Field Demonstration of DERMS with ADMS

CIGRE Grid of the Future 2018

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Together, Building a Better California

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Pacific Gas & Electric Company (PG&E)

Company Facts

- Fortune 200 company located in San Francisco, CA
- Over 20,000 employees

Service Territory

- 70,000 sq. miles with diverse topography
- 125,000 circuit miles of electric trans. and dist. lines
- 49,000 miles of natural gas trans. and dist. pipelines

Energy Supply

- Services to 16M people:
  - 5.4M Electric accounts
  - 4.3M Natural Gas accounts
- Peak electricity demand: Approx. 21,000 MW
- Approx. 60% of PG&E's electric supply comes from non-GHG emitting facilities
- "Decoupling" has removed direct link between energy sales and PG&E's profit

Source: http://www.pge.com/en/about/company/profile/index.page , CEC California Energy Demand Forecast 2014-2024 Preliminary Forecast and PG&E 2015 10-K filing

CA Energy Landscape is Changing Rapidly

Drivers of Change

Environmental leadership policies

- **-40%** 1990 GHG: 2030
- **50%** Renew-ables: 2030
- **1.3GW** Battery Storage: 2024
- **1.5M** EVs: 2025

Rapidly advancing technology

15¢ / kWh Rooftop Solar

>330k Solar Customers

EV Adoption ↑

>160k Registered EVs

Lithium-ion Prices **-73% in 6 Yrs.**

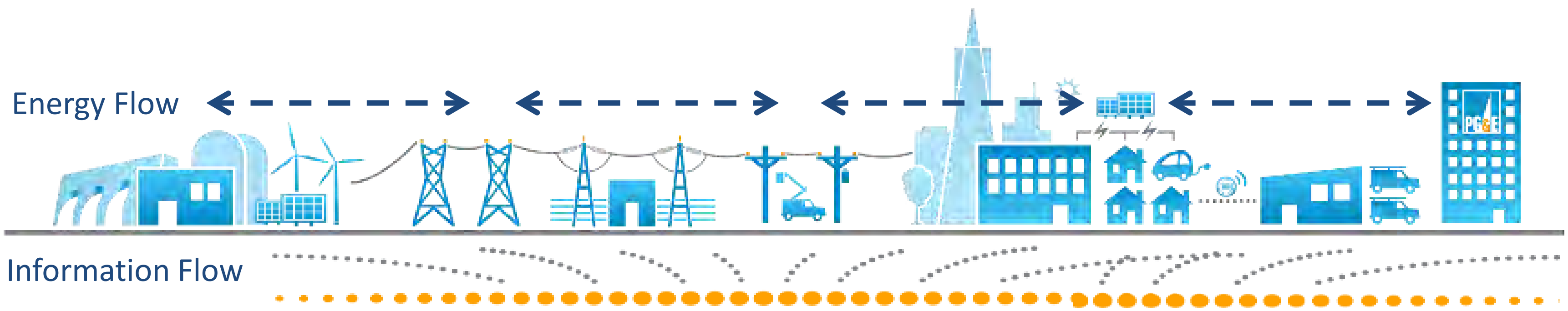
Increasing customer choice and engagement

3,000 MW Customer Solar

146K Electric Vehicles

21% CCA Customers

The Grid has Become More Complex to Operate



Climate Change/Grid Resiliency	*DC Fast Charger Impacts (EV)*	*Frequency of distribution outages and use of switching*	*Volatility in frequency and voltage*	*Public Safety Power Shut Off for extreme fire conditions*	*Communications network reaching capacity limits*
DER Participating in Wholesale Markets	*Two-Way / Unpredictable power flows*	*Higher amount of Masked Loads*	*Integration of Smart Inverter functions & capabilities*	*Integration of Non-Wires Alternatives for Grid Services*	*Maintaining cybersecurity*

DER Management Capabilities Needed

New capabilities are required to enable the safe, reliable, affordable, and clean operation of the high DER penetration grid

1. **Situational Awareness** of real-time and forecasted DER contributions, flexibility, and "hidden load"

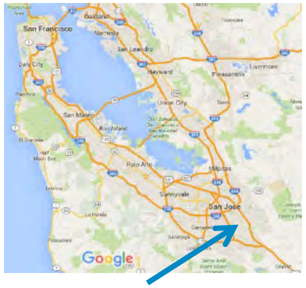
2. **Power System and Economic Optimization** to enable DERs while maintaining grid safety

3. **Integration and Control** w/ utility and 3rd party DERs for reliable dispatch and coordination

DERMS EPIC Project Overview

WHAT

- Built **proof of concept MVP** DERMS system in a ‘sandbox’
- Designed/executed ~100 tests, over multiple DERMS use cases
- Electric Program Investment Charge (EPIC) Funded



San Jose, California

Covered 3 Major Themes:

1. **Situational Awareness with DERs**
2. **Distribution Services – Capacity & Voltage via kW & kVAR**
3. **Market Operations and Coordination**

WHY

- Enable PG&E and industry learning about people, process, technology
- Objectives:
  - Evaluate **technical ability to coordinate DERs** (incl. through aggregators) for distribution services
  - Clarify **DERMS requirements**, and characterize **barriers to deployment at scale** relative to today

WHEN

- 2015 project ideation and design
- 2016 DER customer acquisition, DERMS deployment
- 2017-2018 DER deployment & Field Demonstration

San Jose DER EPIC Demonstrations

Unlocking the Next-Gen Grid through Distributed Energy Resources

Driving a clean energy future through innovation, integration of new technologies, and collaboration

PG&E: Demonstrating how smart inverters and battery storage can be dispatched by DERMS to meet grid needs.

