Ultra-fast Battery Charging

And what are the implications

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Isidor Buchmann, CEO & founder of Cadex Electronics Inc.
www.BatteryUniversity.com; answers@cadex.com

Nowhere is fast-charging in higher demand than with the electric car. Recharging an EV in minutes replicates the convenience of filling up 50 liters (13 gallons) of gasoline into a tank that is capable of delivering 600kWh of energy. Such large storage of energy in an electrochemical system is difficult to fathom and a battery holding this capacity would weigh 6 tons. However, electric energy from a battery delivers far more efficient and cleaner propulsion than the internal combustion engine.

Charging an EV will always take longer than filling a tank with liquid fuel, and the battery will always deliver less energy per weight than fossil fuel. This ratio with current battery technology is roughly 1:100 in favor of fossil fuel. Breaking the rule and forcing ultra-fast charging would cause undue stress to the battery and strain the power grid by dimming the city. When talking about ultra-fast charging we must remember that the battery is an electrochemical device that is sluggish and loses performance with use and aging. Charging a battery cannot be compared to filling a tank with fuel that contains 12,000Wh of calorific value per liter. Furthermore, while a fuel tank keeps its volumetric dimensions, a battery begins to fade by the time it leaves the factory.

Ultra-fast Chargers

Ultra-fast chargers have been around for many years. Most NiCd and specialty types of Li-ion batteries can be charged at a very high rate up to 70 percent state-of-charge (SoC). At a rate of 10C, or 10 times the rated current, a 1A battery could theoretically be charged in six minutes, but there are limits. To apply an ultra-fast charge, the following conditions must be observed:

- The battery must be designed to accept an ultra-fast charge. Current handing poses limitation with many pack designs.
- Ultra-fast charging only applies during the first charge phase. The charge current must be lowered when the 70 percent state-of-charge threshold is reached.
- All cells in the pack must be balanced and in good condition. Older batteries with high internal resistance will heat up; they are no longer suitable for ultra-fast charging.
- Ultra-fast charging can only be done under moderate temperatures. Low temperature slows the chemical reaction, and energy that cannot be absorbed causes gassing and heat buildup.
- The charger must include temperature compensations and other safety provisions to halt the charge if the battery gets unduly stressed. Failure to heed to these conditions could cause rapid disintegration of the battery and fire.

An ultra-fast charger can be compared to a high-speed train that is capable to travel 300km per hour (188 mph) on a track built for it. The tracks, and not the machinery, govern the maximum speed. Adding power to a charger is relatively simple; the intelligence lies in assessing the condition of the battery and applying the right amount of maximum charge. A properly designed ultra-fast charger will lower the current when certain conditions occur. In essence, only newer batteries can be ultra-fast charged.

Do not ultra-fast charge batteries if possible and charge at a more moderate rate of 1C or less. (A maker of the 18650 Li-ion recommends 0.7C.) Makers of electric cars prefer if EV owners charge at an eight-hour or 16-hour charge, both of which are below 1C. The 30-minute charge which a three-phase 440V outlet charges the battery at above 1C and this method should only be used if no other option exists. (1C is the current rating of a battery. A 1C charge or discharge of a battery rated at 1Ah is 1A.)

Figure 1 compares the cycle life of a lithium-ion battery when charged and discharged at 1C, 2C and 3C. A full charge and discharge cycle at 1C causes the capacity drop from 650mAh to 550mAh after 500 cycles. This leaves the battery with a remaining capacity of roughly 84 percent. A 2C accelerates capacity fade to 310mAh and leaves the battery with about 47 percent remaining capacity, and with 3C the battery fails after only 360 cycles and the remaining capacity is around 26 percent.

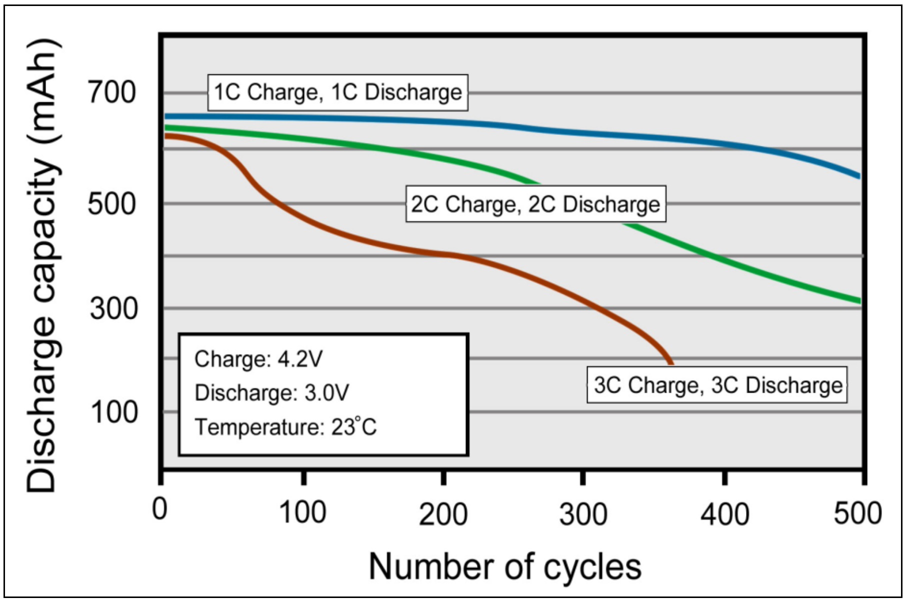

Figure 1: Cycle performance of Li-ion with 1C, 2C and 3C charge and discharge

Charging and discharging Li-ion above 1C reduces service life. Use a slower charge and discharge if possible. This applies to most batteries.

Although the battery performs best at a gentle rate of 1C and less, we must keep in mind that some applications require high charge and discharge rates, and the user must take shorter life expectation into account. If full cycles with rapid charge and discharge are the norm, consider using a larger battery. This will not only provide more reserve capacity but it will also lower the C-rate in that a given charge and discharge current is less intrusive on the larger pack. An analogy can be made with an underpowered engine pulling a large vehicle; the stress is too large and the engine will not last.

About the Author
Isidor Buchmann is the founder and CEO of Cadex Electronics Inc. For three decades, Buchmann has studied the behavior of rechargeable batteries in practical, everyday applications, has written award-winning articles including the best-selling book “Batteries in a Portable World,” now in its third edition. Cadex specializes in the design and manufacturing of battery chargers, analyzers and monitoring devices. For more information on batteries, visit www.batteryuniversity.com; product information is on www.cadex.com.