LiFePO4 Battery Project 2017

Ideas and Methods collected from phone calls, emails, and the Internet. I guarantee NOTHING that is written here, nor do I have specific recommendations at this time. I did NOT install LiFePO4 batteries because NONE of my charging equipment was designed for them. To modify these systems would have taken more time than I had in 2017. Instead I took the easy (coward's) way out and replaced my 900AH bank -- 6 x 900AH 2v AGM Lifeline bank. LiFePO4 will have to wait for the next set of batteries.

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1.1.1 Maine Sail

Marine How To Articles

IMHO the bare minimums would be:

*Individual cell level monitoring that can trigger LVC / HVC
*The ability and tools to top balance the pack unless you are an epowered-boat and want to bottom balance.
*Proper over-current protection.
*Safe charge voltages and products than can do this with the best accuracy possible
*No solar controllers with built in temp compensation
*No voltage regulators with built in battery temp compensation
*Load bus / charge bus
*Alarm points that warn before LVC/HVC
*Cell compression case
*Adequate coverage for battery terminals
*Accurate voltage sensing for alternator charging
*Ah counter
*Solid state relay to cut battery charger

Products I use:

Balmar MC-614 Regulator
Mark Grasser 160A Alternator
Junsi Cell Log 8S - Individual Cell Voltage Monitoring
HousePower BMS and Cell Boards (bank HVC/LVC protection)
Link-Pro Battery Monitor (Ah counting)
Rogue Solar Controller
Class T Fuse
Tyco EV200 LVC Contactor
70A DPDT relays for Balmar and Solar HVC
Piezzo Buzzer for Alarms
Mastech 3030EX Benchtop Power Supply (balancing/charging in the shop)
Mastech 3050EX Benchtop Power Supply (balancing/charging in the shop)
*Sterling ProCharge Ultra shore charger (using custom program)
*Sterling Battery Chemistry Module to charge start battery

1.2 KP44 Group

1.2.1 Dwain on Dancy

Raul, One of the best attributes of Li are the acceptance rates. Unlike LA these batteries will take full or nearly full amperage right up until 100% full. They are easily capable of 1C discharge and charge rates, and most are higher. So my 700 AH bank could use a 700A-2100A Charger! On a boat there's no possibility of giving them too high of a rate. In reality the use we give them as a house bank is not stressing them at all. They are designed for EV use which is very demanding with high discharge and charge rates and running them very low to very full.

However, that same acceptance rate, while it'll shorten generator/alternator charge times significantly, is also one concern about existing charge sources. IE: Your/my/most alternators can't run at full output for extended periods. They will burn themselves up, so some kind of programmable regulator is required not only for the charge profile but to keep the alternator from overheating. So I have my 120A Balmar "detuned" to 80% with the MC614, plus it has temperature sensing.

It's hard to give a "normal" rate of discharge for my use as the solar is always contributing during the day. With the solar running we rarely get down to a -200ahr, more commonly around -80-100ahr in the am. We run everything a "normal" boat would run (occasional icemaker and microwave) and I use the shop vac and turn on the water heater when the engine hasn't been on for a few days. I think the water heater draws about 80A while running and I'll run it for about 45 minutes.

The other good attribute is the "useable" ahr. Li can safely and easily be used from 20%-100% Soc. So a 700ahr bank can give (80% x 700ahr) 560 useable ahr. For a LA bank you'd need nearly 1000 ahr bank for the same. (LA usable down to 50% would be 1120 ahr bank, but that same bank is rarely charged above 85% so add another 15% or so.)

The drawbacks are; the voltage curve is very flat there by making it difficult to determine SoC on voltage alone. The need to have charge sources that you can program completely, not just some pre-programmed settings. (As a side note, most current products that have a Li setting are set too high!) Although some products have a "Gel" setting that's usually around 14.1V for Absorption and that could be lived with if not left on and unattended. You can charge at higher voltages you just don't want to take the cells up there and hold it. There is no reason to keep these cells at 100% SoC, in fact for longevity it's been recommended not to. The damage done by overcharging is not a sudden catastrophic event, just like LA, once full, charging energy is turned into heat and if left to continue the cells will swell and eventually vent. At that point they're toast just like an LA battery! Continue on and bad things are likely to happen, just like LA! If you drive them down into negative voltage they are toast. Also proper and safe fusing is very important as these cells are capable of very high and extended discharges!
Li is not for the average DIY! However, if you're moderately electrically astute it's doable. If you can read the schematics, and understand the whys, of a BMS system you can do it. While Stan H's system that Jeff referenced is VERY Nice, and if I were starting from scratch I'd strive for something similar, but it doesn't have to be that complicated. Look up and read "MaineSail"/ Compass Marine's articles, he covers a lot of information in a concise and understandable way.

A word on or my take on "Cycle Life". These cells are rated at crazy high cycle rates.   Those cycles are complete depth discharges to a set point, which we rarely would do, also end of life is calculated as when the cell is down to 80% of original capacity, which would still be very usable in a house bank. We don't use these cells like that and nobody knows how long they will last in house bank use. Could be we'll shorten life by the way we use them, could be we'll extend it. Nobody has wore out a set yet! (barring misuse or abuse) It's more likely that Li banks in house use will die a "calendar" death as opposed to a cycle death. We don't know what that is either though.

It's always fun,
Dwain
S/V Dancy KP44 #279
San Diego

Jeff, Most of my use has been a few week long trips a year and most recently 6 months in MX. We weren't on the boat the whole 6 months though, But I also haven't plugged in my shore power for over a year now. On our trip down Baja we motored very little and had several days and nights with only the solar. If my memory recalls, overnight with autopilot, chartplotter, radar, and Nav lights we'd be down around 100-120 ahrs by the time the solar would start putting back into the bank. 690 W had no problem covering the usage and the replacement during the day. Of course on the way back up there were days of motoring producing too much power and the BMS would occasionally cutoff the Alternator and the solar would just float all day.

I use the House Power BMS as a monitor and failsafe. (Not charge control or balancing.) My charge sources are programmable and control themselves. The HP BMS will alarm at a high or low voltage event and disconnect before a critical level is reached. While Stan H's system is very nice and thorough, it is a bit complicated and perhaps a bit over done. No harm in that while it all works.

I run the pack at 13.4v when not aboard and 13.8v when on board. Most charging is done though 3- 230w Sun Power panels and a TriStar MPPT 60 (I shut down all but one when away.). My main Alternator is able to be shut down by the BMS but as the Balmar MC614 is programmed for the Li it rarely happens. I don't use the shore power charger, but if I do it is a Programmable Sterling ProCharge 60 and would only be used when onboard. My 150 amp 12v generator is also controlled by a programed MC614 and is never run except under supervision.
I used to watch the bank very closely, but have come to trust it and rarely check on it now. With a 700 ahr bank I have a theoretical usable 560 ahr so I tend to use power without worrying about it. The toughest thing to get over is feeling the need to keep the pack "full". I honestly can't think of a time, with my usage that I've thought "I'm low and need to recharge". I've seen the pack as low as 12.9 v and -300 ahr and not worried about it as I might be motoring soon or the sun was out. The point being, it's ok to be sitting at 50-60-70% and left that way! (unless of course you needed the extra power for something) These cells are much more robust and forgiving then many would have you believe. Run them between 12.4v and 13.8-14v and you run no risk of damaging them and can get 95-99% of their capacity out of them without pushing any limits. Also remember the "risks" aren't necessarily fire and catastrophic events, but mostly damaging the cells and the related wallet damage. As a note I bought my cells as factory used, 25 cycles or less, for $400/ 700ahr cell, so my entry level was pretty low. I had to buy 5 ultimately as I stuck a drill bit though one terminal when playing with them, so I've seen what a dead internal short produces.

