Energy Technologies Area   Lawrence Berkeley National Laboratory

Grid-Modernization Technology Webinar

Presented to:

Hawaii Public Utilities Commission &

Rhode Island Public Utilities Commission

Presented by: Peter Cappers (LBNL), Chuck Goldman (LBNL)

Ronald Hofmann, Daniel Partridge, Michael Kast, Charles McParland

Agenda

- Policy Drivers for Grid Modernization (Ron Hofmann) … 2 minutes
- Evolution of Power Grid, Concepts, Standards (Ron Hofmann) … 15 minutes
- Grid-facing Technologies (Dan Partridge) … 25 minutes
- Consumer-facing Technologies (Mike Kast) … 20 minutes
- Cyber Security & Privacy (Chuck McParland) … 15 minutes
- Summary (Ron Hofmann) … 3 minutes
- Q&A (everyone) … 40 minutes

Policy Drivers for Grid Modernization

Policy Drivers for Grid Modernization

- Incentivize high-penetration of renewables replacing central fossil-fuel power plants
  - Utility (medium-voltage, distribution grid) vs. consumer (low-voltage, behind the meter)
- Encourage micro-grids
  - Residential communities
  - Industrial parks
  - Commercial buildings
- Implement dynamic pricing and incentive-based programs
  - Facilitate real-time demand response and 24/7 energy efficiency
- Allow virtual power plants (VPP)
  - Reduce renewable costs & minimize fossil fuel costs
- Deploy strategic distributed energy storage systems (ESS)
  - Utility (distribution grid) and consumer (behind the meter) installations
- Enable demand-side (load) management (DSM)
  - C&I energy management and information systems
  - Residential information gateways and home area networks

Evolution of Power Grid, Concepts, Standards

Evolution of Power Grid (1 of 2)

- The 20th-century grid was designed for power to flow from large centrally located generators to geographically distant uses called loads
- Grid topology
  - Transmission grid (T-grid)
    - Mesh network over long distances (100's of miles), bidirectional power flows
    - Voltages > 35 kV, 35-66 kV sometimes referred to as the sub-transmission grid
  - Distribution grid (D-grid)
    - Radial feeders over shorter distances (1-10's of miles), unidirectional power flows
      - Primary D-grid carries medium voltages (4-35 kV) – 1-10 miles
      - Secondary D-grid carries low voltages (100's of volts) – 100's of feet
  - Substations are the interfaces between various grids and sub-grids

Evolution of Power Grid (2 of 2)

- The 21st-century physical grid will need to accommodate significant penetration of distributed energy resources (DER) such as demand-side management (DSM), distributed generation (DG) and energy storage systems (ESS) located anywhere on the primary and secondary D-grids
- Grid modernization involves adding digital intelligence to grid-facing and consumer-facing equipment in the form of
  - Communications for information exchange
  - Programmable controls for system management
  - Computer intelligence for real-time situational awareness
- Late 20th-century initiatives were steps to Grid Modernization
  - Substation Automation (SA), Distribution Automation (DA), …
  - Intelligrid, Utility Communication Architecture (UCA), IEC-61850, …
  - Programmable communicating thermostats (PCT’s)

Recent Examples of Grid Modernization

- Florida Power & Light (FPL)
  - Advanced Meter Infrastructure (AMI) from Silver Spring Networks
  - Distribution Automation (DA) from S&C Electric and others
  - Line sensors from Sentient Energy
- Pacific gas & Electric (PG&E)
  - Advanced Meter Infrastructure (AMI) from Silver Spring Networks
  - Demand-Side Management (DSM) PCT's from Cannon/Honeywell
- Southern California Electric (SCE)
  - Advanced Meter Infrastructure (AMI) from Itron
  - Distribution Automation (DA) from S&C Electric and others

