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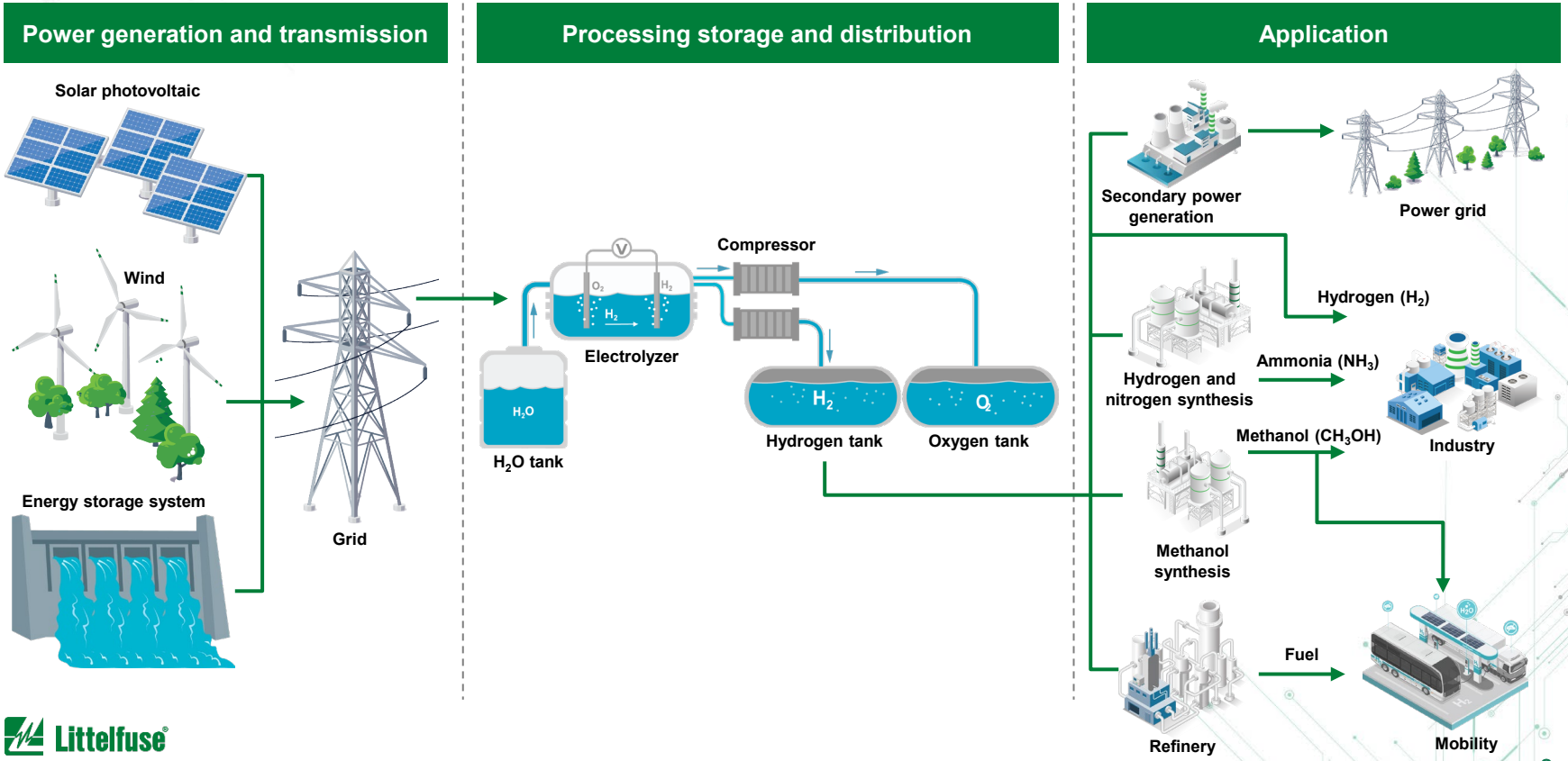
Green Hydrogen

Alternative Energy

Users must independently evaluate the suitability of and test each product selected for their own specific applications. It is the User's sole responsibility to determine fitness for a particular system or use based on their own performance criteria, conditions, specific application, compatibility with other parts, and environmental conditions. Users must independently provide appropriate design and operating safeguards to minimize any risks associated with their applications and products. Littelfuse products are not designed for, and may not be used in, all applications. Read complete Disclaimer Notice at littelfuse.com/legal/disclaimers/product-disclaimer.

REV0524

Green hydrogen production and usage cycle



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Hydrogen electrolyzer market is poised to grow at a CAGR of 26% from 2024 to 2032

Market trends and drivers

The hydrogen electrolyzer market was valued at 588M USD in 2023 and is expected to exceed 4.4B USD by 2032. Main growth drivers for hydrogen electrolyzer are lower cost of renewable energy and greater demand for green hydrogen.

