



Solar Inverters & Battery Energy Storage Systems (BESS)

-  Protect
-  Control
-  Sense

 **Littelfuse®**
Expertise Applied | Answers Delivered



Littelfuse product portfolio overview

Littelfuse: over 90 years of serving global customers

Littelfuse at a glance

Global leader in **circuit protection**

Growing provider of leading **power control** and **sensing** technologies

Deliver high-quality products to over 100,000 customers for a safer, greener, increasingly connected world

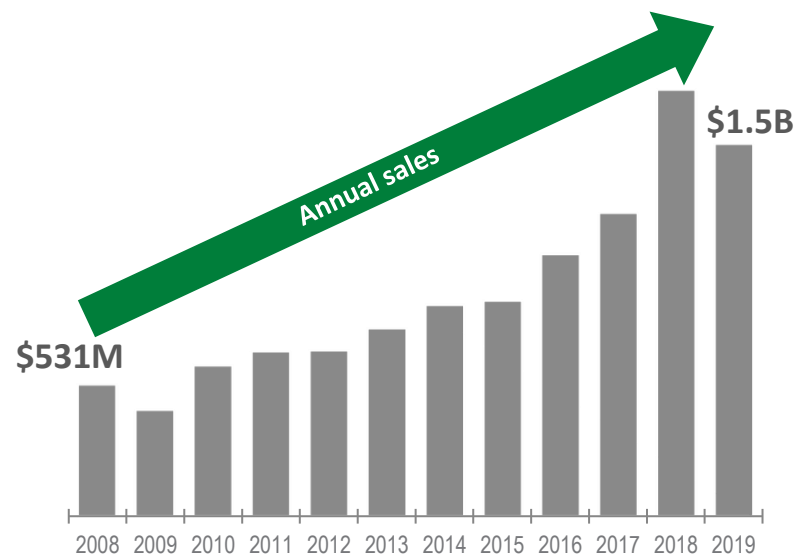
Global sales in over 150 countries, manufacturing & engineering in over 50 countries

\$1.5 billion of annual sales in 2019

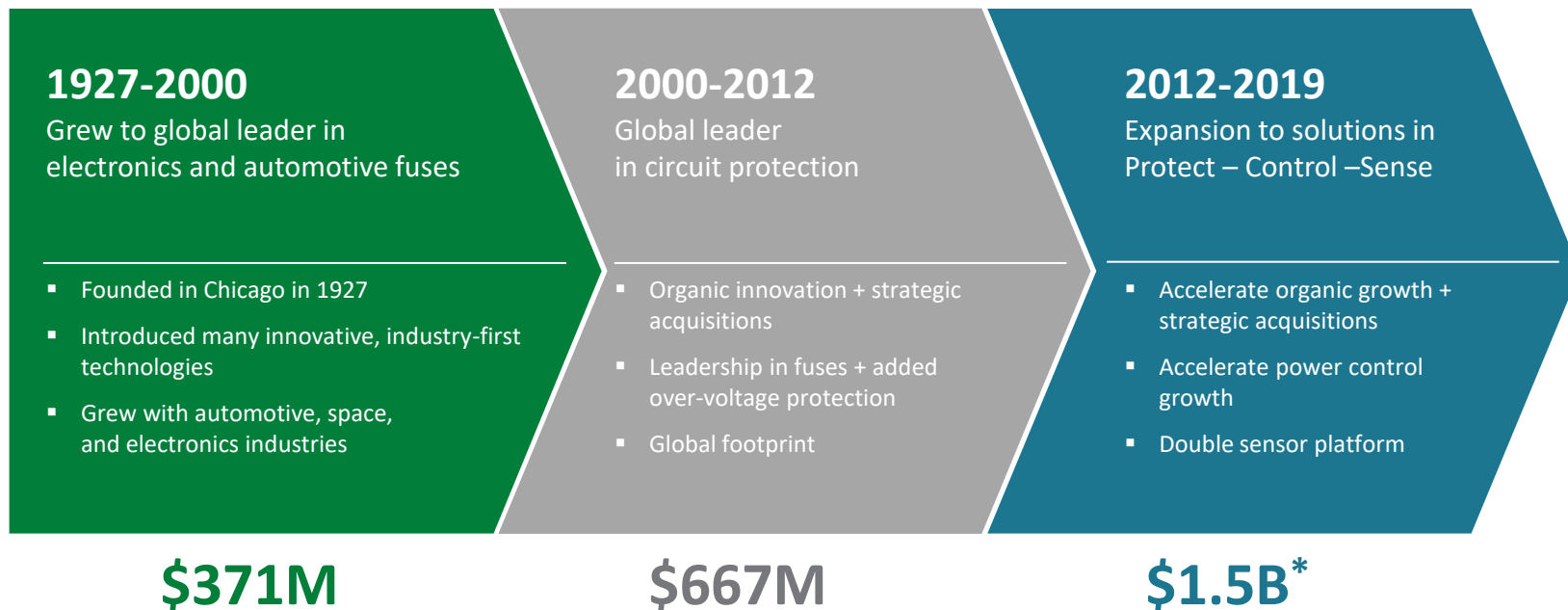
11,000+ dedicated and innovative employees

Founded in 1927, Headquartered in Chicago, IL, USA

Littelfuse annual sales (2008 – 2019)



Track record of technology and product innovation



Technology strength accelerated through acquisitions



Protect



Control



Sense



2013 – Hamlin, Inc

Products: Sensors

Markets: Automotive, Appliances,
Building Automation, Industrial



2015 – Sigmar SRL

Products: Sensors

Markets: Automotive &
Commercial Vehicles



2016 – Member's S.p.A.

Products: Battery Switches,
Trailer Connectors

Markets: Commercial Vehicles



2017 – U.S. Sensor Corporation

Products: Temperature Sensors
& Assemblies

Markets: Appliances,
Building Automation, HVAC



2018 – Monolith Semiconductor, Inc.

Products: Silicon Carbide

Power Semiconductors

Markets: Power Electronics



2018 – IXYS Corporation

Products: Power semiconductors

Markets: Industrial, Automotive,
Data center & Cloud Infrastructure



**2016 – Select Product Portfolio
of ON Semiconductor**

Products: IGBTs, Switching
Thyristors, TVS Diodes

Markets: Automotive, General Electronics



2014 – SymCom, Inc.

Products: Overload Relays,
Pump Controllers,
Time Delay Relays

Markets: Industrial



2012 - ACCEL AB

Products: Sensors,
Switches

Markets: Automotive



Expertise Applied | Answers Delivered

Protect | Control | Sense – solutions for many markets



Aerospace



Appliances



Automotive



Building
Automation



Data center
& Cloud



EV
Infrastructure



Healthcare



Industrial



LED
Lighting



Mobile &
Wearable



Renewable
Energy



Transportation

Protect: industry's broadest circuit protection products offering



Fuses



PolySwitch® PPTC
devices



GDTs



TVS diodes



Varistors



SIDACTor® Protection
thyristors



Diode arrays (SPA®) & ESD
protectors



Surge protection
modules

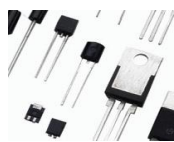


LED protectors

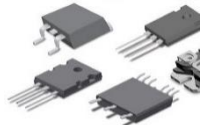
- **Helping make equipment safer and more reliable:** broadest portfolio of circuit protection technologies with many industry-first solutions
- **Industry standard's expertise and application testing capabilities:** independent testing for compliance with various standards including UL, IEC, ITU, AEC-Q, and others
- **Solutions for many applications including:** renewable energy, industrial automation, data centers, consumer electronics, mobile and wearables, healthcare, building automation, automotive, appliances, etc.

Power control:

Wide portfolio of power semiconductor technologies



Bipolar (Diodes & Thyristors)



IGBTs & MOSFETs



Bipolar, IGBT & MOSFET modules



Gate drivers



Solid state relays



High Power (Stacks, Devices)



SiC MOSFETs & Schottky diodes



Schottky & Fast recovery diodes



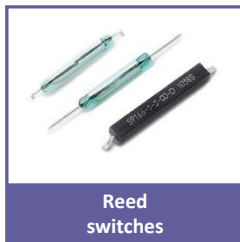
Ignition IGBTs

- **Power conversion systems:** wide range of discrete devices and power modules to address wide spectrum of power conversion
- **Extensive packaging capabilities:** industry standard packages, as well as innovative packaging and thermal management solutions
- **Standard and custom assemblies:** standard sub-assemblies for multi-megawatt power systems
- **Solutions for many applications including:** industrial motor drives, EV charging infrastructure, industrial power supplies, and renewable energy

Sensing: standard and customized magnetic and temperature solutions



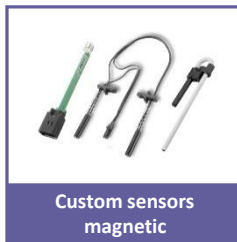
SENSE



Reed switches



Hall effect sensors



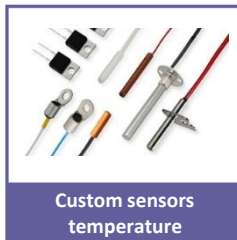
Custom sensors magnetic



NTCs



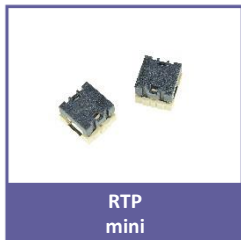
RTDs



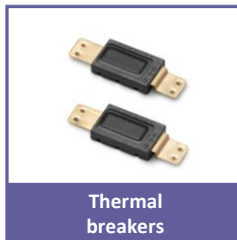
Custom sensors temperature



Digital temperature indicators setP™



RTP mini



Thermal breakers

- **Magnetic sensing:** a global leader in Reed, Hall-effect as well as bare and packaged magnetic actuators
- **Temperature sensing:** broad range of thermistors, RTDs, digital temperature indicators as well as assemblies
- **Custom sensor design support:** deep applications know-how, and magnetic and mechanical modeling expertise
- **Solutions for many application including** appliances, smart meters, battery management, automotive, EV, HVAC and others



Application expertise + testing capabilities to help reliability, safety, and regulatory compliance

GLOBAL LABS



Dedicated
Application
engineers

Tech
expertise



15
Global
labs



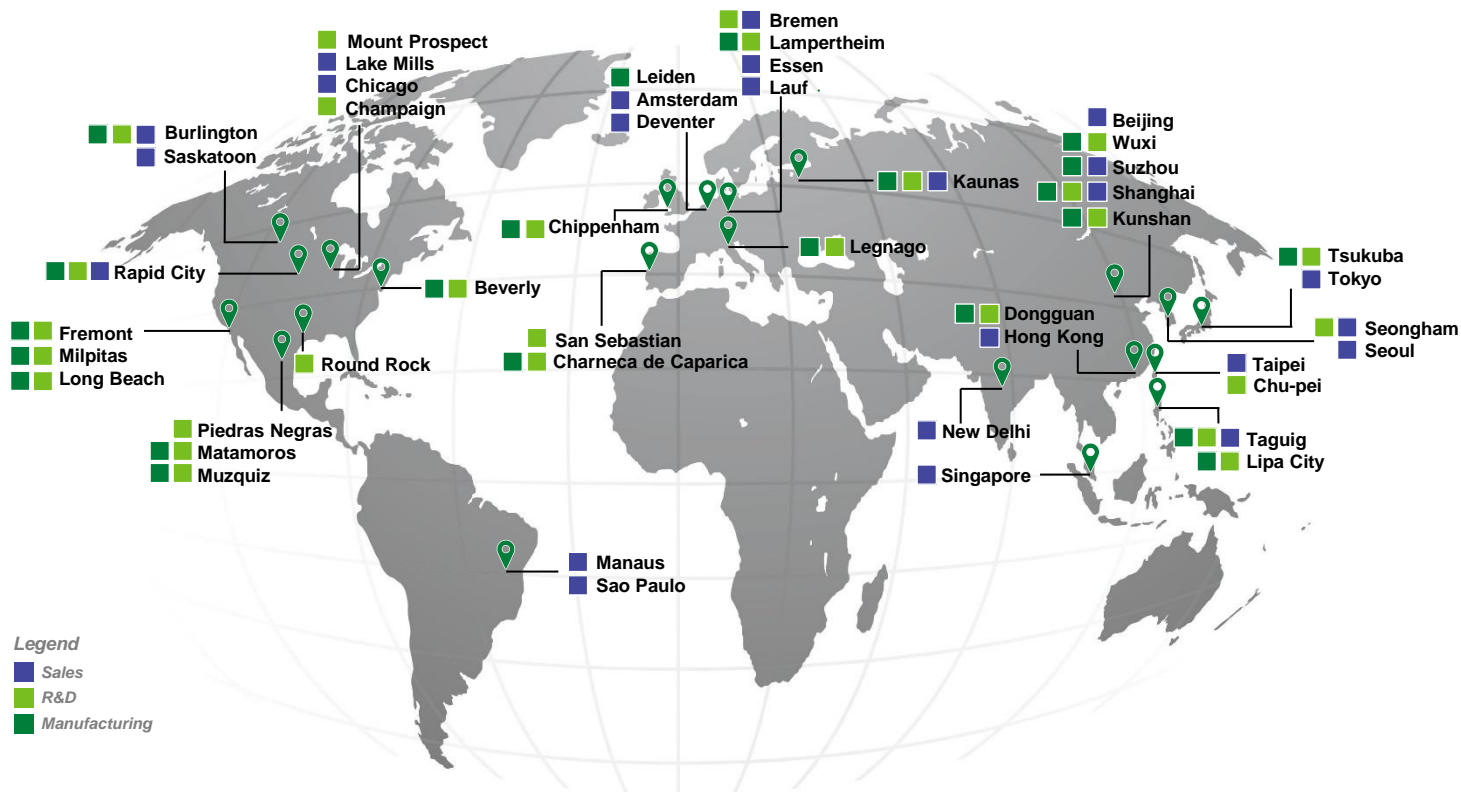
Testing to
regulatory
standards



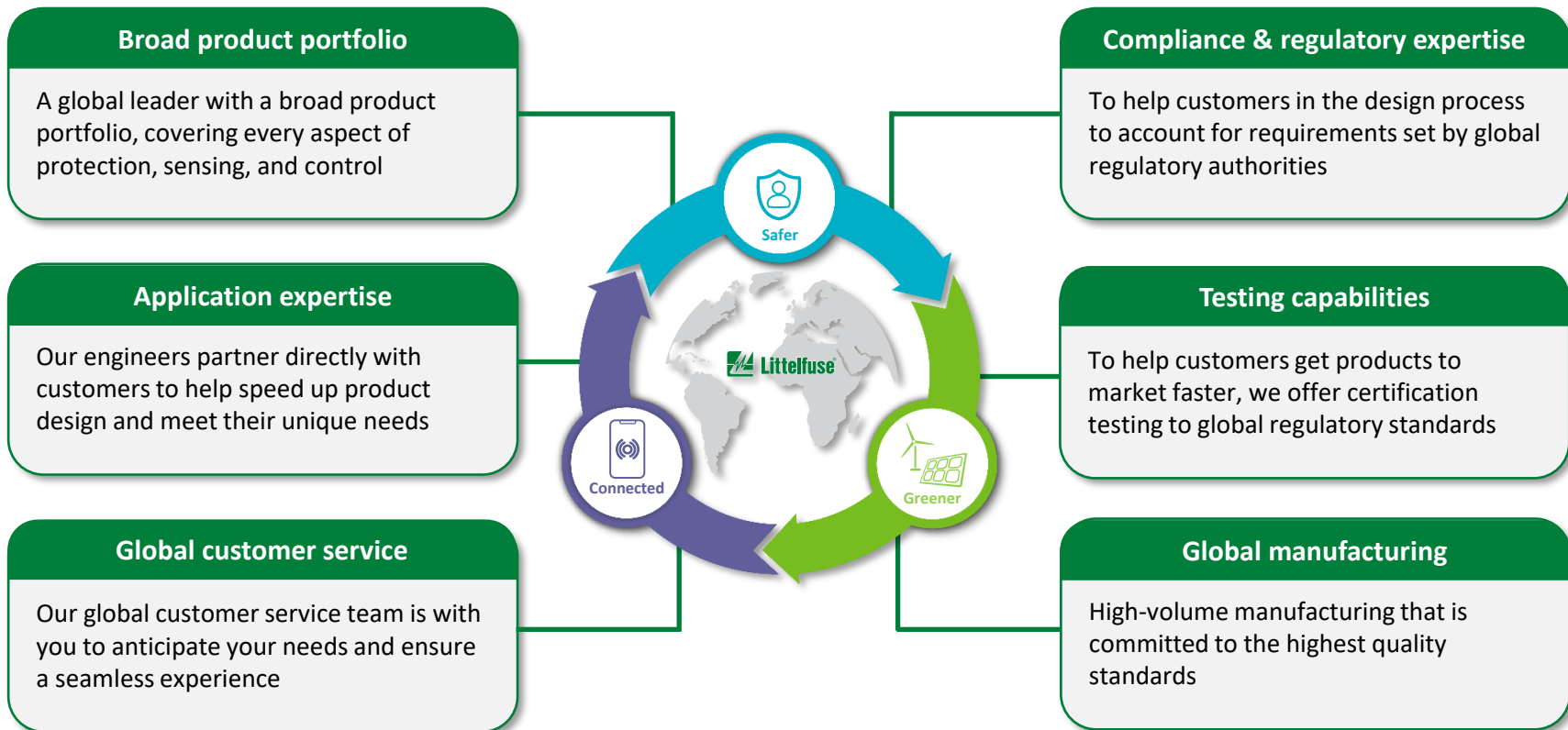
3D
proto-
typing

- **Application expertise:** our engineers partner directly with customers to help speed up product design and meet their unique needs
- **Compliance & regulatory expertise:** to help customers in design process to account for requirements set by industry standards and regulatory bodies
- **Testing capabilities:** to help customer get products to market faster, we offer certification testing to global regulatory standards
- **Simulation & prototyping:** to help reduce product development cycle time and tooling costs by leveraging our simulation and prototyping expertise

Local resources supporting our global customers



Partner for tomorrow's electronic systems





Power semiconductor solutions

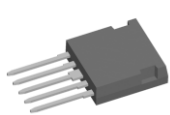
- Discrete: Bipolar, MOSFET & IGBT
- Power modules
- High power
- Gate drivers & SSRs



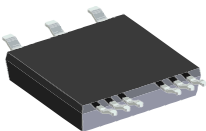
Innovative packaging solutions

ISOPLUS™ Technology

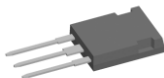
Features/Benefits



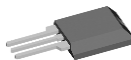
ISOPLUS i4-Pac



ISOPLUS-SMPD



ISOPLUS-247

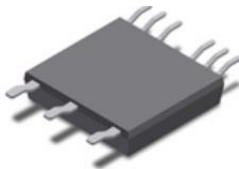
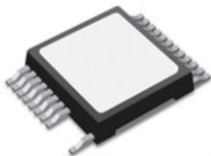
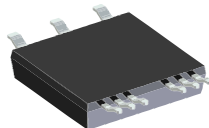


ISOPLUS220

- Low thermal resistance, reduce EMI & high reliability
- Space savings
- Increased power and temperature cycling
- 3, 4, or 5 lead configurations available
- 3500 V electrical isolation

Surface Mount Power Device (SMPD) Packages → *Top side cooling available*

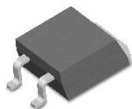
Features/Benefits



- Ultra-low weight and compact package profile
- Surface mountable
- Up to 4500 V ceramic isolation (DCB)
- Low package inductance & excellent thermal performance
- High power cycling capability

High Voltage Packages

Features/Benefits



TO-263HV



PLUS247HV



TO-252HV

- Increased distance between leads
- Arc-prevention in high voltage applications
- Electrical isolated tab for heat sinking
- Excellent thermal performance
- Best-in-class power and temperature cycling capabilities

Wide range of discrete and modules Bipolar, MOSFET & IGBT solutions to help make systems more efficient