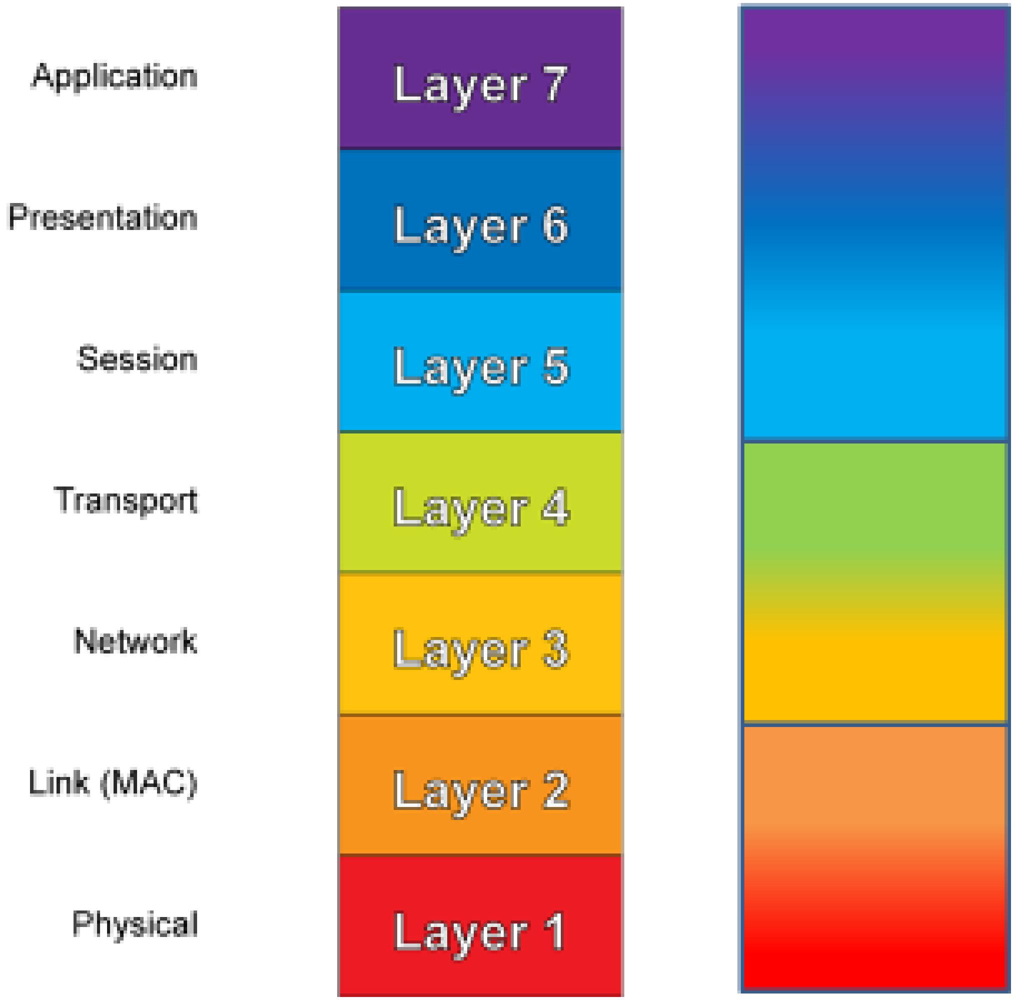
Important Grid-Modernization Concepts

- Three fundamental characteristics
  - Information exchange using digital communications
  - System management using programmable controls
  - Real-time situational awareness using sensors and computer-based analytics
- Technological issues
  - Central command vs. hierarchical, layered distributed control
  - One- vs. two-way communications
  - Public vs. private networks separated by firewalls
  - Information models (e.g., OpenADR) vs. point-to-point data exchange
  - Interoperability vs. plug and play (physical, data, protocols)
  - Standards (de facto & de jure), e.g., IEEE, IEC, IETF, etc., vs. proprietary protocols

Grid-Modernization Initiatives & Standards

- GWAC (GridWise® Architecture Council)
  - Erich Gunther
- GMI (Grid Modernization Initiative) funded by DOE
- Standards Groups
  - IEC PC 118 (Chairman: Richard Schomberg)
  - IEEE P2030.5 has published SEP 2.0 (Smart Energy Profile)
  - IEC 61850
- Industry Alliances
  - OpenADR 2.0 (Executive Director: Barry Haaser)
  - USNAP developed by Radio Thermostat Company of America
  - Wi Fi
  - Z-Wave developed by Zensys

7-Layer vs. 3-Layer OSI Reference Model



Application Domain: Where most innovation happens due to the low cost of development

Network/Transport Domain: Usually IP because it is open and robust

Physical Domain: Most Capital Intensive to develop and deploy

Grid-Facing Technologies

Technology Types

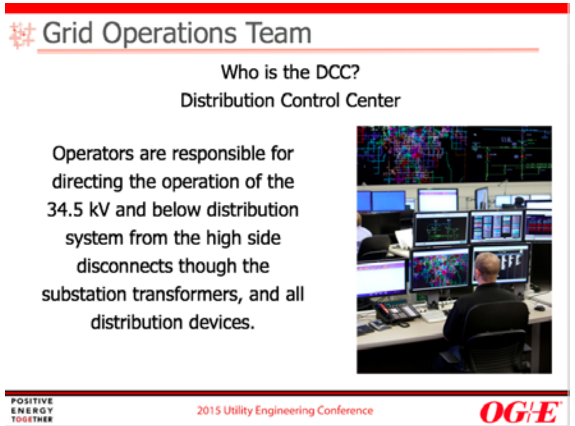
- SCADA (Supervisory Control And Data Acquisition)
  - Substation relays and telemetering
  - Traditional and modern
- AMI Infrastructure
  - Large Commercial & Industrial (C&I) (>200 kW) 3-phase with point-to-point communications (not mass-AMI)
  - Residential & light commercial (<200 kW) with mesh communications (AMI)
- Line Automation & Management
  - Line-sensor systems
  - Remotely operable line SCADA
  - Automatic circuit reconfiguration
  - Reclosers (SCADA & non-SCADA)
  - CVR (Conservation Voltage Reduction)
  - DERMS (Distributed Energy Resources Management System)
  - DMS (Distribution Management System) and ADMS (Advanced DMS)
  - FLISR (Fault Location, Isolation and Supply Restoration)
  - VVO (Volt/VAR Optimization)

Technology Challenges

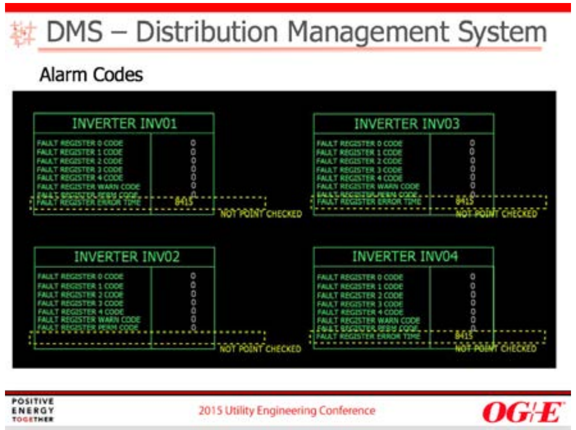
- Technologies are becoming available and being adopted by Electric Utilities at an increasingly rapid pace. However, the situation is problematic:
  - System needs are changing faster than solutions are becoming available.
  - There is never a right time to buy rapidly changing technology, the next generation always has a potential to include something you want
  - Core utility needs have a different life time than consumer technologies.
- This results in risks of stranded assets, and less than optimal solutions

SCADA Evolution: Advanced Distribution Management Systems (ADMS)

- Early
  - Substation centric, minimal integration with line equipment, no integration with customers. Drives problems for D-line communications and control
- Current/near term applications
  - SCADA is still growing
  - Integrated with OMS,
  - Coordinated with Line SCADA in FLISR systems,
  - some VVO integration with line capacitors and line regulators
- Long term evolution and issues
  - Integrated into Advanced Distribution Management Systems (ADMS) combining real time operations, real time sensor data, and continuous line modeling.
  - Present vision for large DG but will it have needed resilience?

