



# Building a Resilient Distribution Grid: SDG&E Experience

**Real-Time Situational Awareness and Enhanced Control**

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# AGENDA



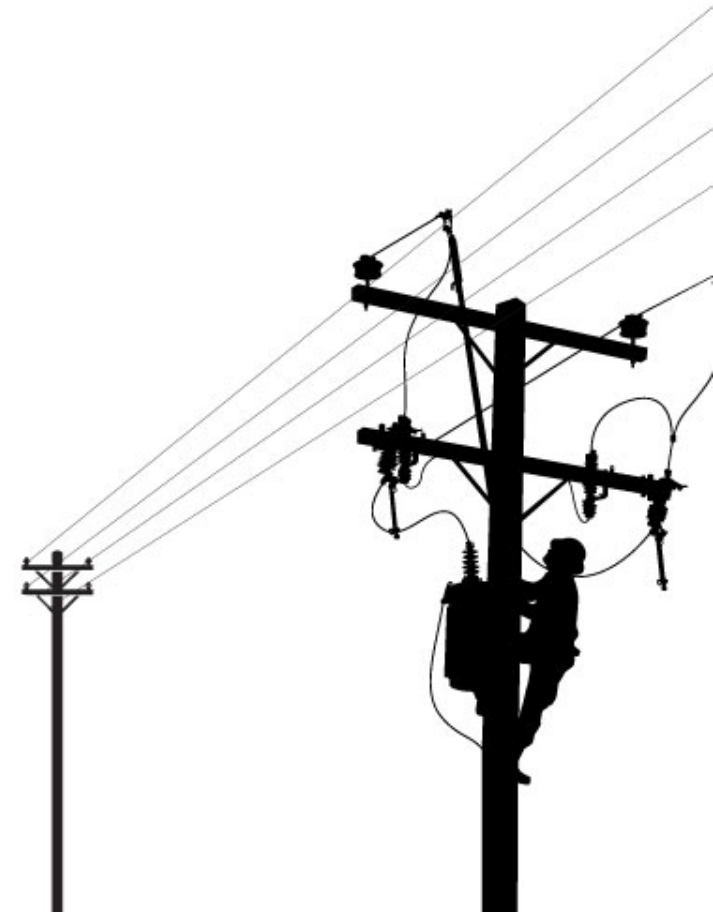
## 1. Electric Distribution Operations

1. ADMS
2. SCADA
3. Microgrid Management & Control

## 2. Innovations & Microgrids

- Borrego Springs Microgrid
- VRF Battery
- POI control via recloser relay
- Falling Conductor Protection (FCP)

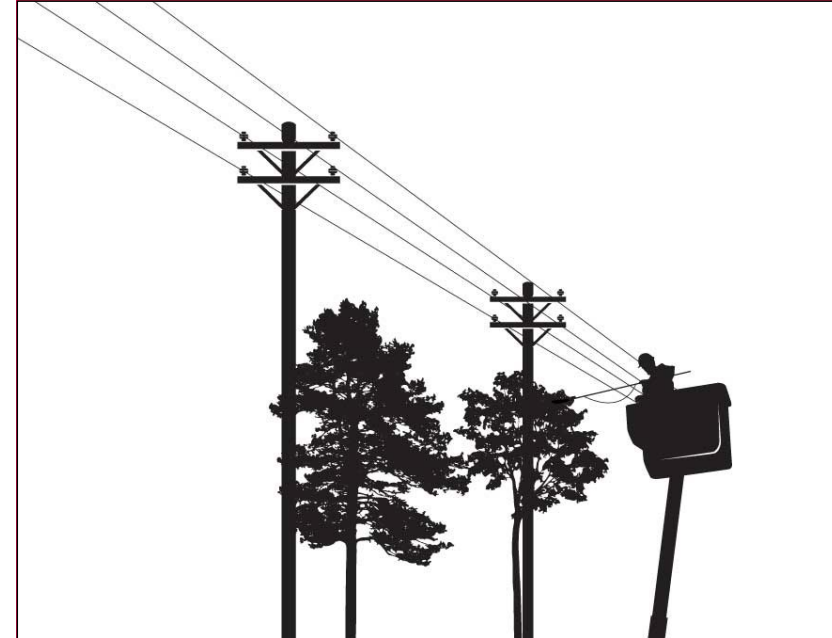
## 3. Challenges



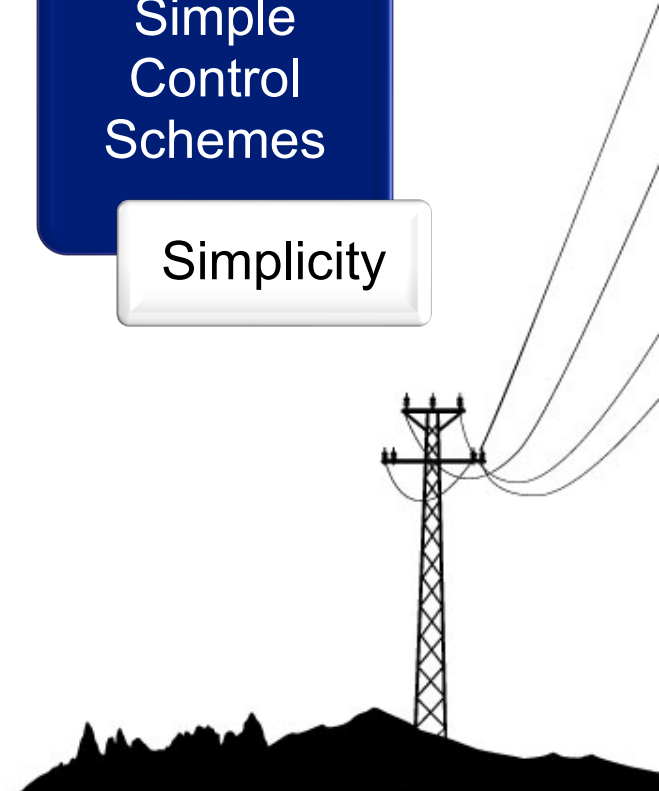
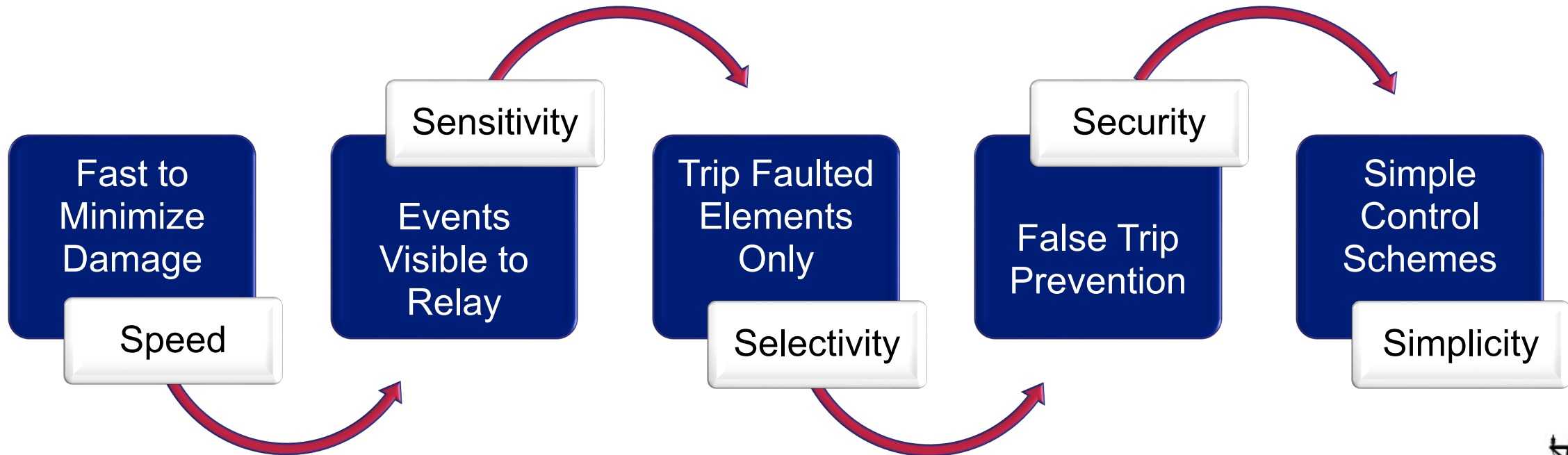
# SDG&E Overhead Distribution System



- Approximately 6,500+ miles of overhead distribution line infrastructure
- Grounded three- and four-wire systems
- Nominally 12kV and 4kV
- High penetration of distribution PV requires new solutions for monitoring, protection and control



# System Protection - A Balancing Act





# Advanced Protection Program



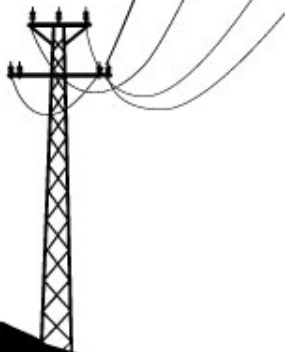
The Advanced Protection Program (APP) develops and implements advanced protection technologies within electric substations and on the electric distribution system to:

Prevent and mitigate the risks of fire incidents

Create higher visibility and situational awareness in fire-prone areas

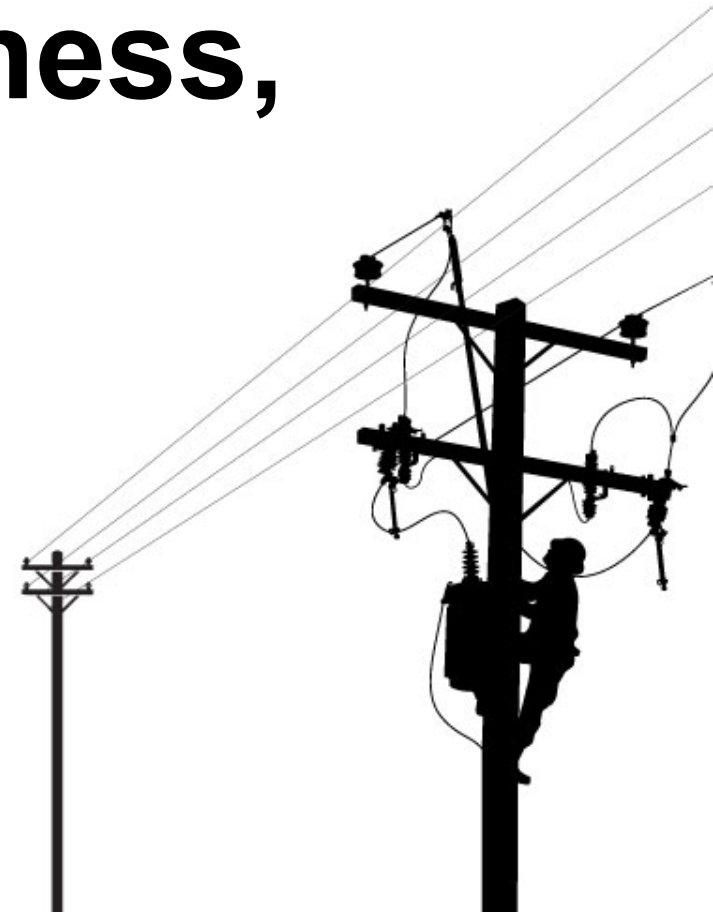
Address high impedance faults through advanced protection coordination techniques

The scope of work encompasses engineering, design and field support for APP initiatives such as Advanced SCADA Devices (ASD) and Falling Conductor Protection (FCP).



