If you are looking for an on-board battery, there are several options. Think an AGM battery, a semi-traction battery, a gel battery or a lithium battery. Rob Ramsey (sailing world) has gained a lot of experience about batteries, and argues to us in a series of articles why he chose a lithium battery, and specifically a LiFePO4

Below in the content statement, the articles Rob has described in sailing world, I have summarised them into one document which you can print out here and read on the couch. I have not changed anything about the content.

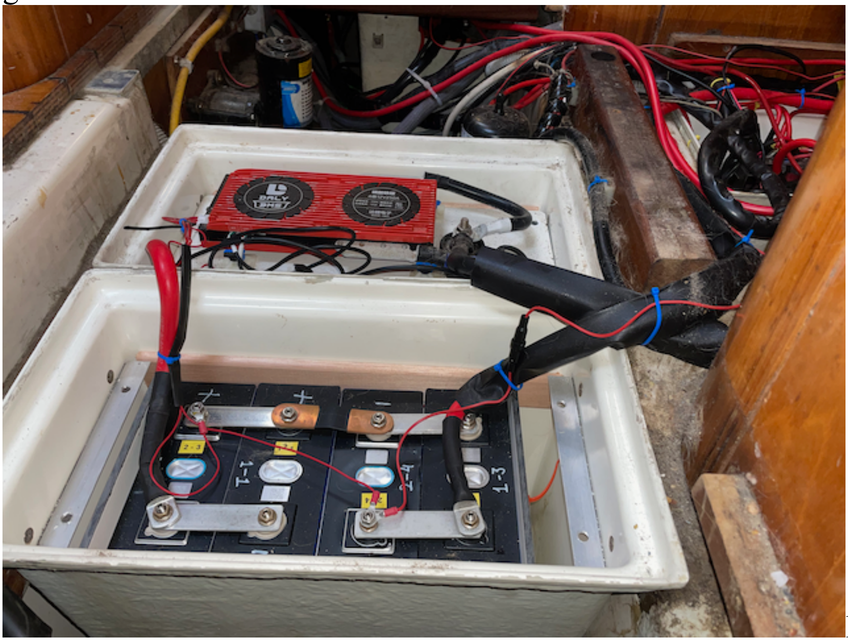
Content

Tekst: Rob Ramsey

LifePO4 batteries a good idea or not?

You have 300Ah of nice AGM batteries on the boat. More than enough right? You can only discharge them to a maximum of half, otherwise they will damage. You are left with 150Ah, which is also plenty. But with charging, the last 15% takes a very long time, so in practice they are often only charged up to 85%. At that point, you will have about 100Ah left. Still, you do need to charge them regularly to 100%, otherwise they will last a lot less.
Let's look at lithium batteries (specifically LiFePO4, the only safe solution). You can discharge these to 20%, and going over this once is no problem. They charge linearly to 100%, so no hassle with that last bit. So it is trouble-free up to 240Ah. A lot easier, and also a lot smaller. Extra bonus: the voltage stays virtually the same for a very, very long time, 13 to 13.5 volts. An AGM battery cannot compete with that.
I myself replaced three 315Ah battery boxes with two 560Ah battery boxes. From just over 100Ah usable current, I went to over 450Ah. They last at least 2,000 discharges, as I average two weeks to one full

discharge. So the battery will be in the will for my daughter, and then again in her will for my
grandson.



De two trays that hold the lithium batteries (LFP battery). On the upper one, the BMS (Battery Management System) sits on top of it

Important ground rules

So much for the simple part. Lithium LiFePO4 batteries can take a lot, but there are some important ground rules. If any individual cell (there are four of them in series in a 12V battery) is discharged beyond 2 volts, they fail immediately. In addition, the battery is damaged at 4.2 volts or higher. This is why you need a kind of insurance policy for your battery: the Battery Management System (BMS). This BMS shuts down your battery if the voltage gets too low or too high, in practice this is usually at less than 2.5 volts or more than 3.7 volts per cell. Of course, it is not meant to go that far, the on-board equipment should intervene before the BMS does. The BMS is really a last resort.

Many LFP batteries come with a built-in BMS, suppliers call these 'drop-ins'. AGM out, LFP in and done. But because you haven't

adjusted the other equipment then, the BMS quickly intervenes. If the current drops below 10V (4×2.5V), you won't get a warning from the BMS. Your light, autopilot and expensive navigation screen all go off at once, and not on again. The experienced skipper knows this trick: you just keep an eye on the voltage, then you know where you stand, right?
Note! When discharging, the voltage of an LFP battery remains very much constant. So how far are you now when the voltage has dropped from 13.15 to 13.12 volts? You don't know what percentage, and therefore how many Ah, you have left. If the battery is almost dead, the voltage suddenly drops tremendously fast and drops below 2.5 volts per cell within a few minutes. 'Plop', everything goes black.
When charging, the same applies, but in reverse. The charge voltage remains almost constant for a very long time, suddenly shooting up like a rocket around 98%. Again: 'plop', everything goes black. If you are charging with the diesel engine (the alternator), and the current suddenly goes off, your alternator is broken. It has nowhere to dispose of the amount of power it has left, so it goes up in smoke. It can happen that your alternator puts that high voltage on your on-board network for a while, in which case it remains to be seen whether your autopilot and navigation equipment can withstand that.

Rob's entire set in 3 battery boxes, at the bottom 2 boxes for the lithium batteries and above the battery box with the electronicsWel of geen lithium accu?

