GWL Technology Report

Long time balancing – a slow way to damage the lithium (LiFePO4) cells

Lithium cell can be destroyed by over charge

Overcharge is defined as charging the cell above the maximum voltage give by the manufacture. (4.0V for Winston cells, 3.9 for CALB cells, 3.7 to 3.9 for many other brands of LiFePO4 cells).

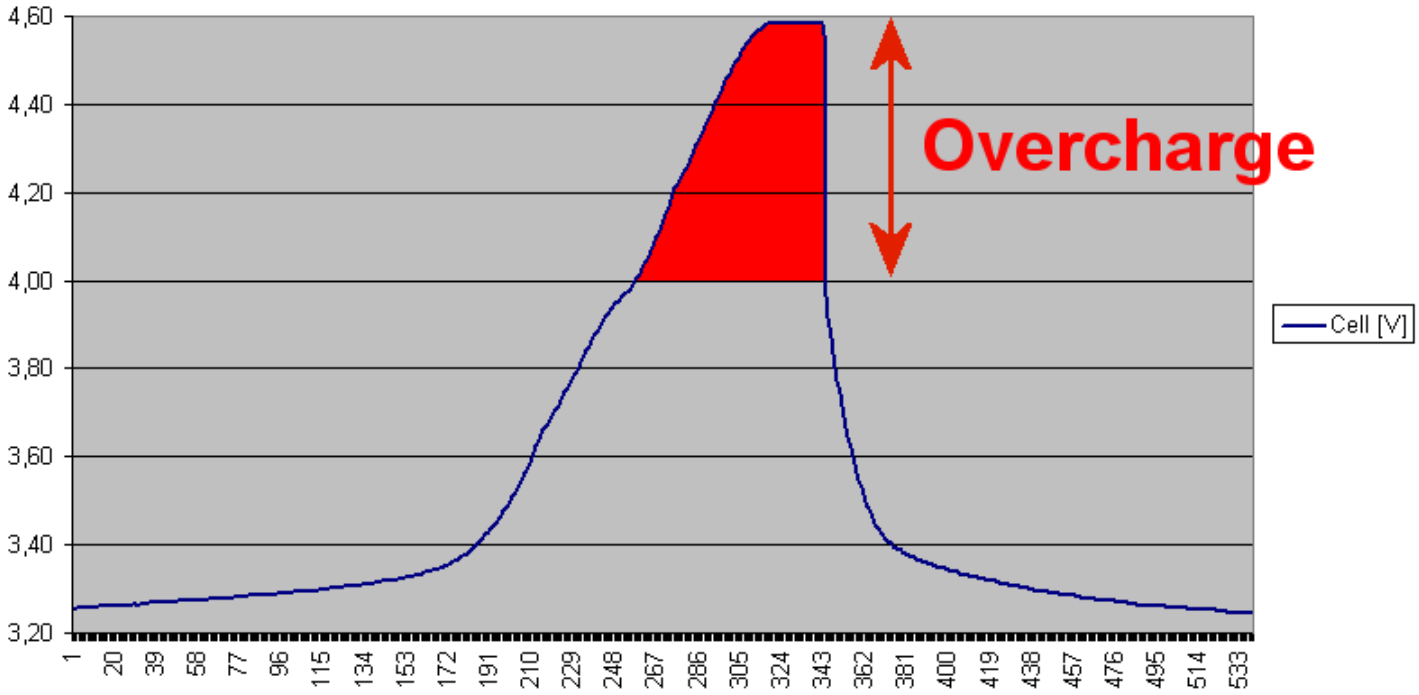

Fig 1 – Overcharge by going beyond the maximal voltage level

The result of the overcharge is damage to the cells.

There is no way to restore a cell that was damaged by overcharge. Additionally there is no warranty for cell performance if the cell was overcharged by the user.

Fig 2. A single lithium cell damaged by over charge. The cell changed it shape and lost its original capacity.

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Additionally, overcharge can be a result of keeping the charging voltage at the full charge voltage for a prolonged period of time.

