POWER AND SIGNAL CONNECTIONS INSIDE LITHIUM-ION & ULTRACAPACITORS BATTERY PACKS ARE NOW MANAGED BY *MERSEN MONITORING BUS BAR*

POWER ELECTRONICS NOTE 3

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INTRODUCTION

Li-ion battery packs and ultracapacitor packs are spreading everywhere. According to Frost and Sullivan, the global lithium-ion battery market was worth $11.7 billion in 2012 and is expected to nearly double by 2016 to $22.5 billion. Similarly, Transparency Market Research notes that the global ultracapacitors market was worth USD $0.672 billion in 2012 and is expected to reach USD $3.12 billion in 2019. Diversification of applications and the global increase in demand for lithium-ion and ultracapacitor battery packs forces manufacturers to continually find innovative solutions to both improve their battery packs' performance and decrease assembly time. *Mersen Monitoring Bus Bar* is the way to achieve these goals, integrating power and signal circuits into a single system.

DEFINITION & OVERVIEW

Mersen Monitoring Bus Bar is defined as "an electrical interconnect solution for virtually any electrical energy storage system such as battery packs, capacitors, and ultracapacitor banks that are used in series to achieve an engineered power level."

First consider how battery power connections are ordinarily made: a series of small copper bars (or straps) are installed, one at a time, to join a power cell together. Others may use a PCB design or cables to join cells together. All of these methods have limits associated with them, such as extensive handling, long assembly times, interconnect wiring errors, or with the case of a PCB, limited current carrying capacity. *Mersen Monitoring Bus Bar* easily solves these problems giving the user improved product quality.

Connecting battery cells through individual straps, while inexpensive, are a nuisance to handle; and when using cables to connect cells together, wire gauge sizes are rarely the right size to accommodate the amount of current, they are often oversized.

GLOSSARY

- **Ultracapacitor:** Electrical component capable of holding hundreds of times more electrical charge quantity than a standard capacitor.
- **Lithium-ion battery:** Type of rechargeable battery with one of the best energy-to-weight ratios, no memory effect and a slow loss of charge when not in use.
- **Flex circuit:** Thin insulating polymer film having conductive circuit patterns affixed thereto.
- **Bus Bar:** A passive component that allows electrical connection between passive and active components while limiting the parasitic inductance.
- **IACS:** Abbreviation for International Annealed Copper Standard and the number preceding "IACS" is the percentage of conductivity a material has relative to copper, which is considered to be 100% conductive.

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Mersen Monitoring Bus Bar is engineered to carry only the precise amount of current needed; and when replacing cables will eliminate a multitude of crimped connection points that could harm the system's performance through reduced efficiency and hot spots.

Second, it is well known that modern battery packs are precisely tuned systems that require constant monitoring for both safety and performance. This monitoring is handled through signal connections on each cell, which usually means a small wire harness attached manually that carries the data to an outside processor. *Mersen Monitoring Bus Bar* includes a flex circuit directly integrated into the bus bar network, thereby eliminating the set-up time needed for attaching the wires harness. This allows collecting the signals from each cell independently, so the status of each cell is delivered to the Battery Management System via a custom connector.

APPLICATION FIELD

Mersen Monitoring Bus Bar addresses all the markets that potentially use lithium-ion battery packs or ultracapacitor packs:

- Among them is the hybrid and electrical vehicle market with niche applications ranging from two-wheeled vehicles such as e-bikes and e-scooters, to four-wheeled vehicles like e-cars, e-buses, e-trucks, and various people or material handling vehicles.
- Today's traction market is also a perfect target with the growing number of modular Li-ion solutions for onboard regenerative hybrid traction battery systems. These provide substantial financial benefits, energy efficiency, and reduced environmental impact by enabling the rail operators to capture, store, and reuse rolling stock braking energy for trains, metros, or tramways.
- The industrial market is also one the main targets for the flex bus bar with segments like medical devices, data collection, aerospace and defense, telecom and data communication, and of course, the energy storage segment to store renewable energy from wind turbines or photovoltaic systems (residential energy storage and community energy storage including on-grid and off-grid systems).

Packs based on cylindrical and prismatic cell types are a particularly good fit for *Mersen Monitoring Bus Bar* since the power and signal connections are often made in the final step of the assembly process. The cell terminals are arranged in such a way that provides a planar surface, thus the *Mersen Monitoring Bus Bar* can be easily installed as a single unit at the end of the manufacturing or assembly process. Orientation of the cell terminals in pouch cell type packs and their usual vertical assembly process can also benefit from the *Mersen Monitoring Bus Bar* with the same system performance as conventional cells, though the physical layout and connection points differ from conventional battery type cells.

Figure 1: Mersen Monitoring Bus Bar ready to plug on lithium-ion cylindrical cells of a battery pack for electric vehicles.

