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USE OF LIFEPO4 **BATTERIES IN SHIPS**

(similarly in campervans, caravans, etc.)

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This article presents typical solutions and important information for the reliable and long-term operation of LiFePO4 battery systems. We know from our communication with customers that it's necessary to clarify the issue of parallel (on-board) batteries and their protection against critical conditions. The topic is described in a comprehensible way for an instructed layman/user so they can decide on a suitable solution. During battery installation, we recommend supervision from an expert with an electrical engineering education and experience with battery system installations.

Less noise

Whether you are going fishing, on a relaxing cruise or you're entering noise-restricted areas, standard petrol (diesel) engines are an obstacle. Unlike electric vehicles that often have a sound generator to alert the surroundings, electric boats make full use of traffic silence and provide uninterrupted sailing.

No pollution

Who enjoys sailing in the smog or the idea of air pollution in beautiful countryside where it passes through? Of course, nothing is 100% green, battery production has its impacts on the environment, but compared to diesel engines it doesn't actively increase pollution in the most beautiful and rarest locations around you.

Lower running costs

Nothing is free and neither are the exhaustible oil reserves, electricity isn't free, but thanks to increased use of solar, wind and water energy all around us, electricity is now drastically cheaper and also cleaner day by day. In addition, unlike diesel engines, the more you use batteries the more you save.

LiFePO4 as a **replacement for a starter battery**

This is primarily a solution in small systems (with little consumption on board). Generally, replacing the original battery is possible and appropriate as the LiFePO4 battery combines the properties of a starter battery (high current for a short time) and a traction battery (lower currents for a long time, deeper discharging).

At the same time, it surpasses them with its lifetime (number of cycles) and energy density. It has a comparable voltage on the cell with the most frequently replaced lead-acid battery. From practice, we know a lot of cases where a simple replacement has been made and the LiFePO4 battery has operated successfully for many years, for example in passenger cars. We recommend directly sold 12V/20 – 90 Ah LiFePO4 batteries with an optimised assembly of individual cells in a monobloc for such a solution.

LiFePO4 batteries are generally sensitive to both undercharging and overcharging. If the critical values of individual cells (2.5 and 4.0 V) are exceeded, the battery can be irreparably destroyed (in practice, for example, a forgotten radio or orientation light is left on, etc.). Therefore, some models are standardly equipped with a single-cell balancing system and battery management systems (BMS). Sudden emergency battery disconnection may cause problems in some starter battery modes (disconnection of high currents when starting, damage to engine power systems during sudden disconnection when loaded, etc.). Therefore, we recommend directly connecting the battery to an alternator and starter. Protective disconnection can be used in a limited amount

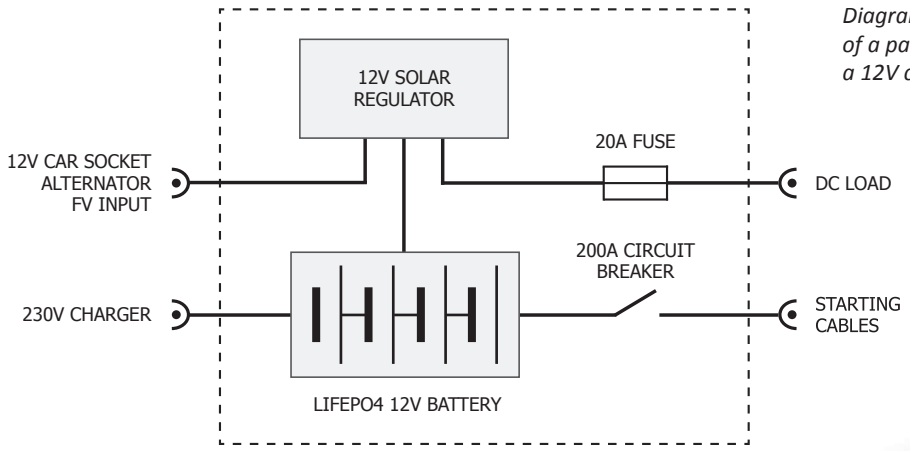


Diagram 1 – A block diagram of a parallel battery with a 12V controller.

to on-board consumption. It's advisable to install a manual disconnector for full battery disconnection which is switched off when a ship is put out of operation. Practice shows that it's often preferable to keep a fixed lead-acid starter battery in the ship system and use the LiFePO4 battery parallelly as an on-board and support battery when starting – see Diagram 1.