So what is my argument, lithium battery or not? I think the LFP battery is really great, but you have to remember beforehand that it places some demands on your other equipment. Among others:

- The battery charger

- The alternator

- The starter battery

- The battery charge information

For this reason, an LFP battery costs more than just the battery itself. A 'drop-in' battery alone is not a good solution to this. In a short series of articles, I will elaborate on this in the coming time. Next time, I will dwell further on battery charging.

On the absorption charge, or not?

Your LFP battery itself prefers to be charged between 3.5 and 3.65 volts, after which you may stop charging. Usually this is not such a problem, but if you're on shore power a lot, your battery will be steaming full all the time. An LFP battery doesn't like that very much, as it prefers not to be fully charged.

So what is wise? If you have bought good (which is different from expensive) LFP batteries, they are well balanced. Balancing once or twice a year (charging to 3.6V or 3.65V per cell) is enough, but you have a decent chance that even that is not necessary. So wisdom is, charge normally to 3.5V or 3.55V per cell (14 volts - 14.2 volts) and then no absorption charging. If you have no way to turn off absorption in your charger, turn on the shortest possible absorption time. If that time is still more than an hour, prefer to charge to 3.5 volts per cell.

Finally, your charger also has the 'float' phase. This is a small trickle charge specifically for lead-acid batteries to keep them capped. This is because lead-acid batteries slowly but surely drain, and instead like to be full. An LFP battery does not suffer from this, so the 'float' is not needed here. Unfortunately, it is almost never possible to turn off this function in your charger. Usually you can set the float voltage, so I recommend setting it to a voltage lower than the resting voltage of your LFP battery: 3.35V per cell (13.2V for a 12V battery).

Can't set your charger, or can't set it properly? Then the advice is: buy a new charger that can be set. And then preferably a charger with a LiFePO4 setting. Of course, the above also applies to an inverter charger (e.g. the Victron Multicompact).

Summing up battery charging

Brief summary, for a 12V battery (for 24V just multiply by two):

- Bulk: 14V to 14.2V (lower, up to 13.8 is also allowed)

- Absorption: off or as short as possible

- Float: 13.2V

More on battery charging next time. Rob will then explain to us about charging with the engine's alternator.

Charging a LifePO4 battery

Rob Ramsey warmed you up to a lithium battery (LifePO4 or LFP) last time, he also immediately put you under a cold shower. After all, you can't just replace your old battery with an LFP battery. In this article, he goes into more detail about some features for handling this battery and charging it.

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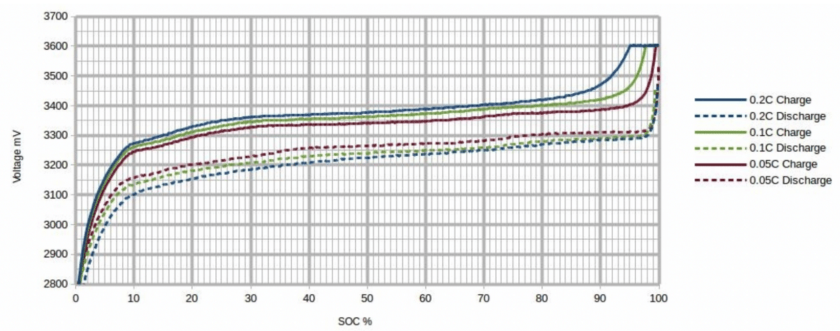
The BMS balances

It's not the only thing the BMS does. In a 12V battery there are 4 cells. Over time, those cells can become a bit disjointed and deliver more or less than the other cells. Since your BMS monitors at the cell level, it is the weakest cell that determines what your battery capacity is. This means that the other cells may have quite a bit left if your BMS shuts down the battery because one cell drops below 2.5V. So the BMS also 'balances' the cells, it constantly ensures that all cells are at an equal level.



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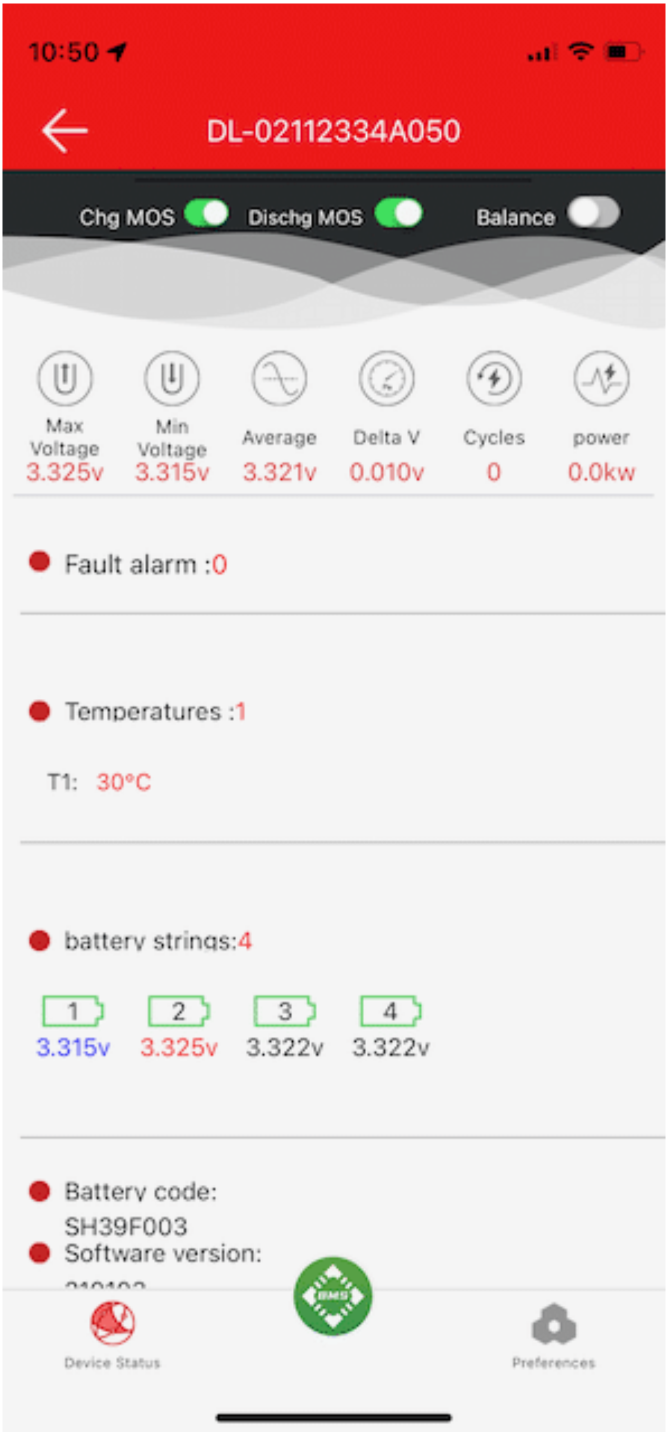
Currencurve fron a LFP battery

