Mersen solutions for EV/HEV

Thomas Edison electric car (1913)
EV/HEV MARKET SEGMENT PERFORMANCE ADDED-VALUES

Electric Power

Duty-cycle severity
(Request for fast charge/discharge)

Bubble diameter: relative market size by 2020

10kW
Low

100 kW

200kW

> 250kW

Non-premium Car BEV

Non-premium Car HEV

Premium Luxury Car

BEV

BEV

BEV

BEV

e-truck

Sport car

e-bus

Standard cooling technology
Standard fuse technology

Improved cooling technology
Advanced fuse technology

Advanced cooling technology
Advanced DC over current protection technology

Laminated Busbar connections

Busbar electric connections

Cable or PCB electric connections

(10kW to 100 kW)

(100 kW to 200 kW)

(200 kW to > 250 kW)
**What Mersen Product for What Function in EV?**

- **EV pack fuse**
  - Main DC fuse
  - Auxiliaries DC fuse
  - Hybrid OCPD
  - Hybrid DC Power Relay

- **Battery Pack / BDU / MSD**

- **PDU: Power Distribution Unit**
- **BDU: Battery Disconnect Unit**
- **MSD: Maintenance Safety Disconnect**
- **OCPD: Over Current Protection Device**
- **SPD: Surge Protection Device**

Illustration courtesy of Renault™
LAMINATED BUSBAR
SMART MONITORING BUSBAR TO HANDLE BOTH HIGH POWER AND SMALL SIGNAL IN A SINGLE CONNECTION SOLUTION

- **All-in-One Connection Solution:**
  - Connect Li-ion or supercap cells together
  - Monitor small signals such as
    - Individual cell voltage
    - Local temperature

- **Customer’s Benefits:**
  - Ease assembly process
  - No wiring errors
  - Reduced voltage drop
  - Increase current carrying capability
  - High resistance to shocks and vibrations
**WATER-COOLED BUSBAR TO HANDLE CRITICAL THERMAL APPLICATIONS**

- **TEMPERATURE RISE MANAGEMENT FOR:**
  - Battery modules
  - Capacitor bank
  - High power density inverter

- **CUSTOMER’S BENEFITS:**
  - Hot-spot elimination
  - Dielectric extended life-time
  - Metal cost saving (can use thinner copper)

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**Comparison of the temperature (in °C) between 2 busbars of 3 mm with cooling & without cooling**

- **Copper 3mm**
  - Average Temp.: 43.5°C
  - Reduces Temperature by 23°C

- **Copper 0.8mm**
  - Average Temp.: 86.5°C
  - Reduces Temperature by 58.5°C
Mersen Busbar in EV/HEV Industry

Mersen Smart-Busbar in Mercedes S400 Hybrid

39 cells in series, 4 thermal sensors, voltage sensor on each cell
385 Vdc battery pack, 6.8 kWh, up to 600A peak
Every smart busbar includes:

- 6 temperature sensors
- 5 voltage sensors

- Copper bar 2 mm
- Small signal connector
- PET dielectric
- Temperature sensors

Mersen Busbar in EV/HEV industry

Mersen busbar in EV trucks (15 tons / 400Vdc)
MERSEN BUSBAR IN EV/HEV INDUSTRY

MERSEN BUSBAR FOR SUPERCAPACITOR BANK IN STATIONARY STORAGE

- Busbar for 4x5 cells
- Tin plated
- 54V
- 150A
- -40/+65°C
- Laser welding
- Easy of installation
LBB Design: A Complete Simulation Tool-Set

**Mechanical Simulation**
- Optimization of part placement to save space in the final assembly
- Ensure mechanical constraints of heterogeneous materials

**Electrical Simulation**
- Contact routing to meet clearance & creepage
- Current distribution compliant with admissible current density (A/mm²) to limit self-heating
- Inductance simulation

**Thermal Simulation**
- Current flow heating-up by Joule effect in the conductors
- Power Modules create hot-spots at top terminals level
- Prevent too many heat at capacitor ends
COOLING
BATTERY & INVERTER

Customer A
Customer C
Customer B
Customer D
THREE COOLING TECHNOLOGIES

- To meet customer’s needs at the closest

![Diagram showing three cooling technologies: Air Cooling, Phase-Change Cooling, Liquid Cooling.](image_url)
Three core industrial know-how to manufacture best-in-class cooling products

Vacuum brazing: a key step to seal our liquid cold-plates
- High thermal performance in a monolithic piece
- Perfect water-tightness guarantee
- High pressure withstanding (70 bars and up!)
- No risk of corrosion
- Long lifetime > 20 years

Swaging: a cost-effective and reliable technology for heat-sink fins assembly
- Increase heat transfer surface area over extruded profiles
- Swaged heat sinks offer 14% performance increase over glued fin solution
- Different standard spacing are developed to address challenging thermal applications

