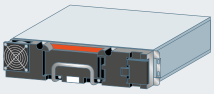
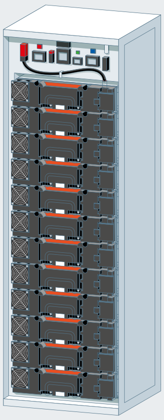
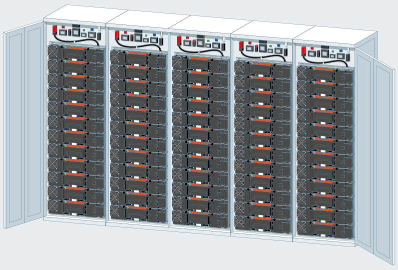
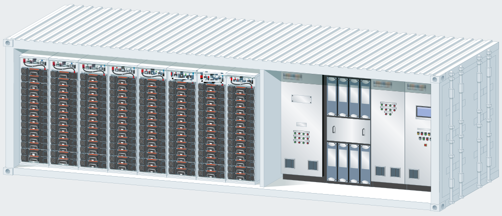
EES APPLICATION GUIDE #1

BATTERY ENERGY STORAGE OVERCURRENT PROTECTION GUIDE









BATTERY ENERGY STORAGE OVERCURRENT PROTECTION GUIDE

Given the increased concerns about global warming and decarbonization targets established around the world, Electrical Energy Storage (EES) solutions are being paid attention to more than ever. At each step in the grid, from generation to transmission, and from distribution to end users, batteries offer many advantages such as grid stabilization, integration of renewable energy, flexibility, reliability as well as independence. As the need for greener energy grows, so does the importance of energy storage.

While Electrical Energy Storage is not new, the increase of power has brought new constraints and challenges for over-current protection devices. DC fuses must withstand a wide range of constraints such as power cycling, high and low fault currents and coordination with other protective devices. EES protective schemes are also far from being standardized, resulting in a multitude of protection architectures according to the system or component manufacturer.

The safety of EES applications has become a major focus. A series of incidents have pointed out that safety has not yet been addressed properly, due certainly to the rapid growth of EES installations. Smart monitoring systems have allowed mitigating catastrophic failures of EES installations; however, fuses remain the safest solution once everything else has failed. Today's EES installers face the challenge of operating voltages of up to 1500 VDC with available fault currents larger than few 100 kA.

The safety of EES applications is now being insured as a result of the introduction of specifically designed fuses for EES applications complimented by test labs simulating actual EES fault currents and development of new IEC standards for battery usage.

The purpose of this document is to guide the reader through the process of selecting the appropriate over-current protecting device from the module up to the container level of their EES system.

CONTENT

I. INTRODUCTION TO ENERGY STORAGE AND FUSES

A. ENERGY STORAGE TOPOLOGY

A typical EES system consists of several levels of different battery assembly:

FIGURE 1: EXAMPLE OF EES BATTERY ASSEMBLIES

Since EES systems answer to a large array of needs and requirements, each system has their own specifications. Factors such as scale, power, voltage among others will influence the topology of the overall system. Still, a common architecture with different levels exists. Below is an example of an EES system:

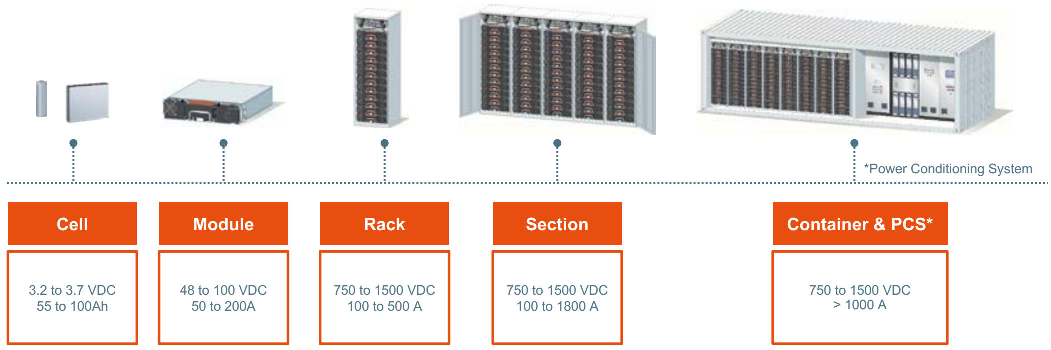
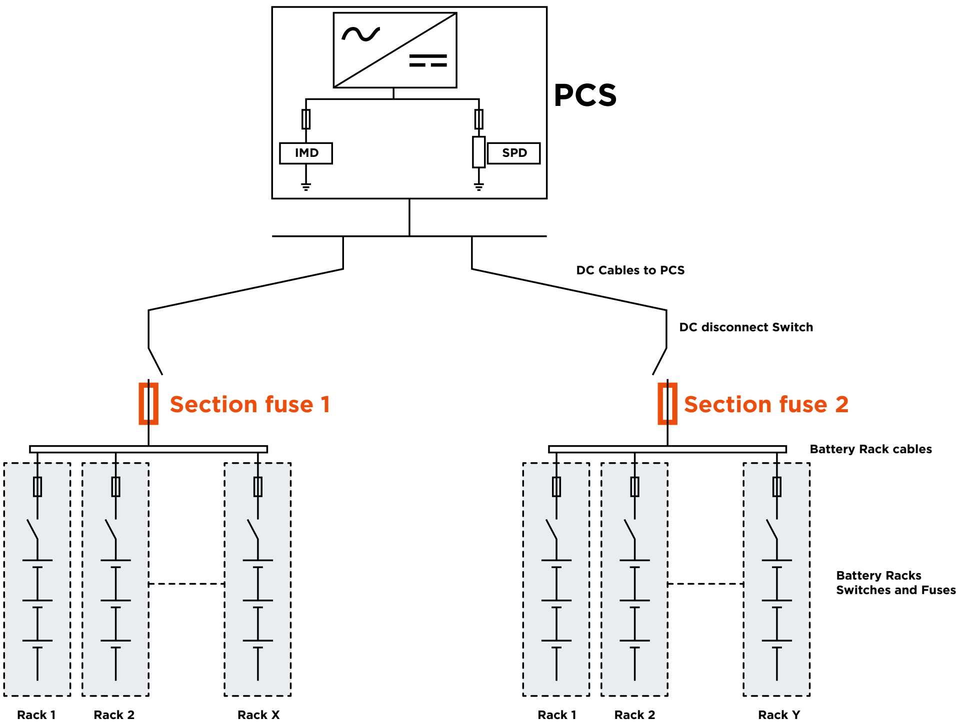