It's been a fun experiment, and best of all it works! I'll add a few photos in the photo section.
Dwain
S/V Dancy KP44 #279

San Diego

I guess I'm in the KISS category. I have around $2000 in my 700 AH pack including controls. Only thing is I have LVC, HVC, and warnings at the cell level and pack level. I have individual cell monitoring with alarms at a 100mv delta. I have alternator and solar shut downs. But none of this does anything on a day to day basis it's just there to protect the pack in the event of some other failure. Plus I have 200 AH of Fireflys in my bilge as a start bank that can be switched into house service if needed. Robust? I think so. After many years now of living with these cells I think they are much more robust than people think. Many of the DIY failures, of which I don't think there are really that many, were poorly executed systems to begin with.
For example the phrase "LiFePO4 batteries SHOULD NEVER BE FLOATED" what does the mean? "Float" in a FLA sense is a maintenance charge, holding the battery at a level slightly above it's resting voltage. Great, sure you wouldn't want or need to hold LI on a continuous charge above it's resting voltage, but that doesn't mean that a programmable charge source that has a stage labeled or called "float" can't be used. For instance my solar control floats at 13.1v, I can assure you that with a resting voltage 13.2-13.3 no current flows. Is that floating the pack? (Actually according to one "expert" selling/designing a BMS it is!)
To me relying on a single Black Box to control all functions of a battery system is the definition of "non-robust". Am I diminishing the overall life of my pack by the way I run it? Perhaps, but the thing is, none of the "experts" have any experience in long term house bank (low C rate, partial cycles) use!

Here's where I would recommend everyone who wants an LI bank start. Understand this and you'll understand how a LI cell works and processes by which it can be damaged.

https://youtu.be/QlDd3jkcxoQ?list=PLKhqOHtqKt_bjwMjztceF_HjL6Rf8xsrk
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Dwain
S/V Dancy Kp44 #279

1.2.2 Paul on s/y Taniwah

3.3V is not an exact number for all LiFePO cells. It appears as if each manufacturers' cells have slightly different voltages, possibly due to slight chemistry differences. Our CALB cells work well there, but I think Dwain's Winston cells might have a slightly higher voltage. Anecdotally some of the small cylindrical cells (such as Tesla's) seem to have quite significantly higher voltages, around 3.5.

It's not hard to work out what works best for any specific cells: just a matter of some charge voltage logging over a few cycles (I did mine manually with a multimeter and pen and paper). It becomes really obvious really quickly. Also, a great thing about LiFePO is you never need to drive a 100% charge, so you can set a voltage point a little below that: you still get 95%+ SOC, and any cell imbalance that you may get over the years becomes irrelevant.

Hi Wayne,

I'm not really sure that I understand your phrase: "What if the charging source ...... is unable to provide enough current to charge the battery."

Provided it can provide over about 3.2 volts per cell then any source will charge the battery no matter how little current is being supplied. If it's a very low current (say 5 amps), then it will take a veeeeery long time (a 400 Ah battery will take over 80 hours to fully charge from empty), but it will eventually charge.

If what you mean is that the charge source provides less current than you are drawing out of the battery, thus putting you in a net discharge state vs a net charge state, then you won't charge the battery (as with any other chemistry).

For all batteries the net charge/discharge state is a product of all the current inputs from charge sources (solar, wind, alternator, shore charger, etc) minus all the current draws (outputs) for loads being used (lights, refrigerators, etc). If your total draw is larger than your total charge current, then you have a net discharge state and your battery is discharging.

One nice thing about all battery chemistries is that they can essentially be treated as a "black box" with regards to their net charge/discharge state. By that I mean that you don't really have to know anything about what's going on within the battery to know whether you have a net charge or discharge state. You only have to add up all the charge input currents, and subtract all the load currents, that are being applied to the battery externally. So, you can do this at the battery terminals and don't need to worry about what's going on for each cell in the battery.

We do that on Taniwha with a high current shunt resistor on the negative buss bar (always put shunts on the negative side) which inputs to a state of charge meter. This shows us net current (charge or discharge) and combined with a pack voltage measurement, we can calculate all the info we need to know about the pack.

Critical to the successful functioning of this monitoring is setting your battery up so the ONLY wires on and off the battery are one on each pole. These lead to large buss bars: through the current shunt resistor on the negative line, and through a master fuse on the positive line. All circuits then originate and terminate at either the positive or the negative main bussbar, so the shunt resistor measures absolutely everything: there are no little loads taken directly from the battery terminals as you often see.

So, answering your original question, we get all the info we need from the above setup, and thus there is no need for a cell level BMS. In fact, I believe such a BMS would be harmful to successful monitoring because it introduces small permanent current draws within the battery pack that you can't account for with the shunt resistor, thus confusing any capacity calculations. Over 5 years I've monitored cell voltages at various stages using a multimeter, including entire charge/discharge cycles, and IN OUR SAILING HOUSE BANK APPLICATION there has been virtually no variability in cell balance. Given that, I don't see any need to introduce the complexity of a cell level BMS.

I hope that answers your question. If not, please let me know and I'll try to address it.

Cheers,
Paul.

Hi all,

Jeff emailed me about this thread topic, so I thought I'd put my 2c in. I haven't been on the forum for a long time as we got very busy moving our lives back to NZ from Malaysia. We still have Taniwha: she's still in Phuket at the moment but we'll be moving her back to NZ in Oct.

I looked back over my notes about our LiFePO installation and see that we installed them in about Jan 2011. So that's over 5 years ago. If you search back posts you'll find details of our installation and various comments, and some photos in the "Taniwha" photo folder on here. I also started the Cruising Forum thread about LiFePO for house banks that Jeff referenced and I posted a tonne of data in that thread early on.

For those who don't know, my background is in electrical engineering, including time working on rechargeable battery technologies many years ago, so I tackled the LiFePO project from a reasonably knowledgeable background.

After running them for so long, I still think they are significantly superior to lead acid technology.

Our usage pattern isn't long term cruising, but occasional week or fortnight sailing, with the boat being left without us in attendance for months at a time. Over the ten years prior to installing LiFePO we managed to chew through 3 sets of wet cell LA batteries through various combinations of accidents and negligence. One case being someone removed our shore power cable in the marina and didn't replug it: when we returned months later the batteries were dead. One set were expensive Trojans.

With the LiFePOs, they have negligible self-discharge, so if your power is unplugged there are no worries. And if you have a low voltage cutoff (as you should have with LA also) you won't ever have a problem with an issue like sulfation.

Charging LiFePOs is very easy also. If you want you can forget about multi stage chargers. A simple car charger (or one stage charger) that is voltage limited is all you need. That was demonstrated to us last year when our 20 year old multi stage shore charger died. We had a fancy new charger in reserve, but that was stolen before we could install it. As a last resort we used an old single stage constant voltage car charger that we could set the voltage on. Perfect. The batteries self regulate the current and end up virtually 100% charged without any monitoring.

My opinion about BMS' and the agonising you read on some forums about getting the voltage set point perfect otherwise you'll get armageddon, is that they're over thinking things and unnecessarily complicating it (maybe trying to sell you something or prove they're more knowledgeable). I think in EVs that's necessary because they have hundreds of parallel and series strings in complicated arrangements with different wire lengths. In house banks like ours and Dwain's there are four cells in series. We have seen less than 0.02V cell variation over 5 years. I think adding a BMS adds tiny direct cell drains that could cause issues and I haven't seen any need to have that level of monitoring.

Regarding voltage charge cutoff, I agree with Dwain that almost all the fancy charge controllers with multi stage charging that now have "lithium" settings have the voltage set too high. Our cells reach about 97% SOC at 3.3V. Beyond that the voltage rises very rapidly and you gain almost no extra capacity. Even at 3.2V you're well over 90% SOC. So set max voltage at 3.3V say and you'll never have any issues. You don't need to trickle charge, but it doesn't seem to hurt the cells over prolonged periods (months), so if you only have a single stage voltage set charger, set it at 3.25V and all will be perfect.

Also, with our limited use the cells are still getting better: we get more capacity out of the cells when we are sailing now than we did 5 years ago (about 420Ah from our nominal 400Ah cells). Since none of our previous LA batteries lasted 5 years I can't compare (or maybe that is the comparison).

I read a lot of people saying that they think LiFePO are too complicated to use. In fact, they're more robust and much easier than LA, and probably cheaper from a total system viewpoint (and yes, you almost certainly can use your existing chargers and charge controllers).

So after 5 1/2 years, I'm more convinced than ever and I'll never go back to LA. Also, I've added a small capacity LiFePO starter battery: small capacity but huge CCA, and no worries about not being able to start.

Hi Guys,

You all have been having fun talking about LiFePo4 batteries without me - what a great discussion. I've just come back on the board after a while away and read all the posts.