CONTROL



Discrete IGBTs



Discrete MOSFETs



SiC MOSFETs



SiC Schottky Diodes



Discrete SCRs, TRIACs



Discrete FRD, Rectifier Diodes



IGBT Modules



Bipolar Modules



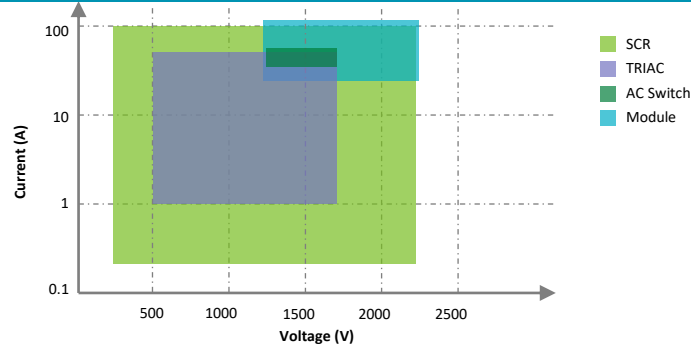
Rectifier, Phase-leg, PFC Modules

- **AC motor drives and soft starters:** IGBT and Bipolar modules for industrial motor drive applications
- **Renewable energy systems, industrial controls, and battery chargers:** power MOSFETs with voltage ratings ranging from 36 to 4,700 V
- **Inverters, input & output rectification:** rectifier diodes for various applications
- **High voltage, low frequency AC applications:** industry's broadest portfolio of Thyristors
- **Automotive:** industry leading AEC-Q ignition IGBT portfolio, covering all gasoline engine requirements

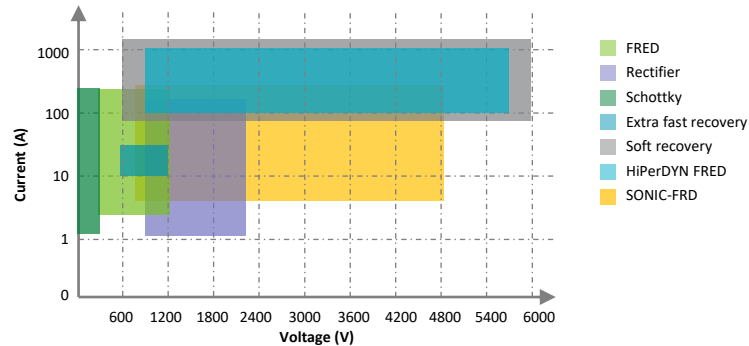
Key highlights of discrete bipolar (diodes and thyristors) offerings



Low-medium power thyristors



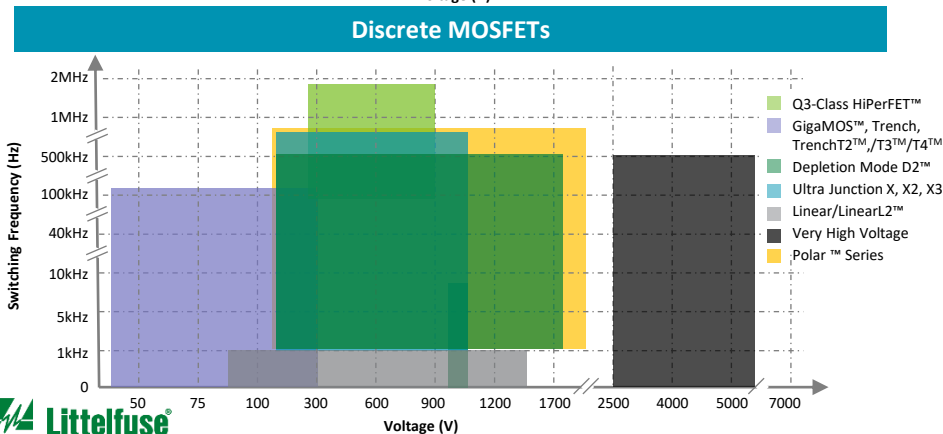
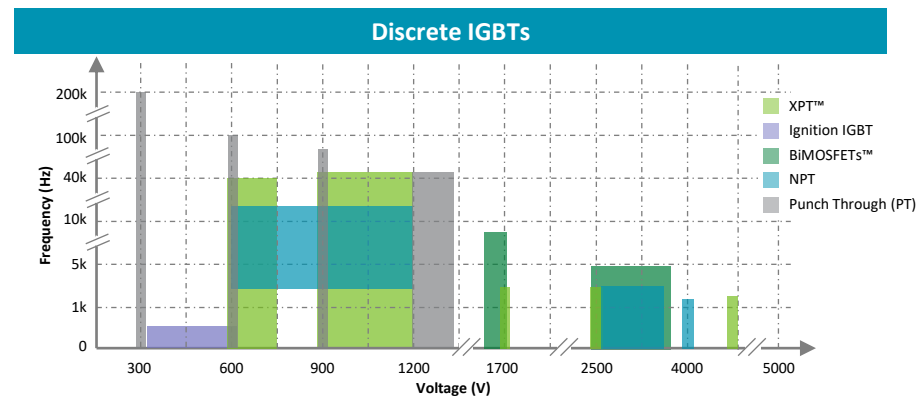
Discrete diodes



- **Higher current SCR:** as compared to competition- up to 100 A SCR
- **High voltage AC switches:** (2000 V) for medical applications
- **TRIAC:** up to 1600 V and 600 A with multiple options for customization
- **FRED:** gold doped offers good recovery w/ respect to V_F
- **HiPerFRED:** 200-1200 V suitable for battery chargers over SiC (lower V_F)
- **SONIC-FRD:** positive temp coefficient; good for paralleling, soft recovery
- **HiPerDyn:** series die connected in package to achieve BV rating



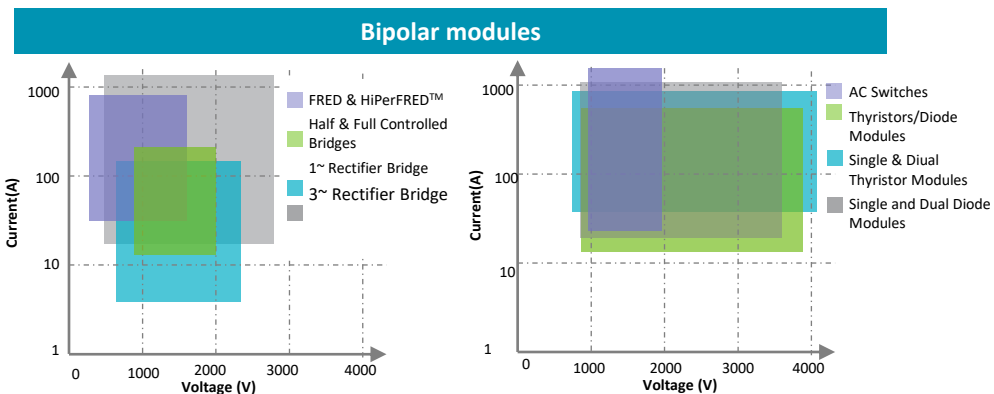
Key highlights of discrete IGBT and MOSFET portfolio



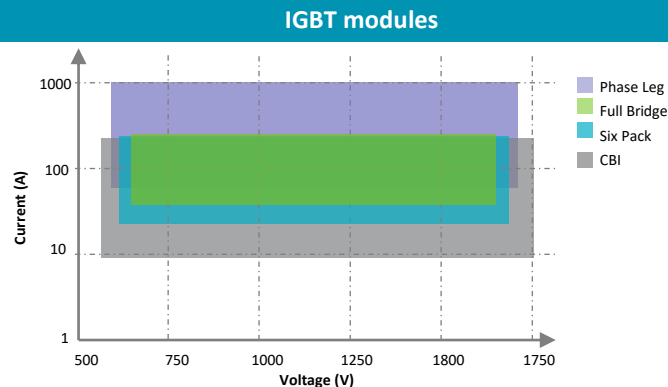
- **Broad power MOSFET portfolio:** voltage ratings from 36 V to 4,700 V
- **No competition:** for over 1700 V MOSFET product
- **Wide IGBT portfolio:** rated from 300 V to 4,500 V with option to customized devices for niche customer needs
- **XPT technology:** offers reduced thermal resistance, low energy & conduction losses, fast switching and positive temperature coefficient
- **Multiple packaging options:** TO-247, ISOPLUS-247, PLUS-247, etc.) with option for high voltage packaging (TO-268HV, TO-263HV, ISOPLUS i5-PAK™)



Key highlights for power module portfolio



- **Leader for SCR/Diode modules:** Standard recovery diode for AC line protection, fast diode for secondary rectification and thyristor for AC rectification, crowbar, etc.
- **Innovative and variety of standard packing options:** Bipolar modules (Press fit, DCB, etc.), IGBT modules (Econo2, Econo3, 34 mm, 62 mm, SimbusF, Minipack 1 B & 2 B)
- **Customization possibilities:** modify standard solutions, different substrate material (Al_2O_3 , Si_3N_4), Shunt, NTC, etc.



High-power semiconductor devices for high-energy, heavy industrial, and heavy transportation sectors



CONTROL



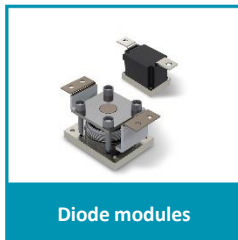
Discrete diodes



Discrete thyristors



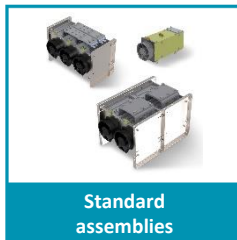
Thyristor modules



Diode modules



Press-pack IGBTs



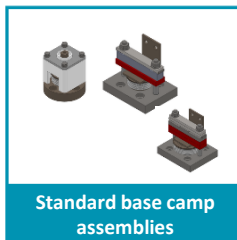
Standard assemblies



Custom assemblies



Accessories



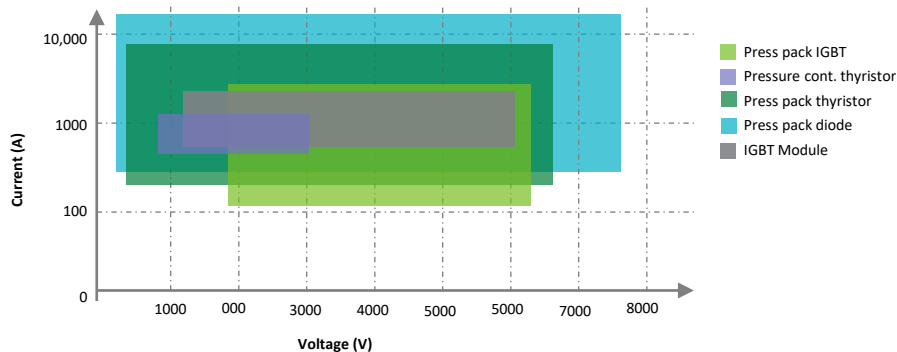
Standard base camp assemblies

- **VFDs, soft starters, high frequency inverters, and UPS:** Wide range of diodes (up to 6 kV) and thyristors (up to 4.5 kV)
- **HVDC, Active VAR controllers and medium voltage drives:** pioneer in press pack IGBTs technology (up to voltage ratings 4.5 kV (2.8 kV DC link))
- **High-power conversion and traction systems:** power semiconductor assemblies for most demanding applications



Key highlights of high power semiconductors

High power semiconductors

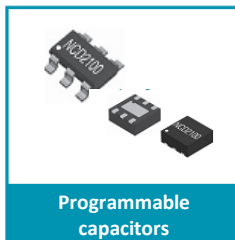
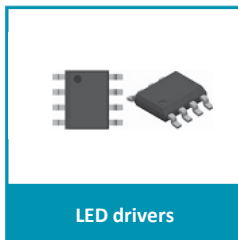
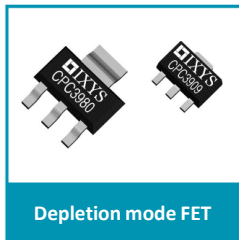
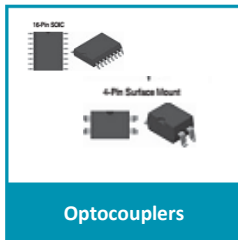
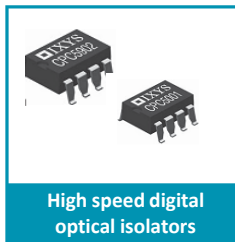
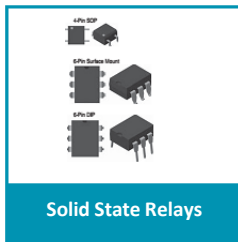


- **Widest portfolio of high power semiconductors:** on the market with leading edge Press-Pack IGBT
- **Range of thyristor and diode technology:** available delivering products to suit a wide range of applications and needs.
- **Customer stack assemblies:** based on custom needs: 100s kW to 10s MW
- **Engineering support:** to assist in device selection, mechanical considerations and cooling requirements
- **3300 V and 4500 V IGBT modules:** offering fully independent alternative supply channel to Infineon, ABB, Mitsubishi



Littelfuse Integrated Circuit portfolio overview

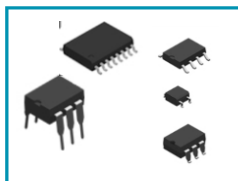
CONTROL



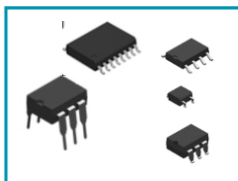
- ***Datacom & Security Systems:*** Solid-state relays can replace electromechanical relays and mechanical switches
- ***Power Supplies and Inverters:*** IGBT and MOSFET gate drivers for efficient power MOSFET and IGBT switching
- ***Lighting and Display Products:*** High-voltage LED drivers with dimming options, PFC control, etc.
- ***Medical:*** Optocouplers and SSRs are used for electrical isolation in medical equipment like ECG, Defibrillators, etc.



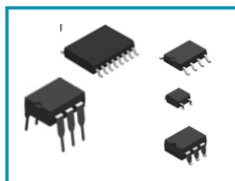
Solid state relay portfolio overview



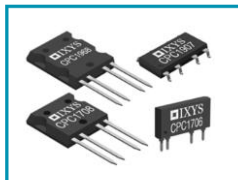
Form-A relays
(normally open)



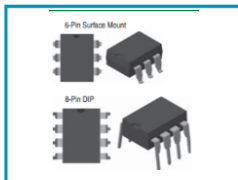
Form-B relays
(normally closed)



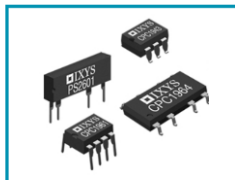
Combination (Form-A
& Form-B)



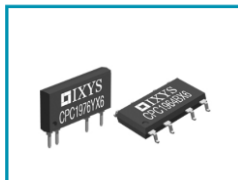
Power relays
(MOSFET-based)



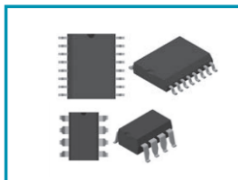
Fault protected relays



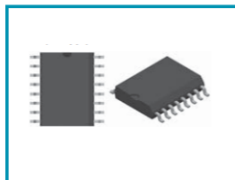
AC power switches
(Zero-Cross Turn-On)



AC power switches
(Rapid Turn-On)



Multifunction
products-General



Multifunction
products-Telecom

- **Form-A & Form-B relays:** replaces electromechanical relays and mechanical switches
- **Power relays (MOSFET-based):** blocking voltage up to $1000V_p$; on-resistance as low as 0.05Ω ; up to $5000 V_{RMS}$ isolation
- **Fault protected relays:** current limited SSRs with thermal management (ThM) and voltage triggered shutdown (VTS)
- **AC Power switches (SCR-based):** Blocking Voltage from 400V to 800V; maximum load current up to $1 A_{RMS}$; Zero-cross & rapid turn-on versions



Expertise Applied | Answers Delivered



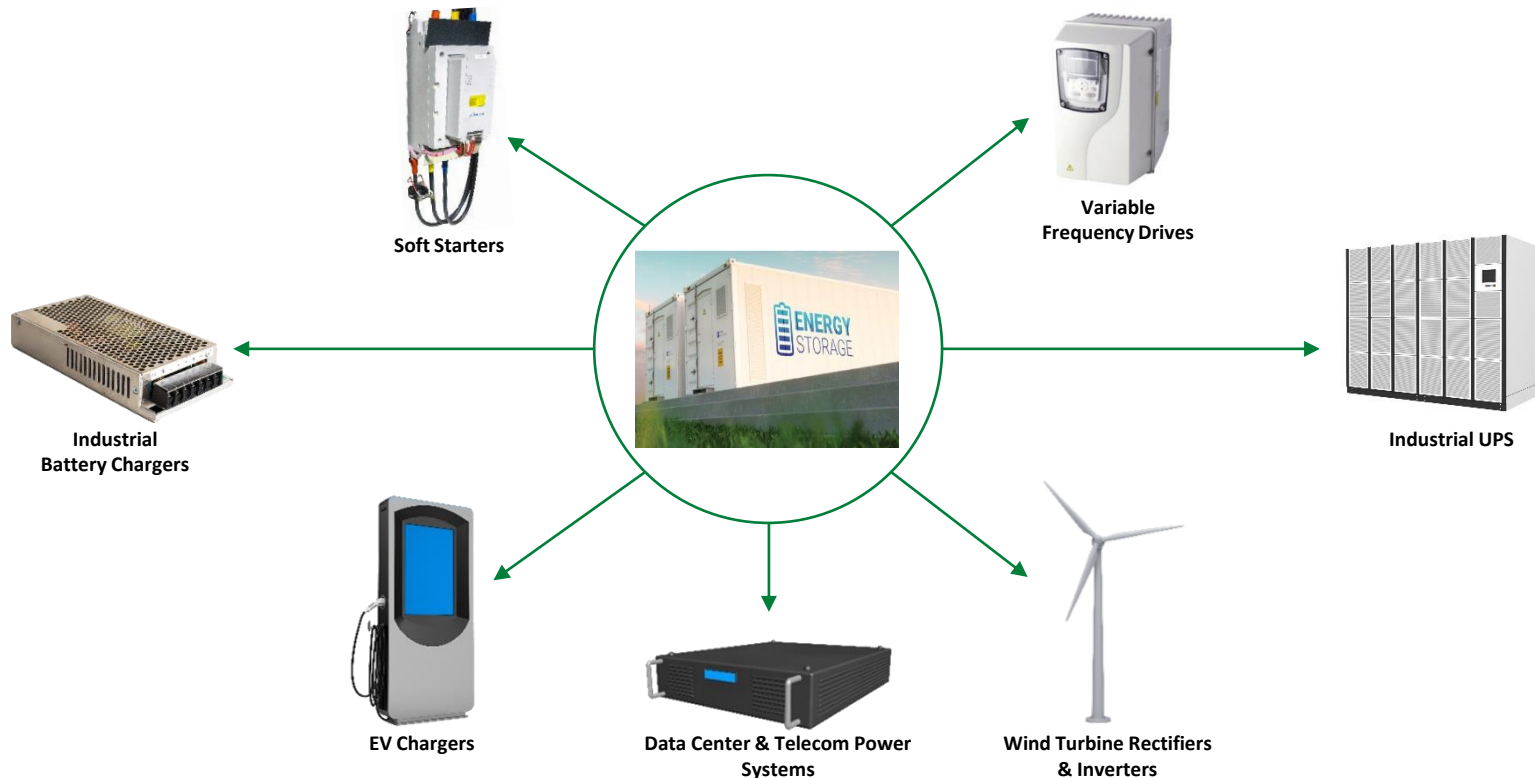
[Littelfuse.com](https://www.littelfuse.com)

