Littelfuse®

Expertise Applied | Answers Delivered

# Residential Energy Storage with Hybrid Inverters

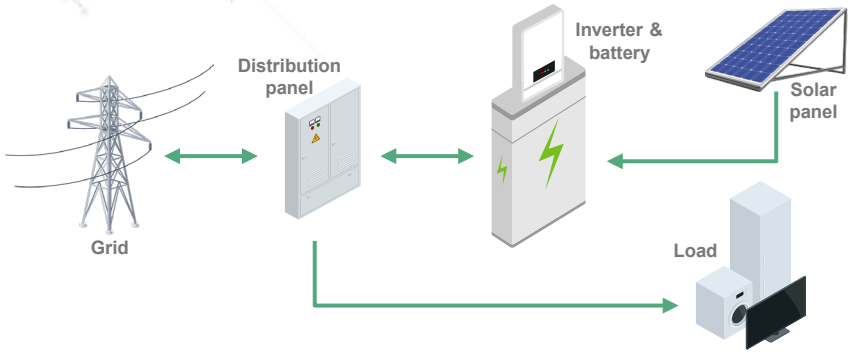
Renewable Energy

Energy Storage

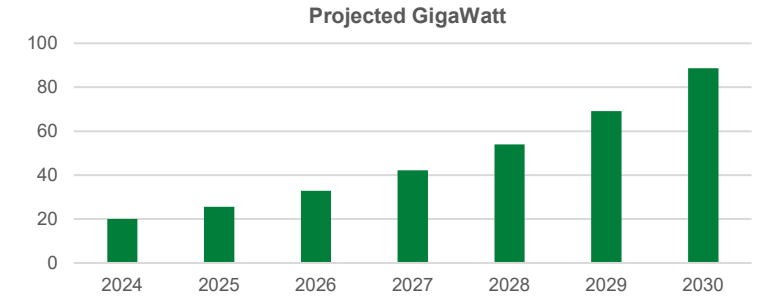


REV0825

# Market for residential energy storage with hybrid inverters




## Residential energy storage forecast




***Source:*** *Littelfuse estimations, Volta Foundation*

## Market trends and drivers

Gains in popularity are primarily driven by battery costs, government policy incentives, and a massive uptick in investments in BESS technology and projects.

Systems that support smart monitoring, load shifting, and grid interaction have been the subject of growing demand. Residential energy storage is increasingly integrated into Virtual power plants (VPPs), enabling homeowners to contribute to grid stability and benefit from participation in the energy market.

Leading battery and solar manufacturers are expanding into residential energy storage, accelerating innovation and driving competitive pricing.

Hybrid inverters, which integrate PV and battery control into one unit, are becoming more popular than traditional dual-inverter systems. They simplify installation, reduce equipment footprint, improve efficiency, and lower overall system costs.

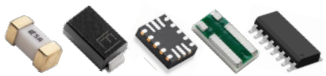
Combining energy storage and power conversion into a single system simplifies wiring and installation but also introduces challenges such as inrush current, fault isolation, and thermal stress. Littelfuse solutions help address these issues and enhance overall system safety and reliability.

# Recommended Littelfuse solutions for residential battery energy storage

**Input protection**
Fuse, MOV,
GDT, NTC

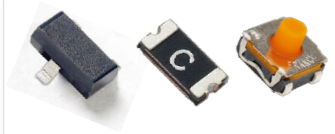
**Power conversion**
MOSFET, IGBT, Rectifier Diode, SiC Schottky Diode, TVS Diode, Gate Driver

**Auxiliary power**
Fuse, TVS Diode, eFuse,
CSR, Gate Driver



**AC line protection**
Fuse, GDT, MOV + SIDACtor®

**Communication & user interface:** TVS Diode Array, PolySwitch® Device, Switch



***Acronyms:***
*MOV: Metal-oxide Varistor*
*GDT: Gas Discharge Tube*
*NTC: Negative Temperature Coefficient*
*IGBT: Insulated-Gate Bipolar Transistor*
*SiC: Silicon Carbide*
*TVS: Transient Voltage Suppression*
*CSR: Current Sensing Resistor*