I agree almost totally with Dwain, the only thing I have changed my mind about over the last 3 years is the initial cell balance: some of the work being done by some others suggests that a bottom-balance initially might be a bit superior to a top balance to cell drift over years. However, I top balanced my cells back almost 3 years ago now, and they're still very close (I reckon 3 cells are within 1% SOC, with the 4th being about 2% different).

I wouldn't touch a BMS as they are described - all those active "balancing" electronics are a recipe for problems in my opinion, and my experience is that for house bank applications there are no problems. Yes, you need cutoffs (high and low), but the charge source should have a cutoff anyway, and we have always used a pack low voltage cutoff device (we use a Victron Battery Protect).

Regarding alternators, I agree with Dwain that these cells are creating some magical new phenomenon. In my view good practise in marine system design says you should have the following in an alternator setup:

1) a continuously rated alternator (i.e. not a car alternator). I've been looking at the Zena's for years but haven't got around to ordering one yet. Our Beta came with a 120A continuously rated Prestolite alternator, and it's been goign pretty well,

2) a good regulator which has customisable voltage settings,

3) alternator temp sensing input to regulator,

4) battery voltage sense wire input to regulator (you'd be surprised how big the voltage drop is through even 120 sq.mm (>4/0) wire),

5) really big wiring to the batteries,

6) fuses on everything,

7) not a battery temp sensing input to regulator (LiFePO4 seems to charge better at slightly higher temps, so doesn't need the rate throttled back - maybe an absolute cutoff at 60 deg.C but I haven't found that yet),

8) really good bussbars and connections - and make sure they're tight. I failed to tighten up one nut properly (but it was hand tight), and the temp increase in the connection was very high,

If you've got a good regulator, then you don't need to worry too much about the alternator as long as it's a good one.

If you don't want to do that, you could just charge using an AC genset and a shore charger - shore chargers are naturally current limited by their design.

I agree that some sparky's are going to worry about things because they don't know. The only solution is to get stuck into it. In my view there's very little that you need to do different from a good, robust LA charge system.

As with Dwain, these are only my experiences, but I think that Dwain and my experiences sound like they are very similar with these batteries (I especially liked his comments on his BMS)

Hi Jean-Claude,

I totally agree with the EVTV regime for care for LiFePO4 cells.

Regarding fully charging the cells: in fact it is very easy to fully charge LiFePO4 cells in a yacht environment, unlike LA cells. The reason is that their charge acceptance doesn't reduce with increasing SOC. (Also, they have a Peukert constant of virtually 1.0).

The ideal charge regime is a Constant Voltage (CV) one, so you simply charge them until the voltage hits that value. For our CALB cells they recommend 3.6V per cell. We actually cutoff between 3.25 Vpc and 3.4 Vpc, depending on which charge source is being used. At those voltages, we're seeing about 99% of capacity in the cells (the charge & discharge curves are VERY flat, and VERY sharp at the ends). We cutoff at lower than the 3.6 Vpc to ensure that we don't over-charge them - as you say, that should lead to increased cycle life, and for virtually no capacity lost.

We use normal LA charge controllers with 3 stage charging algorithms because it's easy to do so and they are proven charge controllers. We just make sure that the controller can have it's voltage point set to a value in the range of 13.0V - 13.6V (not all can). But in practical use they are essentially operating as a 1 stage CV charger.

The first stage CC in these chargers has always been a bit of a misnomer - they are CV chargers with a current limit (limited by the power supply or the alternator). The 1st stage CC just puts the max current that the charger can supply into the batteries because they can accept that. Once the voltage hits the set point, it is automatically in stage 2. By definition this is a CV charger also.

With LiFePO4 cells, what we see is that when they hit that voltage, the current then tapers off VERY quickly. E.G. with our 50A shore charger, it might take 6 hours to reach that voltage (if the cells have been heavily discharged), and then 5 minutes in the CV stage for the current to drop to virtually zero. This is a product of that incredible charge acceptance of these cells.

Then we set the "trickle charge" phase of the charger to a value that is at or below the 3.28V "nominal" cell voltage (we like to set it at 3.2Vpc). You don't need a trickle charge, but in our chargers we can't turn it off, but we can set the voltage. Setting it this low won't ever harm the cells. I believe that there are starting to appear marine chargers with LiFePO4 algorithms (Victron), but your old gear will work if you can change the voltage set points.

One last word on charging. If you read some of the sailing chat room threads on LiFePO4 you'll read a lot of stuff about how you shouldn't even talk about 3-phase charge regimes in relation to LiFePO4, and anyone who does just doesn't know what they're talking about. I would strongly council you to ignore those comments (and the ones saying you must have a BMS).

If we're sitting in a university lab, or a battery manufacturing R&D team, discussing the interstitial process by which LiFePO4 cells operate (which is a really cool discussion because it's so different from LA and other chemistries), then yes, talking about bulk, absorption, and float phases of charging is totally inappropriate.

However, we're not doing that. We want to use LiFePO4 as a replacement in our existing systems for our old LA batteries. And most of us don't need to change our chargers or regulators. So we need to translate how our chargers and regulators, which are 3 stage devices, can be made to successfully charge our new LiFePO4 cells - and they mostly can. So that's why it's still appropriate to talk about the settings for our existing devices in terms of their algorithms. Hence you need to set the Bulk, Absorption, and Float points for your charge devices. (sorry, that's a rant - but it's really important to understand. There seem to be a lot of people out there who want to prove their theoretical knowledge superiority but aren't very helpful in actually implementing something).

Opps, long post.

I hope it helps rather than confuses.

Cheers,
Paul.

Hi Jean-Claude,

I'm familiar with the Sterling Alt to Batt charger, but I'm not aware that it now offers a LiFePO4 setting. Could you please send me a link to that version as I can't find it on the internet site.

1) To my thinking, both the boost (3.7 Vpc) & float (3.45 Vpc) of the Sterling seem too high for LiFePO4: certainly for the CALB cells I have.

I think 3.4-3.5 Vpc (13.6V - 14.0V) for boost, with a max of 3.6 Vpc (14.4V), and then if the charger has a float mode which can't be turned off, then it should be in the 3.2 - 3.3 Vpc (12.8V - 13.2V) or lower.

I'm not sure why Sterling would have done it this way: all I can think of is that a few years ago the recommended voltages were higher, but with experience the battery companies have reduced them to what we talk about today - maybe Sterling developed this algorithm from the earlier spec.s

The boost value of 3.7 Vpc wouldn't damage the cells, just very slightly overcharge on each charge. But I'd be worried with a 3.45Vpc float if you're motoring quite a bit - I think that voltage would overcharge the cells if on for more than a couple of hours.

Given the old specs of the Sterling device, I'd use their "Gel & AGM (US Spec)" setting of 14.2 bulk & 13.5 float. That's 3.55Vpc & 3.375 Vpc respectively. That little bit lower, and the 3.375 is within the natural rest voltage, which is in the 3.28 - 3.38 range. I still think it would overcharge the cells if you run it for days on end, but in normal use it should be fine.

If you can fit an external regulator to your alternator, you may want to look at some of the Mastervolt regulators. They have a model which is fully programmable with voltages down below the level LiFePO4 needs, and the ability to turn off the float. I'd like to get one of those in the future.

2) What you run with on the shore charger I think would depend on your use profile. If you plug into shore power to get a quick charge, then you'd probably need the dual bulk & float mode. But if you leave the shore charger on for significant periods of time, then just float might be the better option. I'd set the float as low as possible, which is 13.2V (3.3 Vpc). Even then I wouldn't suggest that you leave it on continuously.

These are just generic observations. Be aware that a lot will depedn on your power usage - e.g. if you have something that constantly draws battery whilst you're on shore power at a decent rate, then leaving the float on might not be a problem.

What I'd suggest is that you try some settings, monitor closely what's happening the the batteries, and modify based on your findings.

At this stage it's better to be cautious about the FiFePO4 voltage settings, since they charge so well that undercharging isn't much of a problem.

The other thing to remember is that because they essentially don't self discharge, you may not have to leave the shore power plugged in at all. That's what we've found: we can leave the boat for a month not on shore power (with just the bilge pump on), and come back with almost full capacity still in the batteries.

Another point, different LiFePO4 cell manufacturers seem to have slightly different voltage recommendations. Make sure that you're aware of those - my experience is with CALB cells, and may not translate 100% to other brands.

I hope this helps.

Cheers,
Paul.