For that, your BMS needs to read the voltage of the cells. If the battery is at 50%, the difference between the weak cell and the strong cell might only be 1 millivolt. A difference between cells is best determined when the cell voltage is in the rocket phase, i.e. when the

voltage rises very quickly during charging. After all, the weak cell will still be at 3.55 volts while the strongest is already at 3.63. The difference in capacity is minimal but in voltage it is quite measurable. And then your BMS can transfer some current from the strong to the weak cell so that they are 'balanced'.
This is relevant because you need to know what voltage to charge the battery to. In general, each cell is about 98% full if you charge it to 3.5 or 3.55 volts. To make balancing easier for your BMS, it's smart to go even up to 3.65 volts. You see this with some charger suppliers with LFP settings: the batteries are charged ('Bulk') to 3.65 volts and kept there with 'Absorption' for one or two hours so the BMS can balance.

BMS app shows status by cell


10:50
DL-02112334A050
Chg MOS
Dischg MOS
Balance
Max Voltage
3.325v
Min Voltage
3.315v
Average
3.321v
Delta V
0.010v
Cycles
0
power
0.0kw
Fault alarm :0
Temperatures :1
T1: 30°C
battery strings:4
1
3.315v
2
3.325v
3
3.322v
4
3.322v
Battery code:
SH39F003
Software version:
Device Status
Preferences

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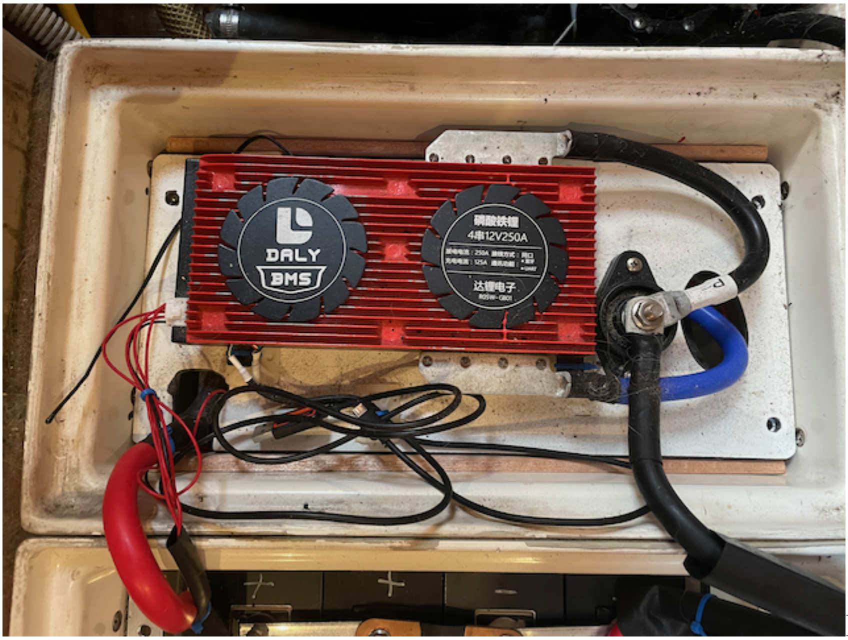
Lifepo4 charging by alternator

Rob Ramsey takes us into the world of the lithium battery (LifePO4 or LFP). In the past two articles, he introduced us to this battery and discussed handling and charging it. This time, he elaborates on charging with the engine alternator.

Charging with the alternator
As described in the first article, a Lithium (LifePO4 or LFP) battery can destroy an alternator by having the BMS disconnect the battery. The alternator is then left with a large amount of current that it cannot discharge and the result is smoke coming out (and, I learned from my father, that smoke is the active ingredient and you don't get it back in).
But there is another problem. Our alternators are made to charge for a while and then take it easy. After all, when you start your engine you only use a little bit of the battery and that's back in no time. Your battery demands very little, especially in the last 15% of charging, and your alternator can handle that. But LFP batteries are different, they are extremely hungry. 60 amps? No problemo. 600 amps? Also good, come on. That means the alternator is delivering maximum current to your LFP battery all the time, and your alternator was just not made for that. It gets hotter and hotter, eventually the smoke escapes.



