



GWL

Your complete power solutions.

HOW TO OPERATE A LIFEPO₄ BATTERY

THE 7 - STEP TECHNICAL GUIDE



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Competitive specification of a LiFePO_4 battery

OR CHOOSING THE RIGHT BATTERY FOR A HOUSE,
SUMMER COTTAGE, CARAVAN, BOAT OR
A WORKING MACHINE





Everywhere, where we plan to use batteries, we request reliability, safety, a good balance between price and performance and the longest possible warranty. Certainly, we pay attention to safety risks in order to avoid fatal consequences in the event that the packaging is damaged (for example, in food or agricultural services).

RELIABILITY

The type of battery that has been in general use the longest is the classic lead-acid battery (sometimes also SLA, AGM or VRLA). We know that these batteries can work for up to 5 years,¹ which corresponds to approximately 300-500 charges, that their function is impaired² in the winter season and that they are relatively heavy.³ However, they are cheap and are suitable for occasional use (backup power supply for a PC, starting an engine, etc.). For frequently used devices, we choose lithium ion batteries. But these are not lithium polymer (Li-Pol) or lithium cobalt manganese (NMC) that look like a slightly larger AA battery,⁴ but what is known as prismatic lithium iron phosphate, abbreviated to LFP or LiFePO₄.⁵ Despite being three times more expensive than lead-acid batteries and about 30% more expensive than the NMC type, they nonetheless last at least ten times

longer and are roughly 50% lighter.⁶ Even if you use them on a daily basis, they last for 10-15 years⁷ in original condition. Lithium titanate batteries (LTO) are even more durable,⁸ they will last at least twenty times longer than lead-acid batteries. How can we claim that? Because we have been supplying them to our customers for many years already and those supplied 10 years ago are still going strong!⁹ Unlike many other lithium technologies (NMC, LCO, NCA, LMO, LTO), LiFePO₄ technology has been in use in industry since 2007. Therefore, real technical references⁹ exist, not just accelerated simulations of behavior, safety and aging.¹¹

SAFETY

Lead-acid batteries cannot combust or explode during normal usage. On the other hand, they are full of lead and sulfuric acid (albeit in gel form), which are dangerous compounds. Likewise, cobalt and manganese contained in lithium NMC batteries are hazardous elements (so-called heavy metals). In addition, when a charger malfunctions, they may ignite and explode;¹³ therefore, their service requires increased security measures and supervision. Lithium phosphate batteries contain no poisonous substances and are a great compromise that combines non-toxicity and

safety: they can neither combust nor explode¹⁴ and are also manufactured with large capacities making it unnecessary to connect them up into multiple-piece blocks.

PRICE/PERFORMANCE

When we break down the cost of lead-acid batteries into one charge and discharge, we find that every 1 kWh of their use costs us between 0.30 and 0.60 EURO. NMC and Li-Pol batteries are somewhat cheaper but LiFePO₄ batteries are the cheapest with a charge and a discharge costing us between 0.04 and



- 1, 2 Here you will find [detailed graphic depictions of the life cycles of lead batteries](#) depending on their depth of discharge and operating temperature. [You can find a comparison with lithium here, for example.](#)
- 3 [Differences between individual Li-Ion battery](#) types and at the end of the article, there is a graph depicting various energy densities for different battery types including lead batteries.
- 4 This is a [detailed depiction of the 18650 battery including an explanation of what's inside](#) and how complicated it is to make large battery packs from these cells.
- 5 [Comprehensive description of the LiFePO4 chemistry](#) on wikipedia.org.
- 6 [Comparison of a lead battery vs LiFePO4 technology](#) in terms of weight and energy.
- 7 [What life cycle can realistically be expected from LiFePO4 batteries](#) and how does it depend on their depth of discharge?
- 8 [Description of LTO technology](#) including graphs indicating the no. of cycles and discharge characteristics.
- 9 The VW Golf Citi Stromer automobile [after 10 years of running on LiFePO4 Winston batteries.](#)
- 11 [Simulation of the aging process](#) of LiFePO4 batteries, [dependence on the depth of discharge and a comparison with lead batteries.](#)
- 13 Regular (not LiFePO4) lithium batteries may catch fire and can even explode, if the separator between the cathode and anode is disturbed. [Electrolyte is a highly-flammable material.](#)
- 14 [LiFePO4 batteries never catch fire or explode,](#) not even during a short circuit or overcharge. They merely puff out and the security valve releases a non-toxic gas. The battery is destroyed but no other damage is incurred. All you have to do is open a window to let some air in.
- 15 [Comparison of the cycle price of LiFePO4 vs lead batteries](#) according to cycle depth and an explanation of how it is calculated.
- 16 [Comparison of the discharge of a 12V lead starter battery, traction battery and a LiFePO4 battery.](#) While being discharged by a current of 100A (about 2.5C), the lead battery only delivered 9 -14% of its nominal capacity, while the LiFePO4 Winston battery managed a full 112%!

0.12 EURO per 1kWh. How is that possible? Well, because you can do this up to 8000 times and the battery will still function.¹⁵

PERFORMANCE

Lead-acid batteries do not respond well to being discharged and charged too quickly. Only starting lead-acid batteries can withstand this but they cannot be discharged for too long, either. Lithium batteries are capable of both, that means you can either charge or discharge them very quickly (high performance), all the way up to their actual declared capacity.¹⁶

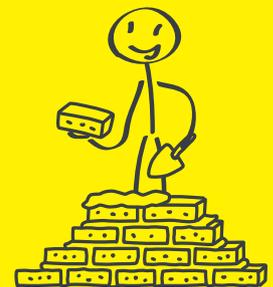
WARRANTY

Although most sellers of lead-acid batteries claim to give a 24-month warranty, try returning a car starter battery that refuses to start in winter after two years' use...In contrast, a reputable lithium battery retailer always specifies the number of cycles and a guaranteed residual capacity of the battery after completing the aforementioned number of cycles. An offer of 5 or even 10 years' warranty is no exception.

SUMMARY

Lead-acid batteries are suitable for undemanding purposes. When you need a light weight alternative and do not require a long service life, use NMC or Li-Pol (hand tools, aviation models). The best available albeit more expensive technology is LTO (lithium titanate cells). In all other instances, choose LiFePO₄ batteries.

TEST QUESTION: WHICH OF THE MATERIALS USED BELOW MOST RESEMBLES AN LFP BATTERY?



