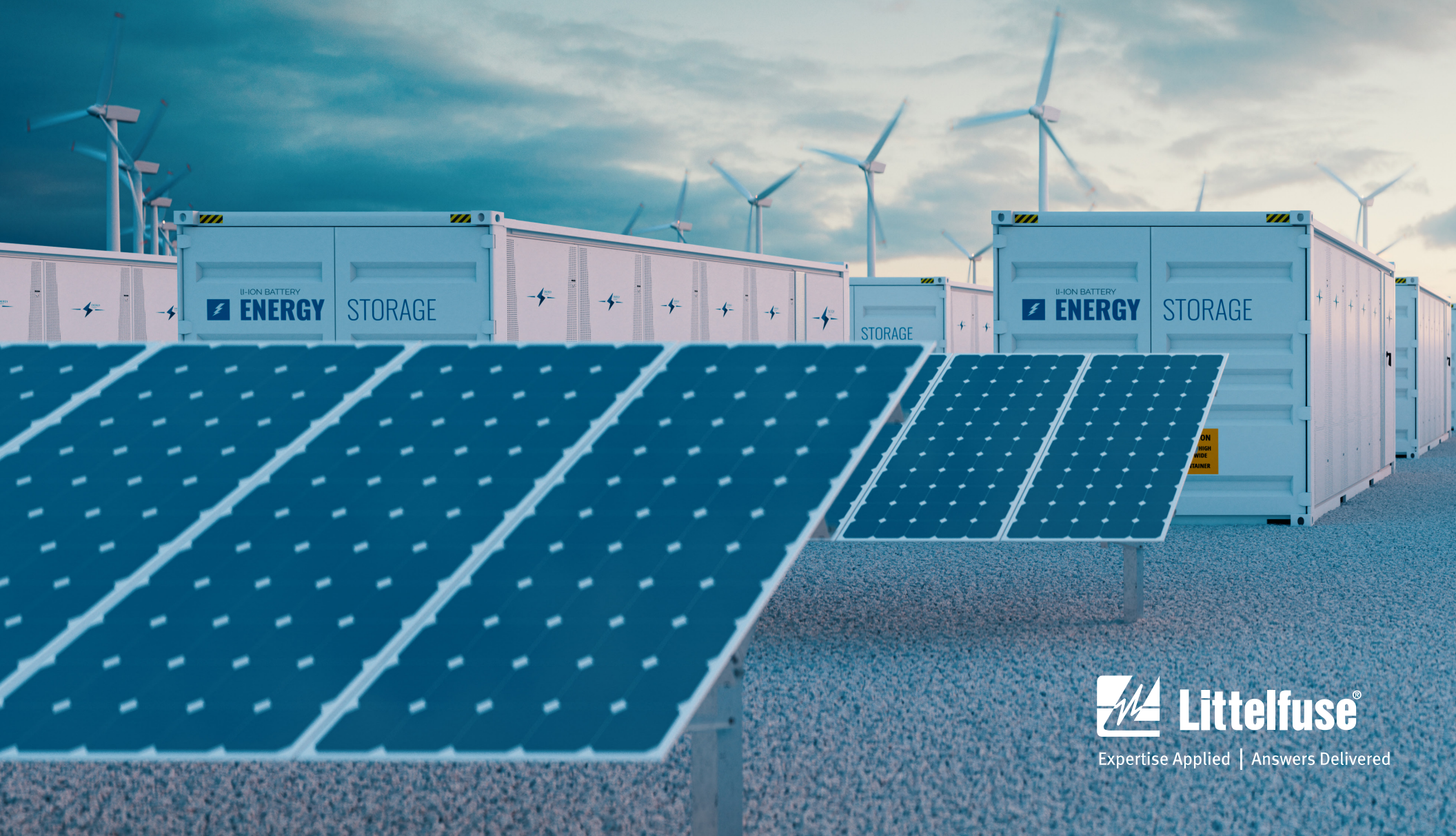


BATTERY ENERGY STORAGE SYSTEMS CAPABILITY GUIDE

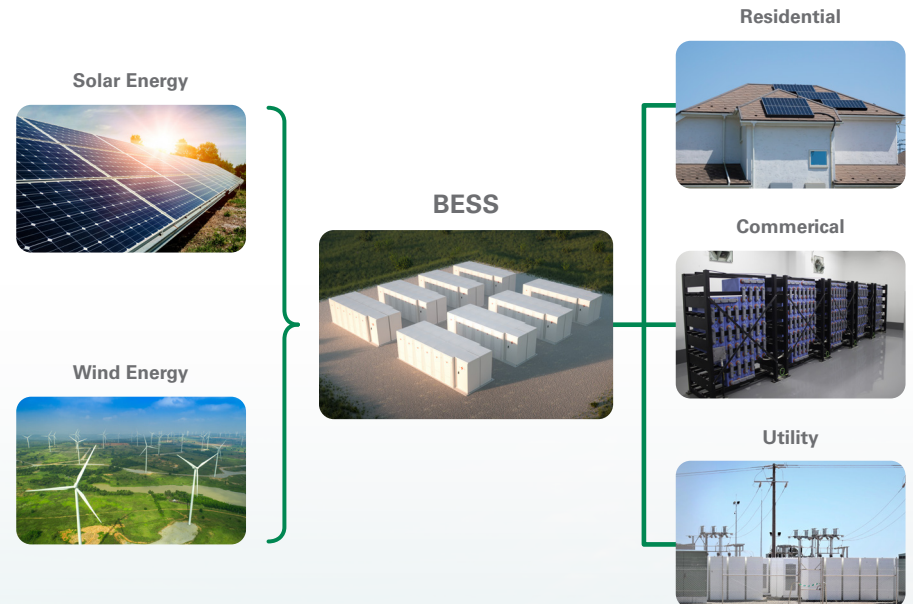


OVERVIEW

The exponential growth in renewable wind and solar energy generation has triggered a corresponding demand for battery energy storage systems (BESSs). With dropping fossil fuel consumption, new country climate goals, lower battery costs, and the prevalence of solar and wind power generation, the need for storage systems has never been greater. Systems that generate and store energy, or are co-located, are becoming the norm. In addition, the majority of upcoming energy storage construction will be for stored power generated from solar or wind energy farms to be used only when needed.

The energy industry is segmented into three categories: residential, commercial or industrial, and utility. Renewable energy generation is growing in all these segments causing an increased demand for storage. For example, through the use of micro-grids, homes and business have begun generating and storing solar power to save money and provide backup power when needed. Also, some countries are providing incentives to install solar panels to reduce stress on the power grid or switch to electrical vehicles to achieve net-zero emission targets.

