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Sizing fuses to protect BESS power circuit from overcurrents

15 November 2023

8:00 am – 9:00 am | PST, Los Angeles
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Marija Maisch
Editor
pv magazine

Immanuel Umenei
Senior Global Segment Manager, Renewable Energy
Littelfuse, Inc.

Welcome!

Do you have any questions? ❓

Send them in via the Q&A tab. 👉 We aim to answer as many as we can today!

You can also let us know of any tech problems there.

We are recording this webinar today. 📹

We‘ll let you know by email where to find it and the slide deck, so you can re-watch it at your convenience. 👀 💡

Fuses for Battery Energy Storage Systems

Sizing Fuses to Protect the BESS Power Circuit from Overcurrents

November 15, 2023

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Expertise Applied | Answers Delivered

Sizing Fuses to Protect the BESS Power Circuit from Overcurrents

Immanuel Umenei

Senior Global Segment Manager, Renewable Energy

Industrial Business Unit

Littelfuse

Webinar Topics Covered

- Littelfuse Overview
- Energy Storage Market Overview
- Where Circuit Protection is Important in a BESS
- Fuse Coordination
- How to Size Fuses to Protect Against Low-Resistance Short Circuits
  - How to Size Fuses at the Module
  - How to Size Fuses at the Battery Rack, Dc Panel, and Power Conversion System
- Case Studies
- Q&A

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Littelfuse has over 60 million devices installed in power systems across the globe

