Electrical Power for the Overland Camper – The Problem

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Note/Disclaimer:

The information contained in this paper is correct to the best of my knowledge. It is compiled for the specific purpose of designing an electrical system for my own Overland Camper. It may or may not be useful or applicable for any other camper or RV. I have drawn from what I believe to be accurate sources, but my conclusions or understanding may be faulty and the sources may be mistaken. All conclusions and resulting assumptions are strictly my own, and cannot be taken as direct advice from any source. Nor can you assume that any of the sources agree with my conclusions or interpretation of their data. This document may be freely shared, I ask only that you:

- *Cite it as a source, and,*
- *Provide feedback, confirming or disproving my conclusions.*

Finally, electricity is ***always*** *dangerous, high voltage, of course, but also low voltage, high amperage circuits. Mistakes can easily result in fire and catastrophic damage to expensive equipment*.

You use this information entirely at your own risk.

Definition of Overland Camper:

Stephen Stewart has written an excellent description of the "Overland Camper Van" which I use as the base for my description of the problem, but the condensed version is this: the Overland Camper is a "Live In" not a "Live Beside" vehicle, with lights, fans, heating, microwave oven, and other larger electrical loads. It is designed for sustained (30 days or more), comfortable travel in rough places, not for roughing it over a weekend.

This is different from the classic 4x4, where one lives and sleeps beside (or on top of) the vehicle (think Land Rover/Cruiser). And this, in turn, is different from a typical "four wheeler" which is intended only for day trips on extreme trails. (Think the classic Jeep or dune buggy.)

A modern camper or RV makes increasing use of electrical components and appliances. While some advances, like LED lighting and efficient fans, have cut electrical demands, other devices, like microwave ovens, furnaces, and the hardest of all, air conditioning, have pushed the demands ever higher.

In conventional RV design, these demands are met with a combination of shore power (*30A for smaller vehicles and 50A for larger vehicles*), an onboard generator (2500W+), and increasingly, solar panels. The engine alternator(s) were typically not an important part of the system. Unfortunately, all of these have limitations for the Overland Camper.

As noted, the usage profile of an Overland Camper is different from either that of a typical RV or a hard-core 4x4 vehicle.

- The Overland Camper moves frequently, often everyday. Fixed stays are more often to be measured only in days rather than weeks.

- Overland Campers are smaller than classic RV's or trailers, greatly reducing the roof space available for solar panels. Similarly, space for batteries is more limited. Moving frequently means that there is less opportunity to use free standing or tilting solar panels, and less chance of parking for optimum solar alignment. The net result is that an Overland Camper will potentially get poorer solar performance than a Class A motor home or a fifth wheel trailer.

- By their very nature, Overland Campers are not designed to be plugged into shore power with any frequency. But when they do, they must accept either 120 or 240 volts while still providing only one or the other to the loads inside the camper. Thus a U.S. spec camper (120v/60Hz) must be able to plug into 240v/50Hz while still providing only 120v/60Hz to the load inside the camper. (And vice versa for a European camper in the U.S.) There is a further complication in that shore power sources outside of the United States will often offer only relatively low amperage.

- The ideal design will not incorporate a dedicated generator because of space, weight, potential noise restrictions, and sometimes the requirement for a separate fuel source. That said, most successful Overland Campers do use a generator.

The Problem(s):

Once you get beyond a simple extra battery mounted under the hood and connected to the truck battery with an ignition-controlled solenoid, several problems present themselves:

- Vehicle batteries are designed for short, deep discharges e.g., starting. This is sometimes defined as a discharge of 15 seconds or less, followed by near immediate recharging. Beyond that, they serve as the buffer in the truck's electrical circuit, smoothing out voltage and current variations. They are *not* designed to provide long term current to devices like refrigerators, a microwave, or, worst of all, air conditioning.

- Many battery chargers, whether shore, solar, or engine powered, are not designed to deliver the correct charging profile required to properly maintain batteries. In some cases, due to either design or execution, they cannot ever provide a full charge to the camper batteries. For the user, the problem can be made worse by disagreements between battery and charger manufacturers as to the best profile to use.

- Batteries that are discharged more than 50% or not fully recharged frequently will have dramatically shorter service lives. (See Technical Manual for Lifeline Batteries) This requires the space, weight, and cost of a battery bank that is twice the size of the actual usable load. This is especially annoying when paying the extra price of AGM batteries.

- House batteries are intended deep discharging and, in a modern Overland Camper, the battery bank is much, much larger than the starting battery(s). These large, deep cycle batteries can provide current over a longer period, but this greater capacity requires lots of energy to recharge, typically 110% or more of the current that has been used. So while it may be relatively easy to build a larger battery bank, it also becomes that much harder to recharge it.