From a large utility's perspective, a BESS offers increased capacity and lower costs by having stored energy available when demand is high. Unlike traditional forms of generation, BESS systems do not require a long time to power up or down, offering a quick and reliable solution to help balance the electrical system as needed.



ABOUT LITTELFUSE

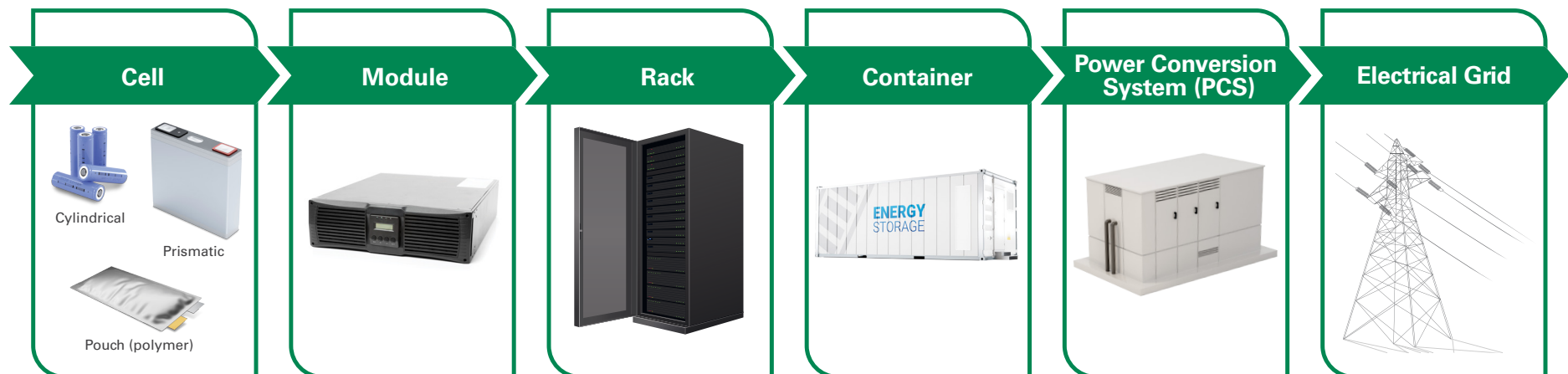
Littelfuse is an industrial technology manufacturing company empowering a sustainable, connected, and safer world. We partner with companies worldwide to design and deliver innovative, reliable energy storage solutions. Our engineers work directly with customers, utilizing our application, compliance and regulatory expertise, to help speed up product design and meet the unique needs of each client. Furthermore, we offer certification testing to global regulatory standards, to help get products to market faster. With our global customer support and manufacturing, we are committed to the highest quality standards and ensure a seamless experience.