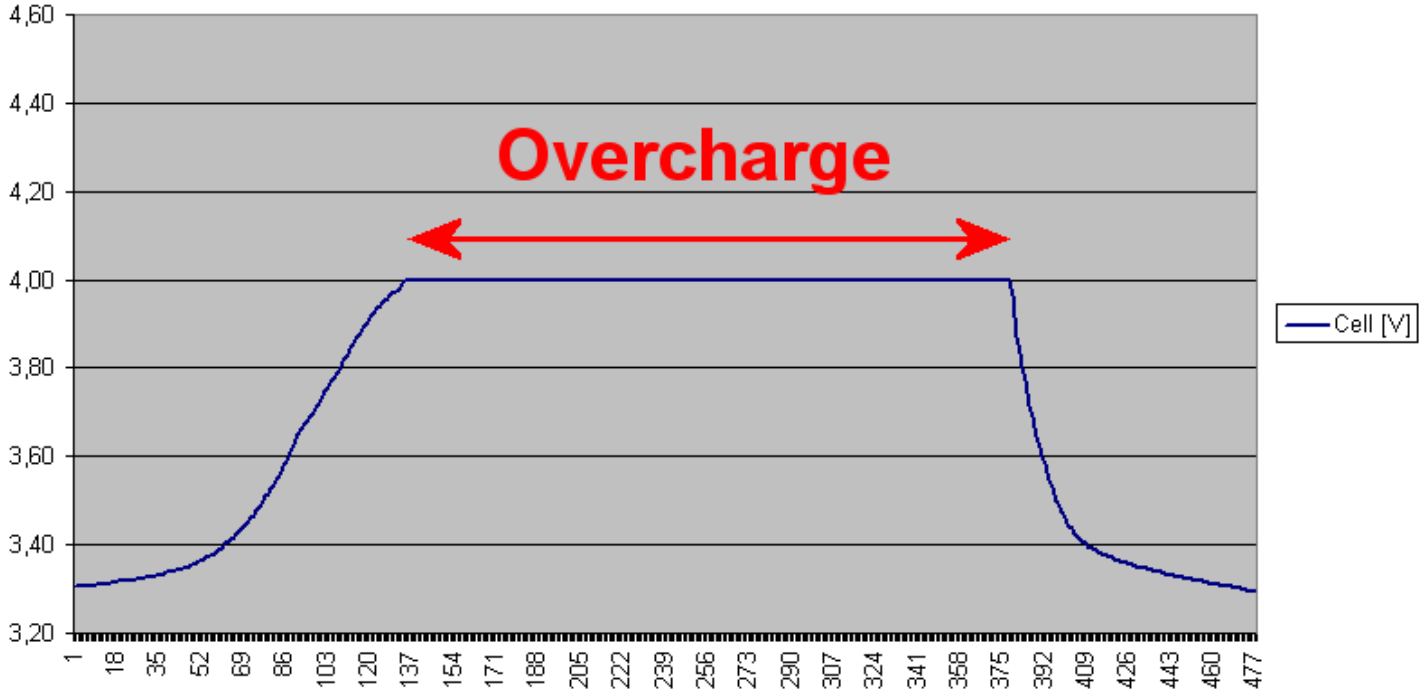


Fig 3 – Overcharge by keeping the cell under full voltage for long period of time

Unlike the lead acid batteries, that allow using the "equalizing voltage" or "trickling voltage" to stay at full charge, the lithium cells are actually damaged when kept at the full voltage. This is the reason why the LFP cell manufacturers **do not recommend using the „floating voltage"** method to charge the cells.

Simply said, when the lithium cell is charged, the charging voltage must be stopped and should not be applied any longer.

The bad results of this kind of overcharging may not be visible at first. However after repeated periods of such overcharging, the cell will gradually **start loosing its capacity** and will have worse performance than the other properly charged cells.

