

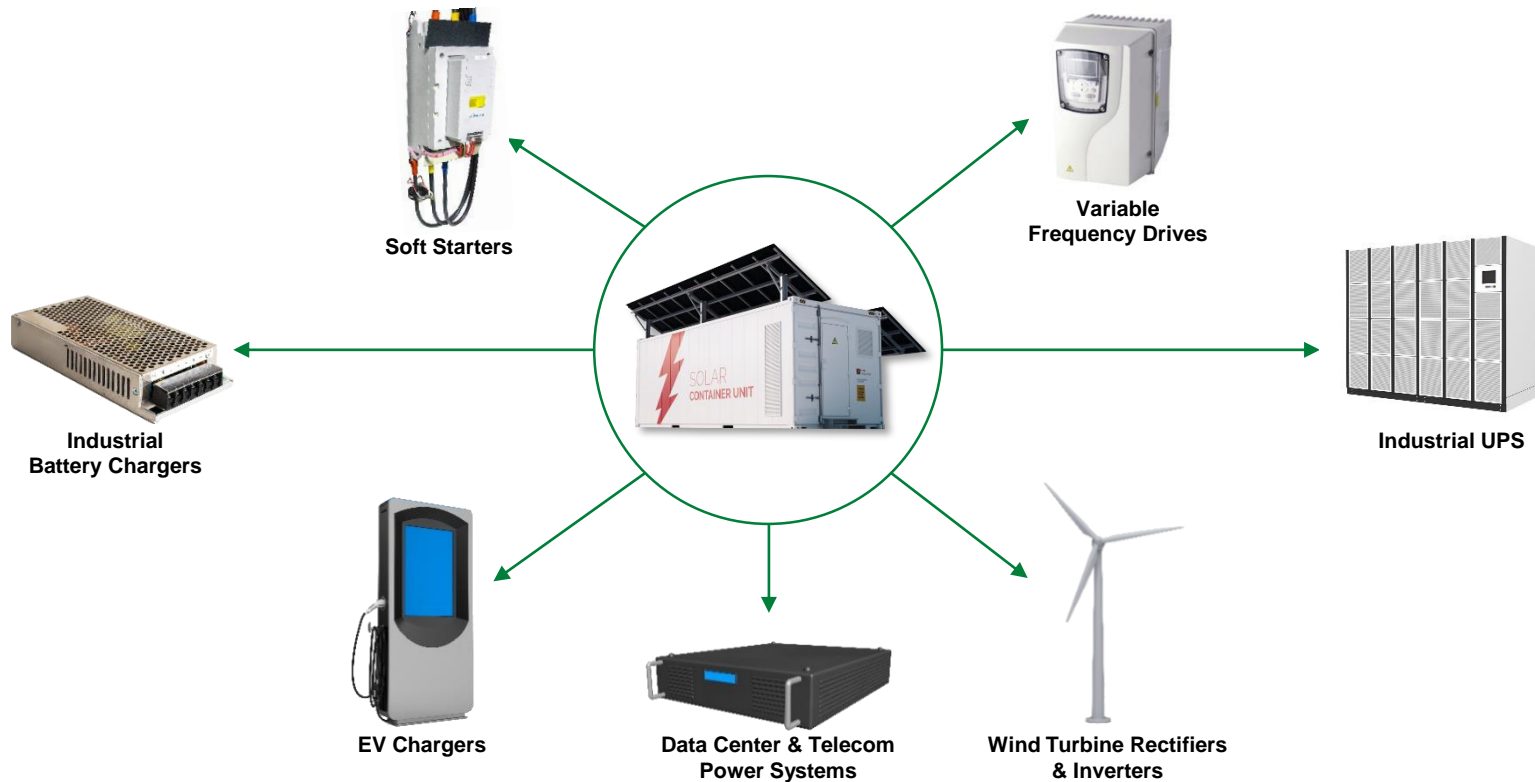


# Solar Inverters & Battery Energy Storage Systems (BESS)

 Alternative Energy

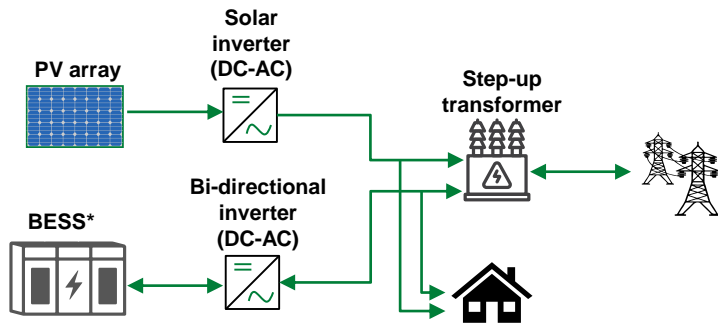
 **Littelfuse®**  
Expertise Applied | Answers Delivered

# Solar inverters share similar architecture with other systems like industrial drives, UPS, EV charging, etc.



# Solar Inverter and Battery Energy Storage System(BESS) architectures

## AC coupled solar system



### Features

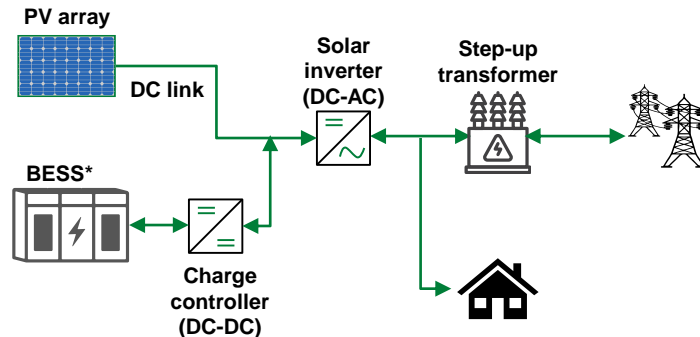
Two inverter: Bi-directional inverter with battery and a solar inverter

Offers higher flexibility. Easier installation, especially for retrofits. Get to keep grid-tied inverter

Less efficient as the energy used by batteries is inverted multiple times. Multiple components: Multiple MV transformers, inverters, etc.

Cost effective if there is an existing PV system

## DC coupled solar system



### Features

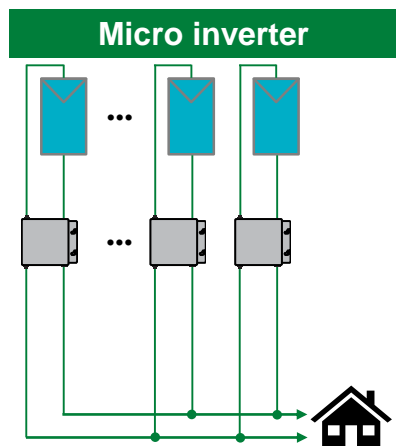
Single inverter to power loads

Not ideal for retrofits. Required to replace existing inverter and in many cases PV array wiring need to be reconfigured

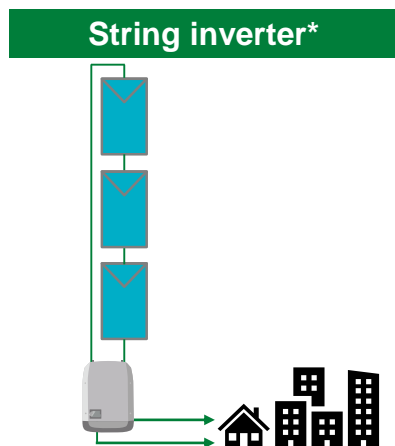
Higher efficiency as the power is not inverted multiple times. Fewer components. Short cables between BESS and PV reduces losses

High cost and complex installation with an existing PV system

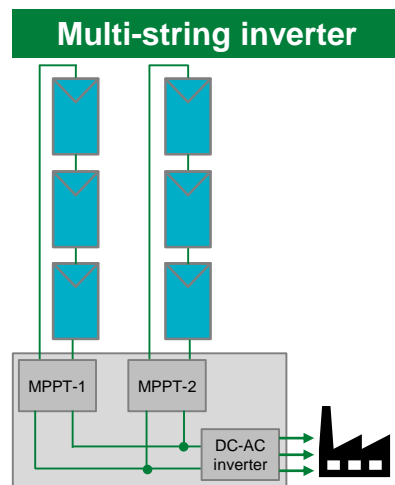
# Types of solar inverter topologies and applications



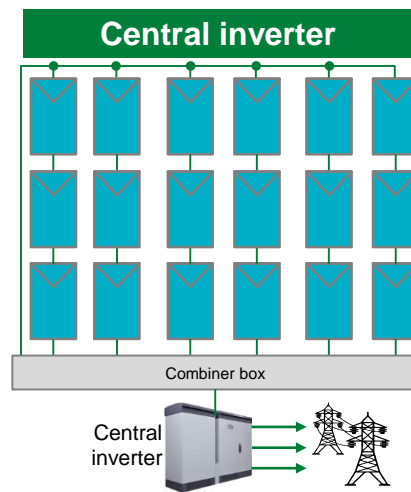
Features
Rated up to 300 W range
Primarily used in residential buildings
Output voltage: 230 VAC
Single phase
Self consumption



Features
Rated 1 kW to 10 kW range
Residential
Output voltage: 230 VAC
Single phase
Mostly for self consumption, fed to grid



Features
Rated 30 kW – 200 kW
Commercial, industrial, and utility
Output voltage: 400 VAC
Three phase
Self consumption; distribution networks



Features
Rated up to a few mega watt range
MV utility grid, PV farms
Output voltage: 400 VAC – 690 VAC
Three phase
MV distribution networks

# Solar inverter and battery energy storage market is set to grow at a CAGR of 15.6% and 33.9% respectively

## Market trends and drivers

The global solar inverter market is projected to grow from USD 8.6 billion in 2020 to USD 17.6 billion by 2025

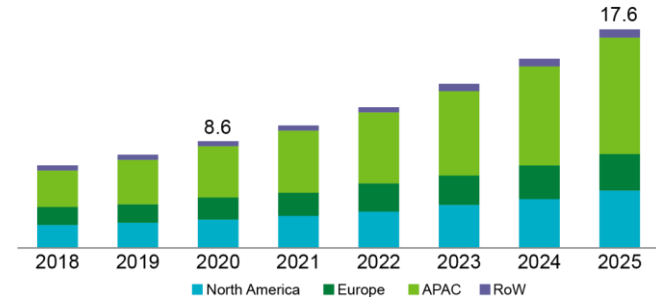
The below 10 kW segment held the largest share of the inverter market in 2019. Inverters with power rating below 10 kW are suitable for use in the residential and commercial sectors

The solar inverter market in APAC projected to grow at the highest CAGR from 2020 to 2025. The rising demand for inverters from the residential, automotive, and PV plants in India, China, and Japan is fueling the growth of the solar inverter market in APAC.