BATTERY ENERGY STORAGE SYSTEM (BESS)

A Battery Energy Storage System or BESS is a large-scale battery system connected to the electrical grid for both power and energy storage. Its components include:

- Individual battery **cells**, that are contained in a battery system, convert chemical energy into electrical energy
- Battery **modules** are made up of cells arranged in series and parallel combinations. The battery module also contains the module battery management system (MBMS) that monitors and controls the operations of these cells
- The **rack** holds a number of modules connected in series and the battery protection unit (BPU)—also known as the battery rack controller
 - The battery protection unit includes the rack battery management system (BMS) and monitors the voltage, temperature and the state of the charge of the battery. It also regulates the charging and discharging cycles of the battery
- The **container** can hold several racks in parallel and may have additional components that help to manage or control the environment within the container
- The **power conversion system** (PCS) or bi-directional inverter converts direct current (dc) produced by the batteries into alternating current (ac) supplied to the grid (facilities or end users). It also charges the batteries by pulling power from the grid when needed

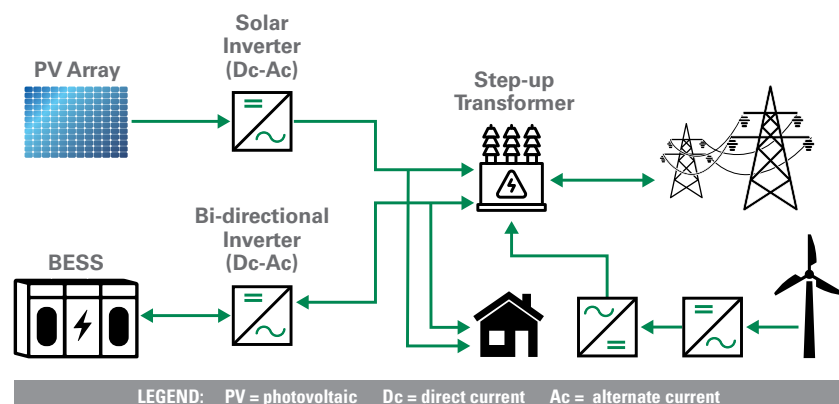
A BESS may also contain some safety systems such as a fire control system, a smoke detector, and a temperature control system or even cooling, heating, ventilation, and air conditioning systems. What is included will depend on what is needed to maintain a safe and efficient BESS operation.



BATTERY ENERGY STORAGE SYSTEM ARCHITECTURES

There are two general ways the components of an energy storage system are wired together—either by alternating current (ac) coupling or direct current (dc) coupling. The difference lies in the path the electricity takes once it is produced. Although solar panels generate dc electricity and solar batteries store electricity in dc, end-users need ac electricity. Thus, a conversion must happen and there are different paths to get there. See below for the pros and cons of each system.