# Real-time situational awareness, monitoring and control

SDG&E Electric Distribution Operations



# Electric Distribution System Operations



**Primary Goal:** Safe and reliable service to our customers

Interpret data & utilize tools to maintain the:

- Safety of crews & public
- Reliability to customers
- System & infrastructure integrity

## Outages

- Average ~ six per day affecting ~ 3,700 customers/day

## Causes

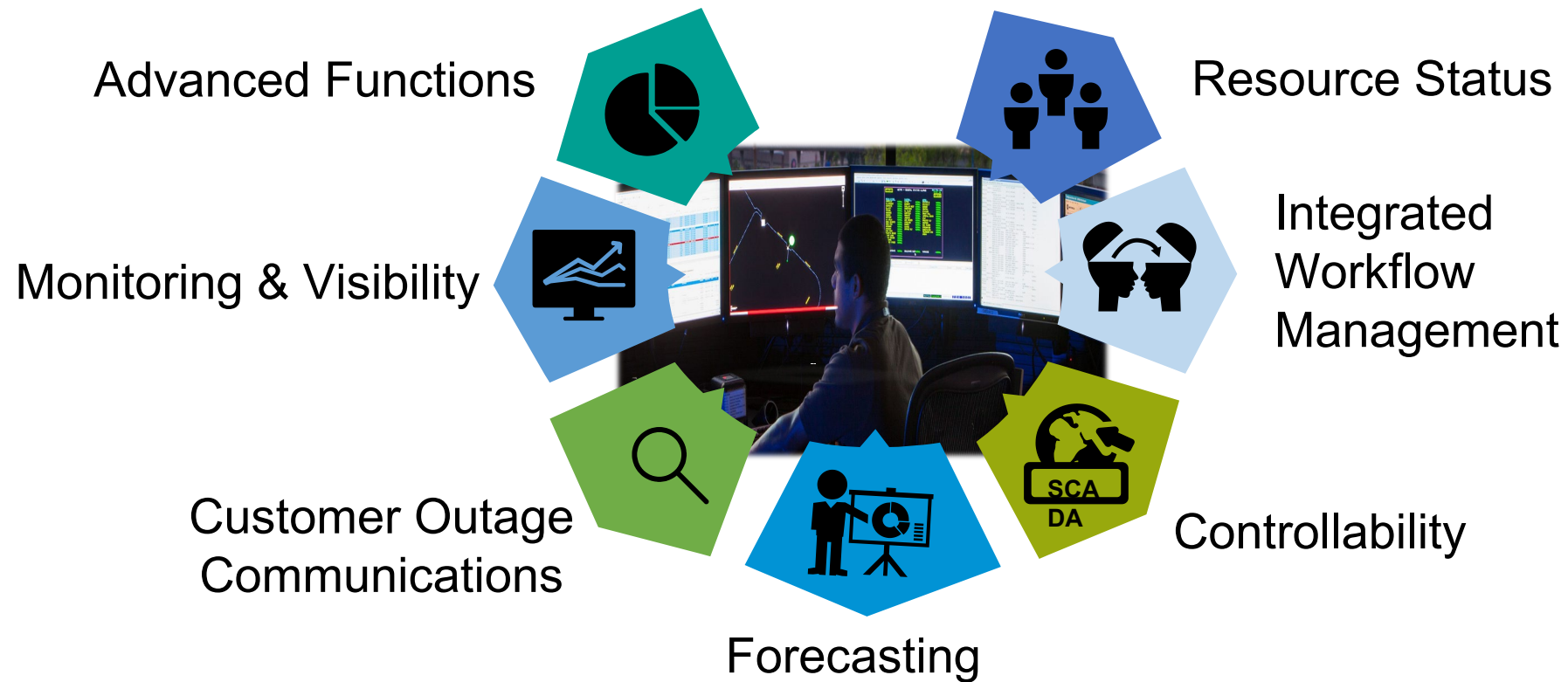
- Weather events
- Vehicle contacts
- Animal contacts
- Equipment failure



# Electric Distribution System Operations



## Advanced Distribution Management System





# Electric Distribution System Operations



## SCADA (Supervisory Control and Data Acquisition)

- 2,400+ Field SCADA Sites
- 100+ Distribution Substations
- 80%+ of Distribution Feeders are SCADA Controlled

Oracle Utilities Network Management System Web Workspace with Web Switching Management

NMS / OUA / OMA

Work Agenda: All

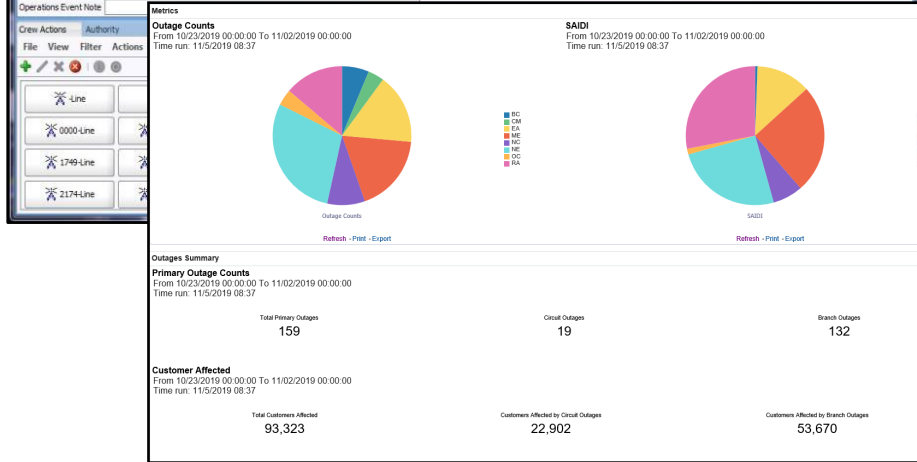
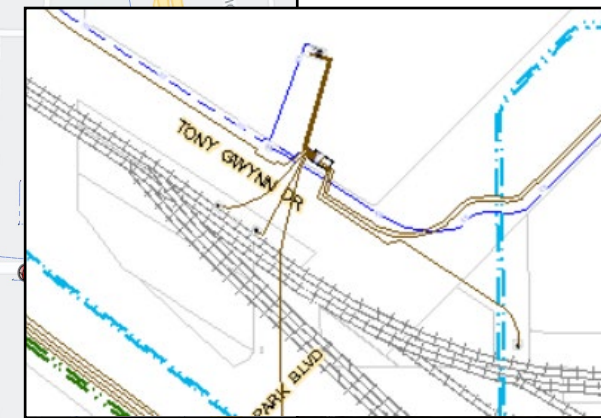
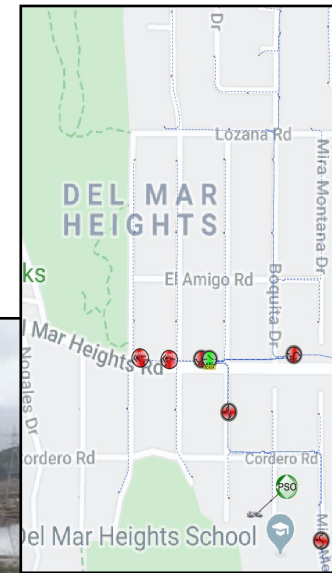
File Sort Filter Actions Help

Trouble DSO Switch Plans

Total Events In View: 4564 | Est Cust Out: 1602998 | Calls: 332874 | URG Cust Out: 93 | ESS Cust Out: 1616 | SA Cust Out: 40607 | Crews En Route/Onsite: 3

Sort: Default | Filter: All | Audio Enabled

Status	Event #	Rel Event #	Evt Type	Rel Type	FLISR Status	Plan #	District	Substation	Circuit	Device	Device Type	Operator	Crew	Start Date	Est R
RCVD	51509	0	PLAN			Plan 1...	CM	SWEETWATER	41	LBE-40631	Load Brea...	smery		04/00/13 23:36	04/2
UAS	51994	0	PLAN			Plan 1...	NC	SAN LUIS REY	900	LBE-368302	Load Brea...	judgena		04/23/13 09:10	04/2
UAS	27162	0	PLAN			Plan 7...	CM	STATION F	361	LBE-206969	Load Brea...	judgena		01/05/13 23:48	01/0
UAS	51863	0	PLAN			Plan 1...	NC	BARTOQUITOS	755	LBE-285079	Load Brea...	judgena		04/22/13 20:59	04/2
UAS	38821	0	PLAN			Plan 6...	NE	AVOCADO	522	<inline_jumper_1281>	Unknown	judgena		02/23/13 08:15	02/2
UAS	55817	0	PLAN			Plan 1...	CM	SWEETWATER	44	Cable Tab-34236	Cable End	judgena		03/08/13 09:14	03/0
CRG	9288	0	PLAN			Plan 3...	EA	CHOKLAS WEST	166	<inline_jumper_1110>	Unknown	smery		10/31/12 13:36	10/3
RCVD	202578	0	POO			Plan 3...	EA	IMPERIAL BEACH	723	723-79	PM Transf...	ETSO		01/26/15 07:00	01/2
DSP	39324	0	PLAN			Plan 1...	NE	LILAC	354	<inline_jumper_1405>	Unknown	judgena		02/25/13 08:17	02/2
NEW	127142	127117	PLAN	S		Plan 5...	EC	SOQUIPS	723	723-97	PM Transf...	judgena		10/09/14 10:56	12/2
UAS	202542	0	POO			Plan 5...	EC	JAMACHA	75	75-52	OH Transf...	alopneye		01/26/15 02:14	01/2
SUS	189188	189132	PLAN	S		Plan 5...	NE	RANCHO CARMEL	937	Tec. 167715	Tec Break...	agetto	JOHN MOKE	12/04/14 09:09	12/0
NEW	189187	189132	PLAN	S		Plan 5...	NE	RANCHO CARMEL	937	937-12AE	Scada IUS...			12/04/14 09:09	12/0
NEW	197180	187176	PLAN	S		Plan 5...	OC	EXCEL ONE	1415	SAS-12KX-1415	Breaker			11/25/14 13:27	12/2
RCVD	202580	0	PSO			Plan 5...	NE	MONSIEGATE	233	233-209	OH Transf...	ETSO		01/26/15 07:07	01/2
RCVD	202583	0	PSO			Plan 5...	CM	SUNNYSIDE	341	341-1103	PM Transf...	ETSO		01/26/15 07:19	01/2
RCVD	202588	0	PSO			Plan 5...	NE	ASH	450	450-390	OH Transf...	ETSO		01/26/15 07:39	01/2
RCVD	202587	0	PSO			Plan 5...	NE	AVOCADO	522	522-448	PM Transf...	ETSO		01/26/15 07:30	01/2
DSP	202579	0	PSO			Plan 5...	EC	LA JOLLA	571	571-126	OH Transf...	4305-ETS		01/26/15 06:10	01/2
DSP	202574	0	PSO			Plan 5...	EA	SPRING VALLEY	753	753-291	OH Transf...	144-ETS		01/26/15 06:28	01/2



W100226

#1 D1 3 C178/936 TRAYER-5

STATUS: ON REPL 175 170 164

SCADA Control Panel with various indicators and status messages.