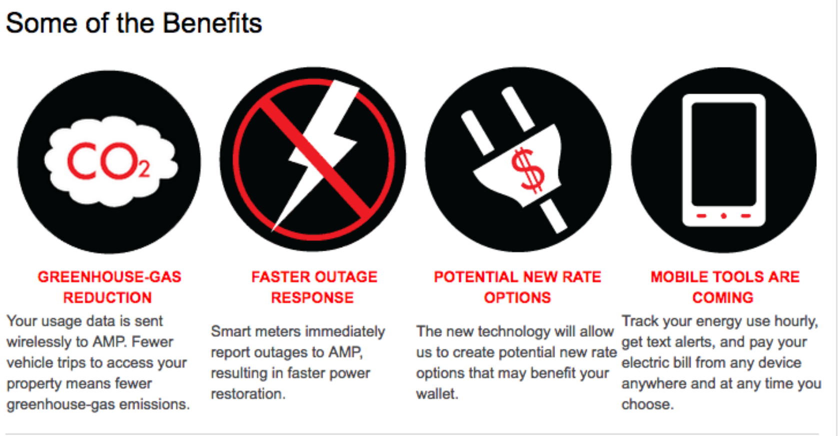


OG&E's SCADA and DMS

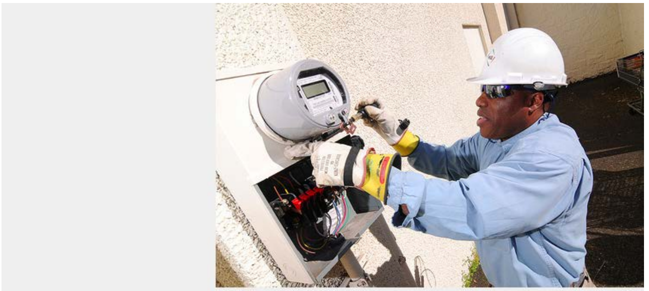


AMI Infrastructure

- Historic decision drivers
  - C&I customers: high value & high function force fit to ubiquitous communications options
  - Residential customers: direct meter reading labor savings, Time of Use, net metering, disconnect values
- Evolving landscape
  - Higher bandwidth is easy, “converged do-all networks”, C&I and DERMS residential have converging requirements
  - Meters can do more that support a bill – data mining, real time operational awareness, accurate customer power status calls
  - Meters can contribute to fault location rather than only scoping
- The evolving requirements have moved the market toward converging AMI and other Line automation systems onto a common communications platform.



Alameda Municipal Power Customer Service Web site



(Photo via Portland General Electric via Creative Commons)

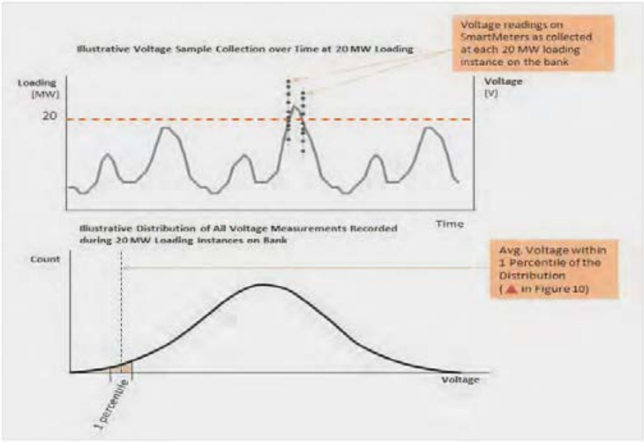
Meter reading was significantly improved in accuracy and timeliness with ARM. AMI further improved metering performance but is also driven by the ability to get much more at a similar cost.

AMI Infrastructure (cont’d)

AMI can be the portal into the customer experience

- Reduce manual read costs and increase read accuracy
- Demand response: Time-based pricing & Incentive-based programs
- Avoid service calls when issue is on customer side of the meter
- Faster turn on of new or paid-up service without field visit
- Remote verification of voltage complaints
- Data for advising customers on use management
- More accurate planning data
- Partial data for status of distributed generation
- Connectivity mapping
- Scope power outage
- Confirm power restoration
- Fault location (advanced)

Voltage recording for studies and operation is one of many AMI benefits



PG&E SmartGrid VVO project final report 12/2016

AMI Functions and Their Alternatives

Function	Description	Alternative
Weights and measures	Meters are tested and then sealed to assure customers are billed accurately	Legacy meters provide an accurate total net usage value
Control energy usage to optimize system and minimize cost	A change in the cost of energy has significant influence on when and how much energy is used	Bill only based on total net usage and identify other methods to incentivize energy conservation and time domain use without the ability to measure and verify
Voltage measurement	There is an increasing use of voltage from meters for system diagnostics and voltage must be managed when connecting Distributed Generation or Storage	Install voltage sensors at critical points throughout the system
Multi-use of communications infrastructure	Utility implementations are trending toward sharing a single communications system between line automation and AMI to minimize costs	Use 3rd party communications rather than utility operated e.g. cell phone
Messaging to customers	Many AMI systems include some type of Home Area Network (HAN) capability	Require customers that participate in HAN type programs have internet connections

Automation Landscape Over Time

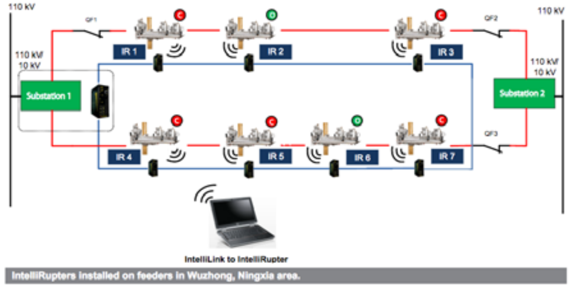
- SCADA (substation) > DMS
- Planning load f tools > DMS
- Line SCADA > Line Automation > DMS
- Line management > CVR > VVO
- Mapping > GIS
- VVO + DMS > Advanced DMS
- ADMS + Edge Devices > DERMS

- Terminology reflects the legacy of independently developed applications
- Higher level systems such as DMS may or may not include all the elements listed

Line Automation & Management

- Contributes to higher reliability levels
  - Line-sensor systems
  - Remotely operable line automation
  - FLISR (Fault Location, Isolation and Supply Restoration)
  - Reclosers (Automated and not-automate)
- Slow to grow, but moving fast now
- Drives real reliability improvements, labor savings very dependent on business process change
- Present systems are not fully addressing DERMS functional challenges for protection (one way versus two way) and voltage management