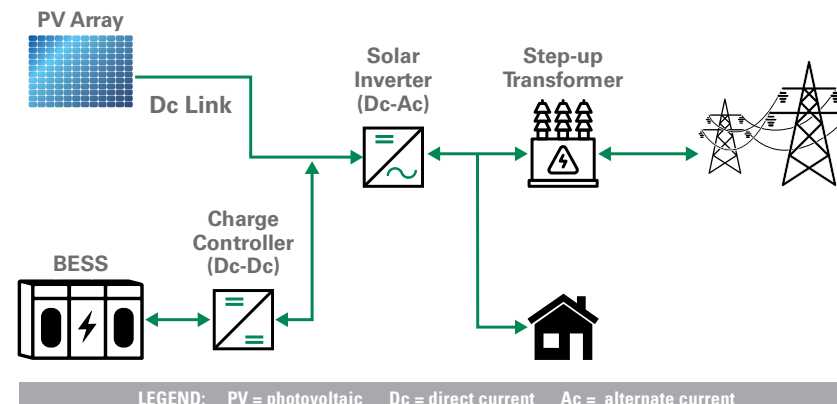
Ac Coupled Solar System



Features:

- Includes two inverters:
 - Solar inverter
 - Bi-directional inverter with battery
- Offers higher flexibility
- Easier installation, especially for retrofits
- Can retain grid-tied inverter to save costs
- The system is less efficient since the energy used by the batteries is inverted multiple times
 - Each level of conversion creates more losses
- Ideal for retrofits
 - This method is more cost effective if there is an existing PV system

Dc Coupled Solar System



Features:

- Utilizes a single inverter to power loads which saves money
- Fewer components reduce costs and maintenance
- Has higher efficiency since the power is not inverted multiple times
 - Less energy losses
- Shorter cables between BESS and PV help reduce losses
- Not ideal for retrofits
 - Need to replace existing inverter
 - In many cases PV array wiring needs to be reconfigured
 - Complex installation with an existing PV system

CIRCUIT PROTECTION PRODUCTS FOR BATTERY ENERGY STORAGE SYSTEMS

Battery Energy Storage Systems (BESSs) demand a comprehensive circuit protection strategy. Within a BESS, the major areas of concern are protection against electrical overcurrent, ground faults, arc flash, and transient overvoltage. Littelfuse offers products that will protect your system and extend the life of your equipment.

Battery Protection Unit:

- Energy Storage Rack (ESR) Battery Protection Fuse
- LS7R Series - Dc Disconnect Switch
- SPD2 Series - Surge Protective Devices

Container:

- PGR-8800 Series - Arc-flash Relay
- Arc-flash Point Sensors

Dc Panel:

- Semiconductor High-speed Fuses
 - PSX High-speed Square Body Fuses (for 1500 V Systems)
 - PSR High-speed Square Body Fuses (for 1000 V Systems)
- SPD2 Series - Surge Protective Devices (if battery racks contain SPDs and are more than 10 meters away from the dc panel)
- AF0025 Series - Arc-flash Relay

Module:

- JLLN Series - UL Class T Fast-acting Fuse
- NTC Thermistor Temperature Sensor
- TPSMC Series - Surface-mount 1500 W TVS Diode
- 501A Series - 1206 AECQ-compliant Fuse

Battery Dc Cabinet:

- Arc-flash Point Sensor
- Semiconductor High-speed Fuses
 - PSX High-speed Square Body Fuses (for 1500 V Systems)
 - PSR High-speed Square Body Fuses (for 1000 V Systems)

Power Conversion System (PCS):

- PGR-8800 Series - Arc-flash Relay
 - Arc-flash Point Sensors
- SE-601 Series - Dc Ground-fault Monitor
- Semiconductor High-speed Fuses
 - PSX High-speed Square Body Fuses (for 1500 V Systems)
 - PSR High-speed Square Body Fuses (for 1000 V Systems)
- Class J Fuse Disconnect Switch

CIRCUIT PROTECTION PRODUCTS FOR BATTERY ENERGY STORAGE SYSTEMS

High-Speed Square Body Fuses

Energy storage customers require higher dc voltage rating, higher dc current rating, and higher interrupting rating fuses to protect batteries and dc circuits. The PSX and PSR square-body fuses deliver high-speed protection at an increased voltage and interrupting rating to help prevent costly catastrophic failures due to overcurrents. In addition, the small case size facilitates the design of more compact high-energy density systems. These semiconductor fuses will protect applications in energy storage and power conversion operations.