Priority: ALL

1: 75770 [0, 28] | AMode: Real Time | DMode: Display Mode 0 | 08/18/2006 15:01:38



# Electric Distribution System Operations



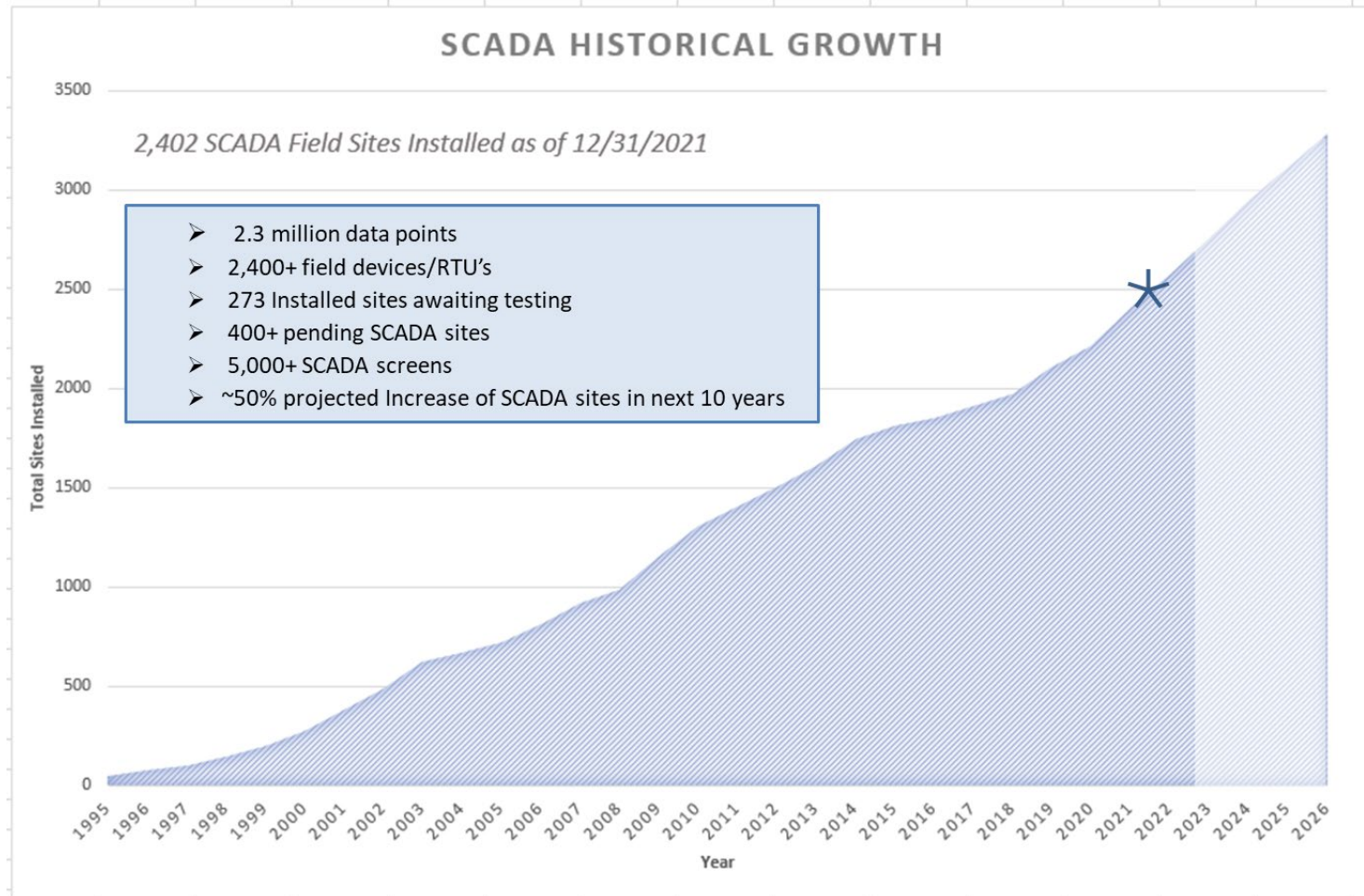
## Distribution SCADA Headend Replacement

Old ACS System	New OSII System
<ul style="list-style-type: none"><li>➤ 25 years old</li><li>➤ &gt; 2.3 million data points</li><li>➤ &gt; 5,000 screens</li><li>➤ 98% serial, 2% IP based communications</li><li>➤ No test environment</li><li>➤ No round-robin polling in IP based RTUs</li></ul>	<ul style="list-style-type: none"><li>➤ 10% ↓ of data points by not populating spare holding points</li><li>➤ Tabular screens replaced some of the existing 5,000+ screens</li><li>➤ New test environment<ul style="list-style-type: none"><li>▪ Communication testing</li><li>▪ Development of new custom scripts and displays</li><li>▪ Capability to bulk import/export data through OSI Excel Add-In</li></ul></li><li>➤ New hardware and latest software technology</li><li>➤ Supports migration to IP-based communication</li><li>➤ Utilizes 4RF to the fullest potential using IP</li><li>➤ Migration away from SCOM Protocol</li></ul>

# Electric Distribution System Operations



## Distribution SCADA Headend Replacement



# Electric Distribution System Operations



## Distribution SCADA Headend Replacement



20 FEP Devices



37 Servers



72 Workstations



Removed 190 – 24” monitors



Installed 130 – 34” monitors

- Distributed (multi-site) SCADA System:
  - Active system at the primary site, when degraded, utilizes some of the server/application resources simultaneously at the secondary site

System Monitor [Default] - Tabular Viewer \*

No.	Mode	Node	Status	Last Update	% CPU Used	% Phy
1	SNMP	mmon-01	Online	08/20/21 08:22:17	1	15
2	SNMP	mmon-02	Online	08/20/21 08:22:17	8	21
3	SNMP	bmon-01	Online	08/20/21 08:22:17	1	5
4	SNMP	bmon-02	Online	08/20/21 08:22:17	1	7
5	SNMP	mchs-01	Online	08/20/21 08:22:17	5	57
6	SNMP	mchs-02	Online	08/20/21 08:22:17	2	55
7	SNMP	bchs-01	Online	08/20/21 08:22:17	1	57
8	SNMP	bchs-02	Online	08/20/21 08:22:17	2	57
9	SNMP	mspie-01	Online	08/20/21 08:22:17	2	63
10	SNMP	mspie-02	Online	08/20/21 08:22:17	4	64
11	SNMP	bspie-01	Online	08/20/21 08:22:17	1	51
12	SNMP	bspie-02	Online	08/20/21 08:22:17	1	50
13	SNMP	mead-01	Online	08/20/21 08:22:17	0	19
14	SNMP	mead-02	Online	08/20/21 08:22:17	1	18
15	SNMP	bead-01	Online	08/20/21 08:22:17	0	13
16	SNMP	bead-02	Online	08/20/21 08:22:17	0	22
17	SNMP	mnow-01	Online	08/20/21 08:22:17	0	52
18	SNMP	bnow-01	Online	08/20/21 08:22:17	0	42
19	PING	mvoy-01	Online	08/20/21 08:22:17	0	0
20	PING	bvoy-01	Online	08/20/21 08:22:17	0	0

RTU5846 C211 RECLOSER SDR  
5846 SDR SEL651  
COMM IN 100 80 80 0 0

P227420

WARNERS SUB CIR 211 OFF REPL 14 10 18

FAULTS TARGETS

SUPY AC PWR OK DOOR CLOSED BATT OK BATTERY CURRENT: 0.00

INITIATE BAT TEST

RECLOSER MISMATCH LOCKED OUT TRIP CIR DISCONNECTED POSITION MANUAL LEVER VAC BOTTLE MALFUNCTION

NORMAL NO NO CLOSE READY NORMAL

HOT LINE TAG OFF by SCADA

RECYCLING OFF REPL BLOCK ENABLE

SGF > MIN TRIP AMPS > MIN TRIP REVERSE POWER FLOW

NO NO NO

NORMAL PROFILE INRUSH RESTRAINT SEN RELAY PROFILE SWITCH MODE

OFF by SCADA

ENABLE DISABLE DISABLE DISABLE

PH MIN TRIP 120 GRD MIN TRIP 100 CLPU PH MIN TRIP 120 SGF MIN TRIP 15

VOLTAGE AMPS

A PHASE 6.87 11 B PHASE 6.99 2 C PHASE 6.94 11 GROUND 1

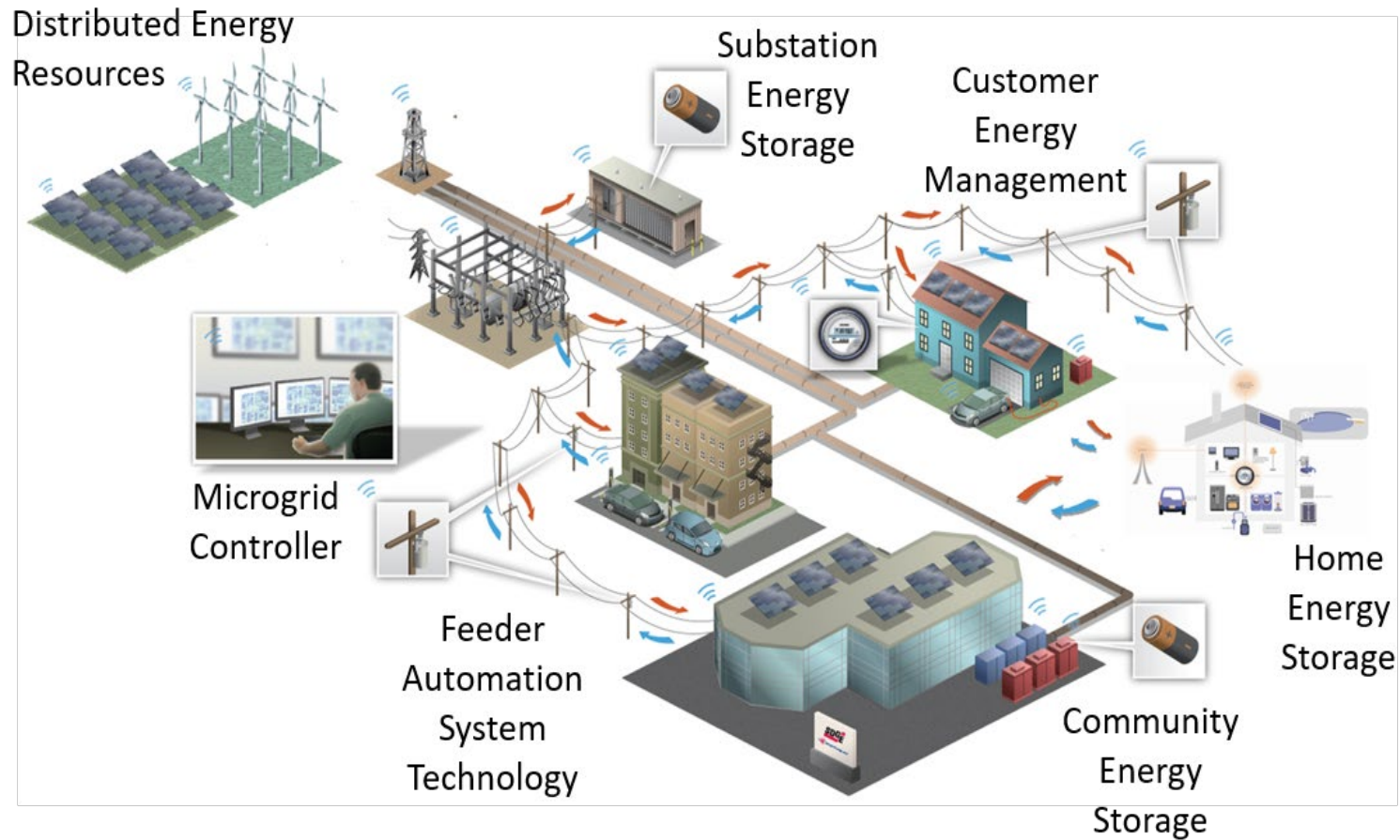
FCP Protection FCP Test Mode FCP Trip Status

