

Building your own Lithium Iron Phosphate Solar Battery



The cost of Lithium batteries range from \$500 to \$700 per KWh, if you have the skill there is a huge saving to be had by building your own battery. Components can be imported from China resulting in a tax and freight paid cost of about \$300 per KWh

OK so now you are all excited, but there are several rabbit holes you could end up in, this article is to point out these pitfalls saving you the pain of the many issues you are likely to encounter.

Purchasing components from China can be done either via Aliexpress or Alibaba that is more of a wholesale outlet and does not necessarily provide a cheaper sourcing than Aliexpress.

Sellers on Aliexpress are rated similar to eBay so you can assess the risk in the dealings, however as in eBay there is good buyer protection offered by the platform.

The construction of a Lithium battery consists of the cells, box and a Battery Manager System.

The cells are nominally rated at 3.2 Volts thus-

4 cells for a 12 Volt battery

8 cells for a 24 Volt battery

16 cells for a 48 Volt system

What voltage system should you use?

Noting that for a given power (Watts) the higher the voltage, the lower will the current be.

The resistance in the copper wiring is a loss, by lowering the current for a given power reduces the loss increasing the system efficiency.

For safety reasons do not exceed 48 Volts, this is a safe voltage value mitigating cable losses.



Wire size

As already mentioned the copper wire will have resistance that is a function of its cross sectional area, it's obvious that the greater the wire circumference the lower the resistance and the loss, using 20 to 26 mm² cable for wiring insures low losses on long cable runs.

DC Isolator

A two pole DC isolator with built in fuses is a must, the rating of the fuses are to be sized to the maximum system current draw or that of your DC inverter/charger, for example a 5 KW inverter will draw on a 48 volt system about 100 Amps, the fuse used should be at least 120 Amps

By choosing a blade fuse holder this can also be used as the isolator switch.



Warning when switching DC current under load

It's very important to understand that switching DC current has a risk attached to it, this risk is a self-sustaining arc, when the opening of a circuit under load an arc is produced, damage to switch contacts and the possibility of starting a fire is possible, the switching of a few amps does not compare when switching 100 plus amps. Never open a switch when it's under load.



DC to AC inverter pre-charge (Soft Start)

some inverters will have a soft start feature so that the inrush current is limited, but many do not have such feature and a pre-charge method must be employed, this consists of flowing current via a limiting resistor to charge up the capacitors in the inverter then thereafter the full battery can be connected to the inverter, this insures no arc is produced by the switching and the battery is not going to go into short circuit protection.



Hazards of batteries

A fair amount of scaremongering has taken place, more driven by those against renewables.

The claim that Lithium catches fire is just based on instances of abuse or in the manner of handling, even the trusty lead technology is equally dangerous, lead batteries have been known to explode.

The two rules to follow regardless of what kind of chemistry used is not to overcharge the battery, only charge to the manufacturer recommended voltage and current settings. A good reliable charger is a must as this is the weak link in the whole system.

The Lithium Iron Phosphate battery used in a home installation, is as safe as Lead acid technology, it is not to be considered the same as the Lithium Ion polymer that under fault or abuse conditions will self ignite, Lithium Iron Phosphate does not catch fire and will withstand considerable abuse that only reduces its cycling life.

Condition of new cells

Upon receiving your new Lithium Iron Phosphate cells carefully inspect for any physical damage, do not use damaged cells. Next measure each cell voltage that should be 3.2 Volts within 10 to 20 mVolts of each other, any cell with a greater deviation of 100 mVolts or greater should be marked and considered for later testing especially if the voltage is considerably lower than 2.5 Volts

For those cells showing a large divergence a full charge discharge cycle test should be done to insure the cell is serviceable, in the least just top charge and keep an eye on how the cell is behaving as it cycles compared to the others, it's not uncommon to receive new cells that have large deviation from each other, usually this is not the case but possible. Some cell manufacturers advise to cycle a new cell a few times before placing into service, this conditioning is to gain the best performance from the cell, this is not very practical but in a home solar system the cells will start cycling from the moment that are placed in service.

