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AUGUST 27, 2026
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Hazards and Response Tactics
EVLO Battery Energy Storage System (BESS)

Agenda

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Battery Energy Storage – Concept & Overview

Battery Energy Storage Concept

Understanding the concept of battery energy storage systems (BESS) is essential for effective response. BESS are typically integrated into larger energy infrastructures, allowing energy to be generated and stored in batteries. These batteries discharge energy when demand peaks, helping to prevent outages and reduce strain on the electrical grid. For example, energy generated by wind turbines can be stored in a BESS and later discharged into the grid to supply nearby homes during high demand periods.

Lithium Ion Cells

Lithium-ion batteries come in three common shapes. Cylindrical cells, resembling AA or AAA batteries, are generally found in micromobility devices like e-bikes or e-scooters and are not typical in energy storage systems. Prismatic cells, shaped like rectangular prisms or bricks, are used in some energy storage systems but not in the EVLO BESS discussed here. The EVLO system uses pouch cells, which are thin, flat, rectangular cells with terminals protruding from the end. These pouch cells feature thinner casing and are sealed for protection rather than being enclosed in metal.

Battery System Anatomy

BESS are constructed from batteries connected at various levels to optimize storage capacity. The most basic component is the single lithium-ion battery (LIB) cell. Multiple cells are wired together in series and/or parallel configurations to form a module. Modules are grouped into battery racks within an enclosure, and several racks are wired together to complete a BESS cabinet. This layered structure balances charging/discharging speed with storage capacity.

Basic Site Equipment

A typical BESS site consists of battery cabinets, each connected to an inverter and a transformer. This setup enables the Battery Management System (BMS) and Supervisory Control and Data Acquisition (SCADA) to monitor the BESS container. Additionally, the inverter and transformer connect to the power grid, facilitating the distribution of stored energy.

Battery System Failures – Cause & Correction

Moss Landing Incident

The Moss Landing BESS incident is an isolated event involving an older, large-scale facility with a design unlike modern BESS sites. The Moss Landing site was built inside a converted power plant with a single-room open design and lacked fire breaks. Installed in 2020, it predates established codes and standards for energy storage systems. For perspective, Moss Landing was 762' x 75', compared to a modern battery cabinet measuring 24' x 9', illustrating the difference between a large warehouse and a small backyard shed.

Water Intrusion

Older BESS sites have faced issues with water intrusion, leading to incidents such as fires in Idaho and two separate installations in New York. Modern BESS containers are now manufactured to be air-tight, preventing the entry of dust, water, insects, and other materials.

System Equipment – General Overview

- Pouch cells: 3.65 volts, 80 amp-hours
- Weight similar to a ream of copy paper
- Each module contains 32 individual battery cells

- Modules are installed into racks and placed within cabinets
- The site is completed with a power conversion skid, which includes a disconnect switch, transformer, and inverter

Battery Management System – Autonomous Control

The Battery Management System (BMS) performs four main functions:

- Calculating state of charge (SOC) and state of health (SOH)
- Balancing cell current, voltage, and charge levels
- Protecting the battery from overcurrent, under/over voltage, under/over temperature, and cyber threats
- Controlling charge/discharge levels, current, voltage, and temperature

The BMS is equipped with alarms to trigger system shutdowns for safety. Shutdowns may result from elevated cell temperature, over voltage or amperage, HVAC failure, communications failure, or fire alarms.

E-Stops – Operation & Limitation

Emergency Stop (E-Stop) buttons are located on both the cabinets and the inverters. There are three levels of E-Stop, which stop the charging and discharging of batteries. These are typically red buttons found on containers and inverters. It's important to note that transformer fires differ from battery fires; transformer fires produce a gaseous plume, while battery fires resemble electrical fires. Battery cabinets also present the risk of stranded energy—energy that remains inside the batteries, potentially causing fire reignition. Stranded energy is considered a Class C hazard.

Detection & Suppression – Alarms & Actions

Detection systems are in place for smoke, heat, and hydrogen. EVLO containers are equipped with external audio and visual alarms. Safety features of battery cabinets include thermal management systems, battery string disconnects, a master disconnect, and an auxiliary power panel.

Hazards

Hazards associated with BESS include chemical, electrical, fire, and explosion risks.

Chemical Hazards

- Freon: Gas under pressure, colorless and volatile with a faint odor, non-flammable. Overexposure can cause dizziness, loss of concentration, central nervous system (CNS) depression, and cardiac arrhythmia. Vapors may cause asphyxiation and, at high temperatures, can decompose into hazardous products such as HF.
- Transformer oil: Non-PCB, approximately 500 gallons per transformer, with a flashpoint of 300°F and autoignition at 795°F
- Thermal runaway gases at 1200°F present dermal and inhalation hazards
- UL9540A testing indicates cell gas composition is about 80%, mostly CO, CO2, H2, and CH4
- Case Study: Escondido BESS Fire: Plume Analysis revealed 2PPM HCN derived from burning plastic. HCN is also generated by cigarette smoke.

