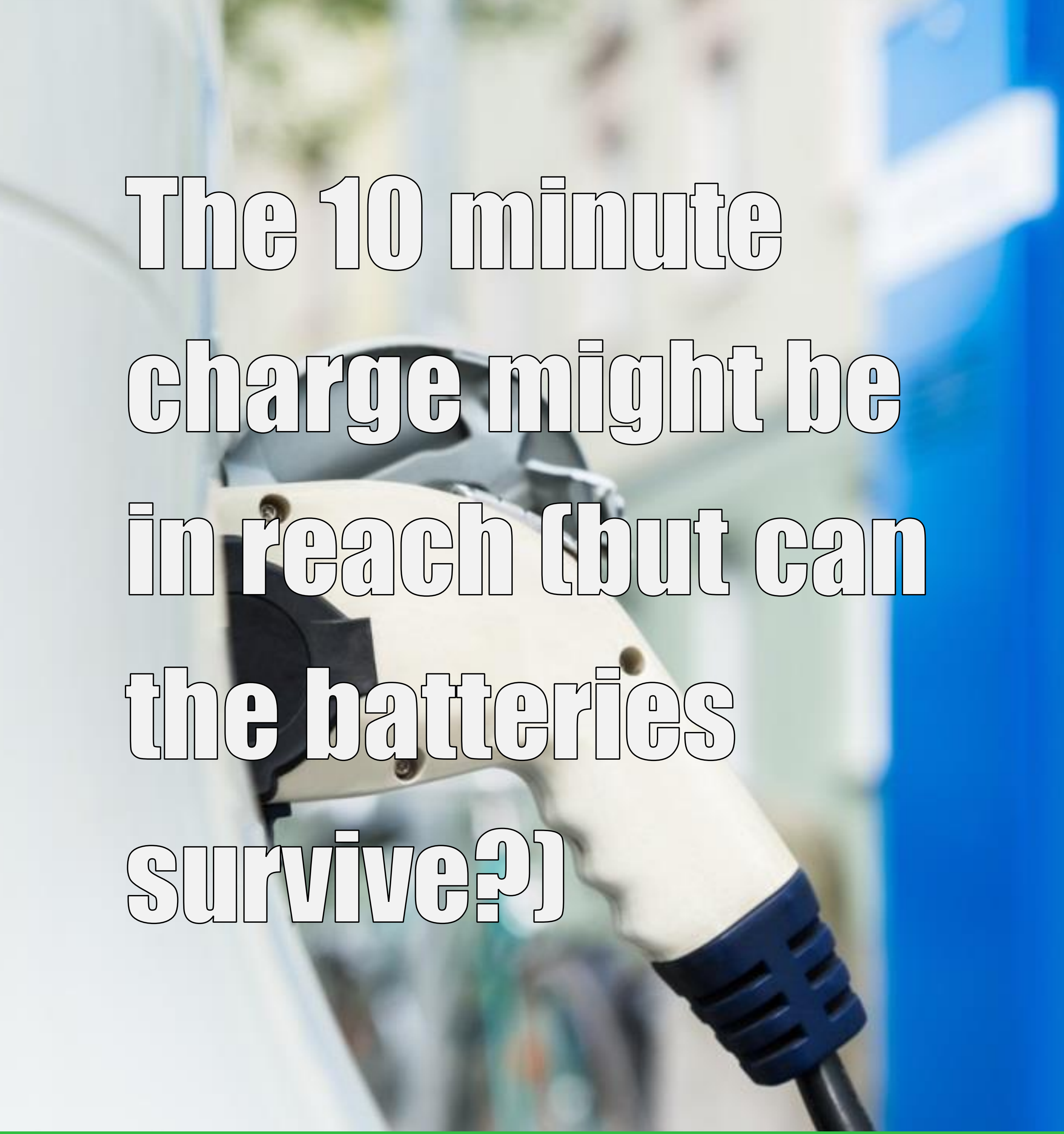

The 10 minute charge might be in reach (but can the batteries survive?)

Energy Management
& Battery Technology
for EV/PHEV

There's a popular saying that goes: "Time is money", and in the world of electrified mobility this has taken on a special meaning!

A common criticism of electric cars is that EVs take too long to charge. Of course, this is based on the prevailing driver's experience of petrol-powered cars where, in the course of a 10-minute pit stop, a few hundred kilometers worth of fuel can be charged. In contrast, electric car charging times are usually measured in hours rather than minutes. Interestingly, this pit stop which typically charges 50 liters of hydrocarbon fuel delivers approximately 600kWh, while current Li-ion batteries are restricted to about 150Wh per kg. To match current fuel energy storage in an electrochemical device the battery would weigh six tons.

Nevertheless the emergence of EV quick charging is closing the gap to the fueling experience of today's internal combustion automobiles. However fast charging, and more recently ultra-fast-charging, face significant technological challenges.

Fast-charging approaches drives expectations, but can the batteries survive?

