Watts Up?

Designing an Electrical System for the Overland Camper

Mild to Wild

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Usual Disclaimers

- This information is correct to the best of my knowledge and belief. The ideas in this presentation have been tested by field use on my personal 4x4 camper. They may or may not work with your vehicle or any other vehicle.

- Products and specifications may change, specific products mentioned are only some of many which may perform the required purpose and may not be the ones actually used on my vehicle.

- Get professional assistance if you are not comfortable working with high amperage circuits.

- When in doubt, follow the instructions of your battery manufacturer over the instructions of your charger manufacturer, this paper, or any other source. Do not undertake any modifications which may void your vehicle's warranty.

- Pay careful attention to fusing - at both ends - and protection of wiring from physical damage.

- YMMV, etc.

- Remember: FUSE IT!

Why Are We Doing This?

Or, do you REALLY need cold beer?

The challenge of designing an electrical system for an overland camper often seems overwhelming. It is actually easy if you do it this way:

- **Determine What You Want to Power** - Lights? Fans? Refrigerator? Microwave? How many minutes of each hour is each appliance going to be on? This will allow you to determine how much power you need for an hour or a day.

- **Determine How Long You Want to Run it all** - In this case, we are basically determine how many days we want to be able to camp without using a generator, running the vehicle engine, or sunlight. This will tell you how large a battery bank you need. The numbers change if you use a generator.

- **Determine How You Will Recharge Your Batteries** - There are several options here, a generator, your vehicle's alternator, solar power, wind power, or shore power. Each has advantages and disadvantages. You will probably need some combination.

This is what you will know at the end of this presentation.

Some Basic Terms/Concepts
(Horribly Oversimplified)

- **Watt** - Standard measure of electrical power, one watt is equal to one Ampere (Amp) at one Volt. Watts are constant at any voltage or amperage. (Technically, a watt is a measure of power.)

- **Volt** - Potential energy in a circuit. Can be imagined as pressure. Usually used to describe a system as being 12v, 24v, 110v or 220v.

- **Ampere** - Actual current. Can be imagined as “volume.” Grossly, the total “amount” of electricity delivered.

Volts and amps are grossly reciprocal. Amps are Watts divided by Voltage. A=W/V.

For a given Wattage, as volts increase, amps drop and vice versa. So a 1500w load will pull 15A at 110v and 150A at 12v.

Some More Basic Terms/Concepts

(Horribly Oversimplified)

There are two main measures in a system, instantaneous power and power over time.

Instantaneous power is expressed in watts (best as it is voltage independent) or amperes at a voltage. Your system must be able to produce enough power to cover your load.

Watt hours or Amp hours are used to describe a load over time, or capacity. Once you have enough power for the load, the question is how long you run it.

- Some loads are small and short – water pump
- Small and long – fan
- Middle size and variable – heat
- Middle and long – refrigerator
- Huge and short – microwave or cooktop
- Huge and long – air conditioner

Where/How to Begin?

Determine your Electrical Load

First, determine what you need - lights, cooking, heat, computer/ camera charging, ventilation, music, TV, etc.

Next, determine how much of your load is going to be electrical and how much LP gas or gasoline/diesel.

- Cooking with propane or diesel is more fuel efficient than cooking electrically.

- Heating or cooling electrically poses almost impossible energy demands.

- Use 12v appliances wherever possible. 110v appliances draw extra power due to inverter losses. (5-20%)

What are Some Typical Loads?

50 qt. Cooler: 2-3A	Induction Cooktop: 75-150A
Water Pump: 5A	12v Refrigerator: 2-5A
Furnace: 5-15A	Computer Charger: 5-10A
Roof Fan: 1.5A	TV (125w/110v): 12A
Microwave: 100-150A	6k BTU Air Conditioner: 40-60A

Note 1: Some loads, like LED lights, can be ignored. But do calculate at ***least*** 1 Ah for miscellaneous loads. (5 Ah would be safer.)

Note 2: 110v loads can be grossly converted to 12v by dividing watts by 10. E.g., 1000w microwave = 100A @ 12v.

Note 3: Use the ratings of your actual appliances rather than this or any other sample table.

So What's Hard?

Nothing, really (That's why you are in this class.)

But there are tremendous variables, many of which are hard to predict.

- Heaters, coolers, and air conditioners vary in their demands and do not run constantly. They cycle depending on things like their contents and ambient temperature.

- Labels are not always accurate. The good news is that many actually overstate the demand as they are trying to make sure that you don't overload a circuit.