What is Required?

A large battery bank wants what is commonly referred to as a "smart" charger with control circuitry that will fully charge the batteries as quickly and as safely as possible. Batteries don't charge in a linear fashion. When they are deeply discharged they accept a charge more quickly. Then, as they approach full charge (say 85% or more) they gradually slow. Then after becoming fully charged they require a small charge to maintain at 100%. For this reason you need a 3 stage (or 4 stage) charger:

- Stage 1 is called Bulk or Boost Charge. When a battery is 50% to 90% charged it will take a charge very quickly. A smart charger senses the battery voltage and supplies maximum current at an increasing voltage level to attain a nearly full charge.

- Stage 2 is called Absorption or Acceptance. At this stage voltage is held at a preset maximum level while current slowly tapers off until the battery is 100% charged. Depending on the type of battery the optimum charge voltage varies, based on temperature, from as low as 13.8 volts to around 15.5 volts.

- Stage 3 is called Float. After a battery is fully charged it requires a lower voltage to maintain its charge while waiting to be used. This is typically 13.5 volts for regular lead/acid flooded cell batteries, and 13.4 volts for AGM batteries. As with stage 2, the optimum voltage varies with temperature.

- Another, 4th stage is known as Conditioning or Equalizing. This involves taking the batteries up to a higher voltage level, about 15.6 volts (or 1 volt higher than Stage 2 if you are using temperature control), for several hours. This ensures all battery cells are equally charged. This is only required when the batteries show signs of decreased capacity. This stage is commonly required for flooded lead acid batteries. With AGM batteries, it varies with manufacturer.

(Interestingly, the Chevrolet (at least) charging system is smart enough to do most of this for the starting battery.)

Thus the problem is how to provide the correct voltages and amperages, fast enough, and long enough, to assure that the camper batteries are fully recharged.

Target Vehicle

For the balance of this paper, we will make the following assumptions:

- Our Overland Camper is a modern vehicle with an alternator(s) of over 150 amperes output; specifically a one-ton Chevrolet, Ford, or RAM pickup truck.

- The battery bank is four 6V, 300Ah batteries. Probably AGM batteries due to their greater flexibility in mounting.

- This gives you 600Ah total; 300Ah usable at 12V if you limit discharge to 50%, as recommended by almost every battery manufacturer.

- The vehicle has 400W of solar panels mounted on the roof.

- All installations are correctly done, with adequate wire gauges, fuses, etc.

- The system has an effective battery meter and the owner will use the data from that meter to manage power consumption as required to avoid exceeding any parameter.

How Long Does it Take to Fully Recharge?

In other words, how hard is the problem? Lifeline provides the following formula for temperatures between 68 and 86F.

Time to reach full charge = [(Depth of Discharge/100) x Rated Capacity (Ah) / Rated output of charger (A)] + 2 hours.

Thus a 100 Ah battery, discharged 50% with a 25A charger would take:
[(50/100) x 100/25] + 2 = 4 hours to reach full charge.

Taking our example Overland Camper and thus assuming a 600 Ah battery bank limited to 50% you have 330Ah required. Assuming also that you can tap 50A from your charger, your worst-case scenario is:

[(50/100) x 600 / 50] + 2 = 8 hours. This translates to eight solid hours of driving, strong daylight, or shore power.

Limit your consumption to 100Ah and increase your charge rate to 100A (call it 15% discharge) and your best case becomes:

[(15/100) x 600 / 100] + 2 = 3 hours (Approximately)

This is a lot more practical given a more normal day's drive or hours of sunlight. On the other hand, real world performance may be worse.

Further, the Lifeline manual calls for the charging current to be as high a possible during the bulk charging stage, a minimum of 20A per 100Ah of battery capacity. (Lower current is said to shorten battery life.) The preferred charging rate is C/1, that is 100A for every 100Ah of battery, up to C/5, that is 500A of charge for every 100Ah of battery. As no one is likely to have a charger of this size, real world performance is going to be worse. Thus there is tremendous incentive to design a system that can produce well over 100A of charge for at least four hours.

However, some experimentation suggests that increasing the charger rating beyond 100 amps will not effectively shorten the charging time. If this is the case, then, an alternate formula might be:

Time to reach full charge = [(battery pack rating in AH) x (% discharged) / (80 amps or 80% of charger rating which ever is smaller)] + 4 hours

Whatever the final numbers, the question remains, where do we get it?