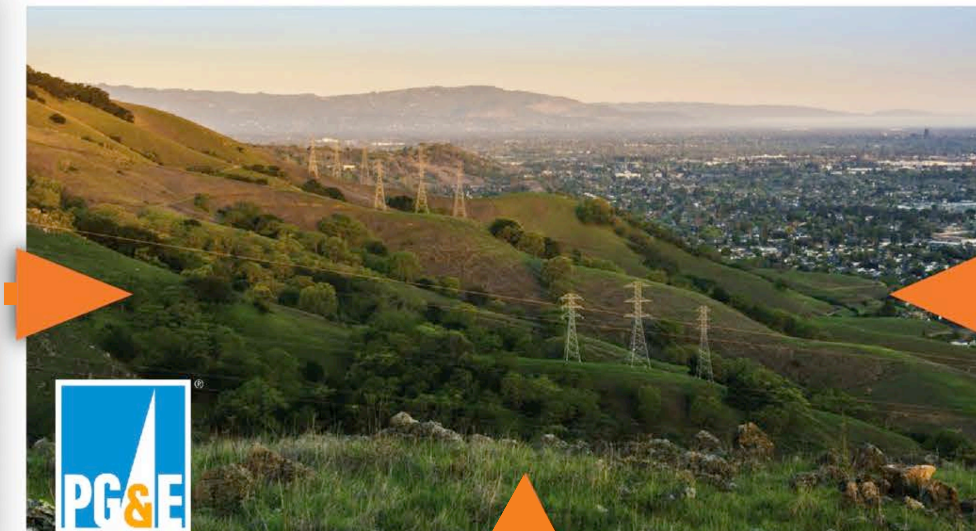
Tesla: Installing and testing residential battery storage systems and smart inverters to evaluate how customer-sited solar can be controlled and coordinated with grid management technology.

Green Charge (Engie): Installing and testing commercial battery storage systems to evaluate how they can be used operationally to support the grid during periods of high electric demand.

GE Grid Solutions: Developing the new Distributed Energy Resource Management system (DERMS).