1.1 for Peukert is essentially an AGM Peukert (Lifeline, Odyssey etc.) and it will cause counting errors. At the loads we are drawing these banks at Peukert is essentially 1.0 - 1.03.

No matter what you do these Ah counters will get out of sync if not regularly reset to 100% SOC. The batteries are very, very predictable and Ah counters were designed for lead acid..

The best performance I have come up with so far is Peukert of 1.0 and charge efficiency set to 100% to avoid any negative counting on the recharge.. Remember a Peukert for a a flooded battery of 100Ah is based on a 5A load. A LFP battery is rated at either .5C or 1C load so a 5A load and a flooded Peukert factor simply does not work well...

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Charging LiFePOs is very easy also. If you want you can forget about multi stage chargers. A simple car charger (or one stage charger) that is voltage limited is all you need. That was demonstrated to us last year when our 20 year old multi stage shore charger died. We had a fancy new charger in reserve, but that was stolen before we could install it. As a last resort we used an old single stage constant voltage car charger that we could set the voltage on. Perfect. The batteries self regulate the current and end up virtually 100% charged without any monitoring.

My opinion about BMS' and the agonising you read on some forums about getting the voltage set point perfect otherwise you'll get armageddon, is that they're over thinking things and unnecessarily complicating it (maybe trying to sell you something or prove they're more knowledgeable). I think in EVs that's necessary because they have hundreds of parallel and series strings in complicated arrangements with different wire lengths. In house banks like ours and Dwain's there are four cells in series. We have seen less than 0.02V cell variation over 5 years. I think adding a BMS adds tiny direct cell drains that could cause issues and I haven't seen any need to have that level of monitoring.

Regarding voltage charge cutoff, I agree with Dwain that almost all the fancy charge controllers with multi stage charging that now have "lithium" settings have the voltage set too high. Our cells reach about 97% SOC at 3.3V. Beyond that the voltage rises very rapidly and you gain almost no extra capacity. Even at 3.2V you're well over 90% SOC. So set max voltage at 3.3V say and you'll never have any issues. You don't need to trickle charge, but it doesn't seem to hurt the cells over prolonged periods (months), so if you only have a single stage voltage set charger, set it at 3.25V and all will be perfect.

Also, with our limited use the cells are still getting better: we get more capacity out of the cells when we are sailing now than we did 5 years ago (about 420Ah from our nominal 400Ah cells). Since none of our previous LA batteries lasted 5 years I can't compare (or maybe that is the comparison).

I read a lot of people saying that they think LiFePO are too complicated to use. In fact, they're more robust and much easier than LA, and probably cheaper from a total system viewpoint (and yes, you almost certainly can use your existing chargers and charge controllers).

So after 5 1/2 years, I'm more convinced than ever and I'll never go back to LA. Also, I've added a small capacity LiFePO starter battery: small capacity but huge CCA, and no worries about not being able to start.

I hope these are interesting and maybe useful comments to some of you.

Cheers,
Paul

SY Taniwha

3.65VPC will unnecessarily stress the LFP cells and will lead to premature failure. A better plan is to charge them to about 0.9C and then _stop charging._ For most cell manufacturers, 0.9C corresponds to a charging voltage of from 3.35VPC to 3.45VPC.

I highly recommend MaineSail's excellent blog: LiFePO4 Batteries - Thoughts & Musings Photo Gallery by Compass Marine How To at pbase.com (http://tinyurl.com/qh985cy)
---End Quote---
It is a misconception to believe that SoC can be controlled using voltage. 3.4V will still charge a LFP cell to 100% given enough time and 3.3V will struggle to achieve 30% no matter what. The transition is so steep that it makes voltage unusable.

Image: http://nordkyndesign.com/wp-content/uploads/2016/04/SOC-vs-Absorption-Voltage.png

The data for the graph came from a published experiment (http://www.powerstream.com/lithium-phosphate-charge-voltage.htm) by Powerstream, which I plotted in a different and much more interesting way some time ago while looking at the characteristics of LFP cells (http://nordkyndesign.com/practical-characteristics-of-lithium-iron-phosphate-battery-cells/).

What would better control SoC is using the combination of end voltage and residual current, but since SLA charge controllers are completely unable to deal with it, all the LFP systems discussed here rely on a fragile balance between "settings" and a necessary consumption to try and work more or less acceptably most of the time.
This balance is easily upset if something changes, like leaving the boat for a time or going from summer to winter.

This is what quickly led me to moving away from using any kind of independent solar charge controller. I now have one control wire going from the BMS to a solid-state switch and no settings at all. Charging LFPs is in fact a part of battery management and this is ultimately inescapable.

2 Charging Issues

2.1 Outback Systems Inverter/Charger

ABSORB SETPOINT:	13.6v (4x3.4)
ABSORB TIME:	depends on battery size? Or just max?
FLOAT SETPOINT:	13.5v ("trickle charge" not required)
FLOAT TIME:	zero
REFLOAT SETPOINT:	12.5v? If triggered, does this also have zero float time?

Also, possibly using "GEN" mode would be an option; except this changes the AUX functions and the extra cooling fans would have to be started some other way, possibly with a thermal switch.

Info on the net indicates that "floating" a LiFePO4 battery in the LA sense is not a good idea.

- The first stage of the charging sequence is the "Bulk" stage. The FX uses as much AC current as possible from the AC input source to raise the battery voltage to the "Absorb" voltage setting. See the "Maximum Current for Battery Charging" heading in the RATINGS section for the FX's default and maximum values of the AC current used for charging. The time period of the "Bulk" stage will vary with the battery bank's age, capacity, voltage and AC source.
- Once the "Absorb" voltage has been reached, the FX will use the necessary AC current to sustain this voltage for the "Absorb Time" (default of 1 hour). The AC current will decrease as the "Absorb" charge continues.
- After the "Absorb Time Period", the FX goes into "Silent" mode. The charger is turned off and the FX continues to monitor the battery voltage. If a generator has been automatically started on a low voltage condition using AGS (see MATE manual), the FX will automatically turn off the generator after the "Absorb Time Period".
- If a generator has been manually started or the utility grid is connected, the FX will let the battery voltage drop to the "Refloat" voltage and then it will start a 'Float' charge.
- The 'Float' stage will raise the battery voltage to the "Float Setpoint" for the "Float Time Limit". The 'Float' stage is meant for maintaining batteries that have DC loads connected to them. If there aren't any DC loads on the batteries, the battery voltage will usually remain above the "Refloat" voltage set point.
- After the "Float Time Limit" (default of 1 hour), the FX goes back into 'Silent' mode and waits until the battery voltage drops to the 'Refloat' voltage again. It then repeats the 'Float' charge for the "Float Time Period". The FX will continue this cycle of 'Silent', 'Refloat' and 'Float' until the AC source is disconnected.

The ABSORB SET POINT is the voltage that the batteries will be charged to during the first stage of the charging process. This stage of charging raises the battery voltage higher than the nominal battery voltage and allows the batteries to regain their charge. The 'Absorb Time Limit' must be long enough for the batteries to regain 100% of their charge. This setting has a range between 13.0 vdc and 16.0 vdc in 0.1 vdc increments.

The ABSORB TIME LIMIT can be adjusted to provide enough time at the 'Absorb Setpoint' to achieve a fully recharged battery. For large batteries a longer time may be required – small batteries may require a lower setting. The FX automatically reduces the 'Absorb Time Limit' when the charger is connected to a partially charged battery. This setting has a range between 0 hours and 24 hours in 0.1

hour increments.

The FLOAT SET POINT is the voltage that the batteries will be 'trickle' charged to. This charge will finish the charging process by putting the last few percentage points of charge into the batteries. This set point can be adjusted to match the specific requirements of the batteries being charged. This setting has a range between 12.0 vdc and 15.0 vdc in 0.1 vdc increments.

The FLOAT TIME PERIOD can be adjusted to set the amount of time that the battery is held at the 'Float Setpoint'. For large batteries a longer time may be required – smaller batteries may use a lower setting. Once the battery has been held at the 'Float Setpoint' for the 'Float Time Period', the battery charger goes silent and provides no charge to the battery. This setting has a range between 0 hours and 24 hours in 0.1 hour increments.

