System-Level Safety for Energy Storage





Energy storage deployments are soaring

The U.S. market is on pace for a record year in 2019, according to Wood Mackenzie. The long-awaited storage boom – a key component of a decarbonized, decentralized and more digitized grid – is just beginning, with a tenfold increase in installations projected over the next five years.

Global Cumulative Energy Storage Capacity



However, as the energy storage industry scales up, it is facing heightened concerns about safety that could threaten its rapid pace of growth. Several storage fires in South Korea, coupled with a fire at Arizona Public Service's grid-scale battery installation outside Phoenix in May 2018 that injured several first responders, have raised new questions about safety.

Although the energy storage market remains nascent, it can look to more mature industries for best-in-class approaches to safety. As it has scaled, the electric vehicle (EV) industry has demonstrated that it is possible to minimize safety concerns related to lithium-ion batteries. However, while these two industries largely share the same type of battery cells, the system-level safety risks and potential solutions are distinctly different for stationary storage applications. In the unique context of the power industry, there is also the issue of regulators struggling to keep pace with rapid industry and technological developments in a way that balances growth and safety.







To move the industry forward, storage integrators like LS Energy Solutions will play a critical role, working closely with one another and with regulators to develop, share and codify best safety practices.

Energy storage system manufacturers, integrators and owners must adopt a systems approach to all levels of safety design, including:





Electrical Safety

Enclosure design and equipment

environment



Site readiness in the design phase



Remote monitoring and fire suppression processes for safe operation

Safety By Design

A focus on safety must begin in the design phase. These best practices are deeply ingrained in the organizational cultures of many leading electrical equipment and systems providers, such as LS Energy Solutions' parent company LS-IS, but there remains room for improvement and further standardization.

Electrical Safety

Most storage fires are caused by thermal runaway in the battery cells. However, overall system integration significantly impacts the potential for thermal runaway – and its mitigation. A design approach that prioritizes safety must begin in the system architecture stage with the proper selection of system components, including the batteries themselves, as well as power conversion and protective equipment. All system elements should have proper certification and testing (e.g., UL1741 and UL9540, IFC 2018 and NFPA 855) as applicable:

- Inverters
- Transformers
- Electrical system branch circuit protection
- AC and DC panels
- Arc flash measures
- Insulation monitoring
- Ground fault detection systems





Storage safety can further be enhanced by building the system in modular units, an approach enabled by incorporating string inverters. By dividing a large installation into smaller pieces, system integrators can minimize short circuit ratings, which represent one of the key challenges of servicing storage systems. A modular design also allows technicians to replace components quickly and safely, as well as providing operational redundancy and fault isolation in the event of a partial system failure or failures on the power grid.

The LS Energy Solutions' PowerBRiC is an example of a smart string inverter designed specifically with this modular approach in mind, the product of the company's decades of experience working with industrial customers in its previous incarnation, Parker Energy Grid Tie division. And since its acquisition by the \$2 billion South Korean conglomerate LS-IS (itself a former subsidiary of LG), LS Energy Solutions' system integration business has benefited from LS-IS' rigorously tested electrical components, combining safety and quality with a reduced impact on system cost.

It is vitally important for storage installations to have adequate onsite backup power resources so battery control and remote monitoring systems can continue functioning properly through any disruption. These remote monitoring systems are critical for ensuring safety, in addition to supporting enhanced battery management and maintenance functions, as discussed in a subsequent section of this brief.









Enclosure Design and Equipment Environment



Modular Architecture

The next step after selecting certified electrical components is ensuring that the system's enclosure is designed according to best practices. A modular architecture facilitates this step by making it easier to design for safety. LS Energy Solutions, for example, builds commercial-scale systems that house battery racks, power conversion systems and controls in separate enclosures, each with its own protection system. Although this design adds cost compared to whole-system enclosures, it increases safety and reliability considerably by isolating components that are malfunctioning or posing other risks, and it may reduce regulatory hurdles in densely populated areas (e.g., buildings in New York City).



Thermal Management

Each enclosure must address thermal management, including properly sized HVAC systems and sufficient ducting to handle expected battery and external heat loads. Above all, equipment must be protected from moisture intrusion, which lowers ground fault resistance, increasing the chance of electrical failure and therefore the risk of thermal runaway incidents in energy storage systems. Water ingress must be minimized through robust humidity control systems as well as proper sealing, which should also protect against salt, dust, rodents and other potential contaminants.



Design for First Responders

The equipment environment should also include features to ensure the safety of technicians, first responders and other on-site personnel, including:

- Warning lights
- Proper lock out, tag out (LOTO) safety, including software lockouts
- Safe working spaces inside and outside the enclosure, including exterior pads and landings
- Tie-off points as needed for safety harnesses and ladders
- Lifting mechanisms for heavy loads

Site Readiness

Operators. Site readiness requires educating external stakeholders. Local system users and operators must be briefed on safety guidelines as well as local electrical and fire safety regulations so onsite personnel are adequately prepared for any situation that arises. This is particularly important for commercial and industrial installations, where users will likely be less familiar with these requirements than are utility personnel.



First responders. Local authorities, fire safety personnel and other first responders also need to be well versed in relevant safety measures. Jurisdictional authorities must be notified of the existence and location of the storage system and provided with necessary guidance on the system and its safety features to ensure an effective and safe response should an incident arise. System owners must also verify that appropriate safety signage is in place, in accordance with NFPA 70E.