FIGURE 2: EXAMPLE OF EES TOPOLOGY



I. INTRODUCTION TO ENERGY STORAGE AND FUSES

B. ROLE OF FUSES IN EES

A fuse is a device for protecting an electrical system against the effects of overcurrents (excess currents), by melting one or more fuse-elements, thus opening and isolating the faulted circuit. Very fast-acting fuses are widely used for the protection power semiconductors in AC and DC power electronic applications and are now used for battery system protection such as energy storage, UPS, and electric vehicles. Current limiting fuses provide excellent protection against the potentially damaging effects of short-circuit currents.

Current-limiting fuses achieve this protection by limiting both the magnitude and duration of the fault which limits the amount of energy produced by an overcurrent and the peak current which is allowed to flow.

In EES, this implies that fuses are not only installed to protect each level of the system from battery short circuits but also protect other over-current protection devices such as contactors and switches from damage when properly selected. In some situations, selective coordination between fuses can be achieved, adding another level of protection.

C. GLOSSARY

TERMINOLOGY	DEFINITION
EES	Electrical Energy Storage
BESS	Battery Energy Storage Systems
ESS	Energy Storage Systems
BMS	Battery Management System
Module	Several battery cells connected in series or parallel
Rack	Several battery modules connected in series
Section	Several battery racks connected in parallel
Container	Several battery sections connected in parallel
PCS	Power Conditioning System
N	Number of paralleled battery racks in a section
A	Ampere
VDC	DC Voltage
L/R_{system}	Time Constant during normal operation usually given in ms
L/R_{Fault}	Time Constant of the fault current usually given in ms taking into account components from the point of the fault back to its source
C-rate	Battery current charge and discharge rate
P-rate	Battery power charge and discharge rate
IR	Fuse Interrupting Rating (also known as Breaking Capacity): the maximal current the fuse has been tested to safely clear at a given voltage and time constant
MBC	Fuse Minimum Breaking Capacity: the smallest current the fuse has been tested to safely clear at a given voltage and time constant
I_{rms}	Long time heating effect of transient or non-continuous current
I_{fuse}	Calculated fuse rated current
VDC_{max}	Maximum System Voltage
V_{nDC}	Fuse DC Voltage Rating
I_1	RMS Overload Current up to a duration of 10 minutes I_{OL}
T_1	Duration of overload current
$I_{fault\ max}$	Maximum Fault Current (also named prospective fault current) It corresponds to the fault current that would flow in the circuit if each fuse were replaced by a conductor of negligible impedance
$I_{fault\ min}$	Minimum Fault Current It corresponds to the smallest fault current the system can provide, and a fuse can safely open
I_{melt}	Fuse Melting RMS current at a given time (also named pre-arc current)
I_n	Fuse current rating
Peak let through	Maximum instantaneous value reached by the fault current during the interrupting operation of a fuse
Melting I^2t	Thermal energy required to melt the fuse element ($Irms^2t$). Also known as the pre-arc i2t.
Clearing I^2t	Thermal energy let thru by the fuse as it clears the circuit ($Irms^2t$). DC Clearing i^2t will differ depending on the voltage, fault current and short circuit time constant of the system.

II. ADJUSTING THE FUSE RATED CURRENT TO ALLOW FOR REAL-WORLD WORKING CONDITIONS

The rated current of a fuse is based on specific type-tests defined by standards which are performed under controlled laboratory conditions. However, in real-world applications, the working conditions in the equipment where fuses are installed are rarely the same as those conditions used during type tests. Fuses are thermal devices: anything that changes how they dissipate heat changes the continuous current carrying capability. To account for the differences between operational and test conditions, an array of correction factors is used to ensure a fuse with adequate current carrying capability is selected.

- Ambient Factors:
  - A_1: Ambient Temperature
  - B_v: Air flow passing across the fuse
  - C_1: Connections
  - C_{ALT} : Altitude
- Current cycling effects:
  - A'_2: Current cycling
  - B'_2: Repetitive transient overloads

Taking everything into account, the following equation is used to calculate the rated current of fuse rating:

$$I_{fuse} \geq \frac{I_{RMS}}{A_1\, B_v\, C_1\, A'_2\, C_{ALT}}$$

As well as the following conditions:

- I_{RMS} in this formula corresponds to the RMS value of perceived continuous current, whose duration is greater than 10 minutes
- The fuse must be sized at a minimum of $1.25 I_{RMS}$
- $I_1 \leq B'_2 I_{melt}$@T1 (on the fuse time current curve)
- V_{nDC}@ $L/R_{fuse} \geq V_{DCMAX}$ @ L/R_{app}

Once the fuse rating is calculated, the withstand ability of over-currents must be checked as well as the coordination with other overcurrent protective devices and contactors:

- Fuse IR > Available Fault Current
- Fuse MBC < Smallest current the fuse must open
- Fuse Peak let thru current < DC Short circuit current withstand rating of components

This application guide is a simplified version of the fuse selection process for EES protection. Evaluating fuse performance and cycling profiles can be complex.
A more detailed study of your application is likely required. Please contact our Technical Service Engineers for guidance on your fuse selection.

