



ART ANDERSON

SMARTGRID LAB MANAGER, PACIFIC GAS & ELECTRIC



The Challenge of Renewable Energy

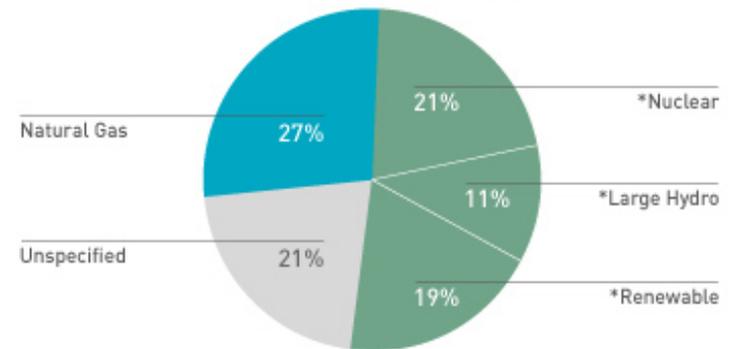
California Renewable Goals

AB327 Expansion

January 5th, 2015

- Governor Brown proposed an ambitious expansion of California's renewable energy goals, from one-third by 2020 to 50 percent by 2030
 - 33% renewables by 2020
 - 50% renewables by 2030
- Brown also proposed that the state set guidelines to cut fossil fuel use in cars and trucks in half over the next fifteen years, and double energy efficiency in existing buildings over the same time.

* These resources are greenhouse gas-free and/or renewable.



Note: Power mix includes all PG&E-owned generation plus PG&E's power purchases. Due to rounding conventions, the numbers above may not add up to 100%.

PG&E Power Mix 2012

Renewables at PG&E

With 175,000 solar installations—which accounts for more than 25 percent of all rooftop solar in the United States.

In fact, we add a new solar customer every 11 minutes, or more than 4,000 each month. We're also among the fastest at getting new solar customers connected to our energy grid.





