Annual BTMS Testing Section (SNL)

Test plan formulation

One of the first milestones of the Behind the Meter Storage (BTMS) program was to develop testing protocols so that the state-of-the-art cell chemistries and form factors could be evaluated against BTMS aggressive performance and lifetime metrics. To help guide this conversation, a pack estimation calculation was run. At the time the team was assuming a worst-case scenario in which the battery alone would need to charge an electric vehicle in 15 minutes with no support from the grid. This calculation varied the amount of current applied by each string or module in the storage system and estimated how many cells (and estimated cost) would be needed to charge an electric vehicle in 15 minutes under the current applied. Results are shown below in Table 1

| Current Applied per String | Current in C rate (assuming 3.5 Ahr) | Capacity consumed | Minimum number of strings | D-Rated Voltage | Minimum Cells in String | Recommended Cells in String | Pack Power (Without Power Electronics) | Total Number of Cells | COST? (k) |
|---|---|---|---|---|---|---|---|---|---|
| 50 | 14.29 | 12.5 | 19.4 | 2.8 | 125 | 138 | 0.374 | 2671 | 10.7 |
| 40 | 11.43 | 10 | 24.3 | 2.9 | 121 | 133 | 0.374 | 3224 | 12.9 |
| 30 | 8.57 | 7.5 | 32.4 | 2.95 | 119 | 131 | 0.374 | 4226 | 16.9 |
| 20 | 5.71 | 5 | 48.6 | 3 | 117 | 128 | 0.374 | 6233 | 24.9 |
| 10 | 2.86 | 2.5 | 97.1 | 3.2 | 109 | 120 | 0.374 | 11688 | 46.8 |
| 5 | 1.43 | 1.25 | 194.3 | 3.3 | 106 | 117 | 0.374 | 22667 | 90.7 |
| 1.75 | 0.50 | 0.4375 | 555.1 | 3.32 | 105 | 116 | 0.374 | 64372 | 257.5 |
| 1 | 0.29 | 0.25 | 971.4 | 3.35 | 104 | 115 | 0.374 | 111642 | 446.6 |

Table 1: Pack estimation calculation. Green row represents 0.5C discharge rate which at the time was the proposed plan.

This calculation demonstrated that lowering the applied current of the string (delivered power) can be cost prohibitive due to the number of cells needed and the implied balance of plant. What resulted from this discussion was a test plan which spanned a variety of use cases from pushing the limits of the cells to standard cycling to fully understand the capabilities of the cells and their aging characteristics.

Testing results

Two different cell constructions are currently being investigated for the LFP/Graphite system. These cells have undergone close to 130 consecutive days of continuous cycling. The effects of this cycling on the capacity fade of the cells can be observed in Figure 1.

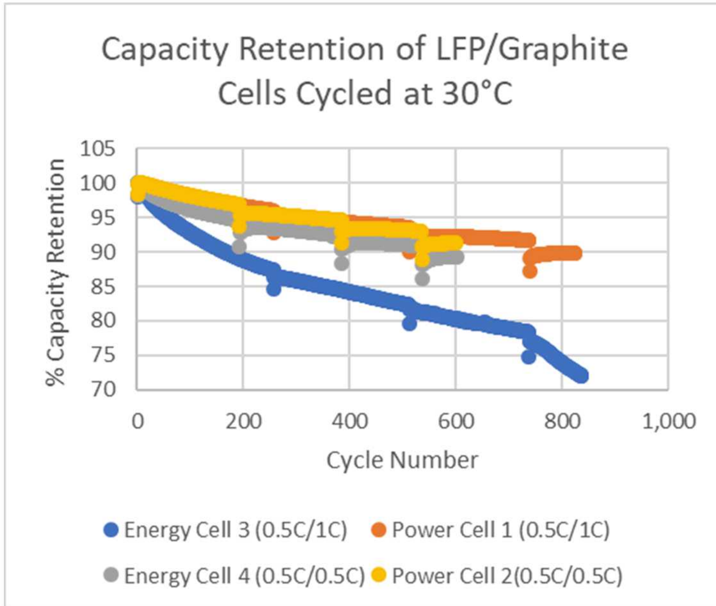


Figure 1. LFP/Graphite Cycling results

Results show that on average the power cells have lost ~10% while the energy cells have lost close to ~30% in the worst case. It is difficult to say of the ~30% loss in the energy cell is representative without additional cells to provide statistics. Differences in the state of health testing of these cells can also be observed as demonstrated in Figure 2.

