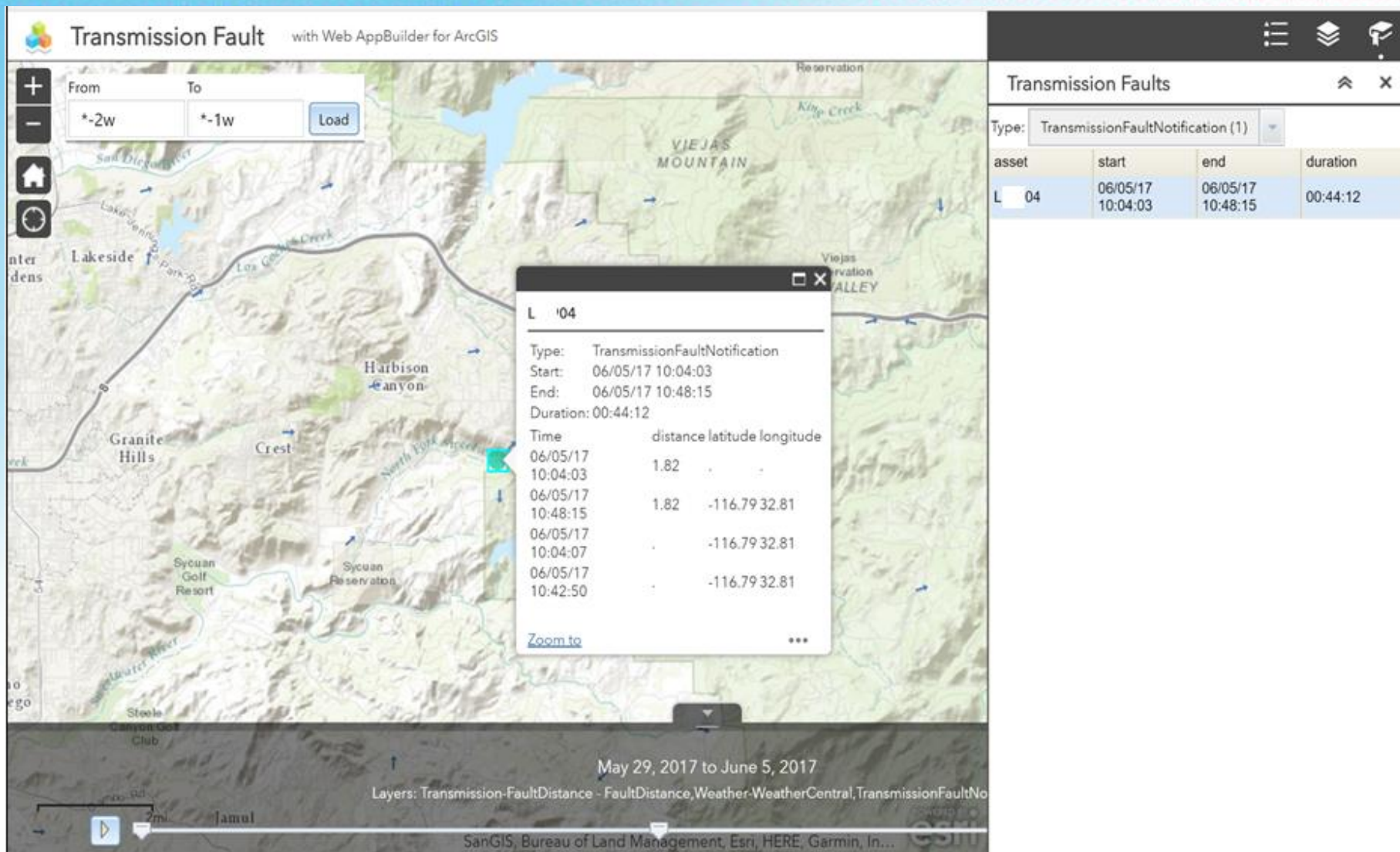
➤ Approach

- 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.