The Duck Curve – The Impact of DG



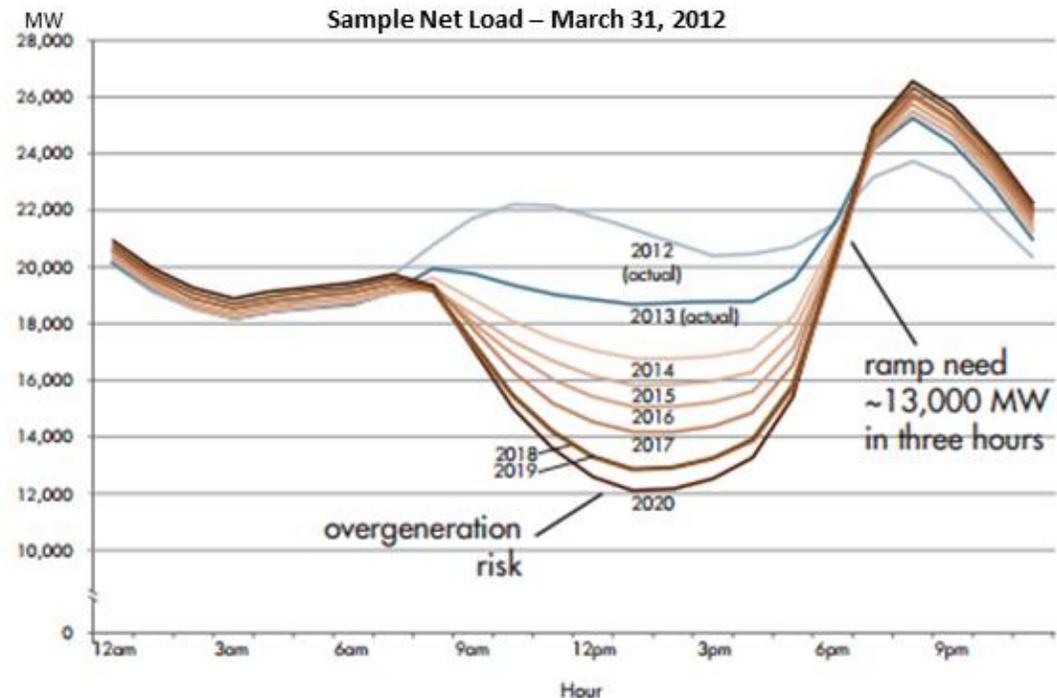
Distributed Generation on the Grid

- Enhancing Capability

DER Challenges

- Changing capacity
- Flexibility - Dynamic Supply
 - Weather (Clouds, Wind)
 - Time of Day (Sun)
- DG Management
 - Supply Peaks Mid Day
 - Load Peaks in the Evening
- Integration
 - Multiple Vendors
 - Different Technologies

The duck curve shows steep ramping needs and overgeneration risk



(from the California Independent System Operator)



Distributed Resources – Scale

Power Grid Evolution - Solutions must be secure and scalable

70,000 square miles, diverse topography

Approximately 20,000 employees

5.2 million Electric Customers

1,008,186 Transformers

6,833 MW of Generation

18,616 miles of electric transmission miles

120,000 miles of electric distribution circuits

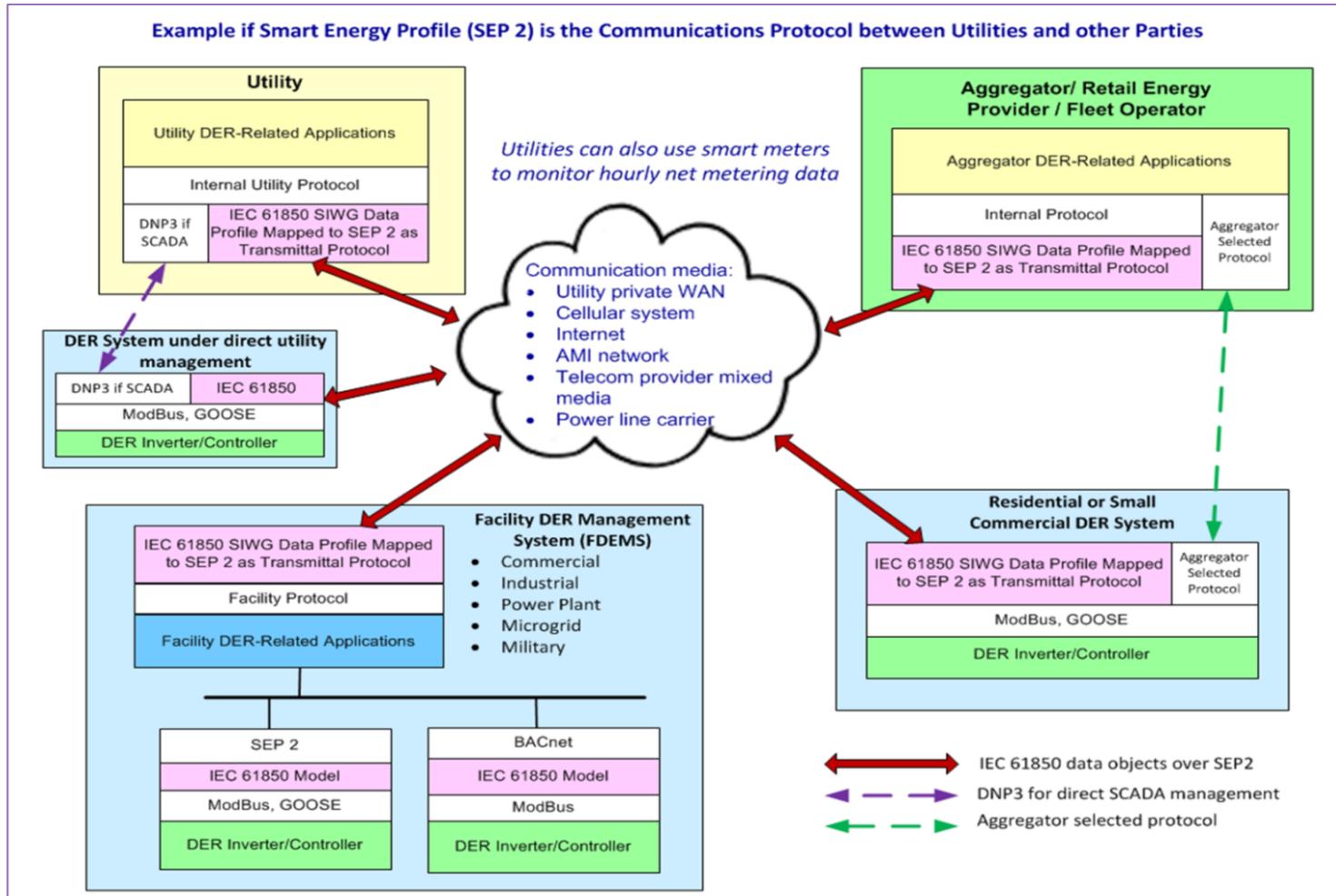
Regulated by the California Public Utilities Commission (CPUC)





