Fire Testing a Lithium Ion Battery Energy Storage System

Presented by:
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Overview

- Project History
- Energy Storage System Fire Tests
  - External Fire Exposure Test
  - Internal Fault Test
- Summary of Tests
- Acknowledgements
Project History
Partnership between:
- NFPA
- OEM
- Exponent, Inc.

Partnership goal:
- This project is the first phase of an overall initiative with the goal to develop safe installation practices, fire protection guidance, and appropriate emergency response tactics for ESSs.
The objective of this first phase project was to create a publically available technical document focusing on ESS fire safety through a preliminary fire hazard assessment of a Li-ion battery ESS.
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This project did not include an analysis or testing of fire detection systems, fire suppression systems, emergency response tactics, or overhaul operations related to Li-ion battery ESS fire scenarios.
ESS Fire Test Setup
ESS Tested

- Two ESS – Tesla PowerPack
- ESS is a 100 kWh unit designed for commercial installation
- ESS is modular, can be expanded to include multiple 100 kWh units to increase capacity
- Outdoor installations typically placed on a concrete pad
- Can be remote from the building or abutting
ESS Tested
Fire Test Overview

• Location: Outdoors in open air
• Battery cells at 100% State-of-Charge (SOC)
• Number of Tests: 2
  — 1 external ignition test
  — 1 internal ignition test
• Data Collected:
  — ESS cabinet pressures
  — Gas sampling of select products of combustion
  — Temperatures – inside ESS cabinet and external of ESS
  — Weather conditions, photography and HD videos
• Suppression: None – free burn
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External Test: Protocol

- Turn on instrumentation
- Ignite ~400 kW propane burner
- Monitor until approximately 20 thermal runaways audibly confirmed
- Turn off burners; allow ESS to burn freely
- Monitor until the fire burns itself out or self-extinguishes
External Test: Video

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• 400 kW burner impinging directly on the outside of the ESS cabinet can induce thermal runaway of the cells inside
• 35 minutes to smoke
• 45 minutes to first audible thermal runaway
• 47 minutes to first flames
• At approximately 1 hour, 20 thermal runaways audibly confirmed, burners were turned off
• Flames observed at exhaust vent and out ESS front door
• Fire conditions slowly spread through the cabinet until it burned itself out at approximately 3 hours 45 minutes
Temperatures inside high: greater than 2,000 °F
External surface temperatures on the opposite side of the burner much lower: 150 °F
External surface temperatures at the front door: 460 °F
HF (excess of 100 ppm) and CO (50 ppm) detected
  — HF detected reached maximum value at 30 minutes and remained above 100 ppm for the duration of the test
CH$_4$ not detected
No violent cell projectiles, explosions, or bursts observed
Post test: all cells consumed and internal electronics damaged, no stranded electricity
Internal Test: Protocol

- Turn on instrumentation
- Power up heater cartridges
- Six (6) 1/8-inch diameter 25-watt cartridge heaters
- Installed in within battery cells
- Monitor until approximately 20 thermal runaways audibly confirmed
- Turn off heaters; allow ESS to progress freely
- Monitor until the event is over
Internal Test: Video

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Internal Test: Test Observations

- 6 heater cartridges simultaneously heating multiple battery cells can induce thermal runaway
- Thermal runaway did not spread outside the initiator pod
- 13 minutes to first audible thermal runaway
- 15 minutes to smoke
- At approximately 40 minutes, 20 thermal runaways audibly confirmed, heaters were turned off
- Smoke conditions peaked at approximately 40-45 minutes, then slowly dissipated until all signs of combustion ceased at approximately 1 hour 15 minutes
Internal Test: Test Data

- Temperatures adjacent to heaters high: greater than 2,000 °F
- Temperatures above and below initiator lower: 80-180 °F
- External surface temperatures much lower: 60-70 °F
- HF (peak 26 ppm), CO (excess of 2,000 ppm), and CH₄ detected
  - HF peaked at approximately 45 minutes during peak observed smoke production
  - CO peaked at approximately 15 minutes
- No flames, violent cell projectiles, explosions, or bursts observed
- Post test: initiator cells damaged, remaining cells functional
Acknowledgements
Acknowledgements

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  — FPRF panel
  — Exponent team

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Questions?

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http://www.nfpa.org/research/fire-protection-research-foundation/projects-reports-and-proceedings/other-research-topics/hazard-assessment-of-lithium-ion-battery-energy-storage-systems