Top Charging

Top charging is the process of charging all cells individually to a equal voltage, this an important factor when wiring cells in series, doing so will prevent cells from raising above the rated maximum voltage and diverging from each other during the charging process, insuring that all cells in the battery will have the same amount energy, when fully charged, note that new cells are likely to have a greater energy capacity than the stated value, this due to slight differences in the manufacturing process, this difference in capacity will show up as voltage in cells raising in above the others this deviation must be kept at the lowest possible value, usually within 20 mVolts. Will discuss later how this is done, but top charging will give you a starting point with all cells at a same voltage with small voltage delta variations.

Note that when having done a top charge, after a period of half hour measure the cell voltages insuring that are within a range of 20 mV from each other.

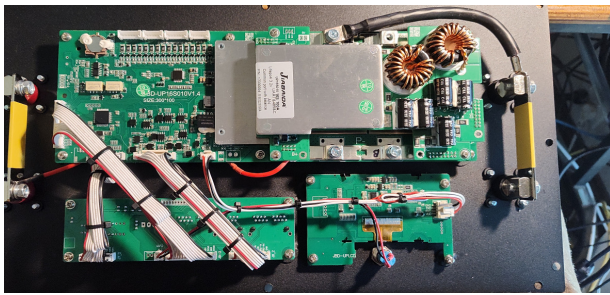
Assembly of a battery pack

The selection of a suitable battery box deserves careful consideration, a snug fit for the cells and room for the cables along with the battery manager. Pay attention that readymade boxes will in fact fit the kind of cells you have selected, most readymade boxes will include all the hardware the likes of outlet terminal posts, rubber spacers and fibreglass spacing plates etc.



If building your own box keep in mind for worst case situations, I mentioned above that the chemistry is as safe as anything else but in all things accidents do happen, if the box is not secure, external factors can lead to severe damage, for example dropping a spanner across the terminals, burning wiring and melting metal. A box that contains all the workings and not easily opened will provide that degree of insurance against mishaps. Be professional in your construction, if unsure ask one that is able to give proper advice, this is most critical for safety reasons, remember that you are dealing with high energy store capable of delivering thousands of amps. The cells in the box are kept under slight compression to control cell swelling, noting that this condition only happens when cells are fully discharged, a condition that is avoided under normal discharge.

The Battery Management System (BMS)



The selection of a BMS has more to do with the maximum magnitude of currents that battery is to handle. For example you wish to have an energy store of 1 KWh but will only draw 10 Amps and charge at 50 Amps, so the BMS has to cope with 50 Amps maximum, but give yourself a bit of head room selecting a 100 Amp BMS, you can use a larger capacity BMS but not one that is smaller.

BMS functions

The BMS performs very important functions in the management of the cells for safety and longevity, each cell and the battery itself is monitored with maximum and minimum value limits, that if exceeded will isolate the battery turning it off, some of the parameters monitored are

- a/ Short circuit protection
- b/ Pack overvoltage
- c/ Pack under voltage
- d/ Cell over Voltage
- e/ Cell under voltage
- f/ System Temperatures limits covering cells and BMS

These parameters are for safety and longevity, Lithium is not forgiving when the charge or discharge parameters are not met, in fact over voltage or over discharge will reduce the life of the cell and in some instances permanently kill the cells.

The other function on some BMS's undertaken is the individual cell balancing insuring cells are within a specified value or delta

Cell Balancing

As already mentioned keeping the individual cells voltages as close to each other is a very important in obtaining the best life and performance from the battery, why is this? When the cells do not have equal voltages the one cell with a higher voltage will cause the charging current to reduce to all the other cells. It may not seem to be a lot however when you have several cells out of balance the loss becomes great.

BMS Built in Balancer

Most BMS units have an integrated balancer, however the balancing current is in the order of 50 to 200 mAmps, (There are unit with larger balancing current), cells are kept to within 20 mVolts of each other, this delta at top of charge is considered good balance.

In practice on DIY batteries when the cells are not matched by the supplier, the BMS will struggle to bring these cells into balance, as the balancing currents used are too low.