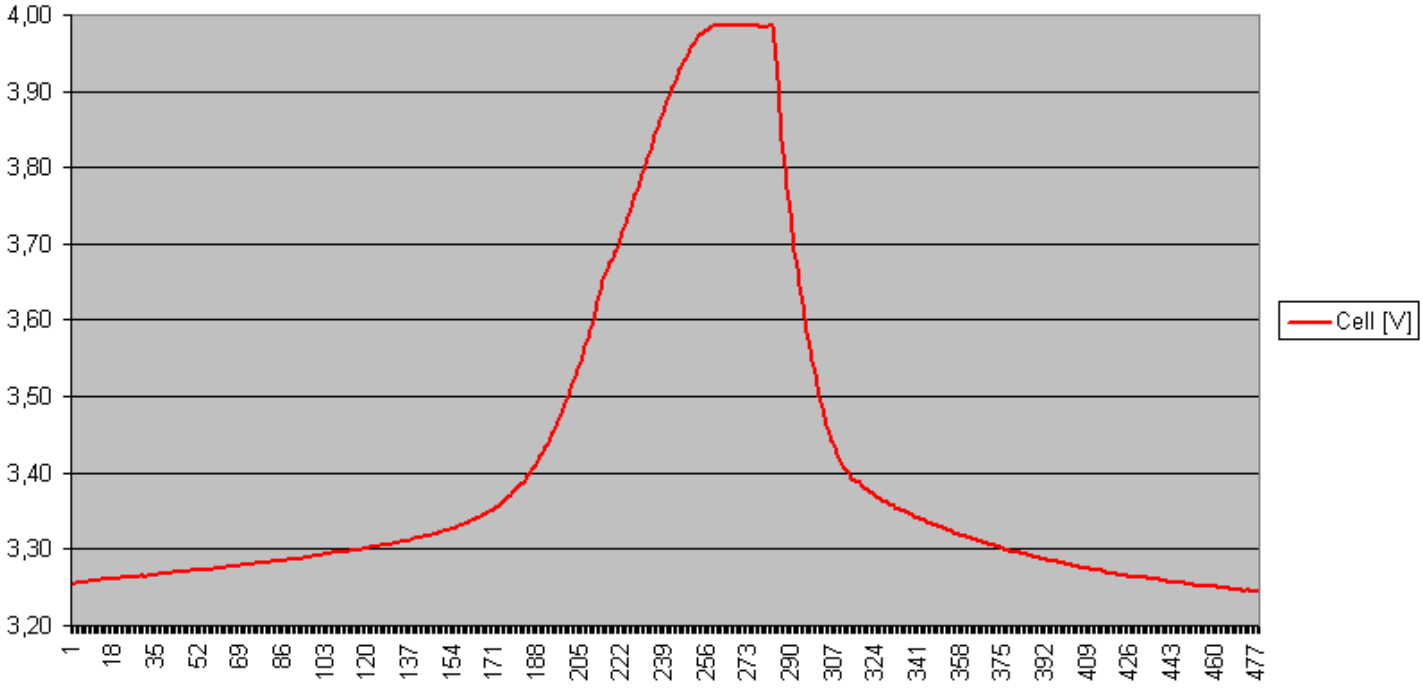


Fig 4 – proper charging of a lithium cell. The period of full voltage is very short.

When charging multiple cells, it is necessary to have all of them to reach the full voltage, to make sure all of the cells in the battery pack have been charged to full. This way the battery pack will be fully charged.

