

More on LiPo deterioration

By Bob Smith

Two issues back (in EFUK 86) I wrote an article about a problem LiPo pack which was performing poorly because one cell (it was a 4S1P pack) was critically low in performance. The pack had been looked after quite well with balanced charging and a low pack voltage cut-off, but the cut-off had not been able to detect that one cell voltage was dropping below the others. This meant that, although the total pack voltage was still at 12 volts (4 x 3 volts), the poor cell was dropping towards 2 volts and each cycle exacerbated this problem.

I concluded that there was a need to look at the balance of the pack discharge in the same way as we do with charge, and although the ideal solution of continuous cell balancing during discharge may not be feasible, units are now on the market to partially protect out batteries. These are sometimes referred to as battery protection units and effectively set a cut-off which assesses individual cells and uses the voltage of the lowest cell to trigger a safe cut out. Such units are available from Aurorra (the FMA Direct Discharge Protection Module), BRC Models (the Leton Lithium Battery Protector), and from West London Models (the Schulze LiPoDiMatics). They all function through the receiver/ESC so that when the worst cell reaches the pre-set low voltage limit the power to the throttle is first reduced and later cut off. There is no balancing involved i.e. no process to keep the cell voltages identical, but the use of such units will prevent any cell deterioration resulting from critical low discharge voltage.

I have actually been doing more testing in this field and have reached an opinion as to one cause of sub-standard LiPo performance. I have suspected for some time that the production of LiPos is an imprecise process. I have been told by visitors to one Chinese factory where they are manufactured, that the process is significantly “hand made”, with the result that slight variations in cell properties are very possible (or even probable). These slight variations are then present in our series packs so that the charging/ discharging cycle will not only affect the individual cells differently, but may also lead to the kind of exacerbation mentioned above.

The problem with this particular pack was fairly obvious when investigated, but I have since discovered that the same problem is incipient in most of my packs. When new, and over their early usage, the slight differences in the cells are only detectable at the very end of the discharge. Balanced charging up to 4.2 volts/cell gives a stable, fully charged pack. During the majority of the discharge the cells remain well balanced. There is a degree of variance in the voltages (as there is with all battery discharge) but the cells all remain on the same mean discharge curve. Only at the very end (more than 95% discharge) does one or two of the cells indicate real variance by dropping over the discharge knee before the other(s). The time difference is often only a few seconds and needs some careful testing to identify it. I have used a set of digital multimeters to observe individual cell voltages in the past but this was a cumbersome process and I have now made a triple unit to simplify the process when working with a 3S pack (see photo). Even this is not ideal because the changes we are trying to identify are quite rapid and I am now looking at logging systems to record voltage changes which I can examine in detail after the event.

If you check back on the two graphs included in the EFUK86 article you will see the clear evidence of the sub-standard cell in Graph 1 but a much better balanced set of cells in the new pack shown in Graph 2. I have drawn an enlarged version of the end of the discharge of a similar new pack in Graph 3 to demonstrate the effect I refer to in this follow-up, but the implication is really in terms of the future life of the pack. The cell voltage differences are quite small in this situation, and a reasonable pack voltage cut-off prevents any major cell damage, but does not prevent all damage. Over a series of cycles there is an accumulation of slight damage to the low cell(s) eventually reaching the point where the cell can no longer hold its voltage until the very end of discharge and begins to drop below the mean value for more and more of the discharge curve. This is an accelerating process (particularly at higher currents) and will eventually lead to pack behavior similar to that in the EFUK 86 article.

The final point to make in this assessment is, I believe, good news. The battery discharge protectors, and, in certain circumstances, a normal ESC pack cut-off, can prevent the problem going beyond the incipient condition. If you look at the graph you will see that if

