Fire Testing a Lithium Ion Battery Energy Storage System

Presented by:
Andrew Blum, P.E., CFEI, CVFI
Senior Fire Protection Engineer
Fisher Engineering, Inc.

Overview

- Project History
- Energy Storage System Fire Tests
  - External Fire Exposure Test
  - Internal Fault Test
- Summary of Tests
- Acknowledgements

Project History

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

Project Objective

- 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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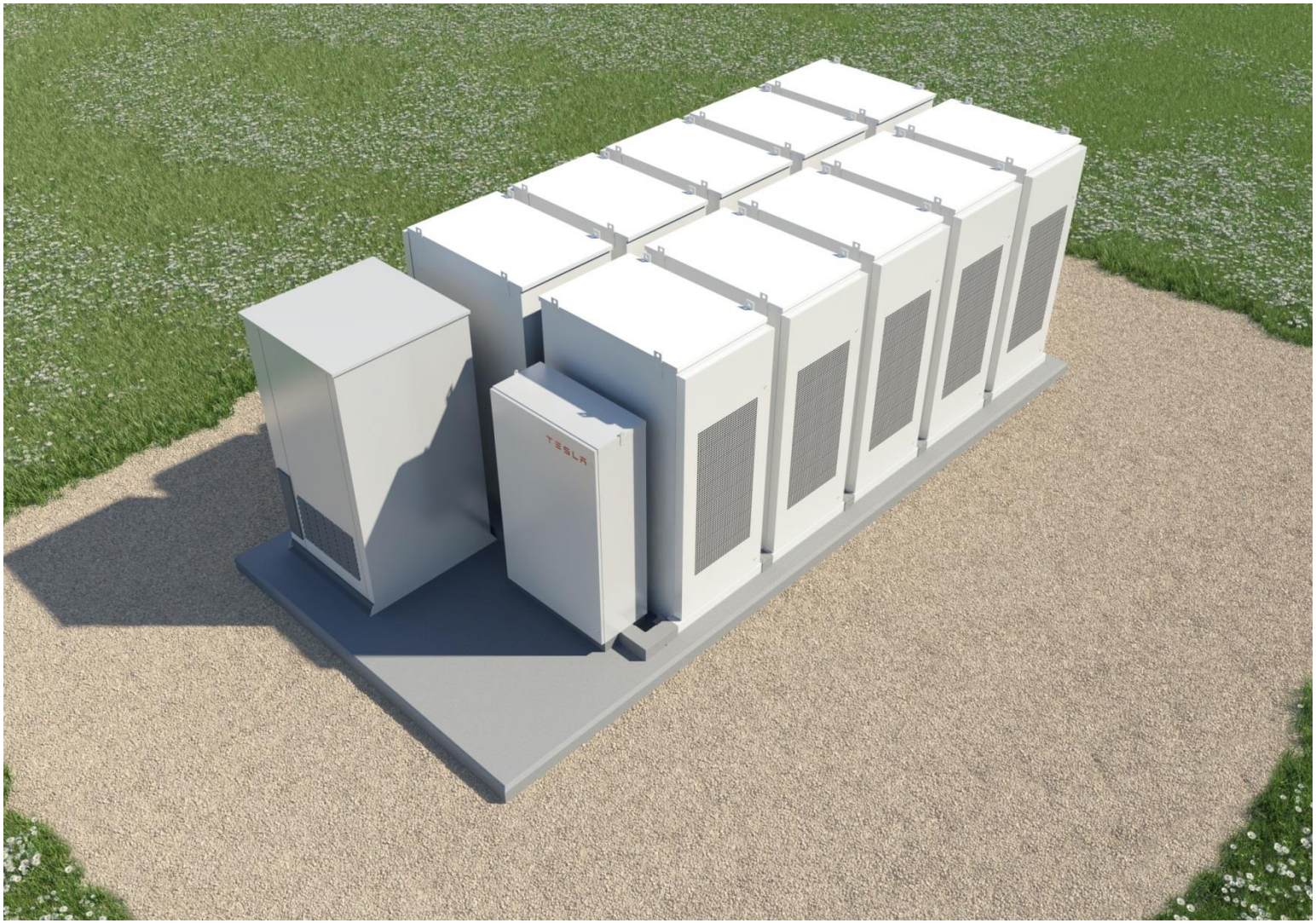
This project did not include an analysis or testing of fire detection systems, fire suppression systems, emergency response tactics, or overhaul operations related to Li-ion battery ESS fire scenarios

