Manual

Lithium iron phosphate ($LiFePO_4$) battery

1 Safety guidelines and measures

1.1 General rules

Observe these instructions and keep them located near the Li-ion Battery for future reference. Work on the Li-ion Battery should be carried out by qualified personnel only.

While working on the Li-ion Battery wear protective eye-glasses and clothing.

Any uncovered battery material such as electrolyte or powder on the skin or in the eyes must be flushed with plenty of clean water immediately. Then seek medical assistance. Spillages on clothing should be rinsed out with water.

Explosion and fire hazard. Terminals of the Li-ion Battery are always a live; therefore do not place items or tools on the Li-ion Battery. Avoid short circuits, too deep discharges and too high charge currents. Use insulated tools. Do not wear any metallic items such as watches, bracelets, et cetera. In case of fire, you must use a type D, foam or CO2 fire extinguisher.

Never try to open or dismantle the Li-ion Battery. Electrolyte is very corrosive. In normal working conditions contact with the electrolyte is impossible. If the battery casing is damaged do not touch the exposed electrolyte or powder because it is corrosive.

Too deep discharges damage the Li-ion battery seriously and can even be dangerous. Therefore, use of an external safety relay is obligatory.

Li-ion Batteries are heavy. If involved in an accident they can become a projectile! Ensure adequate and secure mounting and always use suitable handling equipment for transportation. Handle with care because Li-ion Batteries are sensitive to mechanical shock.

If charged after the Li-ion battery was discharged below the Discharge cut-off voltage, or when the Li-ion battery is damaged or overcharged, the Li-ion battery can release a harmful mixture of gasses such as phosphate.

Non-compliance with operating instructions, repairs made with other than original parts, or repairs made without authorization render the warranty void.

1.2 Transportation warnings

The Li-ion battery must be transported in its original or equivalent package and in an upright position.
If the battery is in its package, use soft slings to avoid damage. Do not stand below a Li-ion battery when it is hoisted. Never lift the battery at the terminals, only lift the battery at the handles.

Batteries are tested according to UN Handbook of Tests and Criteria, part III, sub section 38.3 (ST/SG/AC.10/11/Rev.5).
For transport the batteries belong to the category UN3480, Class 9, Packaging Group II and have to be transported according to this regulation. This means that for land and sea transport (ADR, RID & IMDG) they have to be packed according to packaging instruction P903 and for air transport (IATA) according to packaging instruction P965. The original packaging satisfies these instructions.

1.3 Disposal of Li-ion batteries

Batteries marked with the recycling symbol must be processed via a recognized recycling agency. By agreement, they may be returned to the manufacturer. Batteries must not be mixed with domestic or industrial
waste.

Non-spillable

2 General information about Lithium iron phosphate batteries

Lithium iron phosphate ($LiFePO_4$ or LFP) is the safest of the mainstream li-ion battery types. The nominal voltage of a LFP cell is 3.2V (lead-acid: 2V/cell). A 12.8V LFP battery therefore consists of 4 cells connected in series; and a 25.6V battery consists of 8 cells connected in series.

2.1 Rugged

A lead-acid battery will fail prematurely due to sulfation if :

- it operates in deficit mode during long periods of time (i. e. if the battery is rarely, or never at all, fully charged).
- it is left partially charged or worse, fully discharged.

A LFP battery does not need to be fully charged. This is a major advantage of LFP compared to lead-acid.
Other advantages are the wide operating temperature range, excellent cycling performance, low internal resistance and high efficiency (see below).

LFP is therefore the chemistry of choice for very demanding applications.

2.2 Efficient

In several applications (especially off-grid solar and/or wind), energy efficiency can be of crucial importance.
The round trip energy efficiency (discharge from 100% to 0% and back to 100% charged) of the average lead-acid battery is 80%.
The round trip energy efficiency of a LFP battery is 92%.
The charge process of lead-acid batteries becomes particularly inefficient when the 80% state of charge has been reached, resulting in efficiencies of 50% or even less in solar systems where several days of reserve energy is required (battery operating in 70% to 100% charged state).
In contrast, a LFP battery will still achieve 90% efficiency under shallow discharge conditions.

2.3 Size and weight

Saves up to 70% in space
Saves up to 70% in weight

2.4 Endless flexibility

LFP batteries are easier to charge than lead-acid batteries. The charge voltage may vary from 14V to 16V (as long as no cell is subjected to more than 4.2V), and they do not need to be fully charged. Therefore several batteries can be connected in parallel and no damage will occur if some batteries are less charged than others.

