The Balance Of Power

Learn how to optimize the efficiency of your motorhome's house batteries.

The Balance of Power -- the PDF version of this article contains diagrams of battery configurations.

By Gary Bunzer
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Balance is critical for motorhomes. From a safety standpoint, we are reminded of the placement of cargo. For instance, you wouldn't want to stow your bowling ball collection on the same side of the motorhome as the generator. But have you ever given thought to the relevance of balance when it comes to your battery bank?

What do I mean by battery balance? Well, just as it is vital to ensure that those four large 8D batteries aren't overloading the axle weight rating on one side of the motorhome, it's also important to understand the significance of the "electrical" balance in banks of two or more batteries.

Battery Banks

Most Type A motorhomes and many Type Cs are equipped with multiple batteries connected together to form one big bank of DC electricity availability. The sad news is that 12-volt batteries wired in parallel or 6-volt batteries wired in a series or a series/parallel configuration are often connected in a manner that does not take full advantage of the storage capacity of the batteries in that bank. In some instances, they may have been miswired before they left the factory, or they may not be connected in a way that optimizes the potential of a motorhome's auxiliary battery bank. This becomes crucial especially for motorhome owners who often camp without hookups.

Batteries are an interesting study, and many FMCA members have taken the plunge. This article is not a thorough study of all things battery-related. But for casual motorhome owners or those new to the lifestyle, the following information may seem a bit foreign. The bottom line is that in order to get the most out of the money you put into your batteries, you'll want to get the most out of your auxiliary battery bank. As a means to that end, it might be a wise investment to perform upgrades if necessary and be assured that the battery bank on your motorhome is indeed balanced and optimized.

Since battery installations on motorhomes vary greatly, every coach should be considered individually. The number of batteries in the bank, the type of batteries used, the electrical sizing (amp-hour rating) of the batteries, and the quality of the batteries (how well they are constructed) all play a part in whether we maximize or trivialize the DC power they store. Quite often, because of the demands placed on the RV auxiliary battery system, many motorhome owners find themselves without enough lasting DC power. Just take a quick inventory of the number of 12-volt-DC devices found in a typical motorhome and consider the amount of electricity needed to power the collection.

Considering Mr. Peukert

One of the keys to optimizing DC battery use is to look at discharge rates and a formula called Peukert's equation. I won't bore you with the details, but it is an interesting study if you ever care to indulge yourself. In a nutshell, Mr. Peukert found that discharging a battery at higher rates depletes the capacity more than simple math would indicate. It's better to deplete a battery bank slowly with lower amounts of current flow rather than through large discharges. In other words, discharging a battery at a 5-amp rate does not remove half as much amperage as discharging that same battery at a 10-amp rate. One would think (and correctly so) that a 100 amp-hour battery would service a 5-amp load for 20 hours (the standard time element for rating batteries). One also would assume that the same battery would power a 10-amp load for 10 hours, but Peukert's equation says this is not the case. It actually would take less time to drain the battery at the higher discharge rate. The same concept applies for charging a battery bank.

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$I^n \times T = C$,

where “I” is the amperage draw of a load, “T” is the time in hours, and “C” is the amp-hour capacity of that battery. The superscript “n” is the Peukert exponent for that battery type (wet cell, AGM, gel, etc.). Though the Peukert exponent will vary depending on the battery capacity and manufacturer, a relative figure to use for true deep-cycle, wet-cell batteries ranges from approximately 1.25 to 1.60. For marine/RV hybrid batteries, the exponent typically is around 1.15, and for AGM batteries it is 1.10. Many believe that the lower this exponent, the better a battery can deliver a higher rate of current. Battery age and temperature also come into play.

Battery Bank Resistance

It’s equally important to consider a battery’s internal resistance, otherwise known as the self-discharge rate. It, too, factors into how well a battery bank is optimized. All batteries have internal resistance. It can be calculated by dividing the voltage difference when a known load is applied to a battery by the amperage of that load. Here’s an example: a 12-volt-DC device draws 50 amps of current. The voltage at the battery measures 12.8 volts before the load is applied. During the load, the battery voltage drops to 11.2. The voltage difference, 1.6 volts, is then divided by 50 (the amperage draw of the device). The result is the amount of battery internal resistance measured in ohms.

12.8 minus 11.2 = 1.6
1.6 divided by 50 = 0.032 ohm

When measuring the resistance on a bank of batteries, the resistance measured incorporates the cumulative internal resistance of all batteries in the bank.