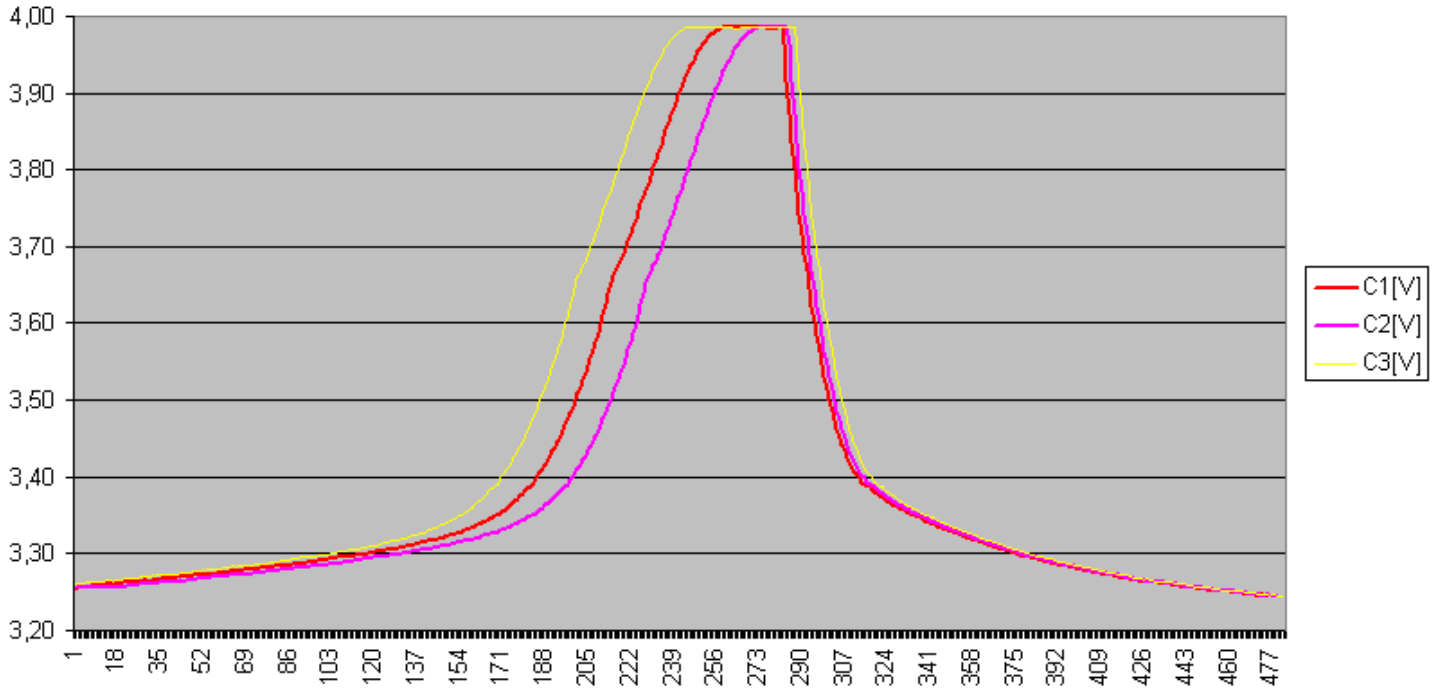


Fig 5 – proper charging of multiple cells. All of the cells have reached the full capacity nearly at the same time.

However in many cases the cells may be misbalanced. This means some of the cells will be charged to full voltage earlier and some cells will reach the full voltage later.

It is the task of the **BMS (battery management system) with the balancing function** to keep the voltage of the cells within the proper voltage limits.

Majority of the BMS systems with balancing, will simply “shunt” the fully charged cell/cells, thus allowing the charging current to bypass the fully charged cell/cells.