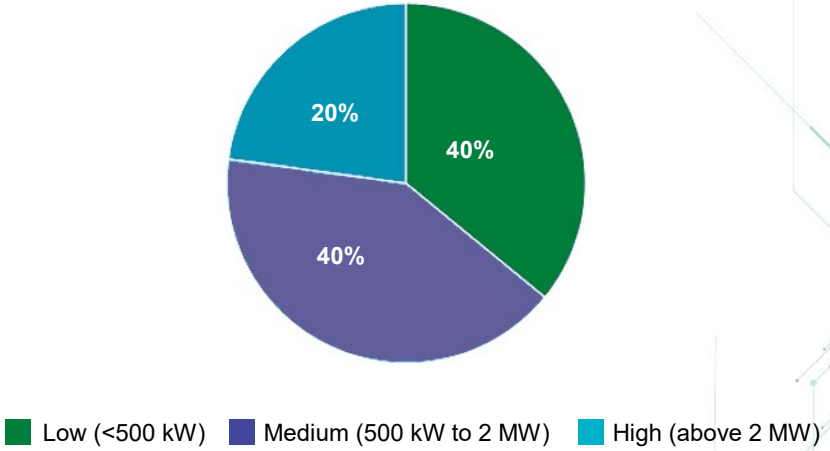
The medium-capacity electrolyzer serves a wide range of industrial applications such as chemical manufacturing, refining, and metallurgy.

Medium capacity electrolyzers convert surplus electricity from renewable sources into hydrogen for energy storage grid balancing and power-to-gas applications.

The global hydrogen electrolyzer market is segmented into solid oxide electrolyzers, alkaline water electrolyzers, and polymer electrolyte membrane (PEM) electrolyzers. PEM electrolyzers are known for their high efficiency and fast response time, making them suitable for applications such as transportation, energy storage, and grid balancing.

The hydrogen electrolyzer market is fragmented due to the presence of local and global players. North America held around 29% of the market share in 2023 and is anticipated to grow to almost 30% by 2032.

Global electrolyzer market revenue share (%)



Source: Global Market Insights and Littelfuse estimates

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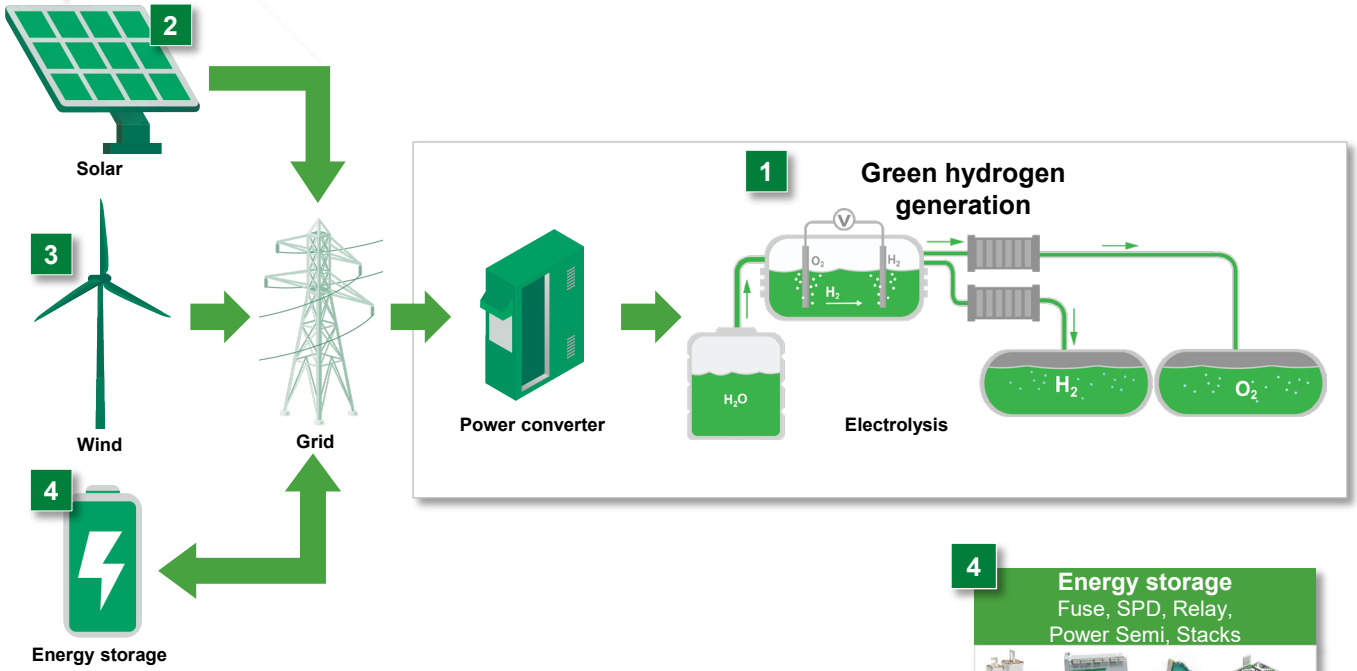
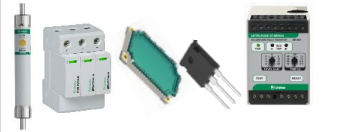
Littelfuse solutions for green hydrogen value chain