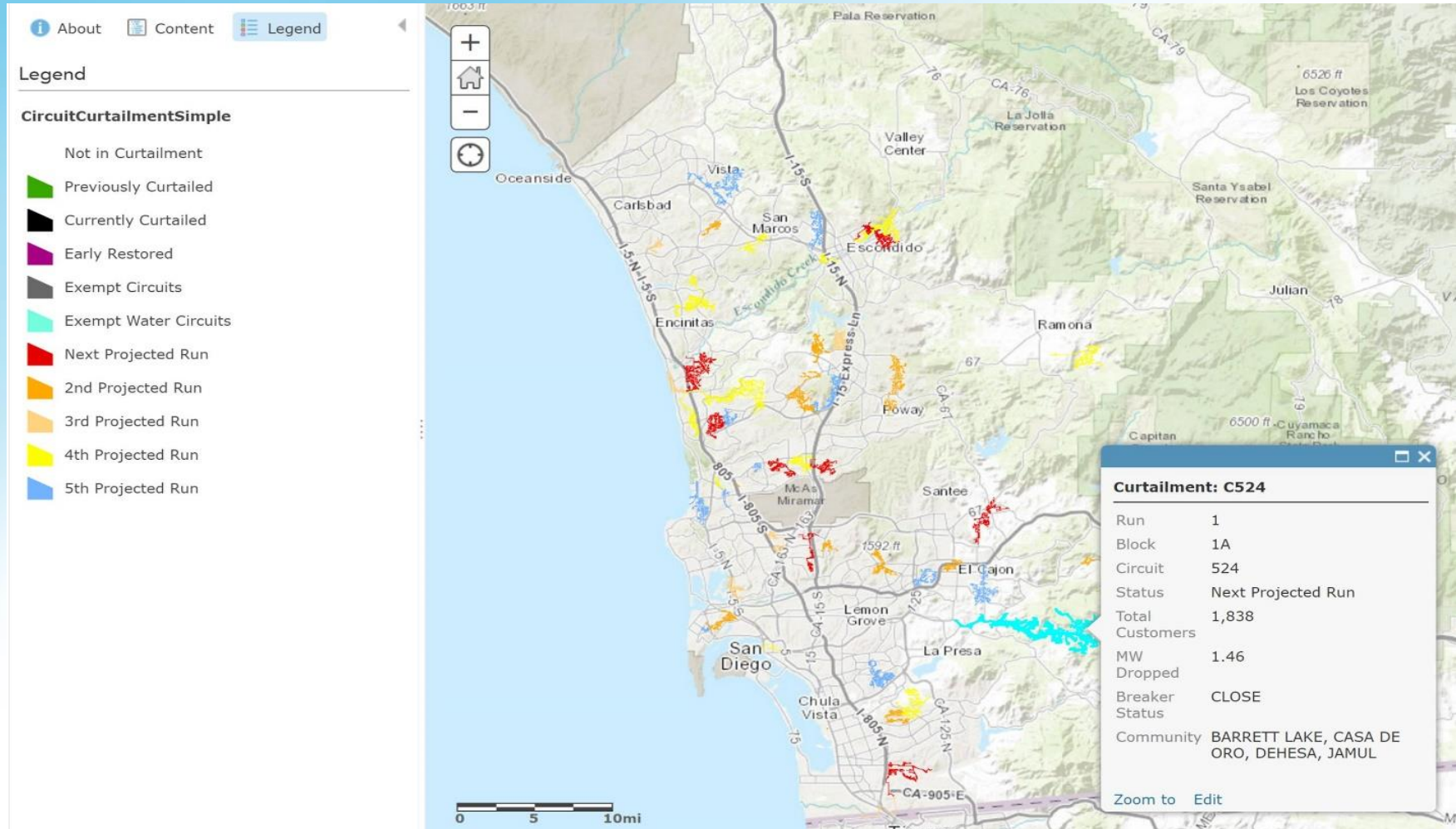
➤ Approach:

- 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.