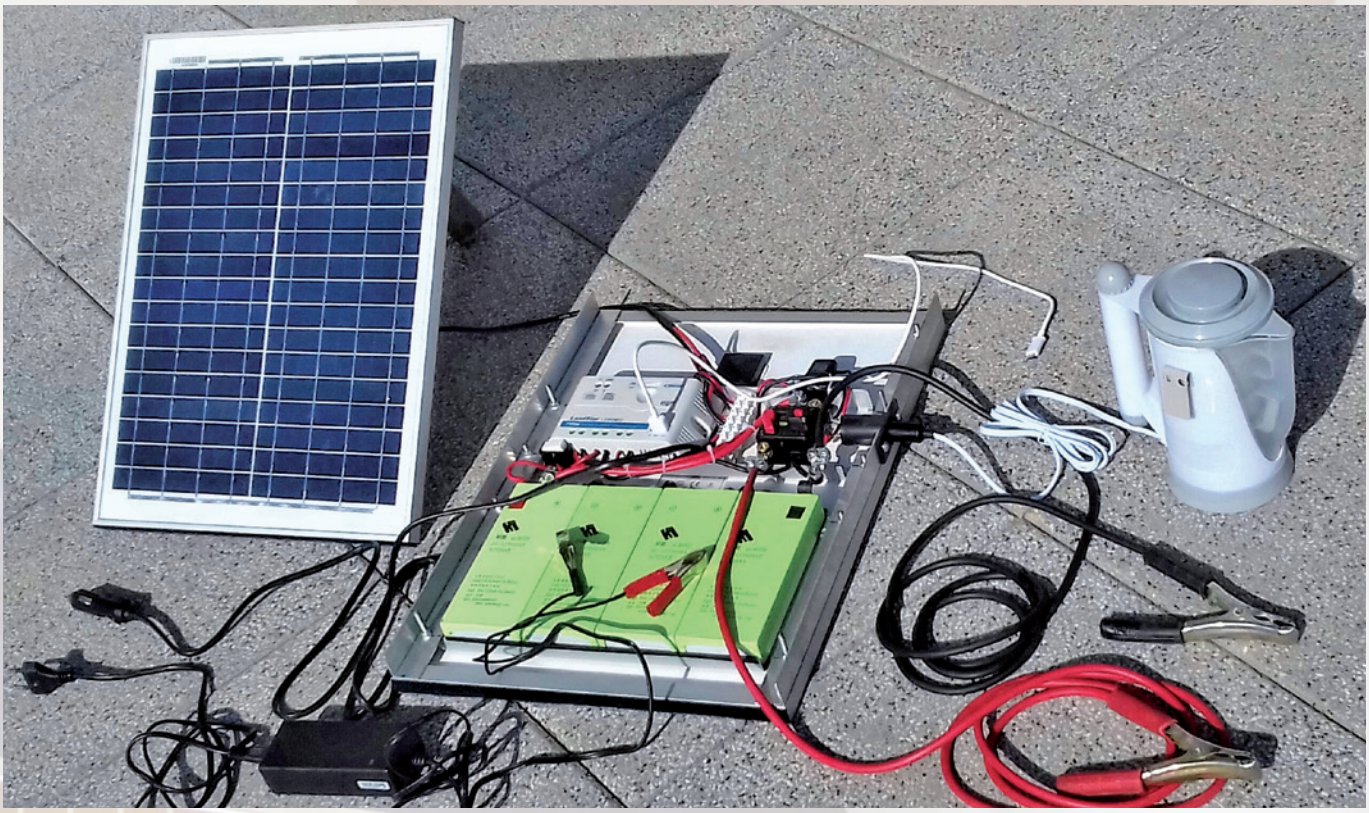


Fig. 1 – Example of a small on-board battery (power bank) with multifunctional charging and use.