1 Hydrogen electrolysis
Fuse, Relay, Power Semi

2 Solar
Fuse, SPD,
Power Semi, Relay



4 Energy storage
Fuse, SPD, Relay,
Power Semi, Stacks

3 Wind
Power Semi, Fuse, Relay,
Stacks

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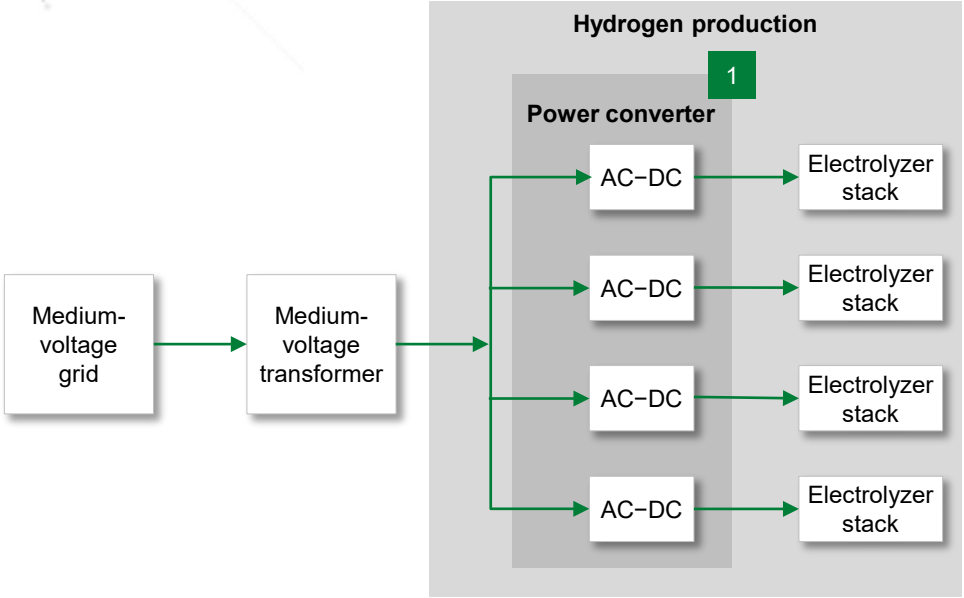
AC-coupled hydrogen electrolysis

Click the product series in the table below for more info

AC-coupled hydrogen electrolysis



	Technology	Product series
1	High-speed Fuse	PSX, PSR, L70QS, L75QS
	Arc Flash Relay	AF0025, AF0100, AF0500, PGR-8800
	Ground Fault Monitoring	SE-601, EL731
	Surge Protection Device	SPD2
	Press Pack Thyristors ***OR*** Press Pack Diodes ***OR*** Press Pack IGBTs ***OR*** Press Pack Sonic Diodes ***OR*** Stacks and Assemblies	Phase Control Thyristors
		Rectifier Diodes
		High-Power IGBTs
		HP Sonic FRD Diodes
		Power Stacks

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Potential Littelfuse products for AC-coupled hydrogen electrolysis

Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	High-speed Fuse	Provides high current limiting short circuit protection to protect high-value sensitive power semiconductor devices, personnel, and surrounding high-value assets	PSX, PSR, L70QS, L75QS	High current-limiting; low watts loss; low I^2ts; high breaking capacity	IEC and UL compliant; available in a variety of mounting types; indication and microswitch accessories for remote monitoring; AC and DC rating included on all product labelling or marking; CE marked
	Arc-Flash Relay	Significantly reduces the incident energy from an arc-flash event by detecting the light from an arc and providing an immediate trip signal (within <1 or <5 ms)	AF0025, AF0100, AF0500, PGR-8800	Arc energy reduction lessens potential for personnel injury and allows personnel to wear lower-rated PPE; ensures smallest downtime from equipment damage after an arc flash; provides always-on protection	Microprocessor-based relays with redundant circuitry; protection is enabled <50 ms after power is applied; point and fiber sensors with continuous self-check; one-, two-, or four-zone protection; plug-and-play installation with minimal configuration; breaker failure detection
	Ground Fault Monitoring	Monitors connection between live conductors and ground (earth), opening the circuit in the event of a fault to ground to help prevent inadvertent electrocution of personnel	SE-601, EL731	Limits fault current to 25 mA on ungrounded systems, ensuring detection of faults and reduction in point-of-fault damage; adjustable trip settings to suit system requirements	Rich feature options, including sensitive pickup levels as low as 1 mA, Modbus TCP, Ethernet IP, and Profibus network communications options, on-screen metering, programmable output contacts, and temperature sensor monitoring
	Surge Protection Device	Reduction of overvoltages caused by switching transients and lightning strikes	SPD2	Clamps overvoltages to maintain acceptable levels, reducing damage to other circuit components and reducing downtime and maintenance	DIN rail mountable; VDE/IEC and UL compliance, reducing inventory needs
	Press Pack Thyristors ***OR*** Press Pack Diodes ***OR*** Press Pack IGBTs ***OR*** Press Pack Sonic Diodes ***OR*** Stacks & Assemblies	Power conversion AC−DC	Phase Control Thyristors	Low conduction loss; maximum current rating and lowest thermal resistance for the package size	Comprehensive ranges of standard phase-control thyristors; voltage ranges from 400 to 6500 V
			Rectifier Diodes	Low conduction loss; low thermal impedance with high overload capacity; designed to survive even the most arduous applications	Comprehensive range of rectifier diodes offers class-leading performance and reliability; blocks voltages from 200 to 6.8 kV
			High-Power IGBTs	Free from wire and solder bonds, which all but eliminates the mechanical fatigue associated with conventional modules	Offers a range of class-leading devices with voltage ratings of 1.7 kV (900 V DC link), 3.3 kV (1.8 kV DC link), 4.5 kV (2.8 kV DC link), and 6.5 kV (3.6 kV DC link)
			HP Sonic FRD Diodes	The wide safe operating area (SOA) makes these ideal as freewheeling diodes for snubberless IGBT and IGCT applications or any application that require a fast, low- loss diode	World-leading class of ultra0fast and ultra-soft recovery diode available from -1.7 to 6.5 kV in current ratings from 270 to 4200 A
			Power Stacks	Custom options available; UL recognized and meets the requirements of the European Union Directive; surge suppression and fusing provides reliable, safe operation	Standard configuration high-power stacks provide fast off-the-shelf solutions for single and multiphase rectifiers in a wide range of power ratings