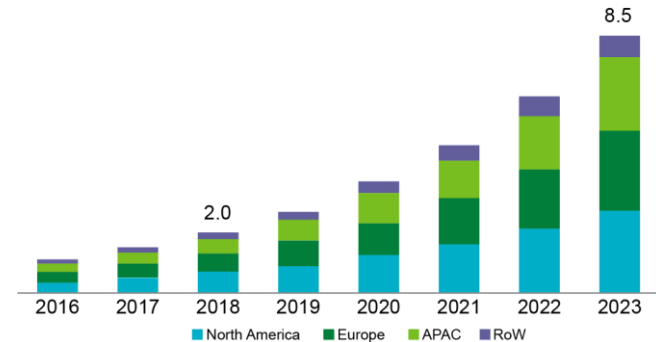
Battery energy storage system market is expected to grow from USD 2.0 billion in 2018 to reach USD 8.5 billion by 2023. APAC to drive the highest growth

Utilities to hold largest size of the battery energy storage system market. Residential energy storage market too grow at 22.8% (3 – 6 kW segment to grow fastest)

## Solar inverter market



## Battery energy storage market



Source: [Solar inverter](#), [Energy storage systems](#)

# Littelfuse solutions for Solar Inverter and Battery Energy Storage System(BESS)

## Input protection

- Fuse
- MOV
- Surge protection device
- Ground fault relay



## DC-DC converter

- MOSFET
- Gate driver
- TVS diode
- Temperature indicator



## DC-AC inverter

- IGBT module
- Gate driver
- TVS diode
- Temperature indicator



## Communication interface

- Diode array
- Multilayer varistors



## Output protection

- Fuse
- MOV
- Surge protection devices
- AC earth fault relay



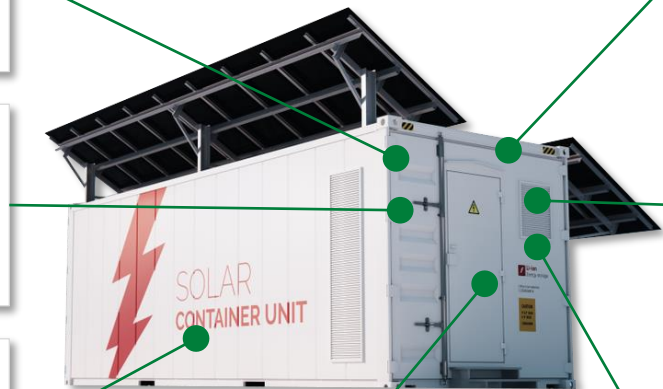
## Auxiliary power supply

- MOSFET
- Gate driver
- TVS diode



## BESS

- UL Class fuse, High-speed fuse
- TVS diode, Diode array
- Arc flash relay
- MOSFET/IGBT module
- Temperature sensor
- Surge protection device
- Ground fault relay





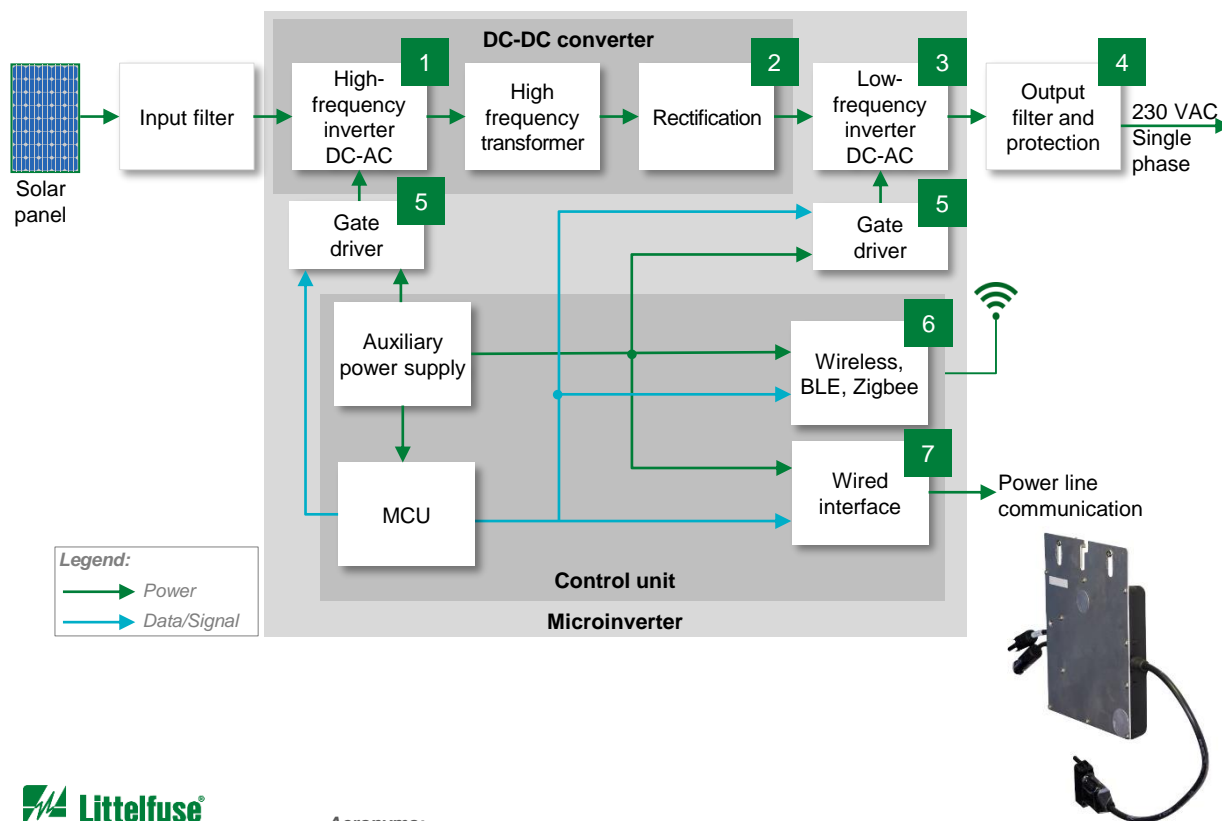
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## Solar inverters



Click on the product series in the table below for more info

# Microinverter block diagram



	Technology	Product series
1	MOSFET	<a href="#">Trench Gate Gen2</a> ,
	TVS diode	<a href="#">SMCJ</a> , <a href="#">SMDJ</a>
	NTC	<a href="#">RA</a> , <a href="#">RB</a> , <a href="#">KR</a>
2	SiC Schottky Diodes	<a href="#">650V diodes</a>
3	MOSFET or IGBT	<a href="#">Ultra-junction X2</a>
	TVS diode	<a href="#">600-650 V Trench</a>
4	MOV	<a href="#">SMBJ</a>
	Cartridge fuse	<a href="#">TMOV</a> , <a href="#">UltraMOV</a> , <a href="#">LA</a>
5	Gate driver	<a href="#">215</a>
	TVS diode	<a href="#">IXD_6xxSI</a>
6	Diode array or MLV	<a href="#">SMBJ</a>
7	Diode array	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>
		<a href="#">SP712</a> , <a href="#">SP2555NUTG</a>

## Acronyms:

MLV: multilayer varistor  
MOV: metal oxide varistor

TVS: transient voltage suppressor  
MCU: microcontroller unit





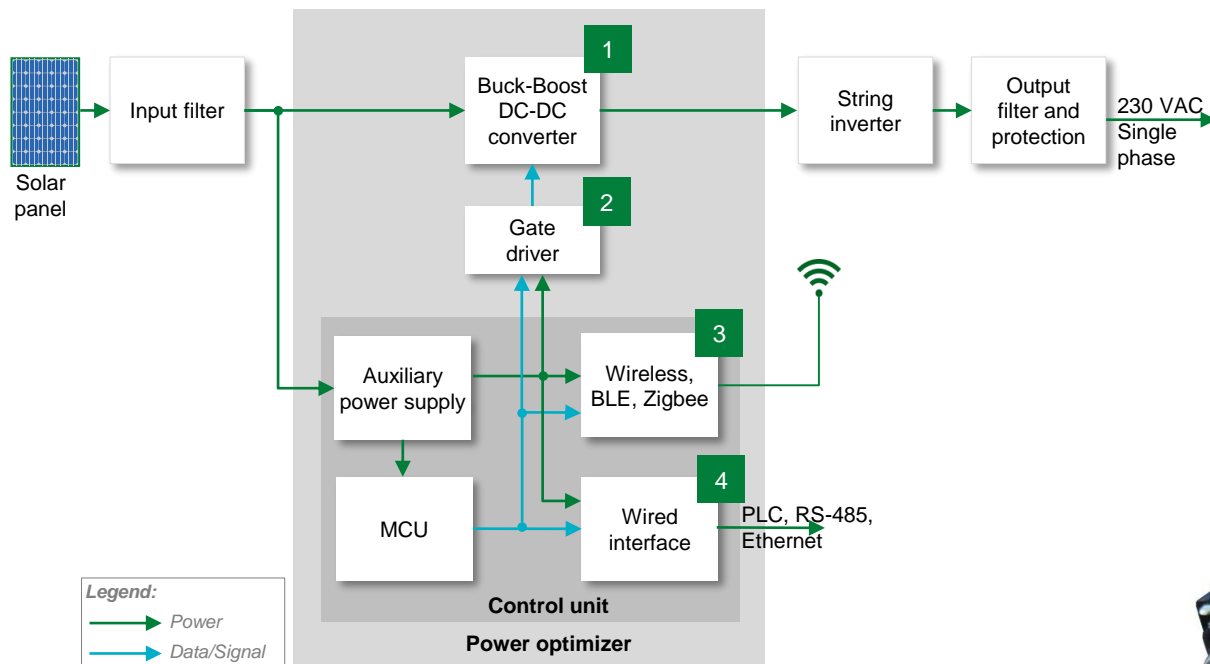
# Potential Littelfuse products for microinverter

