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Advanced Cell Interconnect Structure for Improving Battery Performance While Maximizing Cost Efficiency

New approach enables smoother current distribution across the battery pack, thereby helping to mitigate unwanted hotspot formation in the constituent cells

By Till Wagner, Product Manager, Energy Systems at ENNOVI (formerly known as Interplex)

The battery pack is the most vital element of any electric vehicle (EV). It is through this that the electricity needed by the drivetrain is supplied. The battery also represents the most expensive part of an EV - having a major influence on its overall bill-of-materials (BoM) costs. Ensuring that it delivers prolonged operation is therefore essential. The following article will look at the role that interconnects are going to play in extending the battery pack lifespan.

There are several key objectives that automotive manufacturers need to address when developing EV models. In order of priority these are:

4. Keeping the BoM costs down. Currently EVs are significantly more expensive than internal combustion engine (ICE) vehicles of an equivalent class, and this is still proving problematic for a large proportion of the car buying public. If automotive manufacturers are going to minimize the effects of this pricing discrepancy, then substantial effort is needed to make both production and raw material cost savings wherever possible.

5. Stretching the distance that their vehicles can travel before needing to be recharged - so as to allay car buyers' "range anxiety" concerns that they might run out of battery power before being able to get to somewhere with a charging point. The range that an EV is able to attain will be determined by both the energy storage capacity of the battery pack and the weight of the vehicle. A vehicle model that has a larger, higher density battery pack, alongside a more lightweight construction, will have clear advantages. These attributes are going to help lengthen the range supported, offer greater convenience for users (by not having to charge up their vehicles so regularly) and heighten the EV's market appeal.

6. Keep the battery packs employed in their EVs in a good state of health, so that it is a long period before they need to be replaced. With the battery constituting a considerable proportion of the total cost of ownership (TCO) of the vehicle, having to replace it is something that owners will want to avoid having to do too soon.

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Furthermore, if their vehicles' batteries exhibit relatively brief lifespans, this will reflect badly on the reputation of the automotive manufacturer.

Types of battery cell

In an EV, the foundation of the energy storage relies on cells. These cells are stacked up within a module, and multiple modules are contained within a battery pack. There are three basic forms of cell that can be used in EV battery packs, namely:

4. Cylindrical - Their shape helps to minimize stress and internal pressures, including prevention of swelling. Based on today's components, they are the smallest type of battery cells in usage. This means that more of them will be needed to fill a module and, as a consequence, a greater number of connections will be mandated.

5. Prismatic - These are rectangular-shaped cells enclosed in rigid casings, that are generally larger than cylindrical ones. Even more important is the fact that fewer connections are needed (so less welding work is required). This means they are better aligned with the streamlined EV production procedures the automotive manufacturers are looking to implement.

6. Pouch/polymer - These cells are very similar to prismatic ones. The main difference is that, instead of being enclosed within a rigid casing, they are sealed inside a laminated foil pouch. Offering the ability to be produced in various different shapes, pouch/polymer cells achieve elevated levels of packaging efficiency. They do have drawbacks though, including being prone to swelling and also there being greater risk of their exteriors being punctured or damaged, hence needing a solid case structure to protect them.

Battery module development

There is a steady progression now underway within the battery sector to reduce the number of modules in EV battery packs. Modern packs often comprise just a few modules, each with many cells being contained inside them. Doing so is helping to increase battery storage capacity (as there is less redundant space), as well as making battery packs less complex and keeping their production costs down. Over time this will lead to the adoption of "cell-to-pack" arrangements, with no modules involved at all. This will eliminate components that take up space, which can then be assigned to greater storage, as well as making the batter pack lighter. This change over time will be carefully balanced against the safety aspects of larger battery entities.

How cells contained with modules and battery packs are connected to their accompanying can have serious implications - not only in relation to the system's effectiveness, but also in terms of the associated manufacturing costs. The selected interconnect solution will need a combination of characteristics that will make it favorable for EV deployment.

