My LiFeP04 Battery SOC Indication is Unreliable!

OK, after a lot of chatter back and forth on BMS Calibration, maybe we should discuss the Technical and Science Aspects of State of Charge (SOC) so that we can set proper expectations accordingly when it comes to the illusive SOC Indication.

In controlled environments, LFP Cells (EVE LF105) are matched up by their Internal Resistance and MAP Curves for Charge Voltages, Discharge Voltages and Nominal Voltages through a variety of Temperatures along with other traits. These are collectively known as Cell Parameters and Characteristics. Once matched and assembled, a BMS is then installed to Protect and Watch Over the Cell Family.

PROBLEM

Now, just like Parents, the BMS is susceptible to errors, time SOC drifting and other flaws that either arise from Manufacturing Testing, Storage or Retail Consumer Application Uses which causes the Cells to misbehave or get hurt. The BMS is in-charge of ALL Cell Protections like Over Current Charge+Discharge, Over /Under Voltage Charge+Discharge, Over/Under Temp and lastly, reporting an estimated State of Health (SOH) and State of Charge (SOC) of the Battery Cells as a Group/Family.

It is this last function (SOC) of the BMS that causes the most confusion because, like a car's fuel gauge, everyone looks to see how much time or distance they have left before reaching the 0% SOC Mark which could lead to family/friends pushing the Cart back home.

As some have seen, you can have an SOC Display 30%, for example, and then once the pedal is pressed, it drops to 0% and the cart may or may not operate accordingly. Then they complain the Battery failed, is junk or other choice words. So why did this happen to them?

Mostly because, a SOC Indication is equated to a Moment in Time. The BMS tries to mathematically figure out the estimated SOC using the Coulomb Method.

For those not familiar with this, Coulomb Counting gives a relative change in SOC and not an absolute SOC. If you measure the positive and negative current flow over a given time, you have a measure of the number of Ah that is left or is being received by the battery.

Now while this method is fairly cheap to manufacture creates an OK estimated SOC, it is susceptible to missing High Current Flows in milli or micro seconds (like the initial "wheely" Current Inrush) and Low Current Flows usually below 400mA or so which could be some LED lights, Glow Strips and other accessories that run at extremely low MilliAmps…even the BMS Clock and Bluetooth UART use Micro Amps which is not tracked by the Coulomb Counter (Current Amplifier). So all of this "missed" current flow throws off the BMS SOC over time. Other items that effect SOC are Internal Resistance, The Rate at which Charge and Discharge occurs, Cell Voltages and Temperature.

As the Battery reaches first cell at 2.5V, the BMS turns OFF the Battery DSG FET forcing a recharge event. Now IF you partially recharge the Battery say just to get home, then you have introduced a Counting Error into the BMS SOC "Calibration". As a matter of fact, ANY usage of the Battery with a Current Discharge of greater than .5C to 1C (C=Capacity so 1C equates to: 100Ah = 100Amps / 105Ah = 105Amps, etc) in ANY Temperature outside of an exact 77F (25C) begins to introduce small errors into the SOC.

SOLUTION

Now the good news is, the BMS knows it's cell children are not perfect at all times and does its' best to BALANCE them for you the Consumer.

This Balance is either done via an ACTIVE or PASSIVE or BOTH Methods combined.

- Active Balancing is when the BMS Xfers Power to an adjoining cell via Switching devices whereby basically taking away from the high cell and giving to the low cell and not wasting the energy created
- Passive Balancing occurs when the BMS simply burns off the excessive energy, via resistors, of the High Cell and of course is less efficient but also less expensive.
- Some Expensive Batteries employ Both Methods to achieve Balance. The BMS does this simultaneously, allowing for a more efficient and comprehensive cell balancing process within a battery pack; essentially, the BMS can activate passive balancing when needed while actively transferring charge between cells for faster equalization aka active.

So now that we know about HOW the BMS handles Cell Imbalance, what does that have to do the SOC you may ask…answer is EVERYTHING!!!

The individual Cells must be able to keep up with each other to have a Balanced Battery and the ability to estimate a decent SOC of that Battery. During the Discharge and Charge process of the Battery, any cell that reaches 2.5V or 3.65V respectively first rules the roost so to speak. If that Cell reaches the Limit and the other Cells are lagging behind by say 200-400mv or more, then you have an out of Balance Battery and an SOC that can drop off quickly from say 30% to 0% without any notice just by pushing the GO Pedal and introducing a large Inrush Current to

the BMS. Once that overachieving cell reaches “Protection”, the BMS (if working properly) turns OFF the DSG or CHG MOSFET until the Protection can be resolved either by a charging action or stop charging action.