Technology and Characteristics of Lithium Ion Batteries

OR YOU HAVE CHOSEN THE LiFePO₄ BATTERY - WHAT IS IT MADE OF AND HOW DOES IT WORK?

LiFePO₄ batteries are a subtype of lithium ion batteries. They are mainly used in electricity storage (households and power engineering), for industrial automation and selected types of electric vehicle. What are they made of and why do we choose them from the multitude of lithium batteries?

CONSTRUCTION

An LFP cell contains a positive and a negative electrode with an electrolyte between them. The positive cathode is composed of LiFePO₄ lithium compounds. The negative cathode is composed of carbon material (graphite). The electrolyte is composed of lithium salts (most often LiPF₄) in an organic solvent or ones that are trapped in a special polymer (plastic). When charging, there is almost no chemical reaction, just lithium ions passing from the cathode into the electrolyte and onwards into the anode structure. When discharging, the exactly opposite process takes place: lithium ions return from the anode through the electrolyte to the cathode (hence the name 'lithium ion').³ Because there is electrical voltage between the anode and the cathode, they must be well separated by a membrane that allows movement of ions, but prevents short circuits between the electrodes. A very thin ceramic

film that at first glance looks like paper is most commonly used for that purpose.

SERVICE LIFE

Lithium polymer and manganese/cobalt cells with a nominal voltage of 3.7V begin to degrade chemically after just 300 - 1000 charging cycles. These cells have high voltage (up to 4.2V) and therefore the settling of solidified electrolyte on the electrodes and their oxidation is accelerated. This prevents further exchange of lithium ions, increases the internal resistance of the cells and battery capacity decreases rapidly. In contrast, LiFePO₄ cells retain 80% of their original capacity after 8,000 cycles. How is this possible? The anode electrolyte sedimentation and cathode oxidation occur mostly at a cell voltage above 3.9V and temperatures over 50 °C. However, LFP batteries do not even come close to these voltages and temperatures during operation.

They are usually charged at 3.6V and do not heat up during operation.¹⁴

SAFETY

While other types of Li-Ion batteries with a cathode based on cobalt and manganese can easily combust or even explode in the event of short circuit or overcharging, such reactions are excluded when it comes to LiFePO₄. This is because the cathode material is essentially a natural mineral very similar to olivine. Even at high temperatures, it does not release oxygen (it is difficult to disrupt its chemical bonds) and is oxidation resistant.¹⁵

ENVIRONMENTAL PROTECTION

LiFePO₄ batteries do not contain heavy metals (manganese and cobalt) and are well-suited for future easy recycling.³ Even if there is an accidental leak into the environment, there will be no damage - just the loss of valuable raw materials.



PRACTICAL APPLICABILITY

The features of LFP cells meet the needs of electric vehicles and power engineering perfectly. Since they come in a voltage of 3.2V, a 12.8V battery can be assembled from 4 cells and used as direct replacement for conventional 12V lead-acid batteries. Low internal resistance allows LFP cells to discharge and charge up to 3C currents, so the battery can be fully charged in as little as 20 minutes. During operation, they maintain a constant voltage of about 3.2V regardless of the degree of discharge,¹⁶ eliminating the need for additional control elements.

DISADVANTAGES

Due to their rather low nominal voltage (3.2V), LFP cells therefore have a lower energy density per 1 kg than other batteries. What is more, due to the presence of iron, the density of the cells is about 80-100 Wh/kg. In Li-Pol or NMC cells, double the density - 160 – 200 Wh/kg - can be easily achieved.

- 13 [Composition of various types of lithium batteries.](#)
- 14 [Reasons why lithium batteries don't have an "endless" life cycle](#) and why their capacity decreases over their time of use.
- 15 Videos, showing LiFePO4 batteries being tested (short circuit, overcharge, puncture). They show that while the cell/battery is destroyed, a LiFePO4 cell never catches fire. [Overcharge. Puncture.](#)
- 16 [VA discharge characteristics of a LiFePO4 2G cell show a flat discharge curve.](#) Cell voltage is basically the same at the beginning and at the end of the discharge, even during a high discharge voltage of 5.7C.



TEST QUESTION: WHICH PICTURE DEPICTS THE INTERNAL STRUCTURE OF LFP?



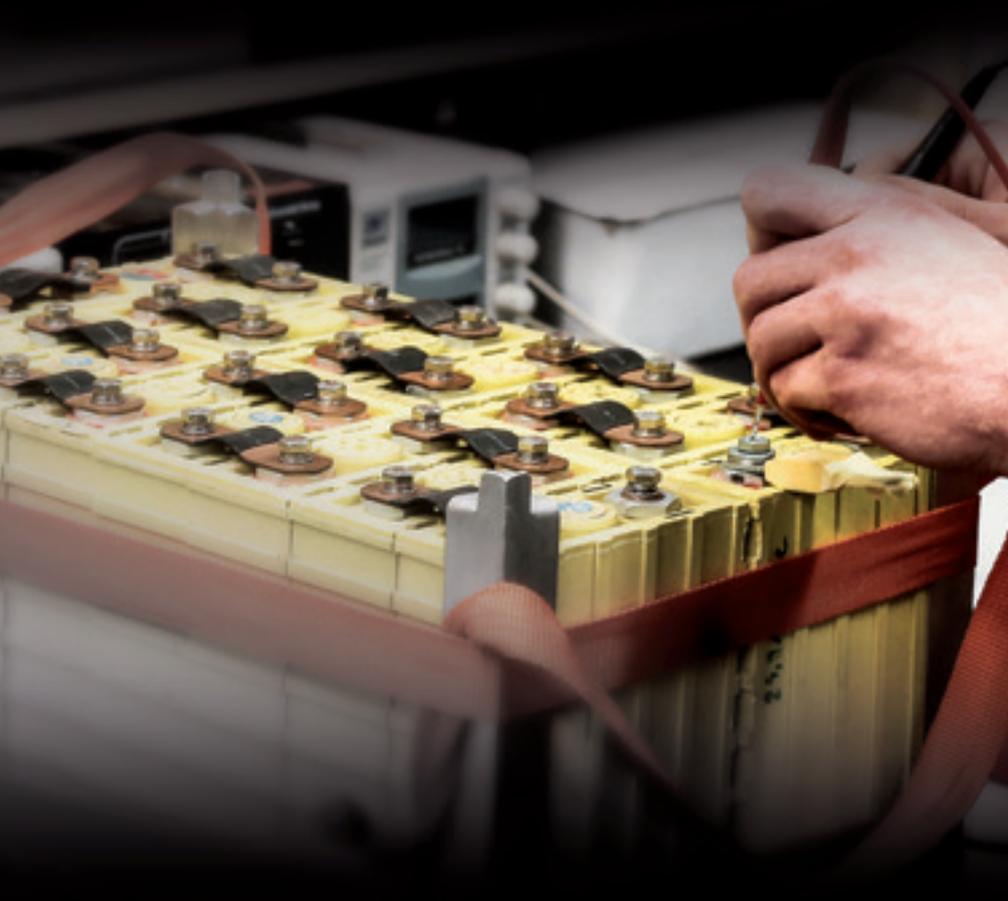
Initial charging, assembly and battery placement