The really hard core can use a meter, like the Kill-A-Watt to measure the draw of 110v appliances. Similarly, if you have an hour counter in your vehicle, you can measure the draw of an appliance.

Calculate a Sample Load

A microwave oven is really handy for vegetables and for reheating food. But it has a voracious appetite for power. How much? Read the label.
In this case, we will assume that it reads “1000w/110v.”

So what is that, at 12v, for a full day’s use?

- 1000w/10v = 100A (You could use 12v, but 10v is easier and helps account for inverter losses.)
- Assume 15 minutes of actual use to heat a meal.
- 100A/4 = 25Ah

And, of course, this will vary depending on the power level, what you are cooking, etc.

Repeat this process for every large load you plan.

Sample Energy Worksheet

Appliance	DC Amps	Hours per Day	Total Ah per Day
Microwave	150	0.5	75
Induction Cooktop	100	0.5	50
Furnace	10	4	40
Etc.			

Add up the fourth column for the bad news. Then multiply by the number of days of autonomy you require. This will tell you how big a battery bank you require.

There are many calculators and spreadsheets that you can find on the Internet. Just depends on how much detail you want.

Decide on the Best Battery Type for YOUR Needs

The new basic question: Lead Acid or Lithium Iron?

Lead Acid Batteries

- Lowest Initial Cost/shortest service life – best service life is half that of the worst Lithium service life
- Greatest size and weight
- Harder to charge properly – failure to charge completely leads to short life
- Harder to damage – can recover from most faults
- Can’t be damaged by freezing

Lithium Iron Batteries

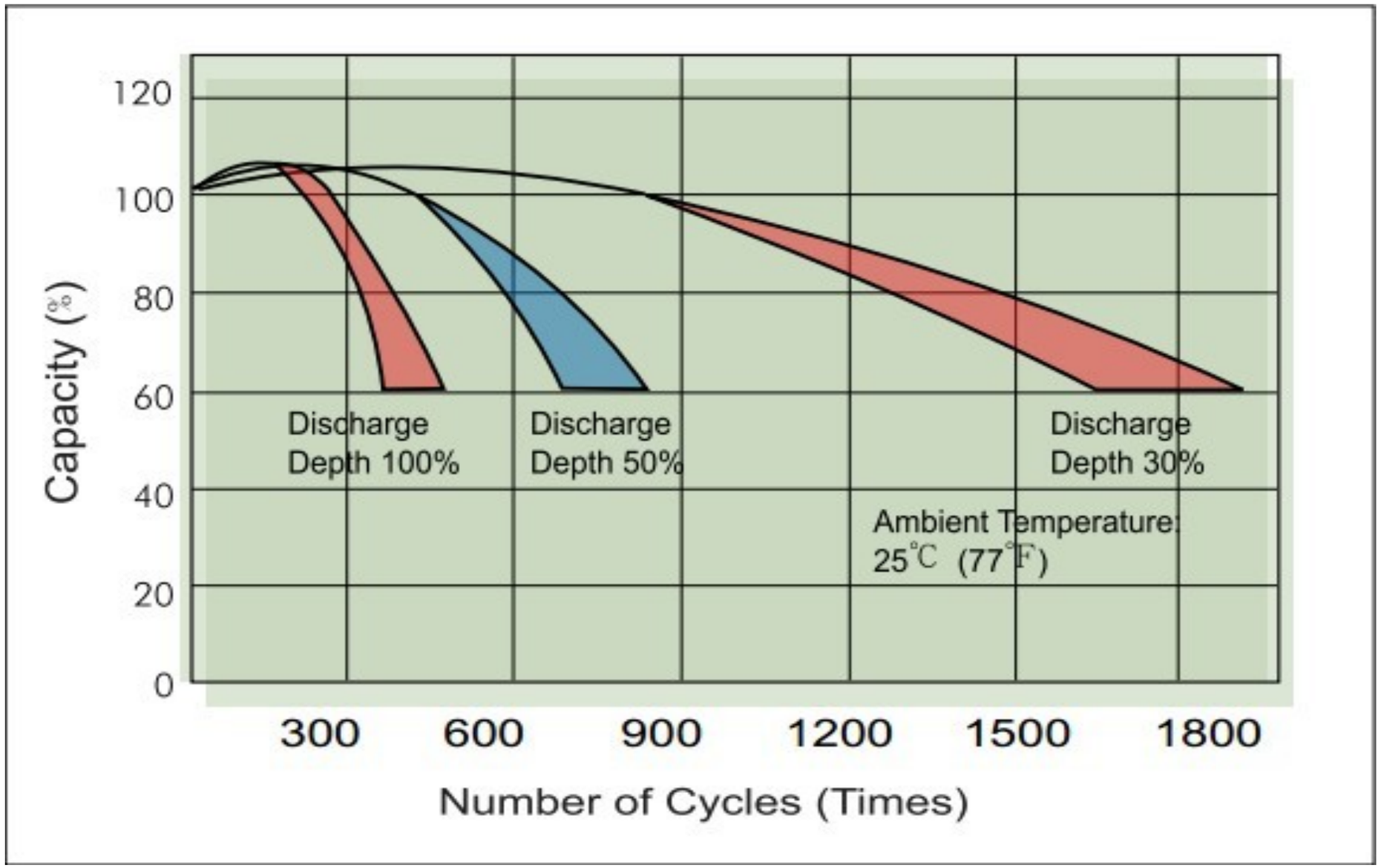
- Highest Initial Cost/longest service life – worst service life is twice that of the best lead acid service life
- Much lighter and smaller, especially as you may be able to use a smaller capacity battery
- Specific charging requirements/BMS essential – But: never have to be fully recharged
- BMS is essential – cannot generally recover from faults
- Can’t be charged if below freezing