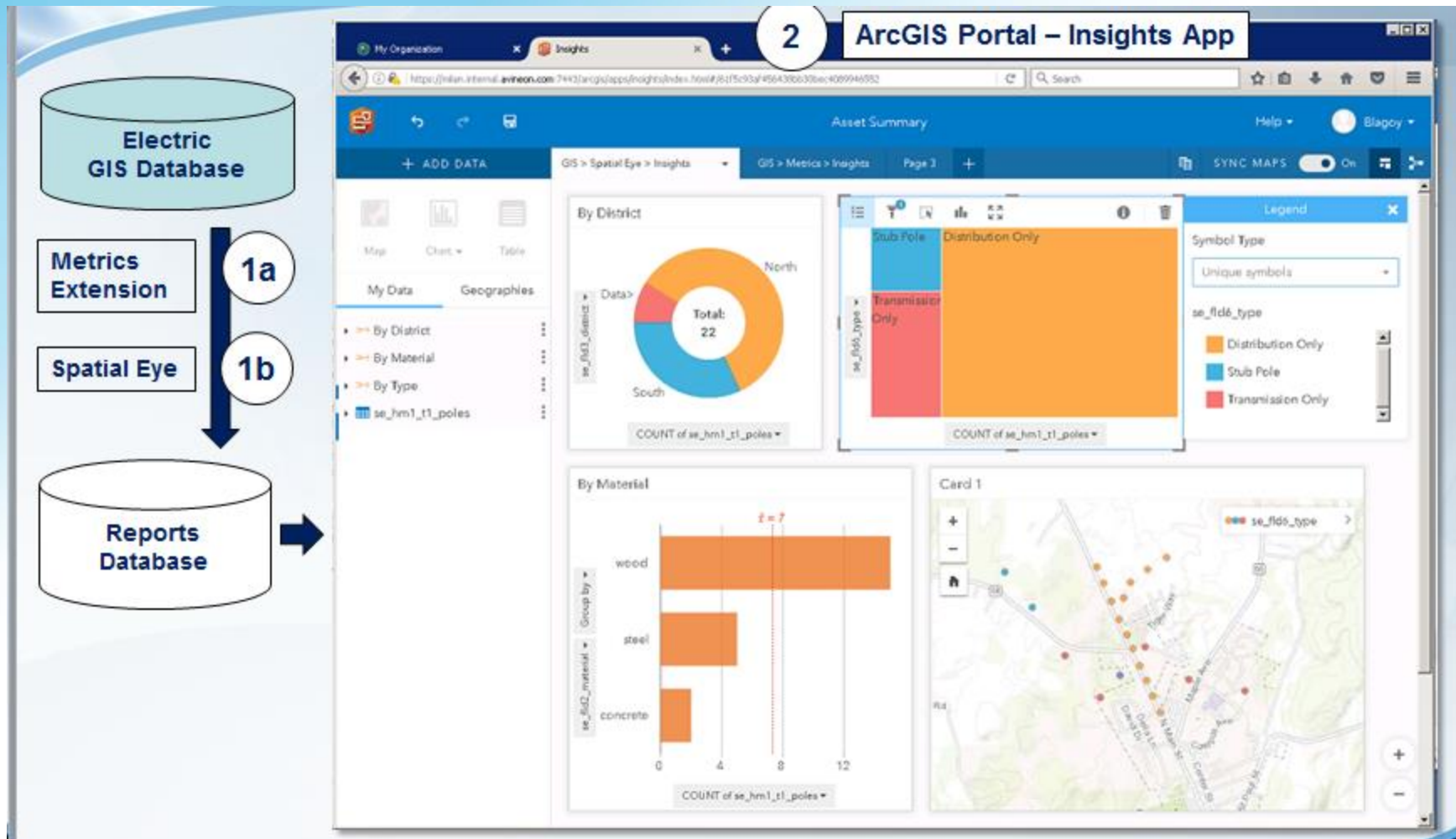
➤ Approach:

- 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

Outage Filter

Feeder ID/District Search....

Feeder ID

District

BC

Find

Time Selection....

Time Period:

7 Days

Date:

From Date:

2014-09-10

To Date:

2017-10-01

Additional Outage Parameters....

Crew Contact

☐ SDG&E Contr. Line fault/tree trimming

☐ SDG&E Crew Line fault/tree trimming

☐ SDG&E Crew error

☐ SDG&E Contr. Personnel contact

☐ SDG&E Crew Personnel contact

☐ SDG&E Crew Vehicle Contact

☐ SDG&E Contr. Heavy equip contact/dig in

☐ SDG&E Contr. Vehicle contact

☐ SDG&E Crew Heavy equip contact/dig in

☐ SDG&E Contr. Crew error

☐ SDG&E Contr. Line fault/hot wash

Foreign Object

☐ Flashover/vegetation

☐ Bird contact

☐ Damage by gunshot

☐ Foreign object in distribution line

☐ Animal contact

☐ Aircraft

☐ Vandalism

Maintenance

☐ Line-xfmr deenerg/maint/const/tap chg

Miscellaneous

☐ Tree Contact

☐ Undetermined

☐ Weather

☐ Equipment

Outages on Map: Loading...

SEARCHCLEAR

Occurrence_Date: 08/16/2015
Occurrence_Time: 21:09
Occurrence_DateTime: August 16, 2015 21:09
District Code: OC

5YearOutages

Esri World Geocoder

Outage Filter

Feeder ID/District Search....

Feeder ID:

District: BC

Find

Time Selection....

Time Period: 7 Days

Date:

From Date:

To Date:

Additional Outage Parameters....