BESS Overview

Solar Energy

Wind Energy

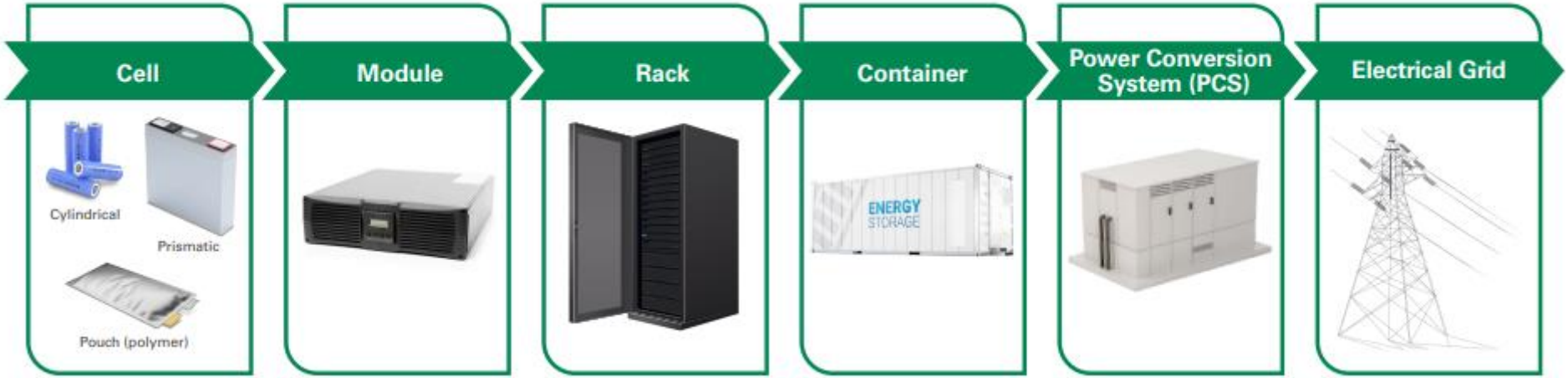
BESS

Residential

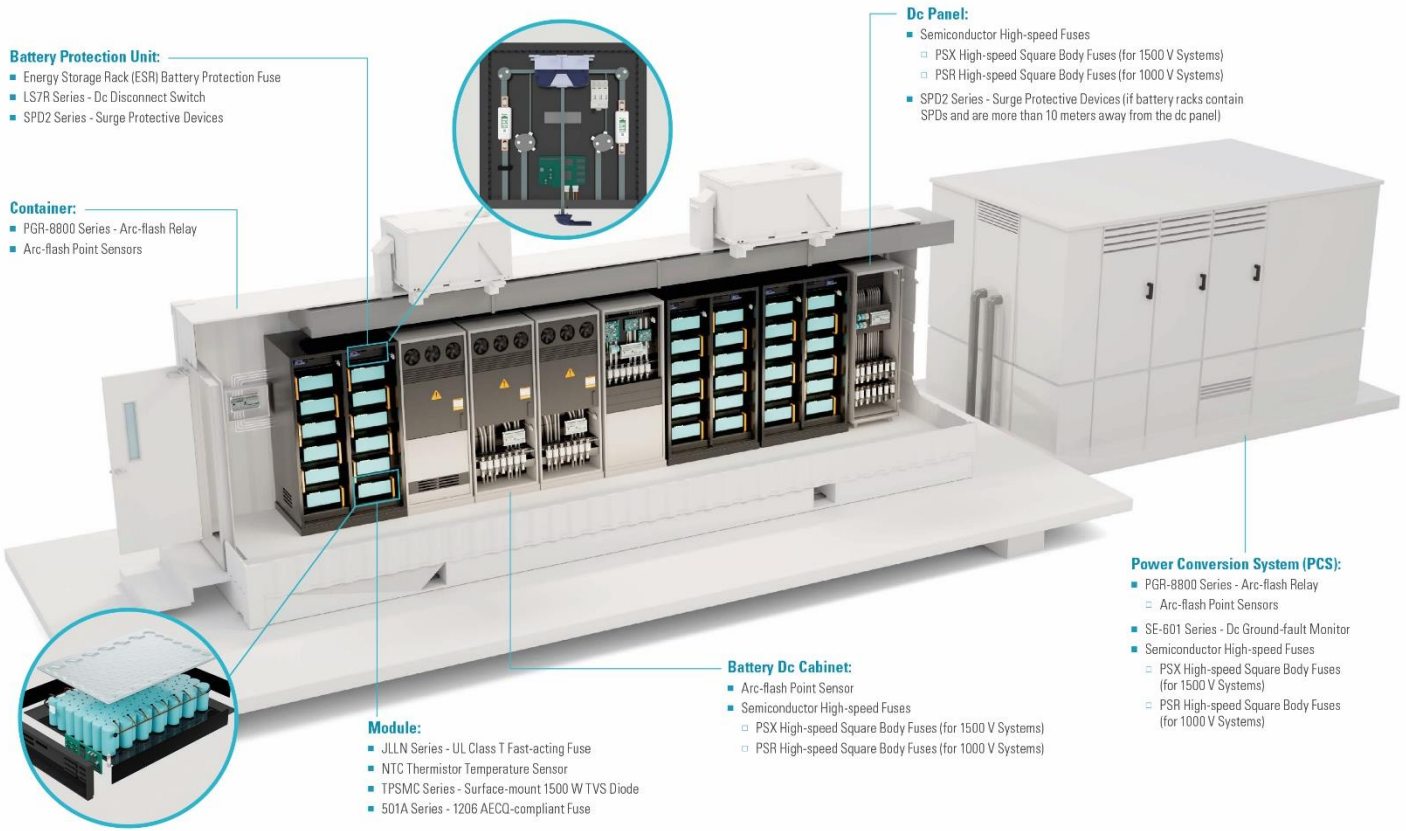
Commerical

Utility

Energy Storage System



Where Circuit Protection is Important in a BESS



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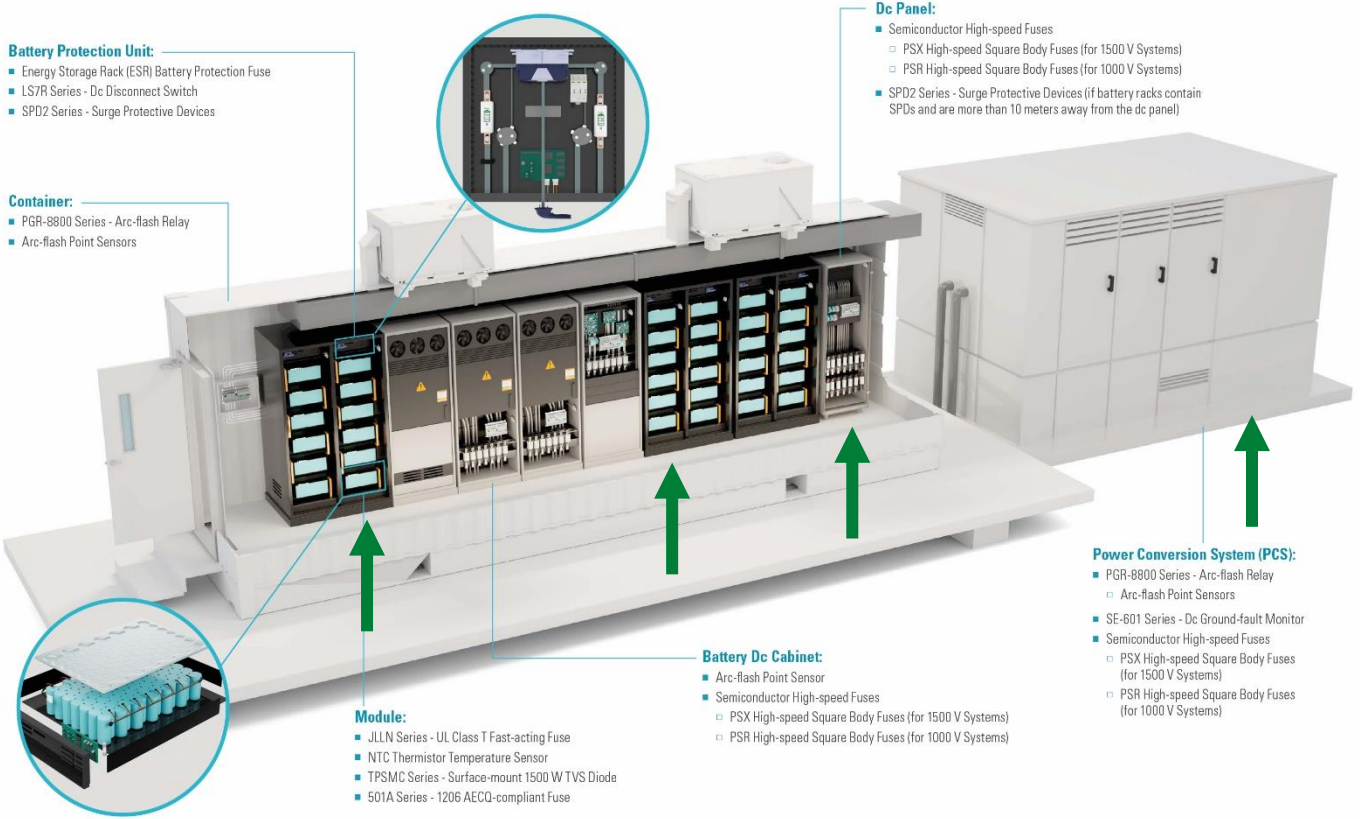
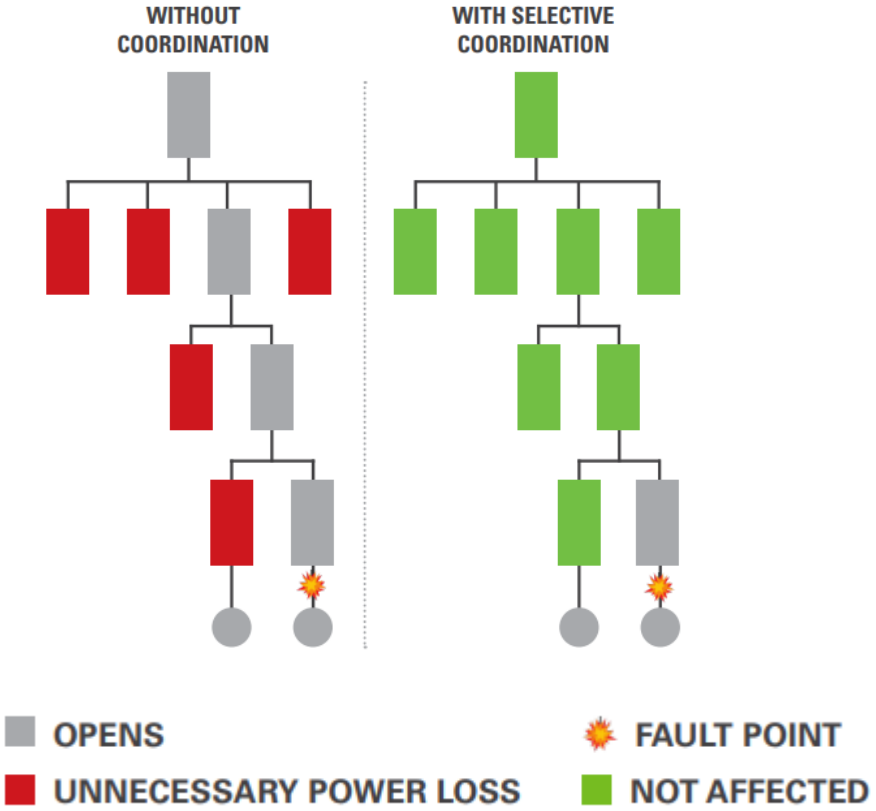
Circuit Protection Poll