De tray of batteries and the 250 amp BMS on top

And then the alternator is also unfriendly to your LFP battery, which wants to charge at a certain voltage for a while and then, when it is full, expects you to stop. Overcharging a lead battery is not such a problem but an LFP battery.... (note: strictly speaking, the resistance of a lead battery increases as it gets fuller and for an LFP battery this is hardly true).

The solutions

So we are looking for a way to:

1. To ensure that the battery is not suddenly disconnected;

2. That the hunger of the LFP battery is somewhat contained;

3. That the alternator can stick to the charging pattern that is good for an LFP battery.

And it can. There are more ways but I find the simplest and most straightforward is a DC-DC charger. That is a battery charger that can charge another battery from one battery.

The scheme for charging a starter battery

The scheme is quite simple: the alternator is connected to the starter battery (and that is a lead battery, not an LFP battery). The starter battery is connected to the LFP battery with a DC-DC charger. Done. You can programme the DC-DC charger so it uses the LFP charging pattern (see the previous article), the DC-DC charger limits the alternator's current draw so it doesn't get too hot. Should the BMS intervene and cut off the battery, the alternator can simply discharge its current into the starter battery.

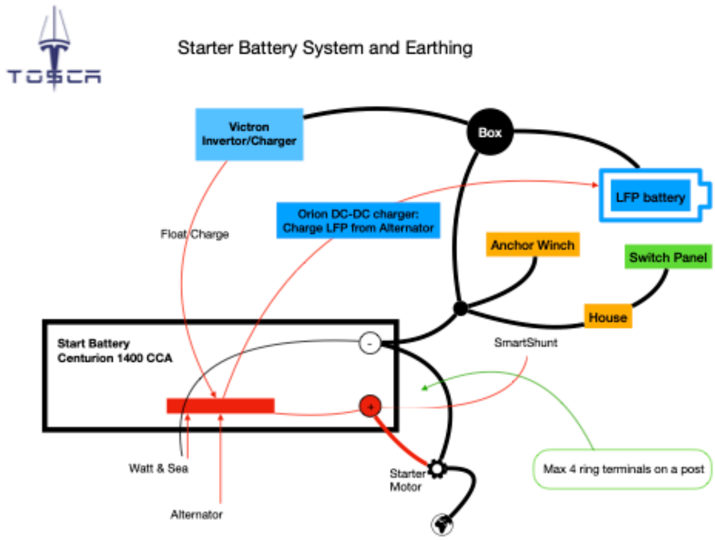


Diagram for charging with the alternator on the starter battery on board Tosca

I also have, in my case, the starter battery completely separate from the house bank (no 'combiner', diodes and so on ... is all from the past) - only the DC-DC charger is in between. If the need arises (and it can't really happen with me because the starter battery is exclusively starter battery), I prefer to use a jumper cable to connect the starter battery to the LFP battery.

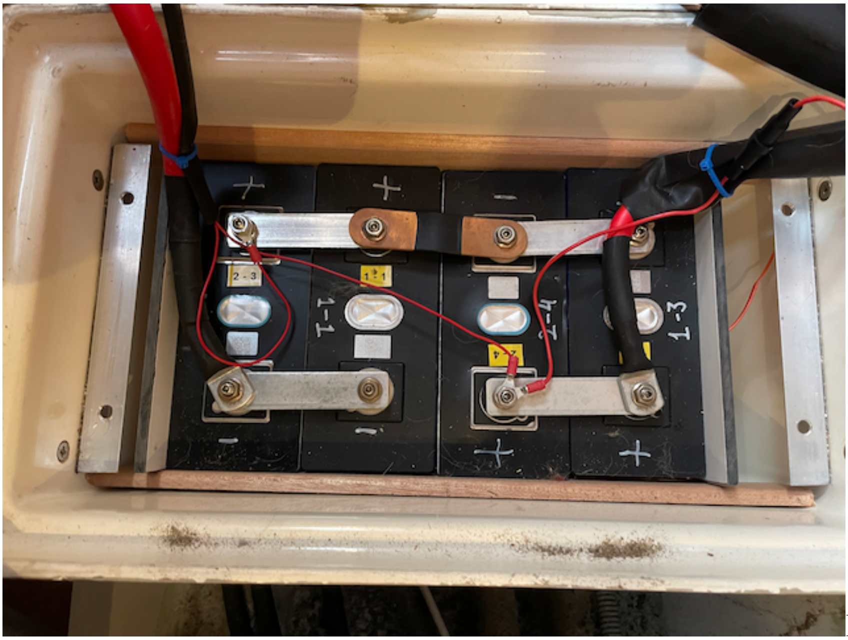
For completeness, two things: with the DC-DC charger, you do not use the maximum capacity of the alternator. In my case, I have a 60A alternator and a 30A DC-DC charger. That's fine, it protects my alternator. But sometimes I want to charge as fast as possible so I have a second DC-DC charger between my starter battery and house bank that I can turn on and off with a switch. 'Turbo charging' it says, which is for limited duration (about an hour).

Second is that an alternator can be protected with an 'alternator regulator'. A wonderful thing (if you buy a good one) that protects your alternator but also makes the most of it. If your alternator gets hot it scales back the decrease to protect your alternator. Good (but pricey) idea that allows you to use a bigger DC-DC charger.