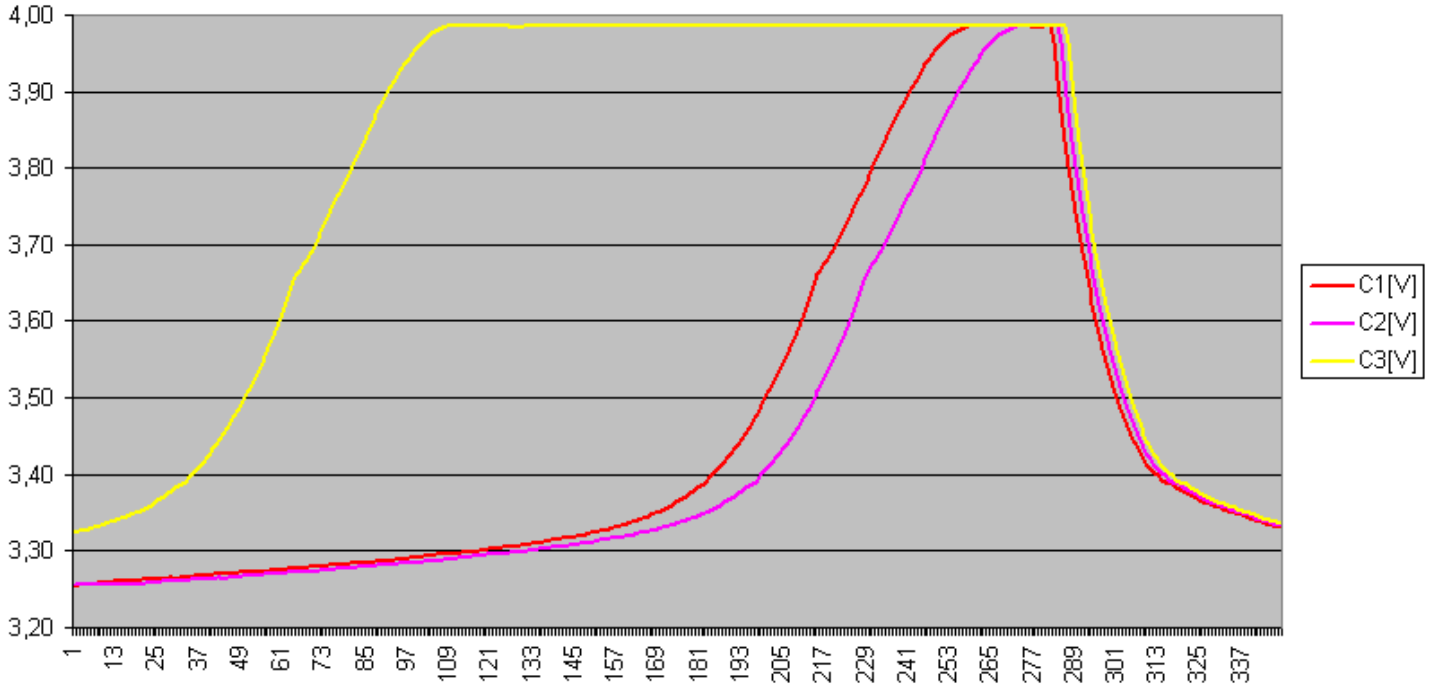


Fig 6 – Cell No. 3 has reached the full voltage earlier and the BMS keeps the voltage of the cell No. 3 within the limits to wait for the other cells to reach the full voltage as well.

Most of the users and the BMS providers do not realize that “balancing the cell” at the full voltage level is actually leading to the cell over charge.

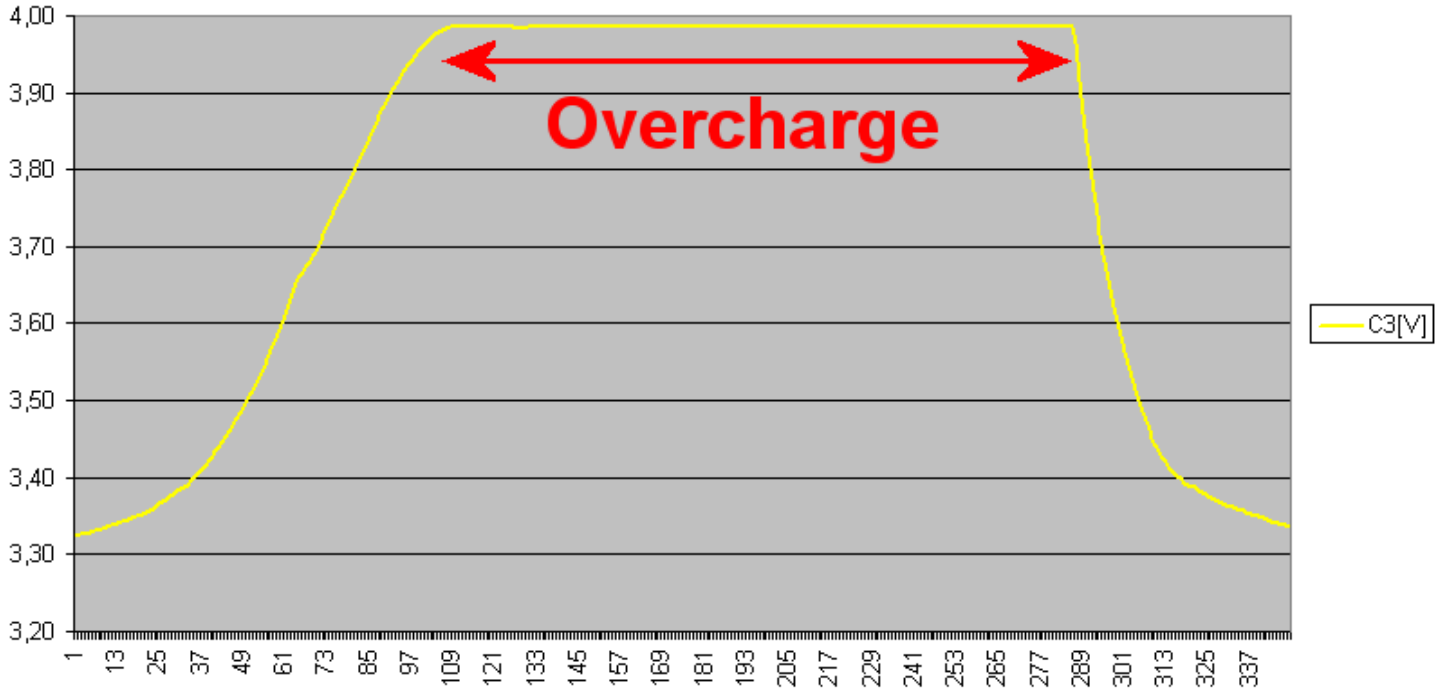


Fig 7 – Cell No. 3 is actually being over charged, because it is maintained at t full voltage for long period of time.