When LS Energy Solutions has a site responsibility, we bring in the local fire marshal in to learn about the installation of their own battery systems and familiarize them with key features of the environment so first responders know what to look out for and where to look for it in the event of an incident. LS Energy Solutions is also developing first responder manuals and other educational materials to assist in site readiness outreach for its customers.

Active Monitoring

Even with a design process that is centered around safety at every phase and level, it takes more to ensure safe operation on an ongoing basis. Of chief importance are remote monitoring, smart software analytics, and proper fire suppression equipment and processes.

Remote Monitoring

Much like the cars and other devices that populate the growing internet-of-things ecosystem, today's battery storage installations can generate massive amounts of real-time and historical performance data on key indicators such as power, energy, current, voltage, temperature, pressure, gases and more. Software algorithms can translate this deluge of raw data into crucial insights on system health and status, in addition to driving efficient system control and performance on a day-to-day basis.



Effective remote monitoring can provide periodic and

condition-based notifications to ensure proper system maintenance, helping to prevent catastrophic events. With a system that actively monitors for grounding, loss of insulation, and other risk factors, operators can proactively detect issues before they become a performance issue or safety hazard. In the event of an incident, the system can automatically trip offline and shutdown while operators, field technicians and first responders are alerted to the issue as soon as it arises.

End users are actively seeking out these remote monitoring capabilities, and they are now mandatory in a number of prominent jurisdictions, such as New York City. LS Energy Solutions' PowerBRiC is a smart string inverter that grants users access to the kind of granular, building block-level data and sophisticated software algorithms that make possible the highest level of performance and safety.



Fire Suppression

The best fire protection is prevention, and many key fire protection features are intrinsic elements of safety-centered design, including the selection of appropriately certified battery equipment and battery management systems, ground fault detection systems and remote monitoring capabilities. However, while fire risk can be minimized, it cannot be eliminated altogether, necessitating additional site-specific systems for this purpose.

Most fire and temperature suppression systems are aerosol or gas-based in order to effectively suppress fire and cool thermal runaway without causing extensive damage to equipment in the event of a false discharge. Secondary systems typically use established water-based solutions such as dry pipe sprinkler systems, pre-action sprinkler systems and deluge sprinkler systems. Installations in remote locations that lack water connections may require additional equipment such as hookups for pumper trucks. Emerging approaches using foam injection systems in place of water for fire suppression are also being developed.

New concepts in fire detection may enable suppression measures to be deployed rapidly and precisely, such as:

- Infrared thermal detection systems that can enable fires to be detected as quickly as smoke detectors while also pinpointing the location of a fire within an enclosure.
- Gas detection systems that can provide critical information about the type of fire and suppression approach required; for example, high hydrogen content fires can be explosive, while low hydrogen content fires are non-explosive but highly toxic.

Leveraging Expertise Far and Wide

Some valuable guidance can be gleaned from the best safety practices of other industries, such as the use of fireproof fabric pads in the aviation sector. However, the energy storage industry is stepping up its efforts to develop its own set of best practices for fire suppression related specifically to stationary batteries. The National Fire Protection Association and the Energy Storage Association are both at the forefront of this work, and LS Energy Solutions and other leading integrators are active participants in these proceedings.

Companies are also partnering with outside institutions to develop better storage-specific solutions. LS Energy Solutions is collaborating with EPIC (Engineering Procurement and Infrastructure Center). EPIC is a part of UNC Charlotte's Lee College of Engineering and the California Energy Commission's Electric Program Investment Charge on a project to document current industry practices, identify potetial risks and gaps, and develop new alarm and fire suppression systems for energy storage facilities. The goal is to design equipment that will detect and deliver alerts on unsafe conditions as well as deploy active measures to counteract and extinguish fires that do break out.





A Collaborative Approach to Safety

Safety-first approaches typically add cost to battery storage installations, although certain capabilities such as remote monitoring and predictive analytics can improve systems' operational bottom line through improved performance and reduced maintenance costs. In general, however, this can be a challenging value proposition for developers familiar with the seemingly endless downward slide of utility-scale solar pricing.

But this added cost is becoming less optional as regulators, industry organizations and battery manufacturers themselves move steadily toward more stringent safety requirements. Indeed, the value of safety goes beyond the bottom line of any one installation or company, as demonstrated by the industry-wide fallout from the Arizona battery incident. South Korea instituted a moratorium on battery installations after a rapid build-out of storage deployments, some of which were hastily constructed, resulted in numerous safety incidents.

LS Energy Solutions/LS-IS, with close to 800 megawatts installed, is actively collaborating with industry organizations and other companies in the battery industry and related sectors to share operational experiences and disseminate best practices. Collaborative engagement with local officials and first responders can also go a long way toward enhancing safety as well as building overall comfort and familiarity with these installations.

Battery storage will be an essential part of the long-term future of the smarter, more decentralized and decarbonized power grid. Taking shortcuts on safety is unnecessary, and it risks slowing down the industry's impressive growth at a critical stage of its development.









For more information on how the PowerBRiC can benefit your energy storage system, contact **LS Energy Solutions**. LS Energy Solutions is an affiliate of LS-IS, Korea's major power solution provider and the largest energy storage system (ESS) solution provider in North America. Since launching the ESS business in 2007, LS Energy Solutions/LS-IS has offered total solution with key technologies in global-level ESS system, PCS design, manufacturing, implementation and service. It has quickly entered the world markets, recording a cumulative deployed supply approaching 800 MW.

Produced in partnership

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