Energy Storage Safety at CPUC 2010-2017

The Energy Storage Safety Forum
February 22-24, 2017

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Safety & Enforcement Division

AGENDA

- **CPUC's 1.3 GW Energy Storage Initiative**
  - Background
  - 2013 Decision – Storage Targets
  - Current State of Market
  - Customer-Side Systems – Local Permitting
  - Safety Considerations in Procurement – Grid Scale
  - Utility Owned -- Inspection Guidelines

1,325 MW in operation by 2024

Summary of AB 2514 (2010 Skinner)

- Directed CPUC to open a proceeding to:
  - Adopt procurement targets, *if appropriate*, for each LSE to procure viable & cost-effective energy storage
    - To be achieved by EOY 2015 & EOY 2020
  - *Consider policies* to encourage deployment of energy storage
- Deadline for CPUC decision by October 2013
- CPUC to re-evaluate its determinations every three years

Storage OIR R.10-12-007

- Established framework of storage applications/Use Cases
  - 21 end uses
  - Distinct types of storage to consider from policy perspective
- Identified regulatory barriers to storage deployment
- Recognized distinct storage flexibility benefits
- Developed specific Use Case descriptions
- Preliminary cost-effectiveness analysis of selected use cases by EPRI & DNV KEMA

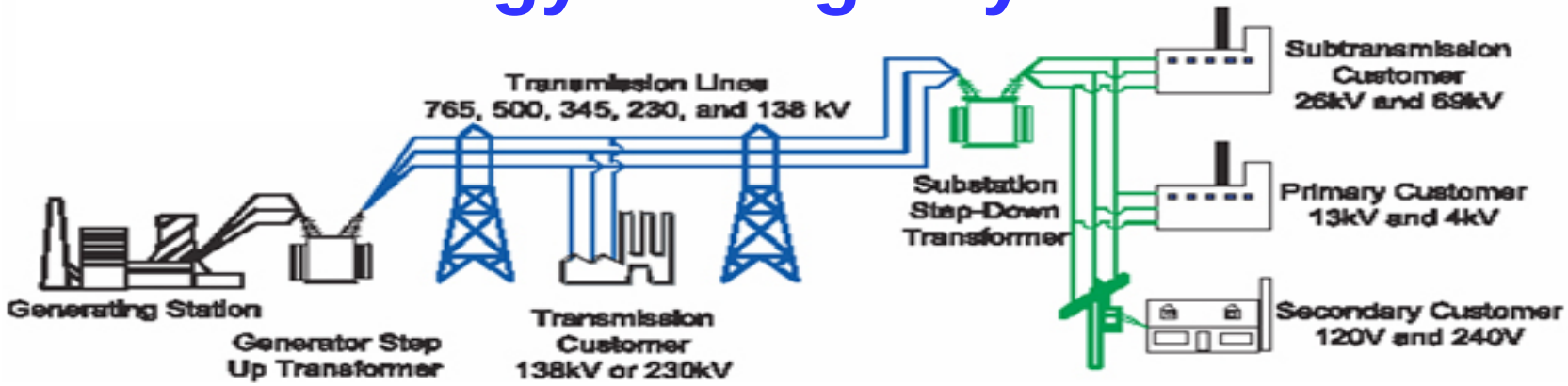
Goals & Objectives

- Goal: To begin integrating energy storage into the power grid in support of statewide strategies to reduce carbon emissions
  - Drive storage market transformation
  - Eliminate or reduce regulatory, commercial, and financial barriers to storage deployment
  - Gain development and operational experience

- Storage projects must address at least one policy objective:
  - Integration of renewable energy sources
  - Grid optimization (peak reduction, reliability needs or T&D deferment)
  - Reduction of GHG emission

Category	Storage "End Use"
Independent System Operator / Wholesale Market	• Frequency regulation • Spin/non-spin/replacement reserves • Ramp • Black start • Real time energy balancing • Energy price arbitrage • Resource adequacy
Renewables Integration	• Intermittent resource integration: wind (ramp/voltage support) • Intermittent resource integration: photovoltaic (time shift, voltage sag) • Supply firming
Transmission & Distribution (Grid Operation)	• Peak shaving: off-to-on peak energy shifting (operational) • Transmission peak capacity support (upgrade deferral) • Transmission operation (short duration performance, inertia, system reliability) • Transmission congestion relief • Distribution peak capacity support (upgrade deferral) • Distribution operation (Voltage Support/VAR Support) • Outage mitigation: micro-grid
Customer Use	• Time-of-use /demand charge bill management (load shift) • Power quality • Peak shaving (demand response), Back-up power