The PSX Series has a voltage rating of 1500 V dc and an interrupting rating of 250 kA dc.

The PSR Series has a voltage rating of 1000 V dc and an interrupting rating of 150 kA dc.

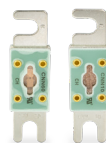
Arc-Flash Protection

Arc-flash relays quickly detect a developing arc flash by sending a trip signal to the circuit breaker, which reduces the total clearing time and any subsequent damage. They do this by providing an output that directly activates an electrical system circuit breaker, which cuts off the current flow to the arcing fault. The installation of an arc-flash relay reduces the total clearing time and the amount of energy that is released through an arcing fault which in turn helps limit damage to equipment and injuries to nearby personnel.



CNN 48 V Dc Fuses

CNN fuses are specifically designed for heavy loads associated with dc battery-powered equipment such as battery systems. Its compact size saves space and provides design flexibility. A window displays fuse status for added convenience.



Dc Disconnect Switches

The energy-efficient and compact dc disconnect switches quickly break or resume the flow of current safely to prevent shock hazards when trying to isolate circuits or repair systems.

Available in various voltage and ampere ratings, they are applicable for energy storage systems, photovoltaic and uninterruptible power supplies (UPS).



Class J Fuse Disconnect Switches

The Class J Fuse Disconnect Switch combines a switch and multiple fuses in a single, compact device. This switch, with both front or side operation, offers a simpler way to manually open and close a circuit while safeguarding against overcurrent and short circuits. When it detects an overload or short circuit, the fuse blows automatically to open or break the circuit both upstream and downstream and shuts off the equipment.



ESR Battery Protection Fuses

The Energy Storage Rack (ESR) series of fuses is designed specifically to protect battery racks in energy storage systems, inverters, and many other dc applications. This 1500 V dc high-speed square body Class aBat partial range fuse is extremely fast-acting. It has superior short circuit protection and low minimum breaking capabilities (MBC) to cover a range of overcurrents that traditional high-speed partial range fuses do not protect against.



Ground-Fault Protection

A variety of factors can contribute to the development of ground faults. Even low-current ground faults can often go unrecognized and cause serious damage. BESSs are typically ungrounded systems and may remain in operation after the first ground fault, resulting in higher voltage on the unfaulted bus with reference to ground but with no current flow. However, subsequent ground faults on the opposite bus can have catastrophic consequences from both an equipment-protection and worker-safety perspective. Ungrounded, and even grounded BESSs, require ground-fault detection and protection to keep systems operating.



Surface Mount Fuses

The 501A series AECQ-compliant fuses and halogen-free fuse series are specifically designed to provide protection to cell monitoring within battery energy storage systems.



Surface Mount TVS Diodes

The TPSMC series of TVS Diodes is designed specifically to protect sensitive electronic equipment from voltage transients induced by lightning and other transient voltage events. Its small size and surface-mount form factor are ideally suited to protect battery sense lines from these events.



Surge Protective Devices

Surge protective devices (SPDs) provide battery energy storage system protection from transient overvoltage events lasting micro-seconds. By limiting the overvoltage to the equipment during these events, costly damage and downtime can be mitigated.



Temperature Sensors

Littelfuse offers a broad selection of Negative Temperature Coefficient (NTC) thermistors, Resistance Temperature Detectors (RTDs), as well as probes and assemblies, to meet the unique temperature sensing needs of your battery energy storage system at the cell and module levels.



TLS Compact Current-Limiting Fuses

The TLS series fuses are engineered to operate up to 170 V dc to provide current-limiting short-circuit protection for cables and components found in the dc power distribution circuits like modules found in battery energy storage systems. The compact design and multiple mounting configurations of the TLS series allow it to be used in a variety of applications.



UL Class T Fast-Acting Fuses

Space-saving Class T fuses are the most compact fuses available in ratings above 30 amperes. In fact, they are less than one-third the size of comparable Class R fuses. When rated in accordance with the NEC, Class T fuses provide fast-acting overload and short circuit protection for non-inductive circuits and equipment.