There may be some extreme cases of users “balancing” the cells while destroying them.

For example a battery pack with 3 cells 300Ah has one cell nearly full, another that is at 60% capacity and another at 40% capacity. The user is charging with 2 Amp current. To charge the weakest cell to full, the total 180Ah of energy is needed. This means it will take some 90 hours charging with the 2 Ah current. This in fact means that the nearly full cell will be kept at the full voltage, while being balanced, for 90 hours. (!) The second cell will be kept at the full voltage for 30 hours. The result will be that the two cells will be internally “boiled” by the extremely long time of being kept at the full voltage.

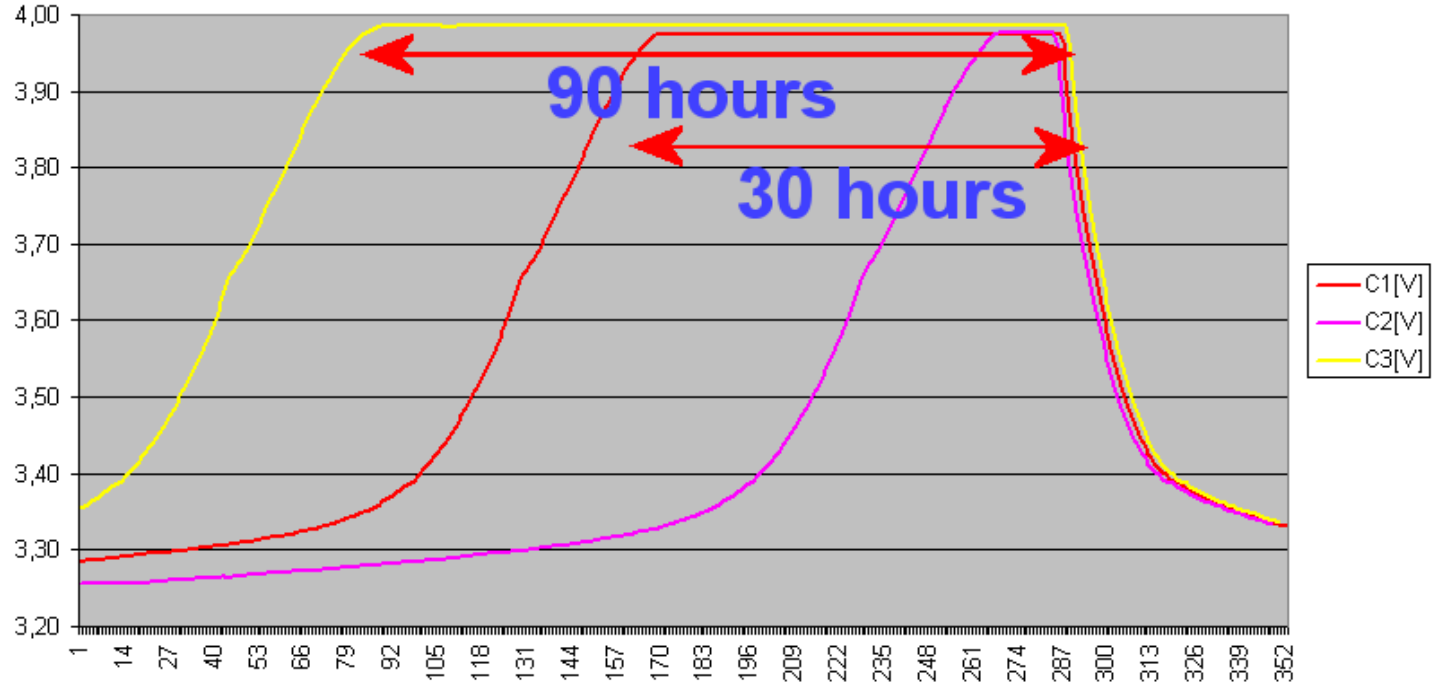


Fig 8 – Cell No. 3 and Cell No. 1 will be overcharged because of being kept balanced at the full voltage for many hours.