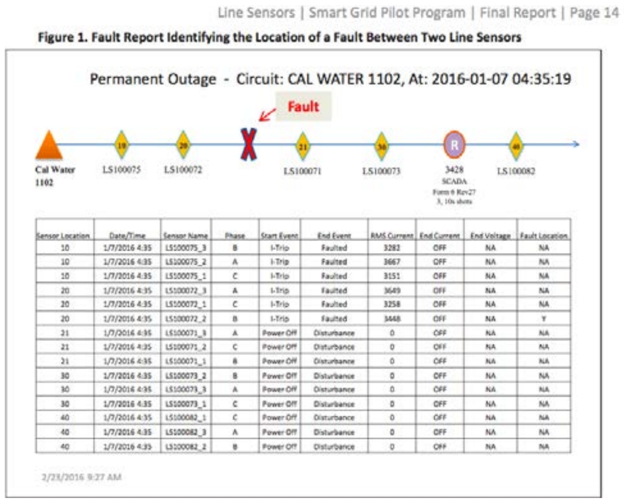
Utilities are increasing their use of FLISER



S&C Electic's FLISR system IntelliTeam™

Automation without communications is common

G&W Electric, line recloser



Line Sensors | Smart Grid Pilot Program | Final Report | Page 14

Figure 1. Fault Report Identifying the Location of a Fault Between Two Line Sensors

Permanent Outage - Circuit: CAL WATER 1102, At: 2016-01-07 04:35:19

Fault

Cal Water 1102 — LS100075 — LS100072 — LS100071 — LS100073 — 3428 SCADA Form 6 Rev27 3, 10s shots — LS100082

Sensor Location	Date/Time	Sensor Name	Phase	Start Event	End Event	RMS Current	End Current	End Voltage	Fault Location
10	1/7/2016 4:35	LS100075_3	B	I-Trip	Faulted	3282	OFF	NA	NA
10	1/7/2016 4:35	LS100075_2	A	I-Trip	Faulted	3667	OFF	NA	NA
10	1/7/2016 4:35	LS100075_1	C	I-Trip	Faulted	3151	OFF	NA	NA
20	1/7/2016 4:35	LS100072_3	A	I-Trip	Faulted	3649	OFF	NA	NA
20	1/7/2016 4:35	LS100072_1	C	I-Trip	Faulted	3258	OFF	NA	NA
20	1/7/2016 4:35	LS100072_2	B	I-Trip	Faulted	3448	OFF	NA	Y
21	1/7/2016 4:35	LS100071_3	A	Power Off	Disturbance	0	OFF	NA	NA
21	1/7/2016 4:35	LS100071_2	C	Power Off	Disturbance	0	OFF	NA	NA
21	1/7/2016 4:35	LS100071_1	B	Power Off	Disturbance	0	OFF	NA	NA
30	1/7/2016 4:35	LS100073_2	B	Power Off	Disturbance	0	OFF	NA	NA
30	1/7/2016 4:35	LS100073_3	A	Power Off	Disturbance	0	OFF	NA	NA
30	1/7/2016 4:35	LS100073_1	C	Power Off	Disturbance	0	OFF	NA	NA
40	1/7/2016 4:35	LS100082_1	C	Power Off	Disturbance	0	OFF	NA	NA
40	1/7/2016 4:35	LS100082_3	A	Power Off	Disturbance	0	OFF	NA	NA
40	1/7/2016 4:35	LS100082_2	B	Power Off	Disturbance	0	OFF	NA	NA

2/23/2016 9:27 AM

PG&E evaluated reliability benefits from sensor systems

Line Automation & Management (cont'd)

- Primarily system management
  - CVR (Conservation Voltage Reduction)
  - Line-sensor systems
  - DERMS (Distributed Energy Resources Management System)
  - DMS (Distribution Management System) and ADMS (Advanced DMS)
  - VVO (Volt/VAR Optimization)
- CVR benefits are customer benefits so these projects are typically driven by regulators not the utility. Also effectiveness may be decreasing due to changes in the technologies used within the home.
- Some type of voltage management and awareness of line segment loading is critical to increased DERMS

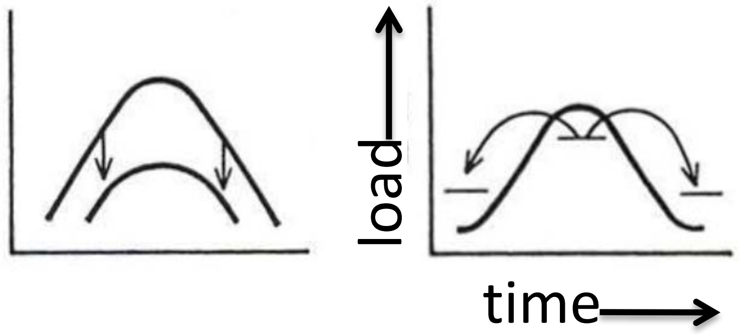
CVR investigations started in the 1980 's and are still a SmartGrid topic

PG&E final report, SmartGrid VVO project 12/2017

Customer-Facing Technologies

Technology Types

- **D**emand **S**ide **M**anagement (DSM)
  - Load reduction and load shifting
    - Residential & small commercial (<200 kW)
    - C&I (loads or demand >200 kW)