SUCCESS STORIES

Expanding Energy Storage System Capacity



Customer: Integrator

Application: Battery Rack

Product: PSR Series High-Speed Semiconductor Fuse

Problem:

A battery energy storage system (BESS) integrator wanted to provide its utility customer the ability to respond faster and longer to increases in power demand while lowering its operating costs.

The integrator selected lithium-ion batteries to address the utility's requirement for a higher-capacity battery module but needed a fast-acting fuse with a higher short-circuit current rating to protect it.

Solution:

With 150 kA dc breaking capacity, the Littelfuse PSR series high-speed semiconductor fuse offered the protection the integrator wanted in order to reduce the dc panel count and add more battery units. In addition, by using the PSR square-body fuse (similar to the previous block-style fuse form factor) the integrator avoided the cost of making significant design changes. This new system design offered the utility the ability to rely on the BESS for a longer period of time during high peak-power demands and lower its operating costs.

Safeguarding a More Efficient Inverter Design



Customer: OEM

Application: Inverter

Product: PSR Series High-Speed Semiconductor Fuse

Problem:

An OEM of solar power systems was designing energy storage systems that incorporated a new, more efficient inverter.

This inverter relied on a high-power insulated gate bi-polar transistor (IGBT) that operates at both high voltage and high current. If the inverter is not protected in the event of a fault, it would result in a catastrophic failure and rupture of the IGBTs. This could cause potential breakdown of the inverter taking the energy storage system offline and forcing an electric utility to buy power at a premium to meet peak demand.

Solution:

The Littelfuse PSR series high-speed semiconductor fuse, with faster interruption time, protects the customer's IGBT from the aforementioned catastrophic failure when a fault occurs. This helps reduce downtime and gets the inverter system back online quicker. In addition, the PSR fuse with lower power consumption and remote monitoring, allows the OEM to give its utility and energy storage customers the ability to meet energy demand cost-effectively and reliably.

Beating the Competition With Design, Service and Delivery



Customer: OEM

Application: Battery Control Panel

Product: PSX Series High-Speed Semiconductor Fuse

Problem:

An OEM of battery control panels needed to provide a reliable and high-performance product that required customization, had a short lead time and strict cost parameters.

With numerous competitors and limited customers in this market, the OEM needed to exceed design expectations, meet tight deadlines and lower expenses to win the contract. To stay ahead of competitors, the OEM frequently updated their designs but needed reliable components to limit risks and wanted reputable suppliers who could supply products—with new specifications—within an extremely limited timeframe and keep costs inline.

Solution:

After working together with the OEM's engineers, Littelfuse was able to provide a new product with better performance in an extremely short development window. The new 1500 V dc fuse had to incorporate the OEM's latest specifications including UL certification for 250 kA interrupting rating. In addition, various departments at Littelfuse including procurement, manufacturing, warehouse, shipping, product management and sales, worked together to deliver the final product within weeks meeting the OEM's truncated and rigid schedule.

Packing in More Power With the Right Fuse Protection



Customer: Integrator

Application: Battery Rack

Product: PSX Series High-Speed Semiconductor Fuse

Problem:

A battery energy storage system (BESS) integrator wanted to provide its utility customer the option of integrating different batteries depending on the energy storage system size and duration.

The integrator selected lithium-ion batteries to address the utility's requirement for a higher-capacity battery module but needed a fast-acting fuse with a higher short-circuit current rating to protect it. As more battery racks are added to a system, the available fault current increases. This creates the need for a fuse with a higher short circuit current interrupting rating to mitigate the let through of that fault current.

Solution:

With 250 kA dc breaking capacity, the Littelfuse PSX series high-speed semiconductor fuse offered the protection the integrator wanted while increasing the system energy density and reducing the balance of system components. This design offered the utility a faster and more cost-efficient power demand response.

