Energy Storage Safety at CPUC
2010-2017

The Energy Storage Safety Forum
February 22-24, 2017

Arthur O’Donnell - Supervisor, Risk Assessment & Safety Advisory
Safety & Enforcement Division
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
<table>
<thead>
<tr>
<th>Category</th>
<th>Storage “End Use”</th>
</tr>
</thead>
</table>
| **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
- Renewable -Sited Storage
  - CSP
  - Wind + Storage

### Xmission
- Transmission Connected Bulk Storage
  - A/S
  - Peaker
  - Load following
  - FERC Jurisdiction

### Distribution
- Transmission Grid Storage
  - Substation Level Storage
  - Distributed Peaker
  - Community ES

### Behind-the-Meter
- Customer-Sited Storage
  - Bill mgt / PLS
  - Power quality
  - EV charging

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![Diagram of energy storage systems](image_url)
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)

<table>
<thead>
<tr>
<th>Storage Grid Domain Point of Interconnection</th>
<th>2014</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
<th>Total</th>
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<tbody>
<tr>
<td><strong>Southern California Edison</strong></td>
<td></td>
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<tr>
<td>Transmission</td>
<td>50</td>
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<td>85</td>
<td>110</td>
<td>310</td>
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<tr>
<td>Distribution</td>
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<td>15</td>
<td>25</td>
<td>35</td>
<td>85</td>
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<tr>
<td><strong>Subtotal SCE</strong></td>
<td>90</td>
<td>120</td>
<td>160</td>
<td>210</td>
<td>580</td>
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<tr>
<td><strong>Pacific Gas and Electric</strong></td>
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<tr>
<td>Transmission</td>
<td>50</td>
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<td>10</td>
<td>15</td>
<td>25</td>
<td>35</td>
<td>85</td>
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<tr>
<td><strong>Subtotal PG&amp;E</strong></td>
<td>90</td>
<td>120</td>
<td>160</td>
<td>210</td>
<td>580</td>
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<tr>
<td><strong>San Diego Gas &amp; Electric</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Transmission</td>
<td>10</td>
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<td>Distribution</td>
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<td>Customer</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>14</td>
<td>30</td>
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<tr>
<td><strong>Subtotal SDG&amp;E</strong></td>
<td>20</td>
<td>30</td>
<td>45</td>
<td>70</td>
<td>165</td>
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<td><strong>Total - all 3 utilities</strong></td>
<td>200</td>
<td>270</td>
<td>365</td>
<td>490</td>
<td>1,325</td>
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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

<table>
<thead>
<tr>
<th>Utility</th>
<th>Total MW Goal By 2024</th>
<th>Total Procured to Date</th>
<th>New AB 2868 Goals</th>
<th>Proposed for 2016 RFO</th>
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</thead>
<tbody>
<tr>
<td>Southern California Edison</td>
<td>580</td>
<td>537.7</td>
<td>~167</td>
<td>20</td>
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<tr>
<td>Pacific Gas &amp; Electric</td>
<td>580</td>
<td>94</td>
<td>~167</td>
<td>115.3</td>
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<td>San Diego Gas &amp; Electric</td>
<td>165</td>
<td>116.6</td>
<td>~167</td>
<td>144</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1,325</strong></td>
<td><strong>749</strong></td>
<td><strong>500</strong></td>
<td><strong>279.3</strong></td>
</tr>
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</table>
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
"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
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.
Safety Best Practices for the Installation of Energy Storage

Many Californians will install batteries and other energy storage technologies in their homes and workplaces in the coming months. Best practices can make installation of energy storage safe. The CPUC offers links to the most relevant best practices and standards from a wide range of sources on this page.

Santa Clara County, California, has developed a relatively advanced set of best practices for installation of energy storage technology as well as templates for signage. Please follow these links to access Santa Clara’s strong work:

- Santa Clara guidelines for installation of energy storage equipment
- Santa Clara required signage for energy storage equipment

Several organizations offer codes, standards, and best practices for energy storage technology. These cover installation, certification, fire protection, outreach to first responders, and much more. Since energy storage technology is developing quickly, standards are also evolving substantially. Please follow the links below to inform your selection, installation, and use of batteries and other storage devices:

- UL 1973 covers energy storage for solar photovoltaics, wind turbine storage, and other stationary applications as well as for light electric rail applications.
- UL 1973 is evolving into UL 9540, a newer standard that covers related systems for storing energy from power sources or providing electricity to power conversion equipment, for example electrical charging or discharging equipment.
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.
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.
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.
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

Pilot Project Timeline

- June 2010: CEC Grant Approved
  - VD BESS under construction. YB project delayed by lease negotiations
- Aug 2011: NGK Battery Fire. Construction halted at Vaca. YB project put on hold
- Sep 2011: NGK issues guidance on steps taken after fire investigation. PG&E begins project restart process
- Fall 2012: Lease for YB project finalized

Data collection for CEC grant deliverables

- August 2013: Vaca BESS begins operational testing
- May 2014: YB BESS begins operational testing
- August 2014: Vaca BESS completes new PG&E storage interconnection process.
- Mar 2015: End date for CEC grant
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.
Cause of Fire (ctd)

Diagram 1: Cause of Fire

1. Hot molten material leaked from the cell top
2. Molten material flowed over the sand layer
3. Short circuit current path

Source: NGK
Key Elements of Safety Plan

- 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 SO₂ alarms
- 24/7 monitoring by a system integrator
- Yearly system inspections
- Twice-yearly testing of fire alarm and external SO₂ detection systems
- Bi-annual replacement of the internal SO₂ detector (inside battery modules)
- Ongoing review of battery performance and temperatures to identify potential problems early.
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
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.
Storage Safety in California Proceedings
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
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, SO₂ 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)
  – SO₂ detector if applicable.
  – Control cabinet.
    • Inspection of cables and wiring.
  – Total system.
    • Protection relay test.
• **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:

Arthur O’Donnell
ao1@cpuc.ca.gov
415-703-1184

www.cpuc.ca.gov