LiFePO4 as a **parallel on-board battery**

A ships electrical systems are mostly composed of a separate starter battery for the internal combustion engine and one or more on-board batteries for use on a ship (lighting, normal appliances, air-conditioning, winches, etc.). On-board batteries are mostly replaced by or already designed as LiFePO4. The system has to ensure correct charging and discharging of individual batteries and their cooperation. Below are two examples of connections:

A **Shared charging of batteries which are separated by diodes, with the possibility of a time-limited connection:**
Simple wiring where both batteries are charged simultaneously from a charging bus (alternator, solar MPPT controller, charger from mains or power generator, etc.). The overflow between the batteries is prevented by a diode insulator. In case of an emergency battery backup power, it's possible to use a connection button or timer – see Diagram 2.

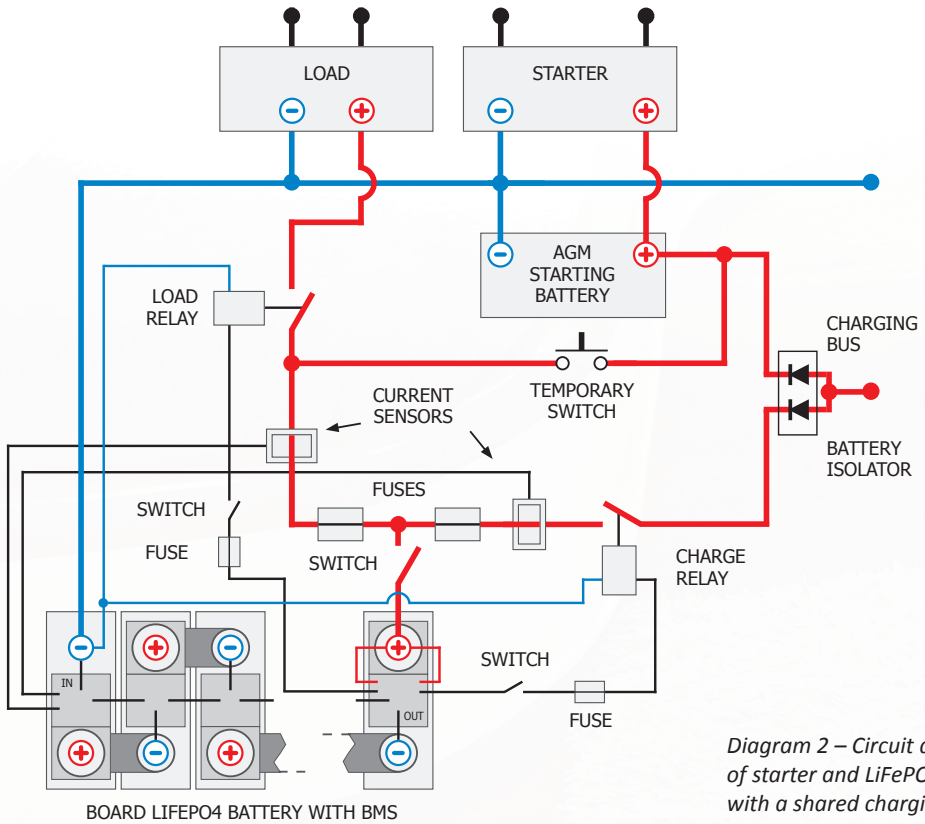


Diagram 2 – Circuit diagram of starter and LiFePO4 batteries with a shared charging bus.

B **Charging batteries that are controlled by an isolation relay (battery connector):**
The relay determines the battery charging priority. After one (usually starter) battery reaches the set voltage, charging is redirected to the other battery (on-board – important systems); once it's charged, even to another battery (less important on-board systems, backup). The adequacy of charging individual batteries according to their importance and capacity can be supported by dividing the charging sources directly for some batteries (for example, a mains charger with two outputs, solar panel distribution, etc.) – see Diagram 3.

