To The Point

Energy Storage System (ESS)

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Overview

As the world is escalating towards decarbonization, Energy Storage System (ESS) installations are being constructed at a record pace. These systems are emerging as an integral component to a resilient and efficient electrical grid. ESS is primarily driven by Renewable Portfolio Standards (RPS) for power generation, peak shaving, and grid load balancing.

ESSs help reduce Carbon/Green House Gas (GHG) emissions by curtailing fossil power generation when the electrical grid is taxed with high demand.[1] ESS provides a fairly simple, cost-effective way to stabilize a power grid, manage peak loads and balance loads, and help manage high and low outputs in power generation from renewable sources such as wind and solar. Load balancing helps smooth the intermittent nature of renewable energy sources such as solar and wind, thus making the grid more stable, reliable, and resilient. As more renewables are installed, grid stability becomes an ever-increasing issue.

While the concept of ESS is not new (batteries have been around a long time), there has been a marked increase in the deployment of larger-scale and higher energy density Li-ion batteries used in modern Energy Storage Systems. These ESSs can be collocated in a wide variety of occupancies.

While there are many benefits to ESSs, there is also the risk of fire loss. The fires are extremely hard to extinguish because of the battery chemistry and the exothermic process. The flammability of the Li-ion electrolyte is a concern, and research is ongoing to produce non-flammable or reduced flammable electrolytes by additives or developing non-organic ionic liquids that offer the same high performance as Li-ion. Recently the primary safety focus has shifted to the fire hazards associated with Li-ion batteries and the potential for a condition known as "thermal runaway." Thermal runaway results from internal shorts inside a battery cell which can occur due to a variety of reasons which ultimately can lead to a fire. Preventing a thermal runaway event in the first place is the most important factor in preventing losses.[2]

Since recent popularity surge, there have been several losses involving Li-ion batteries between 2017 and 2021 worldwide, including South Korea (23 fires), England, Beijing, Australia and the United States. These can be challenging to control; the Australia fire involved two adjacent containers, 150 firefighters, 30 vehicles and took 3 days to extinguish. Since the fire could not be truly extinguished, the firefighters were limited to cooling the outside of the containers to stop the spread/damage to adjacent containers.

ESSs are a set of batteries that get charged and discharged at opportune times. They can be used to supply electricity to utility grids, local microgrids (e.g., campuses and neighborhoods), or the building in which the ESS is located. The ESS collects electricity from various potential sources, including the utility's grid (usually during low demand pricing rates), solar and wind installations, generators, or other sources.

The anatomy of ESSs revolve around a system of interconnected components, hardware, and software and can include batteries, battery chargers, battery management systems (BMS), thermal management systems (e.g., HVAC), and associated enclosures. BMS systems control the operation and safety of the system to prevent thermal runaway and other abnormal parameters.

Li-ion battery-based systems are a common ESS design due to the inherent power density advantages of lithium chemistries. However, it should be noted that ESS and Li-ion batteries should not be considered synonymous. Other chemistries, including traditional lead-acid batteries, and other technologies such as a "flow" ESS using chemicals such as vanadium, can be used. ESSs are typically installed in a building, outside a building within a smaller NEMA-rated enclosure, or within larger intermodal containers.

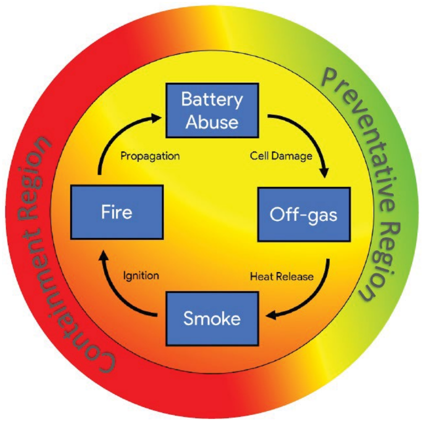
The Battery Management System (BMS) is the brain behind the ESS. A well-designed BMS protects and monitors a lithium-ion battery to optimize performance, maximize lifetime, and ensure safe operation over a wide range of conditions. These conditions include overvoltage/undervoltage, overcurrent, short circuit protection, overtemperature, and cell imbalance. Make sure you have a proven BMS used in your ESS. Ultimately, it is the lifeblood of your system and your early warning system to alarm and shut the system down. Furthermore, BMSs are crucial for your ESSs ongoing Operation and Maintenance (O&M) efforts.