In the next article, we will look at charging with power from other sources

lifepo4 charging with alternative charging sources

Rob Ramsey takes us into the world of the lithium battery (LifePO4 or LFP). In the past three articles, he has introduced us to this battery, discussed handling and charging it and we know how to charge an LFP battery with the engine's alternator. This time, more on charging the battery with different alternative charging sources.
In the previous articles, we have covered charging with the shore power charger and alternator. But there are other alternative charging sources, such as solar, wind, water and generator. At least the core of these is that the charger of these can be programmed (the generator presumably feeds the shore power charger so it is already taken care of there).
What is important, and why Lithium (LiFePO4 or LFP) is a big step forward, is that these charging methods will rarely fully charge the batteries. For lead-acid batteries, this is a problem since they will only last a long time if they are fully charged regularly. But for LFP batteries, absolutely no problem. Worse, LFP batteries don't like being fully charged all the time. They like to be put to good use. With that, this article can be kept nice and short: make sure your source's charger can be set up as described in the article on chargers and you're done.



Een
Of the two battery boxes where half the batteries are in. Here are two 280 Ah batteries lying parralel

Alternative charging sources

Now the big question is, can the different sources be used at the same time? We test it out: the sun is shining, the wind is blowing and we are sailing at 7 knots. The solar, wind generator and drag generator all work at the same time. It's no problem for the LFP batteries.

Now a quick calculation: suppose you have 300w of solar, a 600w wind generator and a 300W tow generator: 1200w total, or a maximum of 100A at 12 volts. Recommended charging current is usually 0.5C.

Huh, if you have a 100Ah battery then 100A (without 'h') equals 1C (one times the capacity). So charging at 0.5C is charging at 50A. But the battery can also often (read the manual accompanying your LFP battery) handle 1C or even 2C. So if you have a 100Ah LFP battery, you normally charge - if you can manage it - with 50A (0.5C) but in the above example, 100A (1C) is also quite possible.

Faster charging with two sources

Incidentally, there often appears to be a misunderstanding about charging with different sources. Suppose you have your charger set to 14 volts. The battery is empty so let's exaggerate: around 10 volts. The battery charger tries to bring the battery to 14 volts but it doesn't succeed, it will take a while. So initially it brings your battery to 10.1 volts, in a while it will be 10.2 and so on.

Now you put a second charger on it, which also tries to bring the battery to 14 volts. Despite the fact that a battery charger is already busy, the second charger also sees 10.1 volts. Therefore, the second charger also tries to bring the battery to 14 volts. So two (or more) chargers can just do it. Only when they are almost at 14 volts do you start to notice that the chargers are not exactly the same. Charger one can see that the battery is at 13.99 volts, while charger two already reads this as 14 volts. As a result, charger two stops charging, and charger one continues for a while. But that's fiddling around and can't do any harm.

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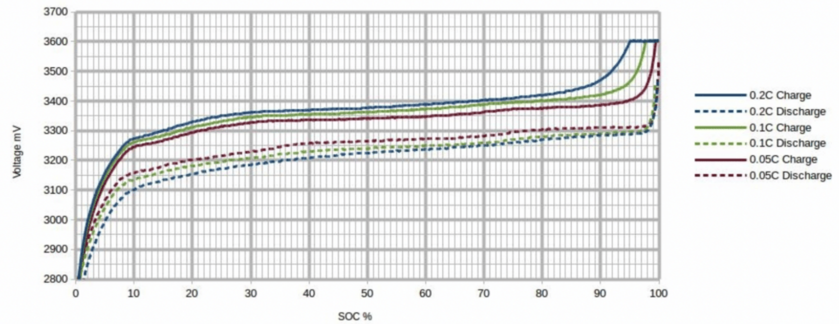