「用電大戶」條款

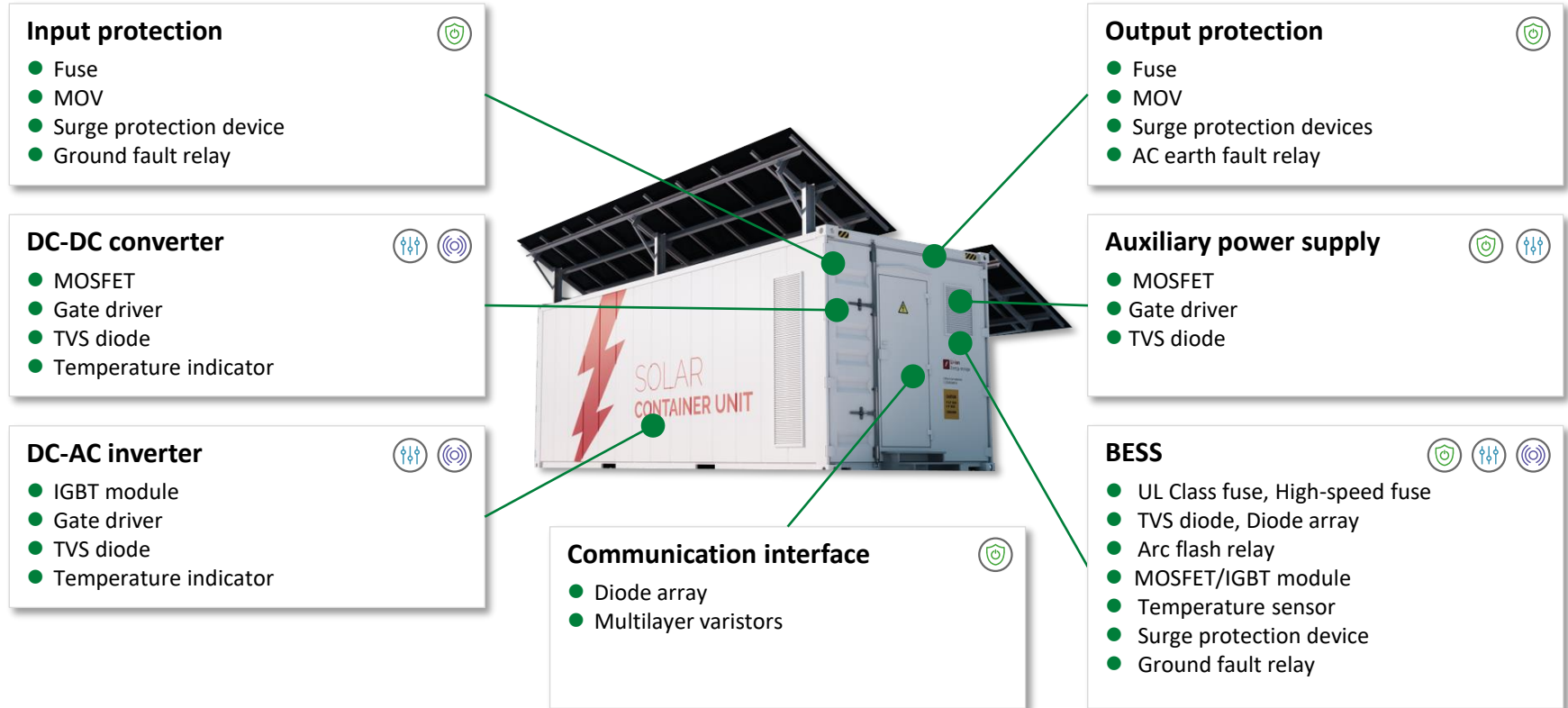
- ◆ 迎接世界各國在後疫情時期為了加速推動經濟反轉成長，對於能源需求持續增加，但因為再生能源不穩定特性，必須廣設**太陽能光電、風力電機與儲能設備**，儼然成為新興高科技產業，被政府列為**6大核心戰略產業**之一。依經濟部公告自今（2021）年元旦起正式上路的《一定契約容量以上之電力用戶應設置再生能源發電設備管理辦法》，（俗稱「**用電大戶**」條款），**規範契約容量5,000kW以上用戶，必須在5年內設置契約容量10%的再生能源**。
- ◆ 根據統計，首波用電大戶數量約506個大戶電號，扣除教育、醫療保健及社會工作服務業等後，約有300多家企業，包含石化、半導體、鋼鐵、電子等工業用戶居多，必須在5年內完成設置契約容量10%的綠電，創造至少約1GW再生能源交易市場。經濟部強調，為協助用電大戶彈性履行義務，業者共有4種履行作法，分別為**設置一定裝置容量的再生能源設備或儲能裝置**、購買再生能源憑證、以及繳交形同罰款的代金。
- ◆ 與之前預告版本不同的是，倘若在辦法實施前已裝設再生能源發電設備者，經濟部將加碼提供最高20%「既設扣減」義務量獎勵；再搭配「早鳥優惠」，提早2年達成義務量者，可享有8折（20%義務量）扣減上限，兩者合計最高可打6折（減免40%義務量）。也就是說，若用電大戶在該條款上路前就安裝既有的綠能發電設施，又在**第三年完成義務裝置容量，就能將再生能源設置量從原本10%義務量打4折，等於僅須達到6%綠能裝置量即可**。



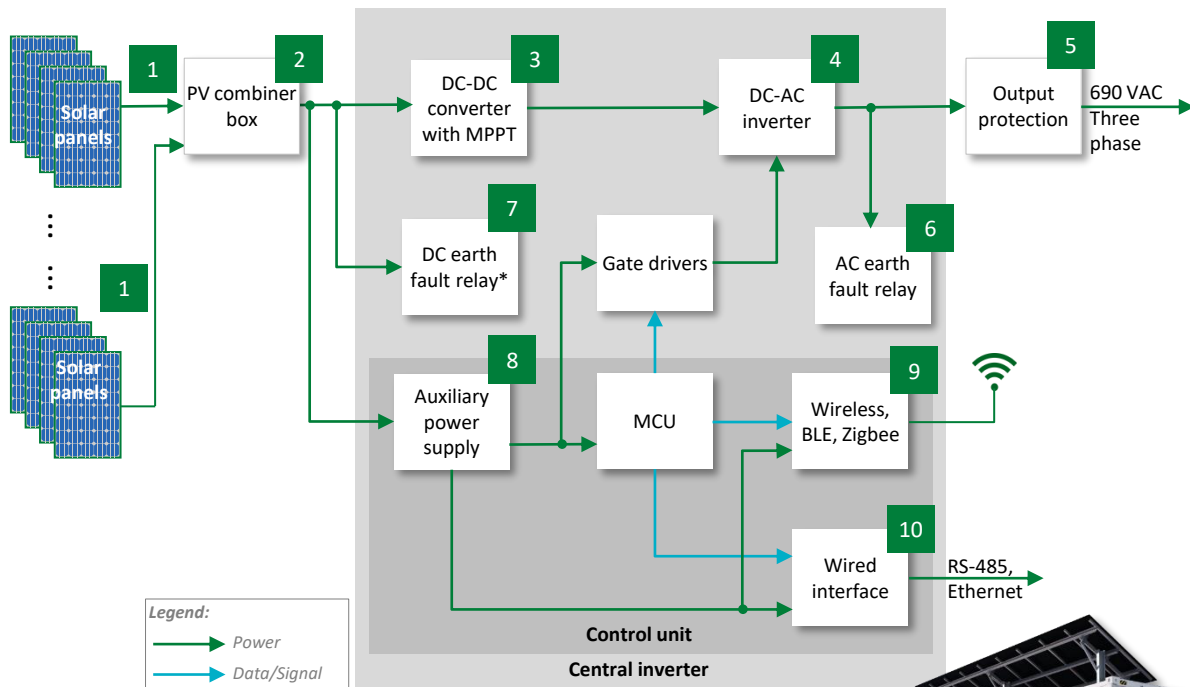
Solar inverters share similar architecture with other systems like industrial drives, UPS, EV charging, etc.



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



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	SPXI
2	Fuse/Holder	SPXV , SPNH , LFPXV
	SPD	SPD2 PV series
3	SiC MOSFET or MOSFET*	LSIC1MO120E0120 ; High Voltage Series
	SiC Diode*	1200 V diode
4	IGBT module	MIXA , MIXG
	High-speed fuse	PSR
	TVS diode	SMBJ
5	Fuse	Class J , Class RK5 , Class L
	SPD	SPD type 2
6	AC ground fault relay	EL-731
7	DC ground fault relay**	EL-731 , SE-601
8	SiC MOSFET or MOSFET	LSIC1MO170E1000 High Voltage Series
	Gate driver	IX4351NE
	TVS diode	SMF
9	Diode array or MLV	SP3130 , MLA , MHS
10	Diode array	SP712 , SM712 SP2555NUTG



Acronyms:

MPPT: maximum power point tracking

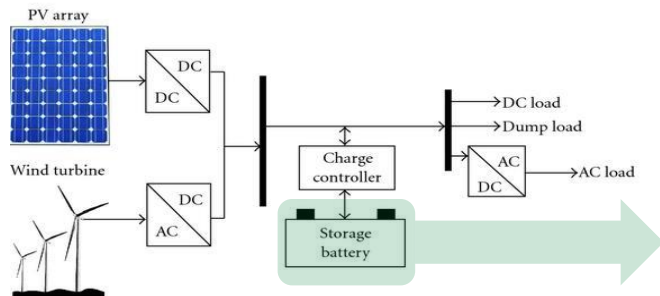
SPD: surge protection devices

TVS: transient voltage suppressor

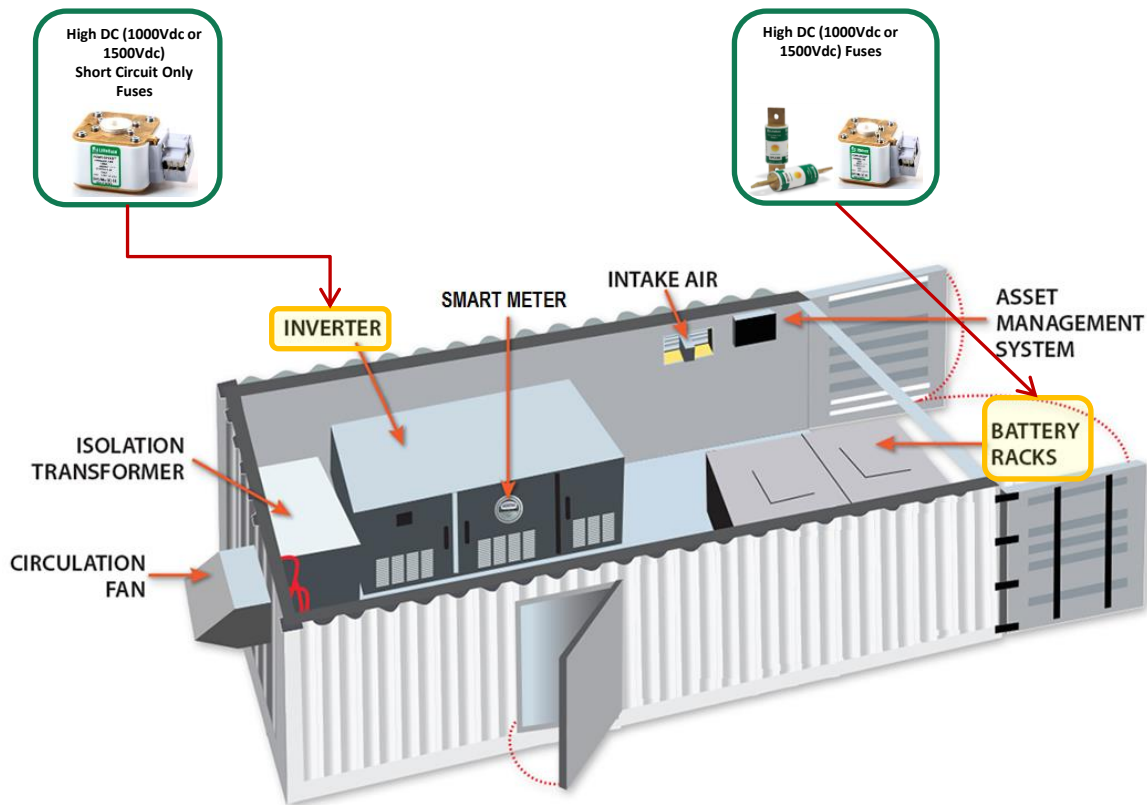
MCU: microcontroller unit

Battery Energy Storage Systems (BESS)

BESS: A large scale battery system connected to the electrical grid for both power and energy storage.



- Peak Shaving
- Reliable Power
- Smart Power Consumption



ESS – Key Circuit Protection Selection Factors

- **Voltage Rating** meeting the ESS Components Ratings
 - Module: ~100Vdc
 - Rack: ~1250dc
 - Container: ~1500Vdc

- **Maximum Short Circuit Protection** (Interrupting Rating)
 - Module: ~ 20kA
 - Rack: ~100kA
 - Container: ~100kA

- **System Coordination** during External Fault
 - Module (Respond Slow)
 - Rack & Container (Respond Fast)

ESS: Circuit Protection Product Options



CELL

- 40Ah/60Ah
- 148Wh/222 Wh



MODULE

- 38Vdc to 100Vdc
- Up-to 100A



RACK

- Up-to 100A
- Up-to 1250Vdc



CONTAINER

- Several thousand Ampere
- Up-to 1500Vdc

ITV Series

36Vdc – 62Vdc
12A to 45A

L15S/JLLN

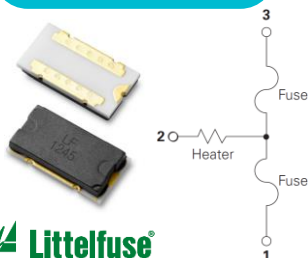
100Vdc – 150Vdc
1A to 1000A
20kA

PSR Series

~1000Vdc
40A to 2000A
150kA

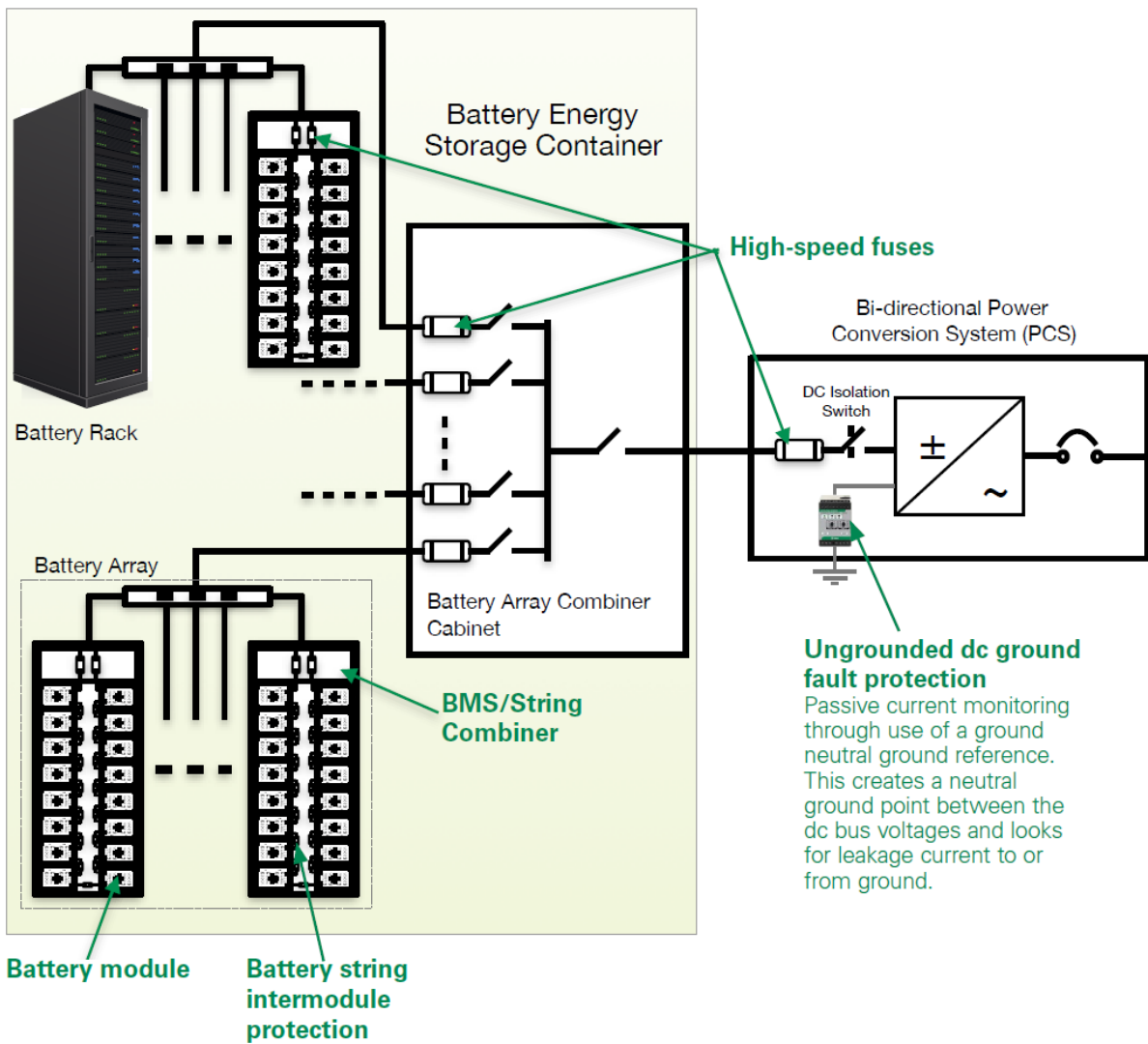
PSX Series

1500Vdc
80A to 1400A
100kA

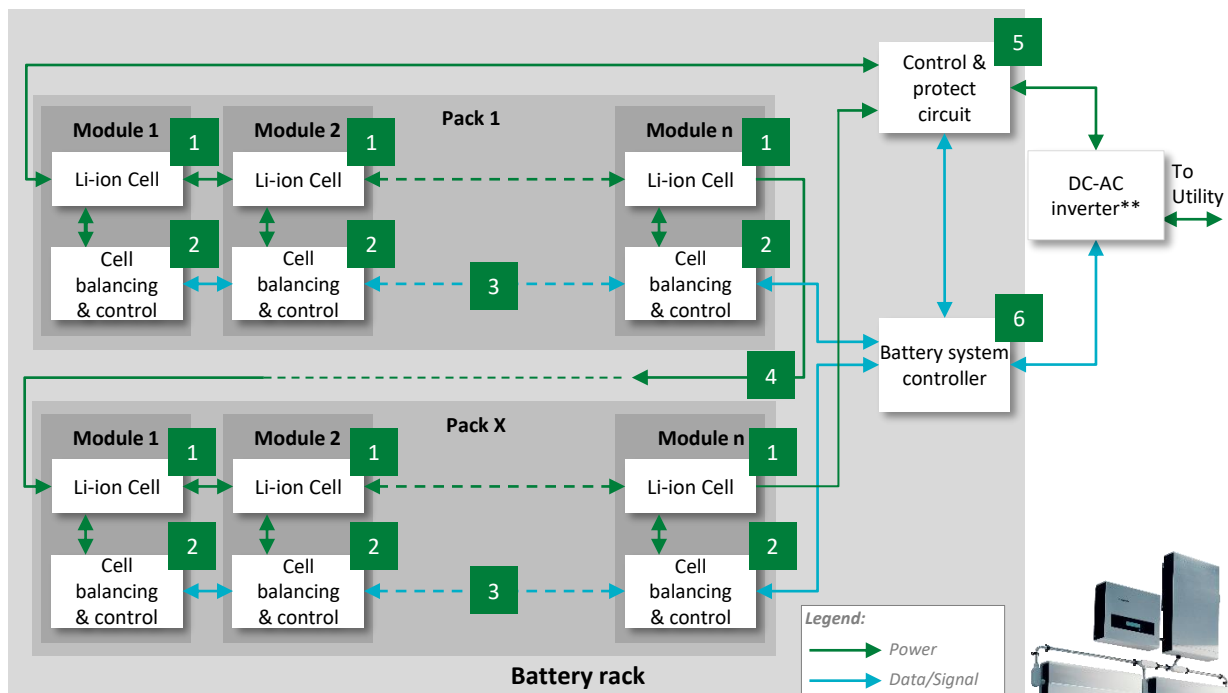


PSX Series

The PSX series high-speed fuses deliver extremely fast-acting performance **up to 1500 V** dc like no other product on the market today. Available in flush-end, DIN-mount, and bolted-blade styles, they are the smallest NH XL package size on the market and range from **80 A to 1400 A**. **Visual blown fuse** indication is standard on all fuses and an optional **microswitch** is available for external indication.