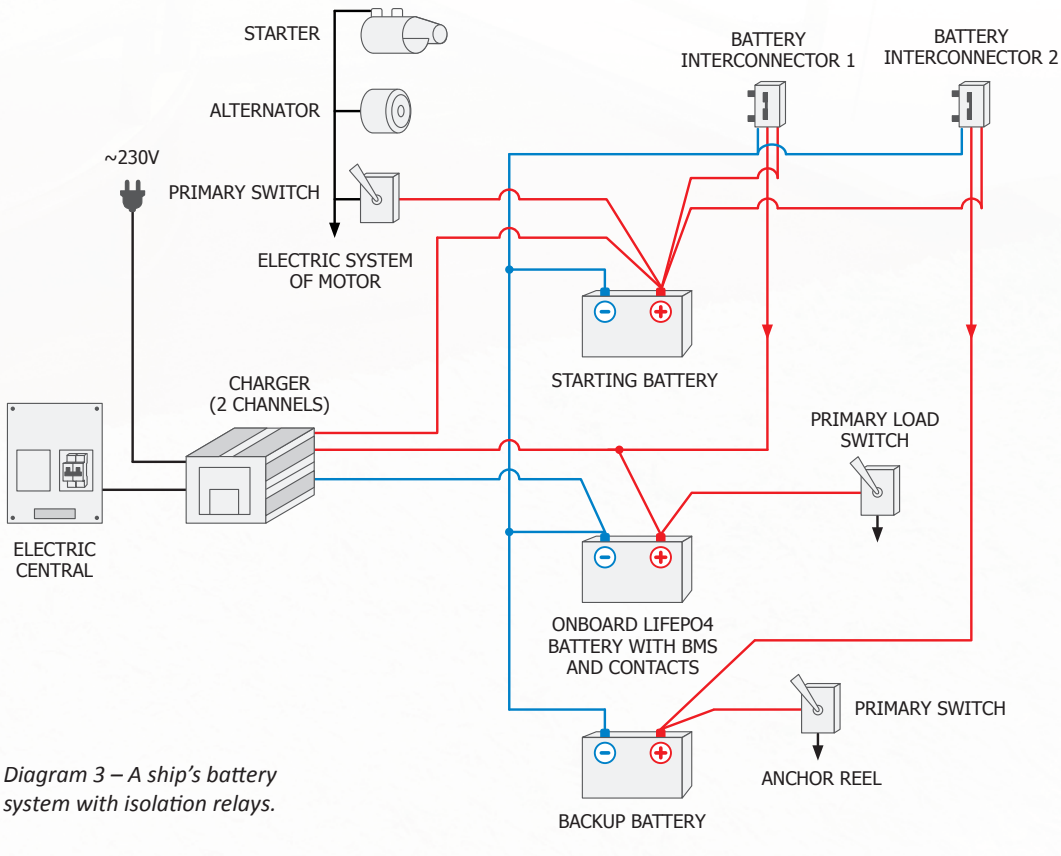


Diagram 3 – A ship's battery system with isolation relays.

Battery management
BMS 123Smart

There are several types of LiFePO4 battery management systems (BMS). We tested and offer BMS 123Smart system which has a very good manufacturer‘s technical support and updates based on feedback from customers.

Fig. 2 – Basic installation of BMS 123Smart which allows balancing and cell monitoring.

The system is additive for a different number of cells, provides a suitable range of settings, an extension module, and various communication options. It’s suitable as a basic protection and for the setting, control and monitoring of the on-board battery for most implementations.

It’s important to connect the battery pack correctly and the BMS with the associated circuit breakers and disconnecting elements of charging and discharging and to integrate this unit (node) into the ship’s system. A standard solution is using power relays controlled from the BMS module’s OUT outputs. Power relays generally