Energy Storage Systems



Bulk Generation		Xmission	Distribution	Behind-the-Meter
Renewable –Sited Storage	**Transmission Connected Bulk Storage**	**Transmission Grid Storage**	**Distribution Grid Storage**	**Customer-Sited Storage**
▪ CSP ▪ Wind + Storage	▪ A/S ▪ Peaker ▪ Load following	***FERC Jurisdiction***	▪ Substation Level Storage ▪ Distributed Peaker ▪ Community ES	▪ Bill mgt / PLS ▪ Power quality ▪ EV charging
←== Transmission-Connected ==→				

What Was in the Initial Decision

On October 17, 2013, the CPUC approved final decision D. 13-10-040 to set storage procurement targets and policies for load-serving entities (utility & non-utility):

- Up to 1,325 MW of storage by 2020 in 4 biennial bidding auctions, starting December 2014;
- PG&E 580 MW; SCE 580 MW; SDG&E 165 MW (totals)
- Storage for Transmission-connected, Distribution-level and Customer-Side of the Meter applications;
- Up to 50% utility ownership for storage across all categories (except);
- Distribution for reliability is utility-owned;
- Storage from other solicitations (SGIP, LTPP) may apply to targets;
- Non-utility LSEs have later targets ~ 1% of peak load by 2020;
- Market Transformation rationale for targets.
- Cost-effectiveness needed to be “disproved” by utilities.

Procurement Targets: by Year and Utility

Proposed Energy Storage Procurement Targets (in MW)[22]

Storage Grid Domain Point of Interconnection	2014	2016	2018	2020	Total
Southern California Edison					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal SCE	**90**	**120**	**160**	**210**	**580**
Pacific Gas and Electric					
Transmission	50	65	85	110	310
Distribution	30	40	50	65	185
Customer	10	15	25	35	85
Subtotal PG&E	**90**	**120**	**160**	**210**	**580**
San Diego Gas & Electric					
Transmission	10	15	22	33	80
Distribution	7	10	15	23	55
Customer	3	5	8	14	30
Subtotal SDG&E	**20**	**30**	**45**	**70**	**165**
Total - all 3 utilities	**200**	**270**	**365**	**490**	**1,325**

