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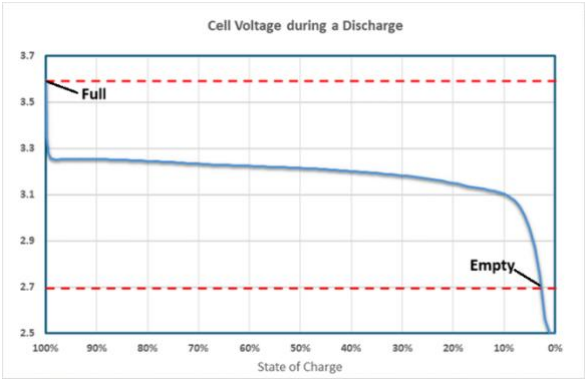
Why do manufacturers recommend using their energy storage in a smaller SOC window than it is rated for?

A discussion of allowable SOC ranges of lithium ion batteries, by C. Michael Hoff

If cell and battery manufacturers rate their cells for a wide operating state of charge (SOC) range and allow their own battery systems to operate in those ranges, why would they recommend that their customers not to do so? Let's peel apart the onion to find out more.

First, let's define what is the SOC range in a battery. SOC is the state of the "fullness" of a battery with respect to how much it can store. Cells are like a gas tank that can hold 20 gallons of fuel. The fullness of the gas tank is how much fuel is in it compared to its rated capacity. Similarly, a battery which can hold 20 Amp-hours of charge, can have an SOC range between zero and 100% corresponding to zero and 20 Amp-hours of charge.

That simple comparison is where the similarities end. Unlike a fuel tank, you can actually put more charge into a battery than it is rated for, but you may end up damaging it by doing so. On the other end, you can draw every last coulomb of charge out of it, you may also damage it. Knowing that there are damaging consequences to over-charging and over discharging a battery, cell manufacturers rate their cells using a practical SOC range corresponding to safe operating conditions. For example, a certain cell-type manufacturer may say that their cells are fully charged when they are held at 3.65V. They may also specify that their cells have reached a fully-discharged state when the terminal voltage reaches 2.0V during a nominal four-hour discharge at 25 °C. Note, I didn't just cite voltages, but other conditions such as rates, temperatures, as well. Typically, cell manufacturers and system manufactures will specify their product's rated energy based on those end conditions.

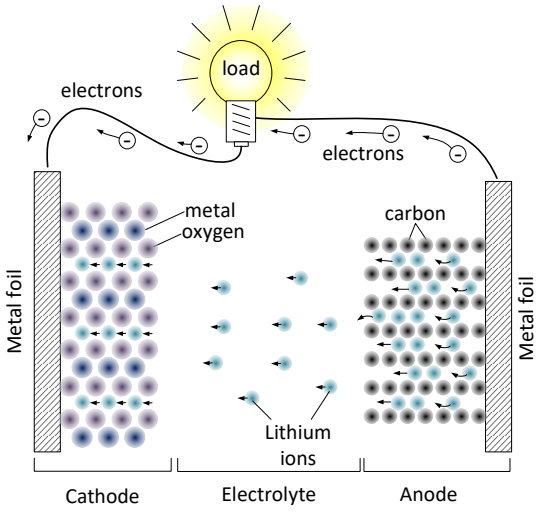


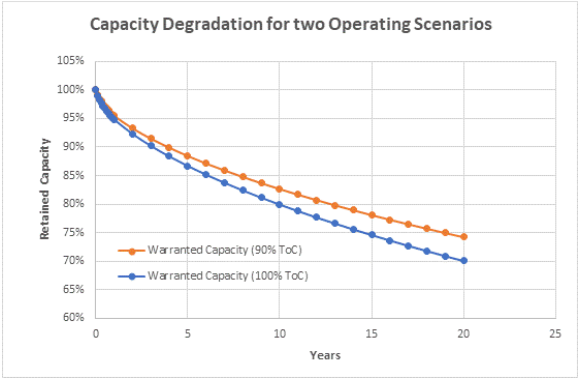
However, those aren't the only limits that users should be aware of. Holding a battery at the top of its charge will accelerate its capacity degradation more so than holding it

at a lower SOC; some more than others. Therefore, some manufacturers may “recommend” holding their products at a lower SOC “to achieve the rated service life” that the manufacturer claims in its warranty. Note that I cited a stipulation on the recommendation: the warranty. It is helpful when the manufacturer specifies why they are recommending the lower range. Is it because the battery will immediately fail under those conditions? Or, is it because it will experience an incrementally higher rate of degradation per month under such conditions? Knowing the repercussions of those conditions, the user can make decisions whether or not accessing the higher energy capacity is worth the reduced service life or other deleterious effects.

Another reason a manufacturer may recommend constraining the range of operating SOC is to reduce the depth-of-discharge during routine cycling. During discharge and recharge cycles, the insides of a cell physically change as the ions move from one electrode to another. As it charges, ions fill the voids in between the layers of carbon atoms causing the carbon particles to grow slightly. When the cell discharges, ions move from the carbon anode into the cathode where they fit in between the covalent bonds of a metal-oxide or phosphate crystal, also changing its overall external dimension. This mechanical “breathing” is repeatable thousands of times but can be more stressful when the full range of SOC is exercised repeatedly. Stress fractures in the carbon and cathode structures can form, leading to decreased pathways and storage places for ions to move and be stored. Although gradual, the incremental damage can lead to significant decline in storage capacity over time. Hence, manufacturers who promised (aka warranted) their products for a certain lifetime of cycling may “recommend” that their users confine their SOC ranges to that which will afford them the warranted service life they expect. Again, it is very helpful to know just how much worse the degradation rate would be under the wider SOC ranges, so users can make informed decisions about their usage profiles.

When considering an energy storage vendor, customers should know a few important things before “running the numbers.”





1. How long and for how many cycles is the product warranted to operate?
2. What is the warranted energy throughout corresponding to such a service life?
3. Under what conditions must the product be held to achieve such a service life?
    a. SOC range, temperature, cycle times, etc.
4. Is the nameplate energy achievable while executing the service life, or does it have to be derated?
5. Under what conditions can the product achieve the nameplate energy, such as:
    a. Environmental temperature,
    b. Rate of discharge,
    c. Pre-charging conditions,
    d. Expected warranty conditions, and
    e. Time between cycles.

Cell Specifications		
Energy Capacity	1000 Wh	500W rate, 25 °C, 3.6V to 2.5V cut-off
Cycle Life	8000	
RTE	95%	
Etc.		

In many cases, the energy storage *system's* ratings are not all mutually achievable. You may not be able to operate under the full temperature range and achieve the rated dischargeable energy, or achieve the round-trip efficiency, so customers must be aware of all the limitations.

A good service that battery vendors can provide to their customers is to specify the actual SOC range and dischargeable energy that they can expect from their product WHILE also achieving their rated cycle-life, service life, and round-trip efficiency. Many vendors are reticent to do so because they will be judged harshly against their competition who may be specifying the best of each rating mutually exclusively. The best service manufacturers can offer to their customers is to communicate, not only the range of allowed operating, but the implications of stretching those boundaries so they can make informed decisions about their project's operations.

In conclusion, the next time you hear the commonly-cited phrase: "Lithium-ion technology can only use xx% of its full capacity" take it with a grain of salt, because you know that there are many reasons for this, some of them more valid than others. More importantly, when you do your own financial assessment of potential technologies, find out the true limitations and caveats on the ratings and performances so that you don't fall into the trap of making broad assumptions where they are not appropriate.