In addition to heat, any electrical resistance is a negative factor when it comes to motorhome battery banks, which brings us to the main intent of this article. The proper battery balance in any battery bank is obtained by keeping the resistance to the flow of current in the system as low as possible. The resistance in any circuit, the internal battery resistance, and Peukert’s exponent must all be considered when fully analyzing a battery system. It’s all relative and typically limited in application to serious troubleshooters and technicians. But the one area where all coach owners can verify or improve their current setup is how the batteries in a given bank are wired together. Let’s begin by looking at a battery bank consisting of multiple 12-volt batteries.

Configuring 12-Volt Battery Banks

It’s been well-documented, and, I hope, understood by everyone, that all batteries in a given bank should be the same type, the same size (amp-hour rating), and the same age. Also factoring into the total resistance of a system are the lengths and diameters of the individual battery cables, the types of connectors (cable lugs) used, and how those connectors are actually connected. In order to be fair (and balanced) to all batteries in a given bank, all cable lengths on one side of the bank should be equal to those on the other side. In other words, the length and diameter of the negative cables and the number of individual connectors and how they are connected should be identical to the positive cables and connectors. Here’s why: every link in the chain — cable to lug, lug to battery connector, and connector to battery post in the bank — carries its own resistive value, as does every foot of cable. Every connecting point at each battery post can yield a resistance of about 0.0015 ohm in addition to the internal resistance in each battery. Considered individually, the resistance is small, but when taken in total, it can lead to an inefficient battery system
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Diagram 1 shows two 12-volt batteries wired in parallel. Some motorhomes actually leave the factory wired in this manner. Notice how the positive and negative leads originate from the same battery at the top. This is one method of wiring two 12-volt batteries in parallel, but it certainly is not the best way. Yes, it does double the storage capacity, but the top battery will have a much shorter life expectancy, since it will be doing most of the work.

If the battery bank consists of only two 12-volt batteries, Diagram 2 shows the optimum configuration. The positive lead originates at one battery and the negative lead originates at the second battery. This configuration really cannot be improved upon, as long as the connectors and cable lengths are identical. Both batteries should age equally and provide an equal amount of current.

Diagram 3 shows an "incorrect" four-battery configuration. Much like the first diagram that featured two batteries, the uppermost battery will be doing the most work and will have the shortest life. And since all batteries should remain the same age, it starts to get expensive when it becomes necessary to replace all four batteries when only one has reached its end of useful service.

If this battery bank were to be powering a 100-amp load, it would be preferable if each battery provided 25 amps, correct? Perfect battery balance! But according to a computer-generated simulation conducted by Smart Gauge Electronics (verified by bench-top experiment), if this configuration were to be powering that 100-amp load, the top battery would provide 35.9 amps, the second battery 26.2 amps, the third battery 20.4 amps, and the fourth battery a measly 17.8 amps. This battery bank is not in balance, since the first battery must work more than twice as hard as the fourth battery.

However, if we change just one connection, we can significantly improve the configuration. Take a look at Diagram 4. By connecting the positive cable to the first battery and the negative cable to the fourth battery, the amperage draw becomes more balanced. Test results for this arrangement indicate that the first and fourth batteries provide 26.7 amps each, while the second and third batteries power 23.2 amps each. This is a much better arrangement, but it can be improved even more.

Diagram 5 depicts another method that more closely balances each battery in the bank. By using a dedicated positive and negative terminal mounted near the battery bank, each positive and negative cable can realistically be of equal length, although the illustration does not truly reflect that fact. This bank is about as balanced as it can be.

The configuration in Diagram 5 works well for odd numbers of 12-volt batteries in the bank, when connecting more than five batteries in parallel, or connecting 6-volt batteries in a series/parallel configuration.

The configuration shown in Diagram 6 also results in almost perfect battery balance and does not require additional components. Two batteries are wired in a parallel pair, and then each pair is connected to the load at opposite sides. In this manner the current draw flows through an equal number of lengths and connections. Basically it's doubling the optimum configuration of the two-battery bank shown earlier.

Note that this configuration works only with a four-battery bank. When connecting three, five, or more 12-volt batteries into one large bank, the configuration shown in Diagram 5, which uses dedicated terminals, becomes a wiser choice.