# Electric Distribution System Operations



## Microgrid Management and Control

- Local Area Distribution Controller LADC



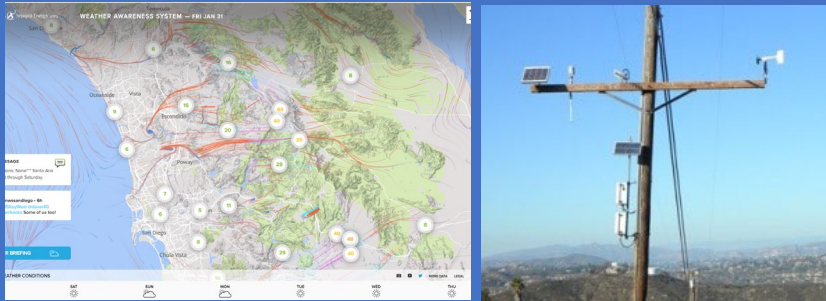


# Electric Distribution System Operations

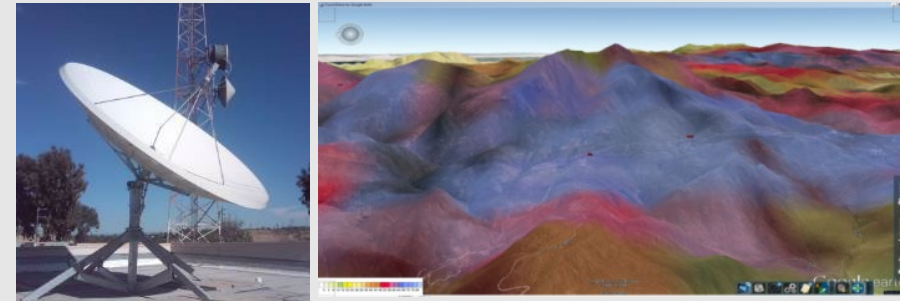


## Enhanced Capabilities & Innovative Tools

SDG&E Weather Station Network: largest utility network in the world, delivering unsurpassed real-time decision support



State-of-the-Art Forecasting System: Superior understanding of weather conditions and vegetation moisture



Mountain-top and tower camera networks allow for real time monitoring of hazardous conditions



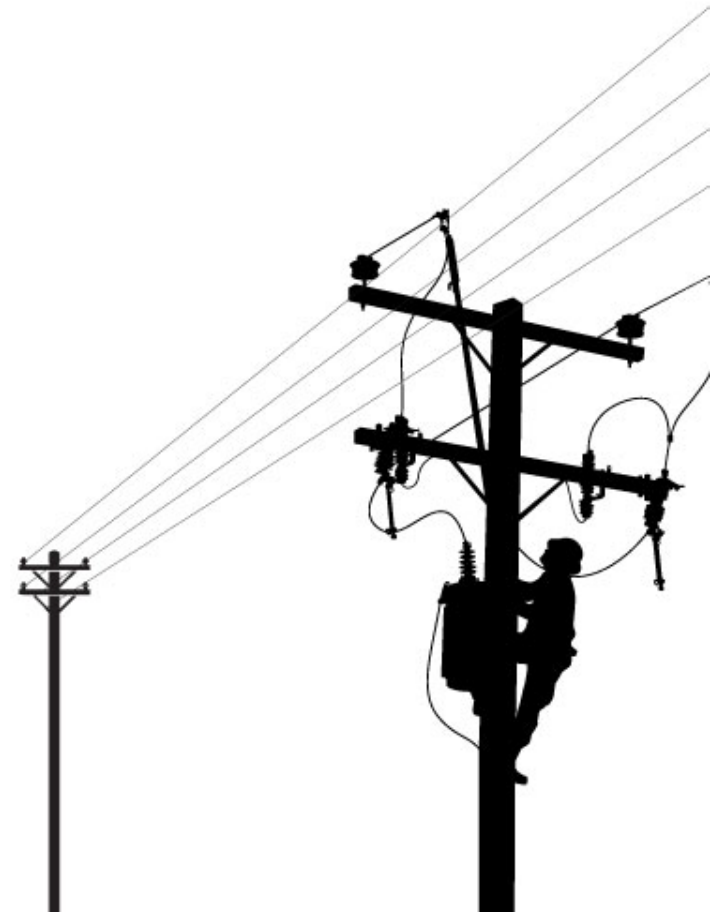
Collaborations with key stakeholders in the local first responder and research communities...





# Innovations & Microgrids

Borrego Springs, Vanadium Redox Flow Batteries  
and Falling Conductor Protection



# Innovations & Microgrids



## Borrego Springs Microgrid

- First utility-owned, community microgrid in America.
- Supports 2,800 people in Borrego Springs,
  - Remote desert town subject to extreme heat and monsoonal weather.
- Microgrids are a miniature power grid
  - May include solar and energy storage
  - Controls and switches to allow it to operate independent of or in parallel to the external electric grid.
- VIDEO: [https://youtu.be/T\\_FGUpFmQ-4](https://youtu.be/T_FGUpFmQ-4)



# Innovations & Microgrids



## Borrego Springs Microgrid

- Upgrading the technology to run on 100% clean energy (\$4.5M US DoE SETO grant 2020).
- SDG&E operates four microgrids, including the Borrego Springs location, within San Diego and southern Orange counties.
- In 2023, SDG&E plans to demonstrate the ability to “black start” the microgrid using only renewable sources.
- If successful, its two diesel generators would only be used for long-term outages or if the batteries fail.



***“Microgrids are one of the tools to enhance community resiliency and maintain energy service during emergencies”***

*(Will Speer, Vice President of Electric Engineering and Construction at SDG&E)*

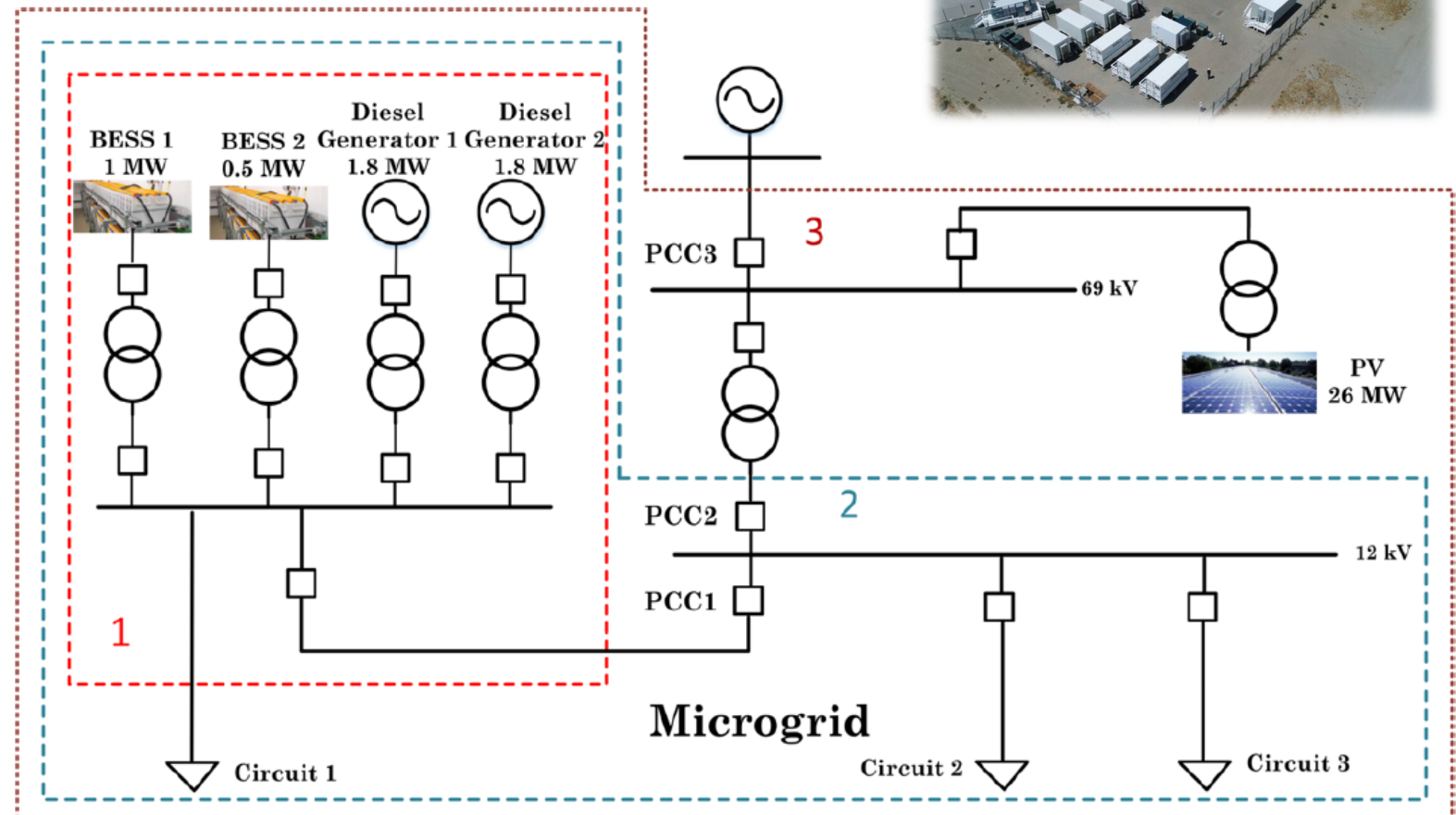


# Innovations & Microgrids



## Borrego Springs Microgrid

- 1 MW/3 MWh Battery Storage System
- 1.8 MW Diesel Generators – 2 units
- 25 kW/50 kWh Li-ion Community Energy Storage Units – 3 units
- 500 kW/1500 kWh Li-ion Substation Energy Storage Unit – 1 unit



# Innovations & Microgrids



## Borrego Springs Microgrid





# Innovations & Microgrids

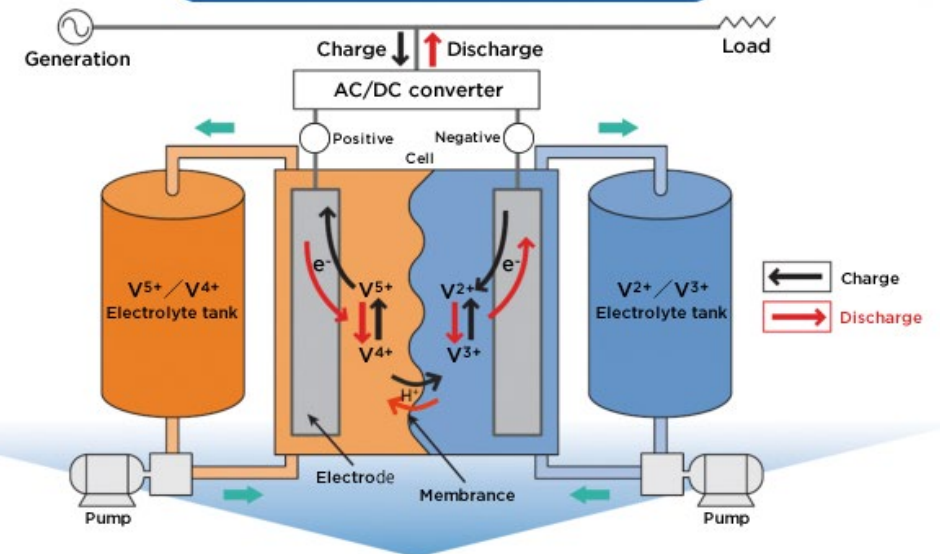


## Vanadium Redox Flow Battery (VRF)

- SDG&E and Sumitomo Electric (SEI) completed a zero-emissions microgrid pilot project using a vanadium redox flow (VRF) battery.
- The five-year project is located in south San Diego County.
- The 2MW battery at the heart of the project can store 8MW hours of energy.
  - Potentially enough to power ~1,000 homes for up to four hours.