Smart Inverter Interconnection

CPUC Smart Inverter Working Group - Rule 21



Phase 1 – Autonomous Control

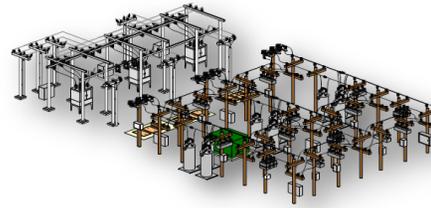
Phase 2 – Interconnection Requirements



Managing the Power Grid

Utility Grid – Control Network

- Closed Network
- High Capacity
- Low Latency
- Protocol Standard
 - DNP3
 - ICPP



Utility Grid



Solar Generation Facility (Ivanpah)

Solar Aggregator

- WiFi
- Ethernet
- Medium Latency (Minutes)
- Protocol Standard
 - IPv6
 - Proprietary



Aggregator



Figure 5. AE STL Series

Inverter Network

Residence

- AMI
- WiFi
- Increased Latency (15+ Minutes)
- Protocol Standard
 - IPv6
 - IEEE 2030.5



Individual Residence



Smart Inverter Communication

Rule 21 Phase 2 - Mapping Functionality

Use Cases to Requirements

Real Power

Limit Power

Volt Parameters

Reactive Power

Power Factor

Volt VAR Curve

Ramp Rates

Frequency Support

Freq. Watt Curves

Emergency Response

Disconnect / Reconnect

Ride Through Curves

Scheduling DER Output, Modes, and/or Functions

Registration

Approval

System Health and Monitoring

Status, Capability, Metering

IEEE 2030.5 Protocol

Real Power

Object level support

Reactive Power

Object level support

Frequency Support

Object level support

Emergency Response

Disconnect / Reconnect – Object level support

Ride Through Curves– Object level support

Anti Islanding setting – not currently supported

Scheduling DER Output, Modes, and/or Functions