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

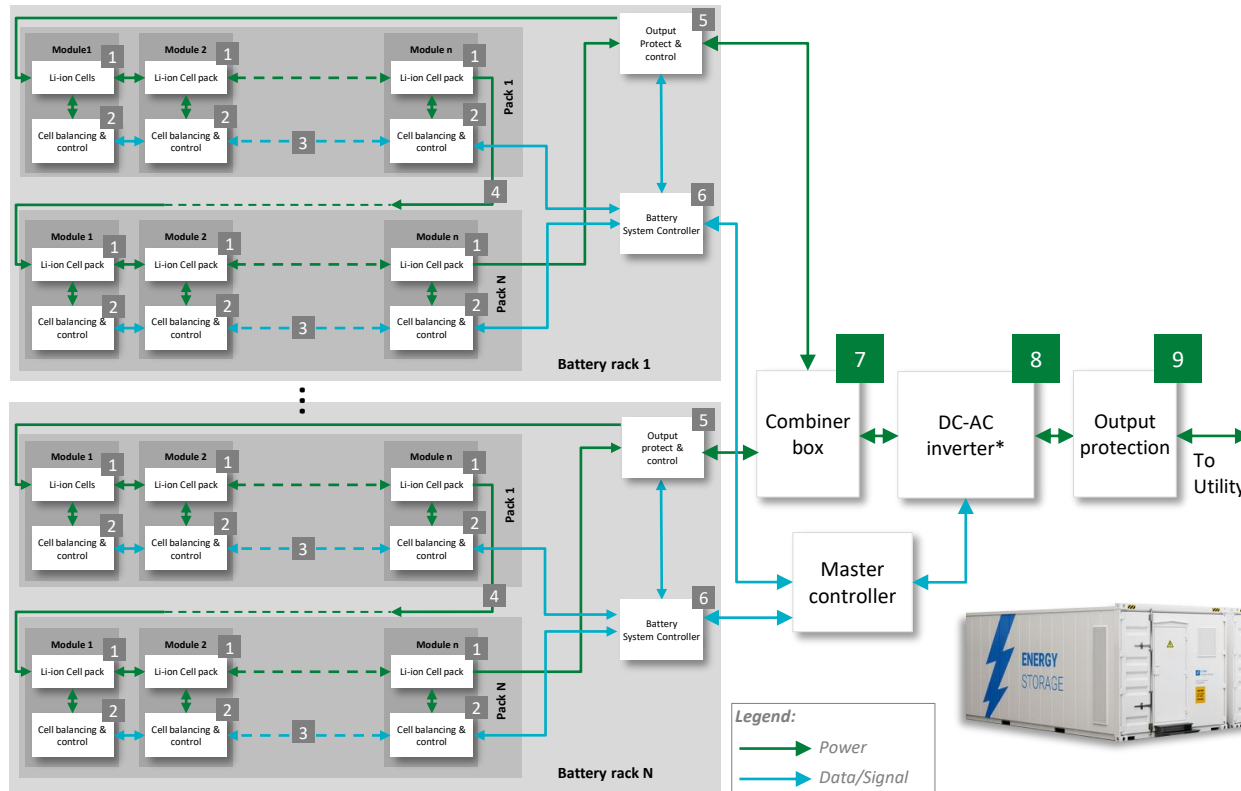


	Technology	Product Series
1	Fuse	501A, 881
	TVS diode	TPSMC, SZ1SMC, SZ1.5SMC
	Temperature sensor	USP16673, RB
2	SMD or In-line fuse	438A, 441A, 521
	TVS diode	TPSMB, SZ1SMB, SZP6SMB
3	Diode array	AQ05C
	TVS diode	TPSMA6L, SZ1SMA
4	Fuse	TLS, JLLN, CNN
5	High-speed fuse	PSR, PSX
	MOSFET	X3 Class
	Gate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

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



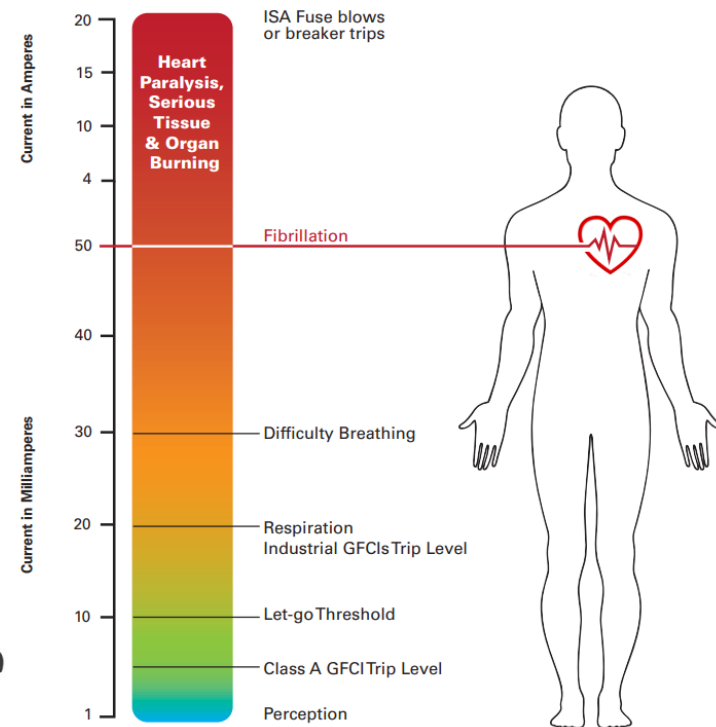
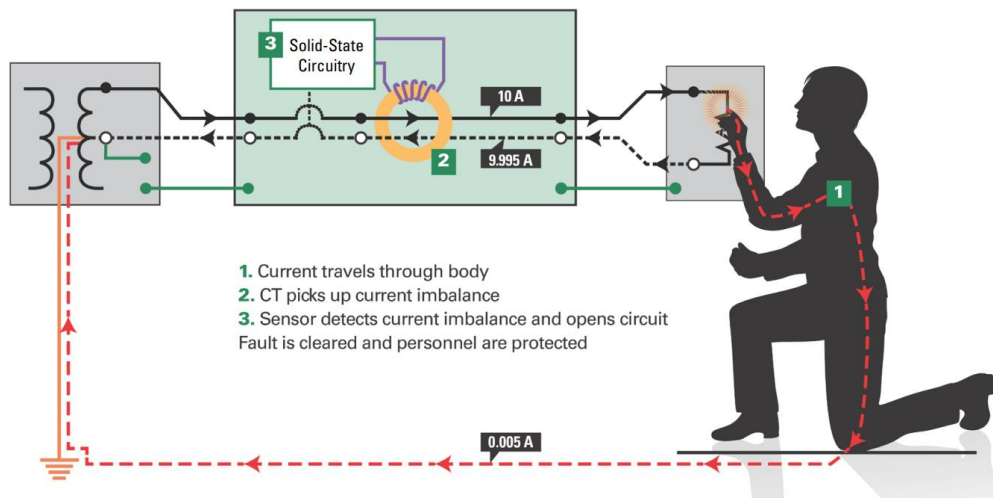
	Technology	Product series
7	High-speed fuse	PSX, PSR
	SPD (DC link)	SPD type 2
8	High-speed fuse	PSX, PSR
	Ground fault relay	SE-601
9	IGBT module	MIXA, MIXG
	Fuse	Class J, Class RK5, Class L
	SPD (AC link)	SPD type 2



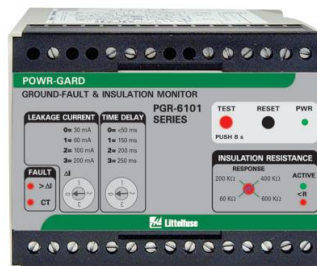
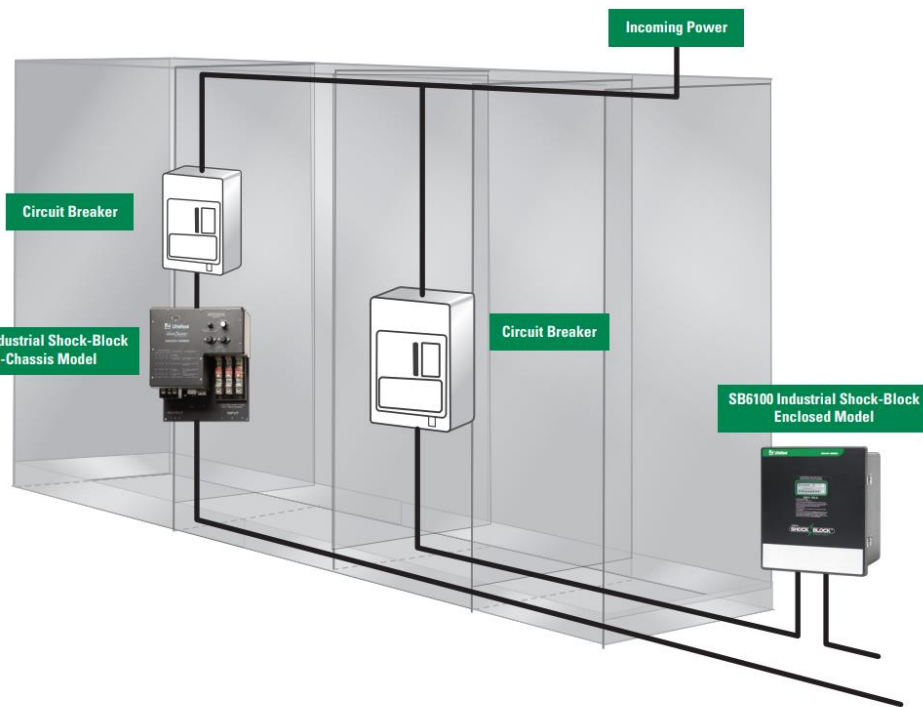
Ground Fault Relays

GFCI is the Answer There is one device that will prevent death or injury from electric shock: Ground-Fault Circuit-Interrupters (GFCI). GFCI actually detects if current — even just a little bit of current — is flowing where it should not and shuts off the power. Touching a live conductor that is protected by a GFCI will still cause a shock, but the GFCI will open the circuit before it becomes lethal.

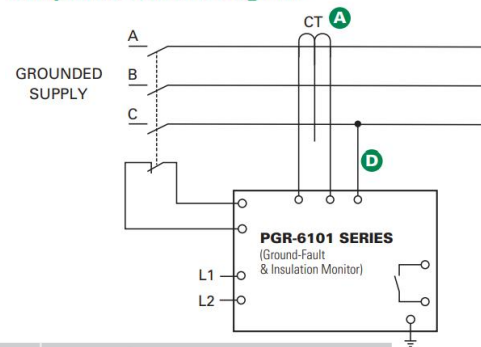
Operation of a single-phase GFCI.



Typical installation of industrial GFCIs



Simplified Circuit Diagram



FEATURES	BENEFITS
Adjustable GF pickup (30-200 mA)	Trip setting provides a wide range of low-level protection and system coordination
Adjustable insulation pickup (60-600 kΩ)	Customizable insulation resistance setpoints for maximum protection
Adjustable time delay (50-250 ms)	Adjustable trip delay for quick protection and system coordination
Output contacts	Two Form C output contacts for ground fault and insulation-resistance fault
Analog outputs (0-1 mA)	Two analog outputs indicate insulation resistance and ground-fault current
CT-Loop monitoring	Alarms when CT is not connected
Selectable contact operating mode	Selectable fail-safe or non-fail-safe operating modes allows connection to shunt or undervoltage breaker coil

DC Disconnect Switch

Dc Disconnect Switch

LS6R0400 1500 V DC SERIES

1500 V dc • 400 A • 1 Pole
1500 V dc • 400 A • 2 Pole (750 V dc per pole)



2 Pole (Type CB)
Dc Ungrounded

1 Pole (Type 4D)
Dc Grounded with handle attached



Description

Specifications

UL 98B Standards

Total Voltage Rating

1500 V dc

Amperage Rating

400 A

SCCR Rating

10 kA

Ambient Temperature

-20 to 50 °C (-4 to 122 °F)

IEC 60947-3 Standards

Insulation Voltage Rating Ui

1500 V dc

Impulse Withstand Voltage

12 kV

Rating Uimp

12 kV

Operational Current DC21B

400 A / 1500 V dc

Rating

400 A / 1500 V dc

REACH ENE CE IEC UL RoHS

Dc Disconnect Switch

LS60400 1000 V DC SERIES

1000 V dc • 400 A • 1 Pole
1000 V dc • 400 A • 2 Pole (500 V dc per pole)



2 Pole (Type 2E)
Dc Ungrounded

1 Pole (Type 1M)
Dc Grounded with Handle Attached



Description

Specifications

UL 98B Standards

Total Voltage Rating

1000 V dc

Amperage Rating

400 A

SCCR Rating

10 kA

Ambient Temperature

-20 to 50 °C (-4 to 122 °F)

IEC 60947-3 Standards

Insulation Voltage Rating Ui

1500 V dc

Impulse Withstand Voltage

12 kV

Rating Uimp

12 kV

Operational Current DC21B

400 A/1000 V dc

Rating

400 A/1000 V dc

Other Characteristics

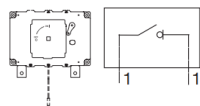
2 Pole (2E): 18.4 watts/pole

Power Losses at 400 A

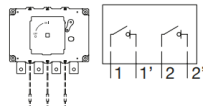
1 Pole (1M): 36.11 watts total

REACH ENE CE IEC UL RoHS

Configuration



Type 1M (1 Pole)



Type 2E (2 Pole)

Littelfuse Part Number	Rated Insulation Voltage Ui (V Dc)	Amperage	Number of Poles	Configuration Type	Grounded or Ungrounded	ABB Part Number
LS602501MS00L	1000 V dc	250 A	1P	1M	Grounded	OTDC250UFS02 OTDC250UFS11
LS602502ES00L	1000 V dc	250 A	2P	2E	Ungrounded	OTDC250UF02 OTDC250UF11
LS604001MS00L	1000 V dc	400 A	1P	1M	Grounded	OTDC320UFS02 OTDC400UFS02 OTDC320UFS11 OTDC400UFS11
LS604002ES00L	1000 V dc	400 A	2P	2E	Ungrounded	OTDC320UF02 OTDC400UF02 OTDC320UF11 OTDC400UF11
LS6R02504DS00L	1500 V dc	250 A	1P	4D	Grounded	OTDC250UFSV02 OTDC250UFSV11
LS6R0250CBS00L	1500 V dc	250 A	2P	CB	Ungrounded	OTDC250UFV02 OTDC250UFV11
LS6R04004DD00L	1500 V dc	400 A	1P	4D	Grounded	OTDC320UFSV02 OTDC400UFSV02 OTDC320UFSV11 OTDC400UFSV11
LS6R0400CBD00L	1500 V dc	400 A	2P	CB	Ungrounded	OTDC320UFV02 OTDC400UFV02 OTDC320UFV11 OTDC400UFV11



Expertise Applied | Answers Delivered

High Voltage DC Contactor Relays

150A-250A	Series Name		DCNEV150				DCNEV250											
	Amperage		150A Continuous Carry				250A Continuous Carry											
	Nom. Coil Voltage		12V DC				12-24V DC				48-72V DC				72V DC			
	Voltage Rating		900V DC				900V DC				900V DC				900V DC			
	Mounting Type		Bottom				Bottom				Bottom				Bottom			
	Auxiliary Circuit		Y		N		Y		N		Y		N		Y		N	
	Terminals		P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP	P	NP
Part Number Suffix		-MA	-MAN	-M	-MN	-MA	-MAN	-M	-MN	-GA	-GAN	-G	-GN	-FA	-FAN	-F	-FN	

P = Polarized NP = Non-Polarized

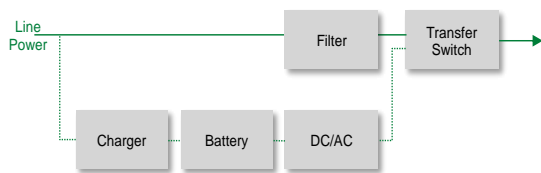


150A-500A	Series Name		DCNEVT150				DCNEVT350				DCNEVT400				DCNEVT500			
	Amperage		150A Continuous Carry				350A Continuous Carry				400A Continuous Carry				500A Continuous Carry			
	Nom. Coil Voltage		12V DC		24V DC		12V DC		24V DC		12V DC		24V DC		12V DC		24V DC	
	Voltage Rating		450V DC		450V DC		1800V DC		1800V DC		1800V DC		1800V DC		1800V DC		1800V DC	
	Mounting Type		Bottom	Side	Bottom	Side	Bottom		Bottom		Bottom		Bottom		Bottom		Bottom	
	Auxiliary Circuit		N	N	N	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
	Terminals		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Part Number Suffix		-B	-BS	-C	-CS	-BA	-B	-CA	-C	-BA	-B	-CA	-C	-BA	-B	-CA	-C	

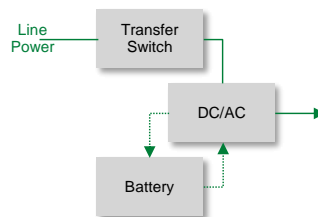
P = Polarized NP = Non-Polarized

Ideal UPS type depends on system priority of key characteristics

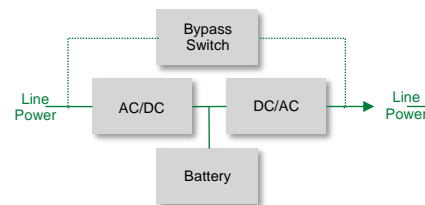
Standby



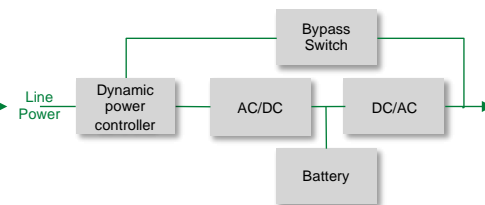
Line interactive



Double conversion on-line



Multi-mode



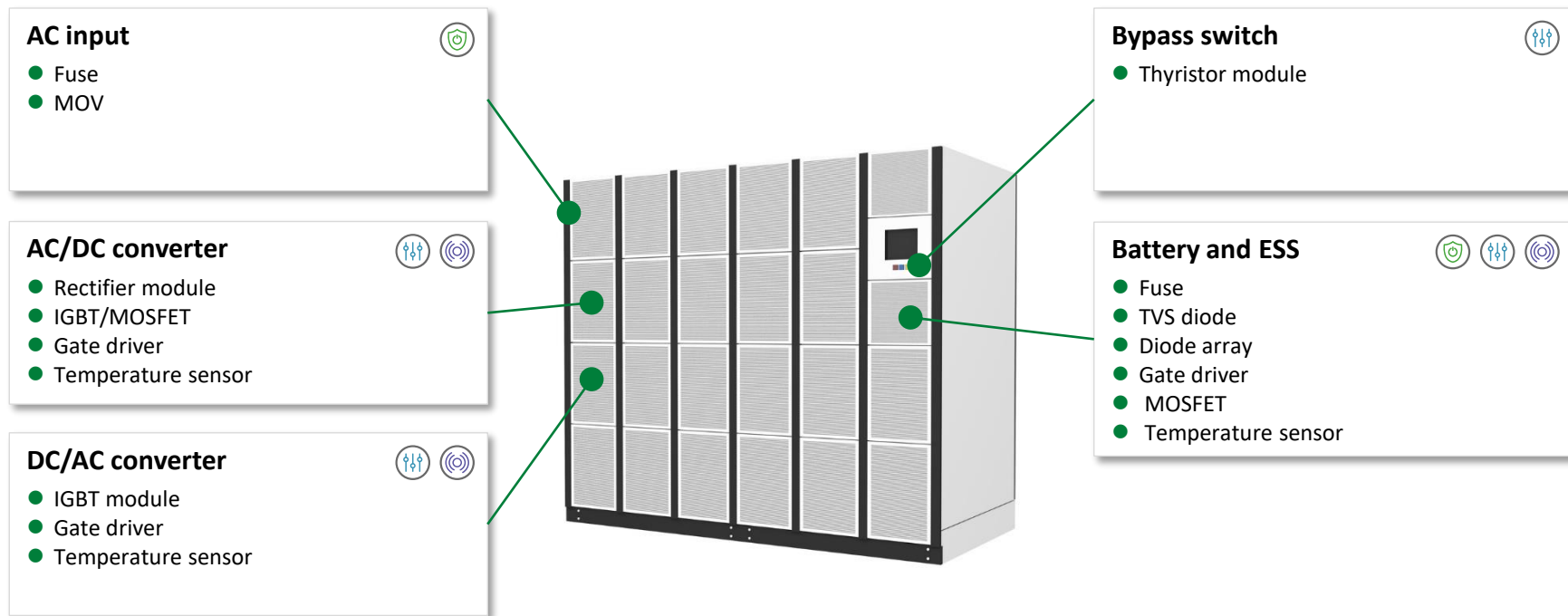
Energy efficiency	Very high
Switching time	High – Switching from line power to battery takes a few electrical cycles
Filtering	Medium
Cost per VA	Low

Very high
Low
High
Medium

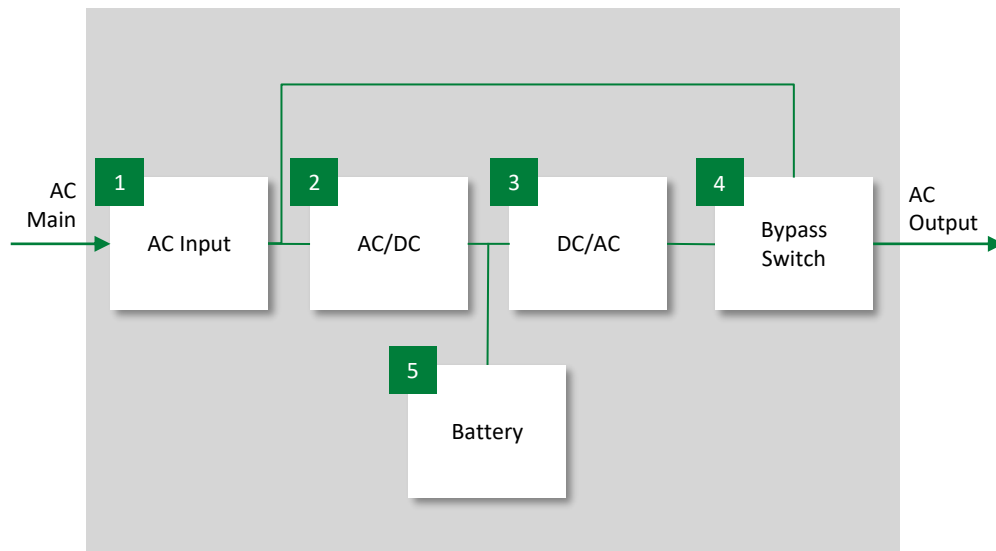
Medium – Power conversion causes some loss
Zero – Power always flows through inverter
Very High
Medium

Medium – Power conversion causes some loss
Zero – Power always flows through inverter
Very High
Medium

Littelfuse solutions for UPS



UPS Block Diagram



Notes:

- I. Double conversion on-line UPS diagram used as representative model. Other topologies will have similar solution needs at common power levels.
- II. Many other fuse options available based on system attributes such as current, voltage, available fault current, surge withstand, and sensitivity of semiconductors.
- III. For faster response, consider P6KE or a combination of a SIDACTor® and an MOV (P3500SCLRP + LA series).
- IV. Rectifier diodes can potentially be substituted with active rectification through IGBT for improved efficiency.
- V. Gate drivers may require an isolator. Contact factory for recommendations.