Conventional EV battery module interconnect assemblies will normally be made from an aluminum-based alloy, as this is more cost-effective than copper-based alloys and lighter. For certain cell types, they can be quite intricate, requiring multiple layer constructions and having elements that differ considerably in thickness. The metal thickness variations and how the current travels through the interconnect causes there to be a lack of uniformity in the current density distribution, and the heat distribution accordingly.

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Not having an even energy density spread, and generating unwanted hot spots, will have knock-on effects with regard to the battery pack lifespan. Such inconsistencies will result in increased likelihood of certain cells aging earlier than expected. A battery is only as good as the least effective of its cells, so if several of them start aging too quickly (and the state of charge they can handle is diminished), the whole module will need to be replaced before it should have been necessary.

Though there are means of cell balancing, compensating for the poorer performing or worse connected cells. In the real world there are limits to balancing though, particularly as battery packs are getting larger, with the number of cells increasing per module.

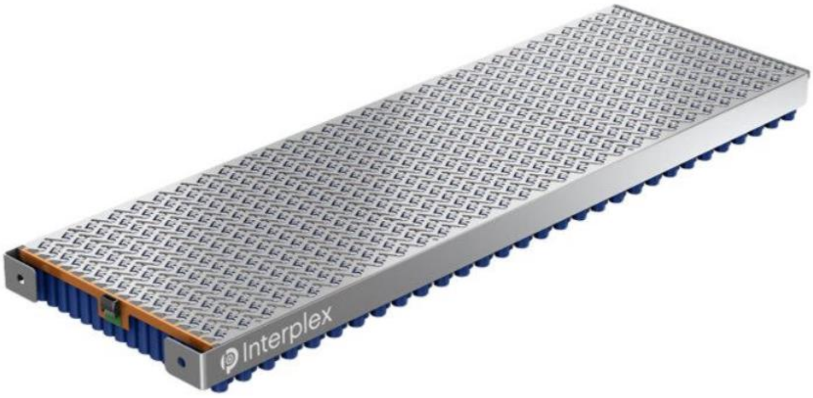

Figure 1: A battery pack assembly featuring ENNOVI (formerly known as Interplex) Cell-PLX™ interconnect technology

Cell interconnect optimization

The ENNOVI (formerly known as Interplex) Cell-PLX™ battery interconnect system is capable of supporting EV battery modules based on both cylindrical and prismatic cells, with laser welding being utilized for cell attachment. This features a unique approach that maintains current density consistency across all the cells it is connected to. The upshot is that it places far less stress on individual battery cells, thereby keeping battery packs in operation for longer.

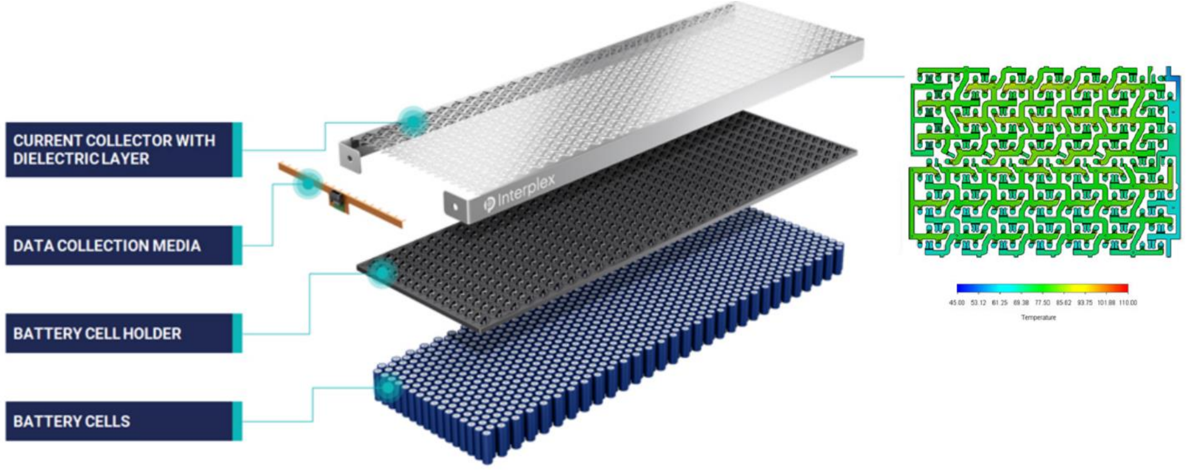

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Figure 2: The proprietary U-Turn design developed by ENNOVI (formerly known as Interplex) delivers better current density and temperature distribution in EV battery interconnects