The REFLOAT SET POINT voltage is used to "trigger" the battery charger back into another FLOAT cycle when the battery voltage falls to this set point. This can provide maintenance charging of batteries and is also useful when intermittent DC loads are operated from a battery system and an AC source is available. This setting has a range between 12.0 vdc and 13.0 vdc in 0.1 vdc increments

Perhaps I am confusing nomenclature: BMS should be "charging source control". The number of posts is approaching 6000 and it would be nice if there were a synthesis somewhere. The best seems to be this. I am just trying to figure out what will work for a 600-700 AH bank without having to go crazy with complexity and expense.

So far it appears to me that the following is a subset of what is good for DIY LiFePO4 vessel battery banks:

1. The batteries can take as much current as you can safely put into them. This reduces expense (diesel/petrol savings) by lowering generator runtime.

2. Each current source is, usually, controlled by a device (alternator regulator, solar charge controller, wind power charge controller, mains power battery charger or inverter/charger). Older units assume a 3-stage charge cycle: bulk/absorption/float which is unsuitable to LiFEPO4 batteries. These units operate on a CC (constant current) in the bulk mode then on CV (constant voltage) in the other phases. The better controllers have custom settings which allow absorption and float to be effectively disabled. The newer devices have “lithium” settings which might not be ideal.

3. I am continually reading that these batteries are not LA and must be handled as a totally new system, yet most practical solutions appear to be voltage-driven and required staying within a safe zone in the SOC. I.e. below 95% SOC and above 25% SOC as indicated... by voltage. Different users seem to have variations on what is acceptable or safe. Is that right?

4. The "BMS" may or may not have top balancing. It is arguable whether, in a properly initially balanced bank, automatic top balancing is needed. There are good arguments for bottom balancing every year or three and not having cell balancers. It may be simpler than we think.

5. What is more important for a "BMS" (or "safety net management") is the ability to disconnect the charging source at a high voltage threshold and then to disconnect the loads at a low voltage threshold. The general thinking appears, to me, that this is your safety net. Not what I would call a “management system” but more like an

emergency disconnect.

6. Ideally the loads and charging sources are on different circuits; but I don't see a huge problem with them being on the same circuit. If the SOC of the bank declines to the LVP threshold you have to start charging and this brings the batteries back on line. An inverter/charger is, by default, using the same cable for charging and inverting.

7. Inside the "safety net" range we need to control all incoming charging sources to stay below a safe voltage/SOC level. If, for some reason, the charging source fails to stop charging and the "safety net" HVP cuts the circuit this could destroy an operating alternator. Alternators need to have the regulator shut down or the exciter wire disconnected. I am not sure what an HV emergency cut-off would do to an operating battery charger. Solar isn't a problem. .

8. Older inverter/chargers are hard to control because the battery voltage sensing is taken off the large DC cables that either power the inverter or deliver the charge. Voltage at the inverter is not necessarily voltage at the battery. If I wanted to be able to control the charging function externally while on shore power, I could bypass the AC input around the inverter charger. Despite earlier criticism, this would NOT be a problem. This is done all the time. Unplugging shore power from an inverter will shift it into INVERT mode if inverter mode is "ON". We charge with a small Honda generator and it when I turn it off (or it runs out of gas), it stops charging. Large power loads like the water heater can have a solid state relay (mine already does) to allow functioning ONLY when on shore power, which for me is rare. I disagree that this is a bad way to control the charging function on an inverter charter; it is actually a normal part of the design. At this point, however, I think a new, separate, battery charger (40A perhaps) with a Lithium program could be used. But, like I said, I'm not sure I trust the battery charger manufacturers lithium profiles.

Sorry for the long post.
Cheers,

Jeff

2.2 From the Net

2.2.1 To Cruiser's Forum

Friday, 28 April 2017, 18:26 AEST

Agreed. Misinformation is everywhere and the trick is to filter for the reasonable options, if any, to manage and charge and protect these LiFePO4 batteries used as house banks.

It is a waste of space to insist LiFePO4 are actually "Lithium Ion". Of course they are, but one thing is clear is that they are the only type of Lithium battery today that is useful for DIY battery banks on a cruising boat. This use is what this forum is about. Although motor homes and vans can make use of this technology, it is still a different application on a boat.

1. By now we all know the benefits of LiFePO4. No disagreement there, so lets stop talking about it.

2. The "trick" is to devise a method to START and STOP charging sources safely which is also as immune to human error factors as possible.
3. It is NOT clear from this thread and others that voltage sensing alone is adequate to this task.
4. It is NOT clear that existing LA charging sources (AC chargers, alternators, solar, wind) are adequate to this task without external control, which can be complex and subject to error.
4. There is disagreement whether cells-in-parallel vs strings-in-parallel are better.
5. There is disagreement whether large cells (>200AH) are safe.
6. It does not seem clear that safety net LVP and HVP devices will be adequate to save a bank. They should be in place but the system has to be designed so they are actually never needed.
7. By "adequate" I mean that the system will not accidentally over or under charge (and thereby destroy) the batteries, leaving the cruiser in a potentially dangerous situation without electrical power, not to mention spending another $4K or more an replacement batteries. One of the arguments for LiFePO4 batteries is that low cost per AH over their as-yet-to-be-determined lifetime. One bank failure wipes out that advantage.

There are many voices on this subject that express opposite viewpoints. I want to see the use cases. Maybe they are all true? Perhaps your method worked 33 times and so did the opposite method? Are we hearing about the failures?

FWIW I am at the end of 6 years of AGM use with 1218 total cycles of about 100AH each and 117,793 total measured amp-hours. This is still short of the factory cycle life, but better than most. The bank is 900AH now degraded to about 1/2 that. The construction is six 900AH AGM lifelines. Parallel strings of LA batteries invariable lead to very short lifetimes. I also now know how to better charge these batteries, largely from studying a potential move to LiFePO4. This is not because they are comparable in any way (except they both store energy) but because I gained a lot of understanding on what works and doesn't work to monitor and control a charging regime.

For me, the jury is still out and whether to simply (and I do mean SIMPLY) replace the 6x AGM bank, good for another 5 years, or undertake the very large and expensive effort to install LiFePO4. (Yes, I crave the light weight, consistent voltage, and long life but it's going to be a LOT of work).

I know I am dreaming, but I would like to see a definite answer to each question or issue, with research and use cases behind the arguments. I know the issues are interlinked but I would like to see some of them separated into separate threads (i.e. cells-in-parallel vs. strings-in-parallel) or whether cell monitors/balancers are useful). I hesitate to do this as it might be beyond the scope of what is usually a modest forum and it would require input from the major contributors.

2.2.2 From Cruiser's Forum

These following posts were made to the thread:
****
Re: LiFePO4 Batteries: Discussion Thread for Those Using Them as House Banks
http://www.cruisersforum.com/forums/f14/lifepo4-batteries-discussion-thread-for-those-using-them-as-house-banks-65069-post2366154.html#post2366154
Posted by: T1 Terry

On: 07-04-2017 08:36

Haven't post here for a long time, can't believe this thread is still running. Now at 6 yrs and well over 200 systems and most operate 24/7 in live aboard type situations although these are off grid houses, houseboats and on road RV's where the owner/user is full time dependent on the battery pack.... boondocking I think it's called over there. So much more to know about the longer term use of lithium batteries than meets the eye for those with 2 yrs or less system ownership.

Memory charge and discharge is real but very different to NiCad etc it is more like a cleaning process to get all the charge back into and all out of the cells. Under charging the cells accelerates the problem and over voltage charging simply increases the internal resistance to the stage the cell can not be fully recharged.
A full service is needed every 3 to 3 1/2yrs, this includes cleaning all the oxidisation from the cell terminals and from the link plates, then a good coating of Alminox to slow the oxidisation down so you get another 3 yrs. Then a full charge and balance with the aim for every cell to hold better than 3.55v for 12 hrs, if it doesn't you haven't cleared the memory charge and therefore haven't fully charged the cell.

All the battery packs we have serviced after the 3 yr service have returned 100% capacity when tested, so it appears we did know what we were talking about all those yrs back :lol: Soon the next 3 yr servicing will be due and it will be interesting to see if the capacity is still there now, they have not shown any signs of capacity loss to date so fingers cross.

A tip for those just changing over from lead acid to lithium, forget everything you knew about batteries as it all related to a different chemistry. Don't store them fully charged, work them hard, they are quite capable of delivering all their advertised capacity without damage so don't be afraid to get down below the 20% SOC occasionally.