TESLA

Solar SI: 124kW Residential
BTM Storage: 66kW, 4 hr



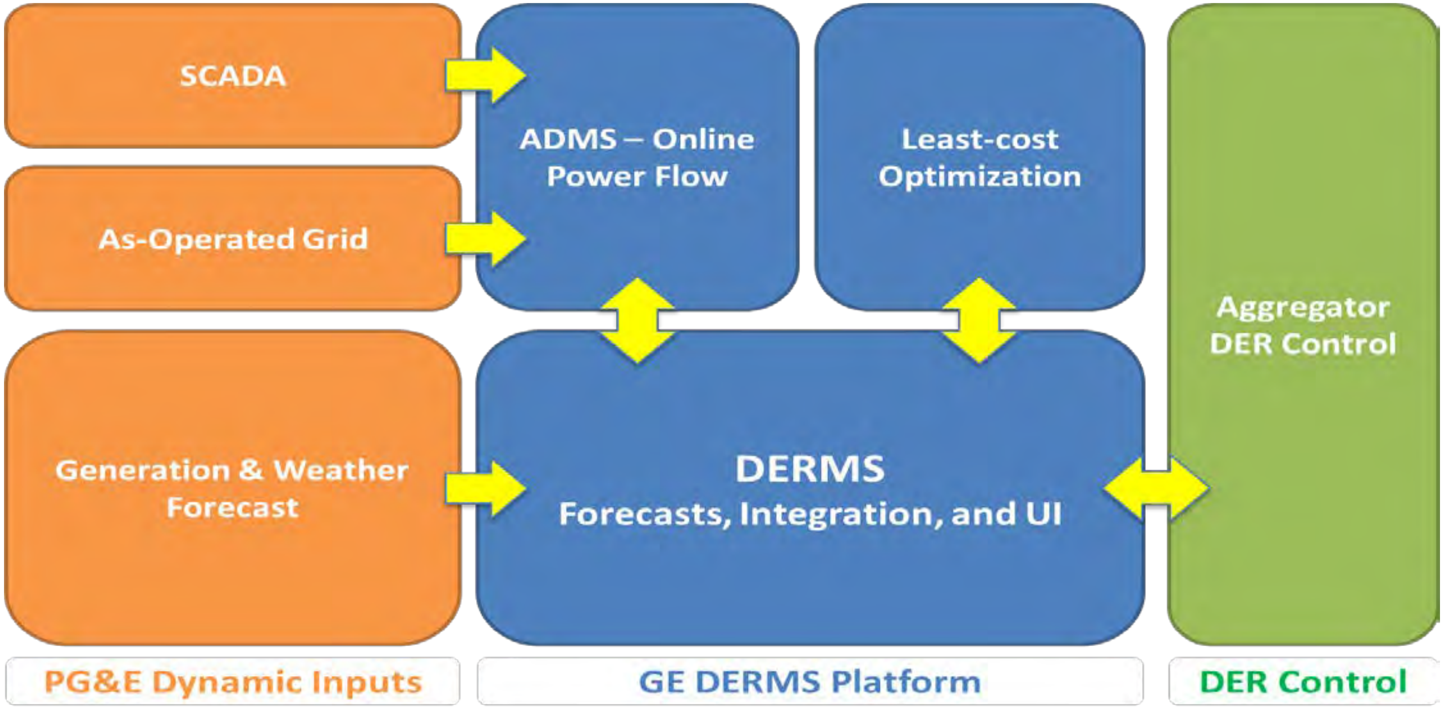
Yerba Buena Battery (BESS): 4MW, 7hr

ENGIE

BTM Storage: 360kW, 2 hr

Demonstration Setup

- Deploy DERs – customer acquisition, permitting, interconnection
- Field verification of utility equipment
- "Mini-ADMS" & advanced modeling
- Optimization engine – prototype system architecture
- Dispatch – Automated IEEE 2030.5 to Aggregators, direct control of PG&E BESS



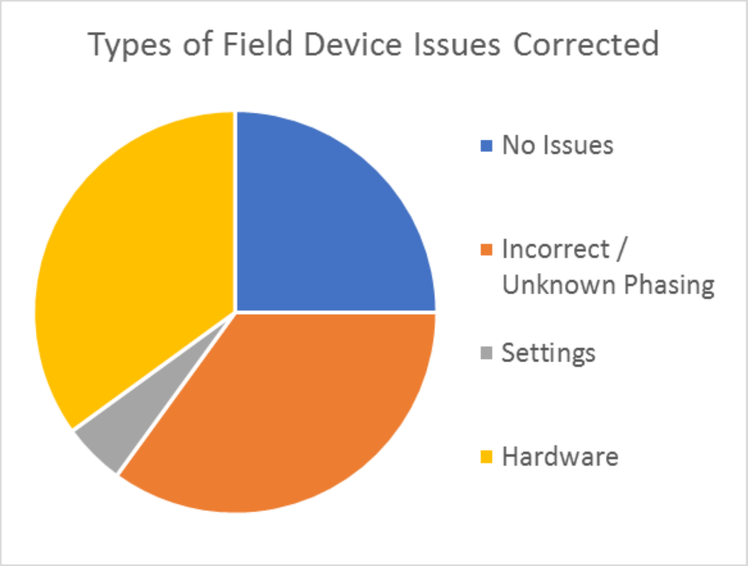
Situational Awareness

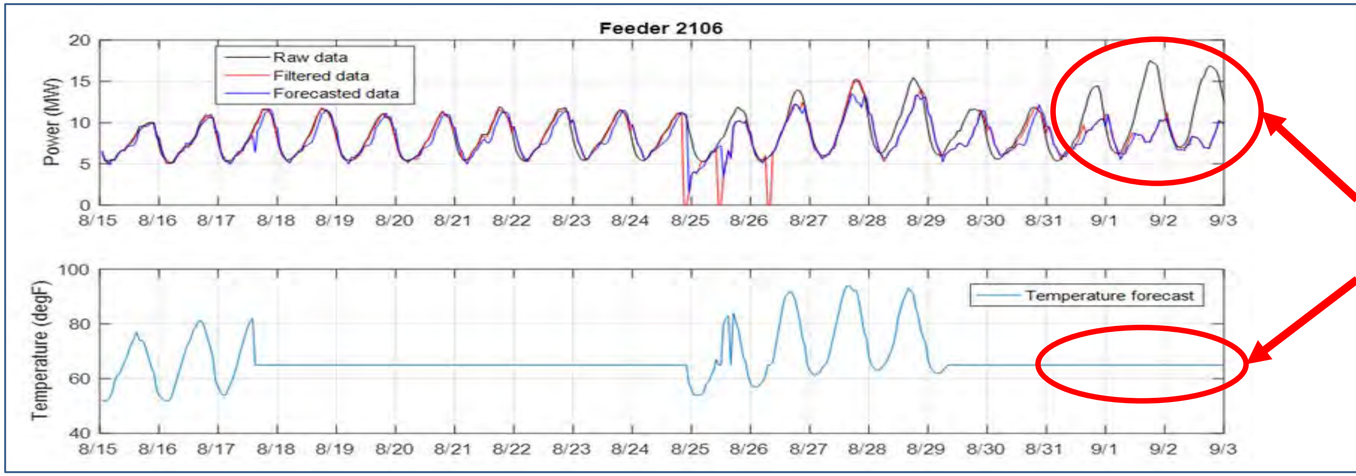
Foundational information required to provide the system "needs" to any subsequent DERMS

Sit. Awareness Challenges – Data Quality

Data Quality is a common challenge for utilities implementing an ADMS

- Model Data
  - Incomplete
  - Disparate Systems
- Field Telemetry Issues
- Lack of Phasing Information
- Failsafe Protocols