Additional Directives in the CPUC Decision

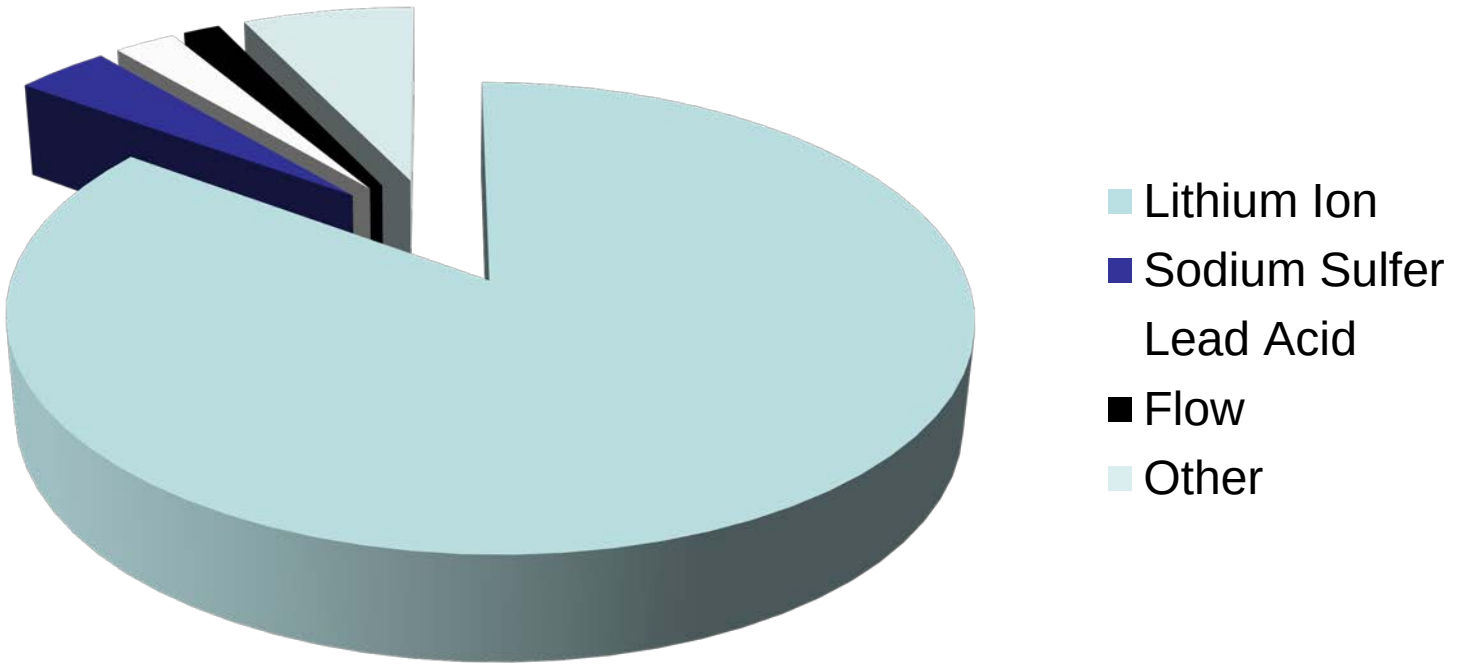
- **Every two years, utility procurement applications due March 1, followed by a solicitation on December 1**
- **Ownership**
  - Utility-owned storage limited to 50% of cumulative targets
  - IOU allowed to own storage assets on customer-premise
  - IOU could contract with either Customer or third party-owned assets
- **Pumped Storage >50 MW not eligible**
- **Target Flexibility**
- **Project Eligibility**
- **Other Guidelines**
  - Program Evaluation
  - Cost Effectiveness Evaluation

Procurement Targets: Current Status

Utility	Total MW Goal By 2024	Total Procured to Date	New AB 2868 Goals	Proposed for 2016 RFO
Southern California Edison	580	537.7	~167	20
Pacific Gas & Electric	580	94	~167	115.3
San Diego Gas & Electric	165	116.6	~167	144
Total	**1,325**	**749**	**500**	**279.3**

Any technology has its problems, especially an emerging technology

Installed by Technology 2013-2015



Lithium Ion remains dominant with ~98% of 2016 installations – GTM Research

Flywheel Storage Device Blast
Poway, California
June 10, 2015

Kahuku Wind Facility Fire, 2012

"The fire had spread through some of the batteries and was now in front of the door so the use of the dry chemical was not sufficient to knock down the fire to the point where we could extinguish,"

-- Capt. Terry Seelig, Honolulu Fire Department

Storage Safety in California Proceedings Customer-Side Systems

In 2014, Commission was determining energy storage eligibility for net energy metering (NEM) program and sought to incorporate safety as a program criterion.

However, CPUC does not have jurisdiction over local permitting for residential and small commercial units under our Rule 21 interconnection process.

In D.14-05-033 Commission staff were directed to work with State Fire Marshall, Governor's Office of Planning & Research and others to "develop a set of comprehensive standards and practices to improve permitting and inspection by local authorities…." and to promulgate them on Commission web site and help promote them statewide.

Storage Safety in California Proceedings
Customer-Side Systems

County of Santa Clara
Development Services Office
Building Inspection Office
Land Development Engineering and Surveying

Interconnection of storage battery systems

Field Inspection Guidelines for interconnected residential battery storage systems

- *Multiple references to National Electrical Code 690.71, etc. & UL 1741*
- A system maintenance plan shall be submitted to the building inspection office at time of permit application in order to ensure the homeowner is aware of the system maintenance requirements.
- Energy storage systems shall be listed to UL 1989 or 9540 as applicable.
- Applicant must provide a letter from the serving utility indicating they have been notified of the proposed battery/ energy storage system installation.
- Any field modifications to the electrical service, or line side connections are subject to field inspector approval and may require accredited third party field evaluation.

County of Santa Clara
Development Services Office
Building Inspection Office
Land Development Engineering and Surveying

All appropriate signage must be installed in accordance with NEC (see Santa Clara County interconnected power system signage guidelines).

- Signs Shall Be Weatherproof and Suitable for the Environment they are Installed.