	Technology	Function in application	Series	Benefits	Features
1	MOSFET	High frequency switching	<a href="#">Trench Gate Gen2</a>	High power density; easy to mount; space saving	Ultra low on-resistance R <sub>DS</sub> ; high current handling capability; fast body diode
	TVS diode	Protects MOSFET from voltage transients	<a href="#">SMCJ</a> , <a href="#">SMDJ</a>	Enables compact design; improves system reliability	3000 W P <sub>PPM</sub> capability; low profile package
	NTC	High temperature detection due to high sunlight, power component failure, etc.	<a href="#">RA</a> , <a href="#">RB</a> , <a href="#">KR</a>	Provides safe operation of PV panels; smaller footprint saves space	Surface mountable; small form-factor
2	SiC Schottky Diodes	Used for rectification	<a href="#">650V diodes</a>	Reduces switching losses; increases system efficiency, reliability and thermal management	High surge capability; negligible reverse recovery current; T <sub>j</sub> = 175 °C
3	MOSFET or IGBT	Convert DC voltage from PV panel to AC line voltage	<a href="#">Ultra-junction X2</a> <a href="#">600-650 V Trench</a>	High efficiency; high power density; easy to mount	Ultra low on-resistance R <sub>DS(ON)</sub> and gate charge Q <sub>g</sub> ; low package inductance; dv/dt ruggedness
	TVS diode	Protect IGBTs from an event of transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600 W peak pulse power capability; excellent clamping capability; small footprint
4	MOV	Protects power unit from voltage transients and lightning	<a href="#">TMOV</a> , <a href="#">UltraMOV</a> , <a href="#">LA</a>	Reduces customer qualification time by complying with third-party safety standards	High energy absorption capability: 40–530 J (2 ms)
	Cartridge fuse	Protects from overcurrent events	<a href="#">215</a>	Reduces customer qualification time by complying with third-party safety standards	High breaking capacity; meets the IEC 60127-2
5	Gate driver	Controls the switching MOSFETs	<a href="#">IXD_6xxSI</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times <10 ns	Tight tolerance; small form factor; fast thermal response
	TVS diode	Protect gate driver from event of transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600 W peak pulse power capability; excellent clamping capability; small footprint
6	Diode array or MLV	Protects ICs from ESD through wireless interface	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>	Smaller form-factor and multi-line protection enables ease of design	Low capacitance of 1.0 pF per I/O
7	Diode array	Protection of data lines from ESD/EFT and surges events	<a href="#">SP712</a> <a href="#">SP2555NUTG</a>	Minimizes signal distortion; reduces voltage over-shoot, and simplified PCB design	Low capacitance of 2.5 pF; low leakage current of 0.1 µA ; small form factor



Click on the product series in the table below for more info

# Power optimizer block diagram



	Technology	Product series
1	MOSFET	<a href="#">Trench Gate Gen2</a> ,
	TVS diode	<a href="#">SMCJ</a> , <a href="#">SMDJ</a>
	NTC	<a href="#">RA</a> , <a href="#">RB</a> , <a href="#">KR</a>
2	Gate driver	<a href="#">IXD_6xxSI</a>
	TVS diode	<a href="#">SMBJ</a>
3	Diode array or MLV	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>
4	Diode array	<a href="#">SP712</a> <a href="#">SP2555NUTG</a> , <a href="#">SM712</a>



## Acronyms:

MLV: multilayer varistor  
NTC: negative temperature coefficient

TVS: transient voltage suppressor  
MCU: microcontroller unit



Click on the product series in the table below for more info

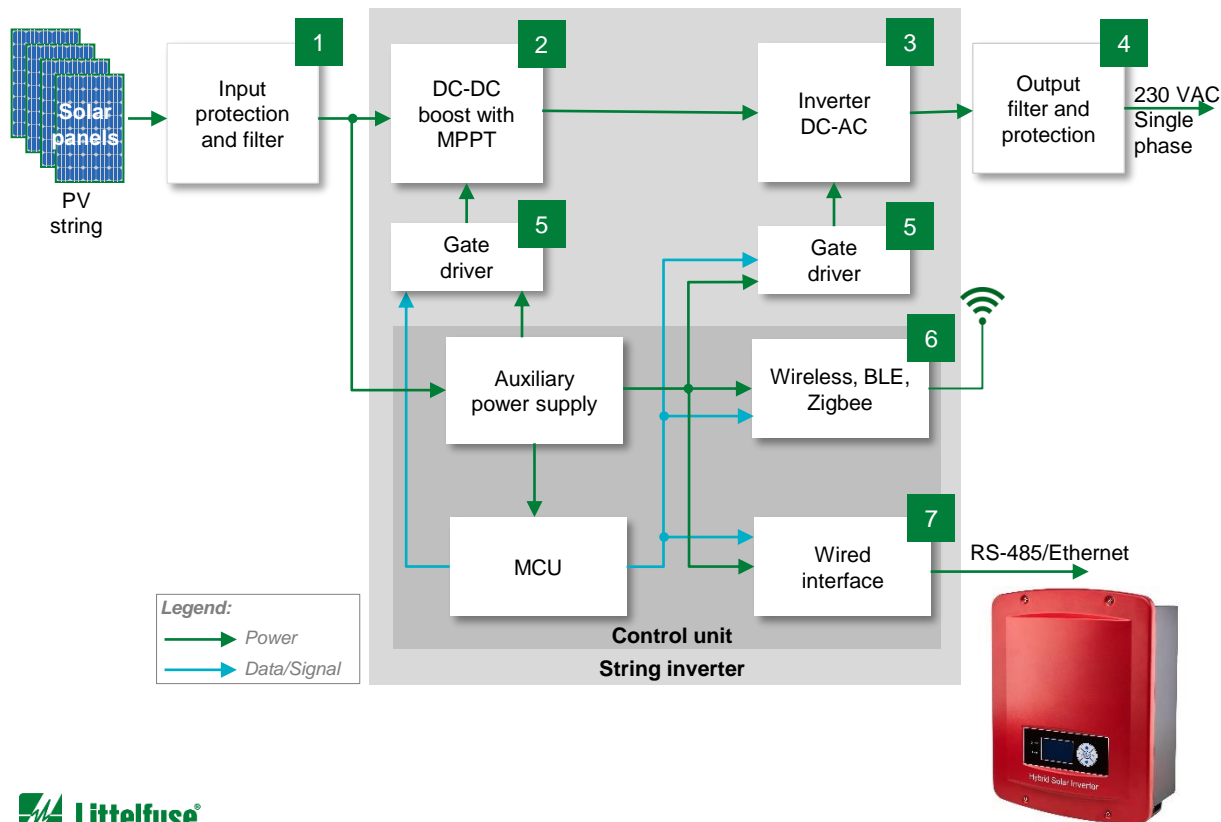
# Potential Littelfuse products in power optimizer

	Technology	Function in application	Series	Benefits	Features
1	MOSFET	High frequency switching	<a href="#">Trench Gate Gen2</a>	High power density; easy to mount; space saving	Ultra-low on-resistance RDS; high current handling capability; fast body diode
	TVS diode	Protects MOSFET from voltage transients	<a href="#">SMCJ</a> , <a href="#">SMDJ</a>	Enables compact design; improves system reliability	3000 W P <sub>PPM</sub> capability; low profile package
	NTC	High temperature detection due to high sunlight, power component failure, etc.	<a href="#">RA</a> , <a href="#">RB</a> , <a href="#">KR</a>	Provides safer operation of PV panels; smaller footprint saves space	Surface mountable; small form-factor
2	Gate driver	Controls the switching MOSFETs	<a href="#">IXD_6xxSI</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times <10 ns	Tight tolerance; small form factor; fast thermal response
	TVS diode	Protect gate driver from event of transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600 W peak pulse power capability; excellent clamping capability; small footprint
3	Diode array or MLV	Protects ICs from ESD through wireless interface	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>	Smaller form-factor and multi-line protection enables ease of design	Low capacitance of 1.0 pF per I/O
4	Diode array	Protection of data lines from ESD/EFT and surges events	<a href="#">SP712</a> , <a href="#">SP2555NUTG</a> , <a href="#">SM712</a>	Minimizes signal distortion, reduces voltage overshoot, and simplified PCB design	Low capacitance of 2.5 pF; low leakage current of 0.1 $\mu$ A ; small form factor