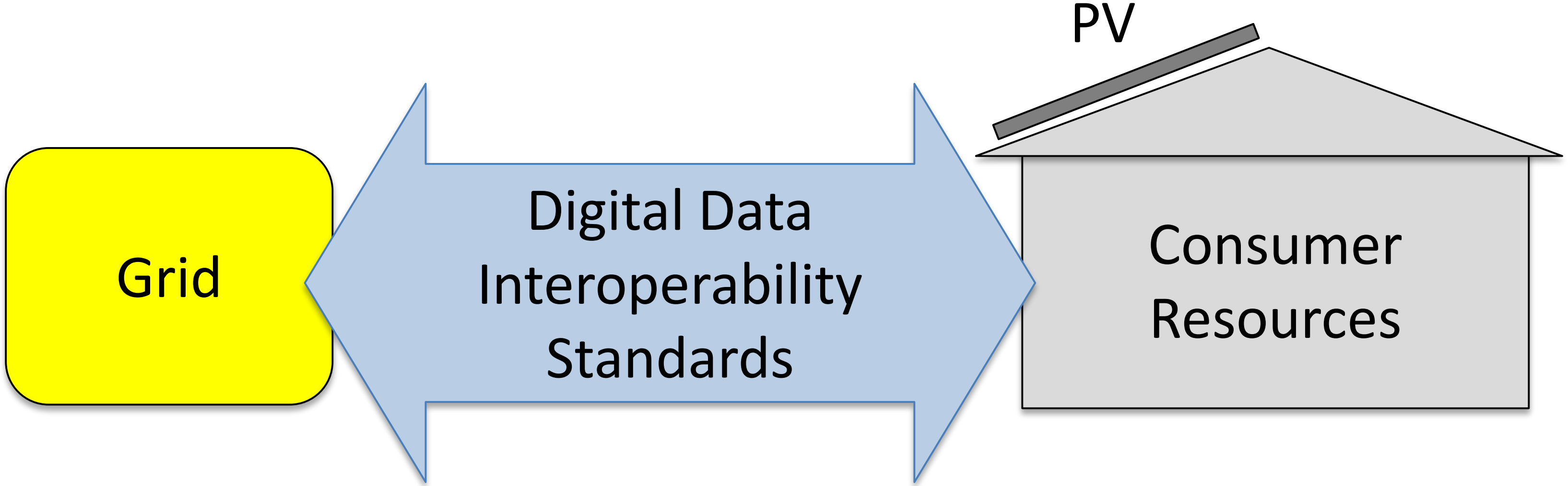
- **D**istributed **G**eneration (DG)
  - Photovoltaic, wind, …
  - Fossil fuel (oil, diesel, etc.)
  - Renewable biomass

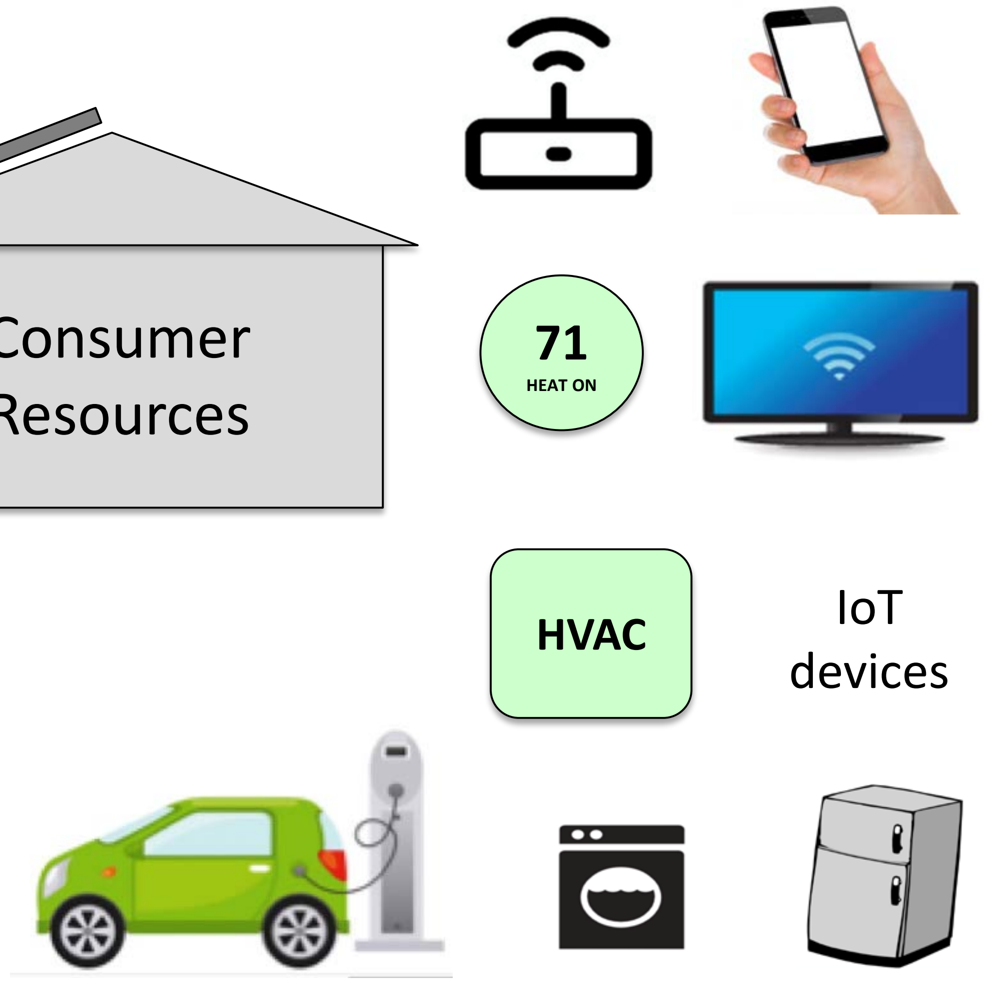
- **E**nergy **S**torage **S**ystem (ESS)
  - Dedicated batteries, electric vehicles
  - Thermal, mechanical

DSM Control Technology Evolution

- 20th Century: Utility Control
  - Utility controls and signals managing consumer loads
  - Direct load control: analog or digital signals that turn loads on and off (AC setback, water heater lockout, etc.), utility managed and controlled
- 21st Century: Consumer Choice
  - Digital information: event and pricing signals for intelligent devices
  - Consumer purchased equipment functioning in concert with Utility programs
- Present: Gateways for DSM – Residential
  - Residential: Utility Smart Meters, Customer equipment, i.e., routers, cable modems, PCT's, smart inverters
  - Commercial & Industrial Customer equipment, i.e., Energy Management Systems, Energy Information Systems
- Future: quickly developing, difficult to predict consumer driven products and services