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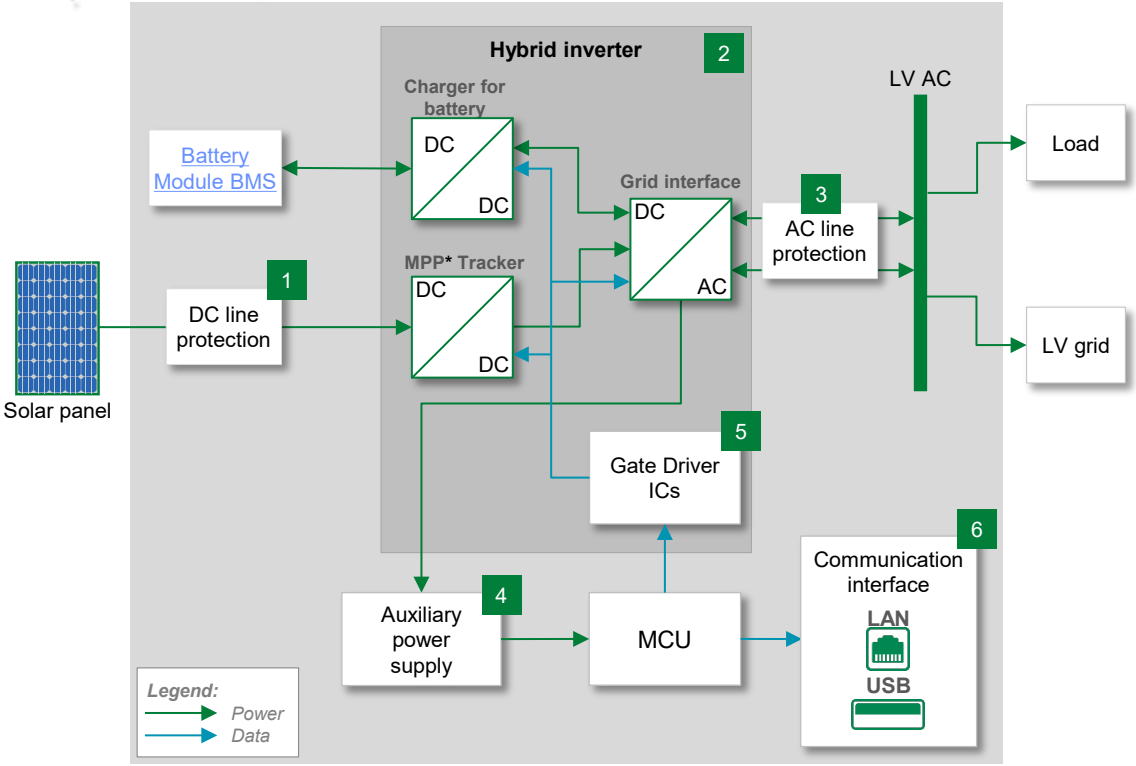
Click the product series in the table below for more info

# Residential energy storage with hybrid inverters




* *MPP: Maximum power point*

| | Technology | Product series |
|---|---|---|
| 1 | MOV | LST, LA |
| 2 | MOSFET | N-Channel Trench Gate |
| | Silicon Carbide | SiC MOSFET |
| | IGBT | XPT |
| | Rectifier Diode | D40 |
| | Si Fast Recovery Diode | HiperFRED Extreme Fast |
| | TVS Diode | SMFA |
| 3 | MOV + SIDACtor® Protection Thyristor | UltraMOV + Pxxx0ME |
| | GDT | CG3/CG4 |
| | Fuse | Class J, KLKD |
| 4 | Fuse | 448 |
| | TVS Diode | SACB, SMAJ |
| | Protection IC (eFuse) | LS2406ERQ23 |
| | Current Sensing Resistor | L4CA/C |
| 5 | Gate Driver | IX4352 |
| 6 | TVS Diode Array | SP712, SM712 |
| | PolySwitch® Device | 1206L |
| | Switch | KSC |