Click on the product series in the table below for more info

# String inverter block diagram



	Technology	Product series
1	MOV	<a href="#">UltraMOV</a> , <a href="#">LA</a> , <a href="#">SM20</a>
	MOSFET	<a href="#">Trench Gate Gen2</a>
2	TVS diode	<a href="#">SMCJ</a> , <a href="#">SMDJ</a>
	SiC Schottky diode	<a href="#">650V diodes</a>
	NTC	<a href="#">RA</a> , <a href="#">RB</a> , <a href="#">KR</a>
3	MOSFET or IGBT	<a href="#">Ultra-junction X2</a>
	TVS diode	<a href="#">600-650 V Trench</a>
4	MOV	<a href="#">SMBJ</a>
	Fuse	<a href="#">TMOV</a> , <a href="#">UltraMOV</a> , <a href="#">LA</a>
5	Gate driver	<a href="#">Class J</a> , <a href="#">Class RK5</a> , <a href="#">KLKD</a>
	TVS diode	<a href="#">IXD_6xxSI</a> , <a href="#">IX4351NE</a>
6	Diode array or MLV	<a href="#">SMBJ</a>
	Diode array	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>
7	Diode array	<a href="#">SP712</a> , <a href="#">SM712</a> , <a href="#">SP2555NUTG</a>

## Acronyms:

MPPT: maximum power point tracking  
MOV: metal oxide varistor

TVS: transient voltage suppressor  
MCU: microcontroller unit



Click on the product series in the table below for more info

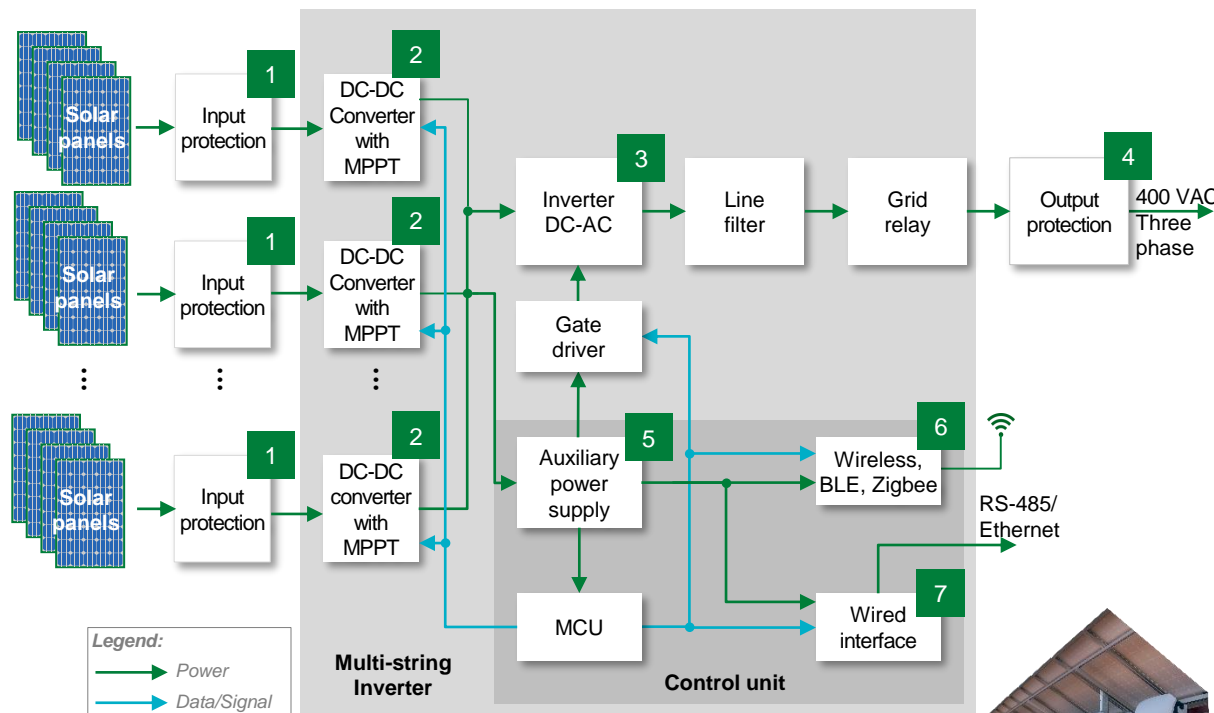
# Potential Littelfuse products for string inverter

	Technology	Function in application	Series	Benefits	Features
1	MOV	Protects from voltage transients and lightning surges	<a href="#">UltraMOV</a> , <a href="#">LA</a> , <a href="#">SM20</a>	Reduces customer qualification time by complying with third-party safety standards	High energy absorption capability: 40–530 J (2 ms)
2	MOSFET	High frequency switching	<a href="#">Trench Gate Gen2</a>	High power density; easy to mount; space-saving	Ultra-low on-resistance RDS; high current handling capability; fast body diode
	TVS diode	Protects MOSFET from voltage transients	<a href="#">SMCJ</a> , <a href="#">SMDJ</a>	Enables compact design; improves system reliability	3000 W P <sub>PPM</sub> capability; low profile package
	SiC Schottky diode	Used for rectification	<a href="#">650V diodes</a>	Reduces switching losses; increases system efficiency, reliability and thermal management	High surge capability; negligible reverse recovery current; T <sub>j</sub> = 175° C
	NTC	High temperature detection due to high sunlight, power component failure, etc.	<a href="#">RA</a> , <a href="#">RB</a> , <a href="#">KR</a>	Provides safe operation of PV panels; smaller footprint saves space	Surface mountable; small form-factor
3	MOSFET or IGBT	Convert DC voltage from PV panel to AC line voltage	<a href="#">Ultra-junction X2</a>	High efficiency; high power density; easy to mount	Ultra low on-resistance R <sub>DS(ON)</sub> and gate charge Q <sub>g</sub> ; low package inductance; dv/dt ruggedness
			<a href="#">600-650 V Trench</a>	Reduced thermal resistance; low energy losses; fast-switching	Low V <sub>sat</sub> , low E <sub>on</sub> /E <sub>off</sub> , high surge current capability; positive thermal coefficient of V <sub>CE(sat)</sub>
4	TVS diode	Protect IGBTs from an event of transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600W peak pulse power capability; excellent clamping capability; small footprint
	MOV	Protects power lines from voltage transients and lightning surges	<a href="#">TMOV</a> , <a href="#">UltraMOV</a> , <a href="#">LA</a>	Reduces customer qualification time by complying with third-party safety standards	High energy absorption capability: 40–530 J (2 ms)
5	Cartridge fuse	Protects from overcurrent events	<a href="#">215</a>	Reduces customer qualification time by complying with third-party safety standards	High breaking capacity; meets the IEC 60127-2
	Gate driver	Controls the switching MOSFETs	<a href="#">IXD_6xSI</a> , <a href="#">IX4351NE</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10 ns	Tight tolerance; small form factor; fast thermal response
6	TVS diode	Protect gate driver from event of transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600W peak pulse power capability; excellent clamping capability; small footprint
	Diode array or MLV	Protects ICs from ESD events	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>	Smaller form-factor; offers design flexibility	Low capacitance of 1.0 pF per I/O
7	Diode array	Protection of data lines from ESD/EFT and surges events	<a href="#">SP712</a> , <a href="#">SM712</a> <a href="#">SP2555NUTG</a>	Minimizes signal distortion, reduces voltage overshoot, and provides a simplified PCB design	Low capacitance of 2.5 pF; low leakage current of 0.1 μA ; small form factor



Click on the product series in the table below for more info

# Multi-string inverter block diagram



\* You do not need a fuse if there are only two PV strings per MPPT

\*\* Recommended for 1000 V PV inverter systems. 1500 V PV system needs 1700 V MOSFET or IGBT



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## Acronyms:

MPPT: maximum power point tracking

SPD: surge protection devices

TVS: transient voltage suppressor

MCU: microcontroller unit

	Technology	Product series
1	Fuse*	<a href="#">SPF</a> , <a href="#">SPFI</a>
	SPD	<a href="#">SPD2 PV series</a>
2	SiC MOSFET or MOSFET**	<a href="#">LSIC1MO120E0120</a> <a href="#">High Voltage Series</a>
	SIC Diode**	<a href="#">1200 V diode</a>
3	IGBT Module	<a href="#">MIXA</a> , <a href="#">MIXG</a>
	High-speed fuse	<a href="#">PSR</a>
4	TVS diode	<a href="#">SMBJ</a>
	Fuse	<a href="#">Class T</a> , <a href="#">Class J</a>
5	MOV or SPD	<a href="#">UltraMOV</a> , <a href="#">LA</a> , <a href="#">SM7 SPD type 2</a>
	SiC MOSFET or MOSFET	<a href="#">LSIC1MO170E1000</a> <a href="#">High Voltage Series</a>
	Gate driver	<a href="#">IX4351NE</a>
6	TVS diode	<a href="#">SMF</a>
	Diode array or MLV	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>
7	Diode array	<a href="#">SP712</a> , <a href="#">SM712</a> <a href="#">SP2555NUTG</a>