When located within a building, the ESS is usually installed in cabinets within mechanical and electrical rooms and will rely on the base building support systems. When installed outside a building, the enclosures typically contain thermal management systems (e.g., HVAC), supporting electrical and fire protection equipment.

Best Practices

- Results from a recent free burn test coupled with ongoing research and development (R&D) for ESS safety from leading experts have reinforced the following best practices for safety and property protection: Lithium-ion and lithium-metal-polymer (LMP) battery systems should be provided with a listed device or another approved method to preclude, detect, and control thermal runaway. Some are generally found within the Battery Management System (BMS). The best-known way to help mitigate this exposure is to use UL 1973-certified battery systems and an off-gas monitoring system.
- If LEL detection is used to monitor hydrogen and other LEL gases, the ventilation system needs to be interlocked to activate if the detection system goes into alarm. As discussed previously, LEL detection is different than off-gas detection. LEL monitored gases are released in the smoke/fire stages after the off-gas stage of thermal runaway.
- New ESSs must be certified to UL 9540 "Standard for Energy Storage Systems and Equipment." This standard was created specifically for ESSs, and it is intended to evaluate the compatibility and safety of the various components integrated into the system. All components must be compatible and able to communicate with each other and perform their function while doing so. UL will certify these approved systems, and ESS manufacturers/integrators will receive a label to affix on the ESS. They will also receive the listing on UL's website proving the ESS is certified to 9540.[3]
- New ESSs must be tested per UL 9540A, "Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems (BESS)." This standard determines the capability of a battery to go into a thermal runaway condition and then evaluates the fire and explosion hazard characteristics. This is not a pass-fail test. It is an evaluation that should be used to determine criteria such as spacing between the systems, fire protection, ventilation, etc. The report should be provided to a qualified person, such as a fire protection engineer, to provide such criteria. UL9540A does not provide a certification like UL9540.[4]
- It is common for container-style ESS to have a modern clean-agent gas fire suppression system. It should be noted that testing has proven clean agent extinguishing systems will not control or extinguish a fire in a thermal runaway condition. The clean agent system can be effective on other types of fires in the system, such as electrical, paper, plastic, etc. However, water suppression is the best practice and is highly preferred for these fires. A wet pipe sprinkler system is the preferred protection. If water is not readily available for container installation, an open head deluge system with a fire department connection (FDC) should be provided. If a clean agent system is used and the unit incorporates ventilation as part of an HVAC system, it will need to be interlocked to maintain the necessary gas concentration.
- Emergency planning is a critical component in the overall protection scheme of ESSs and must include fire department preplanning and an adequate water supply. Some installations are in remote areas where water is not readily available and fire department response time is longer than preferred.
- Industry best practice is to incorporate off-gas detection to prevent thermal runaway. When describing the term off-gas in relation to off-gas detection, it is the electrolyte solvent vapors produced before the battery reaches thermal runaway and not the hydrogen and LEL (lower explosion limit) gases released during thermal runaway. Off-gas devices detect the very beginning of thermal runaway prior to battery cell failure and shut down the power to prevent the battery from reaching the smoking stage. If the battery reaches thermal runaway, it cannot be stopped as it heads toward fire generation. An off-gas monitoring system is an on-off device. Once off-gas is detected, an automatic shutdown is initiated, and a notification alarm is sent to the monitoring company.