Principle of the redox flow battery



# Innovations & Microgrids



## Vanadium Redox Flow Battery (VRF)

- During the pilot, the batteries charged when solar energy was abundant and discharged during peak hours to meet demand.
- Two successful tests demonstrated:
  - Customers did not experience any loss of power when they were transitioned to the microgrid for electric service and
  - Customers experienced a momentary outage before they were transitioned to the microgrid during a **Black Start**.
    - The microgrid provided energy service as expected, even on a cloudy day when solar power output was not optimal.



# Innovations & Microgrids



## Recent Innovation in Control of BESS

- Energy Storage Point of Common Coupling control utilizing a distribution line recloser
  - Applied near the Vanadium Redox Flow Battery site
  - Utilizing an SEL-651R recloser between the 12kV grid and the battery storage unit
  - Could enhance integration of battery storage into existing overhead distribution circuits through common protection settings instead of special applications.
  - All automation and protection logic will reside in the protective relay at the recloser
  - The settings will give the ability to:
    - Island (Auto or Manual)
    - Black start
    - Parallel operation and Resynching to the 12kV grid



# Advanced SCADA Project Applications



## Falling conductor protection (FCP)

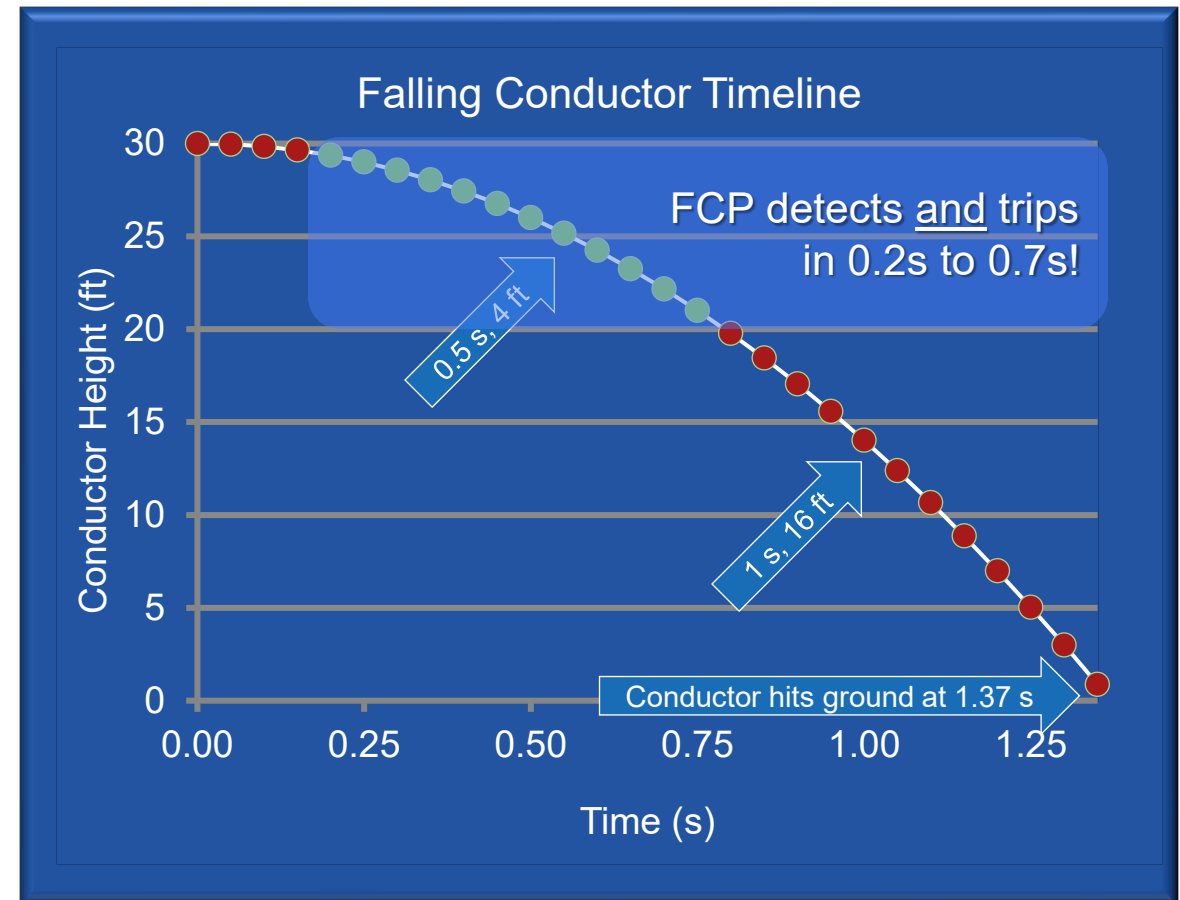
- **Patented & highest priority case for wildfire mitigation**
- Increased accuracy of voltage and current
- Phase angle measurements across circuit
- GPS time-stamped data
- 30 synchrophasor samples per second for fast measurement
- Industry standard control messages for real-time control
- Remote engineering access and event reports (faster real-time response) to events)
- Advanced cyber security features
- More than 60 use cases were defined



# Falling Conductor Protection (FCP) Technology

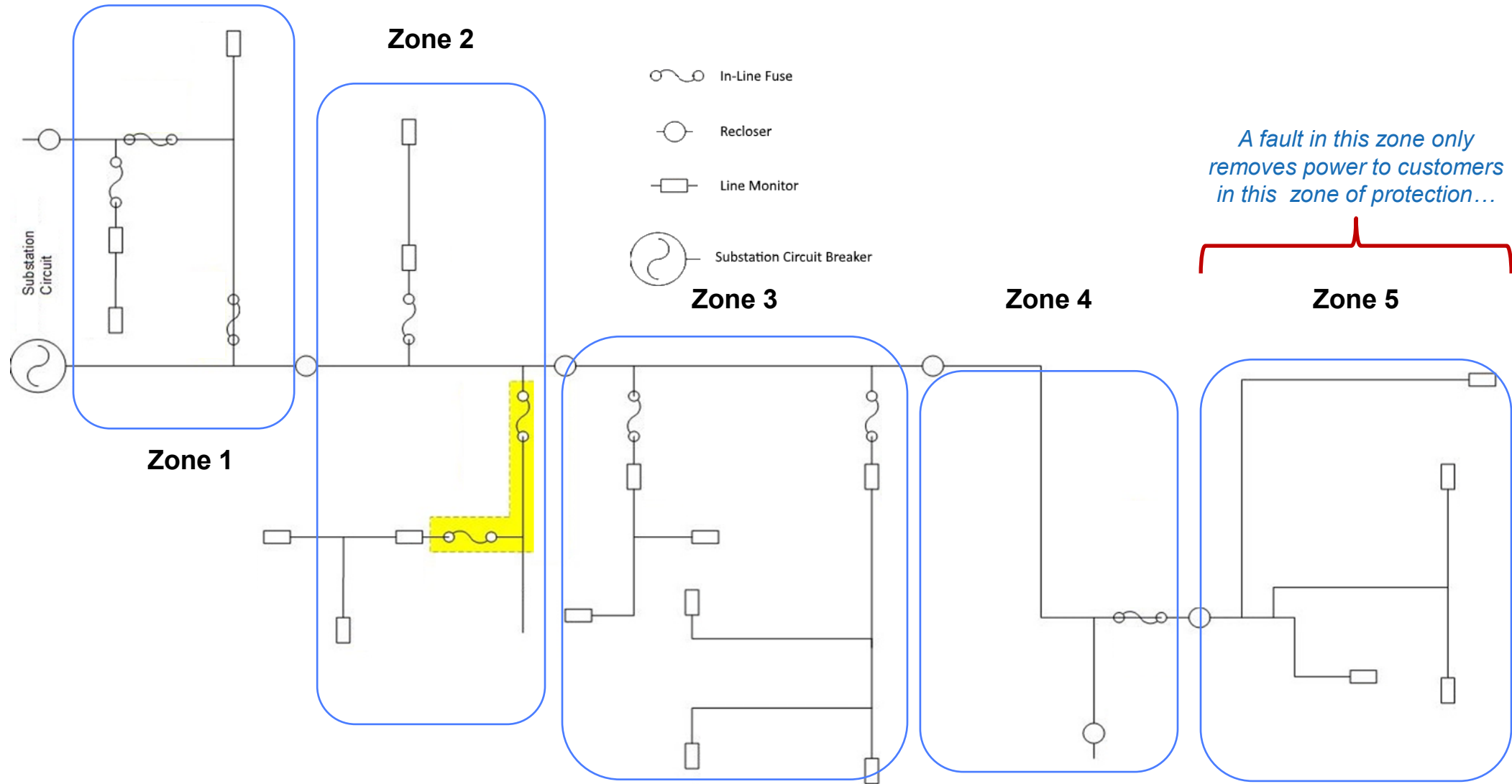


- Failed conductor takes 1.37s to reach ground from 30 feet
- FCP detects and isolates faults  $\leq 0.7$ s
- Isolated 100% of events during lab testing