- *Where in a Battery Energy Storage System do you think Circuit Protection is required?*
- Module
- Battery Rack
- Dc Panel
- Power Conversion System
- All of the above
- None of the above

Where Circuit Protection is Important in a BESS



Selective Fuse Coordination



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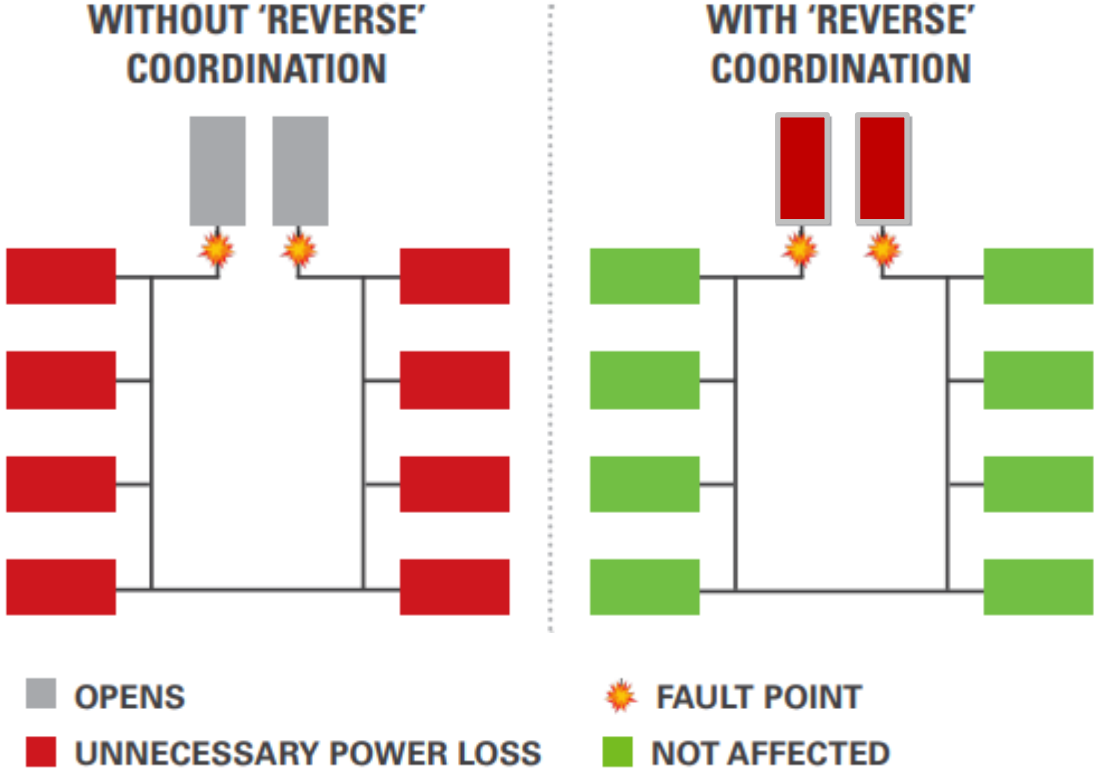
"Reverse" Fuse Coordination



Fuse Coordination Poll

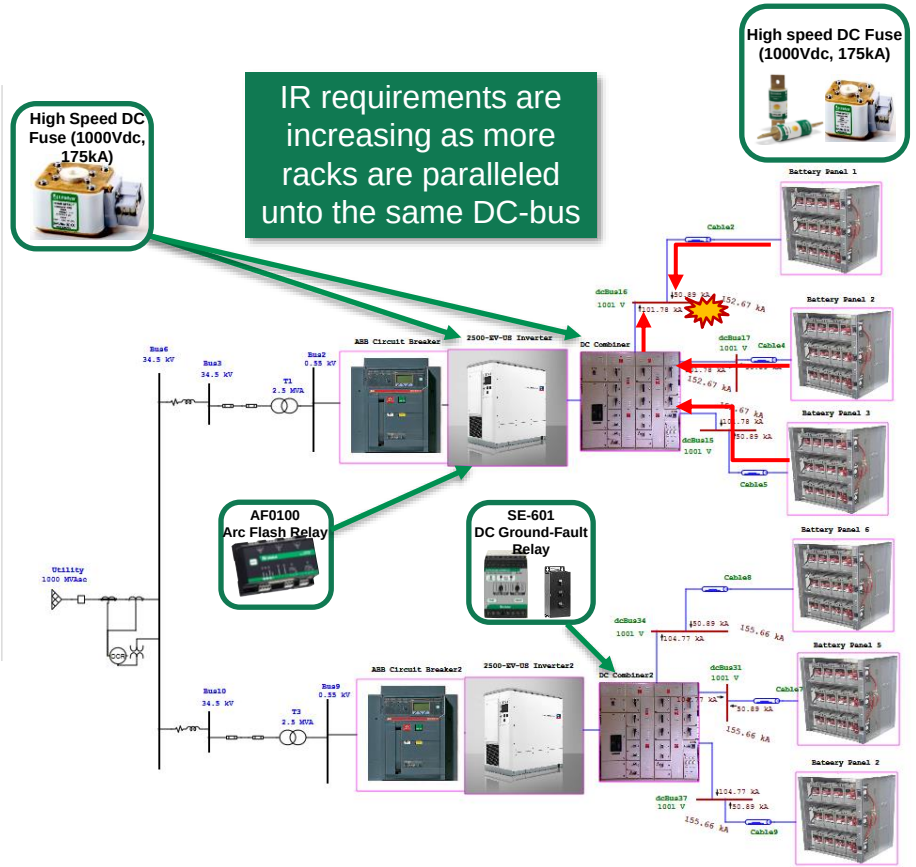
- *What type of Fuse Coordination have you used in the past?*
- Selective Coordination
- “Reverse” Coordination
- I have not used Fuse Coordination in the past
- Not sure