Four Stages of Battery Failure[7]



- Most ESSs will be remotely configurable and, as such, connected to the Internet. To prevent an intentional or inadvertent cyber-induced failure to the ESS, electrical grid, etc., incorporate robust cyber-security controls within the BMS and related firmware and software. Security cannot be an afterthought, and it needs to be "baked into" the system design. Furthermore, cyber risk assessments need to be conducted and vulnerabilities routinely patched/updated as threats evolve. A good standard to reference is the International Society of Automation (ISA) 99.
- ESSs should be utilizing/incorporating UL 1741 certified inverters/inverter systems. An inverter is the hardware (and potentially embedded software) that converts DC electric current to AC electric current.
- Battery systems should be housed in a noncombustible, locked cabinet or other enclosure to prevent access by unauthorized personnel unless located in a separate equipment room accessible only to authorized personnel.
- Rooms or spaces containing ESSs should be separated from other areas of the building. The system should be located in a room with a two hour fire barrier between it and the rest of the building.[5]
- Locate ESSs outside and away from critical buildings or equipment. If the ESSs are installed within a building, locate these systems in an enclosed room that is externally accessible for manual firefighting operations.
- For exterior enclosed ESS containers designed to be outside the building, keep a clear distance of at least 20 feet from the nearby buildings unless adequate thermal barriers are provided to prevent fire from spread from one to another.
- Lithium-ion, lithium metal polymer, or other sealed batteries with immobilized electrolytes do not require spill control.
- ESSs may utilize ventilation as a risk reduction technology, e.g., reducing a flammable atmosphere to less than 25% of LEL. To provide consistent assessment, evaluation, and guidance, refer to NFPA 70, Article 706.[6]
- For rooms that contain Lithium-Ion or Lithium Metal Polymer batteries, the signs should be posted that state the following:
  - Stationary storage battery systems
  - Energized electrical circuits
- An approved automatic smoke detection system should be installed in Li-Ion ESS areas and supervised by an approved central, proprietary, or remote station service.
- Sprinkler protection within the room or enclosure should be designed to at least extra hazard group 1 for new installations.
- Provide temperature monitoring with a high alarm for the battery room and container, tied to a constantly attended station.
- In seismically active areas, battery systems should be seismically braced per the building code.
- A qualified commissioning agent should commission all larger, custom, and/or utility-scale ESSs per the project requirements and basis of design (BoD).
- Operation and maintenance programs are key to ensuring all monitoring and protective devices are in good working order. Regular inspection is necessary to ensure the battery systems are not overheating or show signs of malfunction. Annual (IR) scanning can help ensure the ESS operates within normal parameters.
- All ESSs should have online condition monitoring systems for room's temperature and battery modules for charging, temperature, state of charge, state of health, resistance, capacitance, and alarm.
- Installations should have emergency power disconnects to ensure manual, remote, and local disconnect is possible adjacent to the unit.
- Escaped liquids and water damage is quickly becoming an increased exposure within BESS installations. An ESS containing liquids, including coolant systems, should be provided with a means of leak detection to monitor for loss of coolant/liquid. A loss of coolant/liquid could result in a potentially hazardous condition, including a fire. A detected coolant/liquid leak should alert the ESS monitoring location and initiate a predetermined emergency action plan.

Conclusion

Energy Storage Systems are here to stay, and installations will only grow exponentially over time. In fact, ESS is considered by many energy experts the 'holy grail' in terms of addressing the world's clean energy future. As technology expands on these systems, it will become safer and safer as new chemistries are discovered and implemented into the industry.

These systems fill the gaps between conventional power generation and renewable energy production. They will be crucial for lessening the burden on an aging electrical grid by lessening consumption demand and smoothing out the intermittency issues of renewables.

In summary, ESSs ultimately prevent grid instability, save money over time, and reduce the carbon footprint, which creates a winning combination. Therefore, it is crucial not to introduce unintended consequences into these systems by designing and protecting them with the best available technology and know-how possible.

References

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