Fast charging is the latest trend in the EV industry according to Mike Tinskey, Ford's director of electrification. It's especially useful when undertaking road trips, but also important for everyday use. If the lithium ion battery isn't overheated, it can get up to 80% of full charge in just 15 minutes, which is much more efficient than the typical charge time achieved through rapid charging.

Notwithstanding the significant reduction in charge times, common belief has it that DC fast chargers may result in battery degradation with overuse at high power rates of 25 or 50 kW (or 120 kW for Tesla's Supercharging network).

Li-ion batteries (LiB) with the traditional cathode materials of cobalt, nickel, manganese and aluminum typically charge to 4.20V/cell. The tolerance is +/–50mV/cell. Some nickel-based variants charge to 4.10V/cell; high capacity Li-ion may go to 4.30V/cell. Although higher voltages increase the capacity, exceeding the specification results in degradation of the cell and reduced service life.

This degradation is largely due to the deterioration of the Lithium Cobalt Oxide cathode at elevated temperatures. In particular, the formation and modification of surface films on the electrode as well as the structural/phase changes of the LCO electrode are found to increase the degradation rate of the maximum charge storage of LiB at any given operating temperature range. Larger increases in the Warburg elements and cell impedance are also found with cycling at higher temperature, but they do not seriously affect the state of health (SoH) of LiB.

In contrast, more recent research suggests cell design and not the cathode material may play a substantial role in cell deterioration. The research indicates that avoiding lithium-plating on the anode and controlling the cell temperature, impacts significantly on battery charge rate and life.

A thin anode with high porosity and small graphite particles enables ultra-fast-charging because of the large surface area. Although these so-called Power Cells can be charged and discharged at high currents, the energy density is low. The Energy Cell, in comparison, has a thicker anode and lower porosity but this battery should be charged at less than1C. Some hybrid Cells in NCA (nickel-cobalt-aluminum) can be charged at 4C with only moderate stress.

Real world testing questions whether fast-charging is really detrimental to battery life

Automakers claim that even though DC fast charging is harder on the battery than slow or rapid charging, this isn't the root cause of battery degradation; even if used daily. A study conducted at the Idaho National Laboratory, the results of which were released in 2014, backs up these claims.

In the study, 2 Nissan Leafs were charged using 3.3 kW Level 2 chargers while 2 Leafs were charged using 50 kW DC fast chargers. The vehicles were driven over a fixed public route in Phoenix (Chosen for the elevated ambient temperatures) and charged when their range indicators read 5 miles. After 20,000 miles of driving, the DC fast charged vehicles had lost 8.4% of initial capacity while the Level 2 charged vehicles had actually lost 8.2% of initial capacity; after 40,000 miles, the DC fast charged vehicles had lost 25% of initial capacity while the Level 2 charged vehicles had lost 22% of initial capacity.

These results were achievable because DC fast chargers actually communicate with the vehicle's Battery Management System (BMS) to monitor temperatures and cell voltages. As the battery state of charge increases the charger will ramp down the charge rate to protect the battery.

It's this smart process that prevents overheating that would otherwise reduce battery life. While it may take between 15 to 30 minutes to charge a battery to 80% it can take another 30 minutes to charge the remaining 20%. At 80% state of charge, the charge rate of the DC fast charger will have dropped below 10 kW and will decrease to less than 5 kW by the time the battery is fully charged.

While the results indicate that despite being subjected to a daily fast charge 15-times higher than the slow charge, the two leafs in the test had less than ~3% lower capacity after 40,000 miles. It's important to note that the cell temperature was carefully controlled.

Fast charging requires micro management of cell temperature

An indication of the charge rate, C-rate is a measure of the rate at which a battery is charged or discharged relative to its maximum capacity. A 1C rate means that the charge/ discharge current will discharge the entire battery in 1 hour. For a battery with a capacity of 100 Amp-hrs, this equates to a discharge current of 100 Amps.

With fast charging it's possible to achieve 3 or even 4 C, for the initial charge up to 70 or 80% of total capacity. At these rates it's critical that the battery cells are accurately managed.