By leveraging precision engineering, the thickness of the interconnect can be altered in the required areas - for example, less material in the cell tabs, and more material in the main current paths. Because it is thinner, with a layer being saved, more space is left for energy storage. Furthermore, less metal conductor material is needed, and that means there is less heat that needs to be dissipated.

An inability to remove heat effectively will put more acute strain on the battery cells, accelerating how soon they reach an end-of-life situation. Although other interconnection solutions can potentially get around the heat issue by adding extra insulation, that will only add to the BoM costs. Otherwise the only other thermal management option will be to accentuate the cooling system. This could either be done by specifying a larger cooling system, that takes up space, or run it with more power. Either way more electricity will be drawn - which would mean less battery charge is available for propulsion (and less range can be covered by the vehicle).

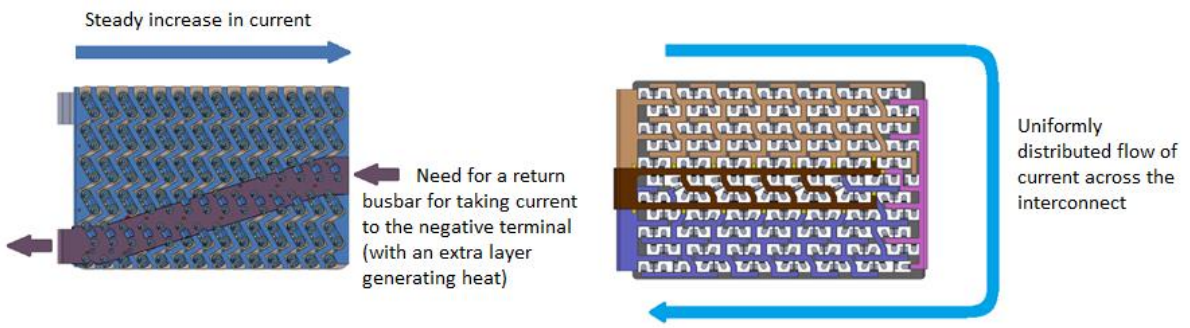

Figure 3: Comparison between the current dispersion in a conventional EV interconnect and one using U-Turn technology

The patented U-Turn technology achieves a much more uniform distribution of current density. Hence, formation of hot spots within the module can be mitigated. Standard interconnects use an additional return busbar (which represents a separate layer and a source for generating extra heat). In contrast, with U-Turn the energy flow is markedly better organized as it moves from the positive to the negative terminal, and only one single conductor layer is needed which also benefits heat dissipation. This solution is fully scalable, enabling modules and battery packs of any conceivable size to be attended to. It is also fully applicable for the high-volume manufacturing demands of the automotive industry.

Conclusion

Having a long lasting battery resource is undoubtedly vital if EV models are going to be attractive to the car-buying market. Maximizing the lifespan of individual cells within the battery pack is thus absolutely paramount. The uneven current and heat distribution exhibited by existing battery interconnects contributes to bringing cells closer to end-of-life at a quicker rate, as well as unnecessarily pushing production and materials costs upwards.

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Migrating to a better optimized for interconnect strategy, applied at a module or at a battery pack level, will bring numerous invaluable benefits to automotive manufacturers. Use of the right technology will result in interconnects that only subject cells to the same amount of stress, so that they age at approximately equal rates. They will simultaneously be simpler and less costly to implement too.

About the Author

Till Wagner is Product Manager Energy Systems at ENNOVI (formerly known as Interplex). He draws on over a decade of industry experience. Prior to joining ENNOVI (formerly known as Interplex), he held a succession of key roles in the industry. Till has an engineering degree from DHBW Mannheim and an MBA from FOM Hochschule.

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