How to Size Fuses to Protect Against Low-Resistance Short Circuits

	POSSIBLE CAUSES	EFFECTS
High-Resistance Short Circuits	■ Internal battery-cell defect or contamination ■ External short circuit	■ Creates a false "self-discharge" ■ Creates a slow drop in cell voltage ■ Slowly discharges the batteries
Low-Resistance Short Circuits	■ Internal battery-cell defect or contamination ■ Manufacturing defect or circuit failure within the battery string or the dc panel ■ External short circuit	■ Fast decrease in cell voltage ■ Rapidly increases the cell temperature ■ Backfeed from healthy battery racks into faulted point on the battery string or the dc panel on a common dc busbar ■ Rapidly discharges the batteries

Fuse Parameters For Adequate Protection

Specifications	
Ampere Range	To be Calculated
Voltage Rating	1500VDC (System Voltage)
Time Constant	3 to 5ms
Interrupting Rating (DC)	**250kA**
Minimum Breaking Current	900%
Operating Characteristics	Class aR
Body Style	NH XL
Case Sizes	NH 1XL: 80A to 630A NH 3XL: 700A to 1400A
Termination	Flush Metric DIN Blade Bolted (US) Blade
Agency Certifications	cURus, CE
Complying Standard	UL 248 - 13 IEC60269-4 IEC60269-7



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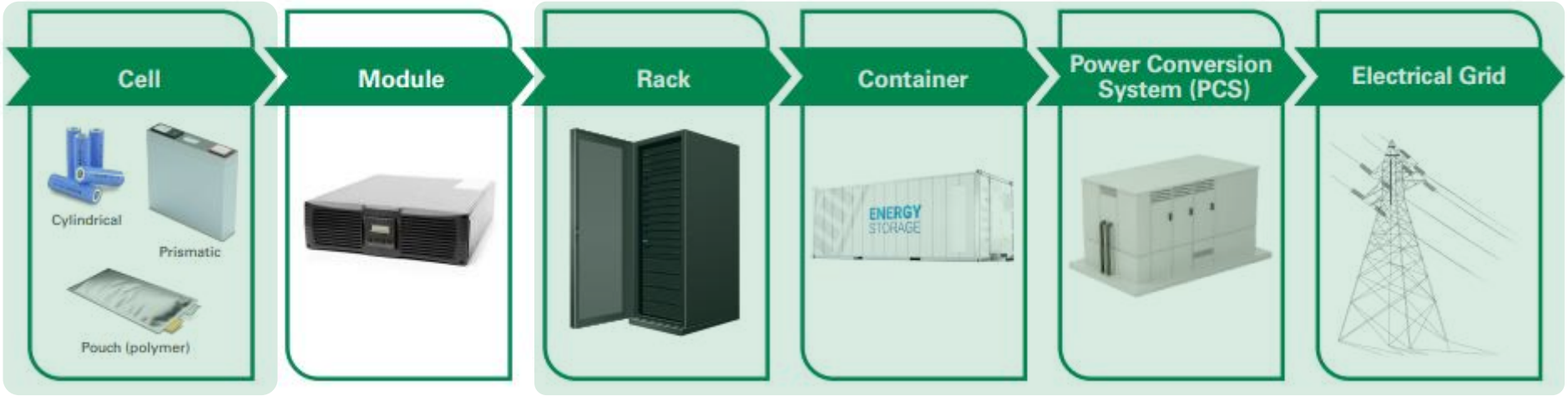
How to Size Fuses at the Battery Module



How to Size Fuses at the Module

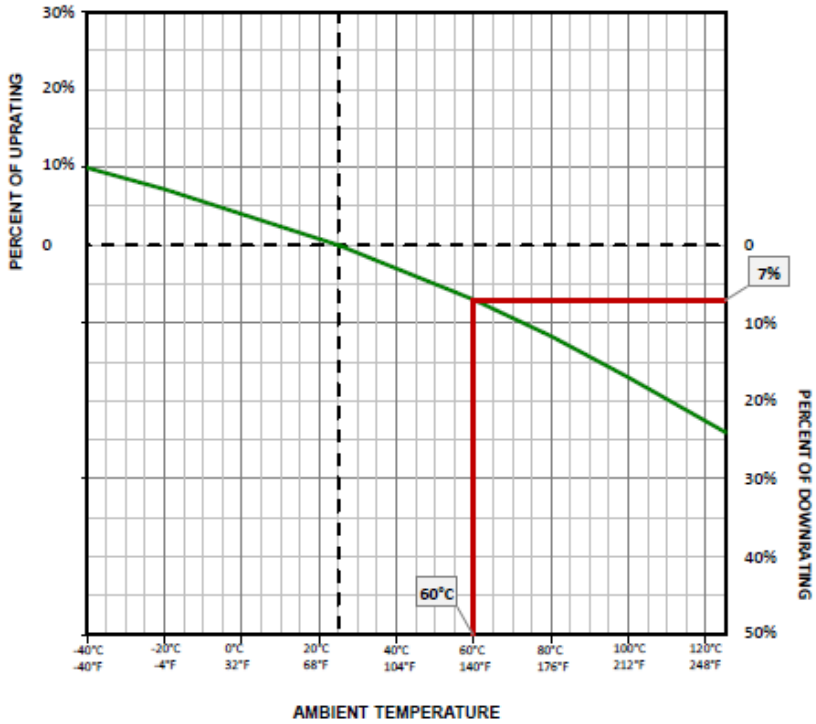
$$I_N = \frac{I_L}{(F_{AT} \ x \ F_L)}$$

I_N = Rated current of the high-speed fuse for the application
I_L = Nominal load discharge current rate
F_{AT} = Temperature derate factor
F_L = Fuse load factor

How to Size Fuses at the Module - Example

Example:

- I_L = 10 A
- 60 ºC ambient temperature
- F_{AT} = 93% (7% derate)
- F_L = 75% of current-carrying capacity at 60 ºC