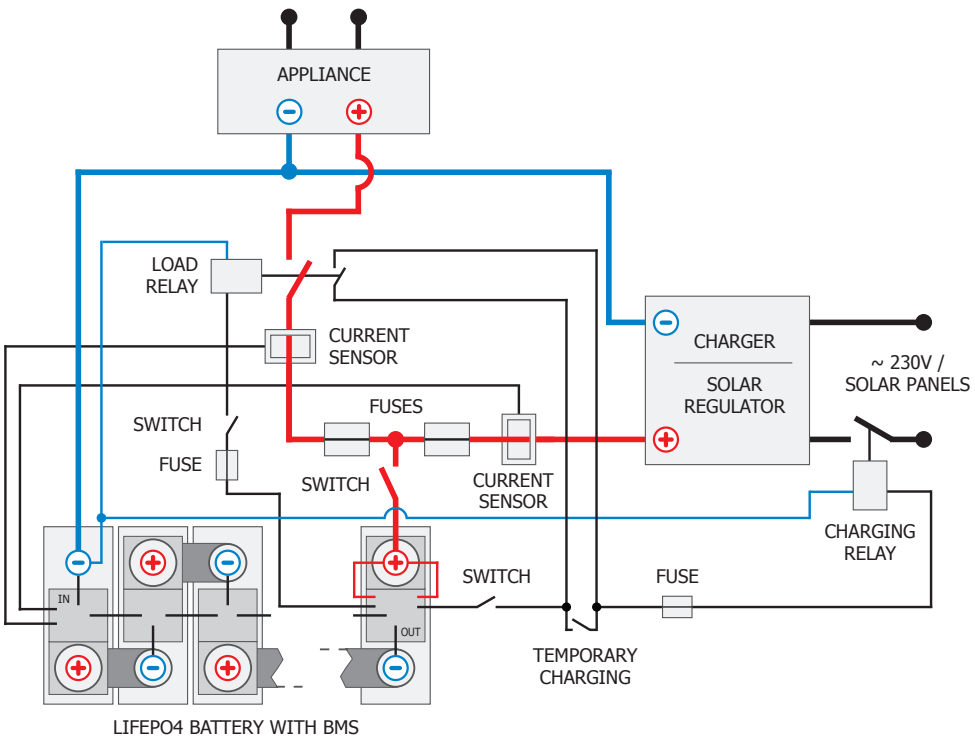


Diagram 4 – Circuit diagram of the BMS 123Smart with power relays and current sensors.

have higher separate consumption. With a basic connection, the charging relay remains connected even when the load relay is switched off, and in some circumstances it could still discharge the battery. As an example, this can be avoided by blocking the charging relay via a load relay auxiliary switch contact, in combination with a parallel switch for forced charging – see Diagram 4. Similarly, possible back consumption of the battery charger may be blocked at its output. We are currently preparing a 2x120A energy-saving Smart relay solution by BMS 123Smart to launch.