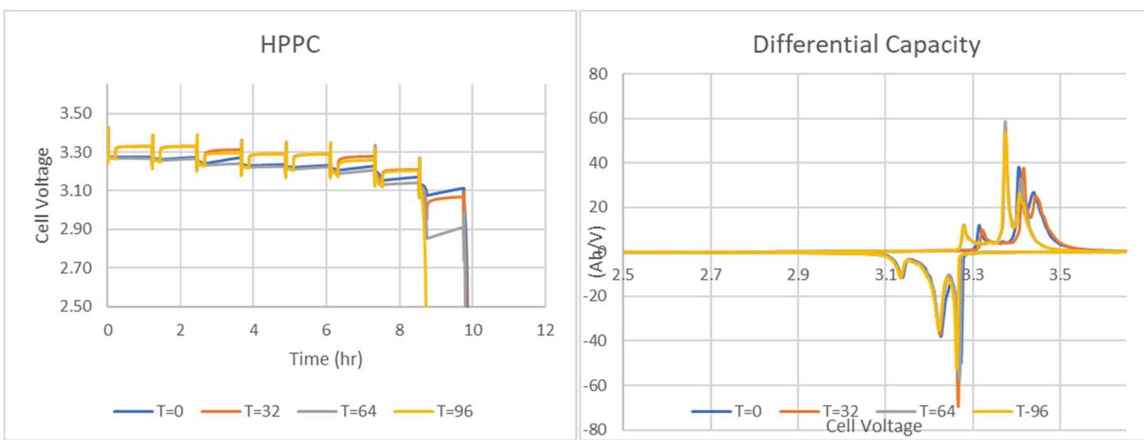


Figure 2: Power Cell 1State of Health Testing of LFP/Graphite Cells

HPPC results show that as the cell continues to cycle, it loses its ability to deliver power at low states of charge. Understanding this phenomenon will be critical for predicting end of life behavior of these cells. The differential capacity results suggest that the loss of performance is most likely attributed to changes in the graphite anode. This is a known problem. Graphite is known to degrade from extensive cycling. In an effort to predict the lifetime of these cells, a simple trend line (which is an overestimate) was fitted to each curve in Figure 1 and the calculated slopes of the line can be found in Figure 3.

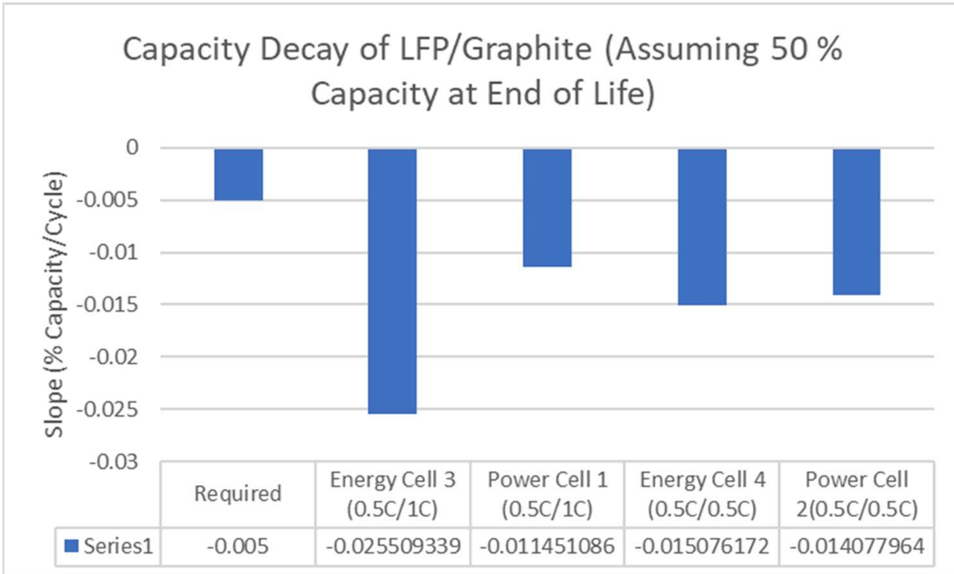


Figure 3: Calculate capacity decay for each cell type.

If we target a 50% capacity retained at end of life after 10,000 cycles the capacity fade rate would need to be .005% capacity fade/cycle represented by the required bar. This estimation suggests that the capacity fade rate of this chemistry in this form factor exceed the desired decay rate by factors of ~2-5, indicating that these cells should not meet our lifetime targets.