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Click the product series in the table below for more info

# Littelfuse solutions in residential energy storage

| | Technology | Function in application | Product series | Benefits | Features |
|---|---|---|---|---|---|
| 1 | MOV | Protects from lighting surges on PV lines | LST, LA | Thermally protected MOV (LST); high surge capability; long life-cycle capability | Wide voltage range up to 1000 V; radial or disk type; UL recognized |
| 2 | MOSFET | Switching or power control | N-Channel Trench Gate | 135–1000 V, $R_{DS(on)}$ as low as 1.99 mOhm; high current ratings; standard SMT THT and unique packages | Low on-state losses; simplifies gate driver; improves efficiency; reduces device paralleling; simplifies design |
| | SiC MOSFET | High-efficiency power switching | SiC MOSFET | Fast switching, low $R_{on}$, wide bandgap MOSFETs | Improved efficiency; higher switching frequency to downsize passive components (Discrete and SMPD) |
| | IGBT | High-power switching | XPT | Positive temperature coefficient for on-state voltage facilitates paralleling; low gate current requirements | Simplified mounting, lower $R_{thJ-H}$ and higher integration versus standard discrete (Discrete and SMPD) |
| | Rectifier Diode | Provides bypass protection | D40 | Advanced Planar design; wide current and voltage range with unique package types | Superior commutation robustness and high surge current capability |
| | Si Fast Recovery Diode | Boost diode | HiperFRED Extreme Fast | Comprehensive portfolio cover $P_t$, $A_u$, $H_e$ doped diffusion; wide current and voltage range with unique package types | The FRED Low Vf series offers improved forward voltage characteristics and breakdown voltages up to 1200V. |
| | TVS Diode | Protects semiconductor switches from voltage transient | SMFA | Improves system reliability by clamping the voltage at safe levels during transients | SOD-123FL low-profile package: maximum height of 1.08 mm, Low inductance, excellent clamping capability, Low dynamic resistance |
| 3 | MOV + SIDACtor® Protection Thyristor | Protects the AC line from voltage transients and lighting surges | UltraMOV + Pxxx0ME | Lower clamp voltage ~912 V at 3 kA 8/20 µs surge current; minimize leakage current | Combining a SIDACtor® and MOV in series offers superior surge protection and extends the life of downstream components–while also reducing overall system cost |
| | GDT | Provides line-to-ground protection from voltage transients and lightning | CG3/CG4 | Small form-factor allows for compact system design; enables product to comply with IEC/UL standards | High energy absorption capability; small form-factor; low leakage current |
| | Fuse | Overcurrent protection for AC connection | Class J, KLKD | Reduces damage to equipment caused by short circuit currents; compact design | Extremely current-limiting; small footprint; 200 kA interrupting rating |