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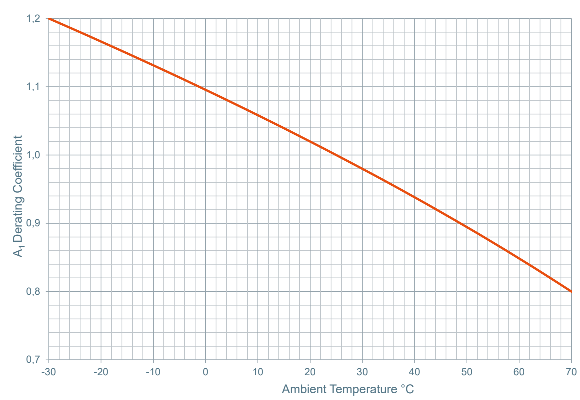
A. FACTORS TO SELECT THE ADEQUATE FUSE RATING

1. AMBIENT TEMPERATURE: A_1 COEFFICIENT

For most EES applications, the ambient temperature surrounding the fuse can range from -5˚C to 70˚C due to heat dissipation from nearby components as well as environmental conditions. The rated current of a fuse is established by standard type tests at 25˚C or 30˚C ambient. Higher ambient temperatures decrease the current carrying capability of the fuse. Consequently, we must apply a corrective coefficient to compensate for the difference in surrounding ambient temperature. The surrounding temperature of the rack fuse typically varies from 30 to 45°C. 40°C can be used as a baseline. As there's often more space, the surrounding temperature of the section fuse typically varies from 25 to 35°C. 30°C can be used as a baseline. Actual ambient temperature surrounding the fuse should be used if know.

Temperature correction coefficient graphs are published to quickly find the correction factor for the expected ambient temperature inside the enclosure where the fuse is installed.
The curve is specific to each fuse range, please refer to product datasheet for the actual curve to be used.

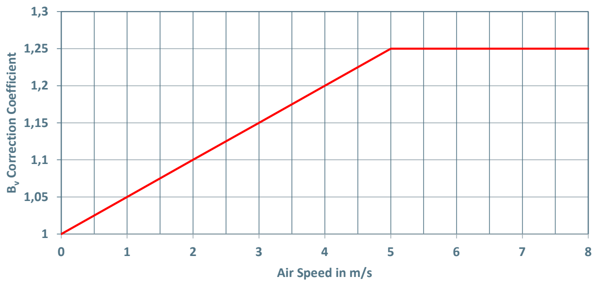
FIGURE 3: EXAMPLE OF TEMPERATURE DERATING CURVE



2. AIR COOLING: BV COEFFICIENT

If the application uses forced air to cool the fuse, this will benefit the current carrying capability of the fuse. The current correction coefficient will increase linearly until an air speed of 5 m/s after which further cooling cannot be achieved.
Installed fuses are often in a location where they are not directly in the air flow. If there is any doubt at all that the fuses see the air flow, 1 should be used as the coefficient.

FIGURE 4: CORRECTION COEFFICIENT B_V VS. AIR SPEED



3. TERMINAL CONNECTIONS SIZE: COEFFICIENT C_1

In actual applications, the cable/bus bar sizes are typically smaller than those used in standard type tests. Since heat is conducted away from the fuse through the conductor connection points at the fuse terminals, using a smaller size cable will have a negative impact on cooling the fuse. The corrective coefficient C_1 is used to compensate for this effect. Starting values to be used in calculations for C_1

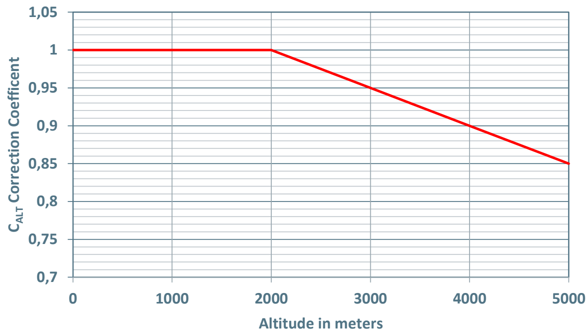
- Rack Fuses: 0.85
- Section Fuses: 0.9

In order to have a more consistent value, please contact Mersen Technical Services Engineers

4. ALTITUDE: COEFFICIENT C_{ALT}

At altitudes above sea level, the atmosphere density is reduced, decreasing fuse cooling which decreases the current carrying capability of the fuse. To account for this, a correction factor for altitude must be included in current rating calculation.
If the EES application requires continued use at elevations above 2000m, an additional derating factor must be used: it will decrease by 0.5 % for every 100m above 2000m.

FIGURE 5: CORRECTION COEFFICIENT C_{ALT} VS. ALTITUDE



5. Effects of « cyclic » variable currents: coefficient A’$_2$

In EES application, the current will vary with changes to the power output which is mainly influenced by the overall system being for power or energy applications and more specifically the battery C-rate (charge and discharge rate). The changing currents create a repetitive “cycle”, which is typically given by the customer in “current profile(s)” and is key factor to properly select a fuse. Cycling can cause element temperature fluctuations. Repeated heating and cooling of the element causes it to expand and contract which can lead to mechanical fatigue.
A’$_2$ is used to make sure the temperature gradient on the fuse element is small enough to mitigate element fatigue, resulting in adequate fuse life for the application. It can vary from 0.65 to 0.9 depending on the load profile and the fuse construction.
A’$_2$ values vary from

- For rack fuses: 0.65 to 0.9 starting with a typical value of 0.72
- For section fuses: 0.65 to 0.9 starting with a typical value of 0.82

It is recommended that the entire application be reviewed by Mersen Technical Services Engineers to make sure the correct factor is chosen.