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Power curve of LFP battery
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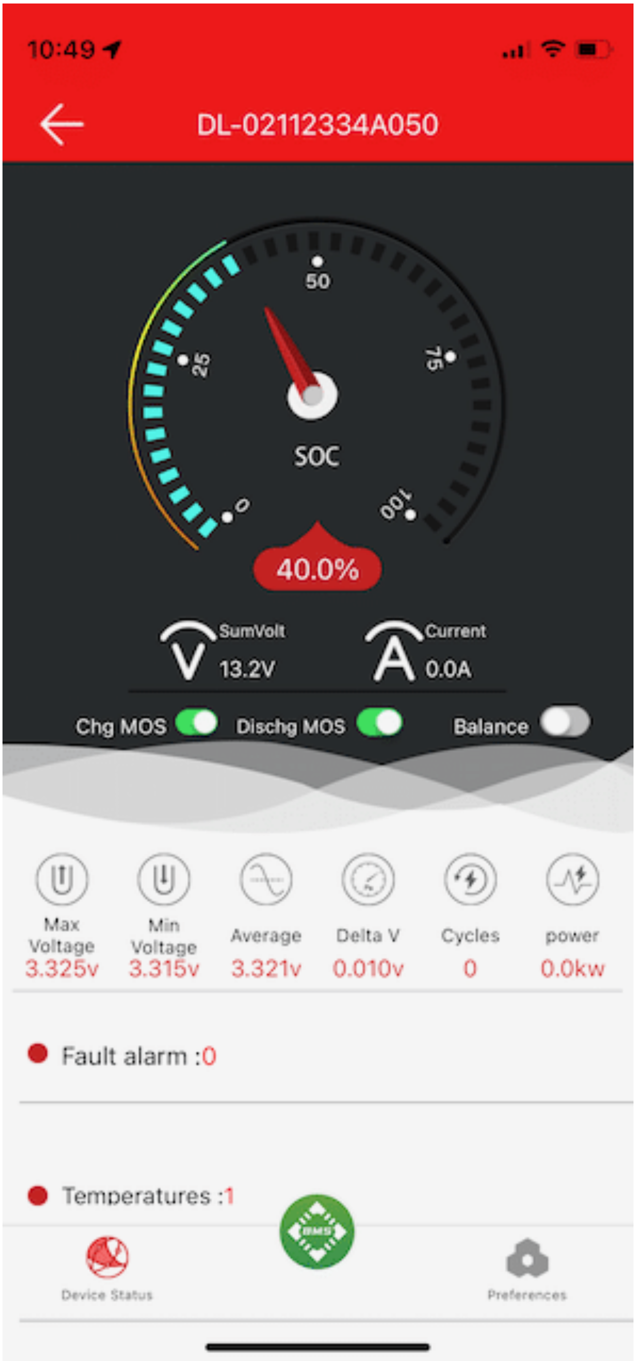
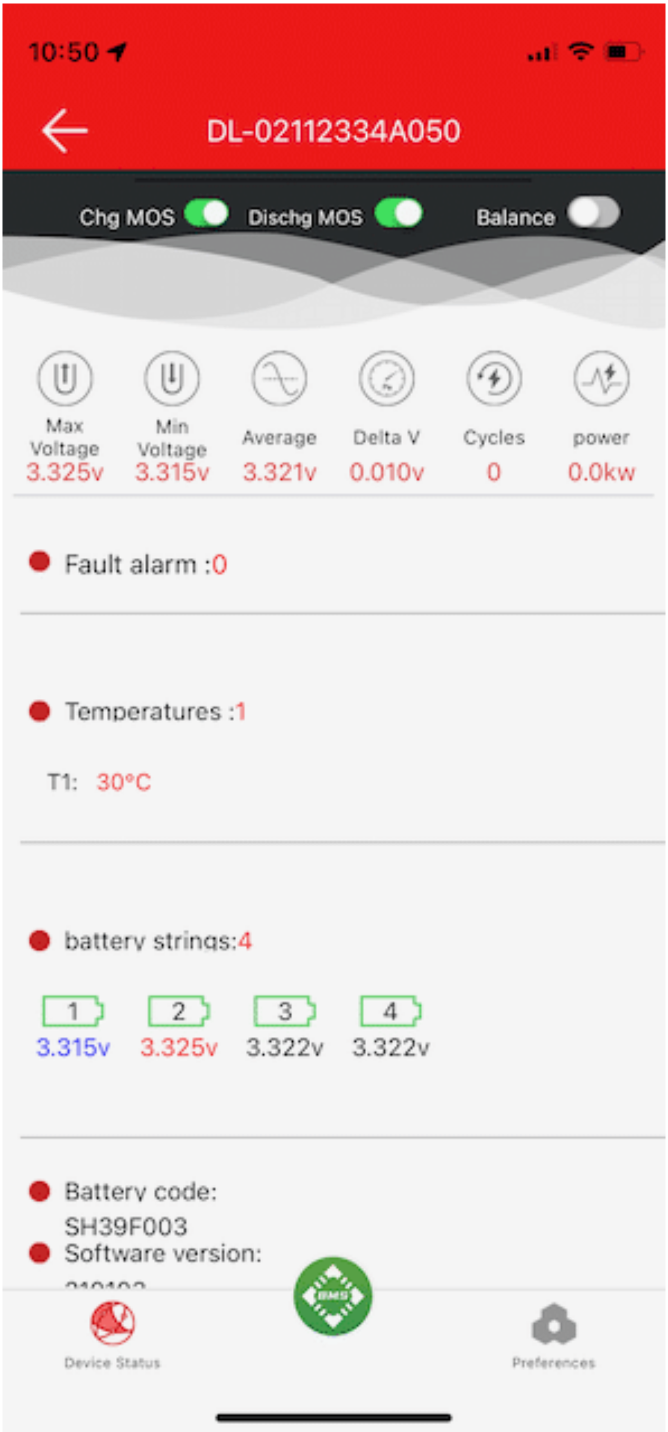


BMS app shows status by cell


10:50
DL-02112334A050
Chg MOS
Dischg MOS
Balance
Max Voltage
3.325v
Min Voltage
3.315v
Average
3.321v
Delta V
0.010v
Cycles
0
power
0.0kw
Fault alarm :0
Temperatures :1
T1: 30°C
battery strings:4
1
3.315v
2
3.325v
3
3.322v
4
3.322v
Battery code:
SH39F003
Software version:
Device Status
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More on battery charging next time. Rob will then explain to us about charging with the engine alternator