Click the product series in the table below for more info

# Littelfuse solutions in residential energy storage

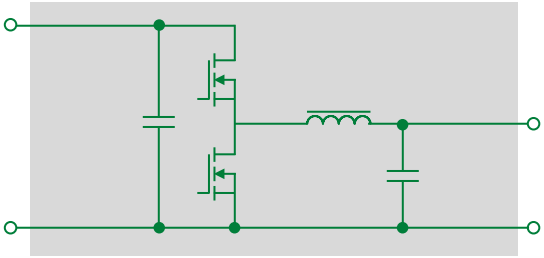
| | Technology | Function in application | Product series | Benefits | Features |
|---|---|---|---|---|---|
| 4 | Fuse | Auxiliary power over-current protection | 448 | Reduces damage to equipment; compact design | Fast acting; SMD fuse with small footprint; low temperature derating |
| | TVS Diode | Protects power units from voltage transients | SACB, SMAJ | Improves system reliability by clamping voltage at safe levels during transients | Excellent clamping capability |
| | Protection IC (eFuse) | Provides protection from overload, short circuit, input voltage surge, over-temperature, excessive inrush current, and reverse current | LS2406ERQ23 | Integrated alternative to discrete components that offers several functions in a single package | Wide operation voltage range from 3 V to 24 V; low profile 16 leads QFN 2.5 mm x 3.2 mm package |
| | Current Sensing Resistor | Part of current measurement circuitry | L4CA/C | Cost-effective solution compared to competing technologies; compact size | Resistance range down to 0.5 mΩ; separate voltage-sensing terminals |
| 5 | Gate Driver | Drive Si/SiC MOSFETs (both Discrete and SMPD) | IX4352 | Most robust Gate Driver on the market; has the highest voltage and current | Allows for more voltage margin; enables easy paralleling of the MOSFETs; SiC driver with integrated charge pump (IX4352) |
| 6 | TVS Diode Array | ESD protection; surge protection for communication ports | SP712, SM712 | High ESD performance in small packages | Low capacitance of 1 to 0.2 pF (TYP) per I/O |
| | PolySwitch® Device | Resettable overcurrent protection for data line connections | 1206L | Saves board space; promotes robust operations | Low internal resistance; highest current-holding capability among competitors; the smallest SMD package |
| | Switch | Switch for function controlling, resetting, etc. | KSC | Available in a wide range of operating forces; rugged sealing and resistant to corrosion; very long operating life | Ultra-low current consumption; operating life of up to 1 million cycles |

*For non-automotive qualified application*

# Power supplies topologies: Charger ~ 400 V voltage battery

Click the product series in the table below for more info

Charger: Bidirectional buck/boost

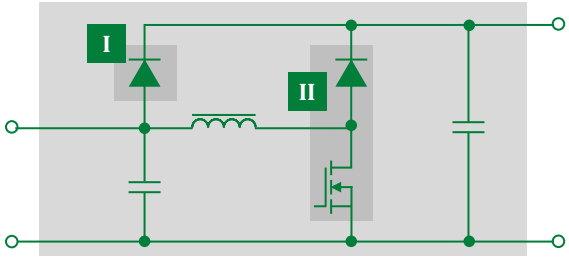


| | Technology | Function in application | Product series | Benefits | Features |
|---|---|---|---|---|---|
| | TVS Diode (Protection) | Protects semiconductors; is applied between gate and source | SMF, SMFA | 200 W peak pulse power capability; excellent clamping capability; low profile | Improves system reliability by clamping voltage at safe levels during transients |
| | Si MOSFET Discrete | Semiconductor switch | N-Channel Ultra Junction | 135–1000 V, $R_{DS(on)}$ as low as 1.99 mOhm; high current ratings; standard SMT THT and unique packages | Low on-state losses; simplifies gate driver; improves efficiency; reduces device paralleling; simplifies design |
| | Si SMPD | | SMPD Packages-MOSFETs | Pick-and-place compatible; built in isolation; multichip design blocks | Simplified mounting; lower $R_{thJ-H}$ and higher integration versus standard discrete packages |
| | SiC MOSFET Discrete & SMPD | | Silicon Carbide | Fast switching; low $R_{on}$; wide-bandgap MOSFETs | Improved efficiency; higher switching frequency to downsize passive components |
| | High-side/Low-side Drivers & Half-bridge Drivers | Drive Si/SiC MOSFETs (both Discrete and SMPD) | Gate Driver ICs | Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable, cost-efficient solutions in industry-standard pinouts and with enhanced voltage and thermal characteristics | Allows for more voltage margin and facilitates MOSFET paralleling of the MOSFETs; eases implementation and reduces number of components; offers improved alternatives and facilitates the supply chain |