KEY BENEFITS FOR MANUFACTURERS

The benefits of the *Mersen Monitoring Bus Bar* affect all departments: from purchasing, technical engineering, production, and logistics. As mentioned previously, *Mersen Monitoring Bus Bar* offers a highly integrated solution because all the power and signal connections are made using a unique device. This results in improved inventory management and faster assembly time since there is no longer the need to use multiple copper parts to make the power connections, nor to use multiple delicate signal wires to collect the data from the different cells. Wiring errors for both power and signal are also completely eliminated because the *Mersen Monitoring Bus Bar* takes care of all the wiring once it is installed on the battery or ultracapacitor pack. Today, in many manufactured configurations, the signal wires are hand attached via screws onto the copper power bars. The future with the *Mersen Monitoring Bus Bar*, the flex bus bar system utilizes a highly engineered and precision controlled welding technique to assure the best possible quality when the signal is processed by the battery management card. Also, as the cells within the pack have to withstand micro-movements during their regular use, for instance during their charge/discharge process, the *Mersen Monitoring Bus Bar* easily compensates for these variations especially when compared to a PCB solution which by its nature is much more rigid, and may be damaged by such routine movements.

If needed, the *Mersen Monitoring Bus Bar* can withstand more power than a PCB card, since the copper bars can be designed and dimensioned according to whatever electrical density and thermal requirements are needed. In this context, a water cooled system can be integrated into the system to decrease the temperature level and allow the battery pack to generate even more power in a reduced space.

Finally, because of the fully integrated design of the *Mersen Monitoring Bus Bar*, automated or robotic assembly is an option for joining it directly to the battery pack.

CHARACTERISTICS

Mersen Monitoring Bus Bar can be engineered to fit for packs ranging from a few W up to several MW. The power conductors of the *Mersen Monitoring Bus Bar* are in general copper, but aluminum can also be used depending on customer requirements. Most of the time copper bars are preferred for their outstanding electrical and thermal conductivity performance. Thickness of copper bars is typically between 0.5mm to 4mm, but thinner or higher thicker components can also be considered. Electroplating options like tin or silver exist in order to address corrosion risks and to decrease the contact resistance between *Mersen Monitoring Bus Bar* and the energy cells.

Aluminum conductors are sometimes used as a cost/ performance alternative and where weight is important, especially for electric racing cars where every gram counts. On the other hand, aluminum is approximately 60% as conductive as copper according to the IACS, requiring larger conductors to carry the same amount of current as copper conductors, and thus taking more physical space in the battery or ultracapacitor pack.

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Concerning the power section of the *Mersen Monitoring Bus Bar,* there is no real current limitation other than the pack available space, and there is no real voltage limitation either since a single insulation layer within the system has a dielectric strength above 18kVAC. The typical design rules for the power connection bars is based on a current density of 5A/mm² for applications below 300A, and depends on specific charts above 300A, to take into account the thermal considerations throughout the battery system and its environment. As mentioned previously, the signal connections of the *Mersen Monitoring Bus Bar* system are designed into a flex circuit that is spot welded on each power bar. This way, the flex circuit delivers complete information directly from each cell of the pack to the main management device, using a customer defined connector. The information collected is generally the voltage level, the charging state, and the temperature level through thermal sensors that are integrated on the *Mersen Monitoring Bus Bar* as desired.

In addition to thermal sensors, other components can also be integrated on the flex bus bar, such as water cooling pipes or fuses.
The insulation material is selected and sized according to the requirements of the application in terms of temperature, pollution degree, and percentage of humidity of the direct environment. Thus, a wide range of insulation materials can be used to permanently withstand temperatures ranging from -40°C up to 220°C. This includes PET (polyethylene terephthalate), Aramid paper, PEN (polyethylene naphtalate), PVF (Polyvinyl fluoride), and PI (Polyimide).

Depending on customers' specifications, *Mersen Monitoring Bus Bar* can be mounted to the cell pack using a variety of different ways, such as threaded fasteners or laser welding.

CONCLUSION

Thanks to its full integration of power and signal and ability to withstand higher power and temperatures, *Mersen Monitoring Bus Bar* is the perfect custom answer to the growing need of quick assembly and power increase of lithium-ion and ultracapacitor packs. It provides a smart alternative to PCB solutions or to power connections with separated copper bars. It solves substantial problems that manufacturers face, such as overheating, slow assembly process of the cells, risk of cabling errors, and the need for flexibility during the charge/discharge process to allow micro-movements of the cells without altering the power connections. The same way, *Mersen Monitoring Bus Bar* provides significant benefits in signal connections, allowing a perfect quality of signal with a spot-welded connection in the delivery of data information to the main management system such as voltage, charging state, and temperature from each single cell of the pack. It also avoids the time-consuming and often messy organization of the signal wires that many manufacturers face when they assemble each signal wire separately on each power bar. In addition, components such as thermal sensors, fuses, or complete water cooling systems can be integrated on *Mersen Monitoring Bus Bar* to allow the battery pack to generate even more power in a reduced space. This innovative technology is already running in mass production in automotive and storage applications, and chances are that it becomes a standard technology among lithium-ion and ultracapacitor manufacturers in the years to come.

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