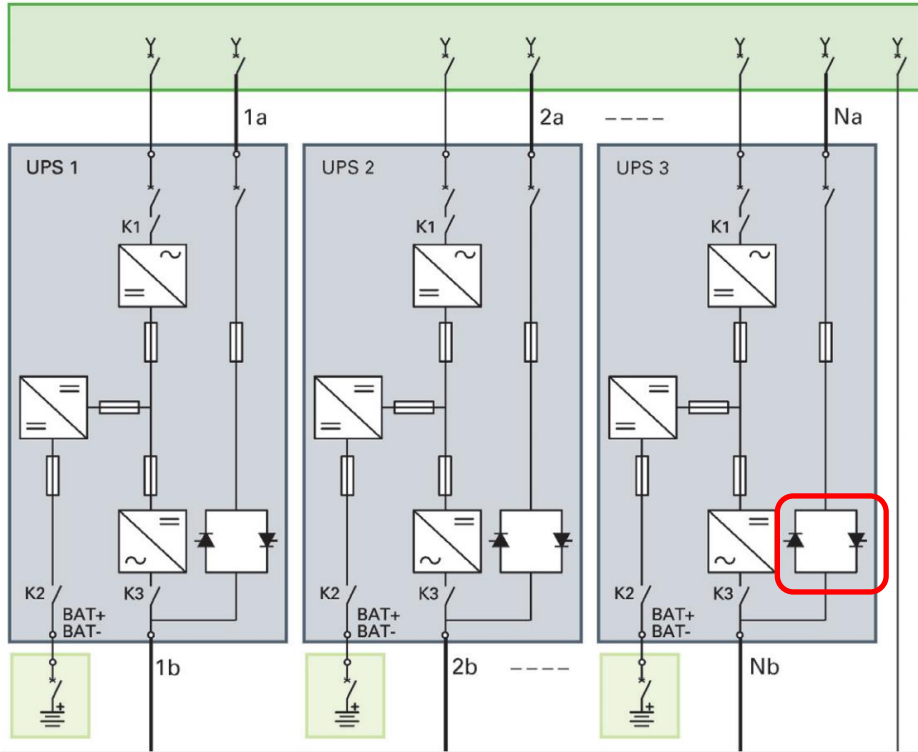
	Technology	Product series
1	Fuse ^{II}	PSR , JLLS , 505
	MOV ^{III}	TMOV
2	Rectifier module ^{IV}	MDD , VUO , MDMA
	IGBT and MOSFET	XPT and Ultra junction X-Class
	Gate driver ^V	IXD_6xx
	Temperature sensor	USP10976
3	IGBT module	MIXA , MIXG
	Gate driver ^V	IXD_6xx
	Temperature sensor	USP10976
4	Thyristor module	MCC , MCMA

Acronyms:

UPS: uninterruptible power supply
MOV: metal oxide varistor

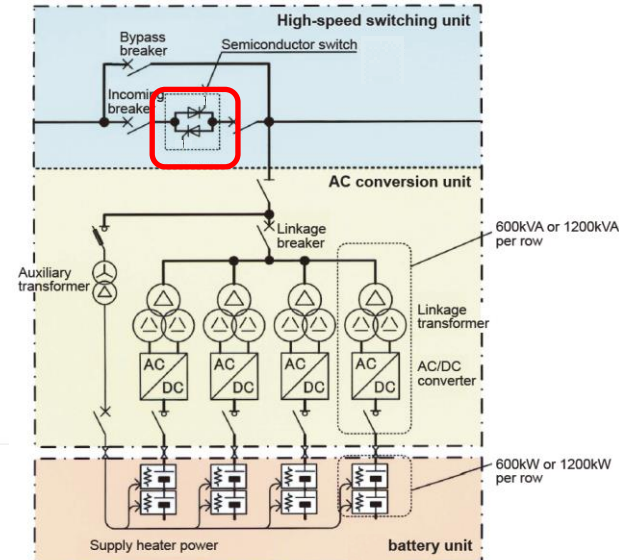
TVS: transient voltage suppressor
SMD: surface mount device

About the STS

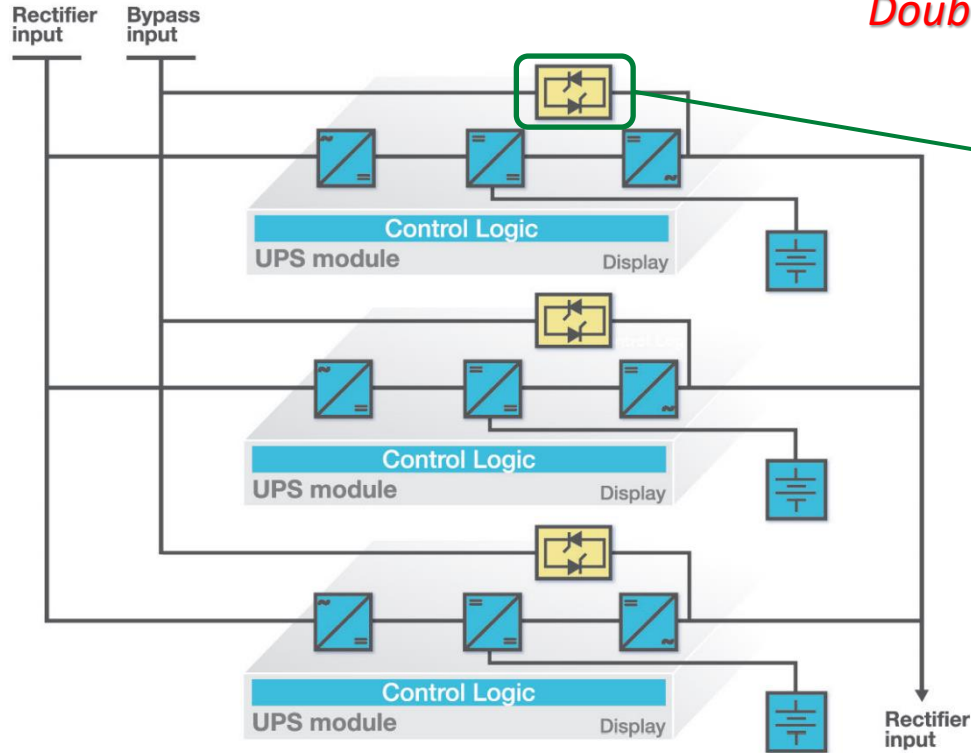


Paralleling provides an excellent solution for matching an organization's growth needs while extending the value of existing UPSs.

Centralized Bypass systems and Distributed Bypass systems to help you determine the suitable solution for your organization. For example, the Distributed Bypass system, with each UPS module having its own **static transfer switch(STS)**.



Thyristor for Power Management



Double side cooling and extremal low $R_{th(jc)}$

IXYS
UK WESTCODE

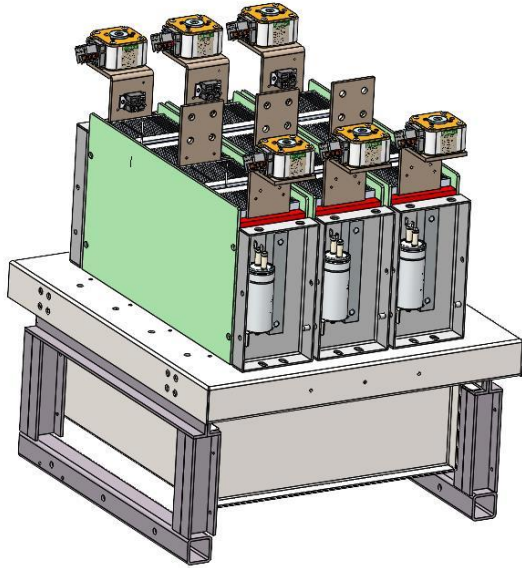
Wespack Phase Control
Types N4472HK160 to N4472HK160

Absolute Maximum Ratings

	VOLTAGE RATINGS	MAXIMUM LIMITS	UNITS
V_{CSM}	Repetitive peak off-state voltage, (note 1)	1800-1800	V
V_{DSM}	Non-repetitive peak off-state voltage, (note 1)	1800-1800	V
V_{RRM}	Repetitive peak reverse voltage, (note 1)	1800-1800	V
V_{RRM}	Non-repetitive peak reverse voltage, (note 1)	1700-1900	V

	OTHER RATINGS	MAXIMUM LIMITS	UNITS
$I_{T(AV)}$	Maximum average on-state current, $T_{amb}=55^{\circ}\text{C}$, (note 2)	4472	A
$I_{T(AV)}$	Maximum average on-state current, $T_{amb}=85^{\circ}\text{C}$, (note 2)	2984	A
$I_{T(AV)}$	Maximum average on-state current, $T_{amb}=85^{\circ}\text{C}$, (note 3)	1600	A
$I_{T(RMS)}$	Nominal RMS on-state current, $T_{amb}=25^{\circ}\text{C}$, (note 2)	8967	A
$I_{T(DC)}$	D.C. on-state current, $T_{amb}=25^{\circ}\text{C}$, (note 4)	7446	A
I_{TSM}	Peak non-repetitive surge $t_p=10\text{ms}$, $V_{an}=60\%V_{DSM}$, (note 5)	59.0	kA
I_{TSM}	Peak non-repetitive surge $t_p=10\text{ms}$, $V_{an}=10\text{V}$, (note 5)	65.0	kA
PI	PI capacity for fusing $t_p=10\text{ms}$, $V_{an}=60\%V_{DSM}$, (note 5)	17.40×10^6	A ² s
PI	PI capacity for fusing $t_p=10\text{ms}$, $V_{an}=10\text{V}$, (note 5)	21.13×10^6	A ² s

Suggested Realization of Three-Phases



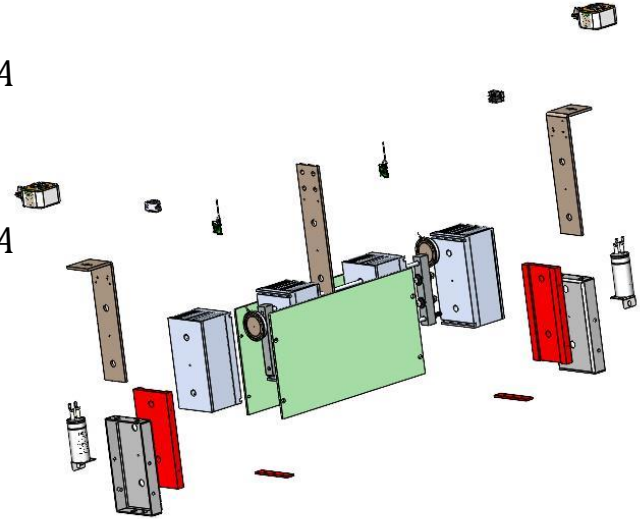
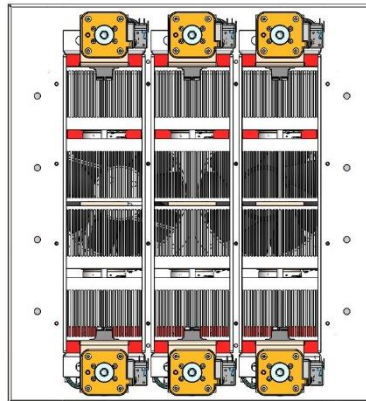
- The proposed device is Littelfuse's **N3904HK220** thyristor.
- Bypass Phase Current (Halfwave Average)

$$\frac{2841 A \sqrt{2}}{\pi} = 1279 A$$

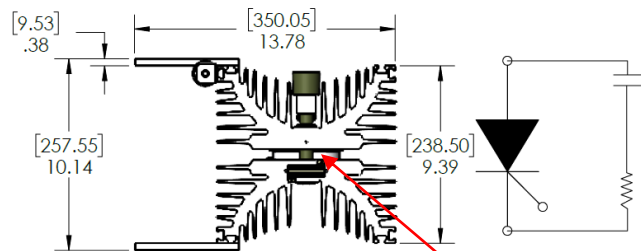
- Bypass Phase Current (Halfwave RMS)

$$\frac{2841 A \sqrt{2}}{2} = 2009 A$$

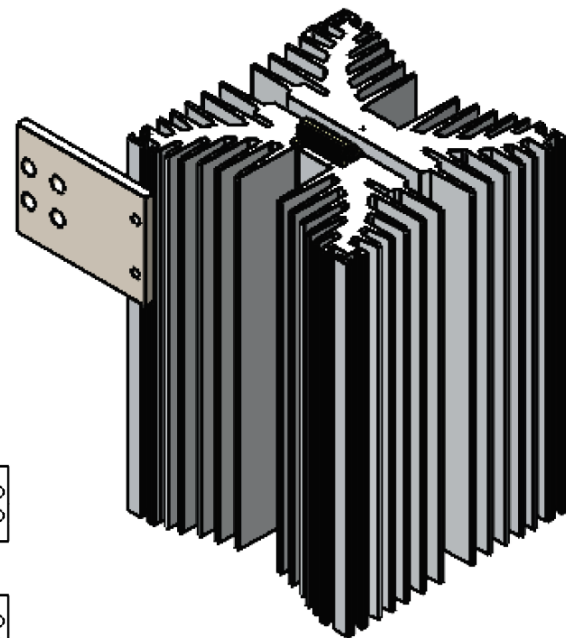
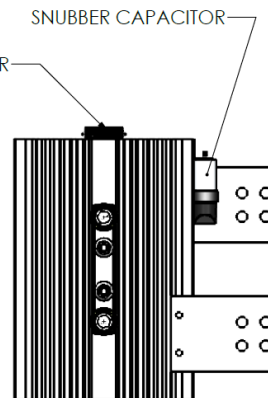
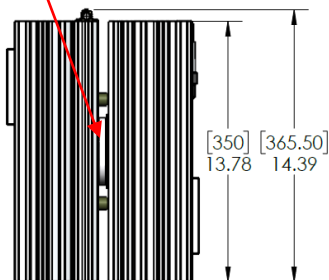
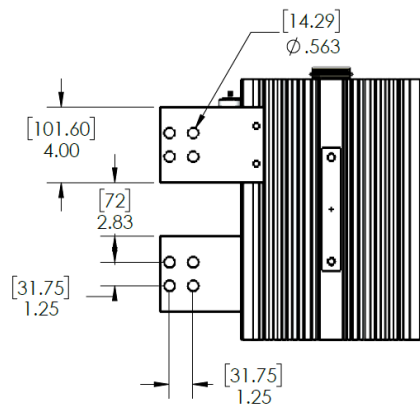
With an ambient temperature of 25 °C.



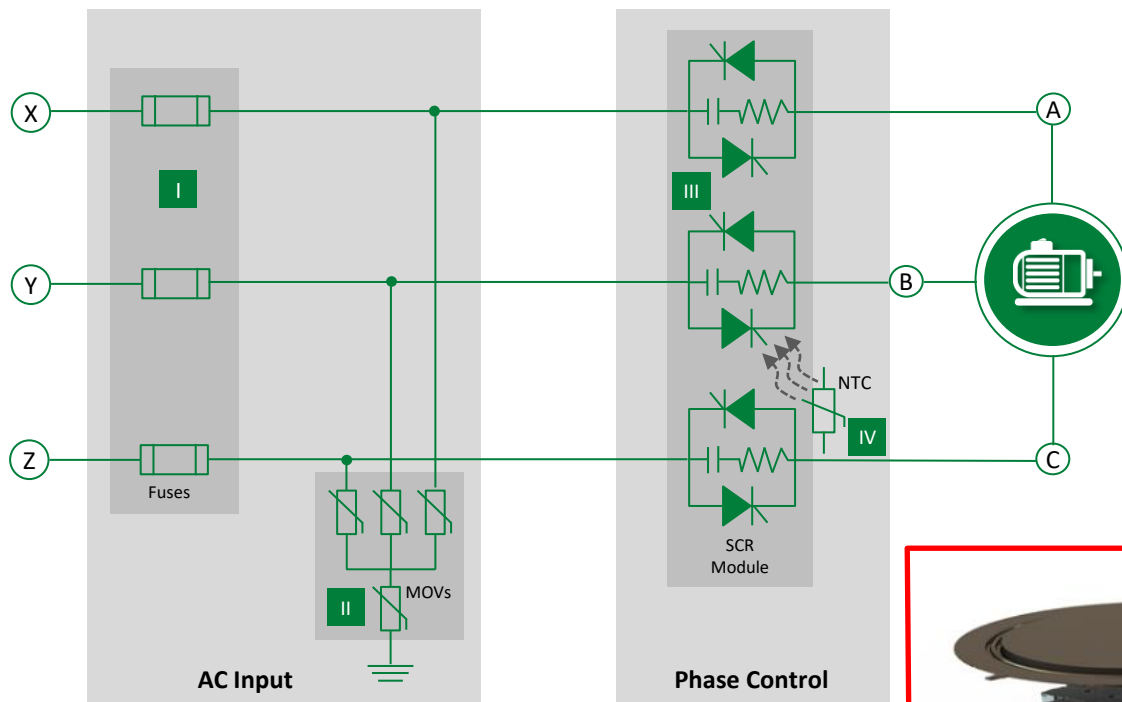
Single SCR for PCS Bypass Circuit



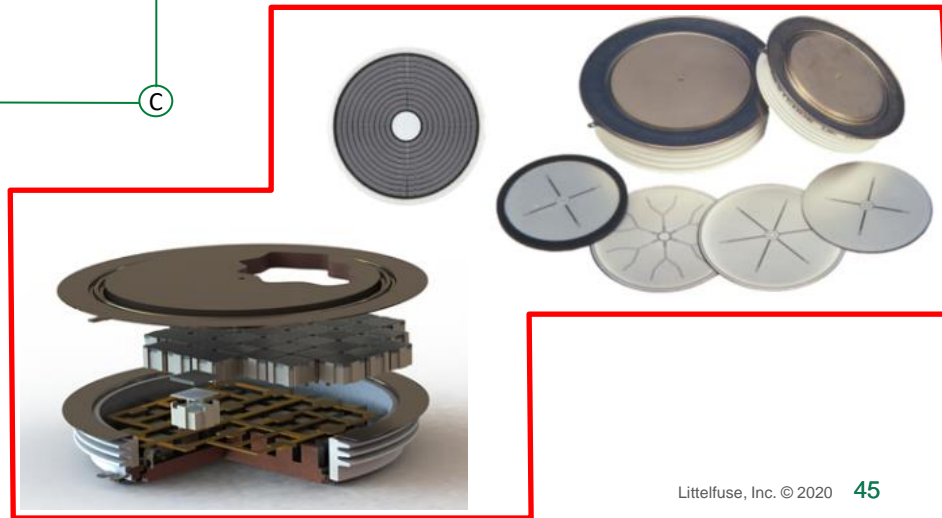
N4472HK180



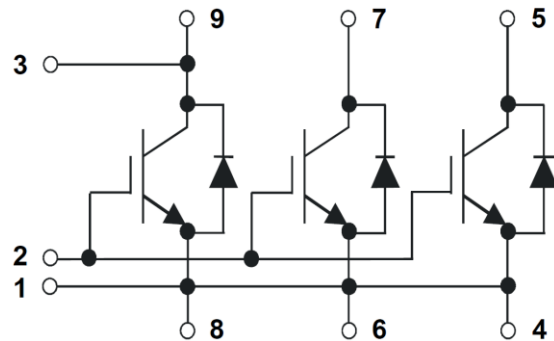
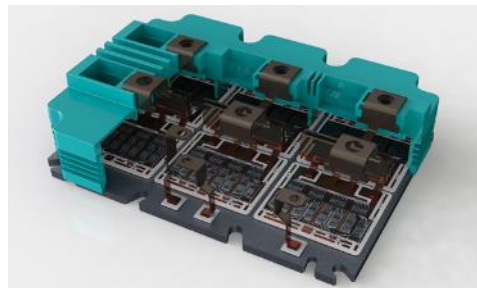
Protection and Phase Control for Soft Start Topology