B. CURRENT CYCLING: IMPACT AND CORRECTION FACTORS ON FUSE CURRENT RATING

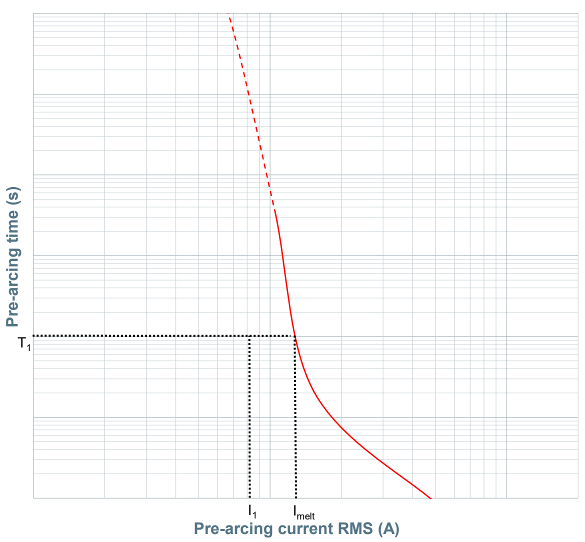
1. REPETITIVE OVERLOADS: COEFFICIENT B'$_2$

Naturally, it is also necessary to review the different power cycles as they will vary in magnitude and duration. We must make sure that the fuse is able to withstand transient overload currents that occur under normal operation. The transient overloads to be examined are in the 10's to 100's of seconds. Please contact our engineers if the overload duration is less than 10s.

This necessary assessment is made after the fuse rating calculation with the time current curve (TCC) of the selected fuse rating.

The TCC gives the melting point (I_{MELT}) at a given time. A simple method of ensuring that the fuse is large enough to withstand the cyclic overload is to require that the ON current I_1 (calculated in RMS value during time T_1) does not exceed a certain fraction B'$_2$ of the current which would cause the fuse to melt in the time T_1. The equation for this is: $I_1 \leq B'_2 I_{melt} @ T_1$ (on the fuse time current curve)

FIGURE 6: OVERLOAD CURRENT VS. FUSE MELTING POINT



The coefficient B'$_2$ is directly related to the number of cycles. These factors vary depending on the fuse design. The table below are examples:

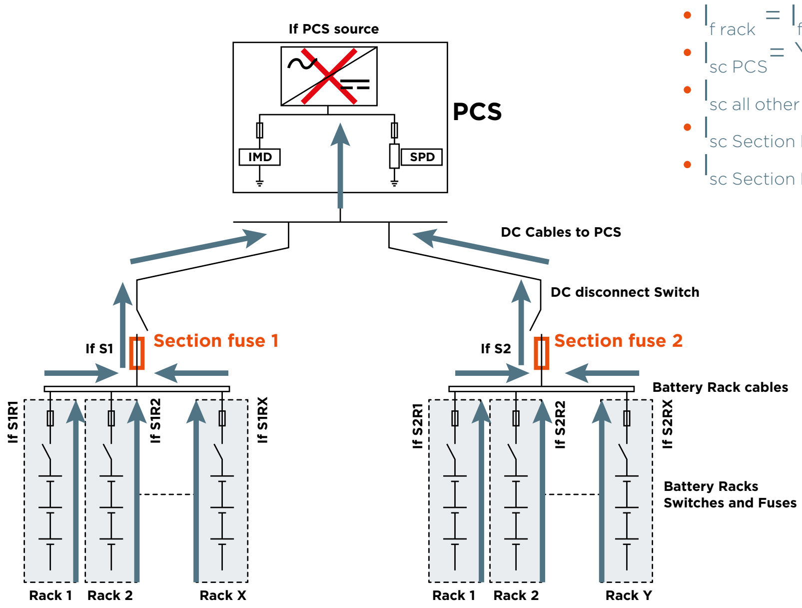
B'2 CORRECTION COEFFICIENT	NUMBER OF CYCLES
0.31	10^6
0.35	10^5
0.45	10^4
0.5	4000
0.55	2000

It is recommended that the entire application be reviewed by Mersen Technical Services Engineers to make sure the correct factor is chosen.

A. TYPES OF PROSPECTIVE FAULTS

1. FAULT IN PCS

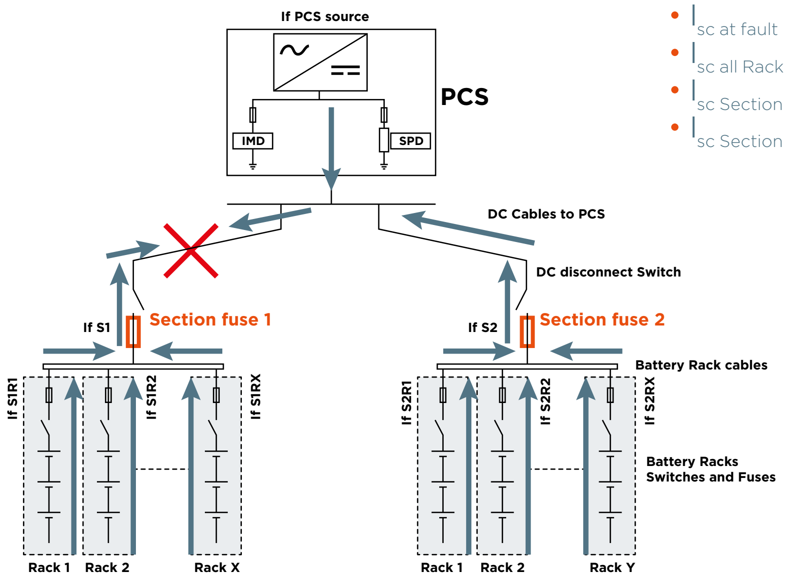
FIGURE 7: EXAMPLE OF FAULT IN PCS



- $I_{fault\ rack}$ = Fault current from a single rack
- $I_{f\ rack} = I_{f\ S1R1} = I_{f\ S1R2} = I_{f\ S1RX} = I_{f\ S2R1} = I_{f\ S2R2} = I_{f\ S2RY}$
- $I_{sc\ PCS} = Y(I_{fault\ rack}) + X\ (I_{fault\ rack}) + I_{sc\ grid}$
- $I_{sc\ all\ other\ racks} = I_{fault\ rack}$
- $I_{sc\ Section\ Fuse\ 1} = X(I_{fault\ rack})$
- $I_{sc\ Section\ Fuse\ 2} = Y(I_{fault\ rack})$