Click the product series in the table below for more info

# Power supplies topologies: MPP tracker

Unidirectional boost + bypass

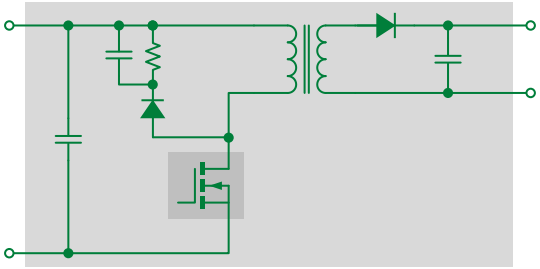



| | Technology | Function in application | Product series | Benefits | Features |
|---|---|---|---|---|---|
| I | Rectifier Diode | Bypass protection | Rectifier | Advanced planar design; wide current and voltage range with unique package types | Best-in-class commutation robustness and high surge current capability |
| II | Si Fast Recovery Diode | Boost diode | Fast Recovery | Comprehensive portfolio cover $P_t$, $A_u$, $H_e$ doped diffusion; wide current and voltage range with unique package types | Unique recovery behavior for extensive application needs |
| | SiC Schottky Diode | | Schottky (SiC) | Fast-switching wide-bandgap material; zero recovery | Increases application power density and improves efficiency |
| | Si MOSFET Discrete | Semiconductor switch | N-Channel Ultra Junction | 135–1000 V; high current ratings; one of the best-in-class $F_{OM}$ $R_{DS(on)}$*$Q_g$; standard SMT THT and unique packages | Low on-state losses; simplifies gate driver; improves efficiency; reduces device paralleling; simplifies design |
| | Si SMPD | Semiconductor switch and boost diode | SMPD Packages-MOSFETs | Pick-and-place compatible; built-in isolation; multichip design blocks | Simplified mounting; lower $R_{thJ-H}$ and higher integration versus standard discrete package |
| | SiC MOSFET Discrete | Semiconductor switch | Silicon Carbide | Fast switching; low $R_{on}$; wide-bandgap MOSFETs | Improved efficiency; higher switching frequency to downsize passive components |
| | Low-side Drivers | Drive Si/SiC MOSFETs (both Discrete and SMPD) | Gate Driver ICs | Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable and cost-efficient solutions in industry-standard pinouts and with enhanced voltage & thermal characteristics | Allows for greater voltage margin and easier paralleling of MOSFETs; eases implementation and reduces number of components; offers improved alternatives; facilitates the supply chain |
| | TVS Diode (Protections) | Protects semiconductors; applied between gate and source | SMF, SMFA | Peak pulse power capability of 200 W; excellent clamping capability; low profile | Improves system reliability by clamping voltage at safe levels during transients |
| | Rectifier Diode | Bypass protection | Rectifier | Advanced planar design; wide current and voltage range with unique package types | Superior commutation robustness and high surge current capability |