Charging with the Engine Alternator

The electrical system of a modern truck is very sophisticated and very different from a simple alternator – voltage regulator – battery – load system. All of these functions are performed, to be sure, but with much greater automation than in the past. In the case of a Chevrolet truck you have two computers (Engine Control Module and Body Control Module) connected by a local area network (GMLAN), managing things. This allows very high performance: the system measures temperatures at various points, loads, switch positions of lights, wipers, and air conditioning, etc., engine speed, and several other factors to keep your lights bright, charge your battery, and even improve your fuel mileage.

The problem is that all of this sophistication is turned to the problem of charging a relatively small (140Ah) starting battery, not a 400AH+ battery bank. That same sophistication also makes it desirable to limit any alterations that might produce unintended results in regard to the original vehicle systems or void warranties.

The challenge is to make full use of the 100A+ that might be available from the engine alternator. Lifeline specifically notes that a slightly low charging voltage is not as great a problem as inadequate charging time and charging at too low a current.

It turns out that this problem may not be a great as assumed; it merely requires that the vehicle alternator/regulator system treat all of your batteries as if they were simply one big battery. To do this you must remember that a six-volt battery is merely three two-volt cells and a twelve-volt battery is merely six cells, all internally connected. So the challenge is to connect two physically separate and distant batteries so that they behave as if they were only one, large battery. This can be done but it requires cabling that is, by an order of magnitude, larger than typically found on RV's. Basically the connection between the two batteries must be large enough and have a low enough resistance to allow both batteries to quickly reach their common voltage so that the alternator/regulator system notes the voltage drop and responds.

Charging with an Inverter/Charger

Modern Inverter/Chargers can provide the proper charging profile, especially if all the settings are user adjustable. The key factor is to assure that the profile set by the Inverter/Charger manufacturer matches that of the battery manufacturer and this is not always the case. Inverter/Chargers in the 2000w+ range typically claim charge rates of 80A and up. When plugged into a 30A shore power circuit for eight hours, it should be possible to achieve a full recharge. Similar results could also be expected from an onboard generator, assuming that there was enough fuel and noise tolerance available. (Most Inverter/Chargers are wired so that input from a generator and input from shore power are treated the same way.)

N.B. Some Inverter/Charger manufacturers recommend a battery bank of greater than 400Ah if their inverter is to handle loads greater than 1,000W.

Charging with Solar Panels and Controller

Assuming a well designed and installed solar power system, that is one with a modern controller, properly mounted, un-shaded panels, and adequate wiring, there are two large impediments to solar power in an Overland Camper:

- Roof space is limited and thus the largest array may be limited to only 400W, and,

- It is not always possible to park the vehicle to capture maximum sunlight. Similarly, tilt arms cannot be used when the vehicle is moving and can be impractical to deploy routinely when the vehicle is moved frequently.

The rule of thumb is that you want one watt of solar panel for every one ampere of battery. Thus our 600 Ah battery bank should have 600W of solar panels - very hard in a small camper.

Actual solar output is, of course, highly variable, but the following estimates are common:

- Four hours of sunlight, per day.

- 100W panel will produce 6A per peak hour.

This gives a reasonable expectation of 20Ah of solar output, per 100W panel, per day. Some tables will predict as high as 30Ah. Of course, one errant shadow or cloud can reduce this dramatically. To this end, more, smaller panels in parallel will produce better real world performance than fewer, larger panels or panels in series. (Series is desirable to produce higher voltage.)

So given our example Overland Camper, we can expect, at best, 80Ah of solar charge on a good day. Thus unless we can increase our panels to 600W, we will always have a solar deficit on the order of 20Ah, if we limit daily power consumption to 100Ah per day.

References:

These some of the best articles and writings that I have found. All of the authors have real world scars and experience.

Choosing an Overland Camper Van -
http://www.xor.org.uk/silkroute/equipment/choosevan.htm
Stephen Stewart's exhaustive analysis of what makes these beasts unique. A must read for anyone who wants other than an off the shelf RV.

Technical Manual for Lifeline Batteries - http://www.lifelinebatteries.com/manual.pdf
Many people like AGM batteries for various reasons. This is the bible for their care and feeding.

Handy Bob - http://handybobsolar.wordpress.com
Robert has lots of real world experience living full time on solar and without a generator.

Jack and Danielle Mayer - http://www.jackdanmayer.com/rv_electrical_and_solar.htm
A lot of good information on solar on a fifth wheel. Some of it is a bit dated. Many, many good links scattered throughout his site.

Solar RV Panels - http://www.solarrvpanels.com
Detailed, step-by-step report on a solar installation on a fifth wheel trailer.

AM Solar's "Education Pages"
http://www.amsolar.com/home/amr/cpage_9/rv_solar_education.html
Naturally aimed at their own products, the information is, none the less, correct.