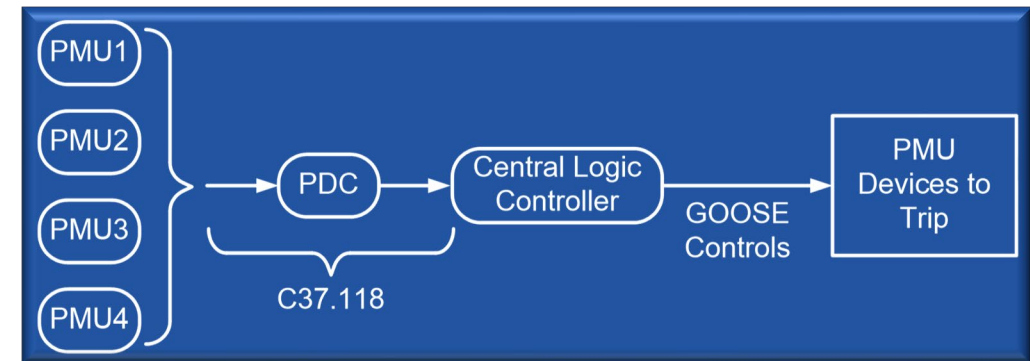
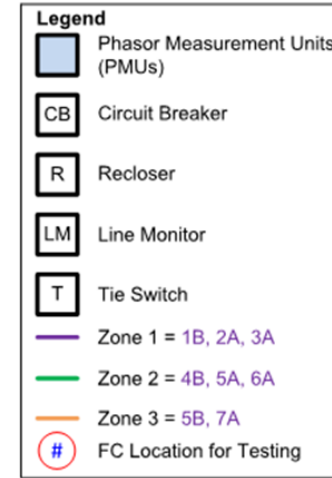
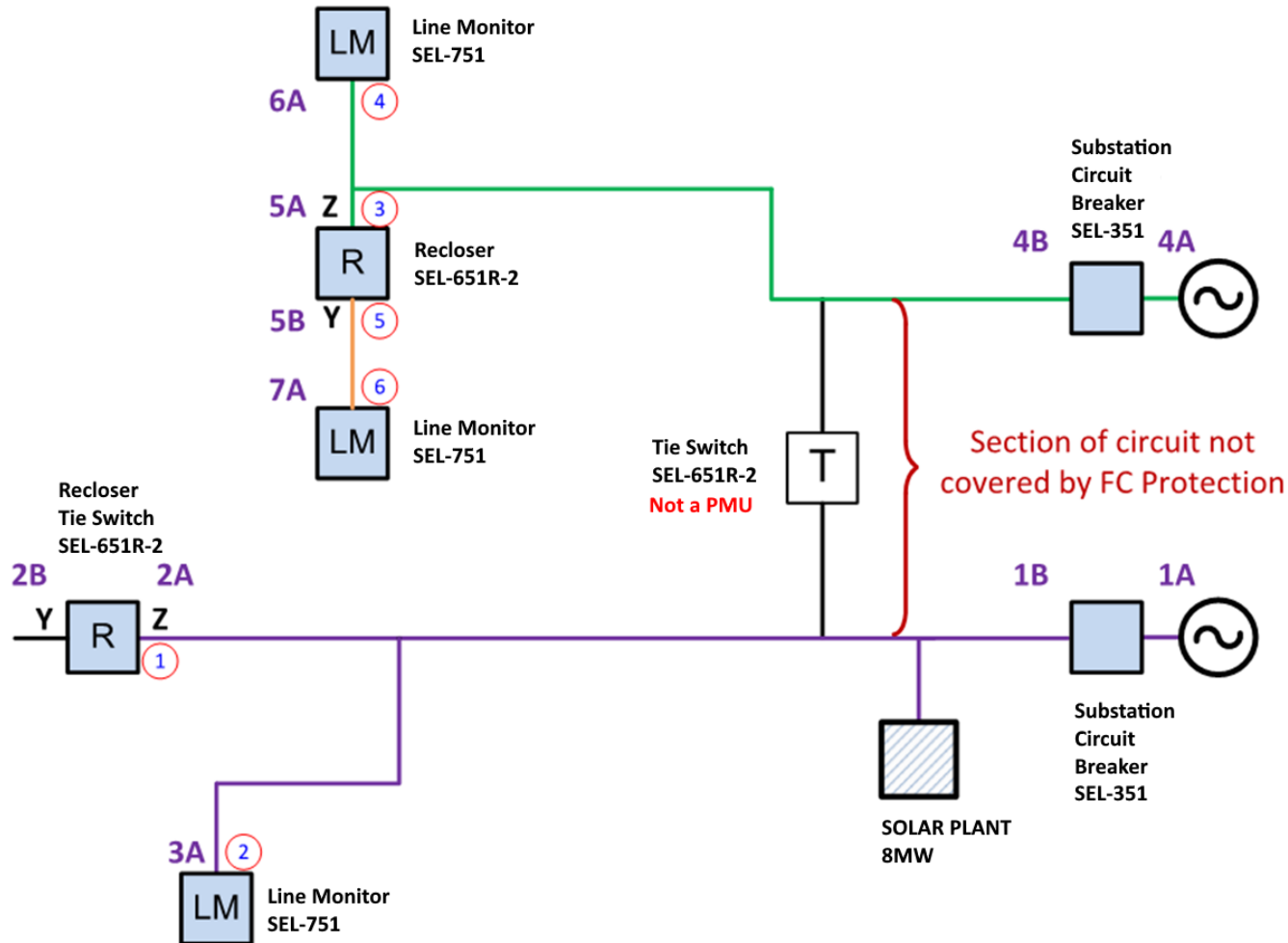




# Falling Conductor Zones of Protection



# FCP Single Line Diagram



# Distribution FCP – Line Side Upgrades



**Circuit Breaker  
Controls, Enable Light & Switch**



**Distribution Recloser**



**Line Monitor Sensor**

# Distribution FCP – Substation Upgrades



## Before FCP Upgrade



**Oil Circuit Breakers**



**Analog Relay Equipment**



**Aging Remote Terminal Units**

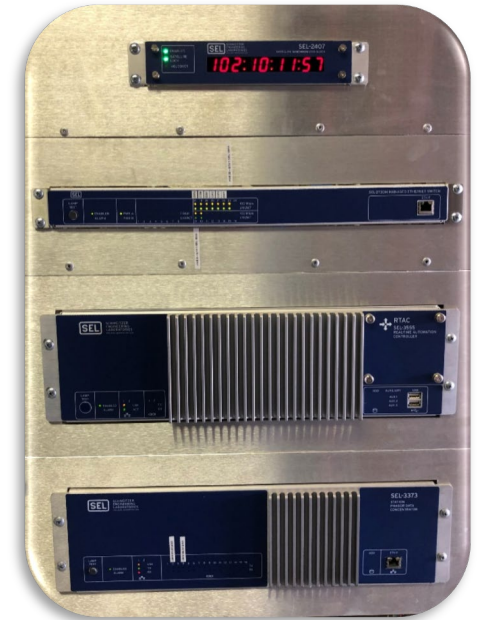


**Vacuum Circuit Breakers**

## After FCP Upgrade



**Digital Relay Equipment**



**Advanced Protection Controls**



# FCP Substation Equipment



GPS Clock



Network Switch



Phasor Data Concentrator



Real-Time Automation Controller



# FCP Circuit Breaker Controls



**FCP Enable/Disable Switch**



**FCP Enabled Indication Light**



**Primary & Backup Protection Controls**





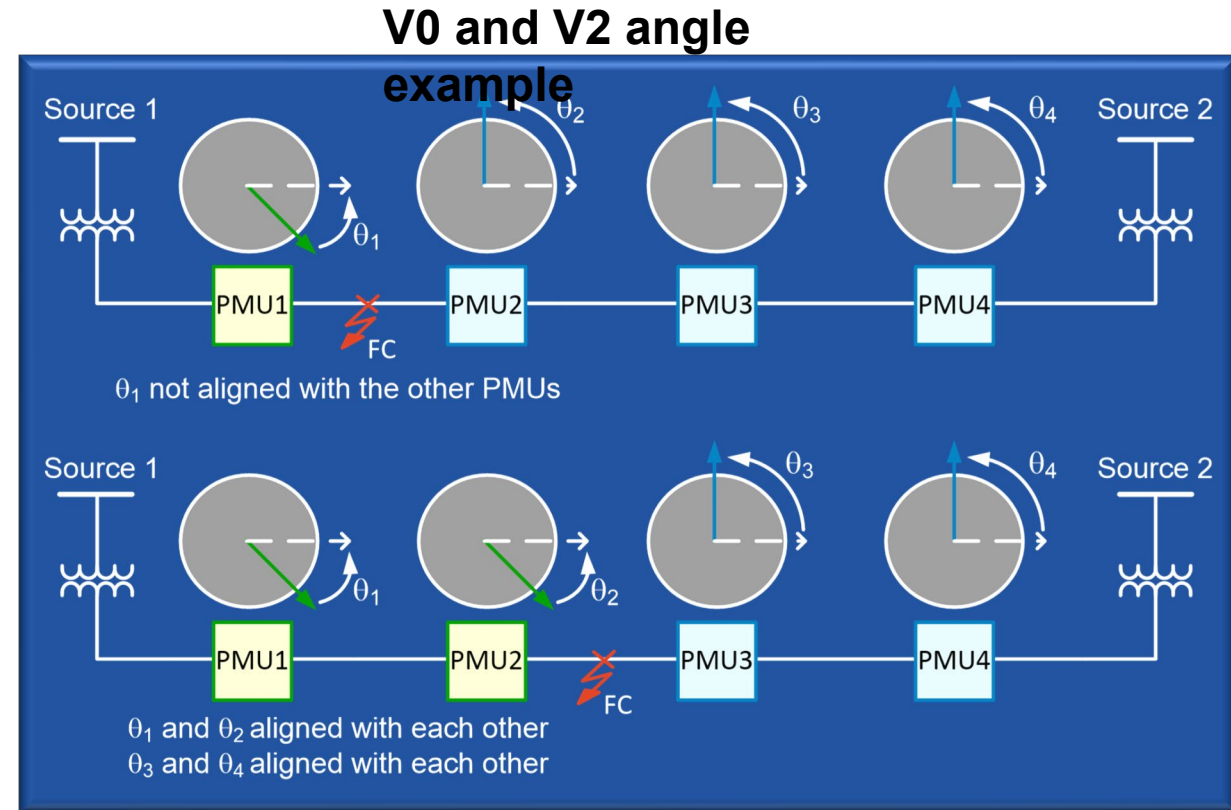
# FCP Detection Methods



- $dv/dt$  - Voltage Rate of Change
- $V_0$ ,  $V_2$  - Voltage magnitude difference
- $V_0$ ,  $V_2$  - Voltage angle difference
- **Restrains on fault current ( $di_0/dt$ ) to allow the normal protection system to operate as designed and coordinated**