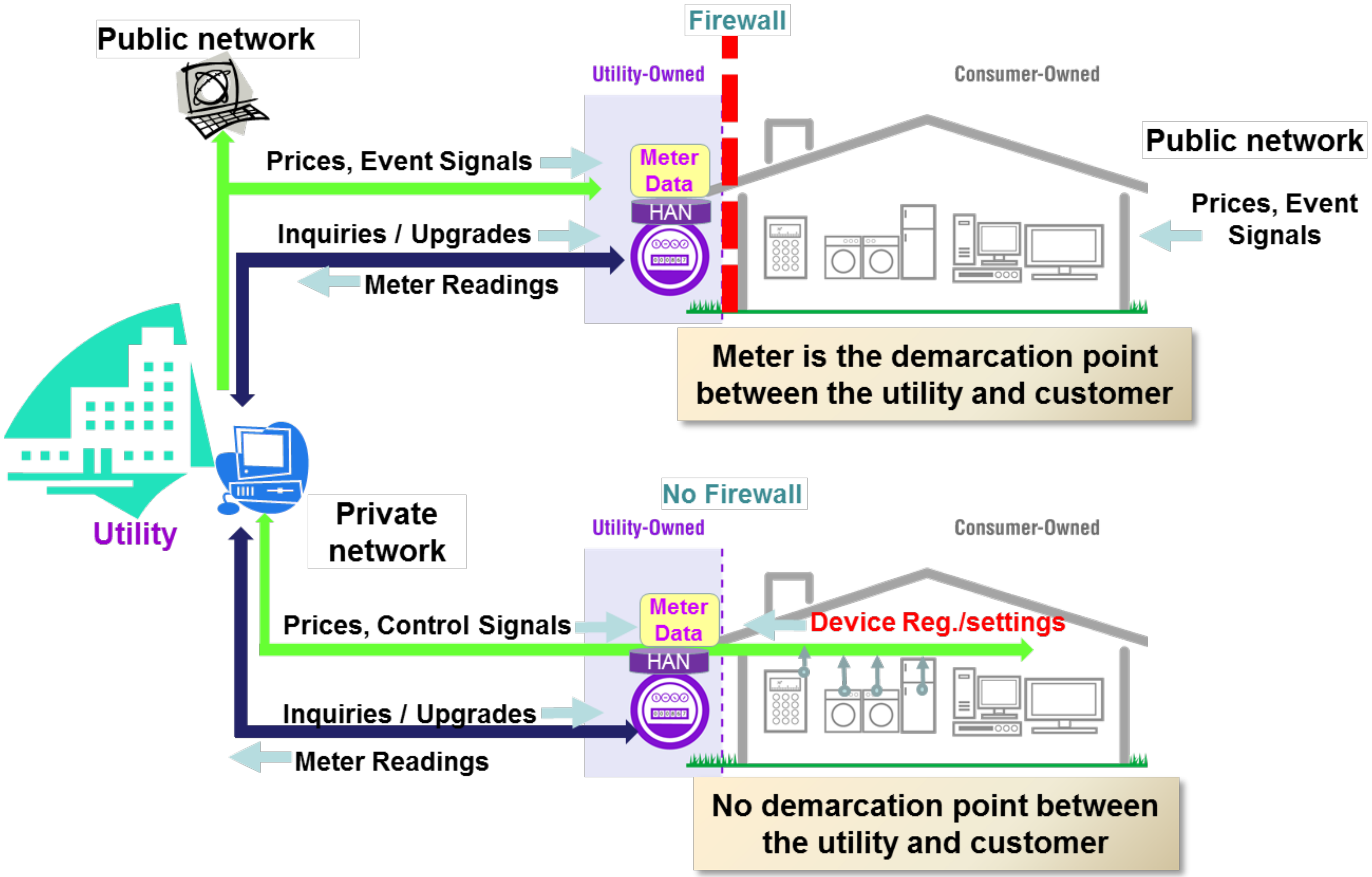
Data Interface Standards Facilitate Grid-Edge Development





Seamless exchange of information between grid-facing and consumer-facing technologies

AMI Firewall Location Defines the Grid Edge



- Grid data incorporated into local control algorithms
- SmartMeter observes and records results

- Utility determines control
- SmartMeter observes and records results
- Or, conventional meter assumes function without verification

Residential Technologies

- Communicating consumer grid-edge devices and control platforms
  - Fast moving commercial development of equipment and software addresses consumer expectations - Utility specific products no longer dominate
  - Comfort & convenience systems: Programmable communicating thermostats, irrigation and lighting controllers, pool filter pump controllers, …
  - Entertainment systems: routers, cable boxes, smart TV's, …
  - Security systems: intrusion detection, fire alarms, …
  - Appliances: clothes washer & dryer, dishwasher, refrigerator & freezer, …
  - Consumer purchased and/or utility or qualified third party provided
- Pricing data and/or control signals from utility, qualified third party
  - Communication through the utility meter or public networks, e.g., Internet
- Home Energy Management Systems (HEMS)
  - application software residing on security and entertainment systems platforms

Commercial & Industrial Technologies

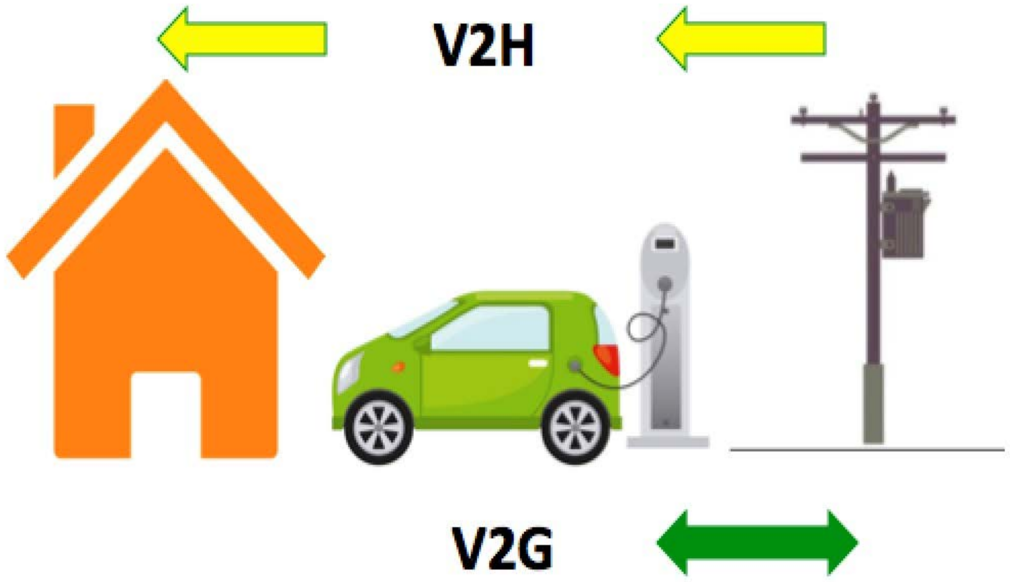
- Established and diverse vendor bases with continuing development
- Energy Management Systems (EMS)
  - Historically a misnomer – focused on comfort not energy
  - Substantial operating history with utility-sponsored DR programs (validated with M&V programs) but recently TOU pricing has emerged
  - Mass deployment of Smart Meters not required - C&I loads can justify specialized communication paths including dedicated telephone lines
- Energy Information Systems (EIS)
  - Software tools that store, analyze, and display energy consumption data
  - Web accessibility, visualization and graphics, calculation of consumption baselines, load profiling, anomaly detection, energy costing, and cost forecasting. Example: Itron (acquired Silicon Energy)