- Lettering Shall Be a Minimum Letter Height of 3/8” Permanently Affixed.

- A Permanent Plaque or Directory, Denoting All Electric Power Sources on or in the Promises Shall Be Installed at Each Service Equipment Location and at Locations of all Power Sources Capable of Being Interconnected.

SANTA CLARA COUNTY BUILDING INSPECTION OFFICE

TYPICAL RESIDENTIAL INTERCONNECTED STORAGE BATTERY SYSTEM REQUIRED SIGNAGE

SIGNS SHALL BE WEATHERPROOF AND SUITABLE FOR THE ENVIRONMENT THEY ARE INSTALLED
LETTERING SHALL BE A MINIMUM LETTER HEIGHT OF 3/8" PERMANENTLY AFFIXED.

CAUTION STORAGE BATTERY SYSTEM
CONNECTED

Label Main Service: CEC 705.12(D)(4)

WARNING
INVERTER OUTPUT CONNECTION
DO NOT RELOCATE THIS
OVERCURRENT DEVICE

Label on POI breaker if OCPDs exceed 100% of bus rating CEC 705.12 (D) (7)

A PERMANENT PLAQUE OR DIRECTORY, DENOTING ALL ELECTRIC POWER SOURCES ON OR IN THE PROMISES SHALL BE INSTALLED AT EACH SERVICE EQUIPMENT LOCATION AND AT LOCATIONS OF ALL POWER SOURCES CAPABLE OF BEING INTERCONNECTED

To be applied at exterior of building in readily visible location.
A directory needs to be installed when utility service disconnect and
PV system disconnect are not in the same location.
Must be at the location of the photovoltaic system disconnecting means.
NEC 705.10

Safety in the California Energy Storage Procurement Proceeding

- Decision 16-01-017 requires “all applications to identify all relevant safety considerations implicated by the application.”

- The Commission had been criticized by the legislature for not originally having safety in the energy storage proceeding.

- The 2014 and 2016 applications from the utilities included safety language but to a very mixed degree. Common elements:
  - Project Safety Plan;
  - System specifications, Factory & Site Acceptance Testing standards;
  - Attestation of performance to safety requirements and Prudent Electrical Practices, by both Seller and a Licensed Professional Engineer;
  - Notification of any safety incidents within 5 days;
  - Shut down in case of serious incidents; utility has to approve restart.

Storage Safety in California Proceedings
Grid-Scale Systems

- In August 2015, CPUC SED and Energy Division staff conducted a workshop to review safety and operational experience of utility installed energy storage:

- UL gave an overview of its safety standards for storage, with a particular focus on development of UL 9540 as well as on UL 1973. UL also discussed certification and labeling of energy storage technologies.

- Sandia National Lab presented on behalf of the Energy Storage Integration Council (ESIC) Subgroup on Safety, Draft of **"Guide to Safety in Utility Integration of Energy Storage Systems"** was presented.

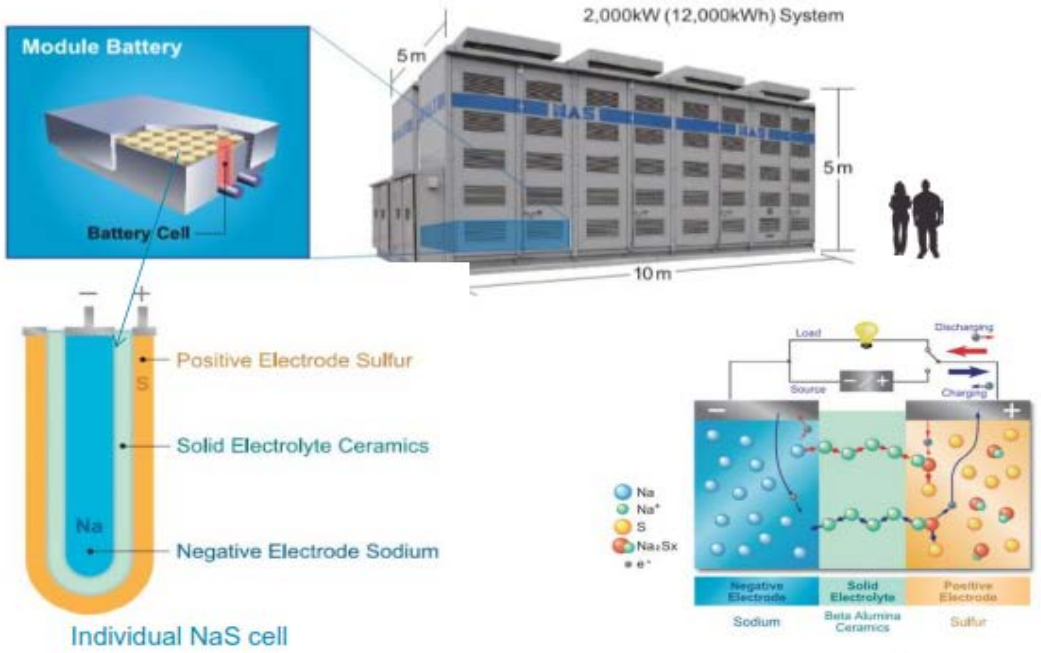
Storage Safety in California Proceedings
Grid-Scale Systems