☐ Crew Contact

☐ SDG&E Contr. Line fault/tree trimming

☐ SDG&E Crew Line fault/tree trimming

☐ SDG&E Crew error

☐ SDG&E Contr. Personnel contact

☐ SDG&E Crew Personnel contact

☐ SDG&E Crew Vehicle Contact

☐ SDG&E Contr. Heavy equip contact/dig in

☐ SDG&E Contr. Vehicle contact

☐ SDG&E Crew Heavy equip contact/dig in

☐ SDG&E Contr. Crew error

☐ SDG&E Contr. Line fault/hot wash

☐ Foreign Object

☐ Flashover/vegetation

☐ Bird contact

☐ Damage by gunshot

☐ Foreign object in distribution line

☐ Animal contact

☐ Aircraft

☐ Vandalism

☐ Maintenance

☐ Line-xfmr deenerg/maint/const/tap chg

☐ Miscellaneous

☐ Tree Contact

☐ Undetermined

☐ Weather

☐ Equipment

☐ Faulted cable

☐ Fuse holder/fuse cabinet failed

☐ Ammeter (lightning) failure

☐ Transformer overloaded/electrical

☐ Terminator overloaded/electrical

☐ Circuit Breaker/Recloser Failure (Sub)

☐ Polehead failure

☐ Guy wire failure

☐ Insulator contact/line span

Outages on Map: 1714

SEARCH CLEAR

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Use Case 5: AMI for Operations

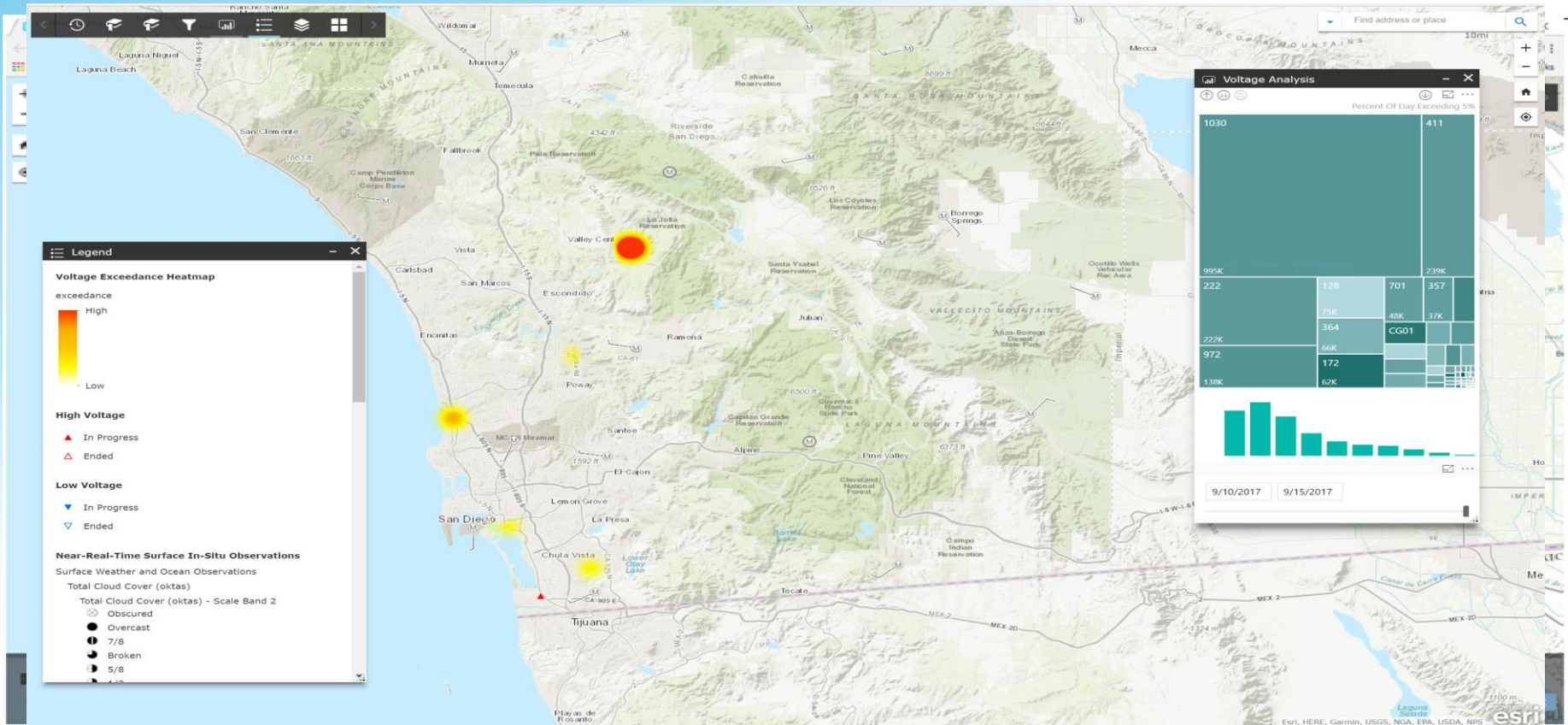
➤ Objective

- 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.