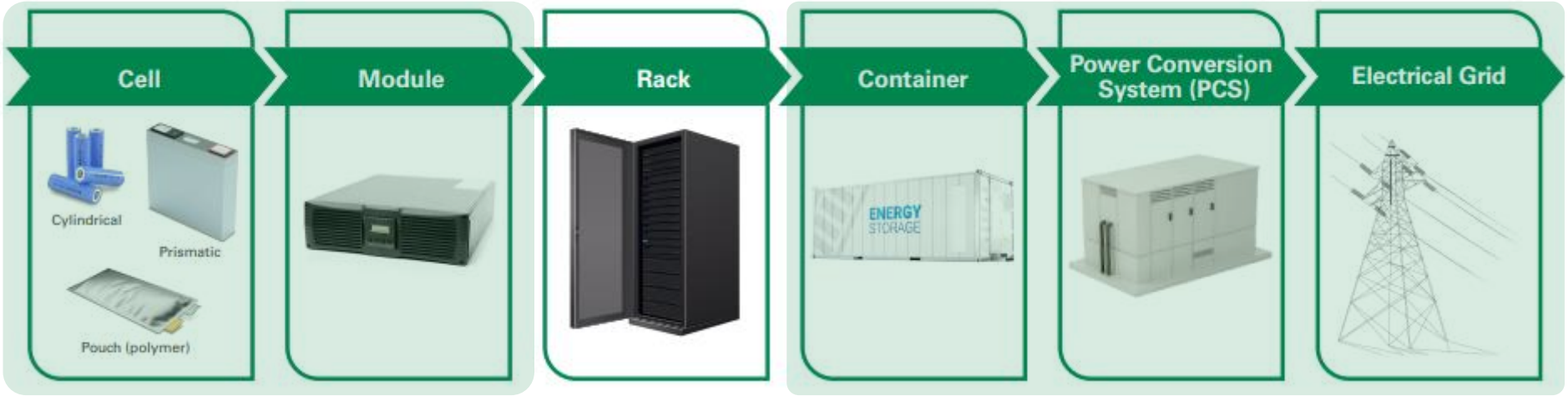
How to Size Fuses at the Module - Example

$$I_N = \frac{I_L}{(F_{AT} \times F_L)}$$

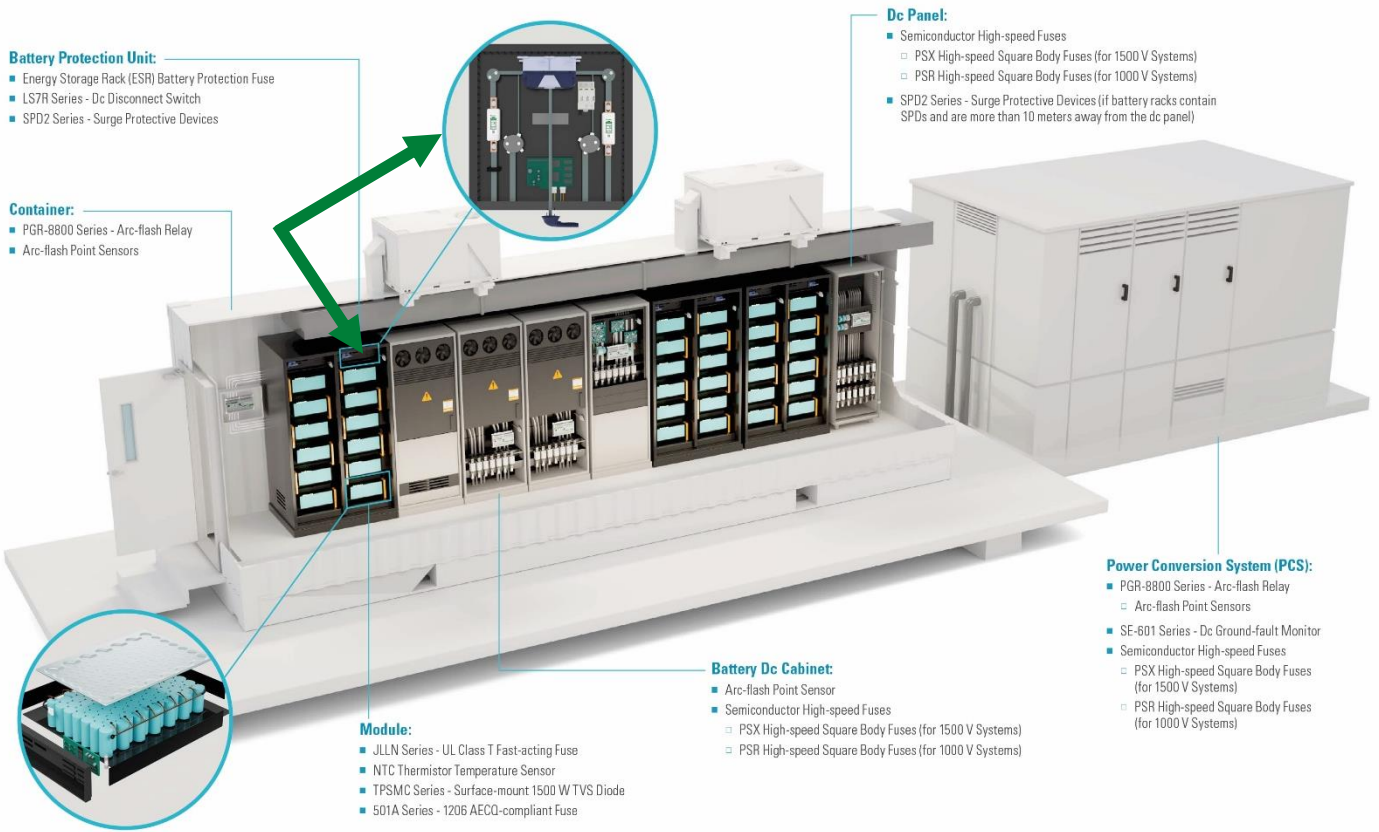
$$I_N = \frac{10\ A}{(0.93 \times 0.75)} = 14.33\ A$$