Click on the product series in the table below for more info

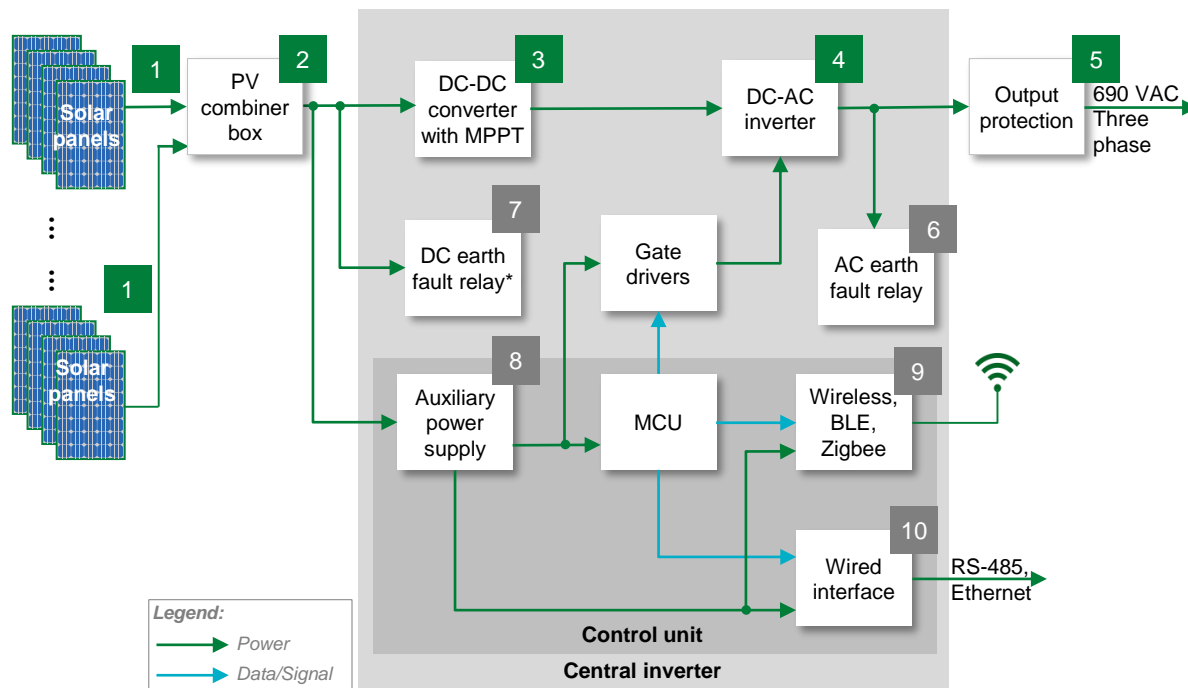
# Potential Littelfuse products for multi-string inverter

	Technology	Function in application	Series	Benefits	Features
1	Fuse	Protect PV modules and conductors from reverse overcurrent conditions	<a href="#">SPF</a> , <a href="#">SPFI</a>	Prevents power generation losses due to nuisance tripping from changes in temperature	Meets UL and IEC standards; 1000 V <sub>DC</sub> , 1–30 A ratings available; max interrupt rating 50 kA
	SPD 2	Provide equipment protection from transient overvoltage events I	<a href="#">SPD2 PV series</a>	Withstand high-energy transients to prevent disruption, downtime, degradation of equipment	Available in 1100 and 1500 V <sub>dc</sub> ; compact footprint; capability to clamp and withstand transients
2	SiC MOSFET or MOSFET*	Boost converter for high-frequency switching	<a href="#">LSIC1MO120E0120</a>	Optimized for high-frequency applications	Ultra-low output capacitance and on-resistance
			<a href="#">High Voltage Series</a>	High power density; easy to mount; space-saving	Fast switching time; ultra-low R <sub>DS(on)</sub>
	SiC Diode		<a href="#">1200 V diode</a>	Reduces switching losses; increases system efficiency, reliability, and thermal management	High surge capability; negligible reverse recovery current; T <sub>j</sub> 175 °C
3	IGBT module	Switches power supplies	<a href="#">MIXA</a> , <a href="#">MIXG</a>	Allows low power consumption and fast response	Rugged design with thin wafer technology; low gate charge; low EMI and competitive low V <sub>CE(SAT)</sub>
	High-speed fuse	Protects semiconductor devices in inverter	<a href="#">PSR</a>	Lower I <sup>2</sup> t performance allows for quick response to protect devices from higher heat energy	550–1300 V <sub>AC</sub> , 500–1000 V <sub>DC</sub> , 40–2000 A
	TVS diode	Protect IGBTs from an event of transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600 W peak pulse power capability; excellent clamping capability; small footprint
4	Fuse	Overcurrent or short circuit protection	<a href="#">Class T</a> , <a href="#">Class J</a>	Reduces damage to equipment caused by heating and magnetic effects of short circuit currents;	Extremely current-limiting; small footprint; 200 kA interrupting rating
	MOV or SPD	Protects from power fluctuations or surges	<a href="#">UltraMOV</a> , <a href="#">LA</a> , <a href="#">SM7 SPD type 2</a>	Withstand high-energy transients to prevent disruption, downtime, degradation of equipment	20 kA nominal interrupting rating and 50 kA maximum interrupting rating
5	SiC MOSFET or MOSFET	High frequency switching	<a href="#">LSIC1MO170E1000 High Voltage Series</a>	Optimized for high-frequency; high power density; easy to mount; space-saving	extremely low gate charge and output capacitance; ultra low on-resistance; fast switching time
	Gate driver	to drive SiC MOSFETs and high power IGBTs	<a href="#">IX4351NE</a>	Eliminates the need for separate negative supply; quick turn-on and turn-off of power SiC MOSFET	Separate 9 A peak source and sink outputs; Internal negative charge pump regulator for
	TVS diode	Protects SiC MOSFET from voltage transient	<a href="#">SMF</a>	Enables compact design; improves system reliability	200W peak pulse power capability; excellent clamping capability; low profile
6	Diode array or MLV	Protects ICs from ESD events	<a href="#">SP3130</a> , <a href="#">MLA</a> , <a href="#">MHS</a>	Smaller form-factor and ease of design	Low capacitance of 1.0 pF per I/O
7	Diode array	Protection of data lines from ESD/EFT and surges events	<a href="#">SP712</a> , <a href="#">SM712</a> <a href="#">SP2555NUTG</a>	Minimizes signal distortion, reduces voltage overshoot, and provides a simplified PCB design	Low capacitance of 2.5 pF; Low leakage current of 0.1 µA; small form factor



Click on the product series in the table below for more info

# Central inverter block diagram



\* Recommended for 1000 V PV inverter systems. 1500 V PV system need 1700 V MOSFET

\*\* Ground Fault detectors should be used for resistive grounded systems. Suggest: [EL731](#)

	Technology	Product series
1	In-line fuse	<a href="#">SPXI</a>
2	Fuse/Holder	<a href="#">SPXV</a> , <a href="#">SPNH</a> , <a href="#">LFPXV</a>
	SPD	<a href="#">SPD2 PV series</a>
3	SiC MOSFET or MOSFET*	<a href="#">LSIC1MO120E0120</a> ; <a href="#">High Voltage Series</a>
	SIC Diode*	<a href="#">1200 V diode</a>
4	IGBT module	<a href="#">MIXA</a> , <a href="#">MIXG</a>
	High-speed fuse	<a href="#">PSR</a>
	TVS diode	<a href="#">SMBJ</a>
5	Fuse	<a href="#">Class J</a> , <a href="#">Class RK5</a> , <a href="#">Class L</a>
	SPD	<a href="#">SPD type 2</a>



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## Acronyms:

MPPT: maximum power point tracking

SPD: surge protection devices

TVS: transient voltage suppressor

MCU: microcontroller unit





Click on the product series in the table below for more info

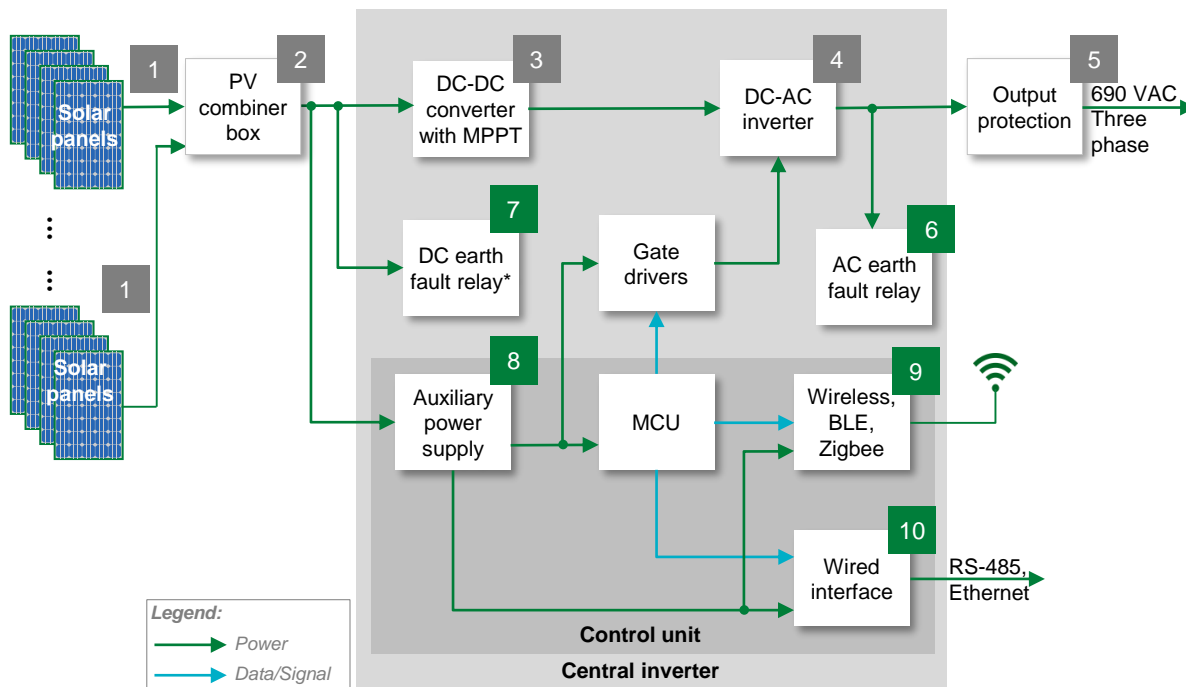
# Potential Littelfuse products for central inverter