The same situation of cells being damaged is a case when cells are balanced to full by many repeated charging cycles. Example: a misbalanced cell will be kept balanced for 15 minutes at each charging. After 50 charging cycles the total time of "overcharging by balancing" will reach 12,5 hours of overcharging time. This will lead to a gradual destruction.

This is especially true of "weaker cells". The cells with lower capacity may be charged first and then kept balanced, waiting for the rest of the battery pack. When this is repeated the „weaker cell" is being always overcharged and its capacity is being reduced by the slow internal destruction, resulting in a looping cycle: the more overcharged, the lower capacity of the cell, the lower capacity, the more time will be needed to have the cell kept at full voltage waiting for the rest of the pack. Thus the situation of the cell is getting worse and worse.

We suggest these 6 tips to avoid the damage to the cells of balancing

1) The cells should be **balanced to full one by one before the assembly** of the battery pack. This way the will have the same capacity and they will need only very little balancing.

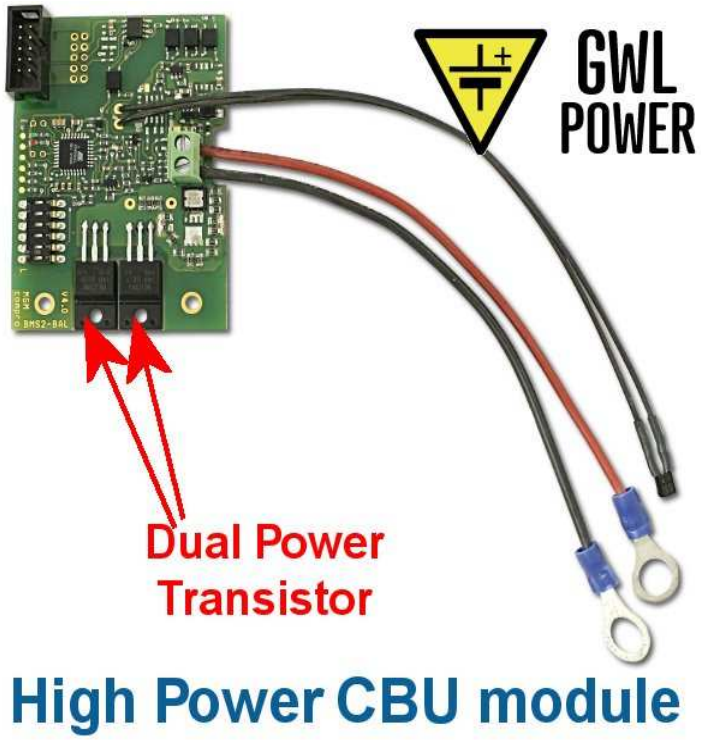
2) If your battery pack has been misbalanced and **you need more than several minutes to balance**, we suggest to check the cells and to balance them individually to get the pack fully balanced again.

3) Limit the full charge of the cells. You can make many cycles while using the cells between the 10% and 90% of the capacity. Simply use (discharge) the battery to full (but avid the deep discharge!) and then charge only partially just as you need. There is **no need for the lithium cells to be charged to full** every time.

4) **Avoid repeated attempts to charge the cells to full**. Some uses have a bad habit to plug the charger to charge to full several times during one day even though the pack is not used, and was not discharged. (They wish "just to be sure the cells are really full".) This is not a good idea.

5) Decrease the full charge voltage level for ordinary charging of the cells. You can make many cycles with the decreased full charge level before making the full charge. **For most cells charging to 3.65V per cell is OK**. Some user charge only to 3.60 per cell.

6) Use a **BMS system that allows high shunting (or bypass) currents**. With 10A balancing current you may be able to balance the cell down quite fast while charging the other cells still at 9 A current. Additionally it will take 5 time less then balancing just with 2 Amp balancing BMS model.



The most ideal solution is to have a BMS system that will allow the cells to get to a „relaxed voltage" level. This means that after reaching the full voltage and keeping at the full voltage for some time, the voltage level of the fully charged cell will be reduced to a safe voltage (usually 3.4V per cell) where the cell is neither charged nor discharged.