2. FAULT IN BETWEEN PCS AND SECTION FUSE

FIGURE 8: EXAMPLE OF FAULT IN BETWEEN PCS AND SECTION FUSE

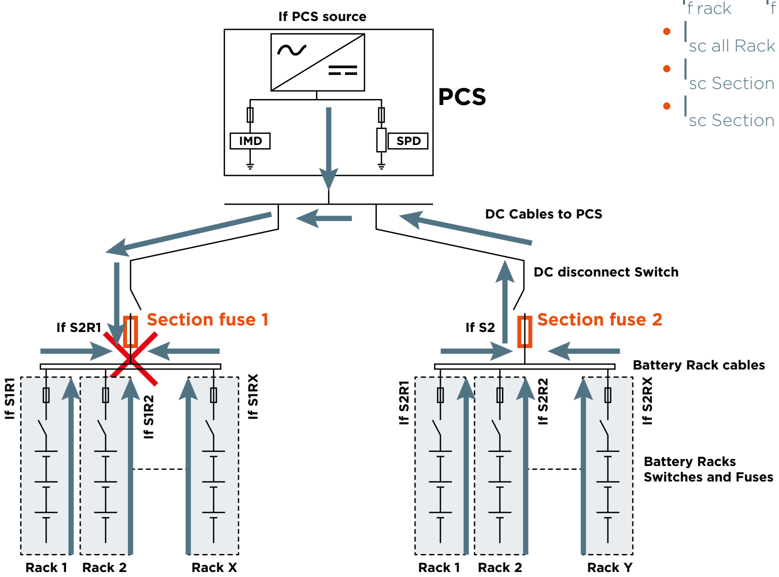


- $I_{fault\ rack}$ = Fault current from a single rack
- $I_{f\ rack} = I_{f\ S1R1} = I_{f\ S1R2} = I_{f\ S1RX} = I_{f\ S2R1} = I_{f\ S2R2} = I_{f\ S2RY}$
- $I_{sc\ at\ fault} = Y(I_{fault\ rack}) + X\ (I_{fault\ rack}) + I_{fault\ PCS}$
- $I_{sc\ all\ Rack\ Fuses} = I_{fault\ rack}$
- $I_{sc\ Section\ Fuse\ 1} = X(I_{fault\ rack})$
- $I_{sc\ Section\ Fuse\ 2} = Y(I_{fault\ rack})$

* Container level may or may not be present in the system

3. FAULT IN BETWEEN SECTION AND RACK FUSE

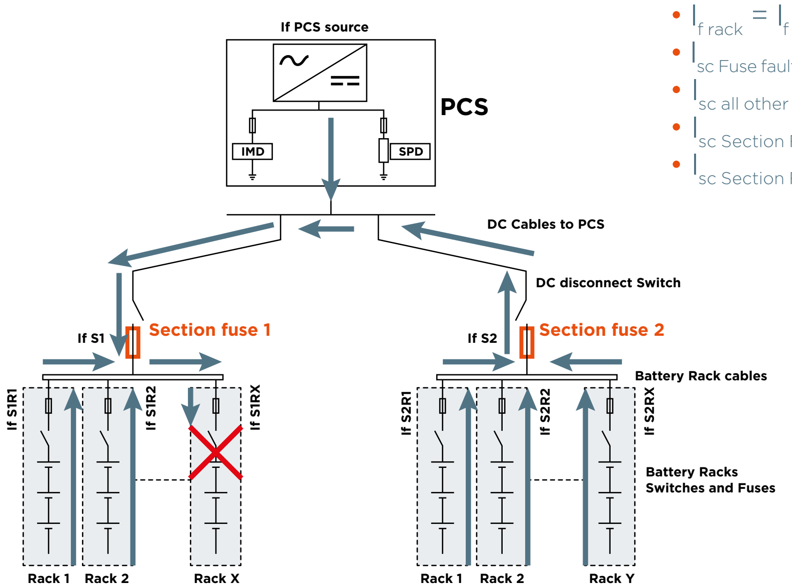
FIGURE 9: EXAMPLE OF FAULT IN BETWEEN SECTION AND RACK FUSE



- $I_{fault\ rack}$ = Fault current from a single rack
- $I_{f\ rack} = I_{f\ S1R1} = I_{f\ S1R2} = I_{f\ S1RX} = I_{f\ S2R1} = I_{f\ S2R2} = I_{f\ S2RY}$
- $I_{sc\ all\ Rack\ Fuses} = I_{fault\ rack}$
- $I_{sc\ Section\ Fuse\ 1} = Y(I_{fault\ rack}) + I_{sc\ pcs}$
- $I_{sc\ Section\ Fuse\ 2} = Y(I_{fault\ rack})$