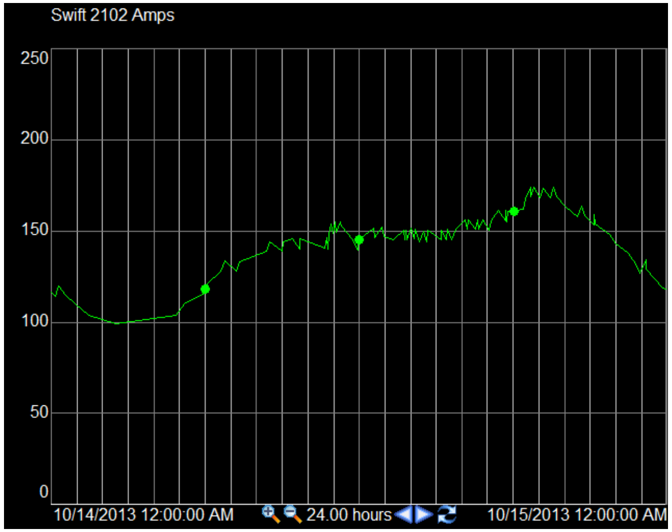


Intermittent temperature data stream impacts forecasts

Sit. Awareness Challenges – Highly Variable Loads

- 4MW YB Battery had a significant impact on the feeder
- Participation in the frequency regulation market caused convergence issues in real-time, and made accurate forecasting difficult

October 2013



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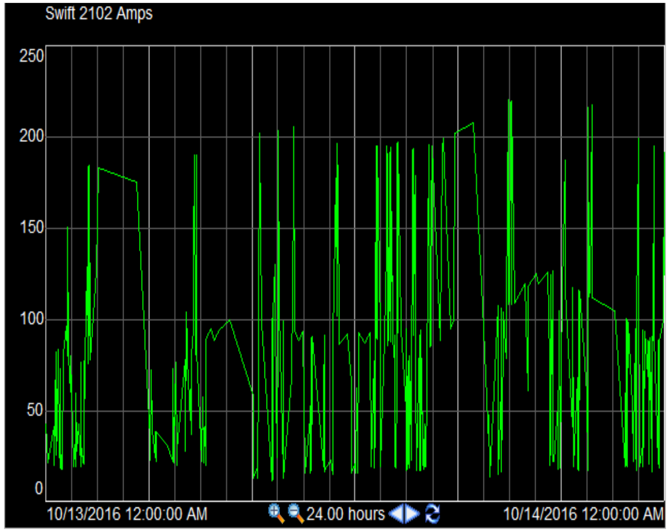
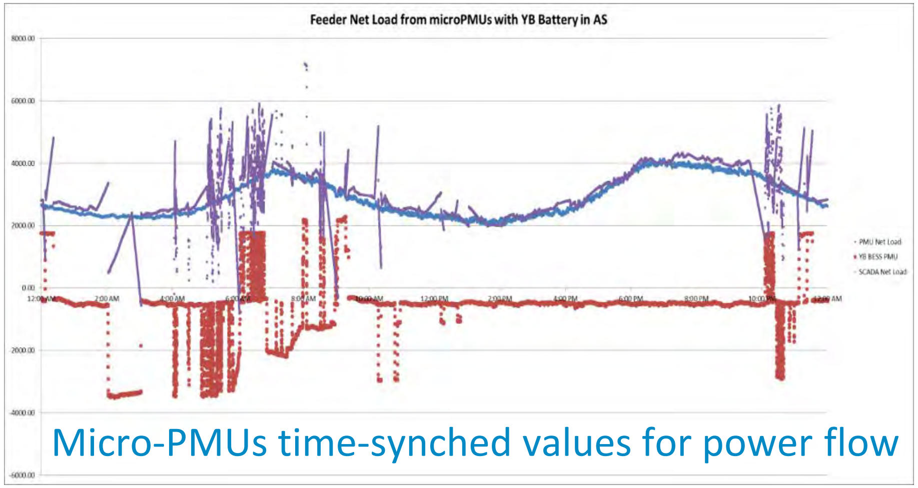
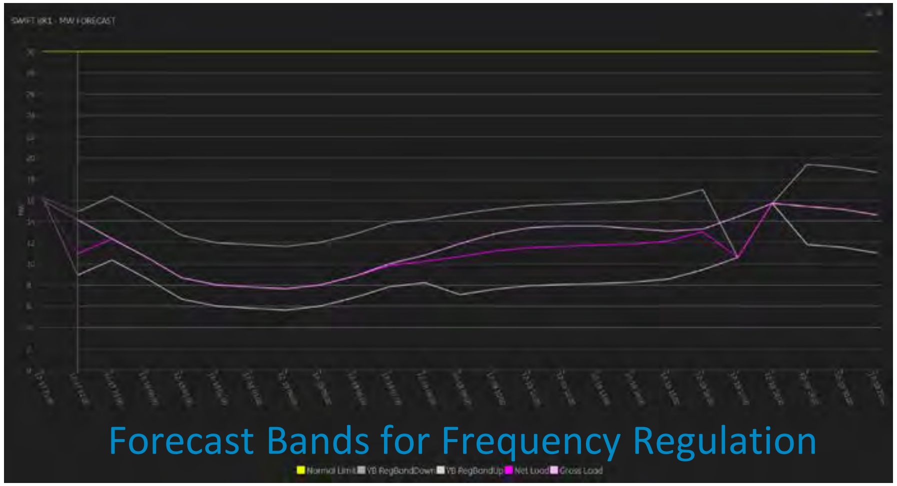




