Energy Storage System Safety: Testing, Installation & Suppression

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Looking Forward for Energy Storage

Energy Storage System (ESS) promise and challenges

Safety: the foundation for sustainable deployment

Evolution of technology, applications & solutions

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Unique safety considerations for energy storage

Energy storage systems by their nature are very energy dense.

They are and will be largely powered by lithium-ion batteries, which have flammable electrolytes and can be vulnerable to thermal runaway.

Market diversification, increasingly complex global supply chains and maximizing energy density have caused challenges with Li-ion batteries.

All of these factors mean that a small event in an ESS can cascade to a large scale event, and constant vigilance is needed to address safety.

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High Profile ESS Fire Events

Mitsubishi Materials Corporation (Japan 2011); 2 MW Sodium Sulfur system, thermal runaway

Kahuku Wind farm (USA, 2012); 15 MW, Advanced lead acid battery

The Landing Mall (USA, 2013); 50 kW Li-ion BESS system in a shopping mall, thermal runaway

>20 incidents with utility/industrial Li-ion BESS in Korea since May 2018

Surprise Arizona explosion April 2019 involving APS Li-ion BESS

Moss Landing event in California, September 2021

https://storagewiki.epri.com/index.php/BESS_Failure_Event_Database

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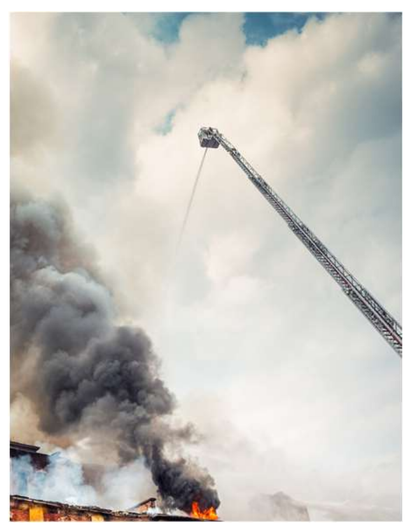
Noted Issues:

Inadequate system of battery protection against electric shock

Inadequate control of operating environment

Careless installation

Inadequate systems for ESS control and protection



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Safety Regulations

Countries are focused on ramping up their energy storage infrastructure as renewables & storage displace aging, or eliminate new, fossil fuel plants

Notable incidents have increasingly brought safety to the forefront as a consideration for ESS deployment.

Approaches include early adoption of new safety codes and leveraging compliance with safety standards, which has been supported by industry.

This is sure to be dynamic as more countries take action based on an evolving deployment of energy storage technologies.

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Codes and Installation Standards

Source: ICC

Source: NFPA

These documents drive safety into the ecosystem by codifying best practices.

They include documents issued by the National Fire Protection Association (NFPA 70 and NFPA 855) and International Code Council (International Building Code, International Fire Code).

These documents leverage compliance of the ESS with product safety standards, and establish how the ESS must be installed – with greater specificity than the IEC 60364 series.

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ESS Safety Standards

Safety standards address the construction and performance aspects of products and systems that are critical for safety, promoting the ease of approval by code authorities as they address installations

UL has been very active in developing a suite of requirements and standards to address safety of battery and energy storage technologies – validating safety of batteries, and then subsequently safety of battery systems, is critical

Most noteworthy among these are UL 9540 for energy storage systems and UL 9540A to address fire characterization of the energy storage systems relative to thermal runaway risks

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UL 9540

Standards are critical for establishing baseline performance and expectations

UL 9540, Safety of Energy Storage Systems, was published in 2014 as the world's first ESS safety standard; it is now the American and Canadian National Standard and used in many countries

IEC TC 120 has been working on the IEC 62933 Series of standards, with the safety approaches of UL 9540 being leveraged, but IEC 62933 is not as rigorous as UL 9540 in key safety requirements