OR YOU HAVE PURCHASED THE CELLS AND THEIR ACCESSORIES - WHAT NEXT?

The selected LiFePO_4 prism cells need to be properly prepped before assembly into a battery pack. This always involves first checking the voltage, polarity and overall condition of all cells. Only then should you initiate the recharging, arrangement, fixing in place and interconnection of individual cells.

INITIAL CHARGING

Immediately post-production, the cells are charged at only about 30% of their actual capacity. Therefore, they all have to be recharged to the same full capacity before first use. This is called initial charging or formatting.¹⁷ The correct procedure is first to clean all contact surfaces of cells (terminals) with fine sandpaper, connect them in parallel with original terminal connectors, connect the charging source cables to the opposite ends of the assembly (charger, laboratory power supply) and charge with the recommended current, according to the datasheet, to a voltage of between 3.6 and 3.8V.¹⁸ After reaching the target voltage, disconnect the parallel assembly and assemble it in series in accordance with the required battery voltage.



PREPARING FOR BMS ASSEMBLY AND CONNECTION

When using terminal BMS (e.g.123Smart), it is advisable to use threaded pins/rods instead of bolts, especially for end terminals.²¹

Tighten the intermediate terminal connector with the first nut on the spike and select the remaining thread above it so that you can independently install BMS or other accessories.²² If you want to use BMS central or just check the cells and balance periodically, it is advisable to connect the wires coming out of the individual connections to a common terminal block on the accessible edge of the battery.²³ Provide end terminals with a fuse and an insulated power connector and mount polarity shields of the appropriate color on all terminals.

BATTERY POSITION AND LOCATION

Place the cells in the assembly so that the terminals and safety valves are facing upward. We do not recommend positioning the battery lying down with the terminals to the side.²⁴ In a long-term horizontal position, the cell loses its capacity which can lead to leakage of electrolyte and/or corrosion of the terminal. When using resistor balancing or high operating currents, it is necessary to ensure heat ventilation. If possible, locate the battery away from environments with a temperature below freezing or above 40 °C.²⁵

SAFETY

While working, use protective equipment and insulated tools.²⁶ Continuously cover live parts of the battery (e.g. with an insulating tape). Remove all metal objects from your hands (watches, rings, bracelets) before assembling in order to avoid a short circuit. An unwanted circuit during battery assembly is the most common cause of cell damage and future failure to recognize a warranty claim.

MECHANICAL CONNECTION OF CELLS INTO A UNIT

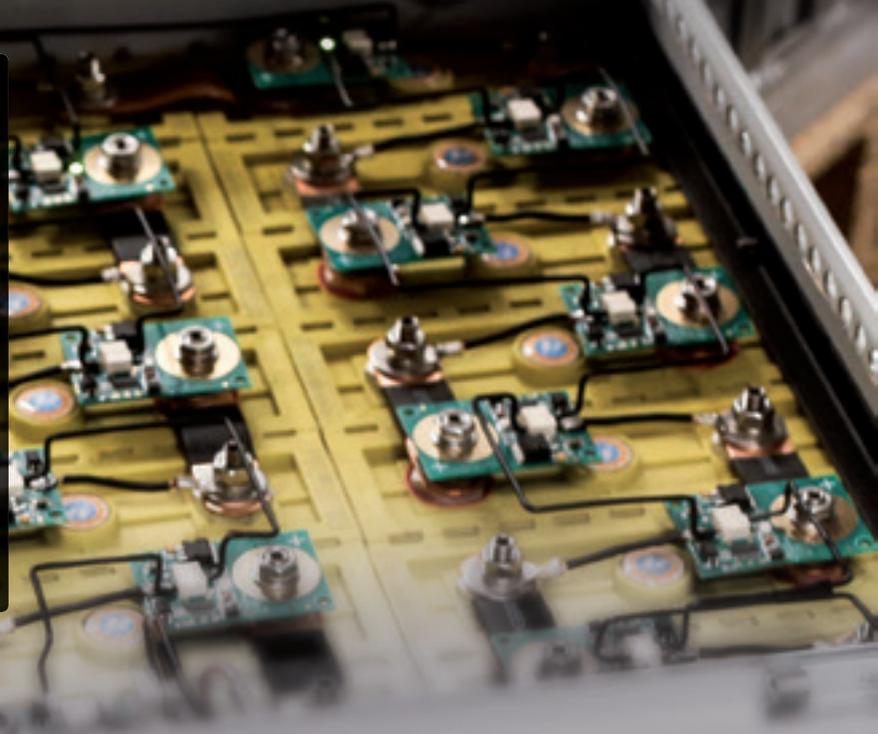
We always design them so that individual cells are arranged with opposite terminals facing each other and thus only the original terminal connectors can be used. Different lengths and designs of terminal connectors always cause cells to unbalance during long-term operation and this is undesirable. In turn, inelastic terminal connectors can cause mechanical loosening of terminals and electrodes, so do not use them, as a matter of principle. The easiest way to fix the cells into a stable unit is with a pallet tightening tape. Another option is to construct a chassis from brackets and metal plates with a common battery housing

cover. For permanent storage of the battery pack, always use a 6-sided, sufficiently mechanically resistant box made of non-combustible material.¹⁹