	Technology	Product Series
I	AC Fuse	L50QS, L70QS, JLS, JLLS
	Fuse Holders	LSCR, LFT, LFI
II	MOV	TMOV
III	Dual SCR Module	MCC
	Discrete SCR	N Capsule series
IV	NTC	USUR1000, SM



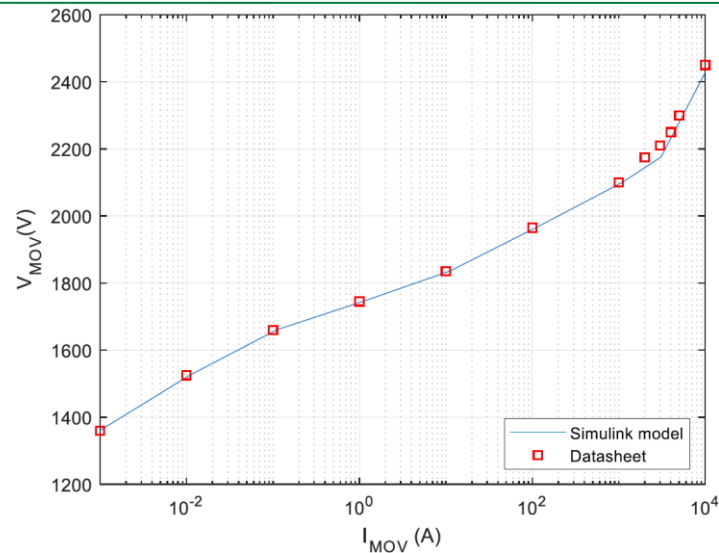
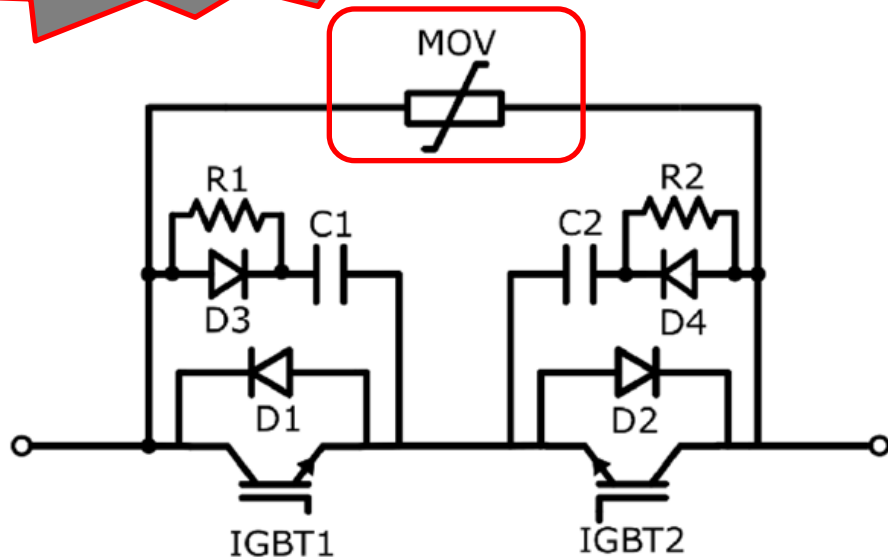
High-Power Rating IGBT module by LF/IXYS (coming soon)



1500A/3300V 140 x 190mm 6.0kV Isolation

How to replace the traditional Contactor Relays?

Frequent switching will lead to high leakage current and damage

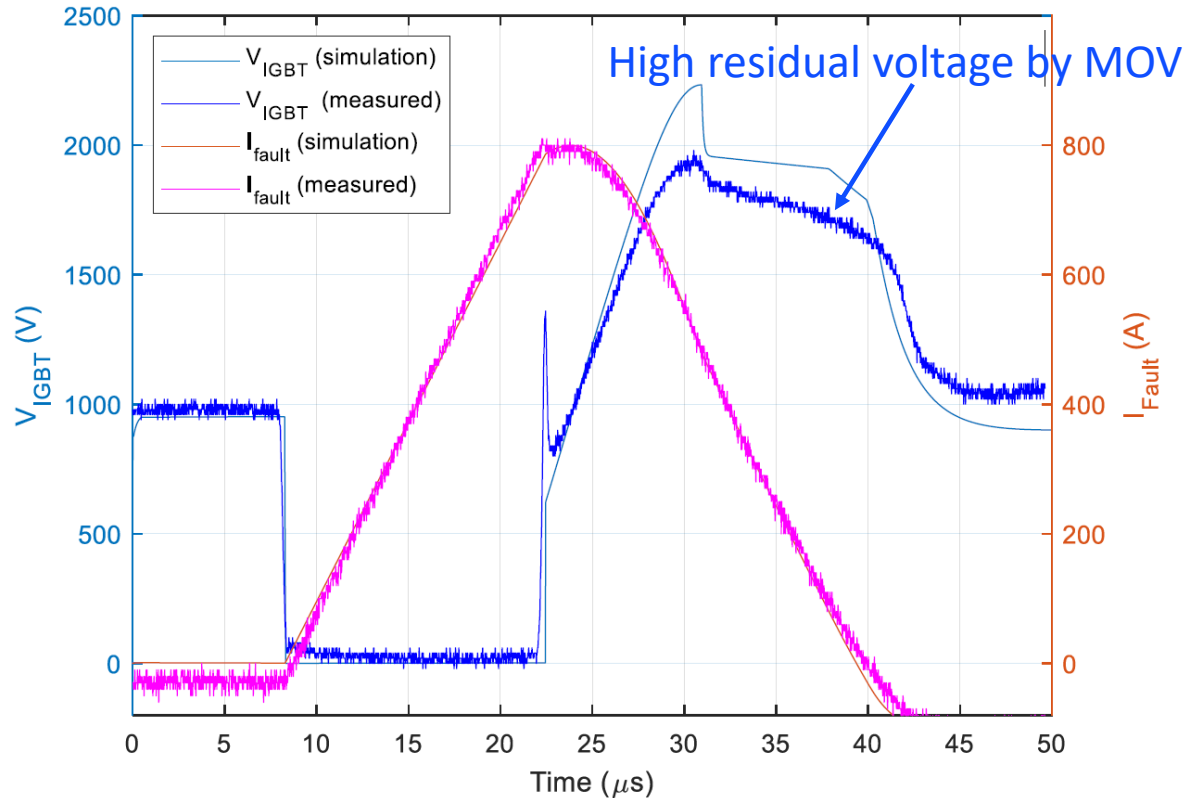


Simulation Conditions

Parameter	Value	Description
V_{DC}	1.1 kV	Bus voltage
L_{MOV}	400 nH	MOV branch stray inductance
L	$\sim 17\mu H$	Line inductance
$C1, C2$	3 μF	Snubber capacitance
$R1, R2$	10 Ω	Snubber resistance
I_{ScRef}	1 kA	Short-circuit current reference

Fault aperture of the SSCB vs. Simulation

Solid-State Circuit Breakers(SSBC)



For SSBC benefits:

- Fast (50 μs vs. 5ms)
- High reliability, no need to replace regularly
- Accuracy
- Expanding possibilities
- Modular possibilities

Discrete Solution to replace the DC Contactor Relays

MOSFET (Discrete)	V _{DSS} (V)	R _{DS(ON)} ,max @ 25 °C (Ohm)	I _{D, cont} @ 25 °C (A)	Gate Charge (nC)	IDM (A)	R _{thJC} (K/W)	Configuration	Package Type	C _{ISS} (pF)	t _{rr,typ} (ns)	P _D (W)
IXFN170N65X2	650	0.013	170	434	340	0.107	Single	SOT-227	27000	270	1170
IXFN70N100X	1000	0.089	65	350	150	0.104	Single	SOT-227	9150	310	1200

IGBT (Discrete)	V _{CES} (V)	I _C @ 25 °C (A)	V _{CE(sat)} (V)	Gate Charge (nC)	ICM (A)	t _{fi} (ns)	Configuration	Package Type	R _{thJC} [IGBT] (K/W)	I _C @ 90 °C (A)	E _{off} @ 150 °C (mJ)
IXXN340N65B4	650	520	1.7	553	1200	80	Single	SOT-227	0.1	340	2.54
IXYN140N120A4	1200	480	1.7	420	1200	320	Single	SOT-227	0.14	>140	20
IXYN50N170CV1	1700	120	3.7	260	485	44	Co-Pack	SOT-227	0.17	50	8.2



Advance Technical Information

**High Voltage
XPT™ IGBT
w/ Diode**

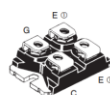
IXYN50N170CV1

V_{CES} = 1700V
I_{C110} = 50A
V_{CE(sat)} ≤ 3.7V
t_{fi}(typ) = 95ns



SOT-227B, miniBLOC
E153432

Symbol	Test Conditions	Maximum Ratings
V _{CES}	T _J = 25°C to 175°C	1700 V
V _{CEM}	T _J = 25°C to 175°C, R _{thJC} = 1mK/W	1700 V
V _{CE(sat)}	Continuous	≤20 V
V _{CE(sat)}	Transient	≤30 V
I _C	T _J = 25°C	120 A
I _{C110}	T _J = 110°C	50 A
I _{C110}	T _J = 110°C	42 A
I _{CE}	T _J = 25°C, 1ms	485 A



G = Gate, C = Collector, E = Emitter
⊕ either emitter terminal can be used as Main or Kelvin Emitter



**1200V XPT™ IGBT
GenX4™**

IXYN140N120A4

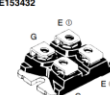
V_{CES} = 1200V
I_{C110} = 140A
V_{CE(sat)} ≤ 1.70V
t_{fi}(typ) = 320ns



Ultra Low-Vsat IGBT for
up to 5kHz Switching

SOT-227B, miniBLOC
E153432

Symbol	Test Conditions	Maximum Ratings
V _{CES}	T _J = 25°C to 175°C	1200 V
V _{CEM}	T _J = 25°C to 175°C, R _{thJC} = 1mK/W	1200 V
V _{CE(sat)}	Continuous	≤20 V
V _{CE(sat)}	Transient	≤30 V
I _C	T _J = 25°C (Chip Capability)	380 A
I _{C110}	Terminal Current Limit	200 A
I _{C110}	T _J = 110°C	140 A
I _{CE}	T _J = 25°C, 1ms	1200 A



G = Gate, C = Collector, E = Emitter
⊕ either emitter terminal can be used as Main or Kelvin Emitter

Why we choose the SOT-227 package type

1. Provide the pretty low thermal resistance and biggest base plant in discrete part.
2. Easy installation: When engineers need to perform maintenance or design verification, that's can be installed without going through the reflow processing.
3. Electrical insulation board: Meet safety requirements and provide th large creepage distance between terminals, so that don't need to consider the arc issue.
4. High current density providing: The lead/pin current can reach to 200A.
5. The terminal can be supporting the copper bus mounting directly.
6. Real Kelvin source connection: Reduce the electromagnetic interference and ground noise issue.
7. RoHS compliant.
8. Industry standard outline.



High Power Protection Thyristor 1KA/3KA/5KA and 10KA

in AC Power L-N (in series with MOV) and RS232/485 outdoor interfaces

LFUS Series	Package	Surge cap /operation current	Application Recommendation	Reverse Standoff Voltage (VR)	Comments
PxxxMTL	TO-218 High Power SIDACtor	10kA 8/20 surge	AC Application	150~480V	Coming soon
PxxxMEL	TO-218 High Power SIDACtor	5kA 8/20 surge	CATV / AC Application	150~480V	Release
PxxxFNL	TO262M High Power SIDACtor	3kA 8/20 Surge	AC Application or ACDC by combing MOV, PoE	64V-380V	Released AECQ qualified
PxxxNNL	TO262M High Power SIDACtor	3kA 8/20 Surge	AC Application or ACDC by combing MOV, PoE	64V-380V	Under Dev
PxxxS3NLRP	DO214AB High Power SIDACtor	2.5kA 8/20 surge	Data port Protection or Low voltage AC	8V~30V	Release
PxxxS3NLRP	DO214AB High Power SIDACtor	2.5kA 8/20 surge	AC Application or ACDC by combing MOV	64~380V	Release

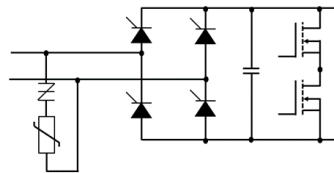
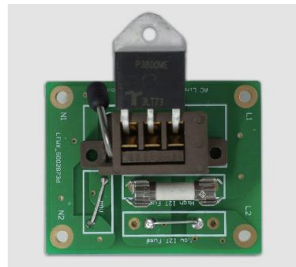
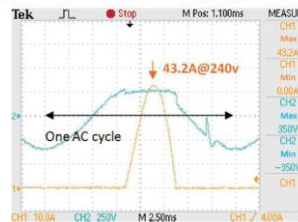
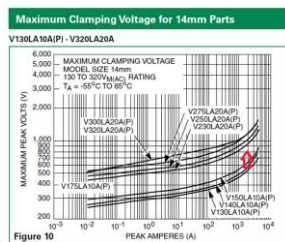


Figure 6: AC current follow on after P2300MEL+V20E130P triggered in 3kA surge (with 240V AC coupling)

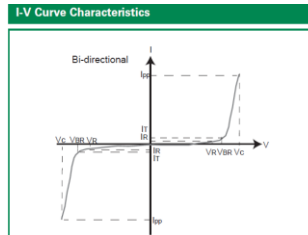


Most Common Overvoltage Suppression Technologies

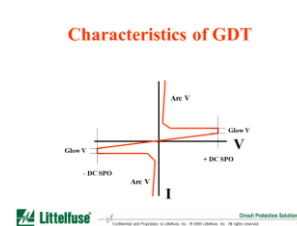
Description	Clamping		Crowbar	
Product Line	<u>MOV</u>	<u>TVS</u>	<u>GDT</u>	SIDACtor® Protection Thyristor
Technology	Ceramic	Silicon	Spark Gap	Silicon
Polarity	Bi-directional only	Uni or Bi-directional	Bi-directional only	Uni or Bi-directional
Let Through Voltage Level	Good	Excellent	Fair	Excellent
Surge Dissipation Level	Highest	Low (With Some Exceptions)	Highest	Medium
Pulse Cycle Capability	Good	Excellent	Good	Excellent
Capacitance	High	Med	Very Low	Low



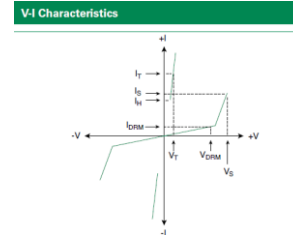
MOV/MLV



TVS Diode



GDT/Arrestor



Protection Thyristor
Littelfuse, Inc. © 2020 52

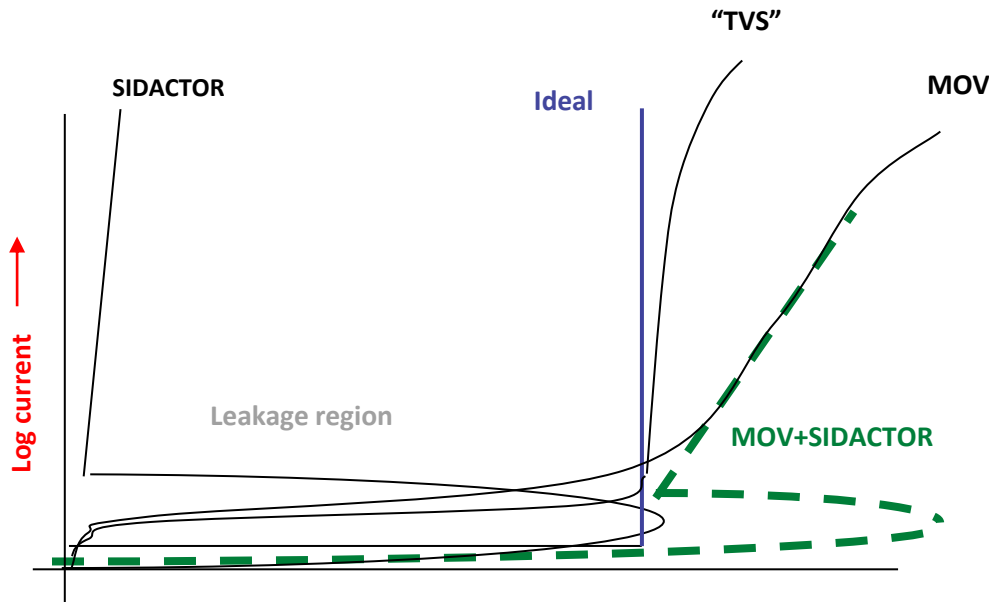
Littelfuse Protection Devices

(Clamping Performance vs. Leakage Level)

So what is the “ideal” device and can we make it?

The “ideal device” would have no leakage current in the normal operating region and clamping voltage is equal or close to VR (standoff voltage)

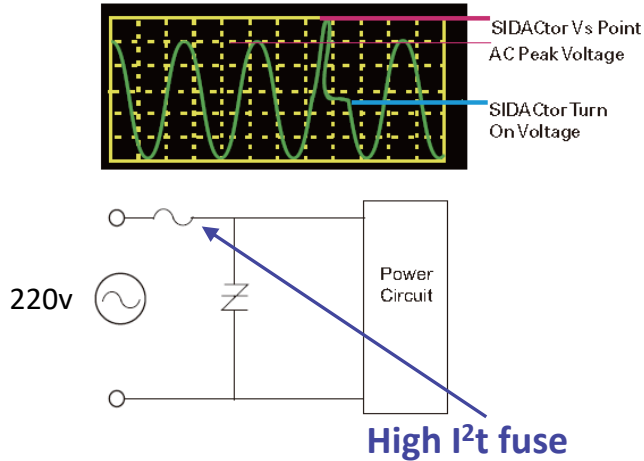
- TVS device has fixed non-dependant leakage
- MOV device has non-linear voltage dependant leakage and clamping voltage $2.5 \times V_R$
- SIDACTOR device is a crowbar solution with low leakage@nA



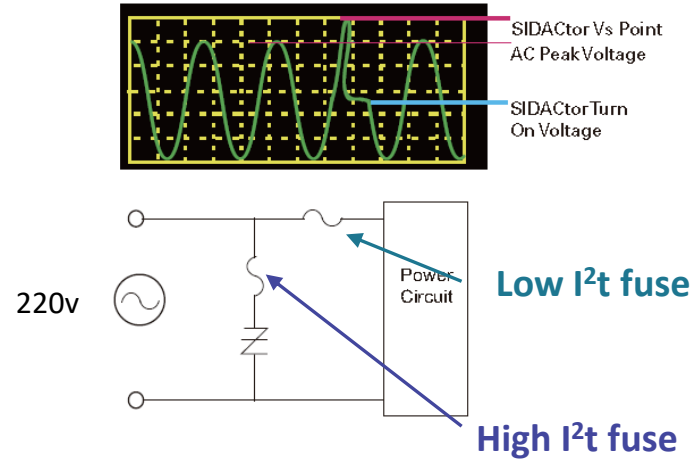
This “SIDACTor + MOV” hybrid solution combines crowbar protection with MOV to offset high clamping voltage of MOV, increase block voltage, and reduce leakage to nano amp (nA) level.