2.5 With or without Battery Management System (BMS)?

Important facts:

1. A LFP cell will fail if the voltage over the cell falls to less than 2.5V (note: recovery by charging with a low current, less than 0.1C, is sometimes possible).
2. A LFP cell will fail if the voltage over the cell increases to more than 4.2V.
3. The cells of a LFP battery do not auto-balance at the end of the charge cycle.

The cells in a battery are not 100% identical. Therefore, when cycled, some cells will be fully charged or discharged earlier than others. The differences will increase if the cells are not balanced/equalized from time to time.

In a lead-acid battery a small current will continue to flow even after one or more cells are fully charged (the main effect of this current is decomposition of water into hydrogen and oxygen). This current helps to fully charge other cells that are lagging behind, thus equalizing the charge state of all cells.

The current through a LFP cell however, when fully charged, is nearly zero, and lagging cells will therefore not be fully charged. Over time the differences between cells may become so extreme that, even though the overall battery voltage is within limits, some cells will fail due to over or under voltage. Cell balancing is therefore highly recommended.

In addition to cell balancing, a BMS will:

- Prevent cell under voltage by timely disconnecting the load.
- Prevent cell over voltage by reducing charge current or stopping the charge process.
- Shut down the system in case of over temperature.

A BMS is therefore indispensable to prevent damage to large Li-ion battery banks.

Important warning
Li-ion batteries are expensive and can be damaged due to over discharge or over charge.
Damage due to over discharge can occur if small loads (such as: alarm systems, relays, standby current of certain loads, back current drain of battery chargers or charge regulators) slowly discharge the battery when the system is not in use.
In case of any doubt about possible residual current draw, isolate the battery by opening the battery switch, pulling the battery fuse(s) or disconnecting the battery plus when the system is not in use.

A residual discharge current is especially dangerous if the system has been discharged completely and a low cell voltage shutdown has occurred. After shutdown due to low cell voltage, a capacity reserve of approximately 1Ah per 100Ah battery capacity is left in the battery. The battery will be damaged if the remaining capacity reserve is drawn from the battery. A residual current of 10mA for example may damage a 200Ah battery if the system is left in discharged state during more than 8 days.

3 Installation

Note: Batteries must always be installed in an upright position.

3.1 Short circuit protection

Single battery installation
The battery must be protected by a fuse.

Series connection
Up to four 12.8V batteries can be series connected.
The batteries must be connected to a BMS.
The string of batteries must be protected by a fuse.

Parallel or series parallel connection
Up to ten batteries or strings of batteries can be parallel connected.
The batteries must be connected to a BMS.

Each battery or string of batteries must be protected by a fuse, see figure 1.

Do not interconnect the intermediate battery to battery connections of two or more parallel strings of batteries.

3.2 Charging batteries before use

The batteries are aproximately 50% charged when shipped.
When charging series connected batteries, the voltage of the batteries or cells with the highest initial state of charge will increase when reaching the fully charged state, while other batteries or cells may lag behind. This may result in over voltage on the batteries or cells with the highest initial state of charge, and the charge process will be interrupted by the BMS.
We therefore recommend to fully charge new batteries before using them in a series or series-parallel configuration.
This can best be done by individually charging the batteries at a low rate (C/20 or less) with a charger or power supply set at 14.2V. An absorption period of several hours at 14.2V is recommended to fully balance the cells.
Parallel connecting the batteries and simultaneous charging is also possible. In this case every battery must be protected by a fuse and the recommended charge rate is again C/20 or less, with C being the capacity of one of the paralleled batteries.

4 Operation

4.1 Cell balancing and alarms

Each 12.8V battery consists of four cells, and the internal cell balancing system will:

a) Measure the voltage of each cell and divert an increasing part of the charge current when cell voltage exceeds 3.4V, which will balance the cells.
b) Give an over voltage (cell voltage > 3.7V) or under voltage (cell voltage < 2.8V) alarm to be processed by the BMS.
c) Give an over temperature (T > 50°C) alarm to be processed by the BMS.

Note: it follows from a) that the batteries must be regularly (at least once every month) charged to at least 4 x 3.4 = 13.6V in order to balance the cells.

4.2 Battery Management System (BMS)

Two BMS's are available to process the information from the batteries.

4.2.1 BMS 12/200

The BMS 12/200 is a simple all-in-one solution intended for 12V systems only. It includes all functions as described under section 4.1, plus an alternator current limiter.
For details, please see the datasheet and manual on our website.

4.2.2 VE.Bus BMS

This BMS is suitable for 12, 24 and 48V systems.
For details and installation examples, please see the datasheet and manual on our website.