	Technology	Function in application	Series	Benefits	Features
1	Inline fuse	Integrates into an in-line assembly within a wire harness	<a href="#">SPXI</a>	Offers higher amperage protection; design flexibility; save space, time, and money	50,000 A interrupting rating; UL recognized
2	Fuse	Designed for protection PV systems	<a href="#">SPXV</a> , <a href="#">SPNH</a> , <a href="#">LFPXV</a>	Offers higher amperage protection; ease of design	50,000 A interrupting rating; fast acting fuse
	SPD	Protection from transient overvoltage	<a href="#">SPD2 PV series</a>	Prevents system disruption and downtime	Available in 1100 and 1500 Vdc; compact footprint
3	SiC MOSFET or MOSFET	Boost converter for high-frequency switching	<a href="#">LSIC1MO120E0120</a>	Optimized for high-frequency applications	Ultra-low output capacitance and on-resistance
			<a href="#">High Voltage Series</a>	High power density; easy to mount; space-saving	Fast switching time; ultra-low $R_{DS(on)}$
	SiC Diode		<a href="#">1200 V diode</a>	Reduces switching losses; increases efficiency,	High surge capability; negligible $I_{RR}$ ; $T_j$ 175 °C
4	IGBT module	Switches power supplies	<a href="#">MIXA</a> , <a href="#">MIXG</a>	Low power consumption and fast response	Rugged design; low EMI and low $V_{CE(SAT)}$
	High-speed fuse	Protects semiconductor devices in inverter	<a href="#">PSR</a>	Lower $I^2t$ performance allows for quick response to protect devices from higher heat energy	550–1300 V <sub>AC</sub> , 500–1000 V <sub>DC</sub> , 40–2000 A
	TVS diode	Protects IGBTs from transient overload	<a href="#">SMBJ</a>	Enables compact design; improves system reliability	600 W P <sub>PPM</sub> capability; low profile package
5	Fuse	Overcurrent or short circuit protection	<a href="#">Class J</a> , <a href="#">Class RK5</a> , <a href="#">Class L</a>	Reduces damage to equipment caused by short circuit currents; compact design	Extremely current-limiting; small footprint; 200 kA interrupting rating
	SPD	Protects from power fluctuations or surges	<a href="#">SPD type 2</a>	Withstand high-energy transients to prevent disruption, downtime, and degradation	20 kA nominal interrupting rating and 50 kA maximum interrupting rating



Click on the product series in the table below for more info

# Central inverter block diagram



\* Recommended for 1000 V PV inverter systems. 1500 V PV system need 1700 V MOSFET

\*\* Ground Fault detectors should be used for resistive grounded systems. Suggest: [EL731](#)

	Technology	Product series
6	AC ground fault relay	<a href="#">EL-731</a>
7	DC ground fault relay**	<a href="#">EL-731, SE-601</a>
8	SiC MOSFET or MOSFET	<a href="#">LSIC1MQ170E1000 High Voltage Series</a>
	Gate driver	<a href="#">IX4351NE</a>
	TVS diode	<a href="#">SMF</a>
9	Diode array or MLV	<a href="#">SP3130, MLA, MHS</a>
10	Diode array	<a href="#">SP712, SM712</a> <a href="#">SP2555NUTG</a>



## Acronyms:

MPPT: maximum power point tracking

SPD: surge protection devices

TVS: transient voltage suppressor

MCU: microcontroller unit



Click on the product series in the table below for more info

# Potential Littelfuse products for central inverter

	Technology	Function in application	Series	Benefits	Features
6	AC ground fault relay	Offers low-level ground-fault protection	<a href="#">EL-731</a>	Adjustable trip setting provides a wide range of low-level protection and system coordination	Adjustable pickup (30-5,000 mA); Frequency range (0-90 Hz, 20-6,000 Hz)
7	DC ground fault relays	Offers low-level ground-fault protection	<a href="#">EL-731,SE-601</a>	Adjustable trip setting provides a wide range of low-level protection	Adjustable pickup EL-731(30-5,000 mA); SE-601(1-20 mA)
8	SiC MOSFET or MOSFET	High frequency switching	<a href="#">LSIC1MO170E1000 High Voltage Series</a>	Optimized for high-frequency applications; high power density; easy to mount; space-saving	Extremely low gate charge and output capacitance; ultra low on-resistance
	Gate driver	to drive SiC MOSFETs and high power IGBTs	<a href="#">IX4351NE</a>	Eliminates the need for separate negative supply; quick turn-on and turn-off of power SiC MOSFET	Separate 9 A peak source and sink outputs; Internal negative charge pump regulator
	TVS diode	Protects SiC MOSFET from voltage transient	<a href="#">SMF</a>	Enables compact design; improves system reliability	200W peak pulse power capability; excellent clamping capability; low profile
9	Diode array	Protects ICs from ESD via wireless interface	<a href="#">SP3130</a>	Smaller form-factor and multi-line protection ease of design	Low capacitance of 1.0 pF per I/O
10	Diode array	Protection of data lines from ESD/EFT and surges events	<a href="#">SP712, SM712 SP2555NUTG</a>	Minimizes signal distortion, reduces voltage overshoot, and provides a simplified PCB design	Low capacitance of 2.5 pF; Low leakage current of 0.1 $\mu$ A; small form factor



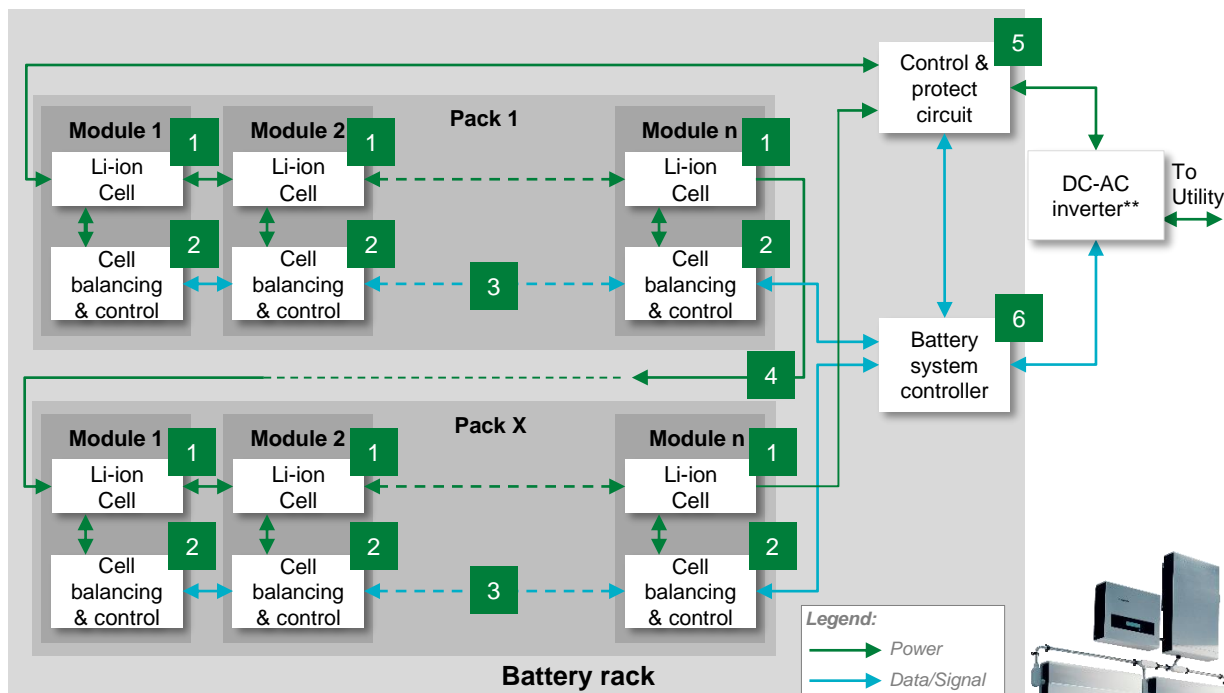
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## Battery Energy Storage System (BESS)



Click on the product series in the table below for more info

# BESS architecture for residential\* and commercial



\* Residential BESS has similar architecture, but the # of packs will be limited depending on the kVA ratings

\*\* Large industrial or utility scale BESS system, multiple battery racks are stacked together through a combiner box

\*\*\* Arc Flash Relays are used in large commercial and higher applications



	Technology	Product Series
1	Fuse	<a href="#">501A</a> , <a href="#">881</a>
	TVS diode	<a href="#">TPSMC</a> , <a href="#">SZ1SMC</a> , <a href="#">SZ1.5SMC</a>
	Temperature sensor	<a href="#">USP16673</a> , <a href="#">RB</a>
2	SMD or In-line fuse	<a href="#">438A</a> , <a href="#">441A</a> , <a href="#">521</a>
	TVS diode	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a>
3	Diode array	<a href="#">AQ05C</a>
	TVS diode	<a href="#">TPSMA6L</a> , <a href="#">SZ1SMA</a>
4	Fuse	<a href="#">TLS</a> , <a href="#">JLLN</a> , <a href="#">CNN</a>
5	High-speed fuse	<a href="#">PSR</a> , <a href="#">PSX</a>
	MOSFET	<a href="#">X3 Class</a>
	Gate driver	<a href="#">IXD_6xxSI</a>
	HVDC contractor relays	<a href="#">DCNxx</a>
6	Arc flash relays***	<a href="#">AF0100</a>
	Diode array	<a href="#">AQ24CAN</a>
	Fuse	<a href="#">885</a>
	TVS diode	<a href="#">TPSMB</a> , <a href="#">TPSMC</a>



Expertise Applied | Answers Delivered

## Acronyms:

BESS: battery energy storage system

Li-ion: Lithium- ion

TVS: transient voltage suppressor

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Click on the product series in the table below for more info