4. FAULT IN RACK X

FIGURE 10: EXAMPLE OF FAULT IN RACK X



- $I_{fault\ rack}$ = Fault current from a single rack
- $I_{f\ rack} = I_{f\ S1R1} = I_{f\ S1R2} = I_{f\ S1RX} = I_{f\ S2R1} = I_{f\ S2R2} = I_{f\ S2RY}$
- $I_{sc\ Fuse\ faulted\ rack} = Y(I_{fault\ rack}) + (X\text{-}1)I_{fault\ rack} + I_{sc\ PCS}$
- $I_{sc\ all\ other\ Rack\ Fuses} = I_{fault\ rack}$
- $I_{sc\ Section\ Fuse\ 1} = Y(I_{fault\ rack}) + I_{sc\ pcs}$
- $I_{sc\ Section\ Fuse\ 2} = Y(I_{fault\ rack})$

5. SUMMARY OF PROTECTION

FAULT	LOCATION	PROTECTED BY
1	Inside Battery module	Module fuse – protects modules from Fault currents during transportation before being installed in a system
2	Inside Battery rack	Rack fuse
3	Inside Battery section	Rack and/or section fuse
4	Inside Battery container	Section and/or container fuse (in case no fuse at the DC of PCS)
5	Inside From PCS	Container fuse *, or section fuse (if no container level)

B. FUSE INTERRUPTING RATING AND MINIMUM BREAKING CAPACITY

The primary function of a fuse is to interrupt the over-currents safely, to protect the components and cables of the system from being damaged. However, every fuse has a range of currents it can interrupt safely, and the fuse should not be relied upon to interrupt currents outside of this range.
The Interrupting Rating (IR) and Minimum Breaking Capacity (MBC) are critical parameters defined by international fuse standards that define the range of currents fuses open safely.

- IR is the maximum prospective current a fuse is tested to safely open at a specific DC voltage and time constant (L/R)
- MBC is the minimum current a fuse is tested to safely open at a specific DC voltage and time constant (L/R).
- Therefore "MBC – IR" is the range of currents a fuse can safely open

The fuse MBC is specified at a given voltage and time constant. It is essential to know that the MBC is a function of system voltage and time constant of the circuit where it is used. If the system which the fuse is applied in has a lower voltage and/or time constant, the fuse's MBC will vary. Contact Mersen Technical Services for additional information on MBC. MBC can vary widely across fuse types. For fuses used in EES applications, MBC can vary from 3 to 15 times the current rating of the fuse. That means for a 1100A fuse, MBC could be as high as 16500A.

While the IR is well-known to users, the MBC is commonly overlooked. In EES applications, the MBC must be taken into consideration, due to limited short-circuit current generating capabilities of batteries. Battery racks typically provide a fault current range between 1 to 12kA and EES systems can go up to 250kA or more when racks or sections are combined in a system.

For the section fuse, the interrupting rating is critical parameter. Nevertheless, it is also important to know the MBC as well, to make sure the fault currents the fuse must interrupt fall within the range of fuse operating range.

For the rack fuse, having a low MBC in the range of 2-3I_n is highly beneficial to promote coordination with and protection of the contactor. The maximum IR is also critical because when there is an internal fault in the rack, the rack fuse may be exposed to high short circuit currents coming from the cascading faults from the adjacent racks.

C. COORDINATION WITH THE CONTACTOR

The ultimate goal in EES battery protection is having a solution that safely disconnects the power and can cover the full spectrum of current loads:

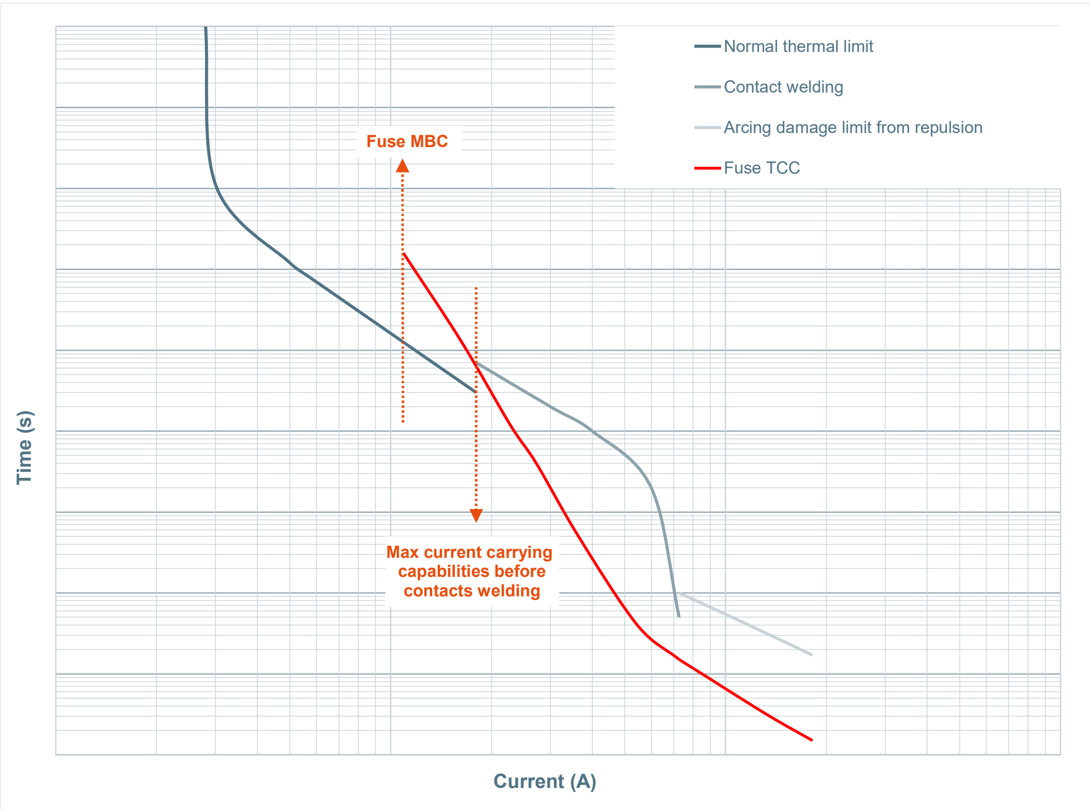
- 0 (no load)
- Nominal current (I_n)
- Maximum overload current (I_{1max})
- Maximum prospective short-circuit current ($I_{faultmax}$)

However, no single over-current protection device (OCPD) can cover this wide range by itself.