Sailnow2011, you can use a Victron 700BMV and set the State of Charge (SOC) to what ever point you want and change the relay contact to normally open or normally closed to suit your purpose. For instance, set to normally open and relay to close at 50% and clear relay alarm at 60% so the contact now opens again. Use this to drive one side of a good quality solid state relay with a good sized heatsink and the load side connected across the solar positive cable going to the battery. Keep in mind, the control side is negative and positive as in the same as a battery, but the load side is the more positive goes to the + and the less positive goes to the - This means the solar goes to the + and the battery to the - even though they are both positive cables and run between the solar positive and the battery positive....... yeah, I know, bloody confusing isn't it but just remember that when charging the battery it becomes the load for the solar panel, so the solar is more positive than the battery.

T1 Terry

2.2.3 Outback Power Forum

http://www.outbackpower.com/forum/viewtopic.php?f=9&t=7620
There are lots of different Lithium Ion batteries, it's a general term, and they need to be charged to different voltages, so if asking about set points, you need to specify which particular chemistry. My comments only apply to my $LiFePO_4$ battery, these are my current set points.

Summer Vabsorb 3.425V/cell up to 1.5hr
Winter Vabsorb 3.51V/cell 1hr (extended periods of not reaching Float, limited charging time to reach fully charged, so higher voltage gets me there faster)
Vfloat 3.34V/cell - this gives a slow decline in SOC after full charge is reached- ie there is a net discharge measured in mA, leading to the slow deline in SOC.

The higher winter Vabsorb does lead to a higher SOC, but it isn't reached as often. For example, I have not

reached Vabsorb for 6 days, and SOC this morning was at 31%, which is no problem with LiFePO4, so long as the cells are in reasonable balance.
In sunny weather a few weeks ago, I was using over 30kWh/day, with 5.4kW of PV and a 21kWh battery.

There is no constant current charging when your input is solar panels, it is entirely dependent on the radiation levels/clouds, your panel arrangement, cell temperature etc, and can fluctuate wildly over short periods, but this is not a problem.

2.2.4 EV forums

You will probably have to unlearn a lot of what you've experienced with lead acid systems and aquaint yourself with lithium cells. **The key is to avoid the extremes of the charge and discharge curves.** Learn what these curves look like and install hardware to avoid them. An excellent item to include in your system would be a JLD404 meter. It counts amphours, has two relays controls that can be set high and low for either amphours or volts. You can set it up so it disconnect the feed lines to the inverter before it causes a problem for your battery pack**. I'm of the non bms, bottom balance school of thought.** You can invest in more cells instead of a bms system. There doesn't seem to be evidence of parallel cell problems but capacity differences can be a real problem, so bone up on that aspect of these systems.

My wine bottle analogy:

Think of your battery pack as a series of inverted wine bottles of slightly different volumes. The openings at the bottom are all at the same level(altitude). As you charge the pack each bottle is filled with the same number of drops(electrons) as they approach the fully charged voltage all these different bottles show different psi(voltage) because the tops of the liquid are all different heights due to the volume differences. The charger stops when the sum of the bottles psi(voltage) reaches it's set point. The key is having all the bottles run out at the same instant. As they empty if some bottles still have higher psi as they reach the empty point they overpower their neighbors and drive them to destruction because they have higher psi(voltage) and are able to do so. If they are all at the same psi when they each empty they have no force to cause the other cells to harm each other.

You can see that in such a system, measuring the voltage near fully charged and making them equal psi or voltage at the top actually ensures that as they reach empty they will all be uneven and cause the death of the cells with less capacity or volume. The closer to empty you can measure and adjust them to equal the better off you will be.

3 LINKS

3.1 Info

http://batteryuniversity.com/learn/article/bu_803a_cell_mismatch_balancing
http://www.thunderstruck-ev.com/battery-management-system-ev.html
http://www.avdweb.nl/solar-bike/electronics/bms.html
http://liionbms.com/php/cells.php
http://kwsaki.blogspot.com/2012/11/bottom-balancing.html
http://www.myelifenow.com/2012/10/lifepo4-charging-method-dont-ruin-your.html
set up a system of LiFePo4 batteries and inverter
http://www.pbase.com/mainecruising/battery_monitor
http://www.pbase.com/mainecruising/programming_a_battery_monitor
http://www.tjinguytech.com/charging-how-tos/balance-connectors
http://revisionmarine.com/?page_id=35
http://greatbearcharters.com/s-v-singawing/

3.2 Equipment

3.2.1 Batteries

http://ev-power.com.au/webstore/ev-power-bms/bms-cell-modules/cm160-cell-module.html
http://www.lithiumion-batteries.com/lithium-marine-batteries.php standard format drop-in. Not bad.

3.2.2 BMS

http://www.mouser.com/new/ams/ams-as8506/ IC for Cell Balancing
http://www.powerstream.com/LLLF.htm
http://www.orionbms.com/
http://elithion.com/
http://liionbms.com/php/index.php
http://liionbms.com/php/links.php

3.2.3 Accessories

http://shop.pkys.com/Victron-Energy-BMV-702-Precision-Battery-Monitor-in-Black_p_3021.html
http://ev-power.com.au/webstore/ev-power-bms.html
https://www.partsales.com/details/autoelec/victron-dual-battery-system-monitor-volt-meter-12-v-12-volt-bmv-702-216848
http://www.evwest.com/catalog/product_info.php?products_id=162 Intelligent AH meter with control
http://wattplot.com/order.htm software to manage Outback devices
http://arduinoalternatorregulator.blogspot.com.au/2015/07/ Arduino based alternator regulator
https://youtu.be/QlDd3jkcxoQ?list=PLKhqOHtqKt_bjwMjztceF_HjL6Rf8xsrk

4 Methods

Here is THE METHOD:

- **Bottom Balance each cell to 2.75V** (Drain them with a resistor until they reach this voltage = empty)

- **Connect them in series** to form a string of the desired voltage

- **Under Charge the string to 3.50V * number of cells with a LiFePO4 Charger**
NB: A LiFePO4 Charger charges at **Constant Current**, then close to the pack voltage, switches to **Constant Voltage** and reduces Current slowly until it reaches the set pack voltage, and eventually **Shuts Down Completely**)

- **When discharging the battery pack,** set a lower limit to 3.1V * number of cells, **start alerting** that you are reaching the end of the pack and **reduce maximum current drawn** on the controller; **When the pack voltage reaches 3V * number of cells, do not go below**, **stop the discharge** at this point by disabling the controller

That's It !!

5 Issues and Questions

5.1 Cell Balancing – top or bottom

5.2 BMS requirements

5.3 Starter Battery

5.3.1 Is it necessary to have a starter battery, what about a backup battery .

5.3.2 Charging – independent alternator/regulator? Yes, simplest method with DDC.

5.3.3 Backup battery in lieu of Starter Battery; e.g.

5.3.4 Dual Bank vs. Single Bank

5.3.5 Replacing the “parallel” switch?

5.3.6 Will the “Digital Duo Charge” work as well as the Sterling DC-DC? Probably.

6 Design for *Beatrix*

6.1 Design Parameters

6.1.1 Why LiFePO4?

1. Smaller weight
2. Consistent higher voltage
3. Longer life

6.1.2 LiFePO4 Requirements

LiFePO4 batteries can be irreparably damaged by over-charge or over-discharge.