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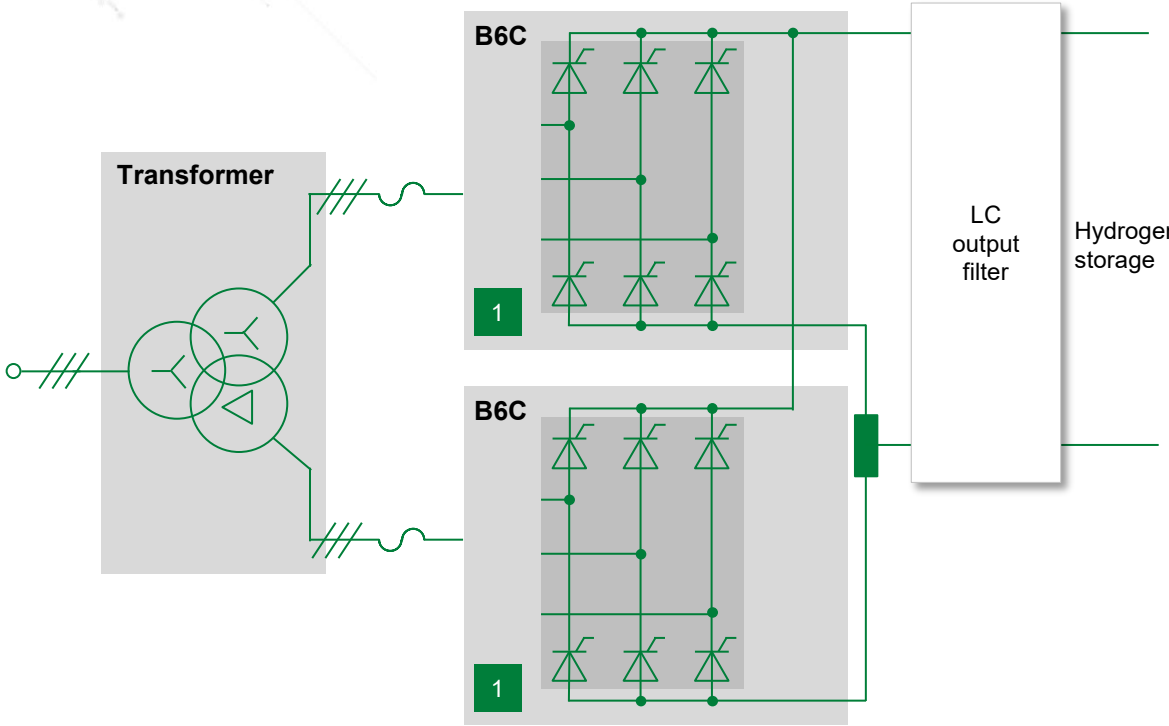
Power conversion example for electrolysis:

Classic approach of Thyristor-controlled B12C driven by a dedicated transformer

Click the product series in the table below for more info



	Technology	Product series
1	High-Speed Fuses	PSX, PSR, L70QS, L75QS
	Phase Control Thyristor	Phase Control Thyristors
	High-power Stacks*	Power Stacks

* *High-power Stacks are used to support 1500 to 2000 ADC.*

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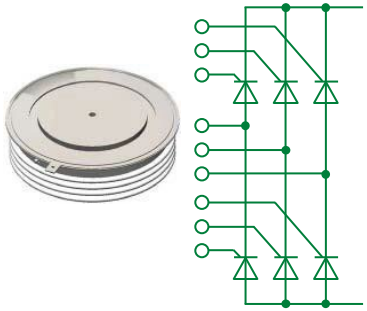
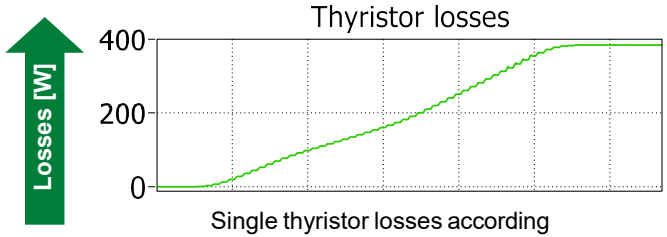
Advantages of Phase Control Thyristors versus wide bandgap solutions (SiC MOSFETs)