Click the product series in the table below for more info

# Power supplies topologies: Auxiliary power supply

Flyback–converter

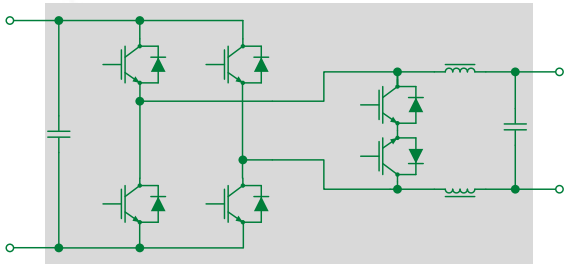


| | Technology | Function in application | Product series | Benefits | Features |
|---|---|---|---|---|---|
| | SiC MOSFET Discrete<br>***OR***<br>HV Si MOSFET Discrete | Semiconductor switch | Silicon Carbide<br>***OR***<br>N-Channel Standard | Fast switching; low $R_{on}$, 1700 V SiC MOSFETs | Improved efficiency; 1700 V $V_{bk}$ allows single-switch flyback topology for high-voltage DC bus |
| | | | | Up to 4.7 k; standard SMT THT and unique packages | Simplifies design, improves reliability, and saves PCB space |
| | Low-Side Drivers | Drive Si/SiC MOSFETs | Gate Driver ICs | Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable, cost-efficient solutions in industry-standard pinouts and with enhanced voltage and thermal characteristics | Allows for greater voltage margin and the easy paralleling of MOSFETs; eases implementation and reduces number of components; offers improved alternatives, thereby facilitating the supply chain |
| | TVS Diode (Protections) | Protects semiconductors; applied between gate and source | SMF, SMFA | Protects semiconductor switches from voltage transients | Peak pulse power capability of 200 W; excellent clamping capability; low profile |

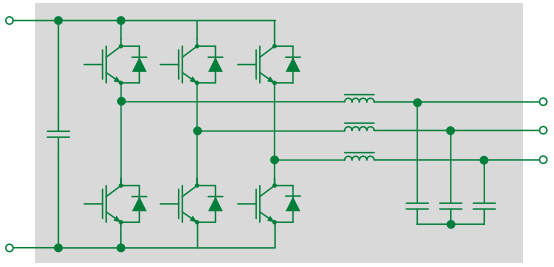
Click the product series in the table below for more info

# Power supplies topologies: Grid interface

Single-phase inverter (HERIC)



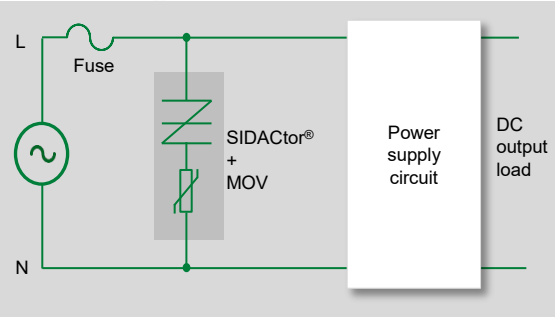
Three-phase inverter (Sixpack)



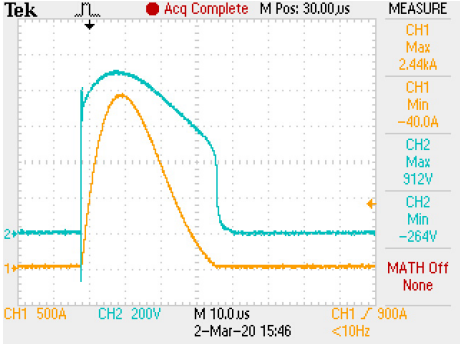
| | Technology | Function in application | Product series | Benefits | Features |
|---|---|---|---|---|---|
| | SiC MOSFET Discrete and SMPD | Semiconductor switch | Silicon Carbide | Fast switching; low $R_{on}$; wide-bandgap MOSFETs | Improved efficiency; higher switching frequency to downsize passive components |
| | IGBT Discrete | | XPT | Pick-and-place compatible; built in isolation; multichip design blocks | Simplified mounting; lower $R_{thJ-H}$ and higher integration versus standard discrete |
| | High-Side/Low-Side Drivers and Half-Bridge Drivers | Drive Si/SiC MOSFETs (both Discrete and SMPD) | Gate Driver ICs | Most robust gate driver on the market; has the highest voltage and current; SiC driver with integrated charge pump (IX4352); reliable and cost-efficient solutions in industry-standard pinouts and with enhanced voltage and thermal characteristics | Allows for greater voltage margin and easier paralleling of MOSFETs; eases the implementation and reduces the number of components; offers improved alternatives to facilitate the supply chain |
| | TVS Diode (Protections) | Protects semiconductors; is applied between gate and source | SMF, SMFA | Peak pulse power capability of 200 W; excellent clamping capability; low profile | Improves system reliability by clamping voltage at safe levels during transients |