Protect AC Power Lines

Solution A: Single SIDACtor Component Solution



P3800MEL / P3800FNL over current and over voltage crowbar protection for AC power line

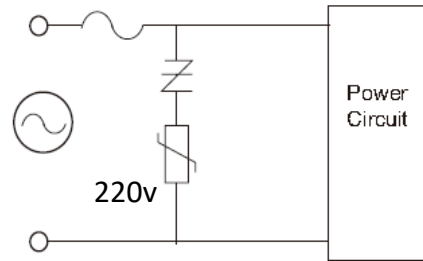
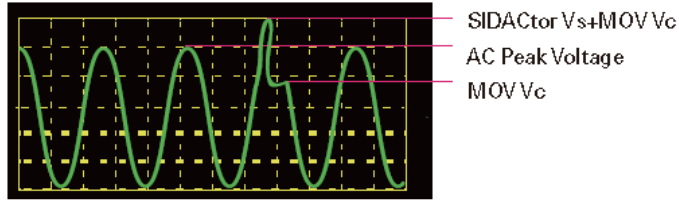


P3800MEL / P3800FNL crowbar protection for AC power line with additional series low I²t fuse for following sensitive circuit

Note: There are different SIDACtor component + fuse topologies and the above are just some examples. Single SIDACtor component application is only available for those AC power source with current limit function.

Protect AC Power Lines

Solution B: SIDACtor Component + MOV In Series



SIDACtor®
Component + MOV

P/N	V _{DRM}
P2300MEL	180 v
V20E130P	170 v

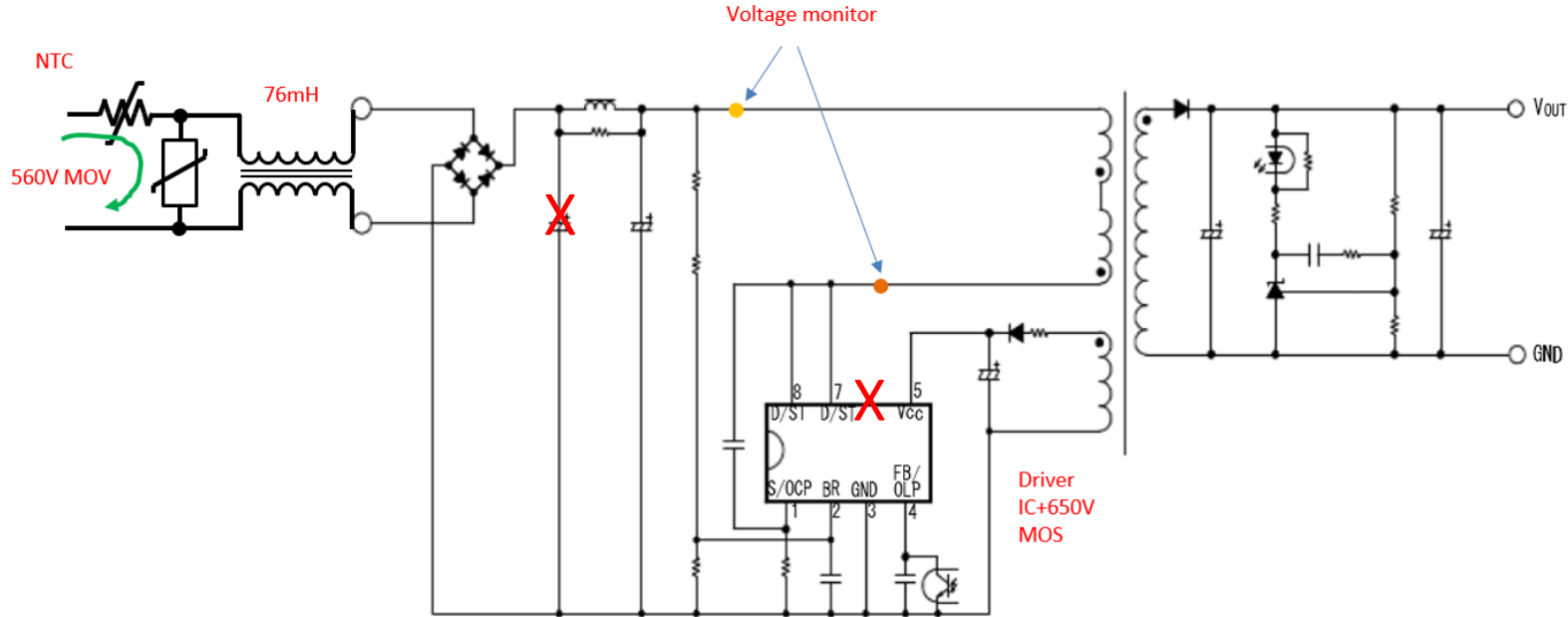
Example:

P2300MEL+V20E130P low clamp protection for AC power line in a 2 kW power system

- SIDACtor P2300MEL+ MOV V20E130P total VDRM is higher than AC peak voltage. (If the power line voltage has high variation, P3500MEL (320 V Vdrm) +V20E250P can be chosen)
- SIDACtor provides a lower overall leakage current (μA range) so that the SIDACtor + MOV combination has a much lower leakage current than the MOV alone solution. And this will enhance the life of the MOV.
- This provides a bit higher clamping voltage compared to standalone SIDACtor solution
- Note: This is just an example to demonstrate how a SIDACtor can work with a MOV. The actual voltage combination depends actual application and line voltage requirements.

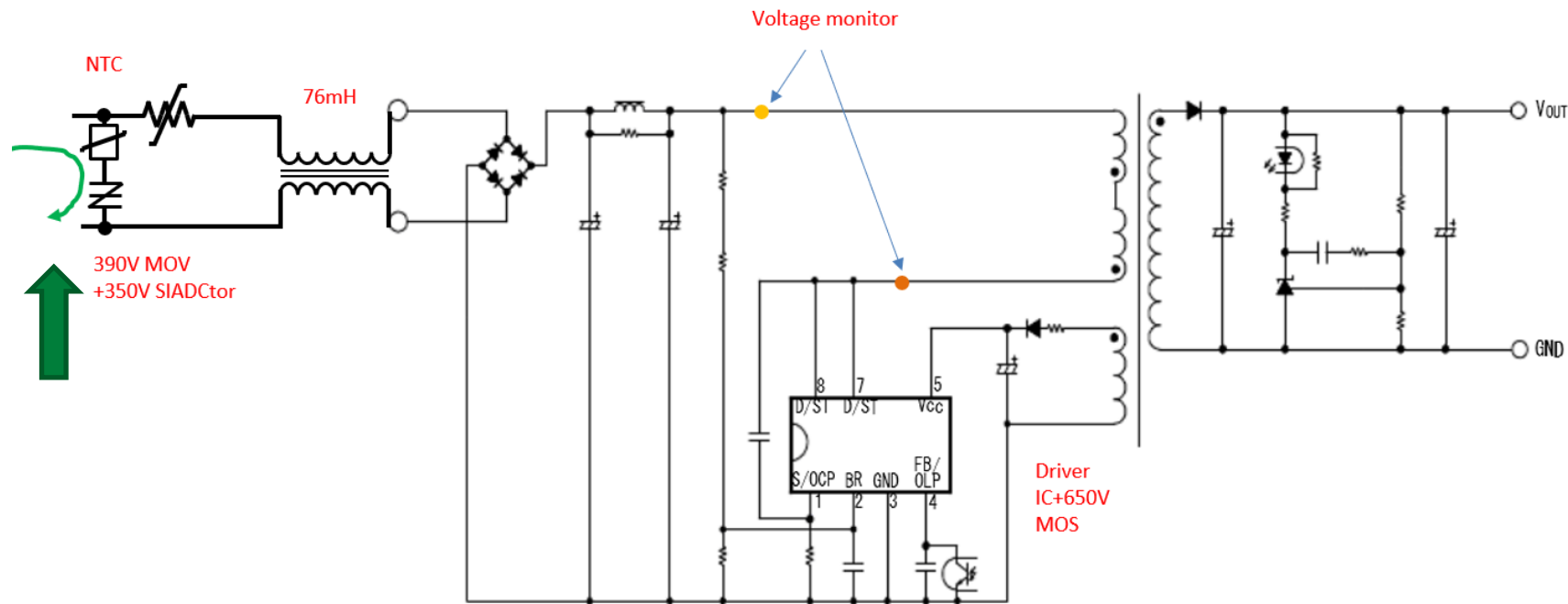
Scenario 1:

Company H 15 W Auxiliary Power



Company H feedback home appliance auxiliary power can be easily damaged in India market, especially with bulk capacitor and switching MOSFET.

15 W Auxiliary Power Circuitry



Littelfuse provides a better solution with AC input low voltage + SIDACTor instead of one high voltage MOV.

15 W Auxiliary Power Resting Results

1.2/50uS	● Clamp voltage at Bulk Capacitor (500 mS decay) <450 V		● MOSFET VDS <650 V	
	560 V MOV	V20E250P+P3500FNL	560 V MOV	V20E250P+P3500FNL
1 kV	420 V	395 V	530.4 V	497.3 V
2 kV	440 V	395 V	554.5 V	495.1 V
3 kV	445 V	405 V	566.2 V	519.2 V
4 kV	450 V	430 V	571.8 V	537.8 V
5 kV		440 V		541.1 V
6 kV	490 V	430 V	656.2 V	536.6 V

Based on the test, we can conclude:

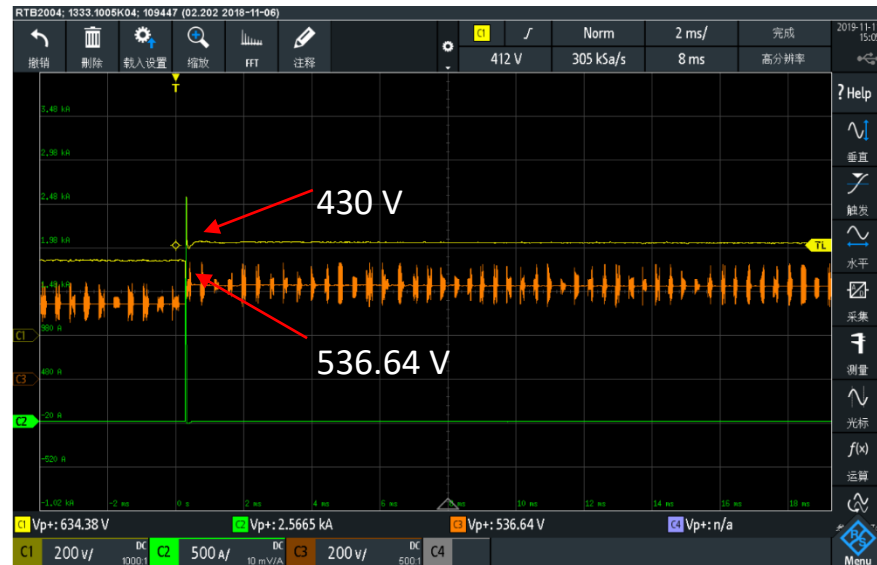
- With single high voltage MOV, both capacitor and MOSFET input point clamp voltage is higher than SIDACTor + low voltage MOV's.
- Capacitor and MOSFET lifetime should extend with SIDACTor + MOV applied.

15 W Auxiliary Power Test Waveform

6 kV 1.2/50 μ s 561 K MOV

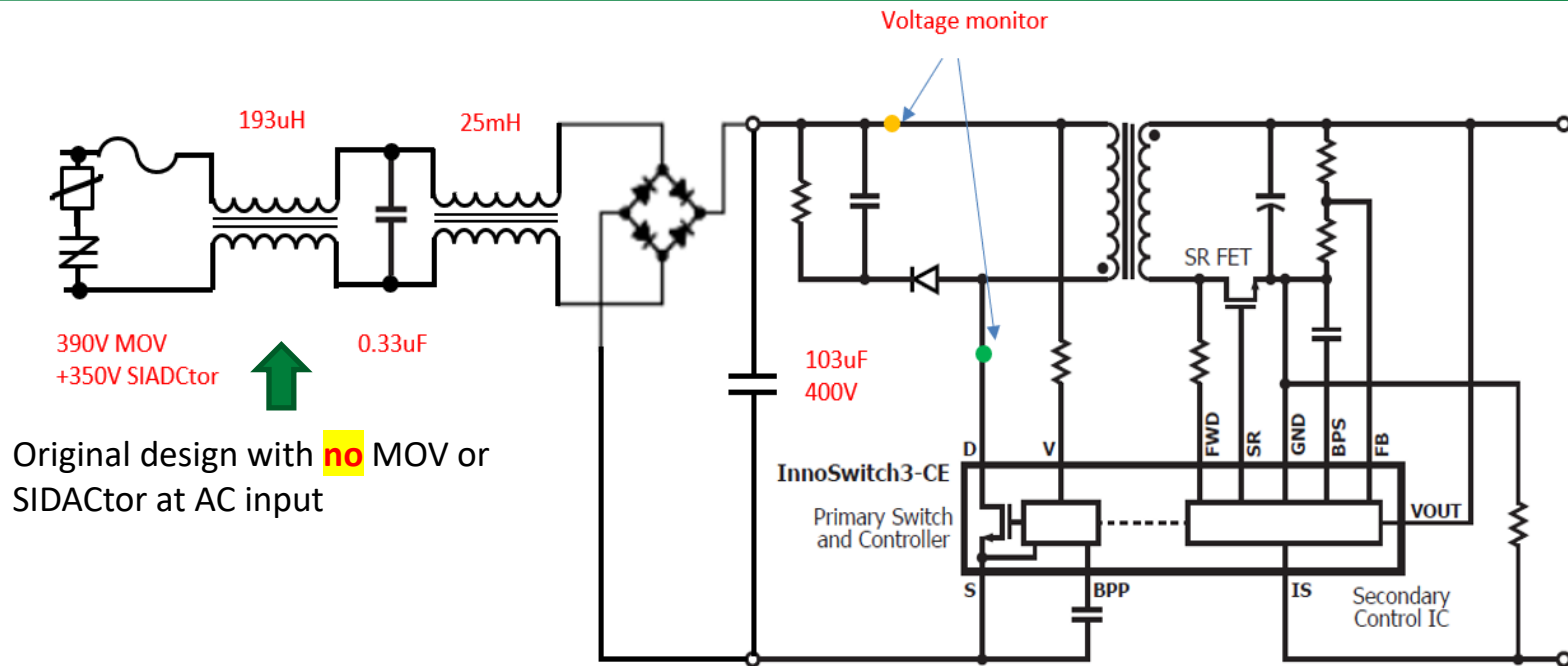


6 kV 1.2/50 μ s V20E250P+P3500FNL



Scenario 2:

Company R – 61 W GaN Power Type-C PD Charger



Circuit is for reference, we focus to common mode inductor, capacitor, transformer, and 650 V GaN MOSFET in the lines.

61 W GaN Type-C Charger Test Results

1.2/5 0uS	Inrush voltage at Bulk Capacitor (~20 uS)		Clamp voltage at Bulk Capacitor (●) (~10 S decay) <450 V		MOSFET VDS <650 V (●)	
	No MOV	V20E250P+P3 500FNL	No MOV	V20E250P+P3500FNL	No MOV	V20E250P+P3500 FNL
2 kV	780.52 V	572.17 V	460 V	440 V	682.86 V	516.97 V
3 kV	896.18 V	598.18 V	470 V	470 V	761.02 V	545.78 V
4 kV	1024 V	629.85 V	520 V	490 V	822.69 V	574.89 V
5 kV	1074.6 V	672.09 V	522 V	510 V	851.56 V	606.14 V
6 kV	1123 V	687.07 V	Voltage Drop	520 V	856.2 V	626.01 V

Based on the test, we can conclude:

- Without MOV group, inrush voltage on capacitor is higher than SIDACTor+low voltage MOV's
- MOSFET input point clamp voltage is well controlled within MOSFET rating with SIDACTor+low voltage MOV's help
- The SMPS without protection group should have reliability issue with high occurrence harmonic voltage/induced surge voltage on AC environment
- Smaller rating SIDACTor component can be placed for lower surge requirement

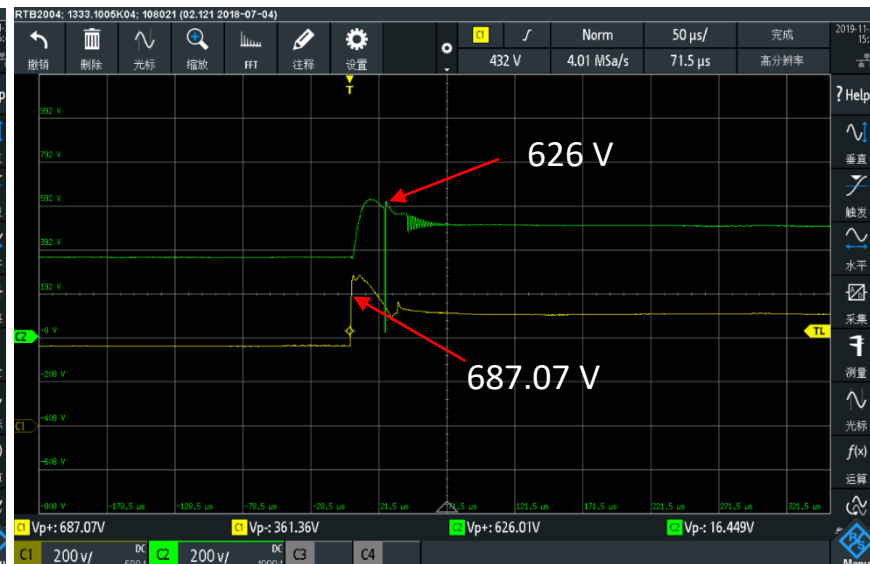
Depending on the applied surge level, the value surge rating of SIDACTor component maybe reduced.

61 W GaN Type-C Charger Test Waveform

5 kV 1.2/50 μ S no MOV



6 kV 1.2/50 μ S V20E250P+P3500FNL



Innovation for Littelfuse Protection Devices

(Clamping Performance vs. Leakage Level)

How about TVS + SIDACTor??

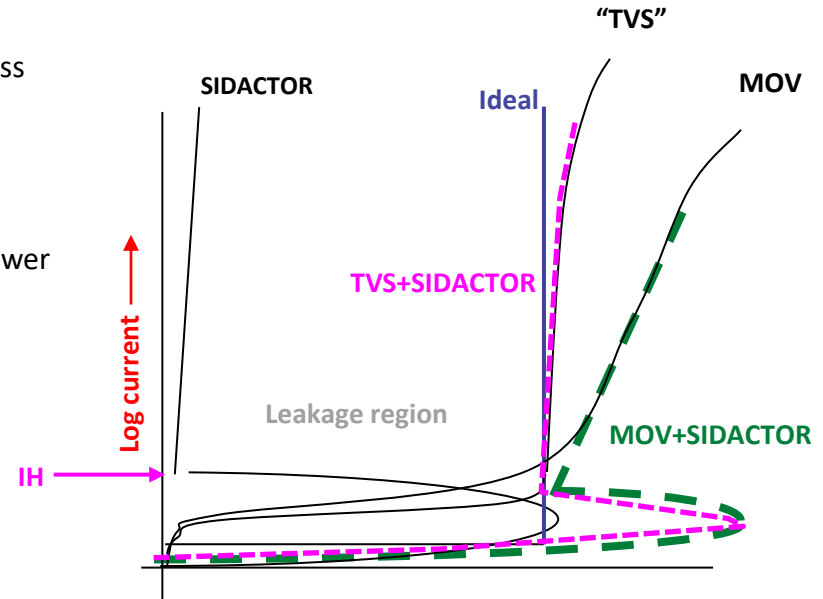
The “ideal device” would have no leakage current in the normal operating region and clamping voltage is equal or close to VR (standoff voltage)

In SIDACTor's technical challenges.....

1. Must withstand the high-energy surges.
2. There needs to be a reset mechanism (the path current needs to be less than the holding current, $I_H \approx 50\text{mA}$).

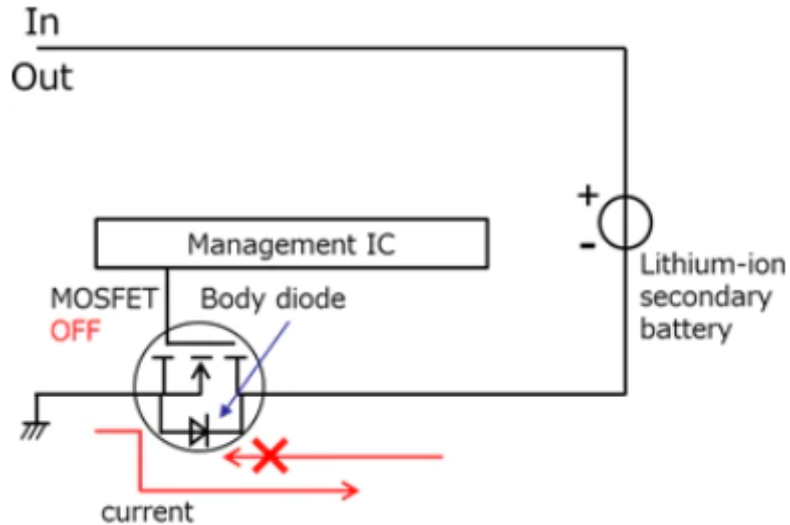
The benefits are:

1. Ultra-low V_{clamp} voltage, around 4 volt.
2. The leakage current(nA) is the semiconductor level when the Bias is lower than the Standoff point.
3. Accurate electrical performance.
4. No wear-out concern.