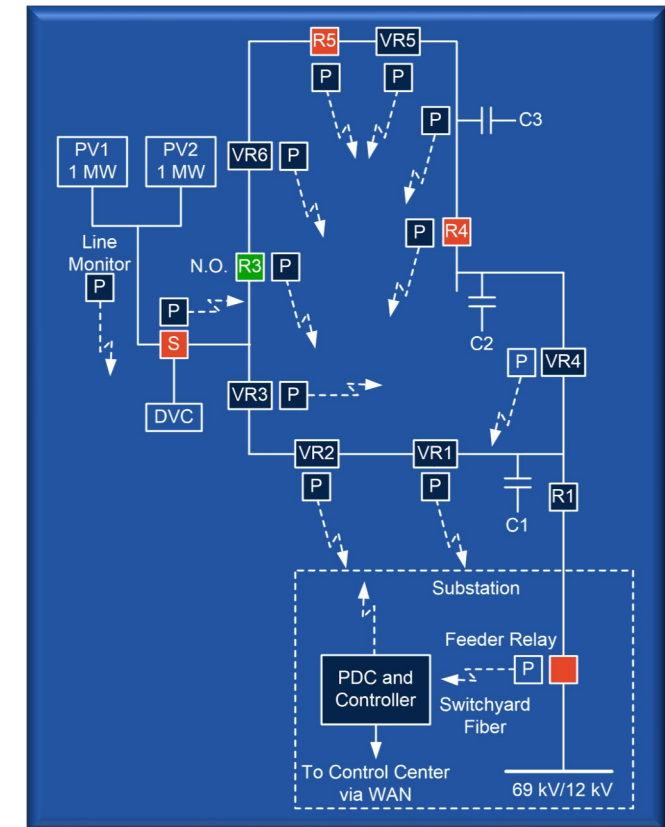
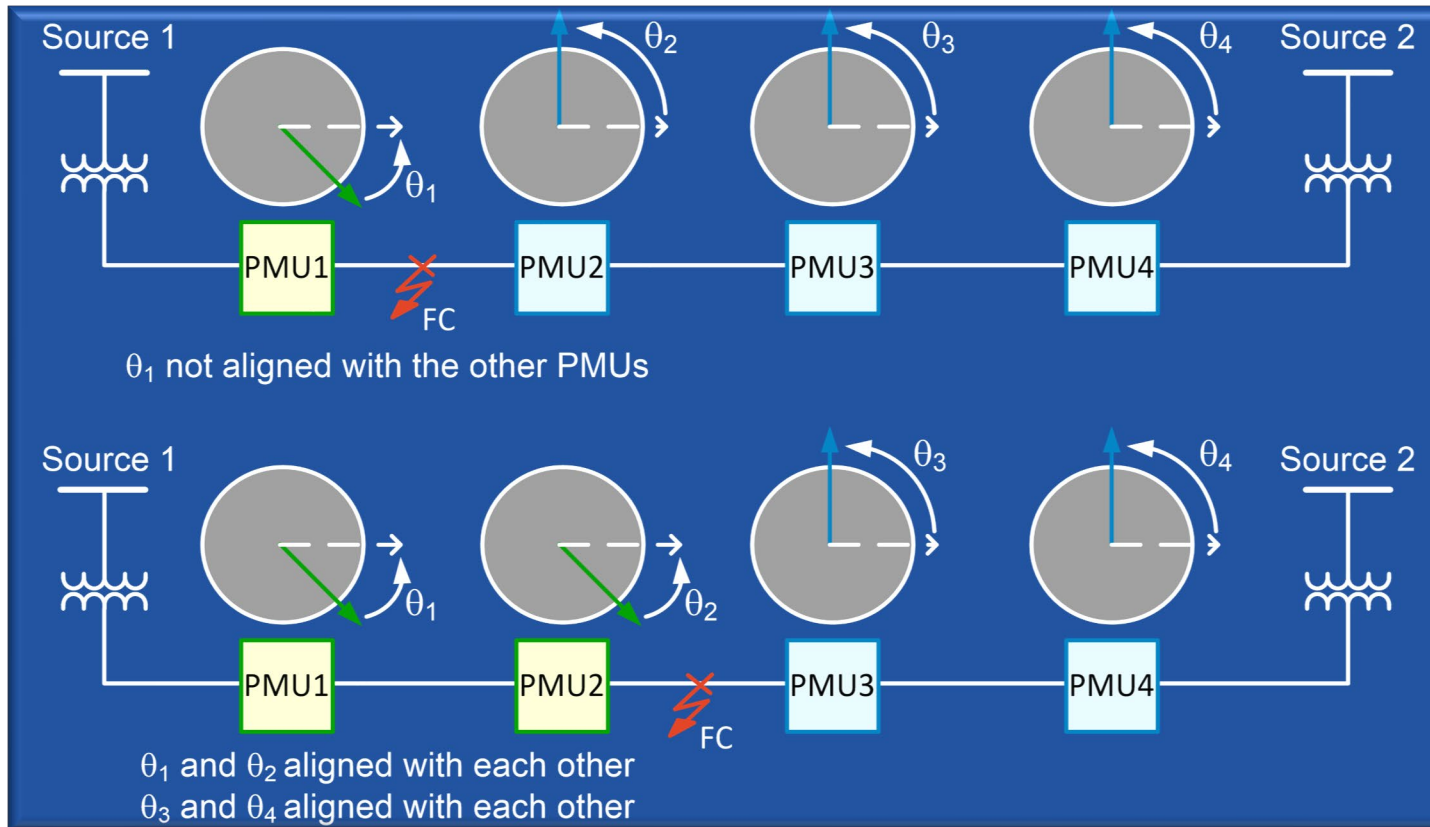
## Note:

- $dv/dt$  = rate of change of voltage with time
- $V_0$  = Zero Sequence Voltage
- $V_2$  = Negative Sequence Voltage
- $I_0$  = Zero Sequence Current (FAULT CURRENT)



# Ease of Application – Adaptive FCP Algorithm

- **Key requirement** - No circuit-dependent application settings
- FCP logic only requires awareness of circuit and PMU IEDs topology

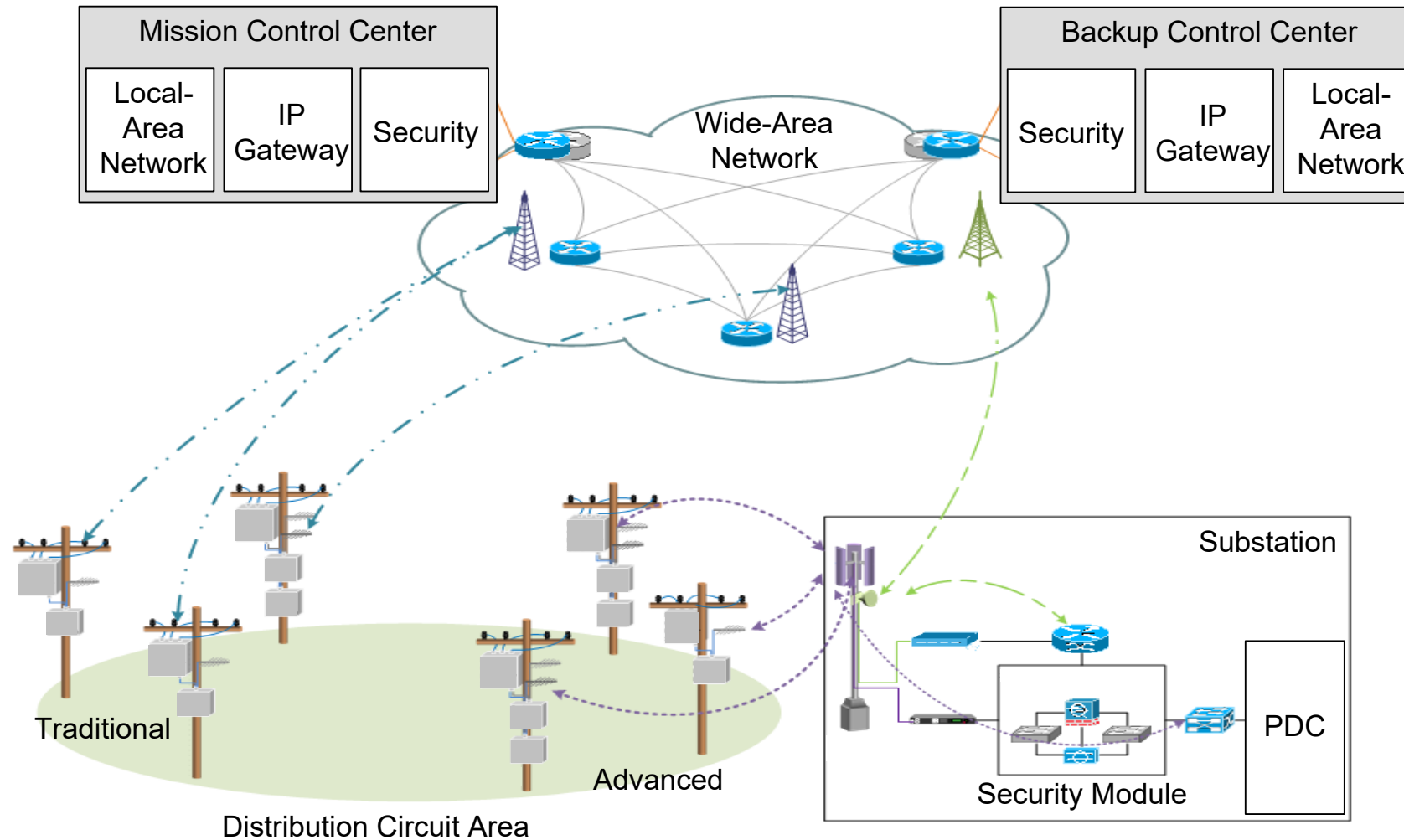




# SCADA Traditional and Advanced Overlay



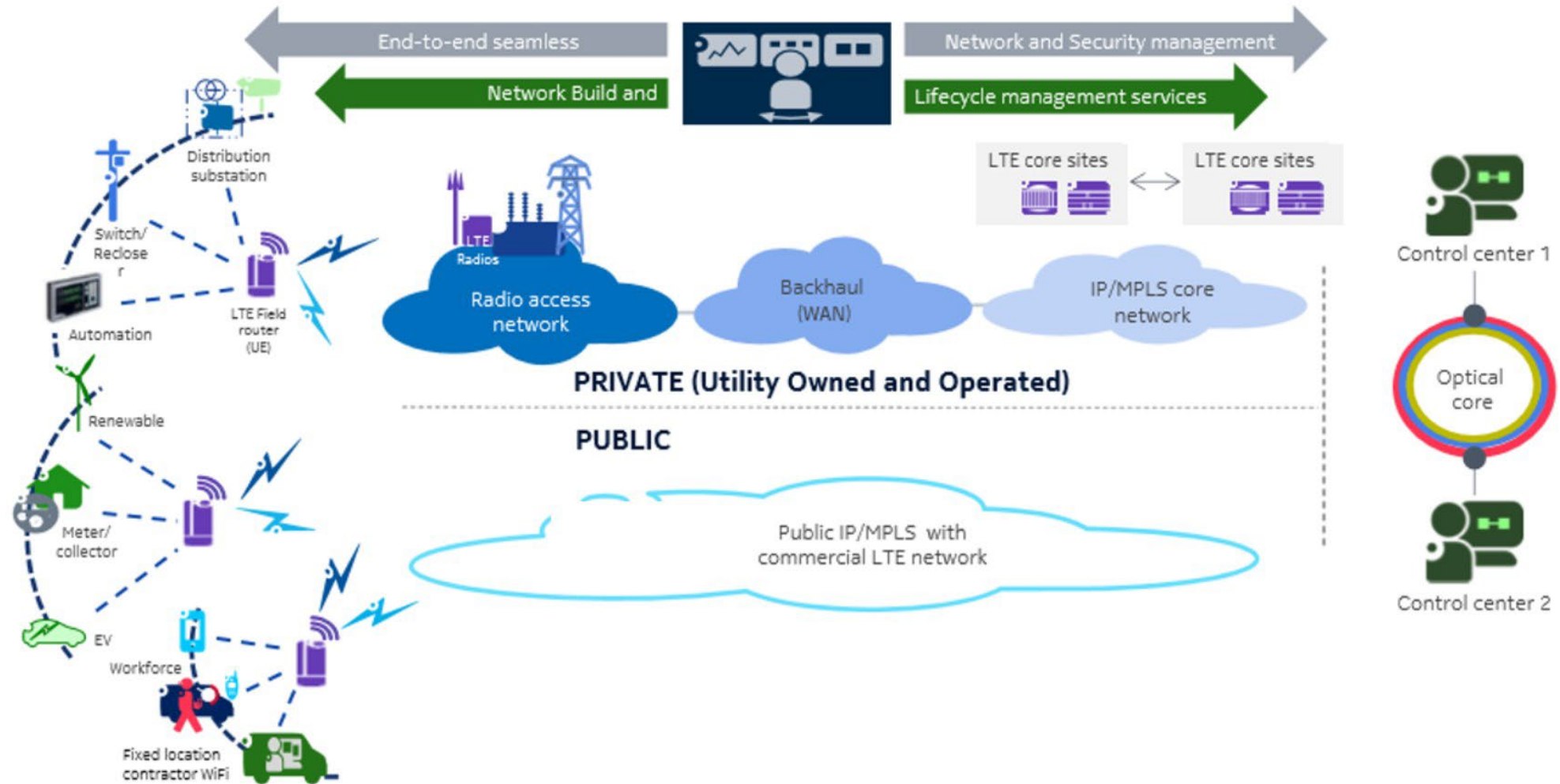
## Existing Communications Infrastructure