Required Fuse - 15A : Choose the next higher standard fuse amperage

How to Size Fuses at the Battery Rack

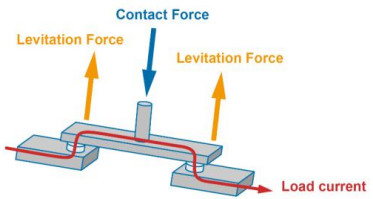


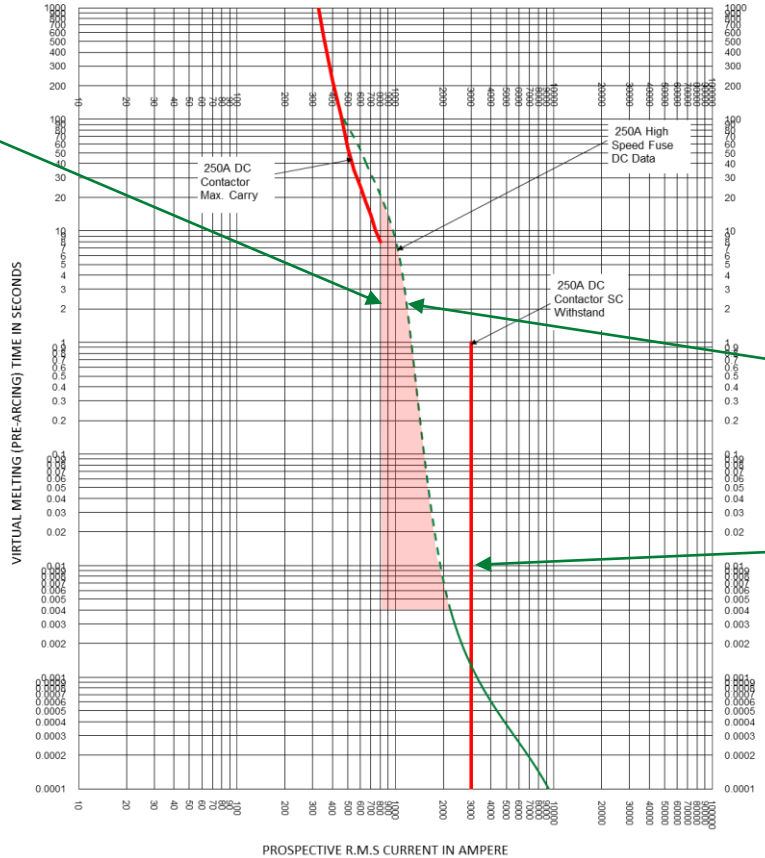
How to Size Fuses at the Battery Rack



Sizing Rack Fuse to Protect Contactor (Partial Protection)

Risk of Overload, Levitation, Arcing / Chattering & Failure





Dashed region indicates high risk of thermal overload of fuse.

Fuse prevents high short circuit damage

https://www.te.com/content/dam/te-com/documents/channel/marketing-materials/auto-white-paper-evc-250-main-contactor-english.pdf

N.B. Customers should be encouraged to test co-ordination of devices as part of validation process.

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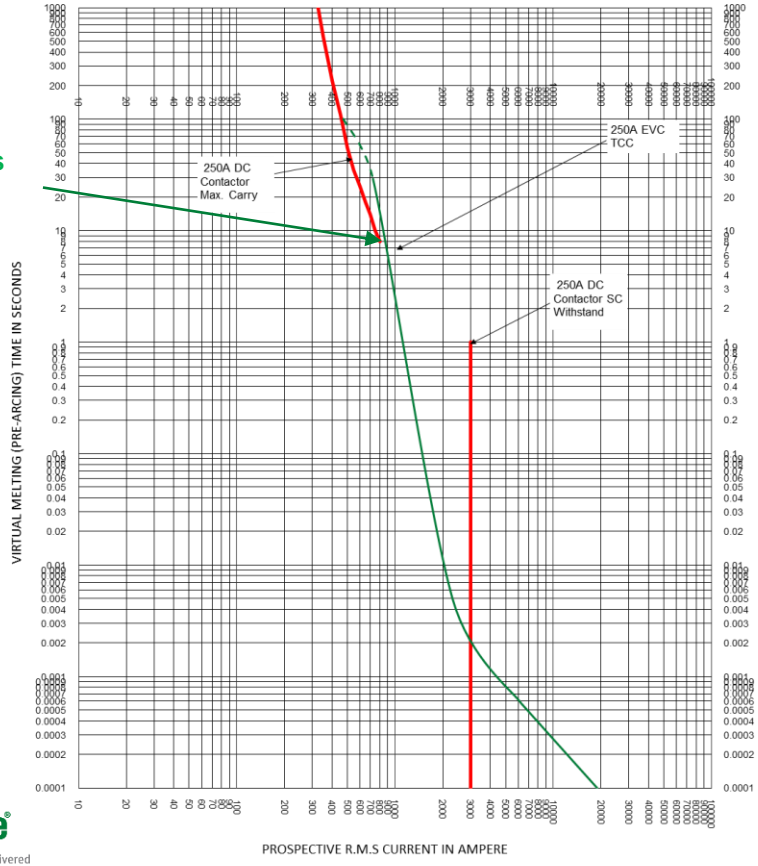
Sizing Rack Fuse to Protect Contactor (Complete Protection)

Max. Carry Current overlaps with the DC min. break



Contactor – Fuse I-T Characteristics

- Overlap indicates complete protection of system
- No need to oversize contactor due to fuse coverage
- System is protected from both short-circuits and overloads
- Adequately sized contactors reduces costs

N.B. Customers should be encouraged to test co-ordination of devices as part of validation process.

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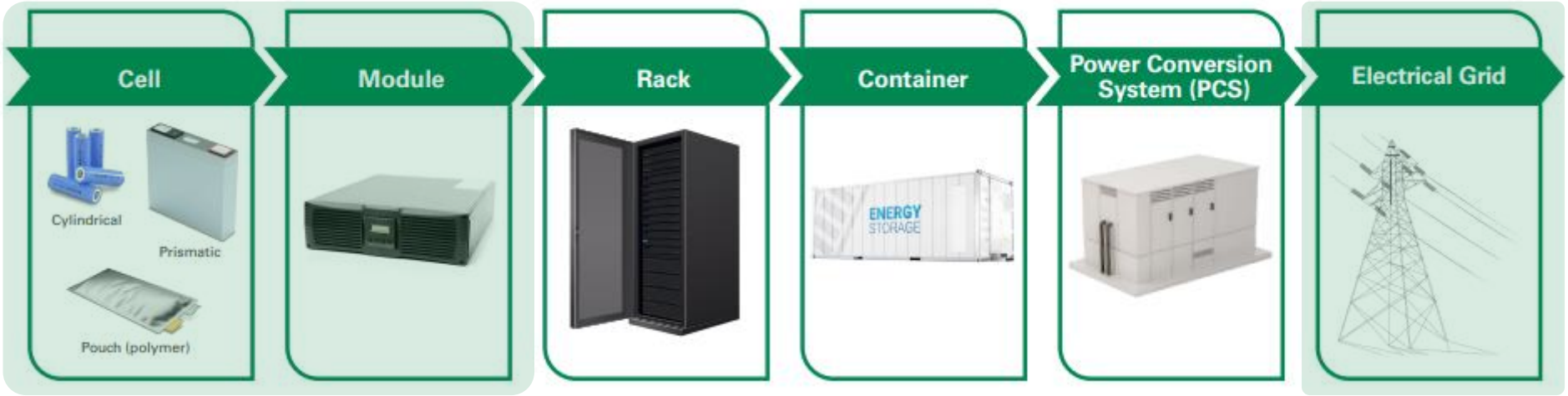
How to Size Fuses at the Battery Rack, DC Panel and PCS