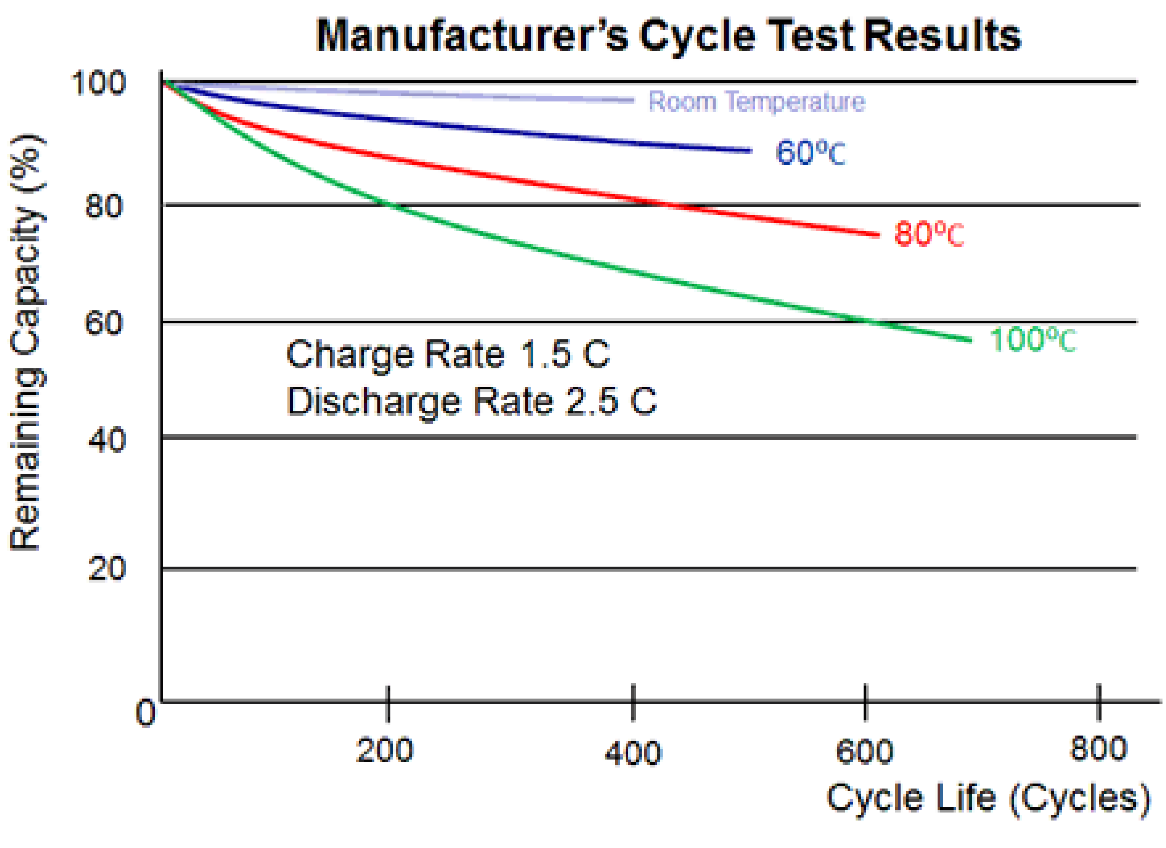

Image credit: www.mpoweruk.com

The safe power density of a battery cell in charge or discharge modes changes as a function of SoC - state of charge, temperature and SoH - state of health.

To maximize the performance of the battery cells, the Battery Management System needs to gather sufficient information about the battery cell characteristics and condition as a function of these parameters so that the individual cells that make up the battery can be managed. This not only prolongs cell life, but also allows more of the theoretical energy held in the cell to be safely used.

While this seems logical, it presents a number of technical challenges when applied to automotive traction batteries: Typically a battery could consist of 100 cells and the control circuits required to move energy between these cells during charging would require several meters of cabling.

In order to accurately micro-manage individual cells Robert Bosch and partners, Pro Design Electronic GmbH, University of Applied Sciences and Arts (Hannover) and the Karlsruhe Institute of Technology (KIT) have undertaken a €4.3-million project to improve battery performance in hybrid and electric vehicles using intelligent battery management.

Dr. Jens Strobel, coordinator of the project at Robert Bosch GmbH, explained that the objective was to design a system that constantly monitors and controls each battery cell individually. The technical basis of the IntLiIon project is an innovative method that uses power line communications systems to efficiently control and monitor each of the up to 100 cells found in a battery pack. This power line system will eliminate the need for the costly extra data-transmission wiring that has been necessary in all the battery systems used to date.

Applying prevailing technologies it is indeed possible to achieve reasonable charge times, however it's important to remember that charge times are only one part of the equation plugin EV's are faced with: Extending the range per charge is possibly even more challenging!

Sources:

• DC fast charging not as damaging to EV batteries as expected – Plugin Cars (Patrick Connor)

• Effect of Temperature on the Aging rate of Li Ion Battery Operating above Room Temperature – Scientific Reports (Feng Leng, Cher Ming Tan & Michael Pecht)

• Good news for EV owners from DC fast charging results – Torque News (Luke Ottaway)

Author: Peter Els

Dear Battery Technology Expert,

IQPC's Energy Management & Battery Technology for EV/HEV Conference will bring speakers from the automotive industry from around the world.

- **Review progress in modelling and simulation of lithium-ion batteries for improved battery design and technology**
- **Discover efficient in-vehicle control of energy concepts for battery life duration enhancement**
- **Learn about fast-charging technology trends and in-vehicle charging technology**
- **Gain a deeper understanding of electric vehicle battery technology and materials**

Early confirmed speakers include:

- Uwe Likar, Manager Advanced Engineering Planning, Mitsubishi Motor R&D Europe
- Martin Brüll, Project Manager Powertrain, Technology & Innovation, Continental AG
- Søren Mohr, Head of Stationary Battery Systems, BMW Group
- Dr. Achim Henkel, Section Manager Powertrain and Electrical Systems, Robert Bosch

For more information and the schedule of events, download the agenda.

If you have any questions, please email at eq@iqpc.de or call +49 (0) 30 20 913 - 274.