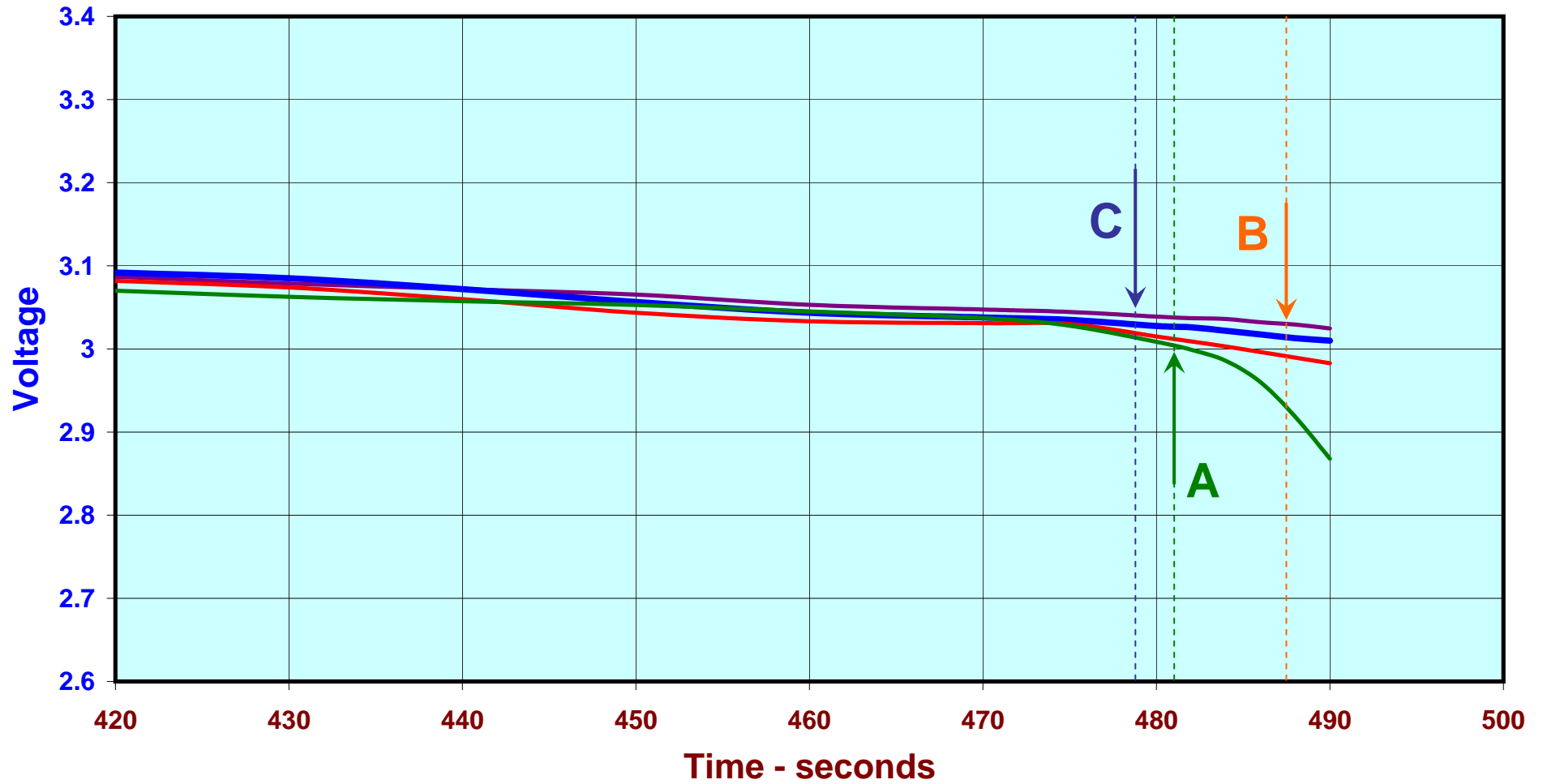
discharge is stopped before any cell reaches the discharge knee, then the cells should remain constantly balanced. If a discharge protector cuts off the discharge when the worst cell in a new pack drops to a voltage offering a safety margin before the discharge knee, then no cell in the pack can be damaged. The same protection can be offered by an ESC pack voltage cut-off, providing it is set high enough to prevent the voltage of any cell in the pack from reaching its knee. To provide this protection the ESC cut-off voltage should be higher than the number of cells multiplied by the discharge protection cut-off voltage. That sounds a bit convoluted but if I suggest 3 volts for the discharge protector (lowest cell) and then 12.2 volts for a 4S pack you will get the idea. On the graph these values would give a discharge protector 3 volts cut-off at point "A" which you will see is safe. If an ESC was set up with a pack voltage cut-off of 12 volts (4 cells at 3 volts) this would be at point "B" and the worst cell will possibly suffer slight damage which would be accumulative with every cycle. If, however, the cut-off was lifted to 12.2 volts, this would be at point "C" and would be fine (and even slightly better than the first case).

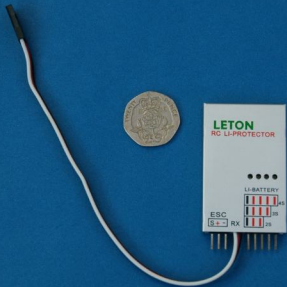
I suspect that these values are a bit higher than most flyers are currently using, and of course there is a price to pay in terms of reduced in-flight battery discharge capacity, but the power remaining in the pack at this stage is very low, probably equivalent to less than 20 seconds of additional full-power flight, and the longevity of the pack is surely worth it. Of course this is not the only possible cause of LiPo deterioration, and I suspect that high current draws, elevated temperatures, and even (in very rare cases of course) impact damage, will be equally significant.

Photo Captions

- 1. Triple digital voltmeter for use on the balancing lead of 3S packs**
- 2. An FMA Direct Discharge Protection Module.**
- 3. The Leton Lithium Discharge Protector**
- 4. Schulze LiPoDiMatic protectors.**
- 5. Graph 3.**

**Graph 3 - Discharge at 20 amps - Individual cell voltage in 4S pack.
n.b. Graphs 1 and 2 were published in EFUK 86**







4.07

V

4.07

V

4.06

V