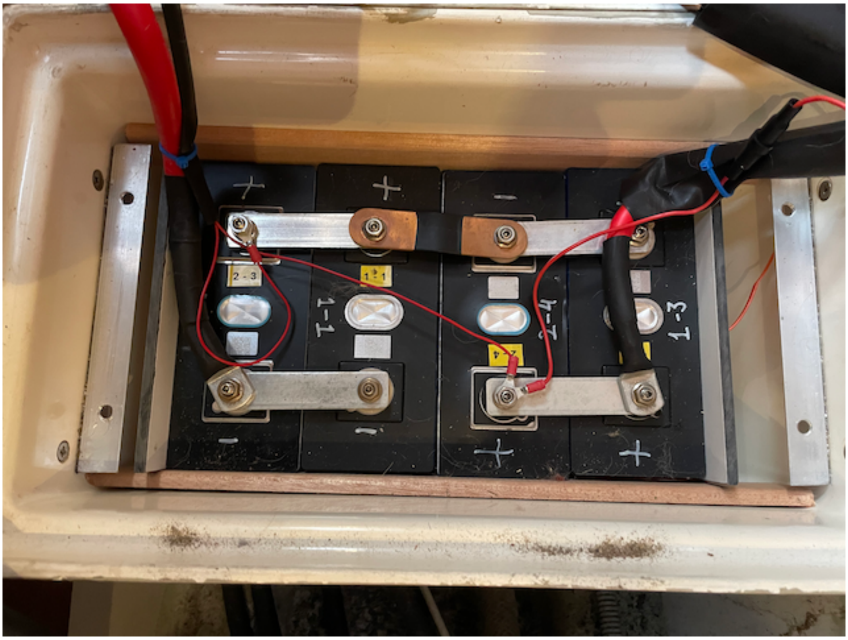
lifepo4 How full is the battery

Rob Ramsey takes us into the world of the lithium battery (LifePO4 or LFP). In the past three articles, he has introduced us to this battery, discussed handling and charging it, and we know how to charge an LFP battery using both the engine alternator and alternative charging sources. This time, we will look at how full the battery actually is.

How full is my battery?

It is important to have a good feel for the 'state of charge' of LFP batteries. How full are they still? You can use the voltage of the lead battery for this, then you will have a nice indication. But earlier in this series I mentioned that this does not work with LFP batteries.

Another way to check the 'state of charge' is with the little meter that counts how many amps have gone in and out of the battery. This is the Battery Monitor, a kind of bookkeeper of your battery. Based on the battery capacity indicated at installation, this little meter shows what percentage the battery has left.



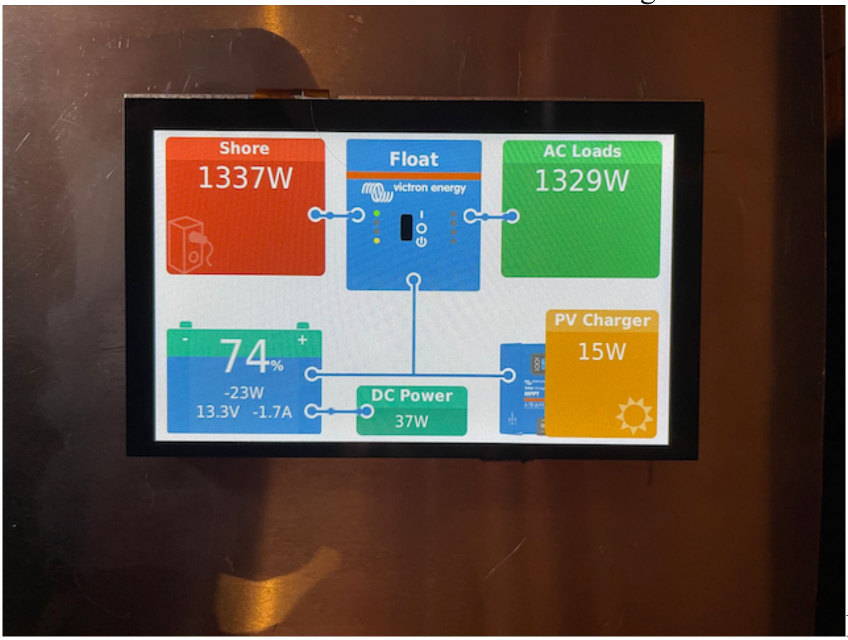
Two 280Ah batteries in parallel
This means: 30 amps from a 150Ah battery means it is still 80% full. It is then usually up to the user to see that 50% actually means 'empty'. There is quite a bit of criticism of these meters. This is because of two characteristics of lead-acid batteries.

Two characteristics of lead-acid batteries

1. First, efficiency. You put 100Ah into the battery and get a maximum of 90Ah out of it. Efficiency is then 90%, which has to be set in the battery meter. But there are no two lead-acid batteries with the same efficiency, so sometimes it's a bit of a guess. Usually it hovers around 80%.
2. The second is called the Peukert number. The number of Ah the battery can return depends on how much you ask for. If you take out 100A for one hour, Peukert says that less is taken out of the battery that if 1A is taken out for 100 hours. The harder you suck, the less you get. That can make a big difference. Your battery meter should then be able to deal with that.

The Shunt

It is for these two reasons that these meters are mostly considered unreliable. By the way, there is a third reason: measuring is done with a 'shunt', a little thingy that sits between the battery's negative terminal and the rest of the boat. This allows the shunt to measure all incoming and outgoing current. But often something else has been added to the boat later and that has been put directly on the negative terminal. You guessed it, the shunt knows nothing about that and so does not include that in the measurement. Result: unreliable reading.



Hoe full is my battery?

Screen showing battery status, consumption and charging

The joke is, that an LFP battery has an efficiency of 98% or more and, on closer inspection, suffers virtually no Peukert. So the Battery Monitor is much more accurate than for a lead-acid battery. Many say: usable now and I concur.

Installing LFP battery on board

I have now explained everything about battery operation and charging. Next time, I'll take you through the last part: installing the LFP battery. For this, I will use the example of how I installed this on my Tosca

.

The installation on Rob Ramsey's Tosca

Rob Ramsey takes us into the world of the lithium battery (LifePO4 or LFP). Read back the past five articles below. And read on to find out how Rob did the installation on his sailing yacht.