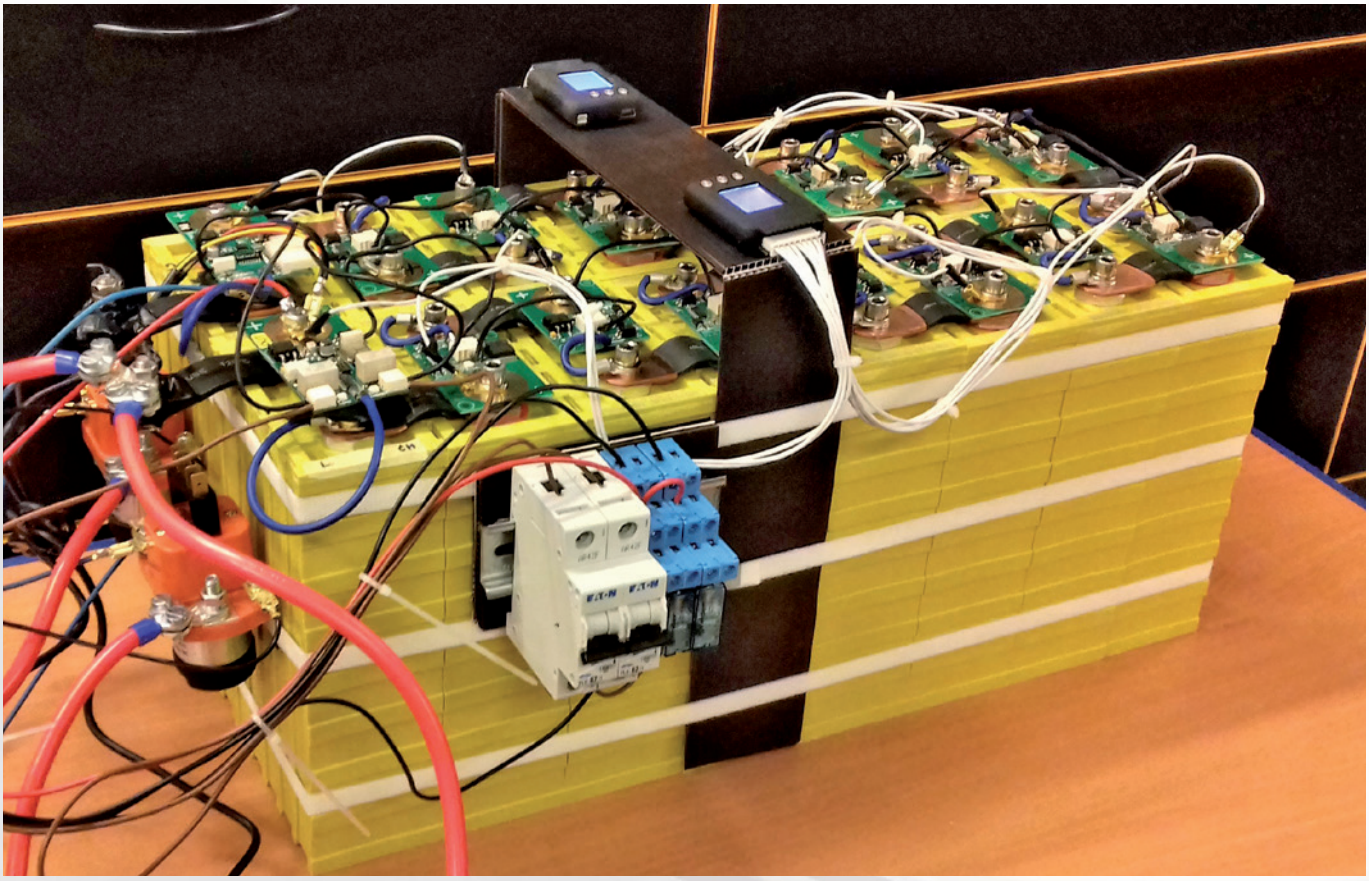


Fig. 3 – Full battery assembly with BMS 123Smart, circuit breakers, power relays and CellLogers, ready to be installed in the system.

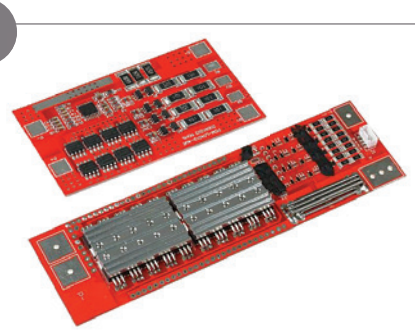
Other battery **management and monitoring options**

To ensure maximum safety, it’s advisable to duplicate battery management with a second protection and monitoring element. In some cases, these solutions can be used as an alternative to the BMS 123Smart.

A

Extended cell voltage monitoring with an alarm and backup battery disconnection function:
It’s possible to keep the existing on-board monitoring when replacing the battery. It may not be sufficient due to the small amount of voltage changes in the LiFePO4 batteries and when only measuring the overall voltage. For example, CellLoger is a suitable supplementary protection. It can monitor each cell in detail, including data storage. If the selected values are reached, an alarm is triggered and a charging or discharging power relay can be disconnected via its output, this is similar to the BMS 123Smart. Unfortunately, this unique product is no longer available and it’s necessary to find another device with similar features.

B



SBM (Simple Battery Management) modules:
The easiest way to protect your battery. Each cell is connected to a central module with a break-type contact which breaks at the bottom and upper critical limit in any of the cells. The battery is protected via the contact in terms of both the load and charging. SBM modules have passive balancing ability, but the balancing currents are very small (tens of mA).

C

CBM (Cell Balancing Module) - strengthening the balancing current in the cells:
In the case of heavy charging, cells can become unbalanced and the required balancing currents are higher than those provided by the basic BMS or SBM. In such cases, the charger disconnects until state of balance by available balancing current. This results in unwanted cycling of the charging relay, prolonged charging time, and loss when using solar systems. The balancing current can be strengthened, for example, by a CBM (Cell Balancing Module, a set of resistors on each cell that prevents overcharging the first charged cells). Therefore, the first charged cell ‘waits’ to achieve unified voltage in all others.