Thyristor and efficiency

- **For example, N1718NC200**



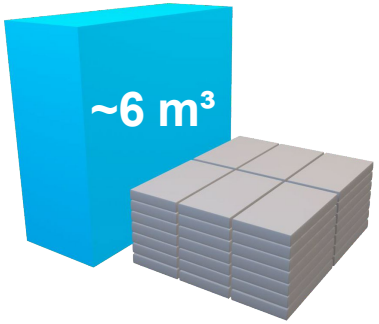
- V_f@500 A: 1064 mV
- V_f@1000 A: 1148 mV
- Estimated losses per bridge at 1000 A: 1000 A·1148 mV+2·(500 A·1064 mV) ➔ 2212 W
- Overall losses: 4423 W
- Overall efficiency: 99.8%



Single thyristor losses according to simulation: 384 W ➔ per bridge 2306 W

η_{si} = 99.8%

Reduction in size and resources per kW installed



Classical approach:
SiC-MOSFETs, liquid cooling
42 AC-DC units, 60 kW each ➔
2.5 MW 97% efficiency ➔ 60 kW losses
20 kW_{el} chiller needed

~0.6 m³

B12C-stack, forced-air cooling
One unit ➔2.5 MW 99.7% efficient 0.6 kW for fans

Thyristors instead of SiC-MOSFETs means:

- Reduced complexity
- Enhanced efficiency
- Superior lifetime
- Lower build volume
- Lower cost, faster ROI
- Far lower TCO

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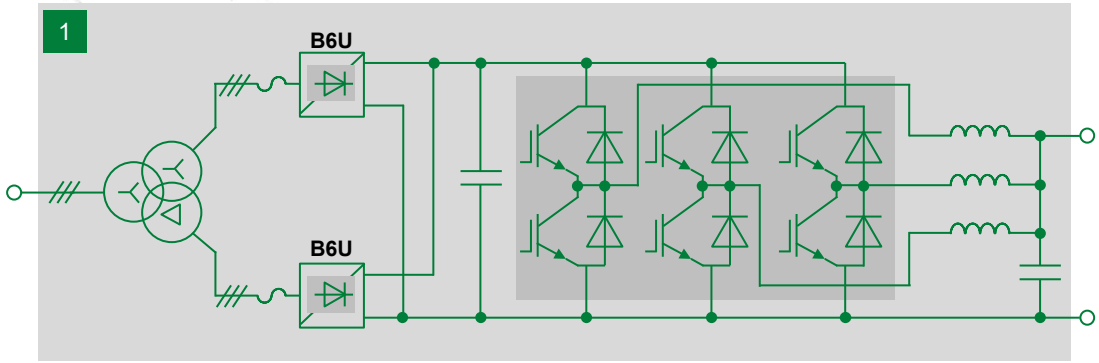
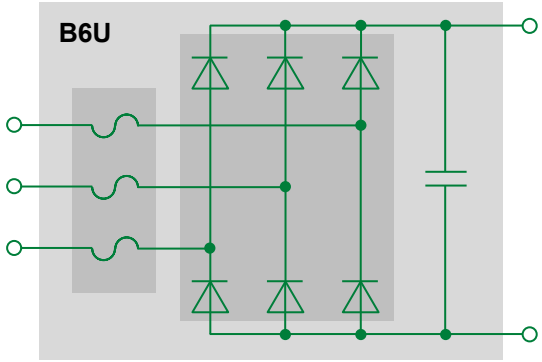
Power conversion example for electrolysis:

B6U rectifiers followed by IGBT-based choppers

Click the product series in the table below for more info





	Technology	Product series
1	High-speed Fuses	Semiconductor Fuses
	Press Pack Diodes ***OR*** Press Pack IGBTs ***OR*** Press Pack Sonic Diodes ***OR*** Stacks and Assemblies	Rectifier Diodes
		High-Power IGBTs
		HP Sonic FRD Diodes
		Power Stacks