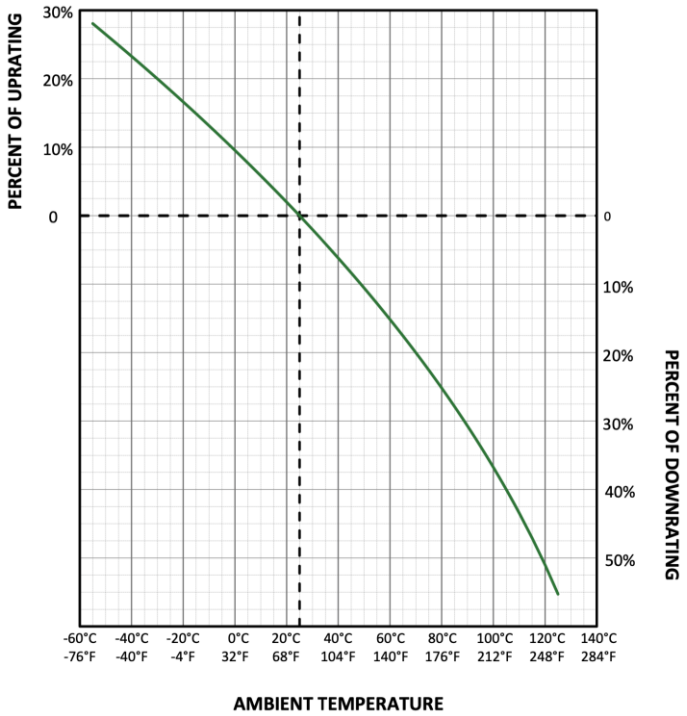
How to Size Fuses at the Battery Rack, Dc Panel & the Power Conversion System

$$I_N = \frac{I_L}{(F_{AT} \times F_L \times F_{SS} \times F_{WR} \times F_{FC})}$$

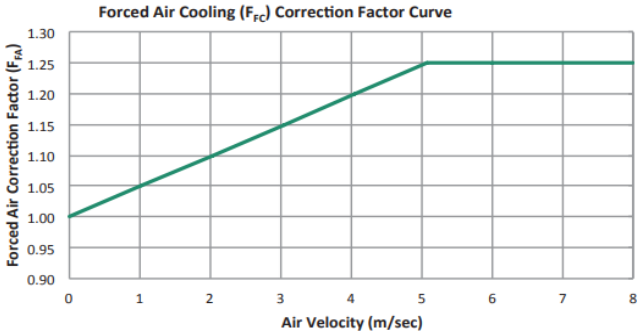
I_N = Rated current of the high-speed fuse for the application
I_L = Nominal load discharge current rate
F_{AT} = Temperature derate factor
F_L = Fuse load factor
F_{SS} = Switching correction factor
F_{WR} = Thermal connection factor
F_{FC} = Forced cooling correction factor

How to Size Fuses at the Battery Rack, Dc Panel & the Power Conversion System

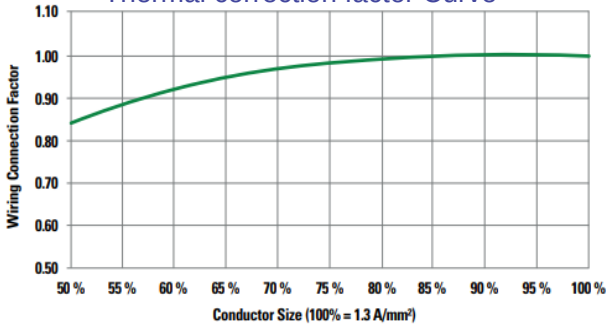
Fuse Ambient Temperature Derating Curve



Forced cooling correction factor Curve



Thermal correction factor Curve



Switching correction factor table

FREQUENCY OF SWITCHING	SWITCHING CORRECTION FACTOR
Less than 12 stops per year	1.00
More than one stop per month	0.95
More than two stops per week	0.90
More than one stop per day	0.85
Several stops per day	0.80

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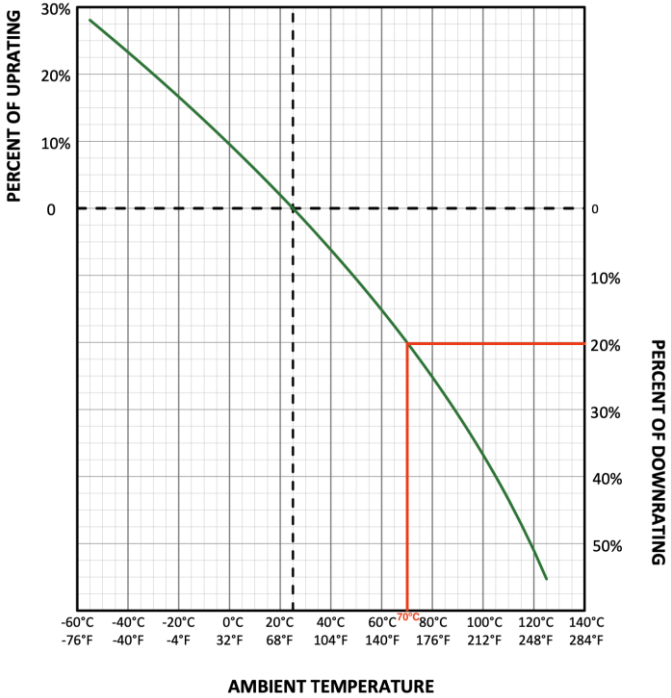
How to Size Fuses at the Battery Rack, Dc Panel & the Power Conversion System

Example:

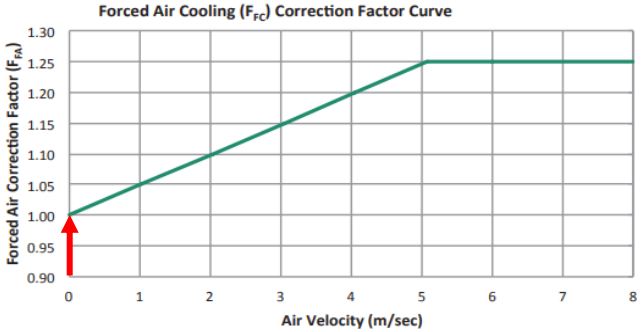
- 200-Ah battery rack
- Operating between 720 V dc and 960 V dc
- Charging and discharging at a 0.25 charge rate
- Battery rack ambient temperature 70 ºCelsius
- No forced cooling in battery rack
- Assume conductor size amperage per mm^2 is $1.4A/mm^2$
- System switches on and off several times a day on a common dc bus
- 8 racks in parallel
  - Each has an 8-kiloampere fault current

How to Size Fuses at the Battery Rack, Dc Panel & the Power Conversion System

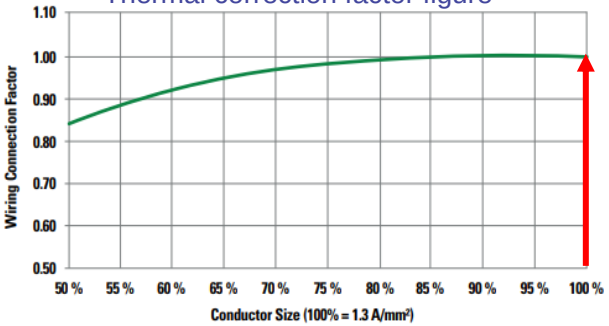
Fuse Ambient Temperature Derating Curve



Forced cooling correction factor figure



Thermal correction factor figure



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How to Size Fuses at the Battery Rack, Dc Panel & the Power Conversion System

$$I_N = \frac{I_L}{(F_{AT} \times F_L \times F_{SS} \times F_{WR} \times F_{FC})}$$

I_L = (0.25 x 200Ah) = 50A
F_{AT} = 0.8 (20% derate)
F_L = 0.8
F_{SS} = 0.8
F_{WR} = 1.0
F_{FC} = 1.0
IR = 8kA x 8 racks = 64kA

$$I_N = \frac{50}{(0.8 \times 0.8 \times 0.8 \times 1.0 \times 1.0)} = 97.66\ A$$

Fuse current rating

Required Fuse: 100A 1000Vdc with IR ≥ 64kA

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Summary: Fuse Sizing Formulas

High-Speed Fuse (Partial Range) Formula: For Rack, DC Panel and PCS

$$I_N = \frac{I_L}{(F_{AT} \times F_L \times F_{SS} \times F_{WR} \times F_{FC})}$$

Full Range fuse Formula: For Module

$$I_N = \frac{I_L}{(F_{AT} \times F_L)}$$

I_N = Rated current of the high-speed fuse for the application
I_L = Nominal load discharge current rate
F_{AT} = Temperature derate factor
F_L = Fuse load factor
F_{SS} = Switching correction factor
F_{WR} = Thermal connection factor
F_{FC} = Forced cooling correction factor

Case Study – High-speed Fuse Prevents ESS Failure

- **Industry**: Energy Storage Systems
- **Application**: Solar/ESS Inverter Protection
- **Customer**: OEM
- **End Users**: State utility companies invested in solar/ESS, micro-grids, community solar, commercial solar power investors, IT infrastructure
- **Required Ratings**: 160 A and 630 A, 1000 V dc
- **Customer Need**: 1000 V dc high-speed fuse with high dc interrupting rating (> 100 kA) along with UL certification
- **Products Designed-in**: PSR flush-end high-speed semiconductor fuses
- **Main reason for PSR Series product selection:**
  - 1000 V dc rated fuses
  - 150 kA dc interrupting rating
  - UL and IEC certifications
  - Dc information available on product label

PSR Series

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Case Study – Packing in More Power with the Right Fuse Protection

- **Industry**: Energy storage systems
- **Application**: Battery bank
- **Customer**: Integrator
- **End Users**: Utility
- **Customer Need**: Higher-capacity battery pack protection
- **Product Designed-in**: PSX high-speed square-body semiconductor fuses
- **Main reason for PSX Series product selection:**
  - 250 kA dc interrupting rating
  - Extremely fast-acting fuse
  - High dc voltage rating up to 1500 V dc

PSX Series

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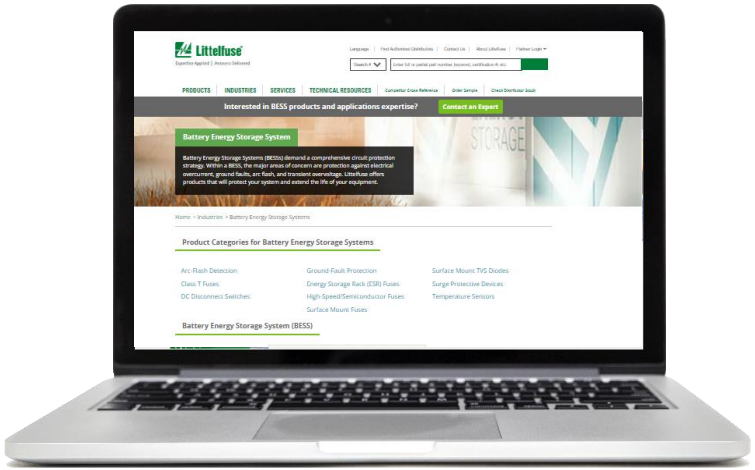
Conclusion

- The battery energy storage market is a rapidly growing market
- Properly sized components are critical to a reliable, robust, and dependable system
- Important fuse parameters to consider in fuse sizing are, voltage, time constants, interrupt rating, minimum breaking current and current rating.
- Rack and module fuse coordination is important in overcurrent protection of Racks to minimize downtime and O&M costs.
- Rack fuse and contactor characteristics must overlap for complete protection of the system.
- Littelfuse can work with companies to establish the right circuit protection strategy through engineer-to-engineer engagement and comprehensive testing tailored to their systems

Q&A and Additional Information



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Thank you!

Live Q&A

For more information including white papers, educational videos, application guides, and technical specifications visit Littelfuse.com/BESS

If you have technical questions post webinar, please contact Immanuel Umenei at Iumenei@Littelfuse.com

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