Micro-PMUs time-synched values for power flow



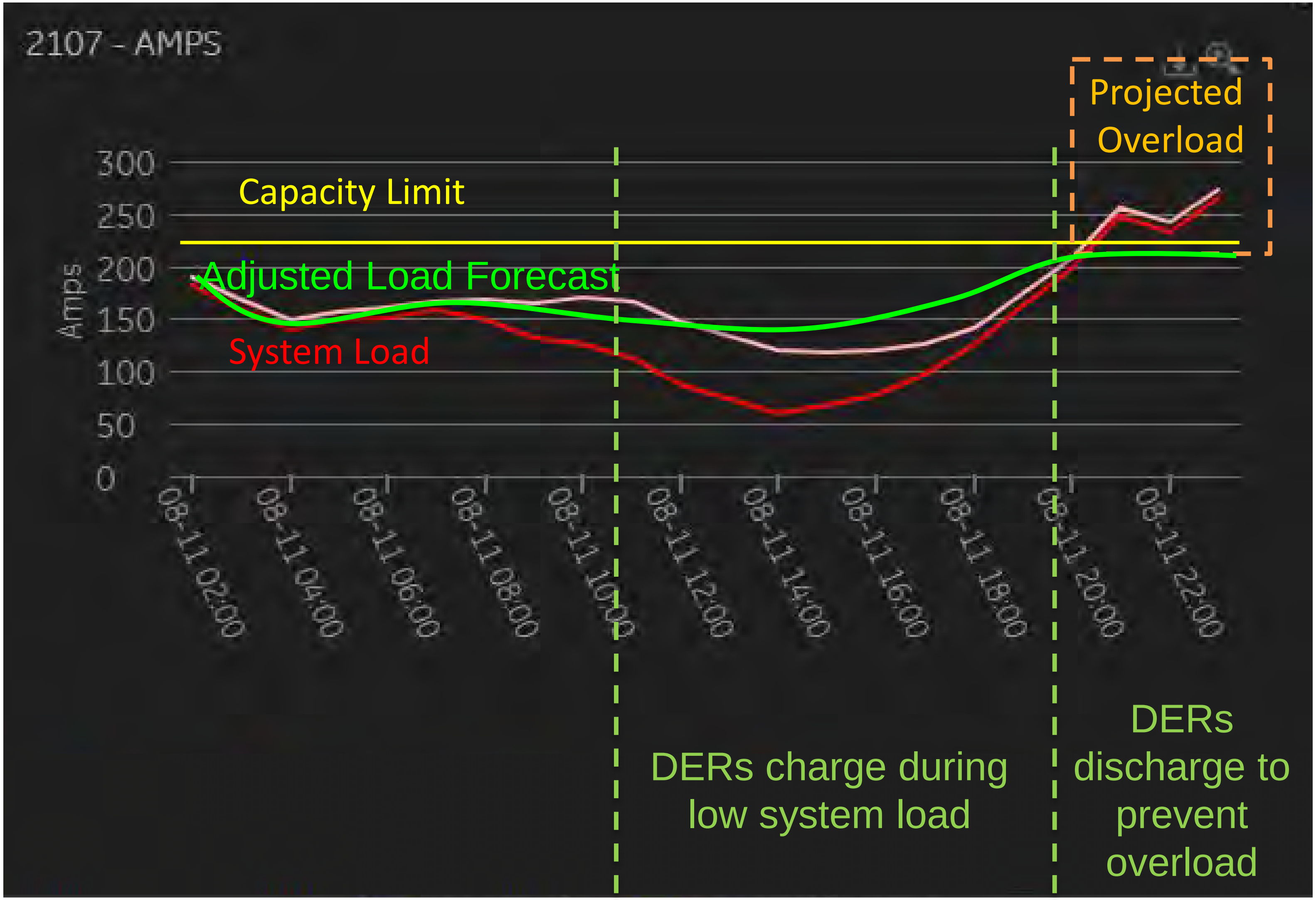
Forecast Bands for Frequency Regulation

Distribution Services

Manage DERs to maintain distribution grid safety and reliability

- Constraints (Do No Harm) vs Active Management
- Demonstrated DERs can technically provide capacity support via kW, and voltage support via kW and kVAR even under abnormal switching conditions
- Optimization based on a least-cost approach
- Barriers remain:
  1. Secure enough controllable DERs
  2. Dependencies of location and circuit characteristics
  3. Potential policy, regulatory, technical, and economic hurdles