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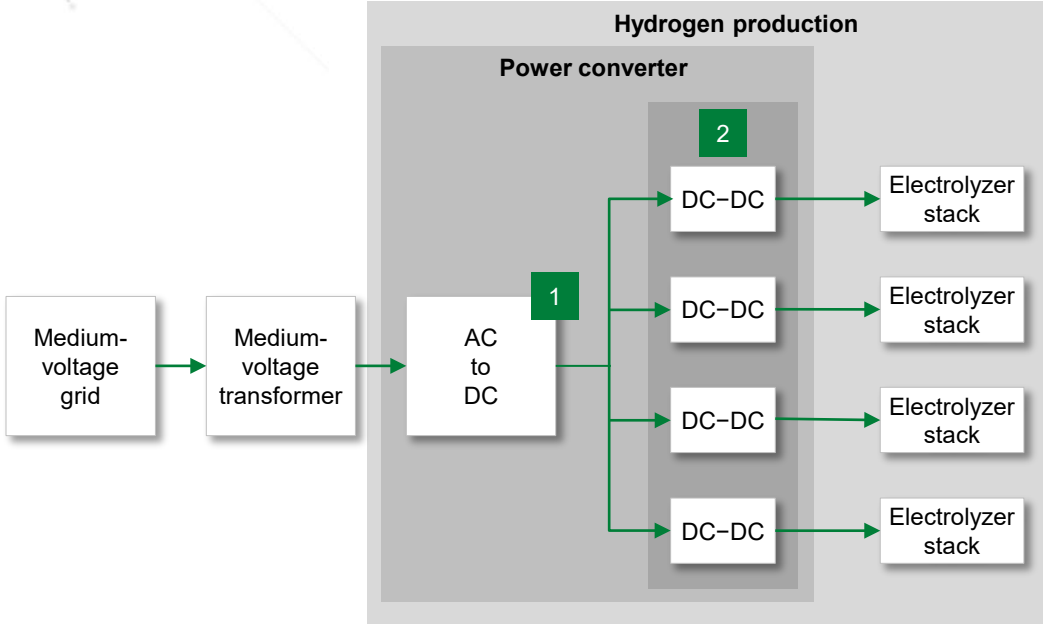
DC-coupled hydrogen electrolysis

Click the product series in the table below for more info

DC-coupled hydrogen electrolysis



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		Rectifier Diodes
		High-Power IGBTs
		HP Sonic FRD Diodes
		Power Stacks
2	High-speed Fuse	PSX, PSR, L70QS, L75QS
	Press Pack IGBTs ***OR*** Stacks and Assemblies	High-Power IGBTs
		Power Stacks

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Potential Littelfuse products for DC-coupled hydrogen electrolysis

Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
1	High-speed Fuse	Provides high current limiting short circuit protection to protect high-value sensitive power semiconductor devices, personnel, and surrounding high-value assets	PSX, PSR, L70QS, L75QS	High current limiting; low watts loss; low I^2ts; high breaking capacity	IEC & UL compliant; available in a variety of mounting types; indication and microswitch accessories for remote monitoring; AC and DC ratings included on all product labelling and marking; CE marked
	Arc-Flash Relay	Significantly reduces the incident energy from an arc-flash event by detecting the light from an arc and providing an immediate trip signal (within <1 or <5 ms)	AF0025, AF0100, AF0500, PGR-8800	Arc energy reduction lessons potential for personnel injury and allows personnel to wear lower-rated PPE; ensures smallest downtime from equipment damage after an arc flash; provides always-on protection	Microprocessor-based relays with redundant circuitry; protection is enabled <50 ms after power is applied; point and fiber sensors with continuous self-check; one-, two-, or four-zone protection; plug-and-play installation with minimal configuration; breaker failure detection
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			High-Power IGBTs	Free from wire and solder bonds, which all but eliminates the mechanical fatigue associated with conventional modules	Offers a range of class-leading devices with voltage ratings of 1.7 kV (900 V DC link), 3.3 kV (1.8 kV DC link), 4.5 kV (2.8 kV DC link), & 6.5 kV (3.6 kV DC link).
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			Power Stacks	Custom options available; UL recognized and meets the requirements of the European Union Directive; surge suppression and fusing provides reliable, safe operation	Standard configuration high-power stacks provide fast off-the-shelf solutions for single and multiphase rectifiers in a wide range of power ratings

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Potential Littelfuse products for DC-coupled hydrogen electrolysis

Click the product series in the table below for more info

	Technology	Function in application	Product series	Benefits	Features
2	High-speed Fuse	Provides high current-limiting short circuit protection to protect high-value sensitive power semiconductor devices, personnel, and surrounding high-value assets	PSX, PSR, L70QS, L75QS	High current limiting; low watts loss; low I^2ts; high breaking capacity	IEC and UL compliant; available in a variety of mounting types; indication and microswitch accessories for remote monitoring; AC and DC rating included on all product labelling/marking; CE marked
	Press Pack IGBTs ***OR*** Stacks and Assemblies	Power conversion DC−DC	High-Power IGBTs	Free from wire and solder bonds, which all but eliminates the mechanical fatigue associated with conventional modules	Offers a range of class leading devices with voltage ratings of 1.7 kV (900 V DC link), 2.5 kV (1.25 kV DC link), 3.3 kV (1.8 kV DC link), 4.5 kV (2.8 kV DC link), and 6.5 kV (3.6 kV DC link).
			Power Stacks	Custom options available; UL recognized and meets the requirements of the European Union Directive; surge suppression and fusing provides reliable, safe operation	Standard configuration high-power stacks provide fast off-the-shelf solutions for single and multiphase rectifiers in a wide range of power ratings

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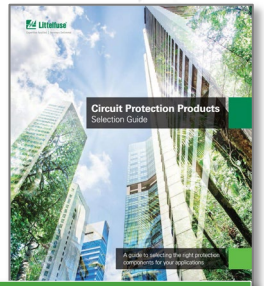
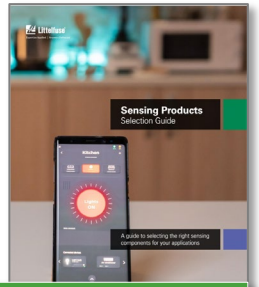
Additional information can be found at Littelfuse.com