DG and ESS – Customer Perspective

Description	Operational Features	Enabling Grid Modernization Elements
Renewables Generation: PV, Wind, Biomass	Load diminishing	Data exchange (hidden load)
Fossil fuel Generation: gas, diesel	Load diminishing	Data exchange (hidden load)
Electric energy storage with fixed installation batteries, e.g., Tesla Powerwall	Load Shifting	Data exchange, Controls
Electric energy storage with Electric Vehicle (EV) batteries, V2G/V2H/V2B	Load Shifting	Data exchange, Controls
Pumped water storage and energy recovery	Load Shifting	Data exchange, Controls
Ice / Chilled water for HVAC cooling	Load Shifting	Data exchange, Controls
Hot-water storage for domestic cleaning , industrial process	Load Shifting	Data exchange, Controls
Quick Response Mechanical storage, i.e., flywheels	Bridge	Data exchange, Controls

ESS Example: Electric Vehicles V2H/V2G

- Specialized consumer owned battery storage
- Potential for bi-directional flow of power
- V2H: Vehicle to Home (also V2B; vehicle to builc
  - Closed system local to customer load
  - Customer decides operating conditions
  - Shares functional aspects with Tesla Powerwall
- V2G: Vehicle to Grid
  - Battery to grid power applied to electric vehicles
  - Complex system
  - Proof of concept trials underway but relatively long development anticipated
- Both approaches require advanced smart inverter technology with data exchange



Cyber Security & Privacy

Overview Concepts

- Cyber security and privacy are different issues.
  - Cyber security enables privacy.
  - Poor cyber security renders privacy moot.
  - Who defines “best practices”.
- Public privacy policies are essential.
  - Public/regulatory guidance essential to inform utility implementation plans.
  - Privacy and security are not absolute – what is “good enough”?

Nomenclature

- 7-layer OSI reference model.
  - Basis for modern discussions about all things related to networks.
- Attack surfaces
  - How do you attack programs and systems?
- “Zero”-day exploits.
  - Undiscovered vulnerabilities that can be exploited to subvert a system.
  - Until seen and publicized, they remain a hidden system weakness.
- Crypto keys, credentials, passwords and “shared secrets”.
  - All the above are responses to system requirements for user “authentication” and “authorization”.
  - Vary widely in effectiveness.

Existing Cyber Threats

- Attackers and their Motivations.
  - Hacker/disgruntled insider.
  - Social/political “stakeholder” attack.
  - Terrorist/nation state attack.
- Attack Modalities.
  - Denial of service (DNS) at multiple levels.
  - Masking of system physical state (N-1 attacks).
  - Probing attacks designed to test continued viability of “highly engineered” attack strategies.

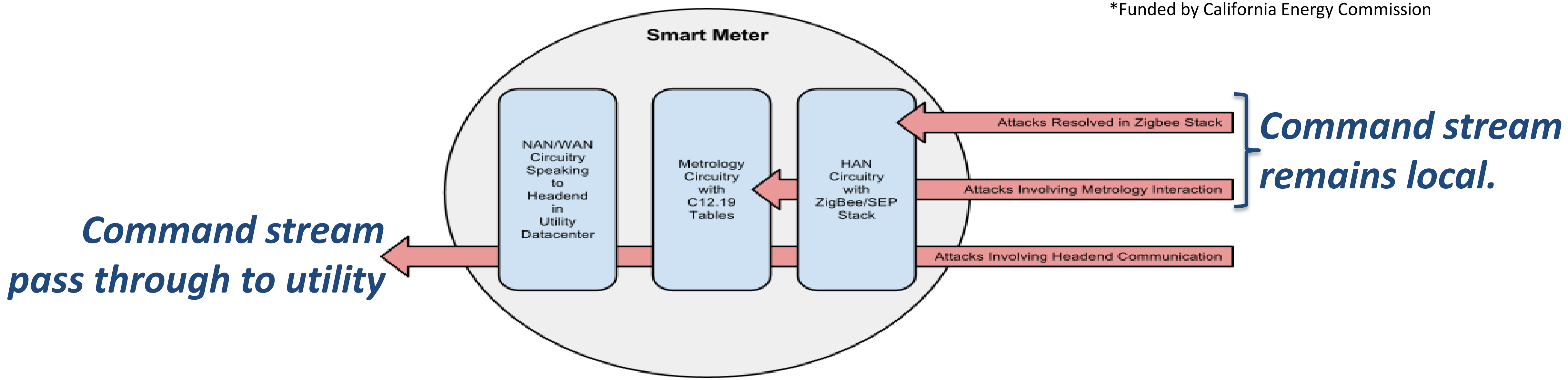
More Than Encrypted Communications

- Planning
  - Protected vs. open networks.
  - System architecture is key to cyber security.
  - Boundary between “attacks” and “accidents” increasingly blurred.
- Assumptions and Approaches
  - Despite best efforts, system will be penetrated.
    - Physical attacks.
    - Social engineering attacks.
  - Risk assessment essential to support “no regrets” policy decisions
    - Start assessment early…cyber security expertise not always necessary.
    - Lack of risk assessment/agreement can make decisions difficult/impossible.
  - Work force considerations (job skills, increased levels of effort.)