Forecasted Overload Mitigation Example



kVAR Dispatch

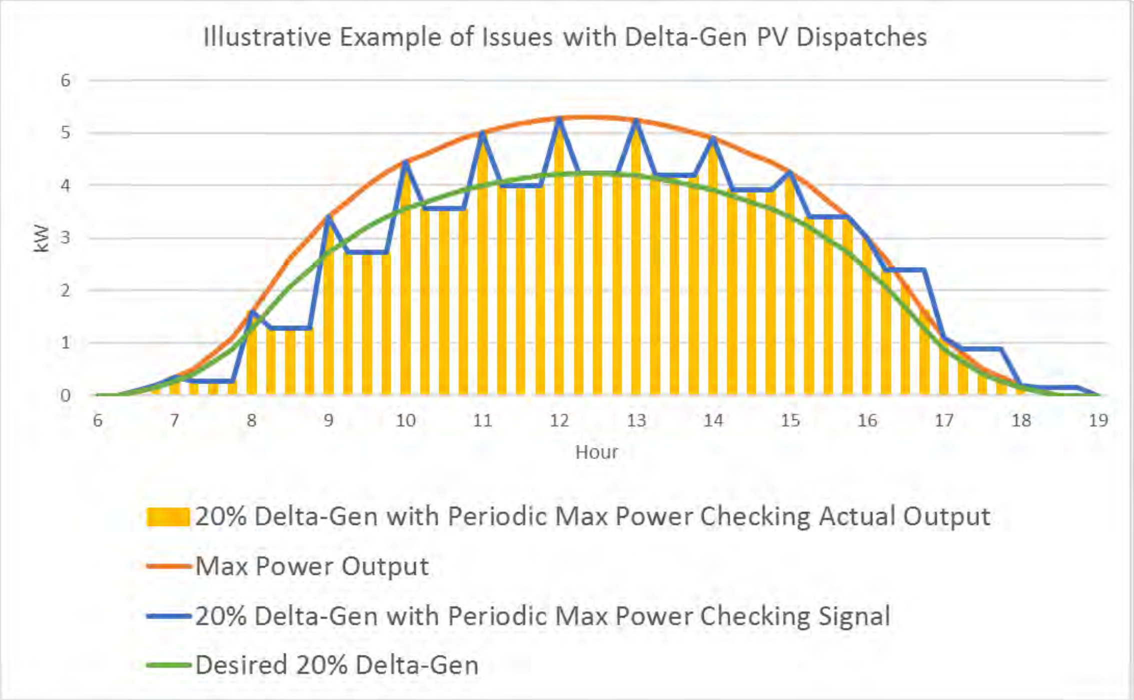
- Impact of kW vs kVAR will be circuit dependent and location dependent
- kVAR dispatch more reliable than PF dispatch
- kVAR dispatch seemed to have minimal impact on SoC, and could be used to provide additional services beyond kW (e.g. provide voltage support if a kW dispatch causing issues)

Measured Voltage Changes in the Field with Varying YB Battery Dispatch								
	X1298	X1920	X1796	XR440	X2000	X2132	BK1	X1330
-1000 kW	-0.54	-0.10	-0.10	-0.32	-0.20	-0.39	-0.21	-0.10
-500 kVAR	-0.87	-0.69	-0.60	-0.52	-0.70	-0.56	-0.36	-0.60
+500 kVAR	0.92	0.67	0.67	0.44	0.66	0.60	0.40	0.59

Note: kVAR results are circuit and DER location dependent, and should not be extrapolated system wide

Dist. Services Challenges – DERs

- **Need enough DERs where you have a problem**
- **Not off the shelf:**
  - All parties had technical and implementation challenges
- **Utility and Aggregator forecasting can be improved**
- **IEEE 2030.5 needed custom extensions to implement pilot**
- **Non max power PV challenges**
  - PV curtailment has no direct measurement
  - Difficult to implement a reduction type dispatch (e.g. “delta-Gen”)



Dist. Services Challenges – Optimization Complexity

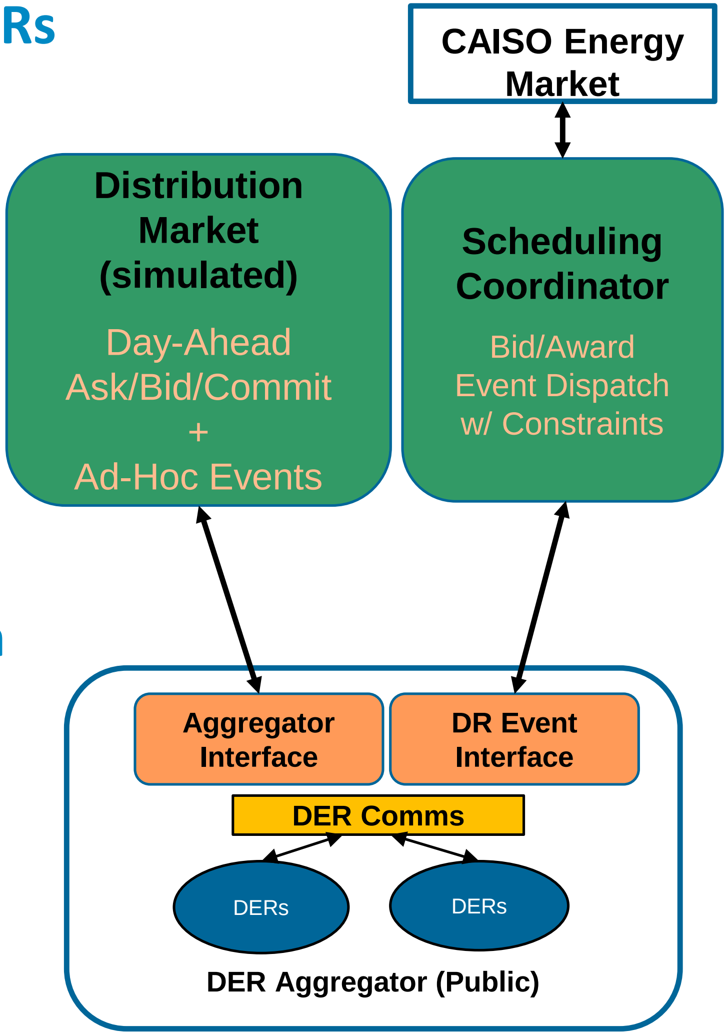
- **Both utility and aggregator real-time data and forecasts are critical to good optimizations**
  - Voltage estimations less accurate than capacity in general