# SIDACtor® Protection Thyristor + MOV in series protect AC power lines solution

**SIDACtor® Protection Thyristor + MOV**




**3kA 8/20 with P3500FNL + V14E230P**




- **How it works:** SIDACtor® Protection Thyristor triggers first to clamp voltage; then, MOV absorbs surge energy.
- **Dual protection:** Low clamping and high energy-absorption in one solution.
- **Higher reliability:** Protects sensitive inverter circuits and extends system life.
- **Cost savings:** Enables smaller MOVs and reduces component stress.
- **Example P3500FNL+V14E230P:** Lower clamp voltage of ~912 V at 3 kA 8/20 µs surge current compared to single solutions featuring 350 V MOV.

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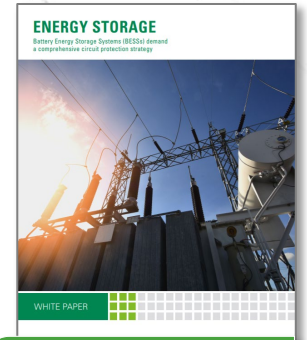
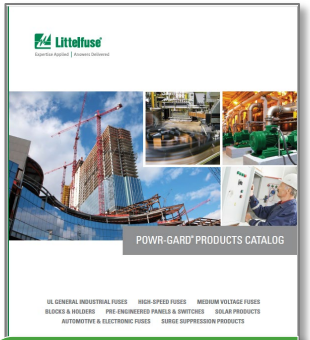
# Additional information can be found at Littelfuse.com

Explore the world of Littelfuse products and applications with ecatalogs (ecatalogs.littelfuse.com)