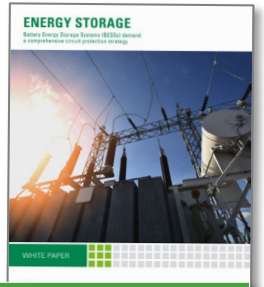
Explore the world of Littelfuse products and applications with ecatalogs (ecatalogs.littelfuse.com)



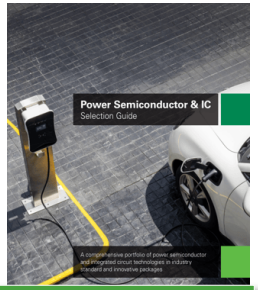
Circuit Protection Selection Guide



Sensing Products Selection Guide



Energy Storage Whitepaper



Power Semiconductor Selection Guide

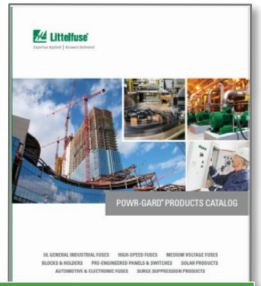
SPDs in PV Systems Application Guide

Click on the images for more information

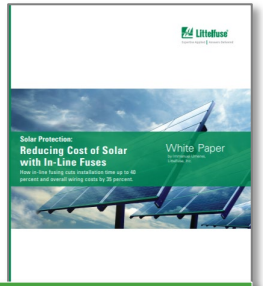
High-Speed Fuses Application Note

High-Speed Fuses Catalog

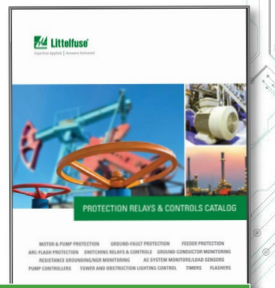
Scan the code to learn more!



Industrial Fuses Catalog



Solar Protection White Paper



Power Relay and Control Catalog

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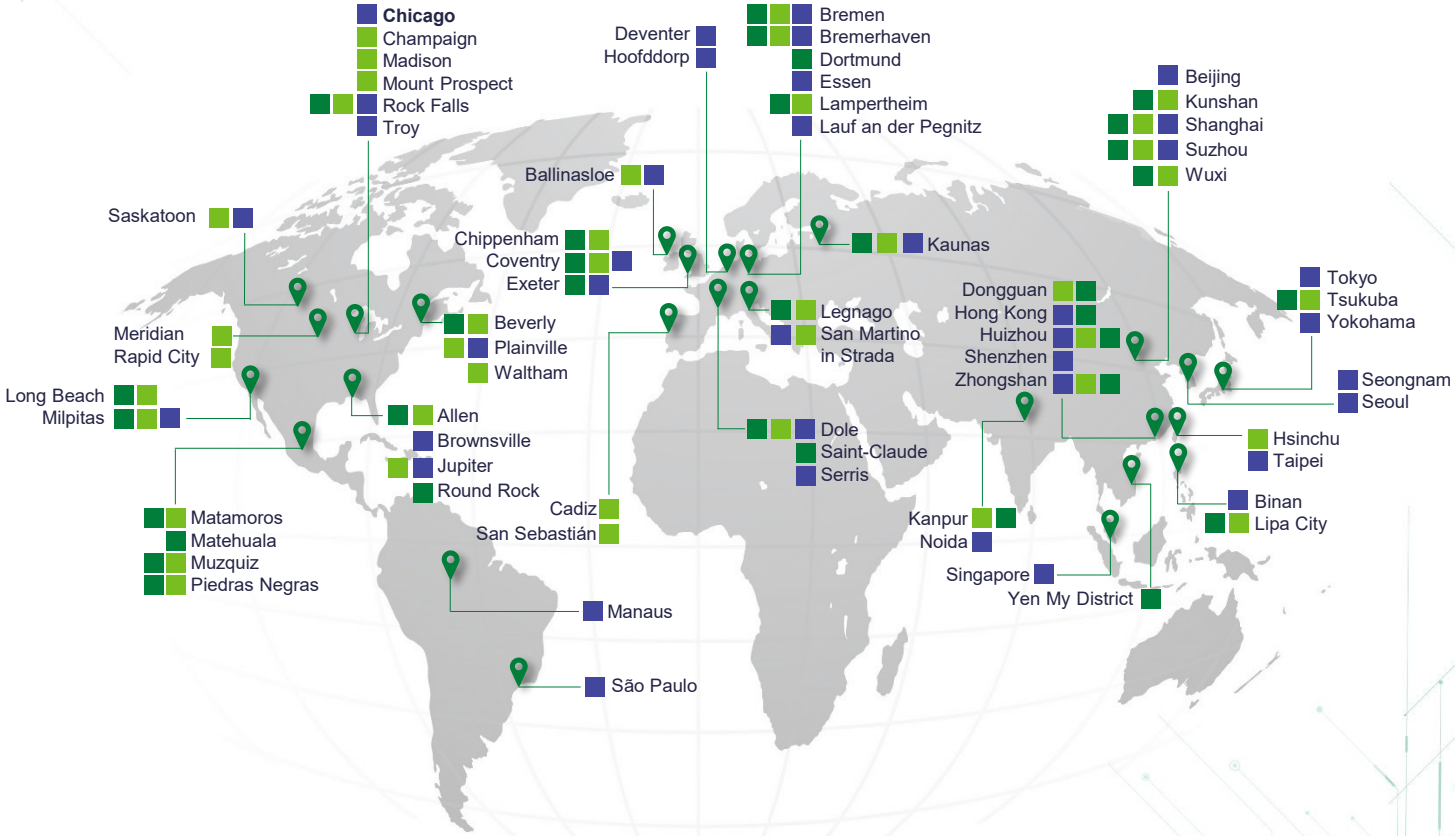
Local resources supporting our global customers