Size Your Battery Bank

Part One: Lead Acid

The basic rule is that you want a lead acid battery bank that is at least twice as many ampere hours as you need; the “Fifty Percent Rule.” This typically gives the best return on investment.

While this rule makes sense, some prefer to accept a shorter battery life to save weight, space, etc. And you can exceed this level of discharge if you are going to recharge immediately. (Of course, you may have so much voltage drop that the battery can’t carry the load …)



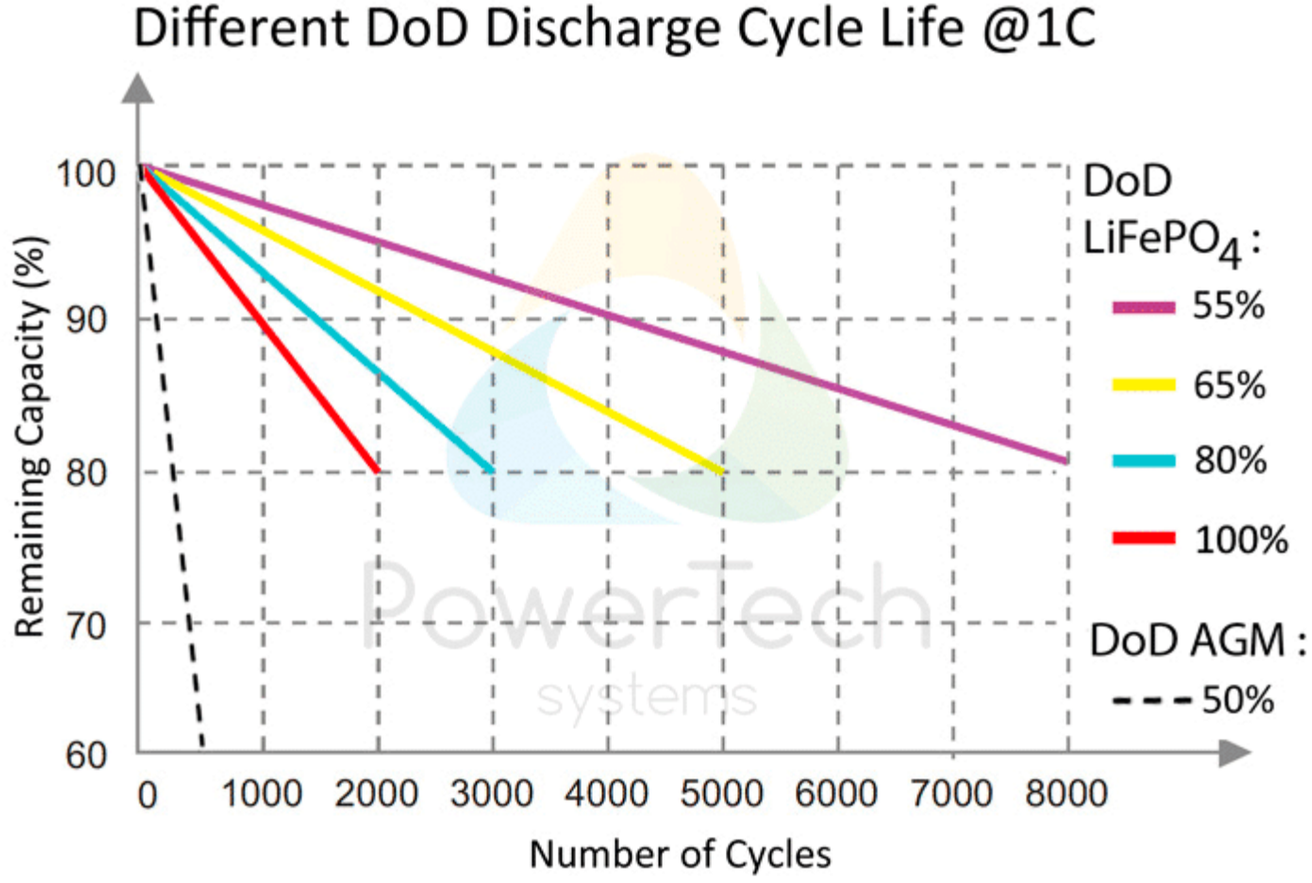
Size Your Battery Bank

Lithium Iron

The claim is that Lithium Iron batteries are “100%” usable. This is sort of true.

Most lithium iron battery manufacturers want at least a 10% reserve against full discharge and many recommend cutting back the charging voltage to somewhere in the 90% range. Thus, as a rule of thumb, let’s call a lithium iron battery at 80-90% usable.

If you assemble your own battery, you have design in your own safety reserves at both ends. If you buy a complete battery, with a built in BMS, it may or may not have these calculated in. As always, caveat emptor.



Decide on the Best Lithium Iron Battery for YOUR Needs

Really basic

Lithium Iron batteries give you a couple of options:

- **Drop In** - These come complete in “standard” sizes. They are claimed to be plug and play. (They are not, at least not completely.) Essential point is that the BMS is internally mounted. Typically most expensive.

- **System Batteries** – These consist of “dumb” lithium cells with external control, including all BMS functions. This can be very powerful and flexible, allowing you adjust every parameter and monitor from control panels, phone, etc. Easier to replace individual batteries should they fail.

- **DIY/Home Brew** – Least expensive, but labor intensive and requires you to set and control all parameters. Comes with an Oklahoma 50/50 guarantee; if it breaks, you own both halves.

How we gonna do this?

Or, charge sources for your camper battery.

There are several options here, a generator, your vehicle's alternator, solar power, wind power, or shore power. Each has advantages and disadvantages. You will probably need some combination.

- **Alternator-** It is there already. Use it.

- **Solar** – Almost indispensable for extended, off grid camping. Can be important for assuring the full charge of lead acid batteries.

- **Genset** – New inverter/generators are much quieter.

- **Shore Power** – Essential for maintenance.

What about your alternator?