- **Static Aggregations**
  - Aggregating by sensitivity (e.g. V/kW) may be best especially for mitigating voltage issues
- **Linear Estimations**
  - Added buffers to fully mitigate some issues
  - Avoided nuisance dispatches of DERs with tiny sensitivities
- **Violation Costs**
  - Valuation of Distribution Services not part of project
  - Violation costs most likely cost curve in future
  - With equal costs for kW vs V violations, kW always prioritized

Market Operations

Optimize DER dispatches economically, and investigate challenges around multiple use applications (MUA) of DERs

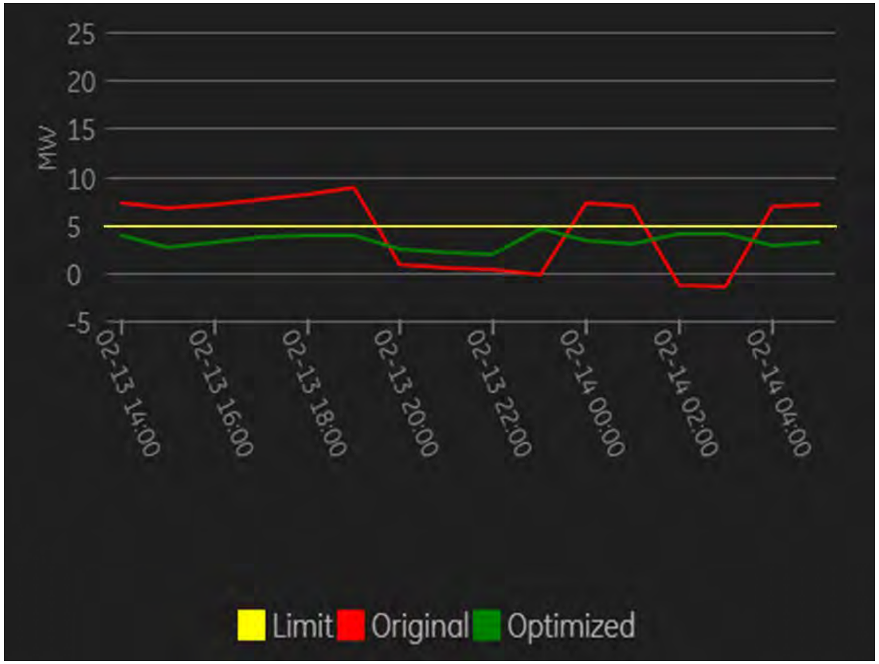
- Least-cost optimization worked well and included energy arbitrage
- Deployed both an ask-bid-commit day ahead market and an hourly ad-hoc market based on available flexibility
- Able to run market autonomously through IEEE 2030.5 with custom extensions
- No conclusions made on best type of market (if any) or valuation of distribution services through this demonstration



Multiple Violation Example

Multiple violations were forecasted during this window:

- Local high voltage near YB Battery
- Backfeed at CB
- Overload at CB (100A limit)



Penalty costs:

- Voltage: $120,000/Volt
- Overload: $10,000/kW
- Backfeed: $30,000/kW

Violation Type	Pre-plan Count	Pre-plan Cost	Post-plan Count	Post-plan Cost
Voltage	6	$562,800	0	$0
Overload	10	$381,690,434	7	$28,101,008
Backfeed	6	$220,494,163	0	$0
Grand Total		$602,747,397		$28,101,008
Percent cost reduction		**95.34%**		

Learnings Overview

PROJECT OBJECTIVES

- Evaluate **technical ability to coordinate DERs** (incl. through aggregators) for capacity and voltage support as dx grid services

LEARNINGS

- DERMS-coordinated DERs can provide distribution services (voltage and capacity)
- **But** DERMS is still not available off the shelf
- Managing 3rd party aggregations is **technically complex** for all parties involved
- Large DERs **participating in freq reg market complicates power flow** calcs/load forecasting