Note that in time new cells will settle with use, the deviation will reduce over time, the danger here is that the cells reaching an overvoltage condition will cause the pack to turn off (BMS protection parameter)

Shunt or Active Balancer

There are several types of balancers, managed shunt, passive shunt, managed active and unmanaged active.

The managed shunt balancer works by shunting or consuming some of the cell current to lower its voltage, this energy is consumed by a resistor been switched on and off by the action of the BMS controller sensing the cell actual voltage and comparing to the others. As already mentioned the currents involved is low thus this method works well on matched cells when the divergence in voltage is less than 100 mVolts. This is the kind of balancer found in most BMS units.

The passive shunt type is a standalone unit separate from the BMS that senses the average cell voltage and lowers those above average by shunting current.

The active balancers fall into two categories managed and unmanaged.

The balancing mechanism is involved in the movement of charges from high voltage cells to low voltage cells, the use of super capacitors is implemented in this process, the high voltage cell charges a capacitor then the capacitor is discharged into the low voltage cell, with this method currents as high as 5 Amps or more can be transferred from high to low cells.

The unmanaged devices have set limits for the balancing set in hardware, the managed type have a programmable controller allowing limits to be set as desired.

This is the best kind of balancer, there are now BMS units that include active smart balancing so I am told.

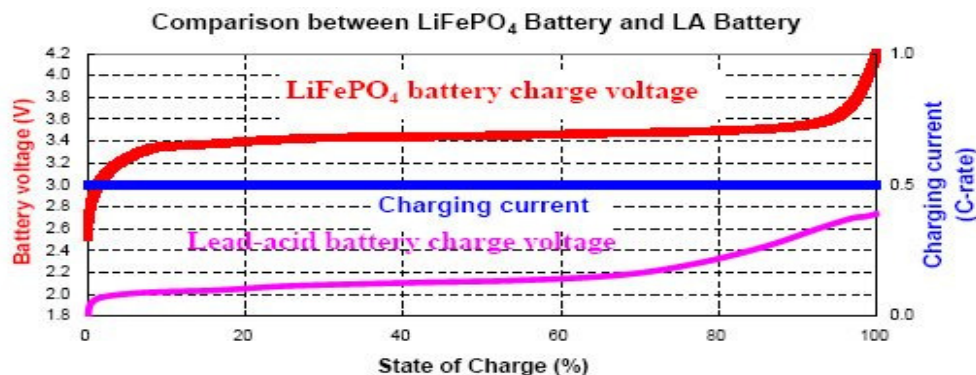


Lithium Iron Phosphate cell properties

This kind of chemistry offers a very flat voltage curve with sharp exponential drop off at end of charge and an exponential raise at top end of charge.

The fully charged voltage is typically between 3.5 to 4.1 volts the percentage of increase of stored energy above 3.5 Volts is very small but the life of the cell is reduced if operating at the higher value.

The discharged voltage is typically 2.5 volts, note that fully discharging a cell reduces its life, it makes sense to operate within limits that gives the longest life or number of cycles, so it's recommended to only discharge to 3.2 volts and top charge to 3.5 volts.



Selecting an energy store size to suit your requirements

This is a very important step and depends a lot on your life style and energy consumption, then if you are an off grid or grid tied situation, the selection depends a lot on what you expect the system to provide. If you have PV panels most of your electrical energy purchase happens during the dark hours, so the consumption during this period is to be covered taking into account any bad weather when there is little generated energy, note that during this period your battery charging becomes part of you usage profile. Having said this the size of the existing PV system plus your consumption trend will largely dictate your storage requirement, if you can afford it the larger is best even if oversized by two to one or more. The reason is that you are not discharging the battery to its allowed minimum state of charge and have in reserve for those bad days when PV generation is low, obtaining the longest service life from the battery.

How long will lithium last?

According to the manufacturers the number stated is between 4000 to 6000 cycles, depending on how they are treated, there is evidence of having lasted ten plus years with some only lasting four to five years. In the early days the advice given by those selling these batteries was that Lithium could be fully discharged with no detriment to battery life, now we know from the early failures that this is not the case, cells cycled past to optimal points will have a reduced life span, clearly the wrong advice was given, ten year later we know better.