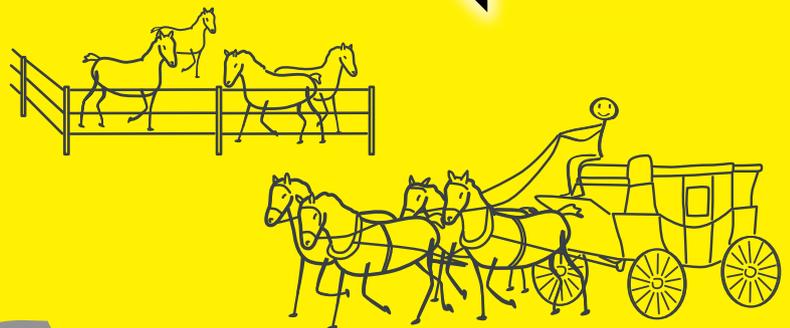
CONNECTING TERMINALS

Fasteners (bolts, washers and nuts) must be made of stainless steel. Always use a flat and a spring washer on each screwed connection. Screw in until most of the thread is in the terminal, but never screw the bolt or threaded rod all the way down the bottom of the terminal because you risk piercing the cell. In a series-parallel arrangement, first link the cells in parallel and subsequently serialize the blocks - never the other way round.²⁰

- 17 An instructional video [on how to set up and carry out an initiatory recharge of a battery pack.](#)
- 18 A constant charge value for all cells is important as is a suitable charge source: example [of how to charge correctly.](#) The reason why it is not possible to constantly charge a 12V LiFePO4 battery using a standard lead [battery charger is explained here.](#)
- 19 [Example of a battery pack assembly.](#)
- 20 Theory of series and [parallel circuits of cells for batteries. A diagram of incorrect and correct series and parallel circuits.](#)
- 21 A photo of a [threaded rod](#), where a jumper is installed first and a BMS module is installed above it.
- 22 [A hole in a BMS module](#) can be enlarged without the warranty being affected depending on the size of the thread terminal.
- 23 A photo [of a connected bus where](#) all the wires are the same length.
- 24 Illustrations [of correct and incorrect positioning.](#)
- 25 [Impact of temperature](#) on the overall capacity of the cell and the minimum discharge voltage.
- 26 Examples of simple [tool modifications.](#)



TEST QUESTION: WHAT IS THE DIFFERENCE BETWEEN HITCHING UP A HORSE AND HITCHING UP BATTERY CELLS?



Charging and discharging during operation and service balancing of the battery

OR HOW TO CORRECTLY OPERATE AND MAINTAIN THE BATTERY

The right choice of battery capacity is crucial for its economical and thus long-term reliable operation. The ordinary operational process of disconnecting a battery from the load and charger is always ensured by the software settings of these modules, not by BMS.

If the assembly is properly designed, the individual series-connected cells do not significantly diverge during operation (unbalance). Always set the system so that the battery does not reach limit states-either a too low or too high voltage of a cell against its permitted minimum and maximum limits. During normal operation, the BMS functions mainly used are the State of Charge (SoC) and controlling the Depth of Discharge (DoD).

INFLUENCE OF SOC AND DOD

The unbalance of cells is mainly caused by the frequency of limit states, where they occur and their minimum differential capacity. The more frequent such occurrences are, the more likely unbalance is to happen; unbalance will also be greater and will increase the need of balancing systems. Therefore, we recommend operating at a maximum of 90% and a minimum of 20% SoC. At a temperature of about 20 °C and the recommended

operating current, these will measure approximately 3.55V and 3.0V.²⁸ Especially with a drop in the ambient temperature, this voltage range changes and SoC needs to be measured by a standard calculation method on the basis of the current drawn and supplied according to the current sensors.

EFFECT OF CHARGING AND DISCHARGING CURRENT

Long-term peak currents, especially at low temperatures and low SoC, will cause unbalance of cells, even at minimum differences in cell resistance. High discharging and charging currents also make it difficult or even impossible to determine SoC and DoD only by means of using battery voltage.