California utilities gave presentations on early operations and lessons learned at their own storage facilities:

- PG&E: The 2 MW battery energy storage project at the Vaca-Dixon substation, operational in August 2012 and commenced market operations in August 2014.
- The 4 MW Yerba Buena battery energy storage project near San Jose, operational in May 2013, completed the interconnection process in August 2014, and began market participation in Fall 2015.

Storage Safety in California Proceedings
Grid-Scale Systems

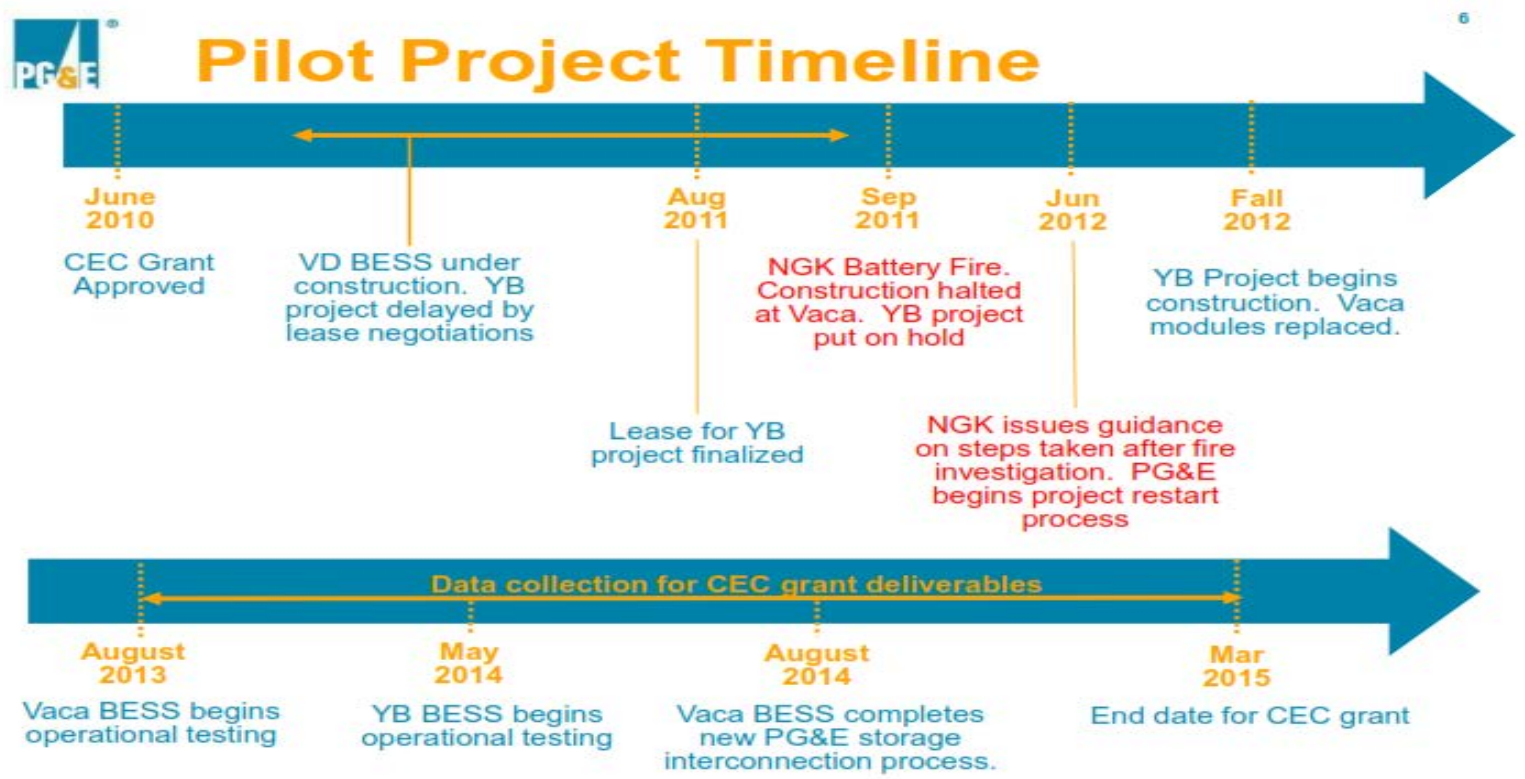
Sodium Sulfur Technology



Normal operating temperature for battery is 300°C.

Sodium and sulfur in liquid form

Storage Safety in California Proceedings
Grid-Scale Systems



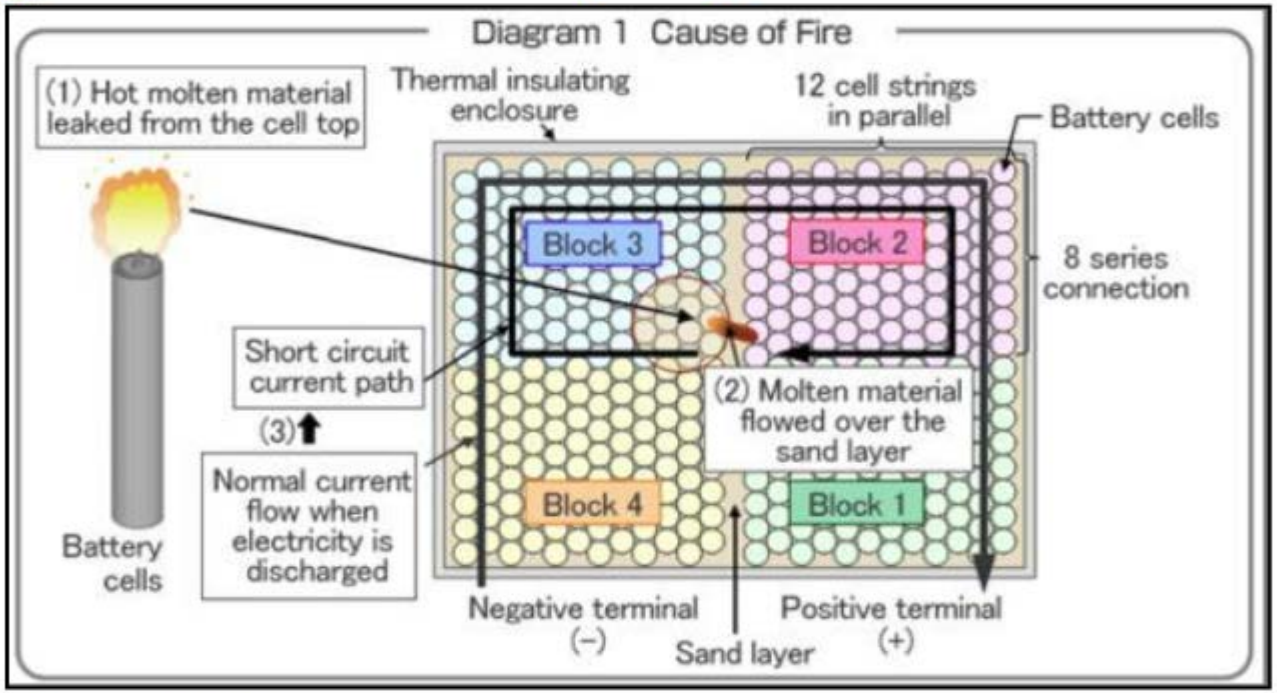
Storage Safety in California Proceedings
Grid-Scale Systems

Key Causes of Fire

- Molten material from a faulty cell leaked and caused a short between battery cells in an adjoining block.
- Due to lack of sufficient fuses the resulting heat, from the short-circuit, caused a number of other battery cells to catch on fire. This fire spread to the whole battery module.
- The combustion of the particular battery module released flames and hot molten material that melted battery cell casings inside battery modules, which caused the fire to spread further.
- Sodium battery fires (like lithium-ion battery fires) are difficult to extinguish because water cannot be used. The primary mitigation measures are shut down the battery to stop electric flow into the fault and to let the fire burn itself out.