CALIBRATION

Now welcome to the Imbalanced Battery World that lead people to wanting to “Calibrate” their BMSs. So they take the imbalanced Battery and run it down to 0% SOC but the Cart still moves and they don’t care…then they charge back up to 100% and notice the Ah are no longer what they were when they received the battery just a couple weeks ago. But, they have performed the “BMS Calibration” of going from 0% to 100% SOC as indicated and now assume all will be well again.

Next trip out, the SOC drops off from 40% to 0%, the cart dies on them this time and now they have to push it back home or get a tow all the while cussing up a storm. So they get it back home, do some ranting on the FB Groups and again they are told to Calibrate their BMS by running it to 0% and then Fully Charge back up.

Now, they charge it up till the charger cuts off and the SOC reads 100% but the outside temperatures have gone from 45F to 65F the next time they use the Cart and they failed to recognize the VDiff (Cell Δ) was over 200mv at the end of the charger cutoff. So they are driving around and when the SOC reads 20% SOC, the Cart Dies on them…now they are extremely ticked off and back to the FB Groups to rant some more. Essentially, no one mentioned the Balancing the BMS does and that the process could again rob some power under the radar and throw off the SOC yet again.

So basically, they have been trying to “Calibrate” this darn battery to no avail and are fed up with it.

The BMS SOC does Drift – that is a Fact. But it is also a Fact that Field BMS Calibrations don’t provide expecting results because of the variables involved. You can only “Calibrate” something with known quantities, fixed temperatures and in a controlled environment for the most part. So what are consumers to do then you ask?....

LEARN THE BATTERY – BE ONE WITH

Just use the Battery! Over time, the BMS will “Learn” your Battery Usage Characteristics and intrinsically modify the SOC Calibration via the internal N**eural Networks**. A neural network can estimate the SOC by learning from large amounts of a battery’s input data, such as voltage, current, and temperature, and reproducing the non-linear relationships between these parameters. This does not happen overnight (may not happen at all for that matter) and can takes years to accomplish since no one operates their devices the exact same each and every time, at the same time and with the same external influences such as weather, so just me mindful.

Now with that said, no one wants to be stranded or look silly on their sooped up Cart right?

So here are some things you **can do** to help the BMS out in raising the Cells and provide with you with a better SOC estimation:

1. Monitor Individual Cell Voltages via the Manufacturer’s BMS APP – if you start to see cells “running away” in either direction from the Group, make note of them and understand your SOC is prob not reporting accurately

2. Monitor the VDiff (Cell Δ) number when the BMS hits 0% as well as when it hits 100% and make notes of anything larger than 100mv and the associated Cell actor(s)
3. Allow the Charger to Turn Itself Off – Don't interrupt a Charge Cycle once you start one unless you have to for REGEN issues and even with that, do so between 90% - 95% SOC and again make note of the VDiff (Cell Δ) voltage
4. Charge your Battery when the Battery "TEMP 1" or "MOS TEMP" as indicated on the Battery APP is at or above 41F (I know you <u>can</u> charge above 32F – but you <u>can</u> play in the street too – but <u>do</u> you?)
5. When the Battery Charger Cuts OFF, make sure the Ah listed on the APP is equal to or exceeds the Battery Ah Rating (100Ah, 105Ah, 150Ah, etc). Usually displayed as XXX/105Ah where the xxx equals the amount of capacity calculated by the BMS during the Charge Cycle.
6. After charging and about a 2hr-4hr rest or the next morning, double check that all of the Cells are within 5-10mv (Cell Δ) or less of each other and that again the Useable Ah meets or exceeds the rated Ah. ANY discrepancies need reported and must be accounted for in SOC indication
7. IF you start to see the Cells get worse, the VDiff (Cell Δ) get worse or the Ah get worse – STOP and ask for assistance in TOP BALANCING the Battery to try to get everything back in line before it gets way out of Balance

So there you have it folks…Understand that the SOC Indication CAN and WILL drive you crazy, but unless you purchased a High End Battery that uses Kalman Filtering, an IC/Microprocessor with OCV Charts and Fuzzy Logic vs a simple Current Amplifier, you will always have to be mindful of the SOC of any battery. Just like a 1980's Automotive Fuel Gauge, nothing is absolute! The more you get to know about your Cart and how much Ah is used during a day, trip or week…the easier it will be to simply forget about the SOC and settle into a charge cycle vs usage habit and then once a awhile, help the BMS get the family again together for a reunion by TOP Balancing the Cells as needed.