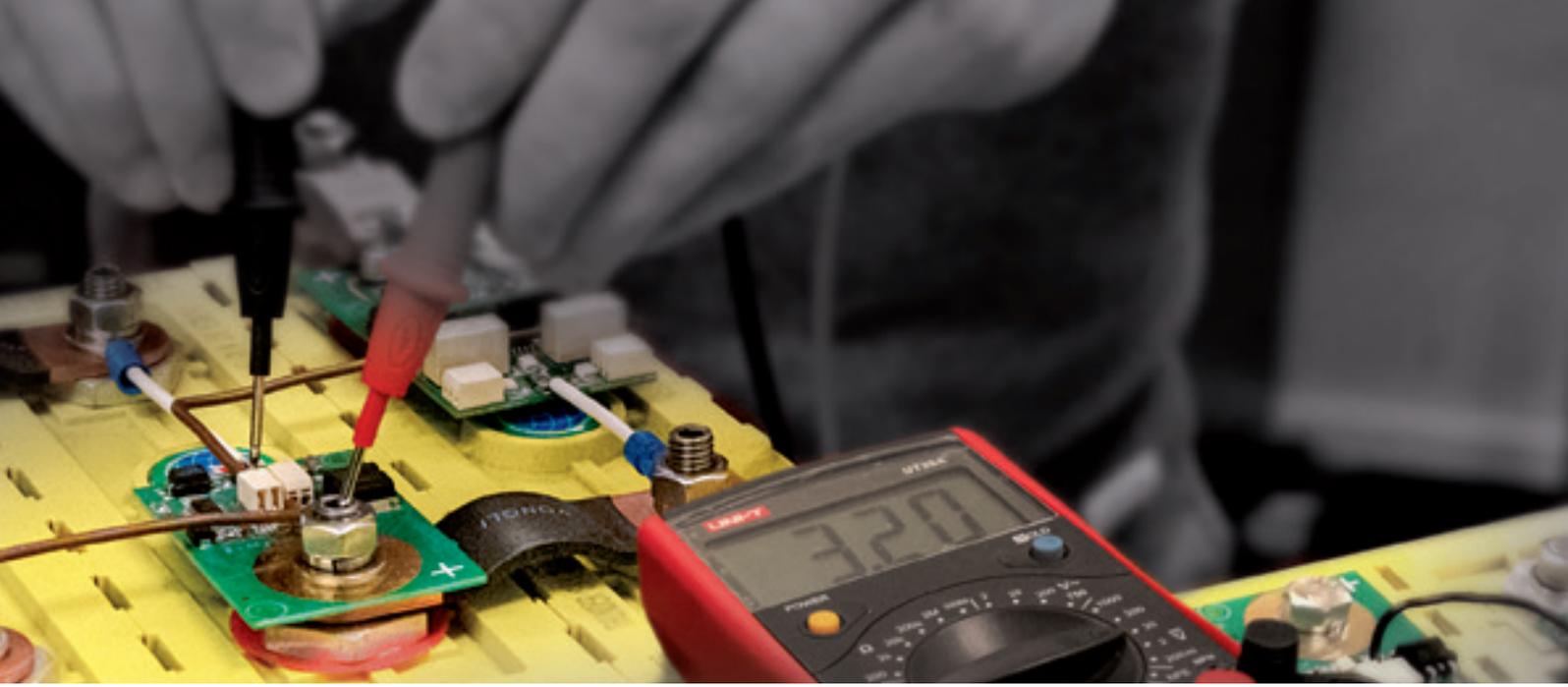
CHARGING CHARACTERISTICS OF GRID CHARGERS

Most of LFP grid chargers charge either by constant voltage (CV), constant current (CC)

or the combination of both: first CC and then CV, having reached the desired SoC %.²⁹ The key function of the charger is to interrupt charging without voltage hysteresis after the required % SoC has been attained (most often this is defined by reaching the set voltage). LFP cells cannot be permanently maintained at a maximum charging voltage or return to it periodically, unless they are at least partially discharged after charging has been completed. Here are referring to capacity hysteresis, not voltage hysteresis.

CHARGING CHARACTERISTICS OF SOLAR CONTROLLERS

The characteristics and principles of charging are similar to those of grid chargers. Nonetheless, charging is unpredictable, reliant on sunshine, so continuous charging at a set % SoC is out of the question and thus determining the remaining capacity of the battery pack by measuring the voltage fails. If the controller does not have an LFP battery mode directly in the menu, it is possible



to use the mode designed for lead-acid „GEL“ battery.

PERMITTED VOLTAGE TOLERANCE OF INDIVIDUAL CELLS

In optimum operation mode, only very minor fluctuations occur in minimum voltage (a matter units or at most tens of mV) and in the maximum capacity of individual cells (up to 2%). The permanent/continuous and intense balancing of cells in this situation is neither necessary nor appropriate. On the contrary, it can sometimes be counterproductive given the energy demands of balancing systems and the „natural“ differences between cells.

SERVICE BALANCING

In applications where deep battery cycling does not occur (up to about 70% DoD/90% SoC), currents do not exceed 1C and temperatures during operation do not fall below freezing point, the successful and long-term servicing of batteries is possible

even without a balancing system. However, it is always necessary to ensure protection of the total voltage pack limit states (limit states of one cell x number of cells, ideally, also of individual cells). It is extremely important to carefully select individual cells of a setup and have them assembled into a battery professionally. Then it is enough to perform periodic calibration of cells, e.g. with a single-cell charger or a laboratory source at rational service intervals.³⁰

BMS FUNCTION

BMS is an emergency fuse against battery pack damage by discharging or overcharging. It most certainly cannot be used for operational load disconnection, which should happen by means of an appropriately set internal logic depending on the total battery pack voltage or % SoC calculation. For example, solar controllers can be set at the LFP value for LiFePO₄ cells or, if that option is not available, they can be set at 'GEL'. Charging or discharging is then

terminated directly by the controller and not by BMS. inverters and chargers may be set up similarly.

SUMMARY

The BMS disconnecting function is similar to a fuse in an electric circuit. It is used as protection against the failure of connected modules (inverter, charger) or against cell unbalance due to a manufacturing deviation or an assembly error. Powerful, sophisticated and high quality BMS for high current battery operation in 100% DoD mode is quite expensive. If, instead of investing into such a BMS, you use this amount to increase the pack capacity and learn about the right operation and servicing of a battery with a simple BMS, you will achieve better results.

- 27 What can happen if a charger fails and the BMS is not populated? [Photo here.](#)
- 28 Here are descriptions of various [voltage values](#), at which charging and discharging of LiFePO4 cells should be stopped with regard for the required percentage DoD value and cell life cycle.
- 29 A laboratory source is a good aid for occasional initiatory charging of cells and for their service balancing. [An article on charging using a laboratory source.](#)
- 30 Definitely in the spring and in the fall, and the optimum service intervals should be set by an expert according to cycle methods. It is ideal to have data available on the difference between the voltage in the strongest and the weakest cell, e.g. using a simple BMS GWL. CPM: here is the product page and the [installation and user manual.](#)



TEST QUESTION: IN THIS SYSTEM, ARE CAPACITY, PERFORMANCE AND LOAD BALANCED?