Object level support

Registration

Out of band process

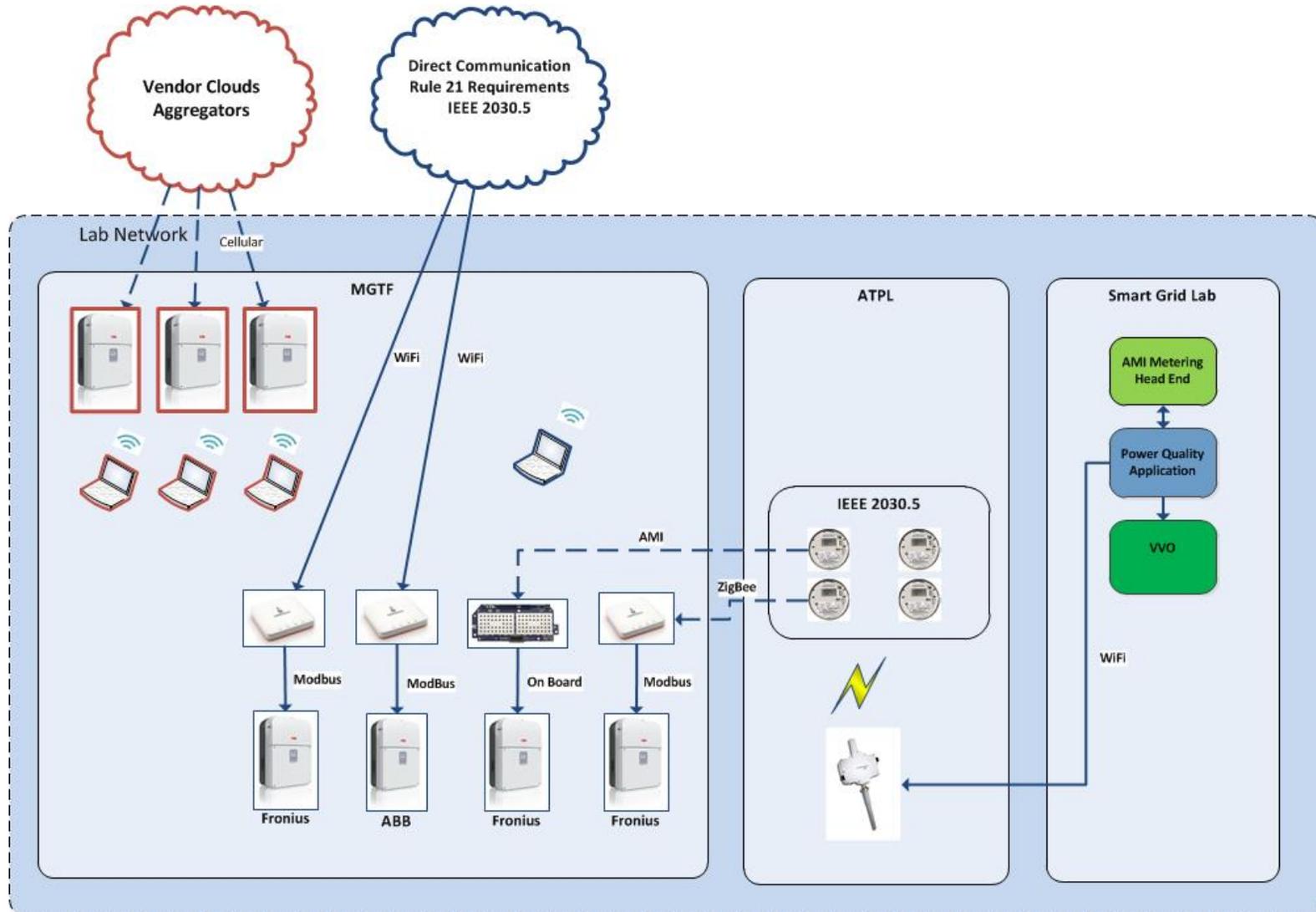
System Health and Monitoring

Status, Capability, Metering - Object level support



Smart Grid Communication Lab

Utility Implementation – Communication Testing Capability





Modular Generation Test Facility

Distributed Generation and Storage

- 500 kW interconnection and internal load capability
- Grid connected or off-grid testing
- PV inverters, micro-turbines, engine gen-sets, fuel cell, battery storage, flywheel storage
- Battery storage technologies
- Flywheel energy storage
- Interconnection of distributed generation and storage technologies





Smart Inverter Working Group

Phase 3

Current Functions

| Capability | Mandatory | Optional |
|--|-----------|----------|
| Monitor DER Status and Output | | X |
| Connect or Disconnect DER | | X |
| Limit Maximum Real Power | | X |
| Set Real Power | | X |
| Set Energy Storage charge /discharge rates | X | |
| Load and generation following | | X |
| Real power smoothing | | X |
| Set Storage Ramp Rates | | X |
| Frequency-Watt | | X |
| Storage Frequency-Watt | | X |
| Voltage-Watt | | X |
| Dynamic Volt-Watt | | X |
| Dynamic Reactive Current Support | X | |
| Scheduling settings and modes | | X |

DER Group Management

Group Creation, Maintenance ,Monitoring
Power Dispatch, Forecasting
Voltage Regulation, Group Curve settings,
Provide Price, Request Cost of Service