D

Decrease in the charging current before reaching full battery capacity:
Another possible solution is to adapt the charging current to the battery's and its management's capabilities. Some chargers have a feature which makes it possible to reduce the charging current at the end of the charging cycle. There is no overloading the cells absorption and balance abilities.
It's also possible to stop charging as soon as the first cell reaches the desired voltage, 'not waiting' for the other cells. The difference in their capacity will be minimal, however, it's recommended to periodically perform individual cell charger calibration.

E

Active cell balancing:
An active balancer strengthens weaker cells from stronger cells in each battery mode. It works on the principle of balancing the potential. The balancing currents can be in amperes.
The system doesn't disconnect the battery in the limit conditions.

The best "management" is a reserve in the battery capacity and its gentle charging and discharging only by recommended or smaller currents. Experience shows that a properly selected, assembled and professionally operated battery (periodic measurement, correction charging, reliable voltage monitoring) can be operated without balancing the cells.

Other options, **advantages and principles** of using LiFePO4 batteries

In practice, we encounter replacing the original batteries (NiCd, Pb) with new LiFePo4 batteries in smaller boats for the main engine (rentals for holidaymakers, fishermen), or larger vessels as an emergency engine to the combustion engine. The procedures and technical principles described in the previous chapters apply to all these implementations accordingly.

LiFePO4 prismatic batteries are a very suitable and safe solution for ships. They don't have a self-discharging or memory effect, they don't explode or ignite under extreme conditions, there's no risk of contamination by electrolyte and fumes from it. High capacity energy storage and long life can be achieved by easy installation of a small number of basic cells. The basic cells dimensional and capacitive variability make it possible to make optimum use of the space available for the batteries on a ship.

The LiFePO4 batteries can provide extremely high current for a long time in case of short circuit, therefore causing damage. This situation must be completely avoided, especially with the appropriate cover of live battery parts, prescribed fuses and manual emergency disconnection. Assembly work on batteries should only be done with insulated instruments and metal objects mustn't be left near the battery terminals as they could fall on them.