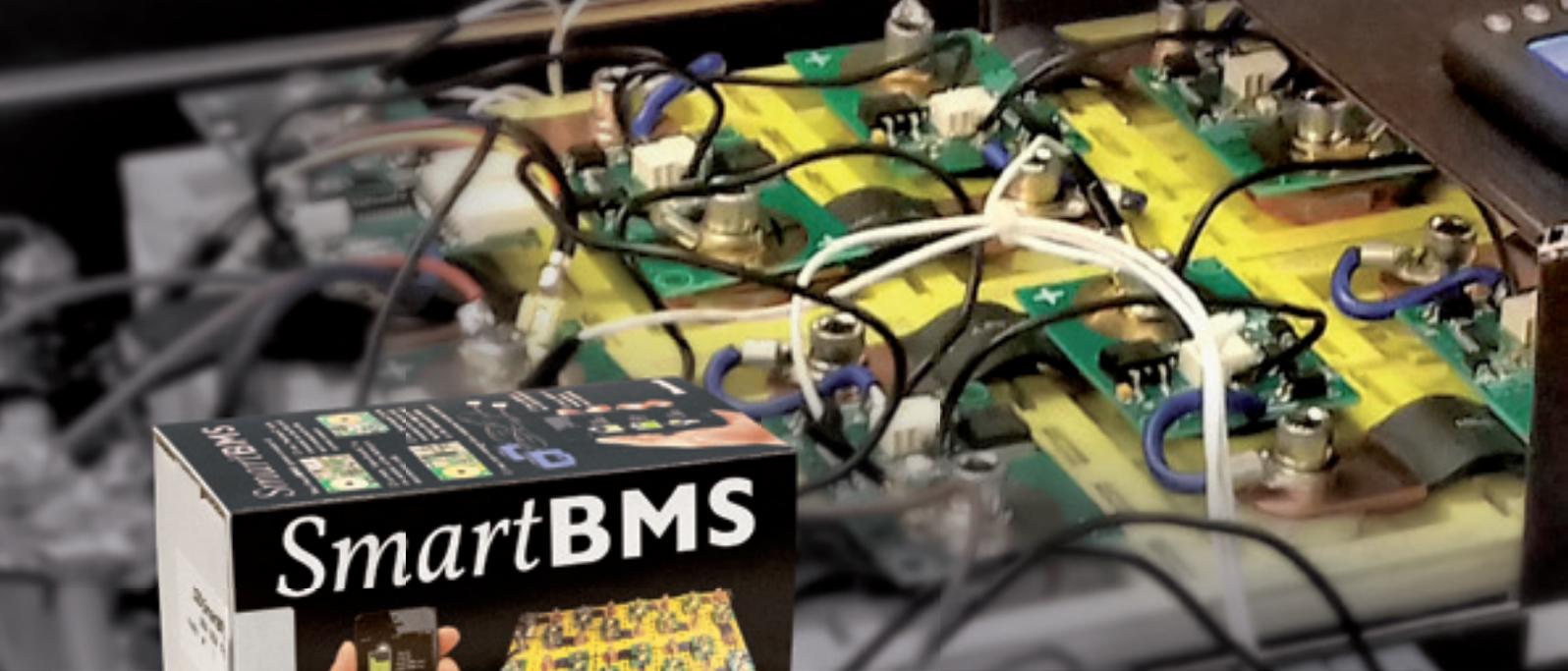


BMSs and their components

OR WHAT ELSE TO MOUNT ONTO THE BATTERY AS A PRECAUTION?

We secure most battery packs with a management and control system (BMS-Battery Management System). This means battery protection against excessive discharge or overcharging. You can imagine this system like the emergency brake that you find in every single train carriage that prevents the entire train from accident. In practice, it is a simple electrical circuit which constantly measures the electrical voltage of each cell connected to the battery and alternatively the currents supplied to the battery and drawn from it. If voltage of a single cell within the battery exceeds the specified value, the BMS will disconnect the entire battery from the charger or load in order to avoid it being damaged.³¹





Sophisticated BMS systems contain a function that calculates the SoC and DoD and also the so-called balancing. What does that mean? In such a situation, a BMS continuously monitors if all cells have the same voltage. If not, it begins either actively or passively balancing their voltage.

PASSIVE BALANCING

This is basically a resistor on every cell that prevents the cells that are charged first from being overcharged by releasing

the discharging (balancing) current at a specified voltage (the so-called bypass voltage regulator). Thus, during charging, the strongest cells undergo slow and controlled discharge and 'wait' until the remaining cells reach a unified voltage.³²

ACTIVE BALANCING

You can imagine this like a pump that pumps the energy out of the strongest cells and into the weaker ones, in every operating mode of the battery. Its work is based on

the principle of cell potential equalization, and it often happens to be an independent module without the function of emergency disconnection.³³ The disadvantage of such a system is its higher complexity, a higher permanent consumption of BMS and, as a result, faster cell ageing. Its advantage lies in easy assembly. A targeted recharging of weaker cells by an external source may also be called an active balancing.

EMERGENCY DISCONNECTION

The efficiency of the balancing system (balancing currents) may not be sufficient in every operating mode, and faults cannot be ruled out, either. Therefore, a disconnection element which in that case will disconnect the battery from the load or a charger (for LiFePO₄ we recommend its activation outside the voltage range of 2.80V – 3.80V) is always a component of any complete BMS.³⁴

BMS CONSTRUCTION TYPES

The systems are manufactured in two basic designs: terminal and central. Terminal



- 31 The basic interval is $U_{min} - U_{max}$ of the cell. Inside, it can include the value at the start of balancing, or a warning value or another operating command. Because of various technological differences, we always recommend to check the setting based on the technical data sheet.
- 32 These balancing modules are usually called **CBM (Cell Balancing Module)** and they can exist as completely separate elements without communication (for simple usage) or as part of a more sophisticated BMS.
- 33 These module high voltage converters usually make an unpleasant whistling sound. It sounds like nothing but in reality it in fact greatly limits their usage. We generally don't recommend these modules as their effect isn't too great and they significantly reduce cell life cycles.
- 34 Experience shows that customers often buy a fairly sophisticated and expensive BMS (e.g. BMS123 Smart) and only connect its modules for the balancing function, meaning only as a CBM. This of course isn't very effective. The BMS123 also contains clamps for the output disconnecting relay. [Recommended values for operating LiFePO4 cells.](#)
- 35 Video [manual for installing the BMS123 Smart.](#)
- 36 Link to the [smart relay product page and its parameters](#). Recommendation: a power appliance behind the battery is best divided and switched using several branches. This way, we distribute the load of the switch elements and limit the creation of an electric arc.
- 37 [You can read more about BMS on our technical blog.](#)

BMS modules (e.g. BMS123Smart) are connected directly onto individual cell terminals and are interconnected either by a communication wire or communicate through a PLC system directly through individual cells. In most cases, BMSs have no central unit – this tends to constitute either by the first or the last module, which contains readouts for superior systems (power relay, Bluetooth, RS485, etc.).³⁵ Central BMSs (for e.g. GWL CPM1) are located outside the battery pack and reads information about the cell voltage via conductors from individual cells. Otherwise, their function is similar to that of a terminal BMS. Their principal advantage is easy upgrade/replacement in case of need.