1. **Low Voltage Disconnect (LVD).** A residual discharge current is especially dangerous if the system has been discharged completely and a low cell voltage shut down has occurred. After shutdown due to low cell voltage, a capacity reserve of approximately 1 Ah per 100 Ah battery capacity is left in a Li-iron battery. The battery will be damaged if the remaining capacity reserve is drawn from the battery. A residual current of 4 mA for example may damage a 100 Ah battery if the system is left in discharged state during more than 10 days (4 mA x 24 h x 10 days = 0,96 Ah). A BMV draws 4 mA from a 12 V battery. The positive supply must therefore be interrupted if a system with Li-ion batteries is left unattended during a period long enough for the current draw by the BMV to completely discharge the battery
2. **High Voltage Disconnect (HVD).** This is the upper limit safety disconnect if controlled charging does not work.
3. **Charging System**
    a. Must be able to accept power from all sources and shut down before 100% SOC.
        i. Voltage limited controls are not good enough.
        ii. Current limiting could be added. E.g. stop when voltage = x and current below y.
        iii. Once charge is achieved disconnect the charging bus.
        iv. A sealed LA battery is used as a “load” buffer to allow solar/wind to protect charge sources when cut off.
    b. Once charge is achieved the batteries should be discharged to < 50% (?) SOC before recharging.
    c. How to accomplish above while still maintaining use of solar/wind power? In L.A. the system just “floats”. If the battery needs to be used, but you have excess power input,

6.1.3 DC Power Sources

DEVICE	CONTROLLER	STARTUP / SHUTDOWN
Generator Alternator	MC-614	Exciter or Switch Wire Interrupt
2 Engine Alternators	MC-612 Dual	Exciter or Switch Wire Interrupt
Solar Array 1	Fangpusun MPPT 100/50	Relay to connect Panel Feed
Solar Array 2	Victron MPPT 100/30	Relay to connect Panel Feed
Outback FX2012ET inverter/charger	Attach to shore power	Disable charging with SS AC bypass relays
Outback FX2012M inverter/charger	Attach to shore power	Disable charging with SS AC bypass relays
Dedicated AC charger on charge bus		

6.2 Components Pricing

Item	Qty	Unit Cost (USD)	Extended Cost	USE	Purchased
Digital Duo Charge (start bat charger)	1	$0.00	$0.00	Both	x
Balmar MC-614	1	$384.43	$384.43	Eng Alt	x
Flexnet DC*	0	$257.00	$0.00	BMS	
Hub-4	0	$135.00	$0.00	Both	x
Victron 702 Battery Monitor	0	$178.50	$0.00	BMS	
Victron BatteryProtect BP200i	0	$136.00	$0.00	BMS	
600AH Battery Bank**	0	$3,272.73	$0.00	LiFePO4	
800AH Battery Bank**	0	$4,363.64	$0.00	LiFePO4	
480AH Battery Bank**	1	$2,618.18	$2,618.18	LiFePO4	
400AH Battery Bank**	0	$2,181.82	$0.00	LiFePO4	
640AH Battery Bank**	0	$3,490.91	$0.00	LiFePO4	`
600AH SE200 Battery	0	$3,465.00	$0.00	LiFePO4	
540AH CALB 180 Cells	0	$3,454.55	$0.00	LiFePO4	
900AH @ 2V AGM Battery	6	$510.00	$3,060.00	AGM	

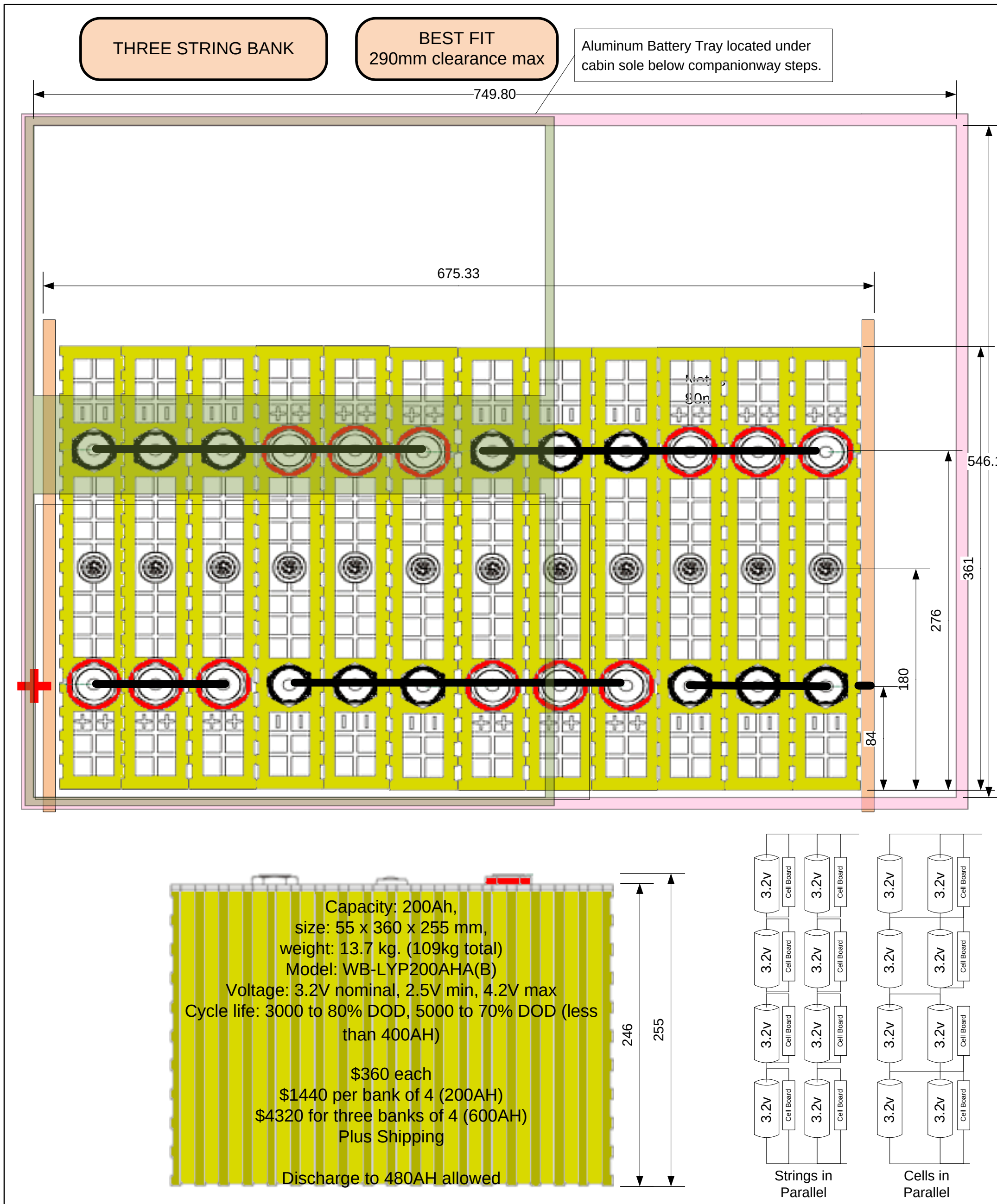
Item	Qty	Unit Cost (USD)	Extended Cost	USE	Purchased
Digital Duo Charge (start bat charger)	1	$0.00	$0.00	Both	x
Balmar MC-614	1	$384.43	$384.43	Eng Alt	x
Flexnet DC*	0	$257.00	$0.00	BMS	
Hub-4	0	$135.00	$0.00	Both	x
Victron 702 Battery Monitor	0	$178.50	$0.00	BMS	
Victron BatteryProtect BP200i	0	$136.00	$0.00	BMS	
600AH Battery Bank**	0	$3,272.73	$0.00	LiFePO4	
800AH Battery Bank**	0	$4,363.64	$0.00	LiFePO4	
480AH Battery Bank**	1	$2,618.18	$2,618.18	LiFePO4	
400AH Battery Bank**	0	$2,181.82	$0.00	LiFePO4	
640AH Battery Bank**	0	$3,490.91	$0.00	LiFePO4	
600AH SE200 Battery	0	$3,465.00	$0.00	LiFePO4	
540AH CALB 180 Cells	0	$3,454.55	$0.00	LiFePO4	
900AH @ 2V AGM Battery	6	$510.00	$3,060.00	AGM	

$226.52	**$0.00**
BMS COST	**$519.91**

0	$226.52	$0.00
	BMS COST	$519.91

Compare to simply replacing existing batteries: A$612 x 6 AGM = A$3060

6.3 Sample Battery Design for 600AH (3P4S with 200AH Cells)



S/V *BEATRIX* - KELLY-PETERSON 44 #286 (1980)			TITLE Main Battery Bank Design - Page-1	
REV	SCALE 1: 4	PAGE 1 OF 1	DATE 9/01/2018	DRAWN BY JEFF

7 Logs

Thursday, 13 April 2017, 08:27 AEST

Outback Power Technical Support – disappointing discussion with Kelly who said the only way to handle charging is to program the absorption state. Adding a FlexNet DC would only work with a HUB-4. He thought I did not understand what he was saying and was critical of me, saying I should contact a systems engineer. Screw that. All we are trying to do with charging LiFePO4 batteries is to CUT OFF charging at the correct SOC. I had a flash idea that the SIMPLEST way to disengage the charger operating off shore power or an AC generator is to disable the AC input. If shore power is needed a bypass relay or bypass switch can energize the AC circuit without going into the inverter:

AC SOURCE	ACTION
SHORE	Bypass charger when SOC threshold reached, connect when low threshold reached
SHORE ALT	Connects to backup charger. Otherwise as above.
GENERATOR	AC Cutoff when SOC threshold reached. Easy.