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UL 9540 Approach

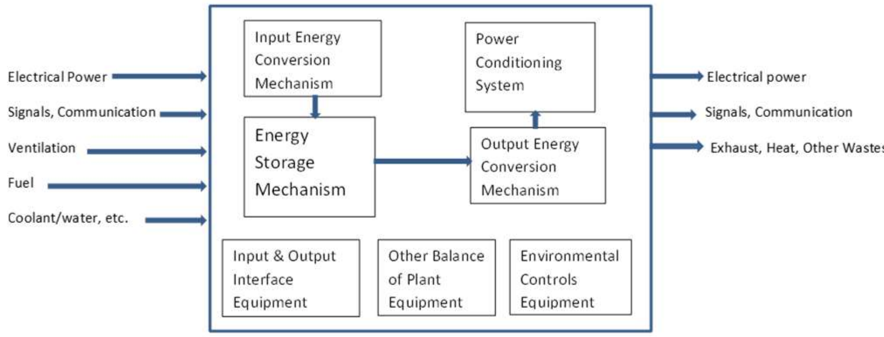

Figure 1 – Block Diagram of Electrical Energy Storage System

Technology	Input Energy Conversion Mechanism	Energy Storage Mechanism	Output Energy Conversion Mechanism
Electrochemical	Charger	Battery	Converter
Chemical	Water Electrolysis H2 Generator	Hydrogen Storage	Fuel Cell
Mechanical	Air Compressor	Flywheel	Motor Generator
Thermal	Heat Pump	Thermal Storage	Heat Generator

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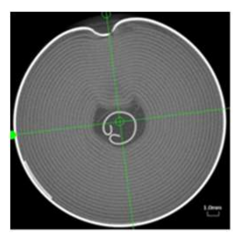
Thermal Runaway

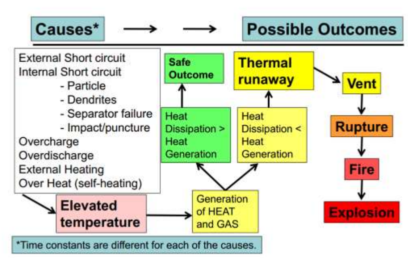


Battery ESS can be vulnerable to thermal runaway, a self-perpetuating phenomenon where the electrochemical performance cannot be controlled

Thermal runaway can lead to fires and explosions, and can induce cascading thermal runaway in other batteries or battery units

Thermal runaway can be caused by a number of root causes including manufacturing defects, physical abuse, inadequate battery management, and environmental conditions

CELL FAILURE



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UL 9540A

Battery ESS can be vulnerable to thermal runaway, a self-perpetuating phenomenon where the electrochemical performance cannot be controlled

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UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, was developed to characterize the fire safety consequences of battery energy storage systems

It is the American and Canadian National Standard, and allows for more sophisticated integration of ESS into buildings and installations

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UL 9540A: Unit Level Testing

Purpose: To document fire propagation and deflagration hazards (direct tie to IFC 2018 and NFPA 855)

Important Data

- **Module to module thermal runaway propagation in Initiating BESS**
- **Heat release rate**
- **Gas composition and volume**
- **Wall temperatures and heat fluxes including at egress path**
- **Target BESS temperatures and heat fluxes**
- **Deflagration hazards**
- **Re-ignition (on-going thermal runaway)**

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Technological Advancements

Functional Safety and related software will continue to play an increasingly important role in battery management systems (BMS) and other safety functions.

Increased sophistication of sensors & protection will continue to be advanced – but data access and use issues will need further vetting for true optimization.

Li-ion batteries will continue to be the workhorse technology for the foreseeable future, but innovations related to chemistries, electrolyte additives etc. will continue.

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Advancing suppression research: clean agent

Test on a containerized ESS involving a clean agent fire protection system

The clean agent system is not intended for thermal runaway events, but tested to understand how it might affect fire dynamics.

Deflagration occurred about 40 minutes after that clean agent system activated, after battery gases built up and likely displaced the clean agent.

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Advancing suppression research: water

Test involving a heavy application rate of water spray from the ceiling.

Water spray had some limited effectiveness in that it prevented unit to unit propagation of thermal runaway, but did not halt module to module thermal runaway in the initiating unit.

As a result, there is still an explosion hazard and in this case a deflagration still occurred even with the water spray system operating.

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Tactical assessment: opening the door

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Energy Storage is key to our planet’s future

Energy storage is critical for enabling grid development and modernization, supporting renewables and clean energy technology, and empowering countries expanding their energy infrastructure.

The energy storage world continues to be extremely dynamic regarding technology, uses and regulations.

Standards, Codes and fire tactics must be, and are being, actively maintained to address these dynamic developments with a strong foundation of safety.

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Thank you.

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https://www.ul.com/services/energy-storage-system-testing-and-certification

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