TYPES OF DISCONNECTION DEVICES

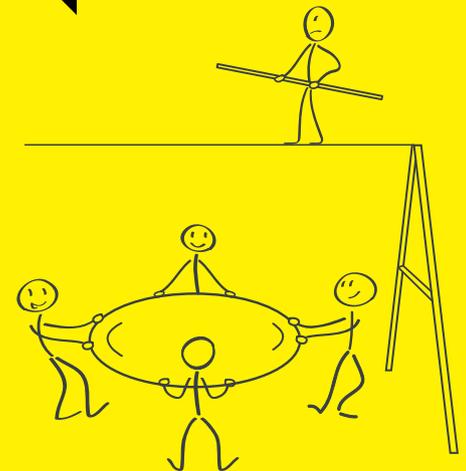
The main disconnection device is a power relay (contactor), whose coil is controlled by permanent closing/opening control voltage from BMS. The disadvantage

of such elements is a higher actual consumption of a few watts. Therefore, a more suitable element is a bistable (double coil) relay, where a short controlling impulse onto a relevant coil is sufficient for the change of status of power contacts, the coils are permanently without voltage, i.e. without actual consumption. One particular type of a bistable relay is a so-called 'smart' relay, which can function economically even when the control voltage from the BMS is permanently switched on. After switching over the coil, it will always limit its consumption to less than 5 mA. Such a relay is therefore suitable for replacing the two original one-coil contactors, maintaining the existing BMS (this being one pair of bistable relays).³⁶

SUMMARY

The use of a BMS in a battery (a basic one costs less than hundred EURO) is rather a must. To operate a lithium battery permanently without BMS is like flying on a plane without a fuel indicator.³⁷

TEST QUESTION: WHAT ARE THE MAIN FUNCTIONS OF A BMS?



Typical uses of Lithium ion batteries

OR SO WHERE DO YOU CONNECT A BATTERY?

The typical uses of LiFePO₄ batteries include:

- A robust backup power supply for manufacturing operations, an office, IT infrastructure or a household.³⁸
- A battery for a photovoltaic power plant, which will charge during electrical power surplus and supply energy when it is not sunny.
- Onboard ship battery, houseboat or caravan battery (a substitute for an original lead-acid battery).³⁹
- Energy storage in an island house (isolated houses, cottages, garden houses, etc.), where the 230V electricity mains is out of reach.
- Industrial applications and selected types of electric vehicles.⁴¹

In each of the aforementioned uses, the battery must be connected to another follow-up system, which will then use its handover working interface (most commonly, DC 12, 24, 48V) for the required function (voltage converter, vehicle traction, etc.).

ALL-IN-ONE SOLUTION

For marketing reasons, follow-up systems are combined into as complex packages as possible, therefore, it is difficult to remove individual elements (making it impossible to fix or improve them). A typical example of such an all-in-one concept is a hybrid inverter for a photovoltaic power plant, which actually houses both a network and island DC/AC converter, a solar MPPT controller, a network switch, securing, detachment and communication elements and a charger. Similarly, for instance, in a railway station electric carts you will usually find one electro block that will make it very difficult to distinguish what belongs to the BMS, what belongs to the frequency charger, what belongs to electric motor control unit, etc.⁴²

MODULAR SOLUTION

Where it is possible to use an open modular solution of functional units, this is certainly a better option.⁴³ What we mean by module here, is an easily replaceable block with documentation and a clear (partial or target) function. Sometimes a module is, in fact, just a widely available product (DC/AC converter,





network charger), at other times it is a sub-unit assembled from such products. A few examples from our experience:

- **UPS with LiFePO₄ battery**

The main 'module' here is a 48V battery pack with a fuse, interconnecting wires and power and indicator output connectors.⁴⁴ The connecting BMS module contains securing and disconnecting elements and a custom BMS CPM1 board with monitoring and communication electronics.⁴⁵ The Aspiro load source module, which ensures an optimal battery charging regime and in synergy with it constitutes uninterruptable high-performance and high-capacity DC backup power, is connected to the output terminal.

- **Backup for original UPS with a lead-acid battery**

A network switch module (BPS-Backup Power System) is attached to the battery module and the BMS.⁴⁶ A power cut in the mains electricity is initially dealt with in a matter of minutes by the existing UPS with a lead-acid battery. If the power cut lasts for a more extended period, the BPS module connects a high-capacity LiFePO₄ battery and a DC/AC converter as a substitute for the 230V network voltage and brings it to the UPS input. This way the backup time is extended from a few minutes to hours and even tens of hours (substitute for gasoline generator). Once the mains power supply is restored, the LFP battery will automatically recharge again via an integrated charger.

- **Modular hybrid converter**

A hybrid converter can be replaced for instance by a separate inverter, a solar MPPT controller and a LiFePO₄ charger.⁴⁷ For such a system, a backup in case of 230V mains electricity power cuts or a functional isolated power plant can be complemented by the BPS module mentioned above. Such a 'hybrid converter' will never crash as a whole and any handy electrician will be able to fix it (i.e. to replace common parts or products) years after the end of the warranty period of any of the original components.

The same is true for the basic and most important module- a pack of prismatic LiFePO₄ batteries. This will facilitate effortless examination, servicing and, where necessary, replacement of its every cell or to upgrade the entire pack together with the related application.

- 38 Link to the [GWL/Modular system product page](#) including photos and component descriptions.
- 39 [Our customer photos](#) of batteries installed on a yacht.
- 40 [A Czech self-sufficient house design project](#), including an energy diagram, construction documentation, photos etc.

- 41 [LiFePO4 batteries are used](#) by city buses SOR, shunter engines at the EuroEst steelworks, on personal boats for voyages in waters where combustion engines are not allowed
- 42 Sometimes this is called a **“Black Box”** solution because we cannot see into it and we're forced to rely on service from the manufacturer.
- 43 [The GWL/Modular system](#) for example.

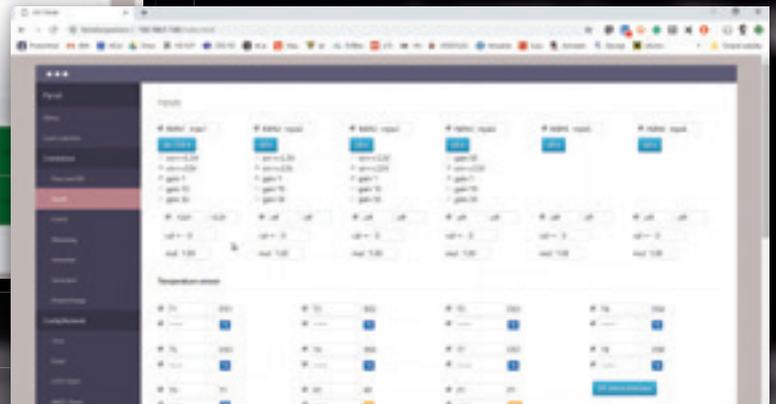
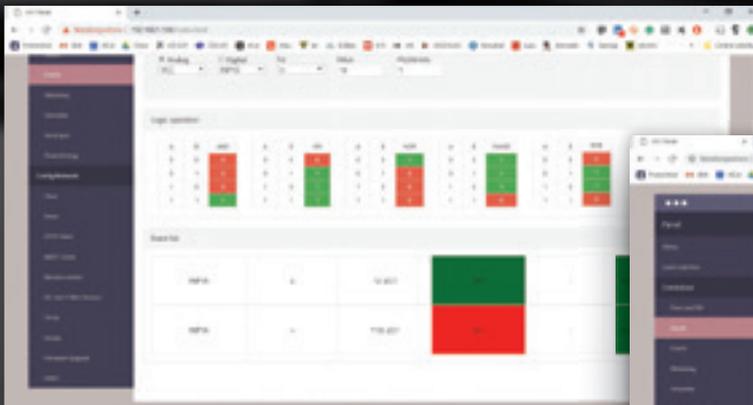
TEST QUESTION:
WHAT DO YOU PREFER?



