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Tapping Secrets of Li-ion Cell Temperature to Improve Cold Performance

Explore the challenges and solutions for EV battery performance in cold weather, including state-of-charge monitoring and advanced temperature-management techniques.

Lithium-ion batteries are the mainstay in powering today's electric vehicles (EVs). A major challenge for EV makers has been cold weather performance, much of which boils down to poor lithium-ion cell performance at lower temperatures. While more advanced electrolytes may eliminate the issues in the future, for now, it's likely to be best addressed by more and better state-of-charge (SOC) and state-of-health (SOH) cell monitoring.

A key factor is optimizing those technologies and the battery-management system (BMS) for those colder temperatures. Temperature data can also help with battery safety management and SOH.

Temperature is a critical barrier to the rapid recharge of batteries. Specifically, fast charging at low temperatures increases the risk of lithium plating, which results in accelerated battery aging.

Since temperature significantly affects Li-ion batteries, considering the thermal state of batteries in the course of battery management is indispensable. Put simply, extreme temperatures are the enemy of these batteries.

Lithium-ion battery cells perform best in a temperature range between 15 to 45° (to a point). Colder temperatures reduce the output of the cells, decreasing range and available power. On the other hand, charging, particularly fast charging, works best at around 55 °. That temperature level reduces internal impedance and facilities the electrochemical changes involved in charging.

Optimizing Battery-Management Systems for Low Temperatures

Battery-management systems (BMS) are often designed to prepare cells for fast charging. The BMS may increase temperature by altering the flow of coolant to a battery pack. Or, if necessary and so equipped, internal heaters can be engaged to bring the cells closer to ideal charging temperature. An increased amount of higher-performing sensors can make this process work more effectively.

Sophisticated models in the BMS determine the best strategy for controlling the heaters and coolant flow. The temperature sensors at the cells and throughout the cooling system are needed to provide real-time data so that the model operates properly. A system that handles thermal management to this degree is often termed a battery thermal-management system (BTMS).

Of course, under warm conditions, a concern is that charging that is too rapid can raise the internal temperature of cells to the point where the battery degrades, perhaps even leading to a dangerous, thermal-runaway situation. A thermal runaway can lead to the release of inflammable gases, potentially leading to explosion or fire.

In cooler situations, especially below 15°, the BTMS may also be tapped to heat the battery as preparation for extracting energy to power the vehicle, or for recharging.

Without such heating, it slows the chemical action within the cell. In turn, it reduces the amount of power that can be extracted and increases impedance, which makes charging more difficult. Attempting to charge cells too quickly in these circumstances, in addition to the plating effect, can result in the formation of dendrites—branch-like crystals—that could potentially penetrate the cathode-anode separator. This could cause a short circuit, ruining the cell or worse.

Techniques for Monitoring Cell Temperature

One cell-temperature monitoring approach is to measure the external temperature of all cells or a large sampling by placing thermistors or thermocouples on them. This can get costly and complex, especially with hundreds of cells involved.

Even if a large percentage of cells have sensors, external measurement may not show the rapid changes in internal temperature during charge and discharge activities, or as external temperatures vary. At the very least, an external sensor will experience some delay in registering internal temperature changes. Embedding sensors internally within the cell would be a nice potential solution—except that it's impractical.

The most promising approach, therefore, is estimation of cell internal temperature through examination of measurable signals such as current, voltage, impedance/resistance, perhaps combined with surface temperature data.

Engineers want to be able to explore bulk temperature of whole packs, core temperature of cells as well as surface temperatures of cells and temperature distribution. Taken together, this information can paint a much clearer picture of battery thermal state and health.

There are electrical approaches to indirectly measure battery temperature based on impedance and resistance.

Impedance spectroscopy, for example, can be measured based on response to an excitation current signal or voltage signal. Generating excitations over a wide range and determining impedance can result in an indirect indicator of internal electrochemistry and processes. Variations in temperature are linked to variations in electrochemistry and, by implication, may indicate what is going on at the anode, for example.

Of course, SOC and SOH also impact both measurement and interpretation of those results. And there's nothing simple about turning this into a reliable measurement. Experimental data would likely be needed for each implementation before it could become a regular, reliable tool for battery management.

Researchers say using similar measurements of DC resistance as a proxy for cell temperature is simpler. However, it's less likely to yield details about the actual internal cell electrochemical processes, since it only provides a general indicator of internal cell temperature. This "average" might significantly underestimate areas of high temperature or stress within a cell.

While there's no single means of achieving improvements in cell and battery temperature monitoring, particularly at low temperatures, achieving these improvements will help to make cells and batteries more efficient and durable.

Direct measurement is difficult and insufficient. Indirect means complex and expensive. Both will likely be needed to take cold weather battery management to a higher level of performance.