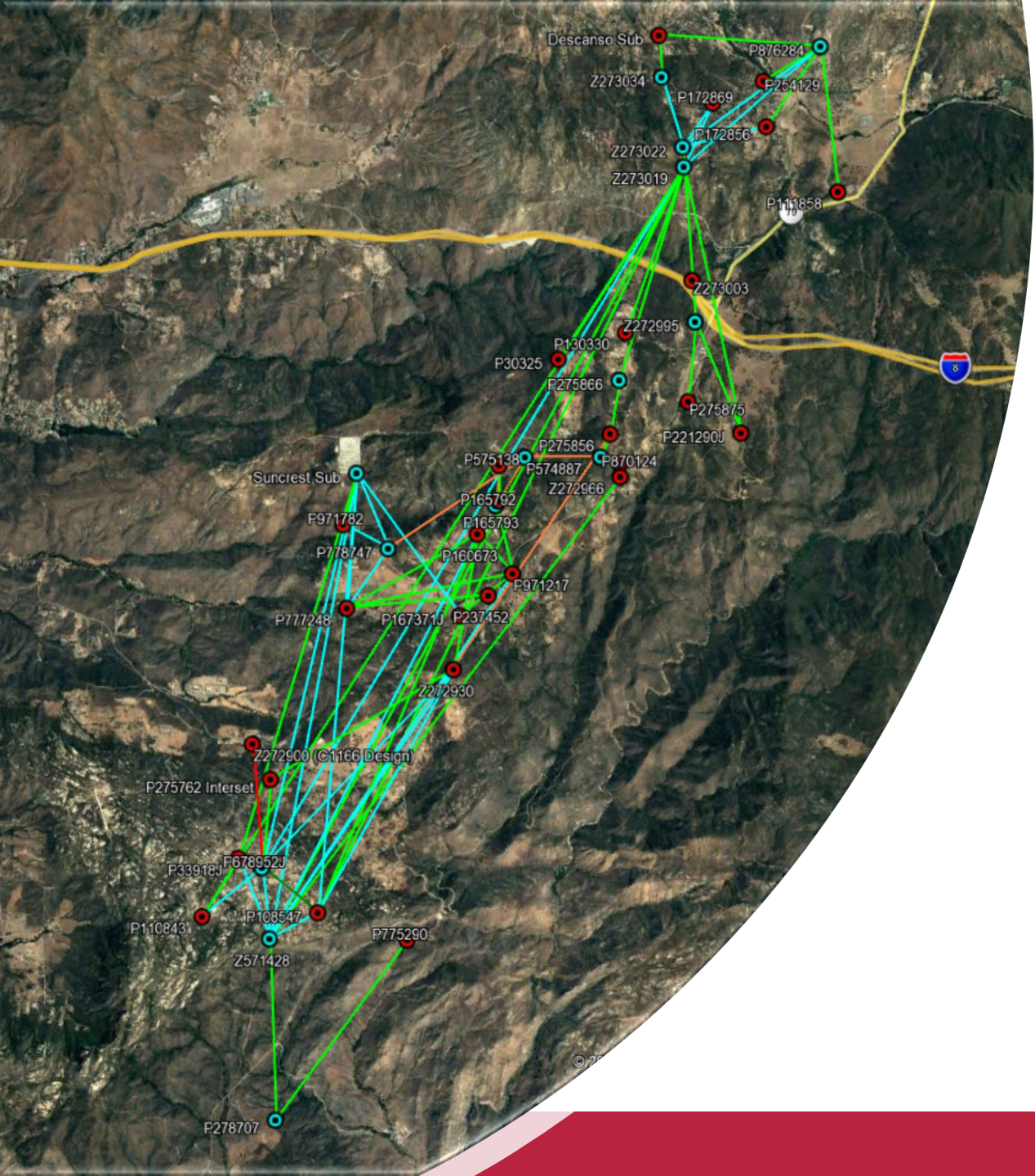
# Private Long-Term Evolution (pLTE)



Decreases FCP Cost / Increases Security







# Falling Conductor Protection Radio Design

- Current radios require line-of-sight
- Back country terrain challenging
  - Multiple repeaters required
  - Requires cross-functional coordination with multiple project teams
  - Additional pole replacements required
- Private LTE (PLTE) simplifies deployment
  - Less radio repeaters & cost
  - Faster installation
  - Higher risk due to project complexity

# Layers of Fault Protection & Wildfire Mitigation



## FCP

- Fastest – detects conductor breaks and trips before a ground fault occurs
- Coordination – FCP should always be first scheme to trip

## Overcurrent – time and instantaneous

- Simple coordination

## Sensitive Ground Fault (SGF)

- Detects high-impedance ground faults
- Slow – 3.5 to 5.5 seconds

## Advanced SGF

- More sensitive than SGF using adaptive set point, spike counting, and/or harmonics
- Slower – > 5 seconds





# FCP Program Status



## Substations

- 64 Total
- 7 in design
- 7 in construction
- 12 complete

## Circuits

- 195 Total
- 72 in HFTD 3
- 123 in HFTD 2
- 7 in design
- 13 in construction
- 2 commissioning
- 8 complete

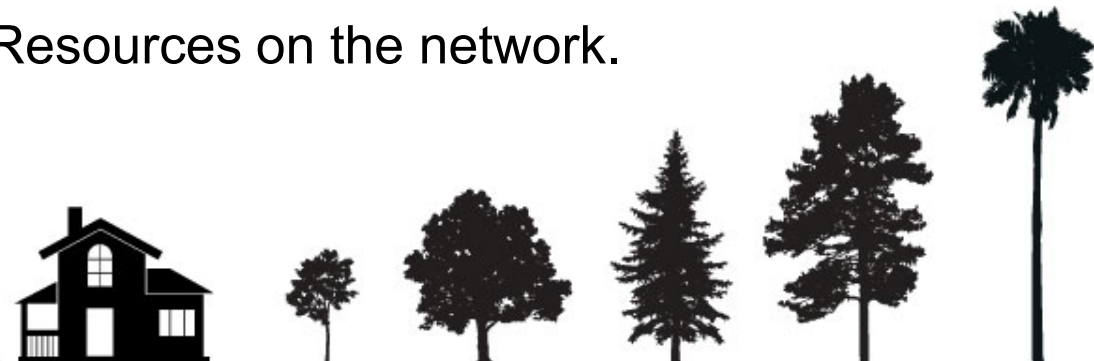
## Project Duration (12 – 31 months)

- Design phase
  - 4 - 9 months
- Construction Phase
  - 6 - 18 months
- Commissioning Phase
  - 2 - 4 months

# Innovation Summary

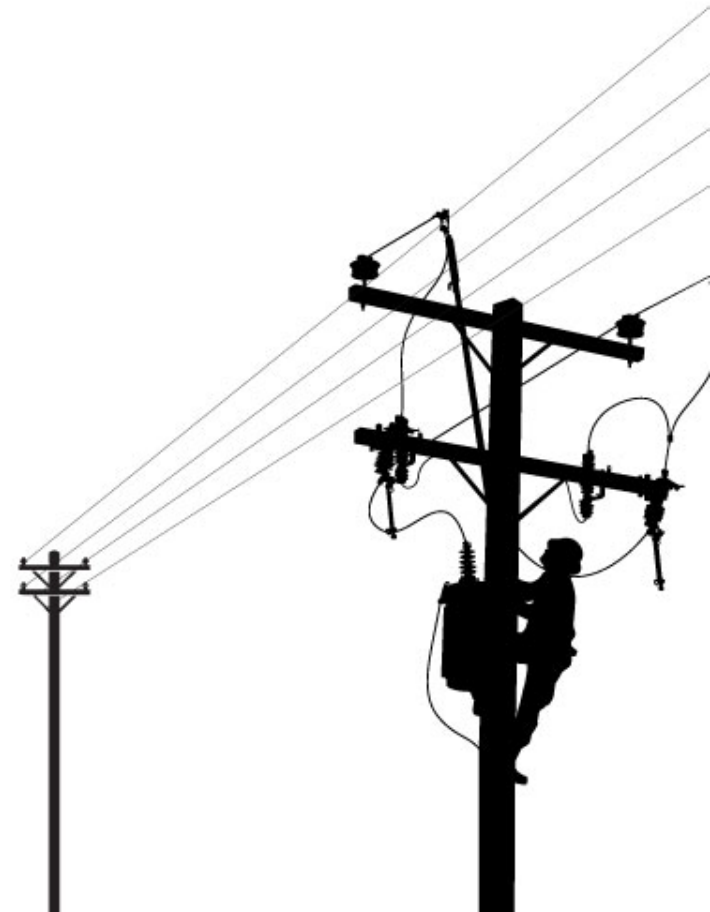


- SDG&E began operating the 1st utility-scale microgrid in U.S. in 2013 and is currently upgrading it to run on 100% renewable energy.
- The utility has 4 microgrids and is on track to integrate about 145MW of utility-owned energy storage with the local grid in 2022.
- Distribution Falling Conductor Technology will help identify, isolate and prevent wildfire ignition and enhance situational awareness.
- Distribution recloser Point-of-Common-Coupling control will expedite and simplify the integration of Battery Energy Storage and other Inverter Based Resources on the network.



# Challenges

Maintaining and enhancing reliability and resilience of the distribution grid



# Challenges



## Gaps and Challenges to Overcome in the Distribution System

- Increased Distributed Generation
- Increased Inverter Based Resources
- Oscillation and voltage stability on the distribution networks
- Operational Technology innovations for Situational Awareness
- Proliferation of Phasor Measurement Technology or Point-on-Wave data, to enhance situational awareness and control
- Engineering and Operator acceptance of technological innovation
- Funding





# References

1. [SDG&E to Upgrade Borrego Springs Microgrid to 100% Renewable Energy | SDGE](#)
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# Questions?

## Building a Resilient Distribution Grid: SDG&E Experience



4,100

Square miles

3.6

Million customers

2

Counties (San Diego & Orange)

25

Communities

16

Federally recognized Tribes



Coastal, mesa, valley, mountain & desert terrain