Heat-pipe assembly: a phase-change technology for most-demanding applications
- High thermal performance
- Temperature homogeneity for power module baseplates
- Instant cooling
- Smoothen temperature peaks
- Maintenance-free
Mersen Cooling in EV/HEV Industry

Mersen Cooling-Plate for Siemens ELFA Hybrid-Bus Drives

Liquid cooling plate for hybrid-bus 50 kW to 180 kW motor inverter
Mersen Cooling in EV/HEV Industry

Mersen Cooling Plate for EV Battery Pack

- Chinese manufacturer
- Passenger cars
- Pin Fin plates to cool down 24 cells single-sided
- 4 plates per battery pack per car
- Brazed connectors
Mersen Cooling in EV/HEV Industry

Mersen Cooling Plate for EV Battery Pack

- Cools down 12 cells on each plate
- Chinese car manufacturer
- 6 plates per pack per car
DC Over Current Protection
## DC PROTECTION AT MERSEN: 3 TECHNOLOGY PATHS

<table>
<thead>
<tr>
<th></th>
<th>Monolithic technology</th>
<th>Hybrid technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product range</strong></td>
<td><strong>EV pack-fuse m-fuse</strong></td>
<td><strong>χp series</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>χs series</strong></td>
</tr>
<tr>
<td><strong>Core technology</strong></td>
<td><strong>DC-Fuse</strong></td>
<td><strong>Pyro + clearing elements</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Semiconductor + Switch</strong></td>
</tr>
<tr>
<td><strong>Value-proposition</strong></td>
<td>Ultra fast-acting fuses (for large fault currents)</td>
<td>Fast-acting protection &lt; 1ms</td>
</tr>
<tr>
<td></td>
<td>Cost-effective &amp; proven technology</td>
<td>Low-cost technology</td>
</tr>
<tr>
<td></td>
<td>DC specific design</td>
<td>Close-to-zero conduction loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Operates for small or large fault current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fully configurable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very compact size</td>
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<tr>
<td></td>
<td></td>
<td>High cycling performances</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High inrush current capabilities</td>
</tr>
<tr>
<td><strong>Visuels</strong></td>
<td><img src="image1.png" alt="Visuals" /></td>
<td><img src="image2.png" alt="Visuals" /></td>
</tr>
<tr>
<td></td>
<td><img src="image3.png" alt="Visuals" /></td>
<td><img src="image4.png" alt="Visuals" /></td>
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</tbody>
</table>
**Typical EV/HEV Protection Topology and Devices**

**Main Battery Pack**
- 1 to 16 battery modules assembled in series/parallel
- (1 fuse per module → up to 16 fuses)

**Maintenance Safety Disconnect MSD**
- (1 fuse + DC contactor)

**Inverter + Motor**
- 450 → 1,000 V
- Up to 800 A

**Junction Box / Battery Disconnect Unit BDU**
- (4 to 8 fuses)
- 450 → 1,000 V
- 10 → 200 A

**Main Battery Pack Diagram**
- 48 V / module
- Up to 200 A / module

**Maintenance Safety Disconnect MSD**
- 450 → 1,000 V
- Up to 800 A

**Inverter + Motor**
- 450 → 1,000 V
- Up to 800 A

**Junction Box / Battery Disconnect Unit BDU**
- (4 to 8 fuses)
- 450 → 1,000 V
- 10 → 200 A
3 FAMILIES OF PROTECTION AND OPERATION DEVICES FOR DC APPLICATIONS

- Hybrid DC power relay
  - $\chi_s$ series

- EV Battery Pack fuse Protection
  - MSD / BDU / Junction Box

- EVpack-fuse

- Hybrid DC protection
  - $\chi_p$ series

- Battery Module Protection
  - M-fuse
4 DC FUSE SERIES FOR BATTERY PROTECTION

- **MEV100 series**
  - 1,000 $V_{DC}$ - 8 to 600 Amp
  - 700 $V_{DC}$ – 35 to 600 Amp

- **MEV70 series**
  - 700 $V_{DC}$ – 35 to 600 Amp

- **MEV55 series**
  - 550 $V_{DC}$ – 5 to 50 Amp

- **MF series**
  - 100 $V_{DC}$ - 50 to 200 Amp
9 FUSE PRODUCTS LINE-UP FOR BATTERY DC PROTECTION

* MEV70V. Specifically designed for large inrush current
MERSEN EVpacked-fuse have been designed to match DC contactor operation. MBC value matters...

- Matching DC contactor with DC fuse is not trivial. Contactors offer a limited max. breaking capacity value beyond which the fuse must clear the circuit in the eventuality of a default. Typical matching scheme looks like:

- Mersen EVpacked-fuse line-up has been designed to protect DC contactors, offering MBC values <3kA over the full range.
The Xp system is composed by fast acting pyro element, controlled by a gate current, plus a parallel clearing element.

This protection meets custom requirements of very fast operating time and very high overload current.