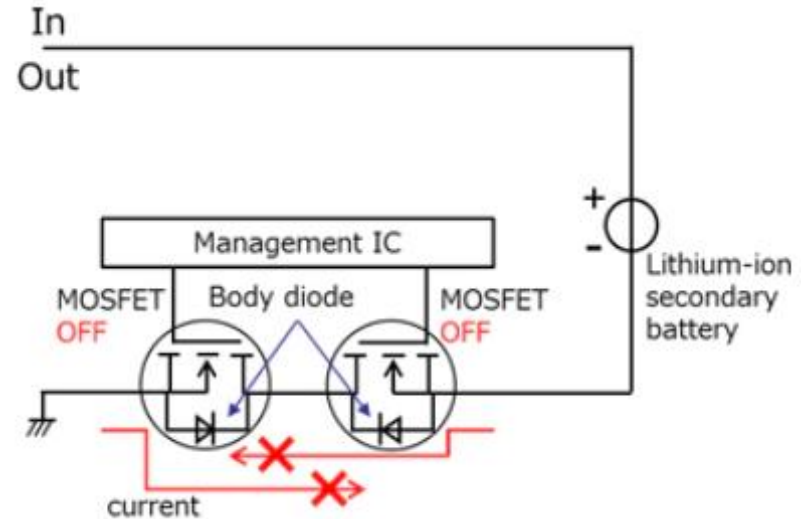


Solid-State Circuit Breakers(SSBC)/ HVDC Breakers

Usually, we call this back-to-back(common source) topology is “**Solid-State Circuit Breakers**” or “**HVDC Breakers**”. The mechanism of using the essential diode of power MOSFET to achieve reverse turn-off



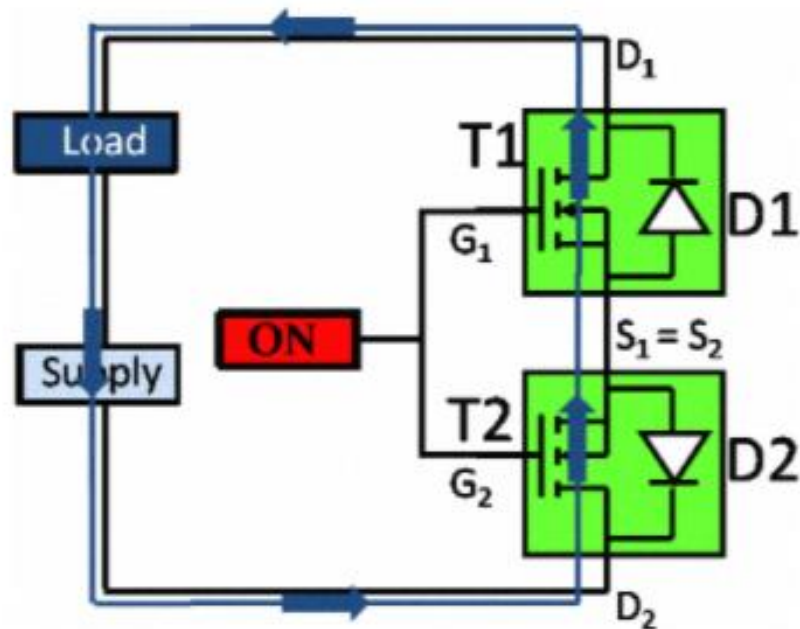
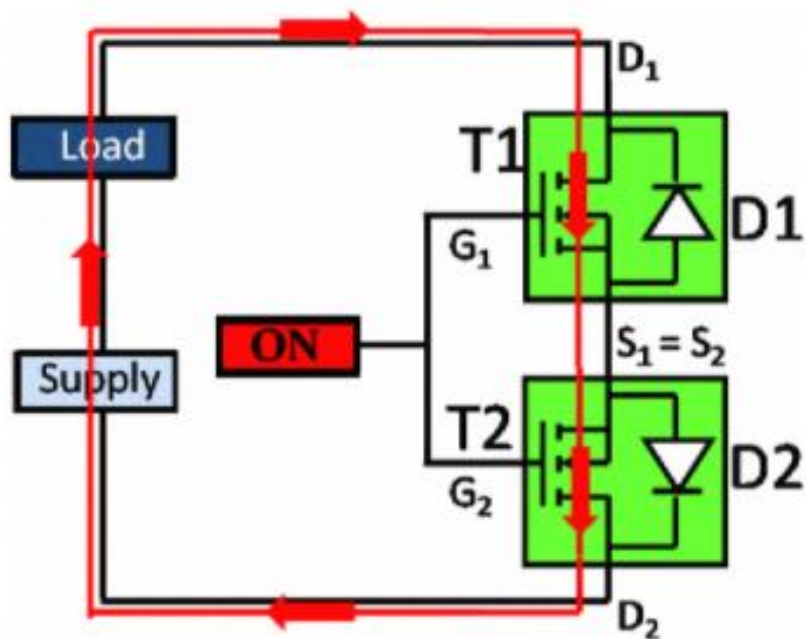
Allow reverse current through by body diode when MOSFET Off.



Blocking when MOSFET Off, like as breaker and provide high-rating.

Working Principle

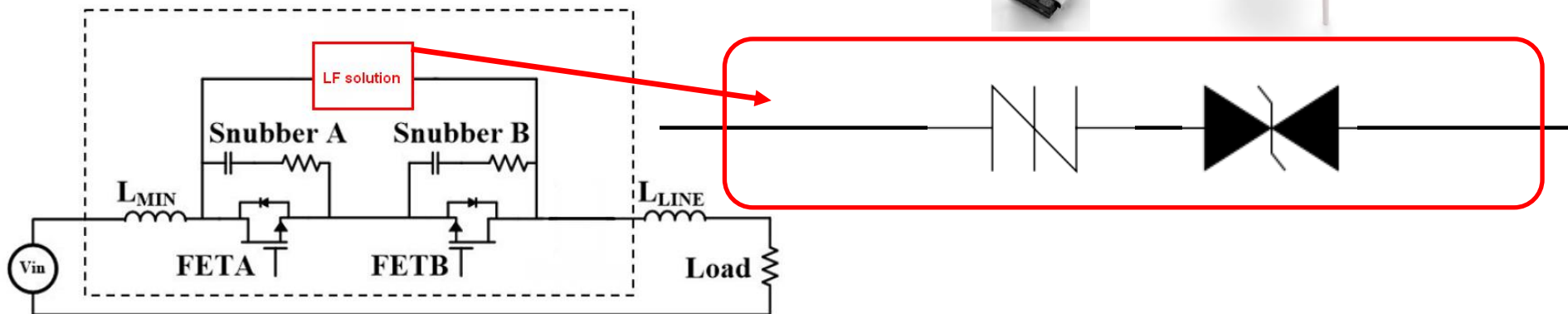
Allow bidirectional current flow on MOSFET turn-on.



For Example:

1. $I_{pp} \approx 3000A$
2. Nominal working voltage is 400V, worst case is 560V
3. The overvoltage should be clamping under 750V
4. Rise time around 2us
5. Bi-directional

LF Solution in Protection



Item	Stand off	VS/ VBR(max)	VT/ Vclamp
(A) P0900S3NLRP-A	75V	98V	4V
(B) AK10-530C-AY	530V	619V	750V

(A) + (B), I_{pp} around **3000A**

- ➔ **SIDACTor** * 1ea + **TVS** * 1ea, action point= 98V + 619V = 717V
- ➔ Stand_off=75+530=605V, Vclamp< 4+750=754V.
- ➔ Without SIDACTor, the Stand_off is 530V, so tht TVS can limit the leakage current to reset SIDACTor(530V>400V>75V).

New Solution for 3300V/1500A IGBT module

Solid-State Circuit Breakers(SSBC)

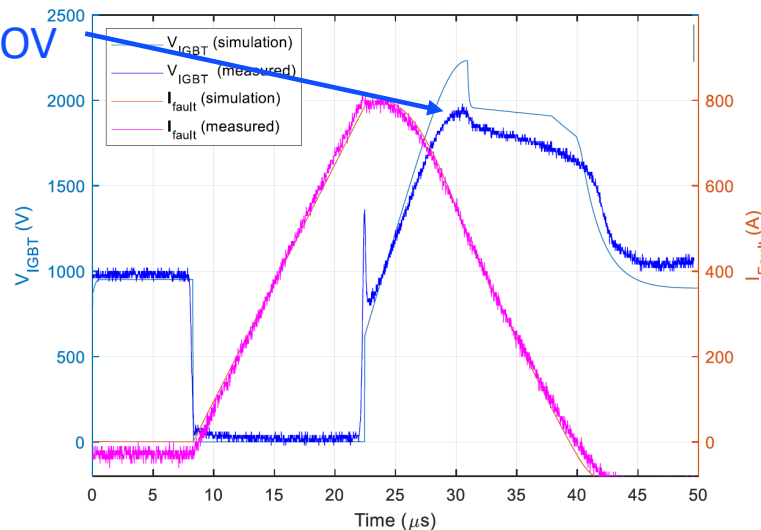
High residual voltage(~2000V) by MOV

New idea on high-power rating SSBC:
P1500MLTL + AK10-530C-Y *2(series), the

1. Max action point: 1418V
2. Max Clamping voltage: **1504V**
3. Stand_Off voltage: 1200V
4. Max Ipp: 10000A

What's benefit for SSBC circuit:

1. **Fixed voltage** protection
2. **Lower residual voltage** provided than MOV
3. **No wear-out** issues
4. **Saving cost** for the IGBT module and **long-life** product when the new design.

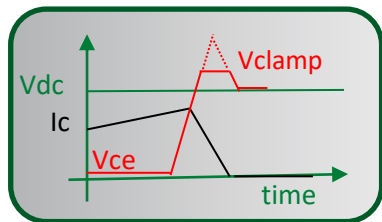


Simulation Conditions

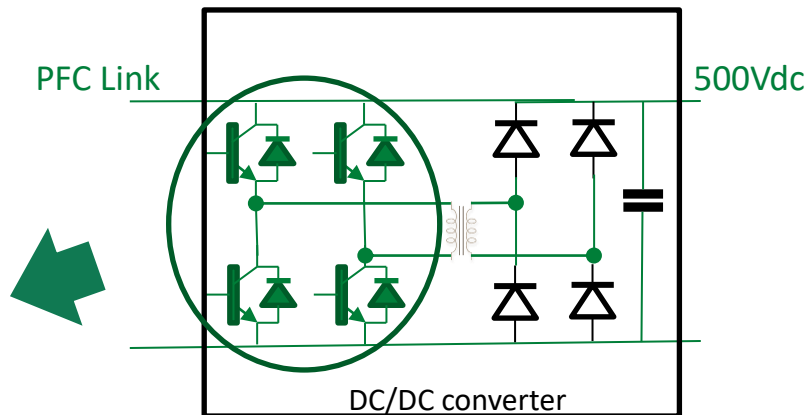
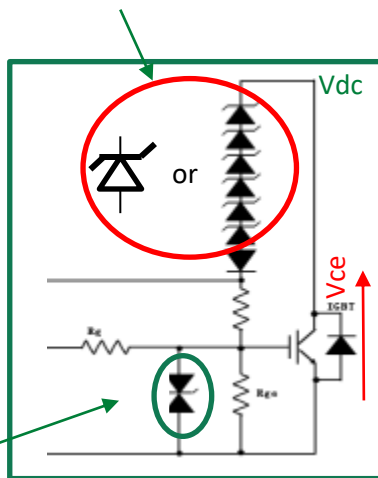
Parameter	Value	Description
V _{DC}	1.1 kV	Bus voltage
L _{MOV}	400 nH	MOV branch stray inductance
L	~17μH	Line inductance
C1, C2	3 μF	Snubber capacitance
R1, R2	10 Ω	Snubber resistance
I _{SCref}	1 kA	Short-circuit current reference

DC/DC Converter Protection – Active Clamping

Single TVS or Stack of TVSs for IGBT
active clamping voltage feature



IGBT/FET Gate
Overvoltage
Protection

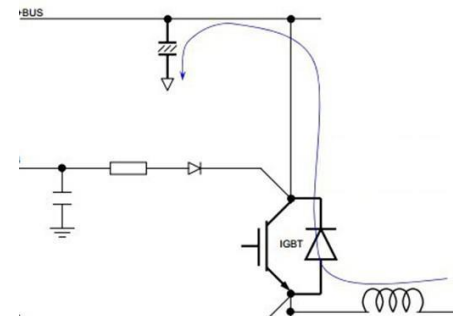


$$V_{CE(peak)} = V_{CE} + L \times di/dt$$

Overvoltage:

TVS: TPSMx Series (AEC-Q101 qualified)

Please contact your Littelfuse sales or FAE for more details.



DC charging station

Service Access Panel

- Reed Sensor

User Interface

- TVS Diode Array
- Polymer ESD Suppressor

Communication

- TVS Diode Array

Rectification & PFC

- SiC/Si MOSFET
- Rectifier Diode/Module
- Gate Driver
- Temperature Sensor

High-frequency Converter

- SiC/Si MOSFET
- Rectifier Diode/Module
- Gate Driver
- Temperature Sensor

Power Distribution Unit

- Fuse

Input Protection

- Fuse
- Surge Protection Device
- TVS Diode

DC Output Protection

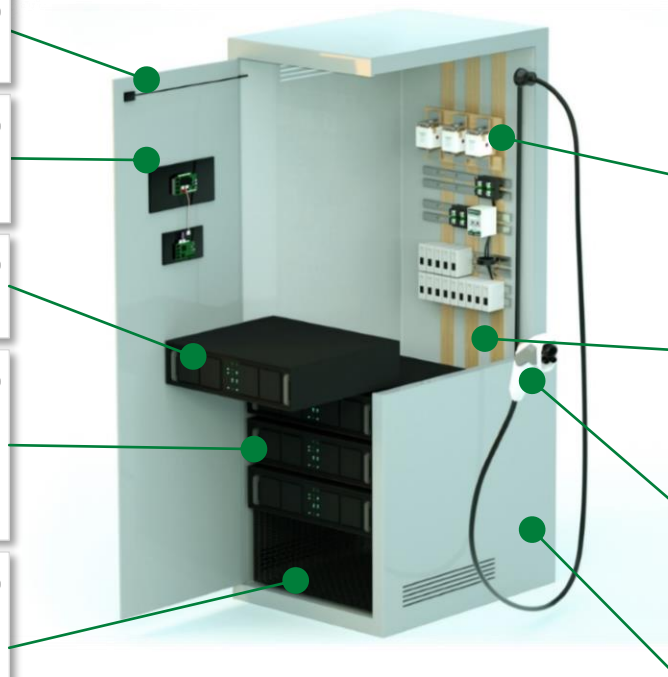
- DC Fuse
- HVDC Contactor
- Earth Fault Relay

Charging Plug

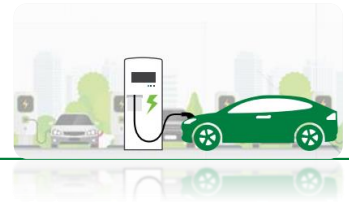
- Temperature Sensor
- Reed Sensor

Auxiliary Power Supply

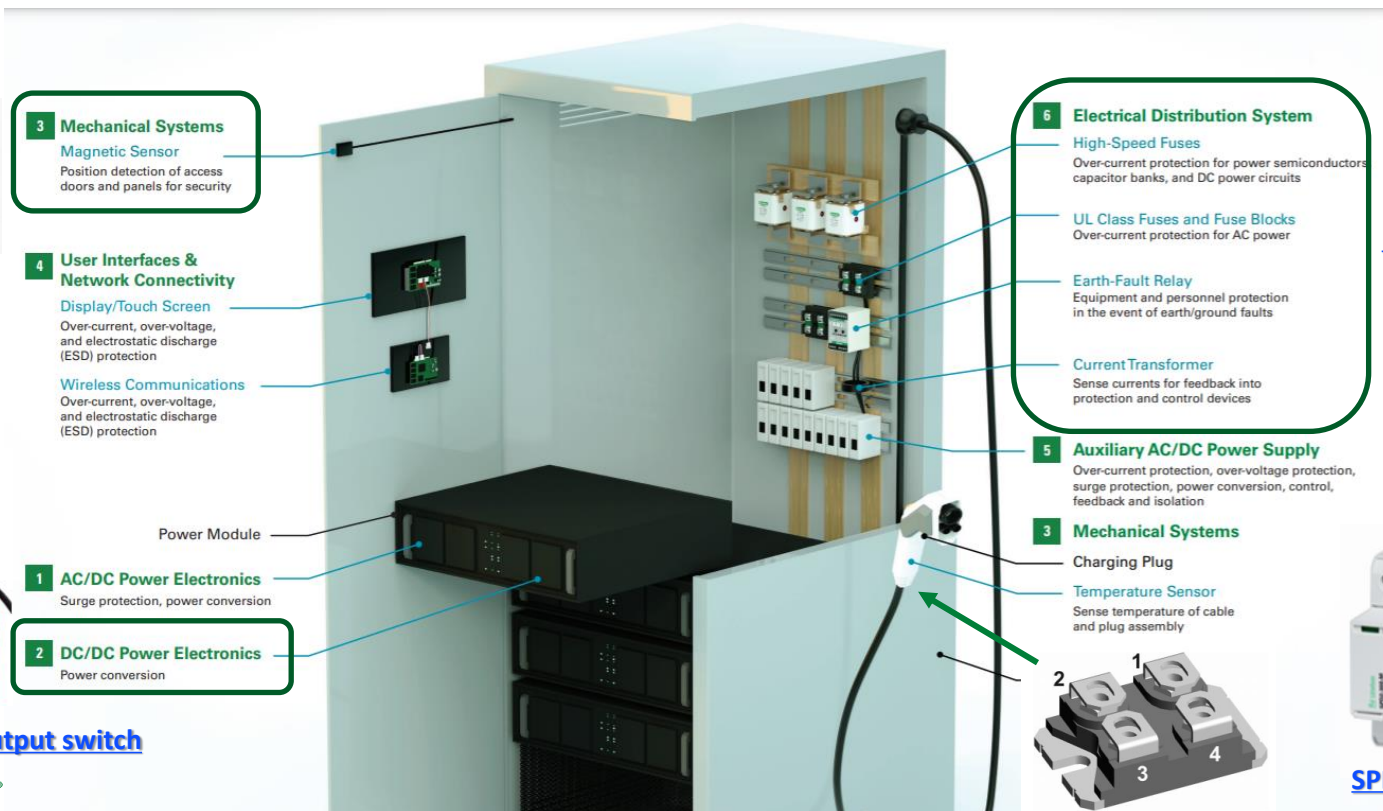
- Fuse
- MOV, GDT
- Si MOSFET
- Rectifier Diode



EV Charger



LF Solution(BOM list) in Taiwan



[59630-1 for Level sensor](#)



[DCNEV250 for DC output switch](#)



Expertise Applied | Answers Delivered



[L75QS, LSC102](#)



[KLKD, L60030M](#)



[SPD2 for AC IN](#)



[DSEI2x101 for ORing Diode](#)

Conclusions

Littelfuse not only provides protective device, but also provides customers with more complete integrated power solutions through power semiconductor, such as MOSFET, IGBT, Thyristor, Gate driver, SiC, Diode, advanced power package type(SMPD), power modules and high-power rating press pack. We are also providing the innovation for Semiconductor Protection Devices play on new application.



■ www.Littelfuse.com

■ www.mouser.com

- EET: <https://www.eettaiwan.com//>
<https://www.eetimes.com/>

- EET Tech Taipei Seminar
<https://site.eettaiwan.com/events/index.html>

Additional information can be found on littelfuse.com

Circuit Protection Selection Guide



Sensor Selection Guide



Power Semiconductor



ESD Protection



Click on each image
to open the catalog

Integrated Circuits Catalog



Small appliances spotlight