Accelerated Aging Through Abuse Testing

As testing continued, it became apparent that conventional methods of cell aging are extremely slow and is the current bottleneck in predicting lifetime. Utilizing our state-of-the-art abuse facility, we began investigating the possibility of using abuse testing to accelerate aging and simulate excessive cycling without compromising the overall results. Our goal was to show that overcharging cells could mimic excessive cycling. Preliminary results for these efforts are shown in Figure 4

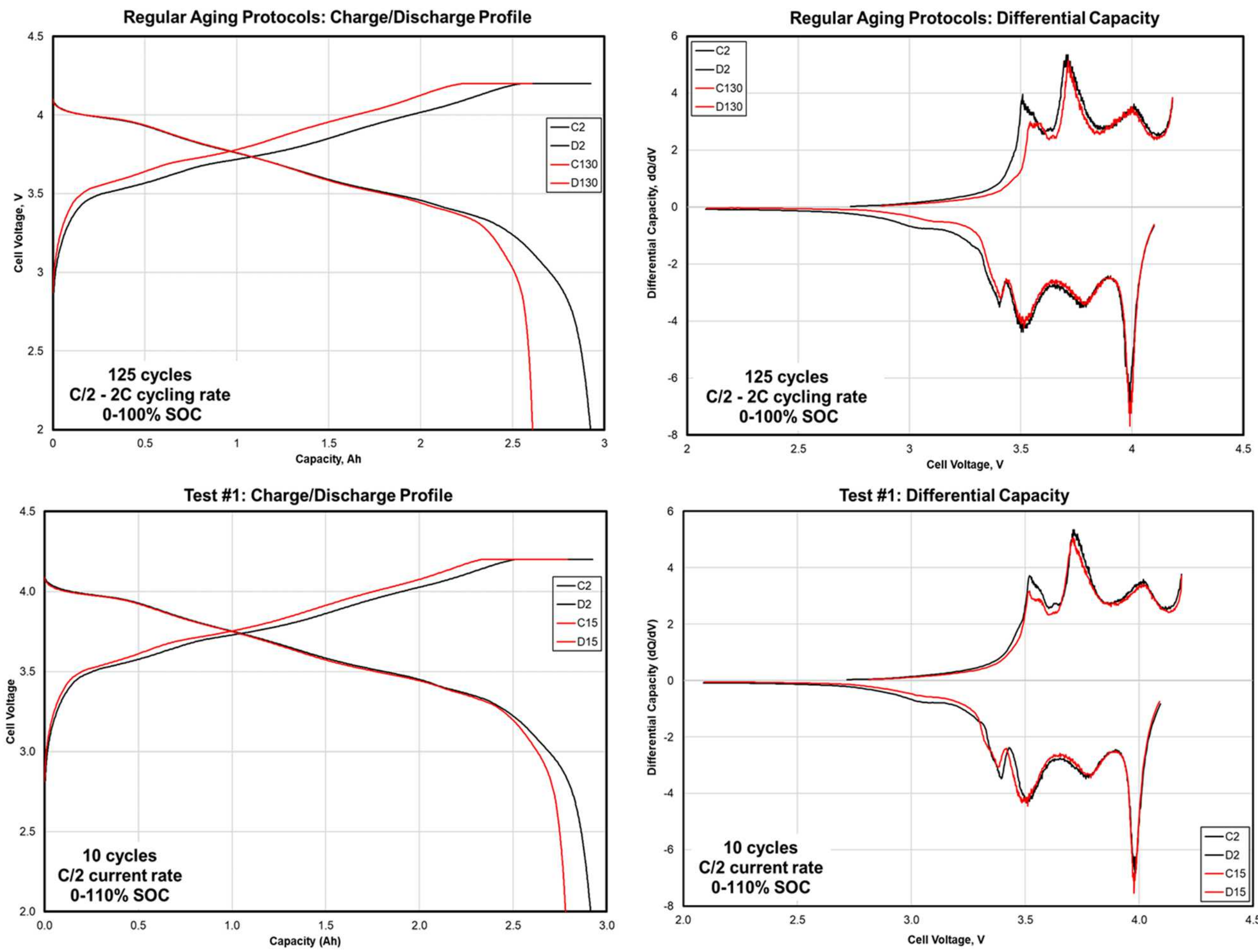


Figure 4: Comparison of Cell Behavior after (top graphs) 125 cycles (bottom graphs) 10 cycles of 110% overcharging. Black lines pristine, red lines cycled.

When comparing the extensively cycled data to the overcharged cycle data, similarities can be observed. The capacity loss of 125 cycles of full depth of discharge cells is around 10%. The differential capacity shows shifts of the anodic peaks, indicating that the graphite electrode is changing, which is most likely the cause of the loss in performance. The cell that was overcharged to 110% 10 times shows a capacity loss of 5% and similar anodic peak shifts in the differential capacity. These results indicate that this method does show some promise in accelerating cell aging via overcharge abuse testing. When 120% state of charge was attempted, the current interrupt device on the cell was triggered. This work will continue in the new FY to explore if the method can be honed, adapted to other chemistries, and have the results support the machine learning efforts.

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