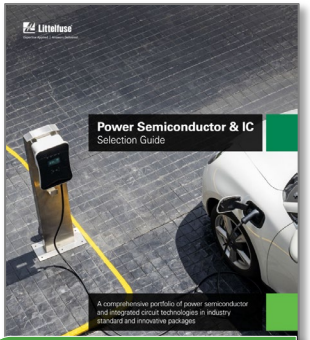



Energy Storage Whitepaper

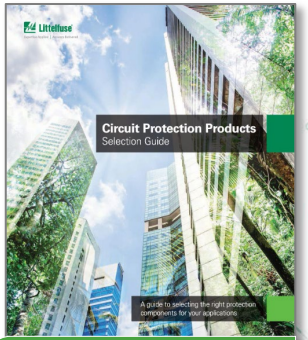

SPDs in PV Systems




Industrial Fuses Catalog




Power Semiconductor Selection Guide

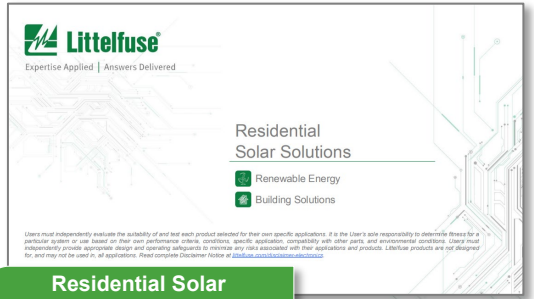



Circuit Protection Selection Guide

**Click** on the images for more information


Solar Protection White Paper


Power Relay & Control Catalog




Residential Solar Solutions Spotlight

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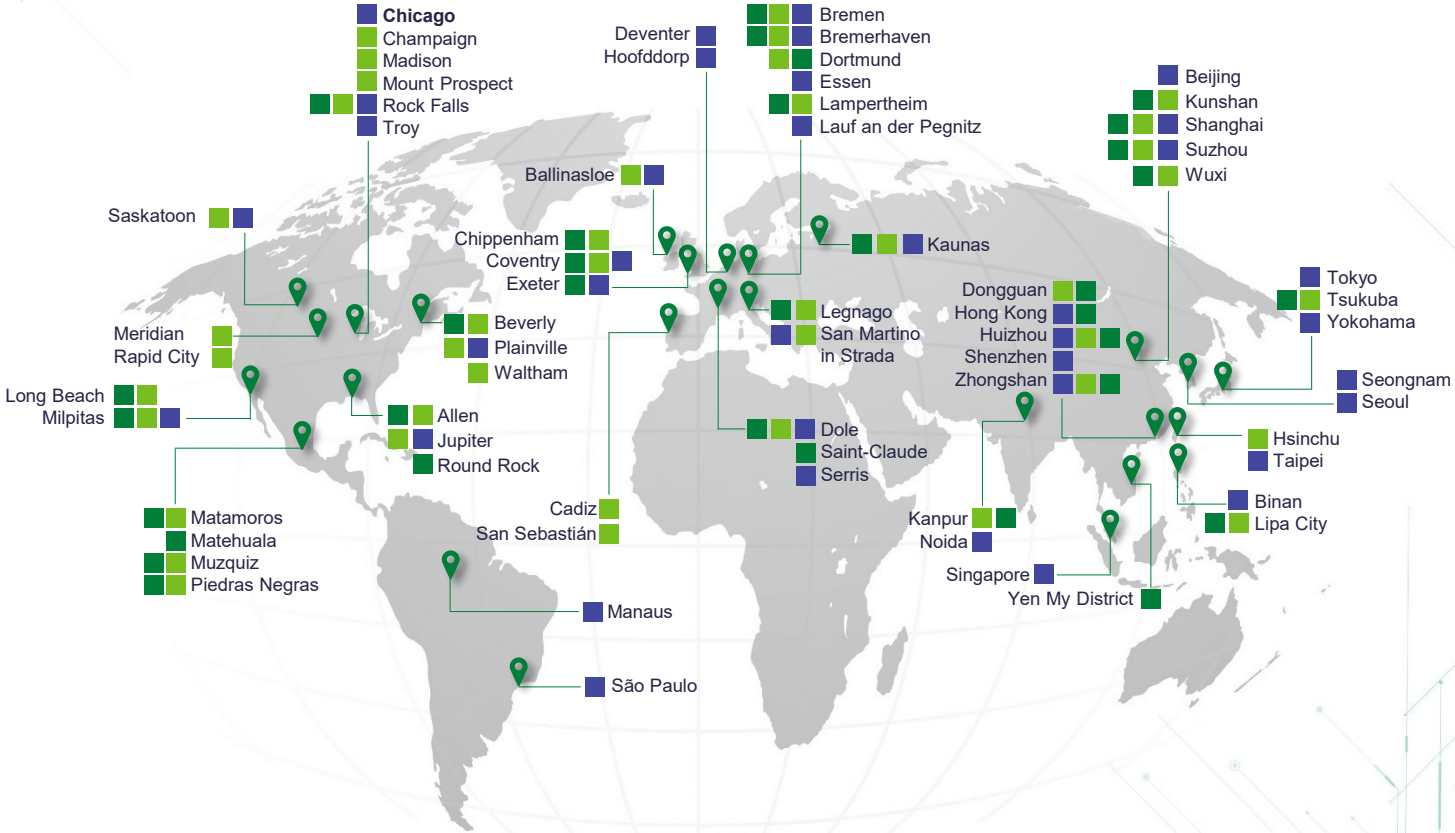
# Local resources supporting our global customers

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**Broad Product Portfolio**

We are an industrial technology manufacturing company empowering a sustainable, connected, and safer world.

**Testing Capabilities**

We help customers get products to market faster, and we offer certification testing to global regulatory standards.


**Application Expertise**

Our engineers partner directly with customers to help speed up product design and meet their unique needs.

**Compliance & Regulatory**

We help customers in the design process to account for requirements set by global regulatory authorities.

**Global Customer Service**

Our global customer service team is with you to anticipate your needs and ensure a seamless experience.

**Global Manufacturing**

We support high volume manufacturing that is committed to the highest quality standards.

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