This way there will be no damage of the cells by balancing at the overcharge voltage level. In addition to a support of the BMS with balancing, this method would however also need a support from the charger so as to reduce the voltage as more and more cells go to the relax voltage.

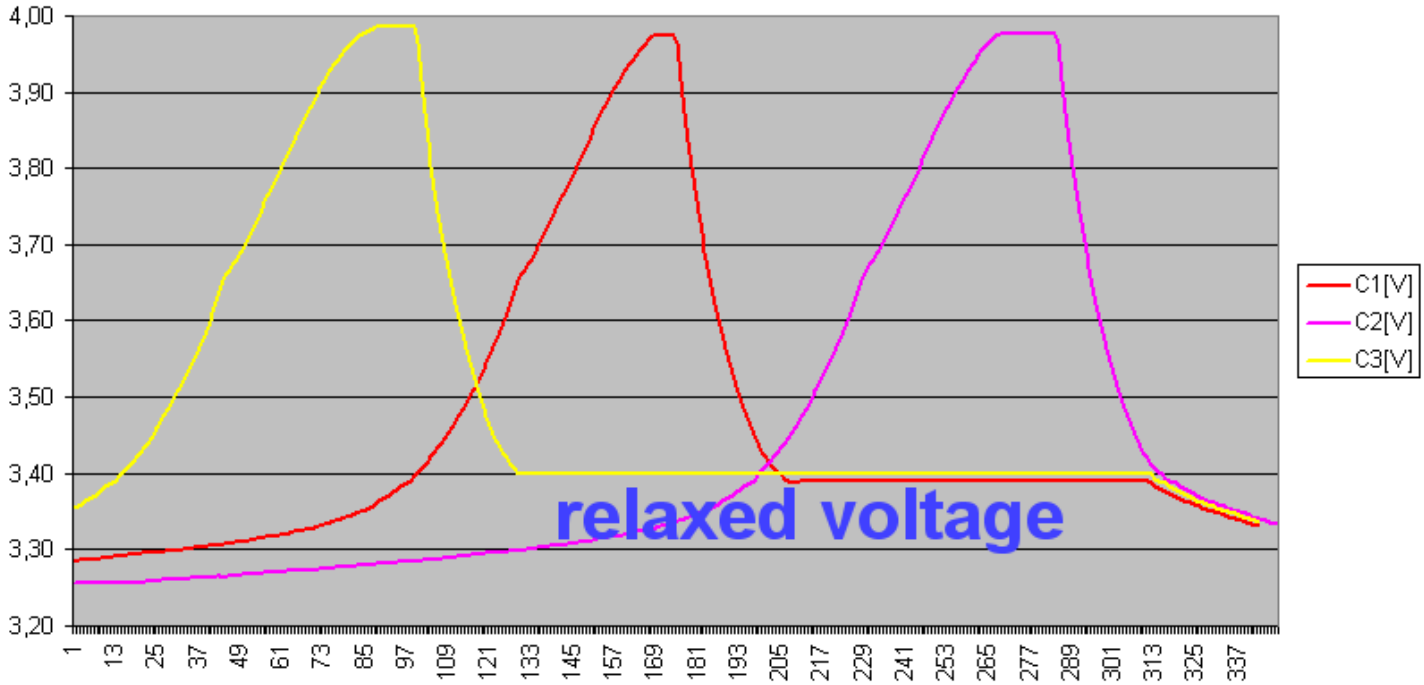


Fig 9 – an idea of balancing at the „relaxed voltage level": Cell No. 3 and Cell No. 1 will be kept at full charge, but not being damaged by over charge.

Conclusion

The damage by the slow over charge at balancing level is the most common reason of a gradual damage to the lithium cells (caused by improper use). We encourage all LiFePO4 users to check their battery pack condition to see of the battery pack is properly charged and balanced. We recommend avoiding continuous balancing of the cells for long time periods. We suggest to use the above 6 tips to change the balancing condition of the cells.

We will be happy to received response from the results of the lithium battery users to enhance the experience and prolong the lifespan of the lithium battery packs.

Note

This information is based on our observations and long-term test data. We try to present and assess the data according to our best knowledge and intentions. However it may be possible that some other person may reach have different results and different conclusions.

Invitation

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