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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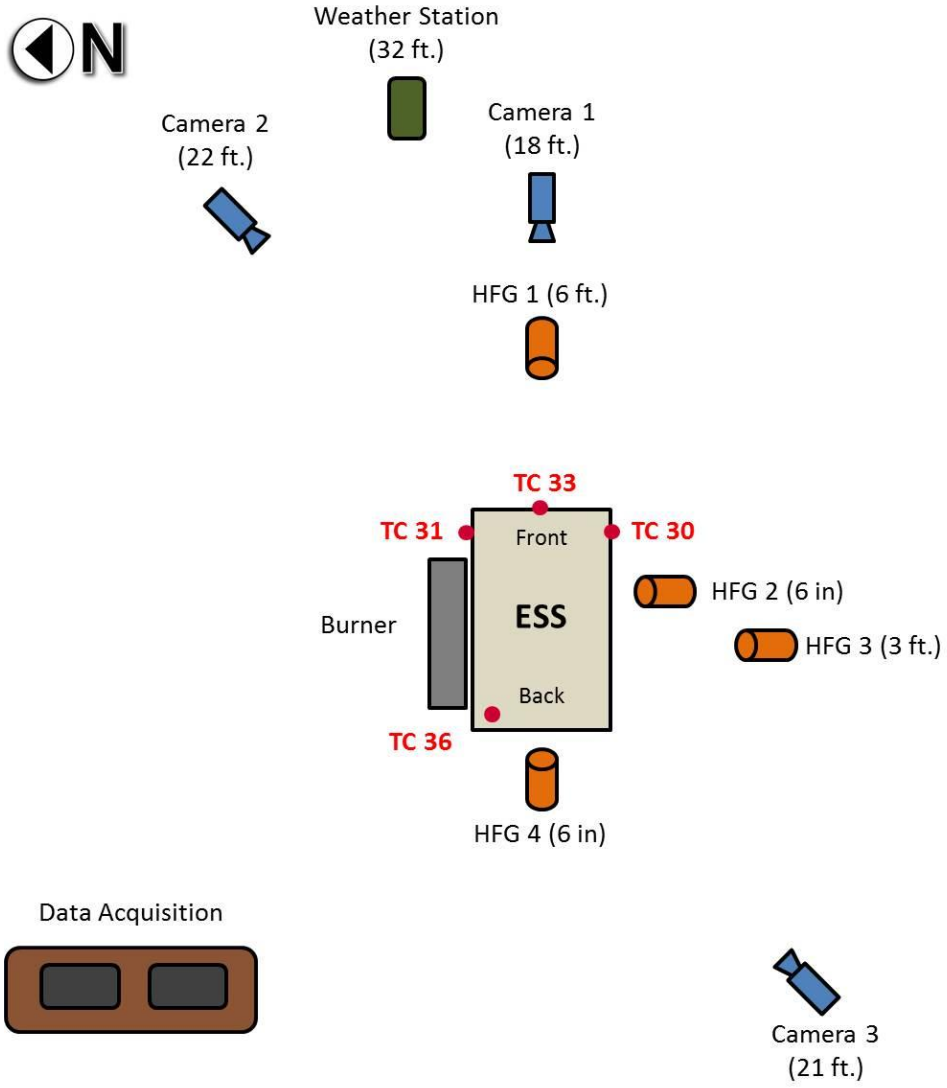
External Test: Instrumentation



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

External Test: Test Observations

- 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

External Test: Test Data

- 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

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 CH_4 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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  - Kathleen Almand, Executive Director, FPRF
  - Daniel Gorham, Research Project Manager, FPRF
  - FPRF panel
  - Exponent team
- Special thanks to the manufacturer who generously donated the ESSs, the test facility and their time – we could not have made this happen without you!

Questions?

Andrew Blum, P.E., CFEI, CVFI

Senior Fire Protection Engineer

Fisher Engineering, Inc.

770-495-7770

Andy.Blum@feifire.com

For the full report please visit:

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