Storage Safety in California Proceedings
Grid-Scale Systems

Cause of Fire (ctd)



Source: NGK

Storage Safety in California Proceedings
Grid-Scale Systems

Key Elements of Safety Plan

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- Enhanced alarm system developed and deployed at battery site
- Sulfur dioxide sensors mounted near battery to detect SO2 (byproduct of a fire).
- Personal SO2 monitors supplied for first responders
- Safety perimeter established around battery to restrict personnel entry in event of fire
- Special sand and sand sprayer provided by NGK to cover modules in event of fire (applied after fire self-extinguishes)

Storage Safety in California Proceedings
Grid-Scale Systems

What PG&E considers necessary for ensuring NAS battery safety:

- 24/7 monitoring by distribution operations with key alerts for fire and SO_2 alarms
- 24/7 monitoring by a system integrator
- Yearly system inspections
- Twice-yearly testing of fire alarm and external SO_2 detection systems
- Bi-annual replacement of the internal SO_2 detector (inside battery modules)
- Ongoing review of battery performance and temperatures to identify potential problems early.

Storage Safety in California Proceedings
Grid-Scale Systems

Lessons from other IOUs not quite so dramatic, but still valuable:

SDG&E – Borrego Springs

- Substation storage,
  Gen 1: 500 kW/1.5 MWh ESS
  Gen 2: 1 MW/3 MWh ESS added
- Community Energy Storage
  (3) 25 kW/50 kWh ESS

Storage Safety in California Proceedings
Grid-Scale Systems

SDG&E offered the following *Lessons Learned* from its integration of energy storage technology:

- Safety standards for grid-scale energy storage are largely under-defined:
  - Site safety: all applicable OSHA, NEC, and NFPA requirements
  - Fire: NFPA 704
  - Operation: IEEE1547/UL1741/UL1642
  - Enclosure: NEMA 3R
  - Signage: ANSI Z535
  - Cybersecurity: NISTIR 7628

Standards development is not at pace with regulatory requirements – and this creates challenges in terms of approvals.

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Grid-Scale Systems

SCE Irvine Smart Grid Projects

- **Residential Energy Storage Unit (RESU)**
  - 4kW / 10kWh
  - Installed in 13 homes
- **Community Energy Storage (CES)**
  - 25kW / 50kWh
  - 1 device serving 9 homes
- **Electric Vehicle Charging Station with PV and Storage (BESS)**
  - 100kW / 100 kWh
  - Paired with 20 EV charging stations & 48 kW PV array
- **Large Distributed Energy Storage System (DBESS)**
  - 2 MW / 500kWh
  - Connected to a 12 kV distribution circuit

Storage Safety in California Proceedings
Grid-Scale Systems

Residential Energy Storage Unit (RWSU)

Garage installation required safety brace to protect against vehicle collisions

RESUs experienced multiple issues in the field that required on-site visits to resolve:

- Software failures
- System lockups that could cause battery over discharge. New software versions introduced fixes to improve reliability.

SCE described a need for coordination with local officials, regional officials, state-level officials, “time consuming but worthwhile.”

CPUC SED Working Group in Action at the Vaca-Dixon Substation

CPUC Safety & Enforcement Division Energy Storage Inspection Guidelines

- CPUC had no precedent in developing protocols;
- For Utility-Scale, Grid-Connected Storage Co-located at Utility Substations and other sites;
- Participation from PG&E, SCE, SDG&E, NGK, NEC, CESA, ESRB, Amber Kinetics;
- CPUC has determined no need to revise General Order 174 (Substations) but SED inspectors are beginning to use the list;
- Application to non-IOU facilities pending.