In the previous articles, I described the principles of, and around, lithium (LiFePO4 or LFP). It is the result of almost a year of research where the number of quacks, in my experience, is 20 to 40 times higher than the number of sources who know what they are talking about. And then when you realise who to listen to, they are very technical people who do not master Jip and Janneke language. I replaced the electricity supply on my sailing yacht Tosca based on the principles in the previous articles.
Before I go into that, I tell you that I use Victron equipment wherever possible. I get no money or gear from Victron, no advice, I have no shares and I have no family or friends at Victron. But I love that Victron devices talk to each other so the whole thing works well together and it's (pricey) quality. 'That's it'.

De inside of aluminium box with electronics for data exchange

I already had a Victron MultiCompact 1600 inverter charger. That one is well adjustable, more on that later.

Setting up battery boxes

I bought eight 280Ah LifePO4 cells from China, the so-called 'EVE' cells. They fit exactly in my battery boxes (I have three). Then I put two each in parallel and four in series: 12V and 560Ah in other words. There is a DALY (from China) BMS on those of up to 250A. That's in two of the three battery boxes. In the third battery box (I only have room for this in the bilge) I have installed the chargers and the shunt. The plus wire from the battery first encounters a big switch (so I can shut the battery off manually). The minus wire first meets a Victron 500A smartshunt and from the shunt a thin wire runs back to the plus pole of the battery for accurate battery voltage measurement.

Also in the battery box is a 100V/50A solar MPPT, a Smart ORION DC-DC charger, 30A, coupled between the starter battery and the LFP battery, a second DC-DC charger (a dumb one this time, not smart) that can be switched on and off with a switch ("Turbocharging" from the alternator). Separation diodes, battery combiners and the like, I have turned off. I connected the starter battery directly to the starter motor.

Devices talk to each other

Interestingly, Victron's 'Smart' devices talk to each other. So for charging by the MultiCompact (shore power), the voltage of the best meter is used: the shunt. And that is really relevant for LFP: 1/10th of a volt is important.

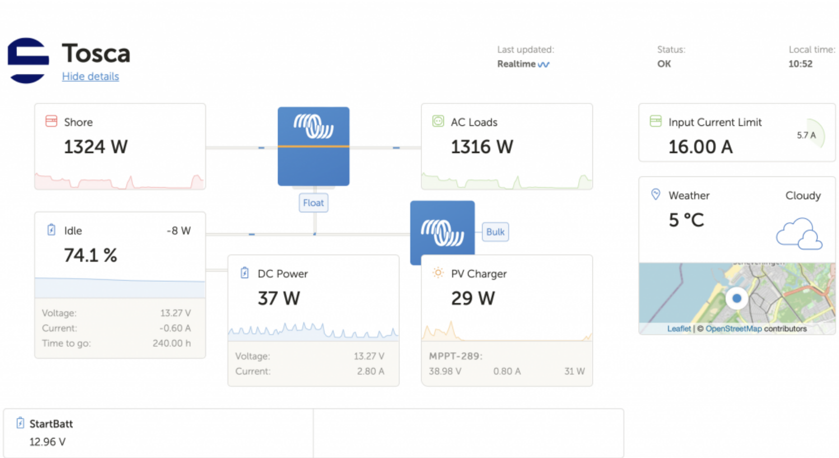
Also interesting is this: if I am on shore power for a long time, I still want to use solar power as much as possible. My Victron MultiCompact is set so that shore power is off and 220V runs through the inverter. The MultiCompact receives current, voltage and 'State of Charge' (percentage of fullness of the battery) from the shunt. If that percentage drops below 20%, the MultiCompact turns on shore power and charges the LFP batteries completely. Then it turns off the shore power again. So I don't have to pay attention to it, and long periods of thick cloudiness are not a problem ashore.

De Victron MultiCompact with a screen below it for the charging status of the LFP batteries. The aluminium box can hinge upwards

Finally, Tosca has a Watt & Sea 500W trolling generator. That one has its own charger and is a bit trickier to set up. So I set that extra safe (lower voltage).

Do I have a generator? I don't see the point of an expensive built-in generator now. All the above sources should be able to supply the vast majority of scenarios. Therefore, I have a cheap portable 900W

generator that, in case of emergency, is connected to the shore power socket. That then charges the batteries via the MultiCompact.
Keeping an eye on everything from home
To round things off, and because I know a lot about it because of my business, I connected a Raspberry Pi computer to the Victron devices (not an easy job by any means), which shows the state of affairs on its own little screen and also sends it to Victron so that I can see what the state of affairs is at home or elsewhere via the internet. The Raspberry Pi also takes care of part of the communication between the Victron devices, which otherwise runs via Bluetooth.



Via
Through the internet, I can keep an eye on the status of the boat
In conclusion, it has turned out to be a huge project where especially gathering good knowledge took a lot of time. Topics like fusing, positioning, compressing batteries, bus bars, bolts for the LFP battery, temperature, specifications of peripherals, settings, which voltages, manual balancing et cetera et cetera. So I know a lot more than what is reflected in this series of articles. But then I would have to consider writing a book of more than 500 pages, and there are already plenty of those (right, Nigel Calder?).
I just enjoy my carefree batteries and am happy to pass on this knowledge!

After Rob submitted this article, we received another little surprise. A very last final piece on the LFP battery. A philosophy from Rob about the world of batteries and also a small summary of the series. Soon to be read on Sailing World!