I have been puzzling over this question -- how to use an inverter/charger that is not designed for use with LiFePO4 and/or does not have a reliable voltage sensing system?

I have TWO Outback inverter chargers: 110V and 220-240V. When I left the USA in 2008 and ended up in Australia it was easier to add a second Outback inverter/charger than mess around with transformers and mismatched hertz. I use 110vac from a Honda 2000i and 240vac when plugged in to shore power.

Now that I want to switch to LiFePO4 batteries (from AGM) I need to control the charging function of the either of the two inverter/chargers.

I.e. I want my management system to switch the charging function of the inverter/chargers OFF or ON when needed. Outback tech support recommended setting the thresholds of the absorption phase accordingly, but I was afraid that would not be adequate as the voltage sensing is not very accurate.

Mainesail wrote *"Voltage sensing at the battery terminals is critical to FAST CHARGING PERFORMANCE. If you use a generator to power an AC charger proper voltage sensing means less generator run time. If a charger or inverter charger does not offer you this option BUY ONE THAT DOES!"*

He recommended, for the Outback unit, adding an Outback FlexNET DC volt sensing unit to the system (I might need two Flexnet DC units and this requires a HUB-4 as well). Total cost around $500.

Then I had this idea! What about controlling the input to the chargers? I.e. when shore power is on and the upper threshold SOC is reached on the batteries, bypass the AC around the inverter/charger. If shore power is on, and SOC is reduced to a lower (programmable) SOC, restore the AC input to the inverter/charger. If shore power is not present, do nothing. This would also work for a standalone charger. It could be done with a few relays (mechanical or solid state).

Any comments?

Saturday, 15 April 2017, 08:02 AEST

Call from Bill Goodward

50% SOC on storage
Disconnect from all charge sources at 80%-90% SOC. DO NOT FLOAT!
CC Charge OK
CV Charge NOT RECOMMENDED
GATEKEEPER SYSTEM ("BMS") SEALED DEVICE ACROSS EACH CELL (cell balancer bypasses between cells).
Link with fuses. ANL. 3 rows of 100AH batteries. 12v parallel. Controllers need to be close to batteries.
USE BMV-700 is better for turn on/turn off. Set parameters.
PUTS A RESISTOR
In LiFePO4 When a cell fails it's a direct short. Recommends 2P4S not 4S2P.
Use fuses as battery links.
williamgoodward@gmail.com
Test systems with battery disconnected. E.g. test solar controller when batt is disconnected.
Use Solid State Relays. Fuses should be internally in the battery box.

If on AC Power disconnect battery from circuit and use as power supply.

Victron MPPT needs to be connected to power even when not working, but use inverter as power supply during the day.

I DROPPED MY CONVERSATION WITH BILL. NOT A GOOD SOURCE.

8 CONCLUSION

After several weeks of research and design on installing a DIY LiFePO4 battery bank in Beatrix, I have decided to simply replace my 7 year old bank of 2V 900AH AGMs. This solution is less expensive, less complex and far less time-consuming then re-jiggering the boat to handle a LiFePO4 system.

Without a doubt, the LiFePO4 cells are brilliant: lighter weight, greater Depth of Discharge (i.e. 400AH of LiFePO4 is equivalent to 800AH of Lead Acid), flatter discharge curve, no requirement to regularly reach 100% SOC, and a longer lifetime. In the long run (if you don't accidentally destroy them) they are also cheaper in terms of $/AH delivered.

I YEARNED for these new batteries to be on Beatrix, delivering heaps of juice and charging quickly with maximum current.

The only problem is that there is still huge disagreement among sailors on charging and monitoring systems. There are THOUSANDS of posts on the subject on Cruiser's Forum. Our fellow KP44 owner, Paul on Taniwha, started the major thread (over 6000 posts) on CF.

I have come to the conclusion that 80% of the CF postings are BS. Dickheads abound. Some early providers of BMS systems have even stopped selling to DIYs and only provide their units to professionals. Part of being a DIY with a new project is to research the problem, but sometimes finding the wheat amongst the chaff is not easy. A few contributors stand out on CF. Two of the stand-out experts on CF corresponded with me and helped me to understand the issues I was facing. That they had diametrically opposing viewpoints helped to convince me that the DIY lithium battery world is not yet mature. My thanks to both. I realized it was going to be too big a job to do right in a short time; and not safe for an offshore voyage. (Safe in the sense of system failure; I saw no evidence that they could sink your boat or burn it up). I have learned a LOT about these batteries and their requirements and if I was going to hang out for a half-a-year I would probably have adapted or replaced my existing equipment, added the dual bus system, and so forth. It would have been a PROJECT. But I am hoping for a VOYAGE this year. There is enough other stuff to fix and repair.

Everything on my boat (and probably your boat as well) is designed to charge LA batteries with a 3-stage charging regime of bulk, absorption, and float. LiFePO4 batteries SHOULD NEVER BE FLOATED. They need to be charged up, and then discharged. This makes it difficult to use surplus power from auxiliary charging systems like wind and solar once the batteries have been charged. The whole system becomes extremely complicated to do right. There are work-arounds, but that is not what I consider robust. Other considerations include de-rating alternators which are not designed for continuous full output, installing expensive high and low voltage safety cut-offs, cell balancing (or not; I've concluded it's unnecessary and possible destructive), creating a dual-bus system to separate charge and load, and installing devices to monitor, manage and control all that.

Now I know there is a set of LiFePO4 users that embrace the KISS principal. The KISS approach is, In short, to cycle the LiFePO4s from say 25% SOC to 95% SOC. BUT HOW DO YOU DO THAT

ACCURATELY? Voltage sensing in onboard chargers is typically not very accurate and these batteries require very high accuracy. They can go to over-charged in a very short time with a small amount of amps. I am certain there are many yachts on the water who are doing this with great success; the whole point of lithium KISS is to stay well away from the dangerous upper and lower regions of the charge curve.

I am also aware that many yachts owners have fried very expensive LiFePO4 batteries through mishap and misadventure. I keep reading and hearing about destroyed banks because of some simple human or mechanical error. Heck, I have an AC to DC charger on board right now that decided 16v was its float level! No big deal with L.A. if caught in time. Big deal with LiFePO4. Yes, there are workarounds using very accurate cell loggers, solid state relays, high-load disconnects, etc., but now we are out of the realm of KISS.

The short answer to lithium banks is that they ought to be supplied with charging sources designed for them and monitored similarly. This includes alternators, regulators, shore chargers, and solar and wind charge controllers. New models of charging systems have a "lithium" setting but this is commonly a reconfiguration of the 3-stage charging profile and often set too high. I am sure that new boats will soon be designed specifically with the proper equipment for LiFePO4 banks.

Anyway, the DIY lithium banks are here, the pioneers are out there seeing how it goes, but I'm not going to be an early adopter. I wanted a ROBUST solution and a SIMPLE solution. This meant a new bank exactly like the old one. I'll be over 80 by the time this bank is used up and then, no doubt, there will be some NEW battery technology to consider.

Monitoring battery SOC is critical for LiFePO4 and important for sealed LA like AGM. The existing units (e.g. Link10, Victron BMV-700) do not maintain their accuracy as the system ages and need to be re-adjusted. You may have bought 900AH, but that capacity changes with age.

My ancient Link10 is breaking so I am also getting a SmartGauge from Balmar which very accurately provides information on the real state of charge of a LA battery bank. It doesn't use a shunt. You don't enter any data about battery capacity. It adjusts its internal parameters (it LEARNS the batteries) automatically and will very accurately tell you when they are 100% full. If something similar were available for LiFePO4 batteries that would simplify a lot of things.

Also, since brining on line 480 watts of additional solar power to provide a total of 830 watts, I get a full charge nearly every day and no longer have to manage the freezer, refrigerator and computer power. I just let the run when they want to. For the time being *Beatrix* is doing fine with old tech.