Talking about crazy statements, there is now advice given to only charge to 80% of capacity, the theory is that this is the point that gives the longest life, then to only discharge to 20% of charge, with this I agree, but not with the top of charge, 3.5 Volts is 15% below the very top of 4.1 Volts that the chemistry allows. The capacity of the battery has already been factored by the manufacturer taking into account the above factors regarding the top voltage charge but they advice to charge to 3.55 Volts, so charging to 3.5 Volts is a good compromise, the loss in stored energy is a very small amount, less than 1 %.

The big moment

You have built your battery and you turn it on for the first time, the lack of smoke or bang, it means that you have paid attention to detail in the construction. You connect the charger observing what is going on using the software that the BMS manufacturer supplied showing you the amount of current going into the battery and the individual cell voltages.

Did you setup the BMS first No? Turn off the charger and set the parameters, don't assume that the BMS manufacturer has done this for you.

It is most important to set the cells over voltage and over current parameters along with the pack over-voltage and under-voltage. On some BMS units when a pack fault is detected the pack will shut down, under this kind of condition and parameters return to normal the pack will not auto reset, to clear the fault condition the pack requires a reset and restart, however when a cell goes over or under voltage the pack will shut down, but when conditions return to normal the pack will restart. Note that the above statement is based on the kind of BMS units I have worked with, not necessarily the rule for all BMS types or brands. This is the problem that the manufacturers are very economical with the provided information, in many instances trial and error is required to determine the behaviour of an individual BMS.

List of recommended parameters

Cell Voltage protection	3.650 Volts
Cell Under Voltage protection	2.500 Volts (Note this a way below the 20% minimum charge)
Pack Overvoltage Protection	58.40 Volts (This value can be lower dependent of your charger)
Pack Under Voltage Protection	48 Volts

The above values are selected to provide a starting point in your setup, the final values will depend on several things as you battery settles.

Note protection will turn the pack off protecting itself, do not force the pack on unless you understand what caused the condition.

The first issue to create problems is that at the top of charge some cells are going past the overvoltage point, the provided software should indicate exactly what cell caused the issue, you have options to overcome this by either lowering the cell voltage with a resistor to be the same voltage as the other cells, this is a long drawn process and not recommended, or by installing an active balancer. Even with the balancer in this case, the procedure is to charge at a lower voltage and current, for example the charge voltage is 3.5 volts and the offending cell raises above this value, lower the voltage to say 3.45 Volts allowing the active balance to balance all the cells to the lowest possible deviation, then later on raise the voltage back to the 3.5 Volts.

The reasons that the cells behave as they do is due to some cells accepting more current than the others, remember that with lithium chemistry the variation of voltage as low as 1 mV that can cause a large magnitude of current to flow. To put things in a simpler way the balancing insures that the charge and discharge curves are on the same vectors.

The charging process and the balance of the cells is more important than the discharge, don't be concerned if large deviation in voltages happens at bottom of charge, in time the balancing process will align that part of the curve as well.

C Rating

Many battery manufacturers including cells specification make reference to current magnitudes using the C rating, this is often not understood to its meaning with respect battery current maximum current parameters.

For instance a battery is rated such-

100 Ah - Charge current C 0.5

Discharge C 1

"C" is a unit of time this is defined as 1 hour, so with respect to the above data the battery capacity is 100 Amps for one hour, the discharge rate is a maximum of 100 Amps for one hour and the battery is fully discharged, but can only be charged at 50 Amps for two hours. When setting up your charger and the applied discharge loads pay attention to these values or premature damage to the cells will take place.

In this article I have provided information that either encourages you to build your own battery having understood the traps for young players or put you completely off and purchase off the shelf units. This is for you to decide. If you decide to do your own build the following basic equipment is required.

a/ Good quality Volt meter, some BMS units require voltage and current calibration for each cell

b/ Variable Voltage and current power supply (Preferably to cover the pack voltage) For top charging and even to calibrate BMS current sensing.

In conclusion a nominal 51.2 Volt 100 Ah pack purchased in Australia is likely to cost you over \$2500.00 to \$3000.00

build your own for \$1500.00 I think the cost differential can finance any extra equipment you will need.

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