Main features and Benefits

- DC application focused design
- Extremely low watt losses (~20W / 400A)
- Excellent cycling performance
- Ultra-fast acting (300 µs)
- Small footprint
- Large inrush current: 15 In for 100 ms
- Self-triggered and/or external triggering
- Tunable Time-Current curve and Minimum Breaking Capacity (MBC) value

Electric data – main circuit

<table>
<thead>
<tr>
<th>Electric Data</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Voltage</td>
<td>Up to 1,000 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Nominal Ampere In</td>
<td>Up to 800 A</td>
</tr>
<tr>
<td>Max breaking capacity</td>
<td>15 kA @ 1000 V&lt;sub&gt;DC&lt;/sub&gt; with L/R = 2 ms</td>
</tr>
<tr>
<td>L/R max</td>
<td>5 ms</td>
</tr>
<tr>
<td>Power dissipation at In</td>
<td>20W @ 25°C</td>
</tr>
<tr>
<td>Gate Control current</td>
<td>2A – 10A (2ms)</td>
</tr>
<tr>
<td>Gate Control resistance</td>
<td>2.2 Ω</td>
</tr>
<tr>
<td>Temperature range</td>
<td>-40°C to +90°C</td>
</tr>
</tbody>
</table>
EV: HYBRID DC POWER RELAY

- XsEV have been engineered to provide high DC switching performances versus conventional mechanical power relay.
- XsEV provides maximum flexibility in equipment design and ultimate DC operation performance. This Power Relay is a Hybrid technology with the capability of switching both high voltage and high current designed specially for electrical vehicle applications.

Main features and Benefits
- Designed for DC applications
- Bidirectional
- Arc-less
- Reduced footprint & mass
- Low conduction losses
- Repeatable current make/break capability for resistive & inductive loads at full rated voltage and current
- Enhanced cycling performances
- Built-in turn ON fault detection

Electric data – main circuit

<table>
<thead>
<tr>
<th>Device current polarity</th>
<th>Bidirectional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal voltage</td>
<td>500 / 1000 V&lt;sub&gt;DC&lt;/sub&gt; (1200 V&lt;sub&gt;DC&lt;/sub&gt; soon available)</td>
</tr>
<tr>
<td>Continuous current</td>
<td>300 A</td>
</tr>
<tr>
<td>Max. ON switching current</td>
<td>1000 A</td>
</tr>
<tr>
<td>Max. OFF switching current</td>
<td>500 / 1000 / 1500 / 2000 A</td>
</tr>
<tr>
<td>L/R max.</td>
<td>≤ 5 ms (for higher ratings please consult Mersen)</td>
</tr>
<tr>
<td>Overvoltage during current clearing</td>
<td>Typ. 1400 V @ 500V&lt;sub&gt;DC&lt;/sub&gt; – 2000 V @ 1000V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Number of cycles versus current and L/R</td>
<td>&gt; 20 cycles at 2000 A / 500 V&lt;sub&gt;DC&lt;/sub&gt; / L/R = 0.5 ms</td>
</tr>
<tr>
<td>Lifetime (mechanical)</td>
<td>&gt; 100 000 cycles</td>
</tr>
<tr>
<td>Insulation resistance</td>
<td>&gt; 100 MΩ (initially)</td>
</tr>
<tr>
<td>Dielectric strength</td>
<td>3000 V&lt;sub&gt;DC&lt;/sub&gt;</td>
</tr>
<tr>
<td>Internal contact gap</td>
<td>3 mm (2x1.5 mm)</td>
</tr>
<tr>
<td>Contact voltage drop</td>
<td>150 mV</td>
</tr>
</tbody>
</table>

A DC power relay that can repetitively clear up to 2kA at 1,000 V<sub>DC</sub>!
## DC protection offer at Mersen: Summary

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<td>DC-Fuse</td>
<td>Pyro + clearing elements</td>
</tr>
<tr>
<td></td>
<td>EV_pack-fuse</td>
<td>χ₀ series</td>
</tr>
<tr>
<td></td>
<td>M-fuse</td>
<td></td>
</tr>
<tr>
<td><strong>Resettable</strong></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Time to clear high fault current</strong></td>
<td>Excellent, 10 of μS</td>
<td>Good, 100’s of μs</td>
</tr>
<tr>
<td><strong>Time to clear low fault current</strong></td>
<td>Slow to melt 10’s of seconds</td>
<td>Excellent Down to 100’s of μs</td>
</tr>
<tr>
<td><strong>Cycling performance</strong></td>
<td>Application dependent</td>
<td>Excellent</td>
</tr>
<tr>
<td><strong>Conduction losses</strong></td>
<td>80W (400A)</td>
<td>20 W (400A)</td>
</tr>
<tr>
<td><strong>Tunable Time-Current curve</strong></td>
<td>Limited</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Self-triggered</strong></td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Mersen: establishing DC protection rules...