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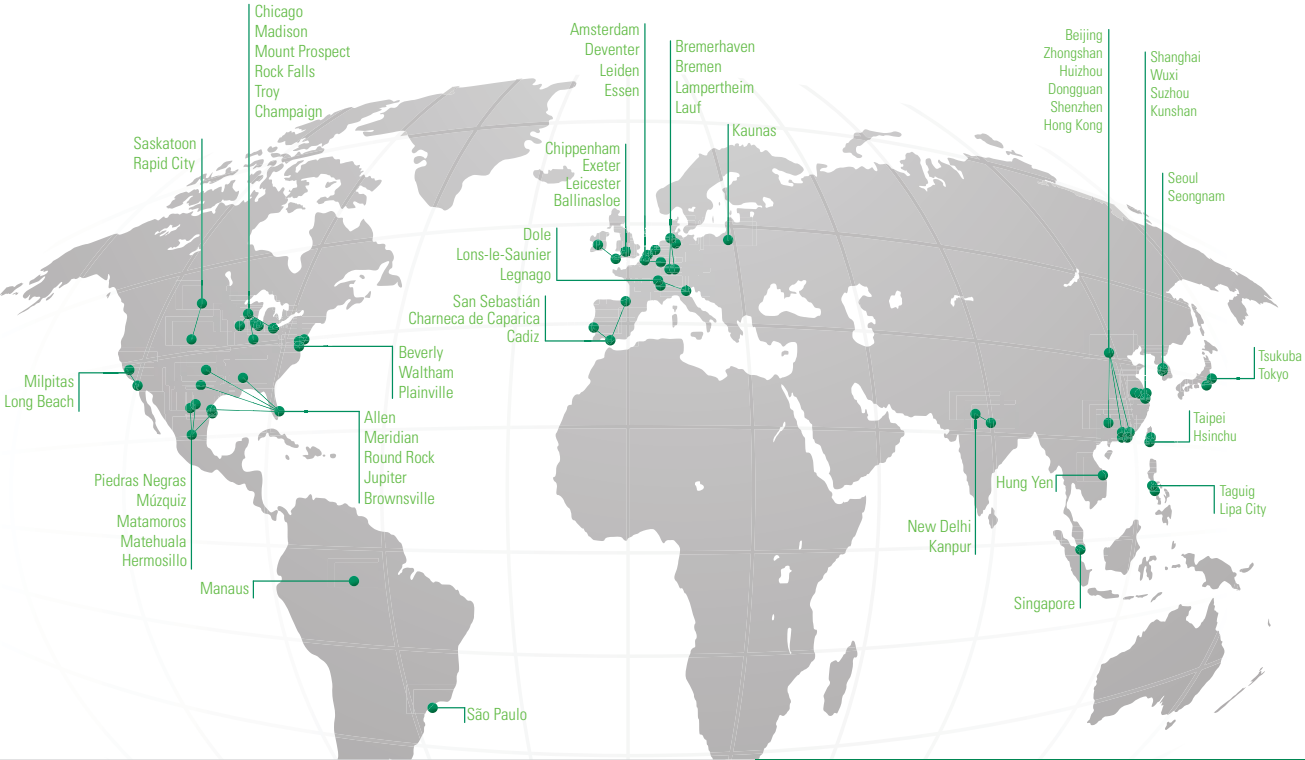
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Littelfuse products live up to the highest standards for performance, reliability, safety and regulatory compliance. Working with Littelfuse offers access to dedicated application engineers who provide expert design consultation, perform comprehensive tests simulating the harshest environments and evaluate results. Our testing facilities are reassessed annually by the certifying bodies to ensure compliance. Choosing Littelfuse components help achieve regulatory compliance for products faster and with less expense.

Standard	Title	General scope	Region
IEC 60269-7	Technical Standards for Low-voltage Power Fuses	This part of IEC 60269 has supplementary requirements that apply to fuse-links for the protection of batteries and battery systems.	Global
UL 1741	Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources	These requirements cover inverters, converters, charge controllers, and interconnection system equipment (ISE) intended for use in stand-alone or grid-connected power systems	North America
UL 1973	Batteries for Use in Stationary and Motive Auxiliary Power Applications	A safety standard for stationary batteries for energy storage applications that is not specific to any one battery technology or chemistry and can apply to Li-ion battery ESSs, as well as ESSs using other battery chemistry.	North America
UL 9540A	Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	This document evaluates the fire characteristics of a battery energy storage system that undergoes thermal runaway	North America

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