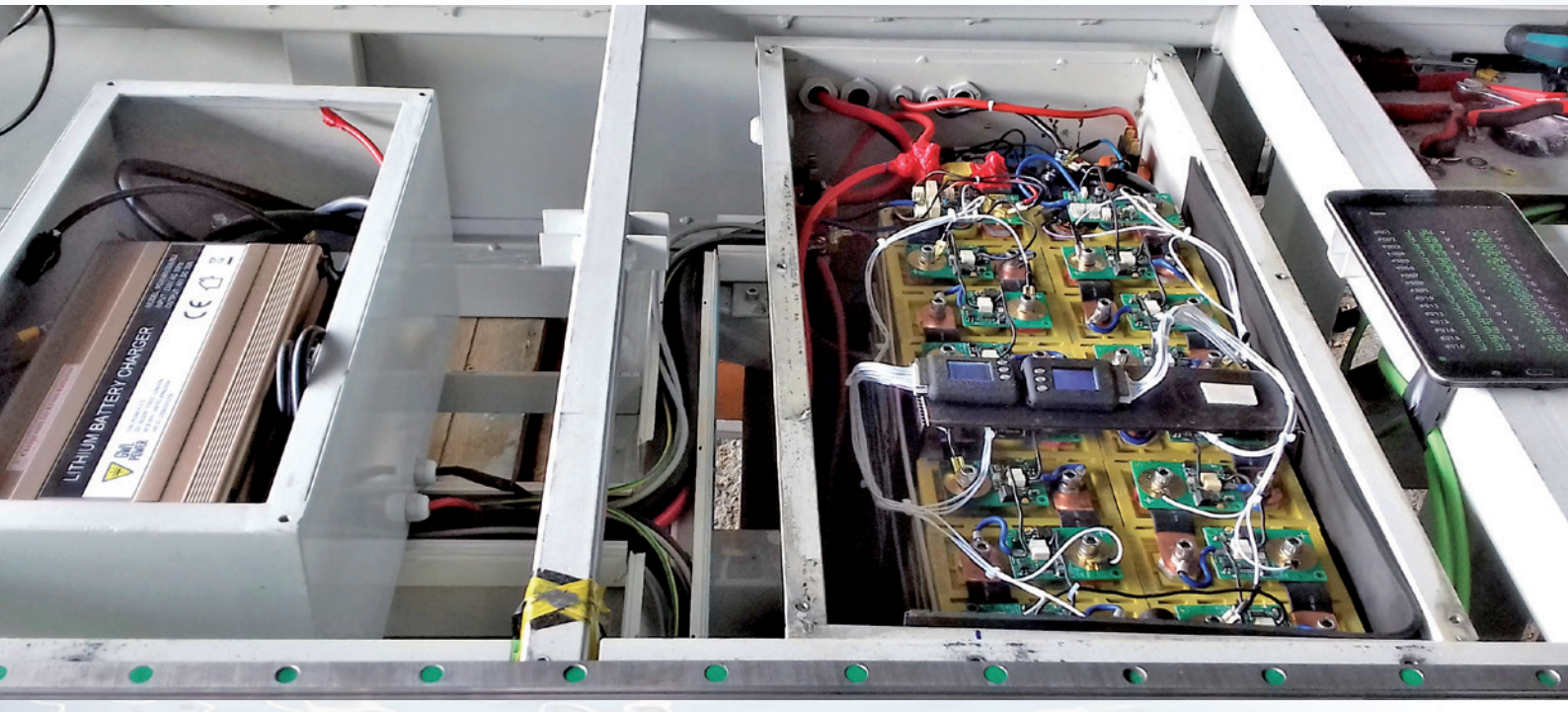
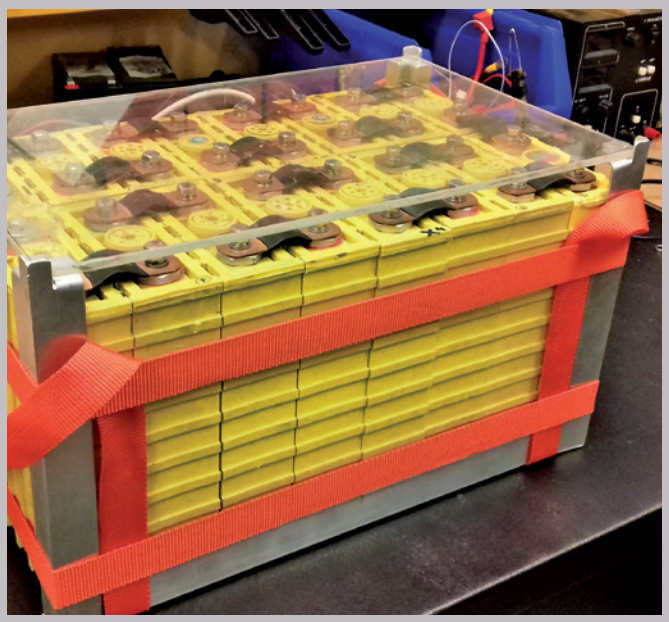


Fig. 5 – Example of installing a battery and charger into a limited space.



LiFePO4 cells can’t be operated in the horizontal position of chemical plates, i.e. placed on the largest surface, for a long time. Assembly must be secured in the ship, electronic systems must be protected against mechanical damage, water and dust.

Attention, monolithic 12V batteries have cells arranged in such a way that the above rule doesn’t apply.

Fig. 4 – Example of the preparation of a battery with a frame, mounting straps and cover.

LiFePO4 technology is very convenient and safe for ship applications, only its use as a starter battery is debatable. In most cases, the battery needs to be equipped with a management system (BMS). The BMS scope depends on the user's responsibility and qualification and its use. A battery pack with BMS needs to be properly integrated into a ship's system and provided with a safety disconnection. The controlled LiFePO4 battery safely takes deep discharging and high load currents. With a reserve in capacity and gentle use, its service life and reliability is increased for decades.

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EVPower a.s., Průmyslová 11, 102 19 Prague 10, Czech Republic
e-mail: export@gwlpower.eu, phone: +420 277 007 500

www.ev-power.eu