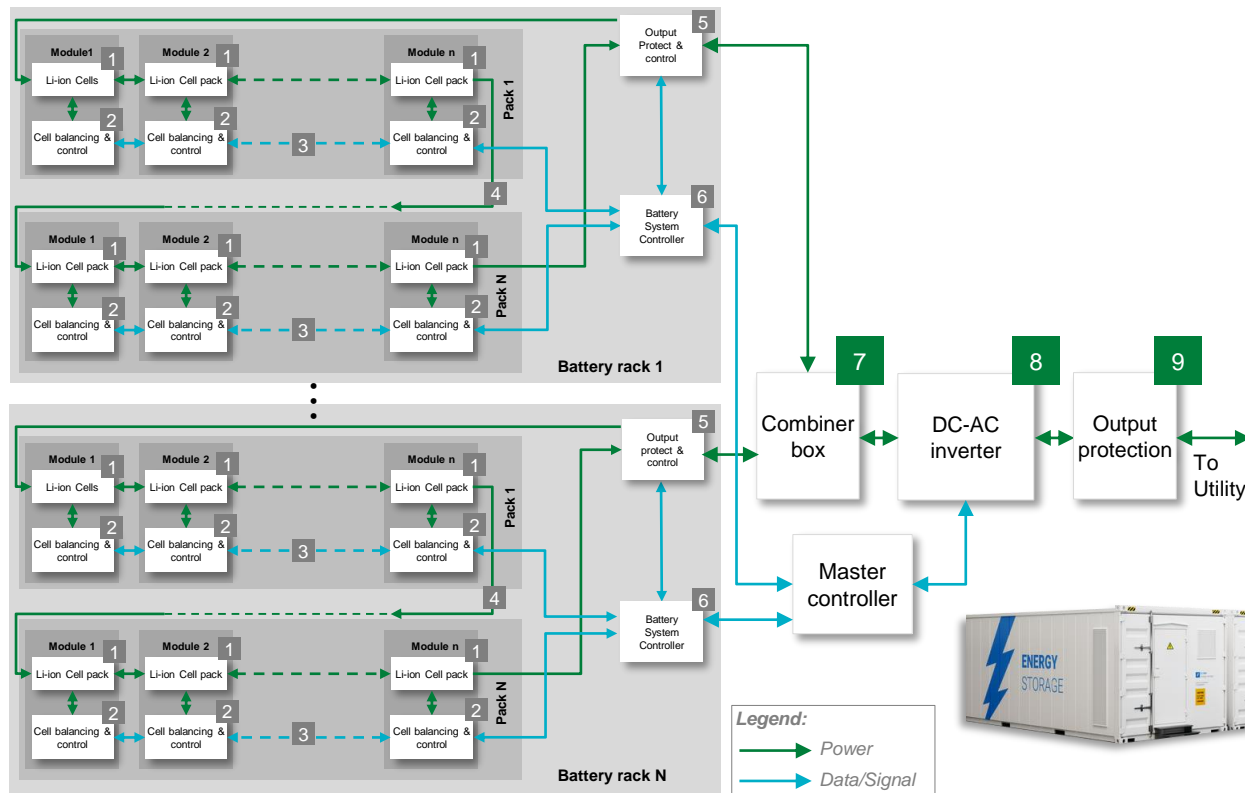
# Potential Littelfuse products for BESS

	Technology	Function in application	Series	Benefits	Features
1	Fuse	Protects cells/BMS components from high-fault currents due to external shorts	<a href="#">501A</a> , <a href="#">881</a>	Excellent temperature stability and performance reliability; compact design	Fast response to fault current; surface mount device
	TVS diode	Transient voltage suppression	<a href="#">TPSMC</a> , <a href="#">SZ1SMC</a> , <a href="#">SZ1.5SMC</a>	Excellent clamping capability; fast response time	Meets IEC standards for ESD protection
	Temperature sensor	Monitoring the system for optimal charging conditions	<a href="#">USP16673</a> , <a href="#">RB</a>	Promotes robust operation; allows design flexibility	Tight tolerance; ultra-thin
2	SMD or In-line fuse	Front end protection due to shorting of power and sense line	<a href="#">438A</a> , <a href="#">441A</a> , <a href="#">521</a>	Excellent temperature stability and performance reliability; compact design	Fast response to fault current; surface mount device
	TVS diode	Protects from transients induced due to assembly and maintenance of batteries	<a href="#">TPSMB</a> , <a href="#">SZ1SMB</a> , <a href="#">SZP6SMB</a>	Excellent clamping capability; fast response time	Meets IEC standards for ESD protection
3	Diode array	Transient voltage suppression	<a href="#">AQ05C</a>	Excellent clamping capability; fast response time	Meets IEC standards for ESD protection
	TVS diode	Protects sensitive electronic ICs from ESD, EFT, and voltage transient	<a href="#">TPSMA6L</a> , <a href="#">SZ1SMA</a>	Ensures reliability of the equipment without performance degradation	Meets IEC standards for ESD protection; low leakage current and clamping voltage
4	Fuse	Protects from short-circuits and overloads between two packs	<a href="#">TLS</a> , <a href="#">JLLN</a> , <a href="#">CNN</a>	Reduces damage to equipment caused by short circuit currents; compact design	Extremely current-limiting; small footprint; 200 kA interrupting rating
5	High-speed fuse	Short-circuit and overload protection resulting due to high-power system	<a href="#">PSR</a> , <a href="#">PSX</a>	Lower I <sup>2</sup> t performance allows for quick response to protect devices from higher heat energy	High DC voltage rating up to 1500 VDC; extremely fast-acting; compact form-factor
	MOSFET	Output power control switch	<a href="#">X3 Class</a>	Low power loss; design flexibility; high efficiency	Low R <sub>DS(ON)</sub> ; fast soft recovery body
	Gate driver	Controls the switching MOSFETs	<a href="#">IXD_6xxSI</a>	Dual outputs provide space-efficient design; high immunity to latch-up; rise/fall times less than 10 ns	Tight tolerance; small form factor; fast thermal response
	HVDC contractor relays	The main contactors connect and disconnect the battery system	<a href="#">DCNxx</a>	Allows a low voltage signal to switch the contacts for a high voltage signal	Wide range of capabilities – can switch from 10's of amps to 1000's of amps, and 10's of volts to 1000's of volts
	Arc flash relays	Reduces damage by detecting the light from an arc flash and rapidly tripping	<a href="#">AF0100</a>	Fits into a wide range of arc-flash applications; monitor two arc-flash sensors; compact design	Input voltage: 100-240 VAC/VDC, 24-48 VDC, dual sensor input; surface mounting DIN RAIL
6	Diode array	Protects from ESD, EFT, and voltage transient	<a href="#">AQ24CAN</a>	Ensures reliability of the equipment without performance degradation	Meets IEC standards for ESD protection; low leakage current and clamping voltage
	Fuse	Protects cells and BMS components from overcurrent	<a href="#">885</a>	Compact design; ensures compatibility with high-temperature environment	Fast response to fault current; surface mount device
	TVS diode	Transient voltage suppression	<a href="#">TPSMB</a> , <a href="#">TPSMC</a>	Excellent clamping capability; fast response time	Meets IEC standards for ESD protection

# BESS architecture for large industrial and utility scale (multiple battery racks connected together)



Click on the product series in the table below for more info



	Technology	Product series
7	High-speed fuse	<a href="#">PSX, PSR</a>
	SPD (DC link)	<a href="#">SPD type 2</a>
8	High-speed fuse	<a href="#">PSX, PSR</a>
	Ground fault relay	<a href="#">SE-601</a>
9	IGBT module	<a href="#">MIXA, MIXG</a>
	Fuse	<a href="#">Class J, Class RK5, Class L</a>
	SPD (AC link)	<a href="#">SPD type 2</a>



# Potential Littelfuse products for industrial and utility scale BESS



Click on the product series in the table below for more info

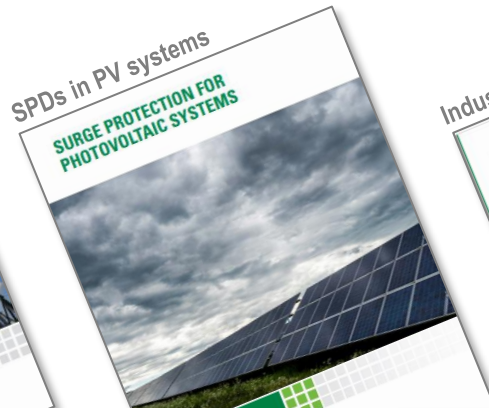
	Technology	Function in application	Series	Benefits	Features
7	High-speed fuse	Short-circuit and overload current protection	<a href="#">PSX</a> , <a href="#">PSR</a>	Lower $I^2t$ performance allows for quick response to protect devices from higher heat energy	High DC voltage rating up to 1500 VDC; extremely fast-acting; compact form-factor
	SPD (DC link)	Provides equipment protection from transient overvoltage events	<a href="#">SPD type 2</a>	Withstands high-energy transients to prevent disruption, downtime, and degradation	20 kA nominal interrupting rating and 50 kA maximum interrupting rating
8	High-speed fuse	Short-circuit and overload current protection for power semiconductors	<a href="#">PSX</a> , <a href="#">PSR</a>	Lower $I^2t$ performance allows for quick response to protect devices from higher heat energy	High DC voltage rating up to 1500 VDC; extremely fast-acting; compact form-factor
	Ground fault relay	Offers low-level ground-fault protection	<a href="#">SE-601</a>	Provides a wide range of low-level protection; adjustable trip delay allows quick protection or delayed response	Adjustable pickup (1-20 mA); adjustable time delay (50 ms-2.5 s); CSA certified, UL Listed (E340889), CE (European Union), C-Tick
	IGBT module	Switches power supplies	<a href="#">MIXA</a> , <a href="#">MIXG</a>	Allows for low power consumption and fast response	Rugged design; low gate charge; low EMI and low $V_{CE(SAT)}$
9	Fuse	Overcurrent or short circuit protection	<a href="#">Class J</a> , <a href="#">Class RK5</a> , <a href="#">Class L</a>	Reduces damage to equipment caused by short circuit currents; compact design	Extremely current-limiting; small footprint; 200 kA interrupting rating
	SPD (AC link)	Protects from power fluctuations or surges	<a href="#">SPD type 2</a>	Withstands high-energy transients to prevent disruption, downtime, and degradation	20 kA nominal interrupting rating and 50 kA maximum interrupting rating