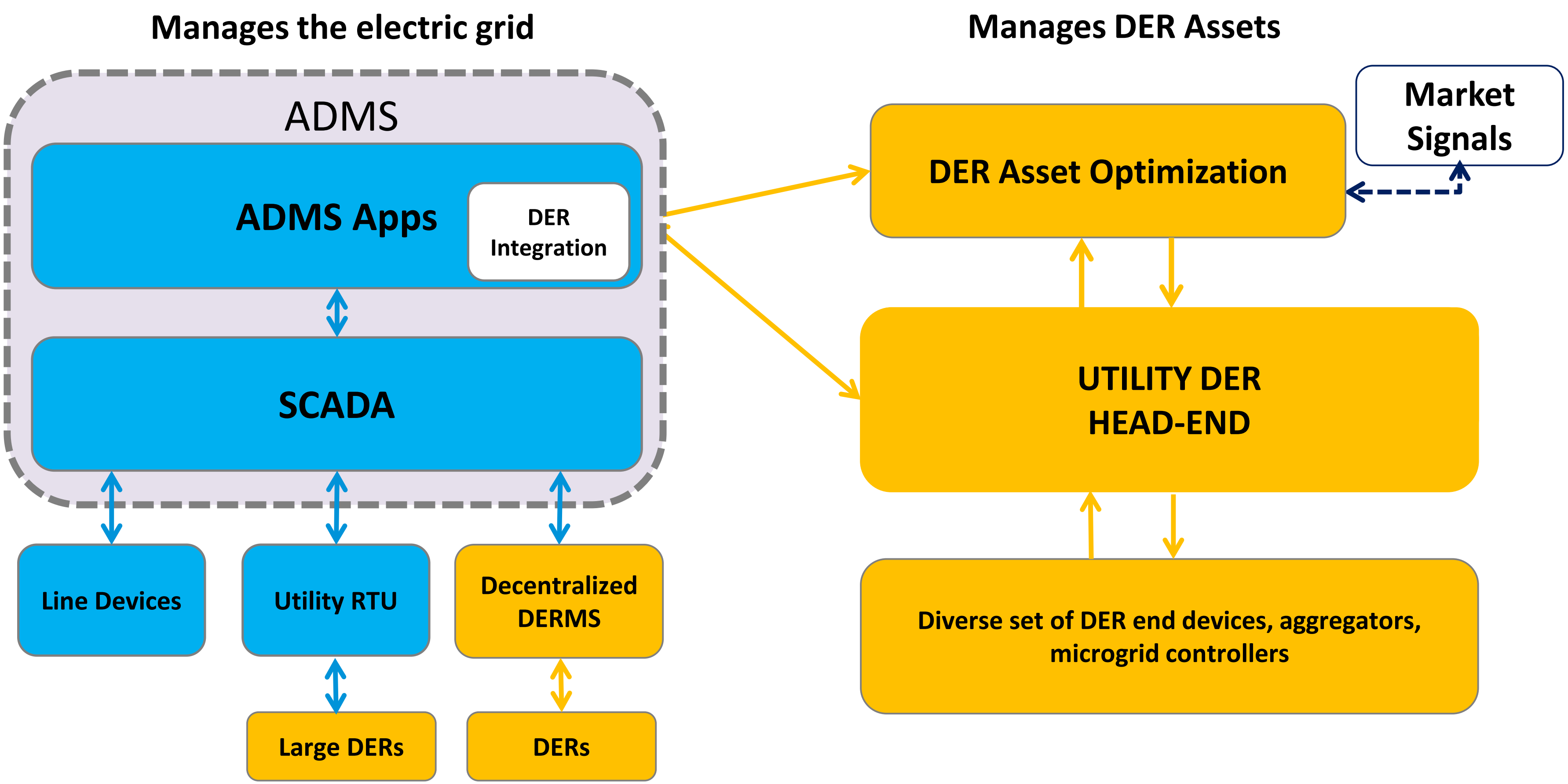
PROJECT OBJECTIVES

- Clarify **DERMS requirements**, and characterize **barriers to deployment at scale** relative to today

LEARNINGS

- Targeted DER customer acquisition / deployment more difficult than expected
- PG&E needs to invest in integrated platform to enable value creation from DERs for all customers…
- …while continuing to develop targeted DERMS solutions for near-term NWA projects

ADMS vs DERMS



DER-Aware ADMS:

1. Situational awareness
2. Ability to define grid electric needs
3. Simple logic for large DERs
4. Plug for future DERMS

DERMS:

1. Not network model aware
2. Customer / Aggregator End Devices
3. IoT Headend
4. Comprehensive DER Attributes

Next Steps – Proposed Future R&D Projects

The EPIC 2 DERMS pilot gives PG&E a strong grasp of how capabilities fit together and what we need to procure for ADMS this year, and what is needed for future applications.

Future Project Concepts

UTILITY DER HEAD-END

connect with DERs across programs, resource types, protocols

GRID AVAILABILITY COORDINATION ENGINE (GrACE)

Determines grid constraints and communicate constraints to DERs

DERMS FOR INTERCONNECTION

physical mitigations and operational constraints implemented by DERMS

LOCALIZED DER MANAGEMENT

Localized, scalable, near-term, targeted solution

Thank You

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