First charge source most people consider:

- **First question is regulation** - Does your vehicle output the correct voltage for your camper battery? If yes, you can probably run a relay based system. If not, you may be in the market for a battery to battery charger.

- **Next question is capacity** – Most OEM alternators, regardless of size, are intended to recharge a starter battery quickly, not to spend hours recharging a camper battery. If you upgrade your alternator, look for one with a 100% duty cycle.

- **Dedicated Second Alternator** – Probably the gold standard, but typically requires a new bracket, belt, alternator, regulator, etc. Basically beyond the scope of this presentation.

- **Still need additional charge sources** – Especially if you ***don't*** drive six hours every day.

What about Solar?

Solar is all but essential for extended off grid use, but you have to understand its proper role:

- **Solar Doesn't "run" anything** - You run your loads off of your batteries; you use solar to recharge your batteries. Thus you don't run out of power when the sun sets. The duration of your autonomy is determined by your battery bank, not your solar.

- **Solar Controllers can give a good charge** – Most can be adjusted to give a very good charge for any type of battery.

- **Solar is probably not enough** – With a few exceptions, you are going to need additional charge sources, typically you want your engine/alternator and shore power. Solar is exceptionally useful in assuring the long absorb stage needed by lead acid. (Check your controller – not all do this properly.)

What about A Genset?

Gensets used to be universal on RV's. Then came the solar/AGM revolution. Now, with quieter inverter/generators, they are back.

The new inverter/generators are only loud at full load. Much of the time they are amazingly quiet. With care, a 2000w unit can even run air conditioning.

There is an argument to be made that rather than spending a ton of money on massive solar and batteries, you simply use shore power when it is available – most campsites will not give you a reduction for not using their power, and run a genset as needed in the bush – perhaps placing it at distance with a long cord. This might be especially attractive to those in the soggy south, where the humidity makes air conditioning especially attractive.

While it might not be the most energy efficient, the genset will also charge your batteries through your shore charger. The quality of the charge depends on the quality of your shore charger.