Resources

- Photovoltaic
- Battery storage
 - Fuel cell
 - Wind
- Thermal
 - Hydro
- Biogas
- Biomass
- Cogeneration
- Compressed Air
 - Flywheel
- **Combination DER**

Actors

Utilities
Aggregators
Independent System Operator
Individuals
Commercial Entities



Building A Sustainable Power Grid

Networks

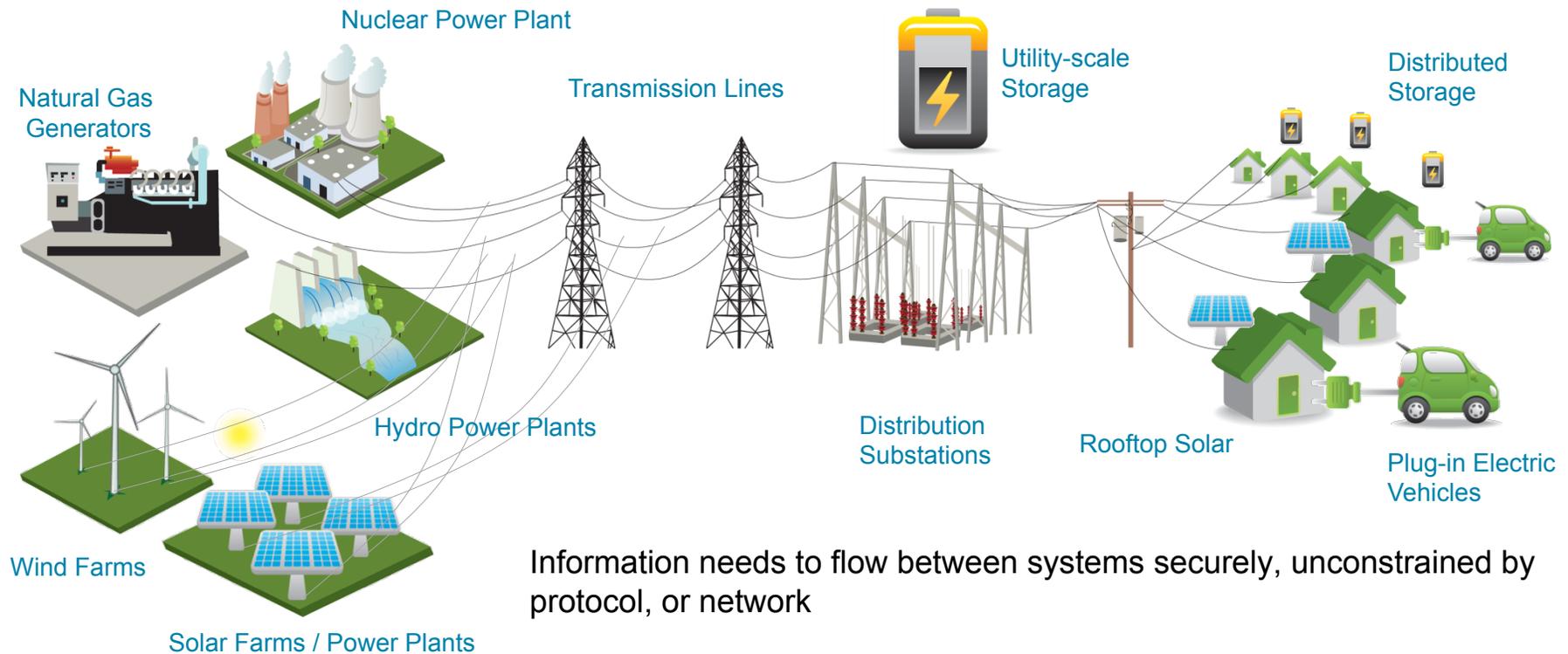
- Operational Data Network
 - Control network
- Corporate Data Network
 - Data Network

Communication Protocols

- Power Grid
 - SCADA
 - Legacy protocols
 - DNP3
 - ICCP

Communication Protocols

- Home Energy Management
 - AMI: IPv6
 - IIEE 2030.5
 - Thread
- Commercial Energy Management
 - Open ADR





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