Smart Meters - System-level Security View

- Utilities are concerned about the potential Smart Meter attacks enabled by the presence of a Home Area Network (HAN) radio interface within the meter.
    - Most HAN requests are handled by the circuitry in the meter
    - Some requests interact with the metrology circuitry and data tables
    - A small number of requests get passed through the meter all the way up to the Smart Meter and Demand Response management servers at the utility operations center.
- A small number of operations – namely those that propagate to the utility itself - represent potential system-level attack surfaces.
    - These attack surfaces and their related exploit probabilities have been evaluated*. Vulnerabilities in deployed systems is minimal.

*Funded by California Energy Commission



By limiting some system capabilities, these risks can be eliminated or managed.

Summary

Concepts

- The 20th century D-grid was/is
  - Unidirectional power flow, a “downhill” topology, minimal real-time situational awareness, predominantly analog technology
- The 21st century D-grid will be
  - Multidirectional power flow, a “complex” topology, maximum real-time situational awareness, predominantly digital technology
  - Characterized by
    - Information exchange (communications) between all distributed energy resources
    - System-wide management using programmable (remotely upgradeable) controls
    - Sensors and computer-based analytics automatically informing decision making

Grid-Facing Technologies

- SCADA (Supervisory Control And Data Acquisition)
  - Evolving architecture but not designed to address distributed energy resources
- AMI (Advanced Metering Infrastructure)
  - Primarily a metering infrastructure but provides information for outage management, remote connect/disconnect, and other utility services
- Line automation & management
  - Ubiquitous sensing that can support a variety of DER-related applications
  - Envisioned to add real-time management to an evolving D-grid
  - Potentially could improve D-grid reliability and resiliency following natural disasters and malicious human attacks

Consumer-Facing Technologies

- Demand-side management (DSM)
  - Individual device load control, e.g., PCT's, on-off switches, smart appliances
    - Consumer choice or utility actuated
  - System load control (EMCS's, HEM, EIS, …)
- Distributed generation (DG)
  - Rooftop PV, wind, biomass
- Energy storage systems (ESS)
  - Batteries (electrochemical) such as Tesla Powerwall & EV V2H
  - Thermal systems such as ice
  - Mechanical systems such as flywheels

Cyber Security & Privacy

- Cyber security
  - Prevention is the key to minimizing threats
  - Best practices must become standard practices
  - Policy must lead the way
  - Standards should not be ignored, e.g., 7-layer communications model
  - Evaluation and elucidation of attack surfaces are critical
  - Planning needs to precede implementation
- Privacy
  - Establish clear firewalls
  - Consumers should have to “opt-in” to allow information to cross firewall

Final Comments

- Smaller utilities will need to find a way to adopt existing solutions
- Firewalls need to clearly limit physical and informational access
- Future proofing requires layered solutions
  - Applications need to be replaceable without adversely affecting other apps
  - Layers need to have well defined interfaces with neighboring layers
- Equipment controls need to be software-based, e.g., remotely fixable and upgradeable
- Communications protocols need to be secure at every layer, i.e., from the physical layer to the application layer

Appendix

Acronyms (1 of 3)

- 6LoWPAN (Version 6 of IP Low-power Wireless Personal Area Network)
- A/C (Air Conditioning)
- ADMS (Advanced DMS)
- ADR (Automated Demand Response)
- AMI (Automated/Advanced Metering Infrastructure)
- AMR (Automatic Meter Reading)
- BACnet (Building Automation and Control network)
- BAS (Building Automation System)
- BMS (Building Management System)
- C&I (Commercial & Industrial)
- CEC (California Energy Commission)
- CFL (Compact Fluorescent)
- CVR (Conservation Voltage Reduction)
- DA (Distribution Automation)
- DER (Distributed Energy Resources)
  - DER = DG + DR + DS
- DERMS (Distributed Energy Resources Management System)
- DG (Distributed Generation)
- DMS (Distribution Management System)
- DNP3 (Distributed Network Protocol version 3)
- DNS (Denial of Service)
- DOE (Department of Energy)
- DR (Demand Response)
- DS (Distributed Storage)
- DSM (Demand-Side Management)

Acronyms (2 of 3)

- EIS (Energy Information System)
- EMCS (Energy Management Control System)
- EMS (Energy Management System)
- EPRI (Electric Power Research Institute)
- ESS (Energy Storage System)
- FAN (Field Area Network)
- FLISR (Fault Location, Isolation & Supply Restoration)
- GMI (Grid Modernization Initiative)
- GWAC (GridWise Architecture Council)
- HAN (Home Area Network)
- HEMS (Home Energy Management System)
- HVAC (Heating Ventilating & Air Conditioning)
- IEC (International Electrotechnical Commission)
- IEEE (Institute of Electrical and Electronics Engineers)
- IETF (Internet Engineering Task Force)
- IoT (Internet of Things)
- IIoT (Industrial Internet of Things)

Acronyms (3 of 3)

- IP (Internet Protocol)
- ISO (Independent System Operator)
- IT (Information Technology)
- LED (Light Emitting Diode)
- LBNL (Lawrence Berkeley National Lab)
- OMS (Outage Management System)
- OpenSEG (Open Smart Energy Gateway)
- OSI (Open Systems Interconnection)
- PCT (Programmable Communicating Thermostat)
- PV (Photovoltaic)
- RTCOA (Radio Thermostat Co. of America)
- RTO (Regional Transmission Organization)
- RTP (Real-Time Pricing)
- SAIDI (System Average Interruption Duration Index)
- SAIFI (System Average Interruption Frequency Index)
- SCADA (Supervisory Control And Data Acquisition)
- SEP (Smart Energy Profile)
- TOU (Time Of Use)
- UCA (Utility Communications Architecture)
- V2G (Vehicle To Grid), V2H (Vehicle to Home)
- VAR (Volt-Ampere Reactive)
- VVO (Volt/VAR Optimization)
- VPP (Virtual Power Plants)