Guidelines for SED Inspectors for Energy Storage Facilities (Page 1)

- **Is an overall safety plan in place?**
  - Does the facility have a safety plan documented?
  - Does it address manmade and natural disasters like wildfire, earthquake, flood, chemical spill, toxic gas release, explosion, terrorism, etc.?
  - Does it include outreach to first responders and local authorities? i.e. conduct periodic drill with fire, police, hazmat, etc.
  - Does it include training?
  - Are signage and safety placards compliant with American National Standards Institute, National Fire Protection Association, and other applicable standards?
  - Does the facility have a monthly in-service inspections and maintenance checklist?
    - Storage management system (fire monitors, SO_2 monitors, wind sock, log book, smoke detectors, etc.)
    - Fire plan box (on substation fence)
    - Equipment (generators, transformers, switch gear and control cabinet, battery towers, etc.)
  - Does the facility have maintenance records, such as a preventative maintenance log?
  - Does the facility have an appropriate access protocol?

Guidelines for SED Inspectors for Energy Storage Facilities (Page 2)

- **Is the facility inspected regularly by the company or utility per manufacturer's recommendations?**
  - Battery Modules.
    - Inspection of cables and wiring.
    - Torque check of bolted connections (when applicable)
    - Insulation resistance measurement (per industry standards)
    - Heater resistance.
    - Battery residence.
  - Cable run.
    - IR or Ultrasound inspection of terminals
    - Insulation resistance measurement (per industry standards)
  - SO_2 detector if applicable.
  - Control cabinet.
    - Inspection of cables and wiring.
  - Total system.
    - Protection relay test.

Guidelines for SED Inspectors for Energy Storage Facilities (Page 3)

- **Is the facility inspected regularly by the company or utility, per manufacturer's recommendations? (flywheels only)**
  - At commissioning, are flywheel units properly installed, with civil design per manufacturer specification?
  - Inspection of cables and wiring.
  - Insulation resistance measurement of cables.
  - Run automated control system test. Verifies control connectivity, functionality of internal sensors within each flywheel unit – voltage, current, vibration sensing, and vacuum system state. Test carried out from control center.
- **SED inspectors examine the following (both visual and records review)**
  - Interconnection equipment
  - Storage facility
  - Battery enclosure
  - Battery module (varies by technology)
  - Hazardous materials policy and management program if applicable

Because energy storage technology will evolve over time, this checklist will also need to evolve over time.

Vaca-Dixon Sodium Sulfur Battery Fire Extinguisher

Do not pour water on a sodium sulfur Battery.

Thank You!

For further information related to Energy Storage & Safety Issues, please contact:

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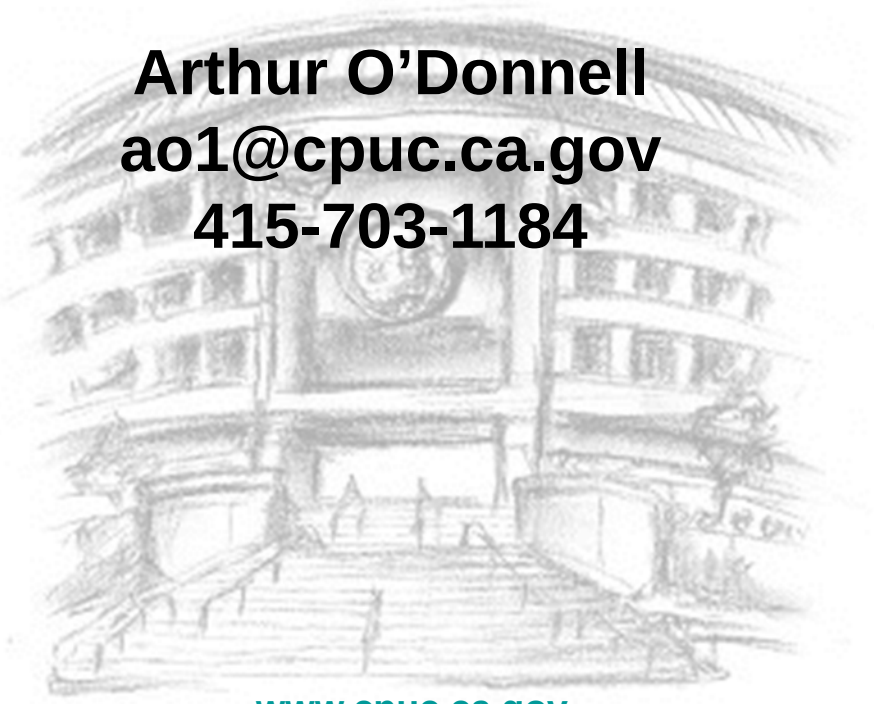

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