# Safety standards for solar inverter and battery energy storage system (BESS)

Standard	Title	General scope	Region
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
IEC 61683	Power conditioners – Procedure for measuring efficiency	This standard describes guidelines for measuring the efficiency of power conditioners used in stand-alone and utility-interactive photovoltaic systems	Global
IEC 62109-1	Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements	This part of IEC 62109 applies to the power conversion equipment (PCE) for use in Photovoltaic (PV) systems where a uniform level of safety is necessary. This standard defines the minimum requirements for the design and manufacture of PCE for protection against fire, energy, electric shock, mechanical, other hazards, etc.	Global
IEC 62109-2	Safety of Power Converters for Use in Photovoltaic Power Systems – Part 2: Particular Requirements for Inverters	This Part 2 of IEC 62109 covers the particular safety requirements relevant to DC to AC inverter products intended for use in photovoltaic power systems	Global
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
EN 50524	Data Sheet and Name Plate for Photovoltaic Inverters	Data sheet and name plate for photovoltaic inverters. The intent of this document is to provide minimum information required to configure a safe and optimal system with photovoltaic inverters.	Europe
EN 50530	Overall Efficiency of Photovoltaic Inverters	This European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected photovoltaic systems.	Europe

# Additional information can be found on [Littelfuse.com](https://www.littelfuse.com)



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Solar Protection White Paper



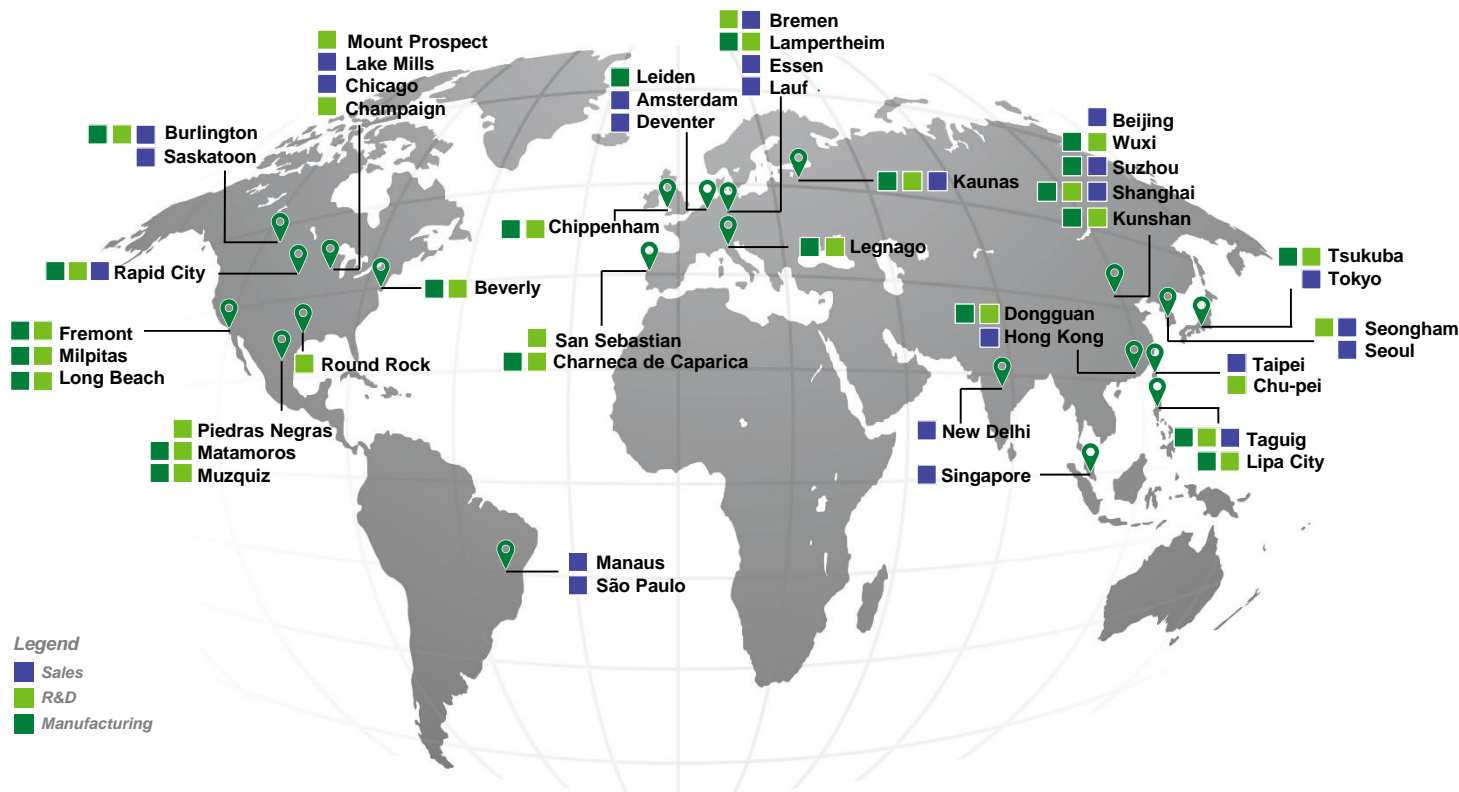
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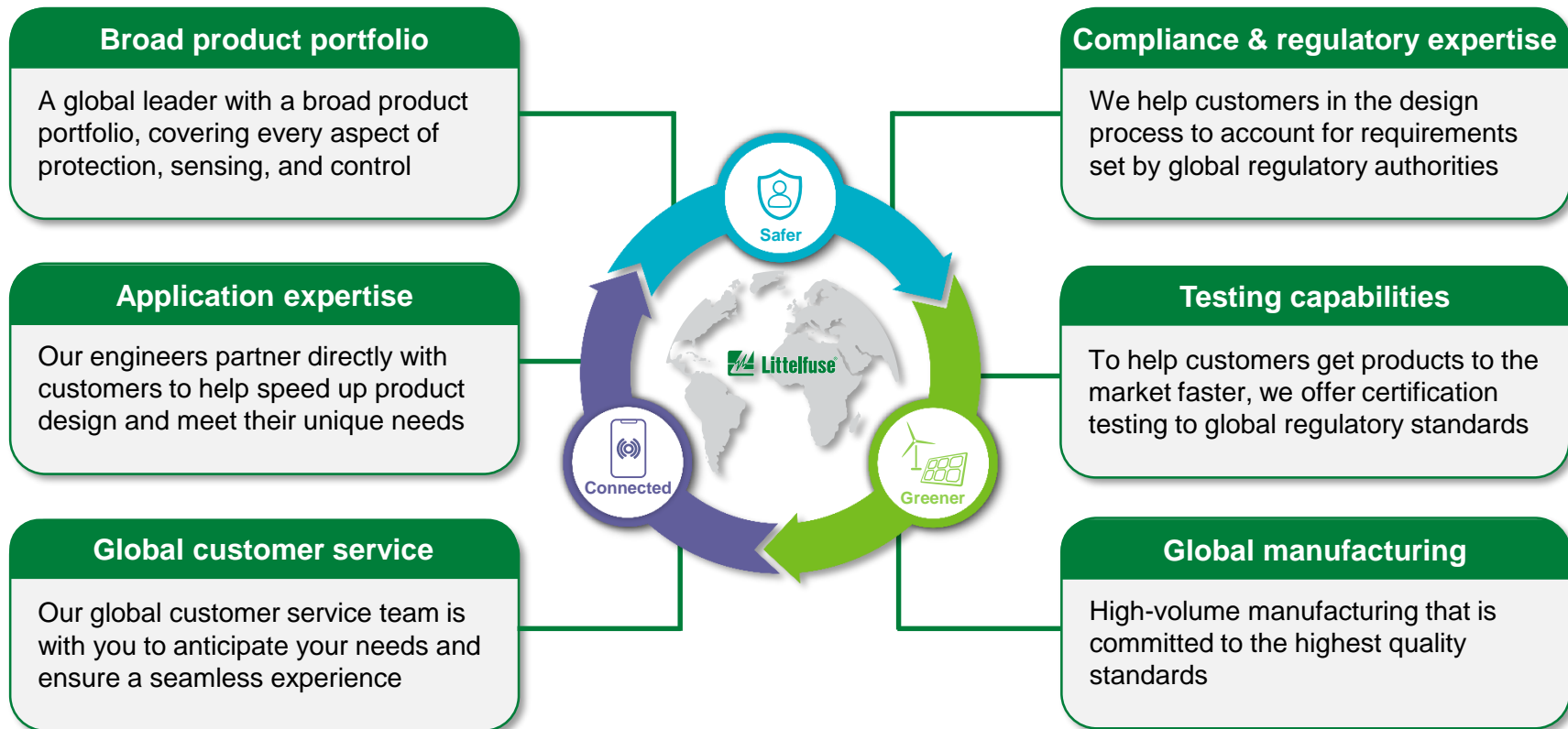
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