What about shore power?

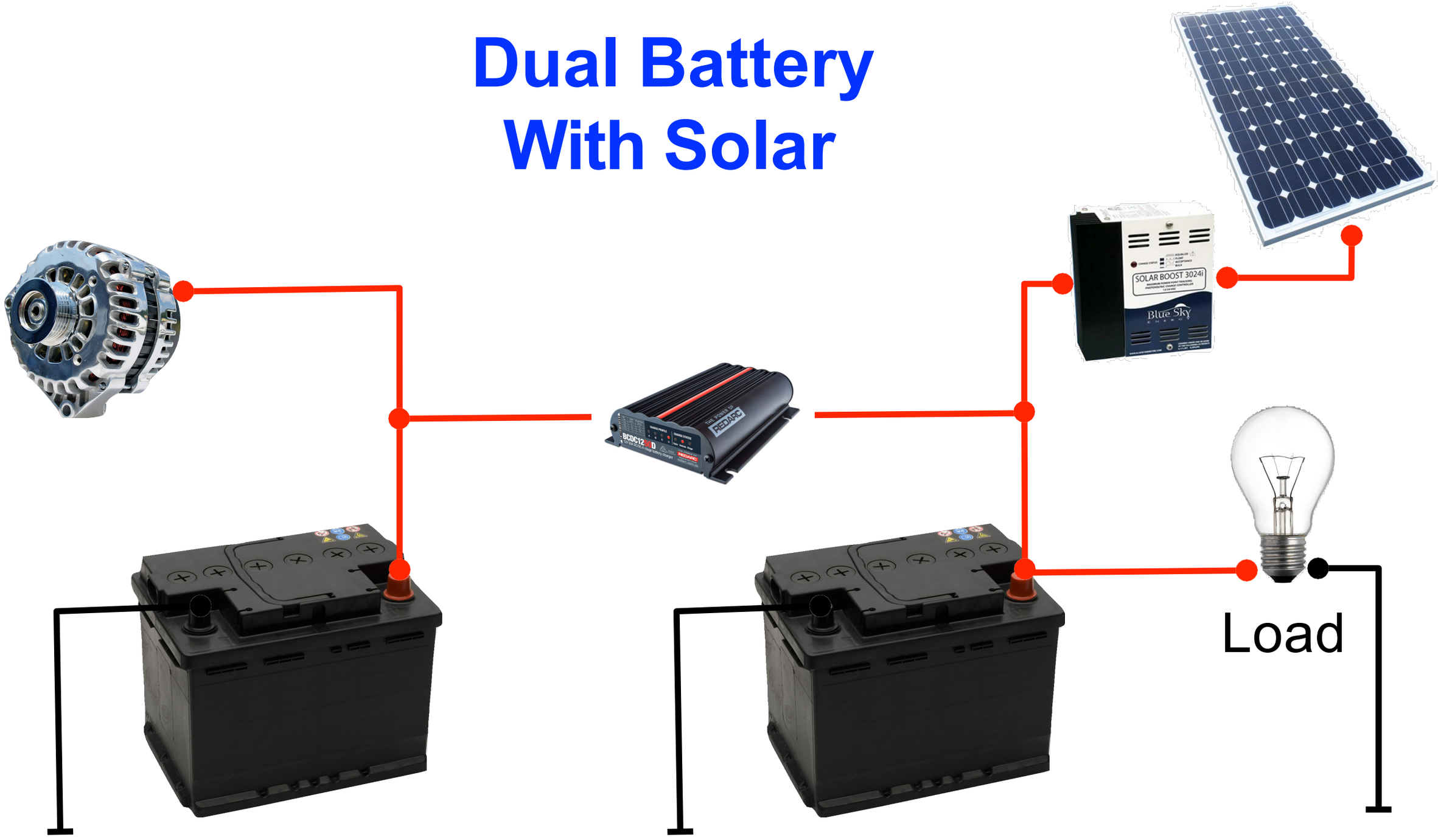
Still essential, even if your goal is an off grid camper:

- **Has the advantage of time** – If, for any reason (e.g. rain) you cannot achieve a full charge, an overnight charge can do wonders; de-sulfation for lead acid, balance for lithium.

- **Better chargers are very sophisticated** – Can deliver exactly the charge you need. Best source for an equalization charge, should that be required. Cheaper converters found in commercial RV's are less capable.

- **Can be useful for off season storage** – With proper wiring and float settings, can keep both truck and camper batteries charged when camper is not being used.

Dual Battery With Solar



This is the basic setup for most overland campers.