As a result, the protection strategy involves 2 devices in series: a resettable DC contactor that operates (make/break), protected upstream by an OCPD, covering faults greater than the breaking capacity of the DC contactor under specific system voltage.
Coordinating the protections from a DC contactor and from an OCPD is not trivial. The need for coordination between both device operations is critical.

A typical coordination scheme looks like:

FIGURE 11: DC CONTACTOR FAILURE I-T CURVES



Requirements include:

- $MBC_{fuse} \leq I_{max\ Contactor}$
- The fuse must open fast enough to protect the contactor
- The contactor must be capable of opening all possible overcurrents less than fuse MBC

IV. INTERNATIONAL STANDARDS

A. NATIONAL ELECTRIC CODE (NEC) REQUIREMENTS

The National Electrical Code (NEC) in the United States have established a set of requirements for fuses installed in EES applications. There are numerous articles in which those requirements are stated:

- Article 706, Energy Storage Systems
- Article 480, Storage Batteries
- Article 690, Solar Photovoltaic (PV) Systems
- Article 691, Large-Scale Photovoltaic (PV) Electric Power Production Facility
- Article 692, Fuel Cell Systems
- Article 694, Wind Electric Systems
- Article 705, Interconnected Electric Power Production Sources
- Article 712, Direct Current Micrograds

The most important article for fuses is Article 706.31: Overcurrent Protection 2020.

Below is a summary of the most important points:

- Circuits shall be protected at the source from Overcurrent
- Overcurrent Protection
  - Sized at not less than 125 percent of maximum current (discharge RMS current)
  - Must have a DC rating when used in a DC and have the appropriate Interrupting Rating.
  - must be listed and labeled current limiting
  - installed adjacent to the ESS for each DC output circuit
    - Exception: Additional current-Limiting over current devices are not required where current limiting Overcurrent protection is provided on the dc output circuit of a listed ESS
  - Shall be provided at the energy storage component end of the circuit where inputs and output terminal pass through a wall, floor or ceiling.
- Fuses must have a disconnecting means from all sources

B. BATTERY PROTECTION STANDARD

A new part of IEC 60 269 "Low Voltage fuses" is dedicated to battery protection IEC 60 269-7, Ed.1: Low Voltage Fuses: Supplementary Requirements for fuse-links for the protection of batteries and battery systems

This part defines 2 new utilization categories of fuses: aBat & gBat.

- "aBat" indicates fuse-links with a partial range d.c. breaking capacity for the protection of batteries and battery systems
- "gBat" indicates fuse-links with a full-range d.c. breaking capacity for the protection of batteries and battery systems.
- "gBat fuses shall be able to clear 2 times their rated current, tested at rated voltage (-0 / +5%).

For each one, the breaking capacity shall be higher than 30kA, tested at rated voltage (-0 / +5%).

For the same rated current, the characteristics of gBat or aBat (time current characteristics, clearing I^2t, power dissipation) fuses are different. Therefore the fuse selection, among these 2 categories, shall be done according to the electrical specification to ensure safety protection.

V. CASE STUDY

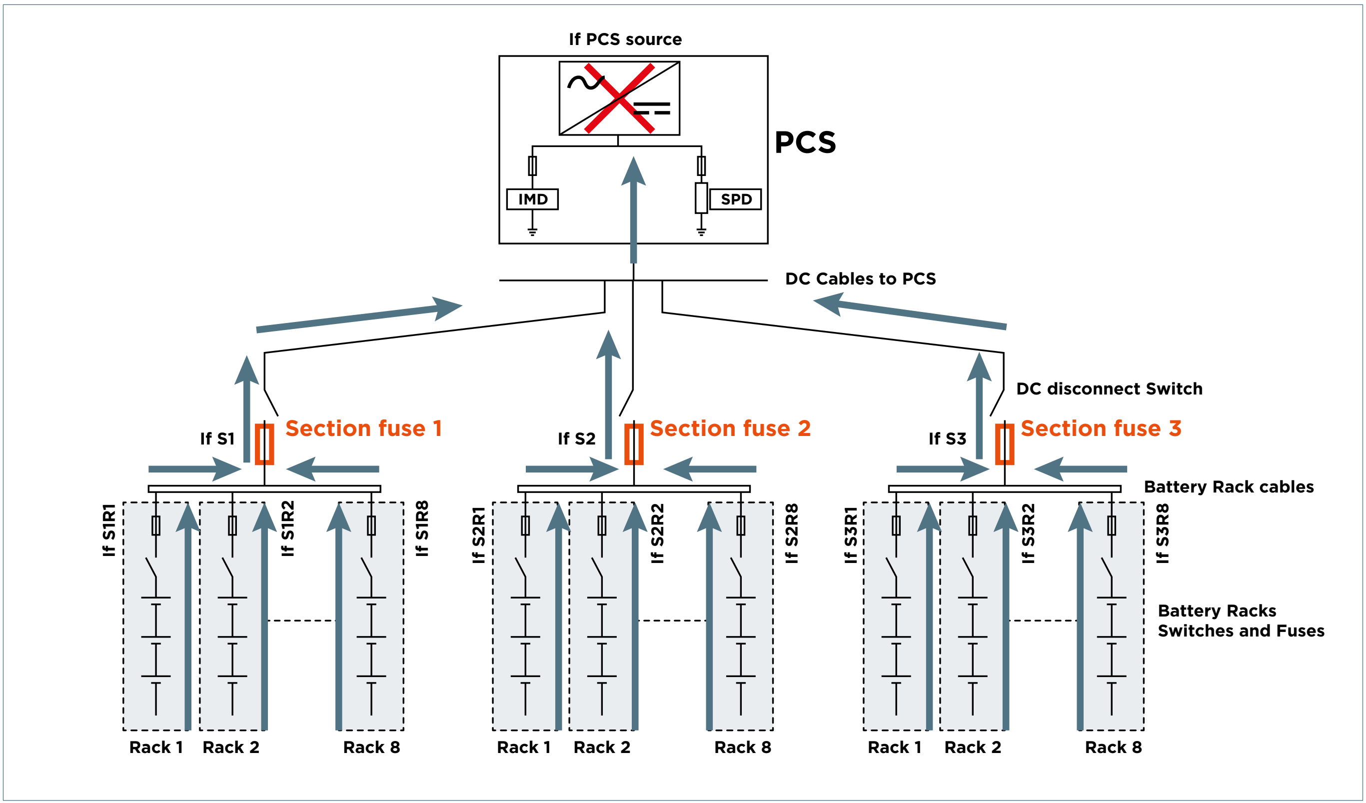
APPLICATION INFORMATION:

- 5MWH EES
  - V_{max} = 1216 VDC
  - V_{nom} = 1152 VDC
  - V_{min} = 1024 VDC
  - Fault current characteristics / rack:
    Prospective fault value: 7806A
  - $L/R_{sc\ PCS}$ = 0.68ms
  - Ambient temp. inside section = 40°C
  - Altitude <2000m
  - Number of racks: 8
  - Number of sections : 3
  - Max permanent RMS value : 50A/rack

APPLICATION REQUIREMENTS:

- Section fuses must coordinate with a fault in the PCS.
- PCS, max instantaneous current withstood : 100kA

FAULT LOCATION:



FUSE CURRENT RATING CALCULATIONS:

- Voltage
  - $V_n > V_{max} = 1216V_{DC}$ with $L/R > L/R_{sc\ PCS} = 0.68ms$
- RMS current calculation:
  - I_{rms}: 50A(8) = 400A
- Correction factors
  - Ambient Temperature: 40°C — $A_1 = 0.95$
  - Air Cooling: none specified — $B_v = 1$
  - Terminal Connection Size: section fuse — $C_1 = 0.9$
  - Altitude: <2000m — $C_{alt} = 1$
  - Variable Current: section fuse — $A'_2 = 0.82$
- Formula of section fuse rating current :

$$I_{Section\ Fuse} \geq \frac{I_{RMS}}{A_1\ B_v\ C_1\ A'_2\ C_{ALT}}$$

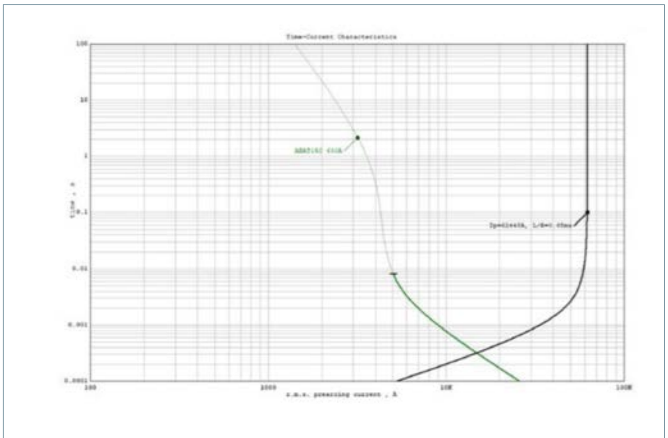
$$I_{Section\ Fuse} \geq \frac{400}{0.95 \times 1 \times 0.9 \times 0.82 \times 1} = 571A$$

  - A 600A fuse can be used for this application: ABAT15C600-AIA

  Rated voltage of ABAT15C600-AIA is 1500VDC (>1216VDC)

PEAK LET THROUGH VERIFICATION:

- Peak let through is limited by each section fuse.
  - Fault value at each section level
  - Prospective value: Isc section = 8*7806 = 62 448A
  - Time constant L/R = 0,68ms
- ABAT15C600-AIA melts in 0.32ms and would give a peak let through of 23.440kA



The total peak let through with for the PCS would be : 3*23.44 = 70.4kA

- 70kA < 100kA of PCS max instantaneous current withstood : the protection is ensured

ABOUT US

Mersen Electrical Power designs innovative solutions to address its client's specific needs to enable them to optimize their manufacturing process in sectors such as energy, transportation, electronics, chemical, pharmaceutical and process industries. We bring our expertise in fuses, surge protection, high power switches, cooling solutions and bus bars designed to meet your application challenges and to make them safe, reliable and profitable.

Visit ep.mersen.com for more information.

CUSTOMIZED FUSES

Our customized fuses can address customer's unique application needs in a quick and reliable fashion. Mersen has implemented this service in order to provide solutions for our customers that are requesting rapid design, development, and manufacturing of specific products.

IN-HOUSE TESTING CAPABILITIES

Fuse selection can often be complex, especially for EES as developments are going faster than international electrical standards. Mersen is able to offer customers an accurate, reliable and confidential process for testing and qualifying products, applications and design concepts, as well as testing to a wide variety of regulatory standards.
The test center actually houses five labs, for both AC and DC high power, electrical performance, PV solar, mechanical, and environmental and process tests through two laboratories — one in Newburyport, Massachusetts, USA and the other in Lyon, France. Our labs also play a critical role in custom-fuse development, enabling us to test prototypes quickly and efficiently to keep pace with customer's development schedule. The labs are an essential part of our quality control program. The test labs have accreditation and approvals from all the main global agencies, including COFRAC, ASEFA, LCIE, VDE, UL, CSA, ISO/IEC 17025, etc...

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