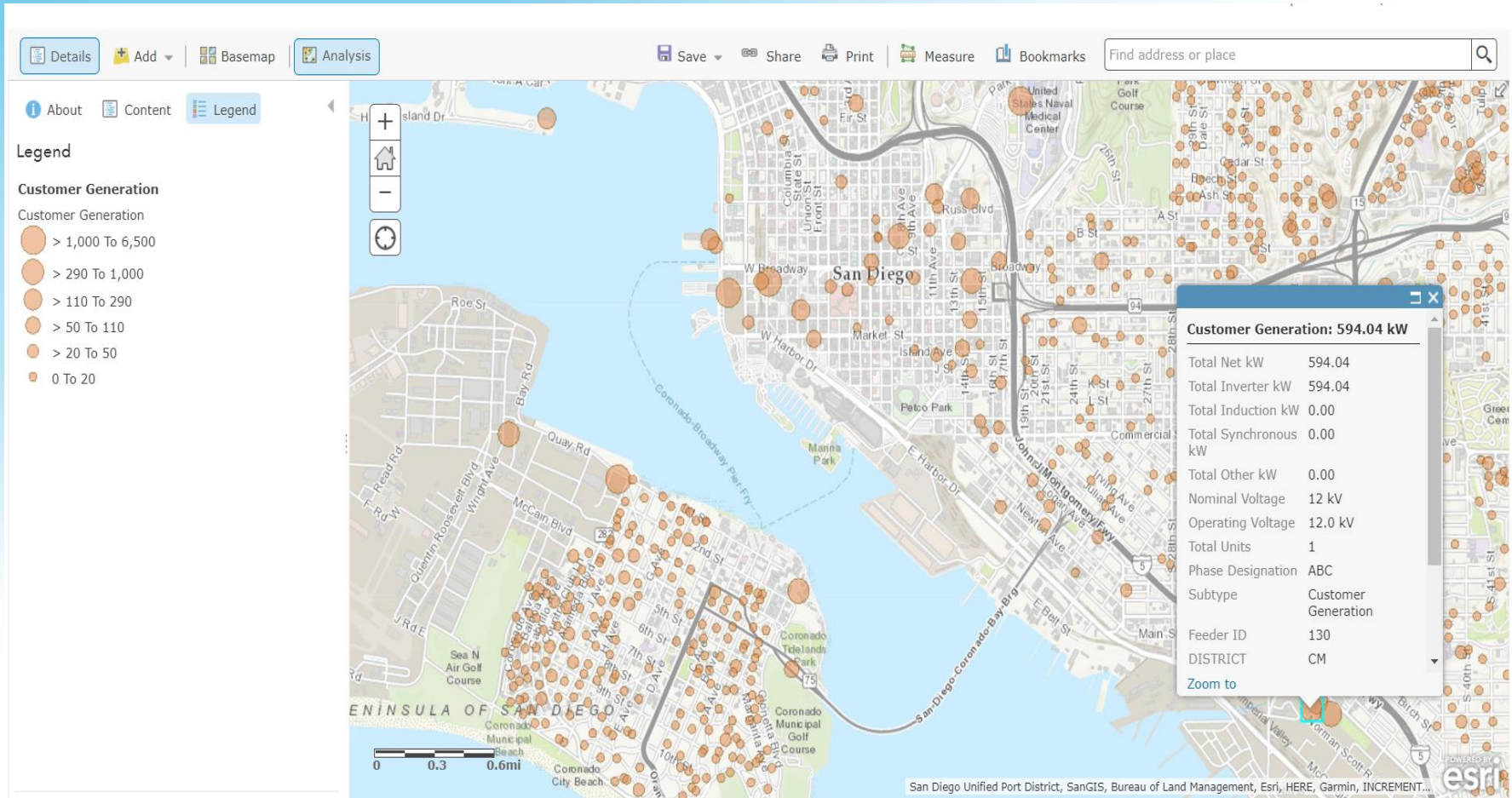
➤ Approach

- 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

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

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