Battery communication in applications

**OR WILL IT ALL FUNCTION WELL ON ITS OWN
AND WILL WE ALSO HAVE AN OVERVIEW?**

Like the emergency brake on a train, disconnection components of the BMS cannot be the only precaution against a crash. A battery pack needs to have a routine method of charging and discharging, like a train's regular service brake. Disconnecting the pack by BMS is an emergency event, not a piece of 'information' for a superior system. Sudden and unexpected disconnection of connected modules from the battery via BMS can cause irreparable damage. Likewise, a sudden outage can be considerably inconvenient for users (equipment 'suddenly' stops working, the lights go out...).





Therefore, more complex BMS systems contain components for communication with a superior system- a charger, controller, converter, etc. The BMS continuously informs them that a certain limit state is approaching (full charge or discharge) and thus they can in advance and appropriately limit their function and provide the user with information about the current situation.⁴⁸

MULTISTAGE ANALOGUE COMMUNICATION

When a system approaches a limit state, the BMS can take interim measures in good time. A typical example is a command to decrease the charging current, if a battery pack is almost charged or, on the contrary, to disconnect any superfluous element consuming power if only very little energy is left in the battery. Such communication by the BMS with superior systems with the assistance of several analog outputs is reliable and also battery pack-friendly. We also recommend keeping this method of 'communication' as a backup, even if you are using an advanced digital BMS controlled by software. An example of such a simple BMS is the CPM1 module from the GWL company.⁴⁹

STATUS DISPLAY, SIGNALIZATION AND LOCAL SERVICE

Depending on the environment and the knowledge level of the local staff, choose a particular method of acoustic signalization

and status visualization, ranging from, for instance, simple three colored 'traffic lights' to a multi-value display. The source values for the display most frequently comprise the cell voltage limit values or, alternatively, the difference between the cells with the highest and lowest voltages. The overall voltage of the battery pack is not sufficient information. Service intervention on the basis of detected values also depends on how knowledgeable the staff is and on system settings. Nonetheless, simple manual emergency disconnection should be made possible in all cases.⁵⁰

DATA TRANSFER, REMOTE MONITORING AND CONTROL

When you operate several battery packs and/or they are difficult to reach physically, we recommend expanding the BMS system by remote monitoring and control. In practice, this means a mini computer (Arduino, Raspberry, Android box, LAN Controller, Tecomat, etc.), that is connected to LAN, a local Wi-Fi net through Ethernet or is supplemented by a LTE/3G modem. Information about the battery pack (total voltage, SoC, the voltage of the weakest and the strongest cells and other values upon need) are converted into the form of the analog voltage (0-3, 3 V, for example) by a BMS, are monitored with the assistance of analog inputs of a mini computer and

sent at regular intervals to the server where they are further processed according to need, see below. Commands for the battery pack, sent via a communication network (www, Internet, text message) are, on the contrary, converted into logical output on control relays. This simple system makes it possible to inform the user about battery status via e-mail/text message, to visualize battery status on a graph on the web, to turn on/off the battery pack, to charge it, etc. remotely.

PC ENVIRONMENT FOR REMOTE MONITORING

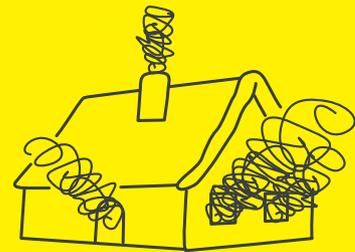
This is the most reliable way of actively sending data from the battery pack (e.g. via HTTPS protocol) to a remote server and saving it in a database (for instance, MS SQL, MySQL, etc.). Passive data reading from the communication module has proved to be impractical, because the majority of mobile operators or cheap Wi-Fi routers usually do not make it possible to access client equipment directly from public Internet. The saved data is then visualized on a webpage where control buttons may also be placed. Such a system does not need a platform and it is possible to constantly follow and manage it through any current or future equipment (touch phone, tablet, PC, etc.).

DIGITAL MODULE COMMUNICATION, COMMUNICATION PROTOCOLS

Various standardized interfaces are used for battery pack communication (or for its BMS, as applicable) with other components (e.g. vehicle dashboard, photovoltaic controller, UPS converter, engine frequency converter, control keypad). Previously, the serial port RS232 was popular, today the RS485 with a Modbus protocol is taking over, along with 1-Wire bus, I2C, etc.

- 48 [The GWL charger product page with the option to connect to a BMS](#) and a description of its connection to the GWL CPM1. Here, you can find out how to connect a charger to the BMS GWL CPM1 so that the charger stops charging the pack automatically if one of the cells reaches a limit voltage value.
- 49 [CPM1 module product page including](#) an a detailed explanation of its functions and how to connect it, as well as the installation and operating manual.
- 50 [Installation and photos of the GWL/Modular BPS module](#) including the emergency disconnect switch.

TEST QUESTION: WHO WILL YOU TRUST WITH SERVICE? WILL YOUR GRANDMA MANAGE IT?





Your complete power solutions.

LiFePO₄ technology is suitable and safe for a wide range of industrial and home applications. In most cases, it is necessary to equip the battery with a management system (BMS). The BMS range depends on the method of use, the qualifications and responsibility of a user. A battery unit with a BMS needs to be correctly integrated into a system with emergency disconnection. A managed LiFePO₄ battery will safely withstand deep discharge and high load currents. Reserve capacity and careful usage will increase its useful lifetime and reliability to decades.

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