Legend

- ***Sales***
- ***R&D***
- ***Manufacturing***

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Littelfuse global labs & manufacturing footprints

Location	Country	Manufacturing facility	Global labs and testing	Product technology	Lab details	Quality certifications				
						ISO 9001	ISO 14001	IATF 16949	AS/EN 9100	Miscellaneous
Beverly	United States	⊙	⊙	Gate Drivers and SSRs		⊙	⊙	⊙		
Brownsville	United States	⊙		Carling Technologies		⊙	⊙	⊙		
Champaign	United States		⊙		High Power					
Long Beach	United States	⊙		High Power (Discrete, Module), Stack		⊙				
Milpitas	United States	⊙	⊙	MOSFETs and IGBT	Material/Application/Reliability	⊙				
Mount Prospect	United States		⊙		Semiconductor/Material/Application					
Matamoros	Mexico	⊙	⊙	Temperature sensors	Product Eval. & Reliability	⊙	⊙	⊙		
Matehuala	Mexico	⊙		Carling Technologies		⊙	⊙	⊙		
Muzquiz	Mexico	⊙		Commercial vehicle products			⊙	⊙		
Piedras Negras	Mexico	⊙	⊙	Fuses and Relays	Material/Application/Reliability	⊙	⊙	⊙		
Rockfalls	United States	⊙		Hartland Controls		⊙				
Round Rock	United States	⊙	⊙	SiC MOSFET/SiC Schottky Diode	Application/Reliability	⊙				
Bremerhaven	Germany	⊙		Wire harnesses (aerospace)		⊙	⊙		⊙	
Bremen	Germany		⊙		Product Eval./Reliability/Application					
Chippenham	United Kingdom	⊙		High Power (Discrete, Module), Stack		⊙	⊙			ISO 45001
Dole	France	⊙	⊙	C&K Switches and Interconnects			⊙	⊙	⊙	ISO 50001
Exeter	United Kingdom	⊙		Carling Technologies		⊙		⊙		
Lampertheim	Germany	⊙		Medium power (Diode, Thyristor, IGBT)		⊙	⊙	⊙		ISO 50001, OHSAS 18001
Legnago	Italy	⊙	⊙	CVP products	Product Eval./Reliability/Application	⊙	⊙	⊙		ISO 45001
Kaunas	Lithuania	⊙	⊙	Sensors	Product Eval./Reliability/Application	⊙	⊙	⊙		ISO 45001
Dongguan	China	⊙	⊙	Varistors	Product Eval./Reliability/Application	⊙	⊙	⊙		UL certified
Hong Kong	China	⊙		Carling Technologies		⊙		⊙		
Huizhou	China	⊙		C&K Switches		⊙	⊙	⊙		
Hanoi	Vietnam	⊙		C&K Switches		⊙	⊙			
Kanpur	India	⊙		Wire harnesses (Aerospace)		⊙	⊙		⊙	
Kunshan	China	⊙		PolySwitch®		⊙	⊙	⊙		
Lipa City	Philippines	⊙	⊙	Module (Bipolar IGBT/MOSFET)	Product Eval./Reliability/Application	⊙	⊙	⊙		UL/TUV certified
Shanghai	China	⊙	⊙	PolySwitch®, Hartland Controls	High-Power/Material/Reliability/Application	⊙	⊙	⊙		UL/TUV certified
Suzhou	China	⊙	⊙	Fuse and Sensor	Product Eval./Reliability/Material	⊙	⊙	⊙		
Tsukuba	Japan	⊙	⊙	Circuit protection	Product Eval./Reliability/ Material/Application	⊙	⊙	⊙		ISO 45001, UL/TUV certified
Wuxi	China	⊙	⊙	Diode, Thyristor, TVS Diode	Semiconductor/Material	⊙	⊙	⊙	EN 9001	ISO 45001, IECQ
Zhongshan	China	⊙		Carling Technologies		⊙	⊙	⊙		

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Partner for tomorrow’s electrical & electronic systems

Broad Product Portfolio

An industrial technology manufacturing company empowering a sustainable, connected, and safer world

Testing Capabilities

We help customers get products to market faster, 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

High-volume manufacturing that is committed to the highest quality standards

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