Firefighters recognize that energy storage fires are similar to residential fires in terms of response priorities. Saving the structure or BESS is not feasible, so efforts focus on protecting surrounding exposures, such as nearby homes or containers. Unlike residential fires, BESS sites are typically unoccupied and do not require search and rescue for occupants. Energy storage fires also differ from commercial fires, as commercial spaces often have more fuel and limited spacing, which can make fires larger. Modern BESS containers are required to have spacing and fire barriers, and the fuel sources are enclosed. Recommended personal protective equipment (PPE) includes the NFPA 1970 firefighting ensemble with a helmet, hood, face mask, SCBA, and gloves.

Electrical Hazards

- There are no exposed electrical conductors in the BESS site that fire services members may come into contact with. Contact with exposed conductors would only occur if locks and doors on the battery cabinets or PCS-skids are breached.
- As such tools shall not be utilized within the site. In addition common tools within the fire service are made of conductive materials making them clearly undesirable for use in the se facilities.

Fire Hazards

Fire conditions may occur on a battery cabinet, inverter, or transformer. Engagement for suppression will not support the preservation of property. Any utility based equipment cannot be saved once it fails and will be discarded.

- Battery Cabinets Fire: This is an energized class c hazard. Water or any other agent should not be applied for suppression. Intervention should be limited to asset protection.
- Inverter Fire: Inverters can be electrically isolated after they fail removing the class c hazard. Combustible products within are limited to the insulation materials which do not support significant fire activity.
- Transformer Fire: A transformer can be isolated removing the class c hazard. If the decision is made to intervene for suppression. Consider should begin with the use of CO_2 or Dry-Chem. Suppression that would require the use of NFPA 11 foam or NFPA 18 water additives will only spread the oil.

Explosion Hazards

The key difference between fires and explosions is four walls, a floor and a ceiling. Essentially a natural gas leak outdoors results in fire. A natural gas leak indoors results in an explosion.

BESS sites include explosion control systems designed by fire protection engineers, following NFPA 68 and 69 standards. These systems use deflagration vents to release gases and prevent explosions.

The EVLO system is designed with an NFPA 69 system augmented by a floor vent that allows for passive air flow throw the roof vent.

Cell Failure: Venting and Thermal Runaway

- Venting: During the venting stage a white gas (H_2) is discreetly discharged from the trouble cell. This is the precursor to thermal runaway.
- Thermal Runaway: During thermal runaway the flammable electrolyte is discharged at a pressure in excess of 7.2 bar and a temperature of over 650 C.

Intervention Triggers – Asset Protection

- Heat alarms
- Façade temperature exceeding 72°C
- Direct flame impingement

Initial Actions – Size-Up

On arrival at a BESS site, responders should note that there is typically no Knox Box as found in commercial buildings. Do not force entry; instead, contact Solarbank using the number posted outside the facility. The Remote Operations Center (ROC) can provide information about personnel accountability, equipment details, active alarms, and other relevant events.

Unescorted Entry – Rescue Operations

- Identify the trouble battery cabinet
- Do not encroach within 30m of the cabinet doors to conduct a rescue.
- Do not attempt to rescue victims hanging out of battery cabinets, as they may be electrically charged.

Scene Size-Up – Eight-Step Process

1. If there is an active fire condition. Conduct air monitoring to ensure community safety; measure air quality 30m feet downwind from the fenceline and compare measured values to CDC IDLH thresholds.
2. Establish a 30m exclusion zone around the trouble battery cabinet
3. Identify if there are any active, smoke, heat or H2 alarms
4. Review the BMS for temperature changes to determine how many modules or racks are affected. Multiple cell temperature alarms confirm an incident.
5. Isolate trouble equipment, including transformers, inverters, and battery cabinets.
6. Assess the explosion control system; if the hydrogen alarm is active without venting, the system may have failed. Maintain the exclusion zone.
7. Smoke or Fire Showing: If conditions begin to eliminate from the trouble battery cabinet the tactical focus must shift to the protection of an adjacent battery cabinet as the initiating unit cannot be saved.

8. Prepare for intervention, which will consist of water delivery onto an adjacent battery cabinet that is experiencing a trigger event. Water should be delivered from outside the exclusion zone.

Post-Incident Operations – Placing the Incident Under Control

Placing an incident under control involves conducting a thermal assessment to confirm that temperatures are below 72°C, indicating thermal runaway has ended. Continue air monitoring for thermal runaway gases, aiming for decreasing or non-detectable levels of CO & H_2. Firefighters should not open container doors during post-incident operations.