Configuring 6-Volt Battery Banks

Many motorhome owners forego the use of 12-volt batteries and opt for 6-volt batteries. There are many benefits to using 6-volt batteries, but that's for another article. And to be fair and balanced, there are benefits of sticking with 12-volt batteries, too.

Since many low-voltage devices in the motorhome are powered by 12 volts DC, when 6-volt batteries are employed, they must be cabled into a "series" configuration. Batteries connected in series double the voltage output while the amp-hour capacity remains the same. Conversely, 12-volt batteries wired in parallel maintain the same voltage output but double the capacity to store current. That's why 6-volt batteries are always configured in pairs.

In Diagram 7, two 6-volt batteries are connected in series. The voltage measured at the positive and negative cable ends would be 12 volts. For a two-battery, 6-volt setup, this configuration is as perfect and balanced as it can be.

But when adding more than two 6-volt batteries, each pair should be considered its own 12-volt unit. In Diagram 8, the two pairs of 6-volt batteries (already connected in series) can now be interconnected into a parallel configuration in order to double the capacity yet retain the necessary 12-volt output. Always think of 6-volt batteries in terms of pairs. The dotted lines signify each 12-volt-producing unit.

But just as 12-volt battery banks can be wired incorrectly, negating perfect balance, so can 6-volt banks. Looking at Diagram 9, can you spot the improper connection? Notice that the positive and negative cable leads originate from the same 12-volt unit (the top two 6

Diagram 10 shows a more balanced approach, accomplished by simply moving one negative cable, but it still is not configured in a way that promotes perfect balance and optimization. Many motorhomes are connected in this manner when utilizing two pairs of 6-volt batteries. Though much better, it can be improved upon.

In order to achieve perfect balance configuring two or more pairs of 6-volt batteries, installing and utilizing dedicated terminal connecting points, as mentioned earlier, is the closest realization of optimum. As you can see in Diagram 11, adding more batteries (in pairs) to the bank is easily accomplished by simply assuring that all cable lengths, the numbers of connectors, etc., remain equal on both the negative and positive sides of the battery bank.

Battery Cables

It is always best to use the shortest cable possible between each of the connecting points in a large battery bank. Every foot of unnecessary cable simply adds more resistance to the electrical circuit, plus it makes for a cluttered look in the storage compartment.

In addition to cable length, the diameter of the cables should be equal on both the positive and negative sides of the bank and be properly sized for the total amount of amp-hour storage in the bank.

Personally, I'm a fan of using welding cable for large battery bank configurations. Welding cable is made up of very fine strands of copper wires, rather than thicker conductors. It is very flexible and easy to route and secure. Plus, its insulation is typically more resistant to grease, oil, abrasions, and heat, all of which are commonplace with the motorhome lifestyle.

Cables should be one size larger (wire gauge) than called for by the total current draw of all loads in the motorhome. This anticipates and provides headroom for the installation of additional electrical devices in the future. If an inverter is included in the electrical system, be sure to consider all AC devices that the battery bank will be powering through the inverter. The bottom line is that the total amp-hour requirement of the motorhome will determine the minimum size cable to employ.

In systems equipped for solar battery charging, in addition to traditional converter/inverter charging, the following general guidelines will prove adequate. For banks that have the ability to store up to 200 amp-hours of current, 2-gauge cable will suffice. For a 300-amp battery bank system, use 1/0 cable. Employ 2/0 cable for banks with up to 400 amp-hour capacity, and use 3/0 cable for 600-amp battery banks. It is recommended that each cable lug be soldered and heat-shrink tubing used, preferably the type with an internal sealant, to minimize moisture intrusion and corrosion.

Also important is circuit protection to keep conductors from becoming overheated during charging and discharging. The main DC fuse should be sized appropriately for the maximum possible current capacity of the main DC cable. In addition, all branch DC circuits should be sized (fuses/breakers and conductor diameter) according to the load rating of each device.

Finally, be sure to keep all battery terminals clean, dry, and tight. Nothing leads to DC electrical system failure, other than a direct short, more than battery terminals with heavy oxidation or corrosion. When it comes to treating and protecting terminals and connections, consider the use of a product such as DeoxIT.

Near-perfect battery balance is attainable for every motorhome battery bank, and perfect balance can be realized with some. Inspect your battery bank and determine whether improvements can be made to optimize the 12-volt system on your motorhome. And remember, RVing is more than a hobby; it's a lifestyle!

Charged Up!
Here are some additional recommendations to keep your batteries fully charged and ready to power your motorhome's appliances.

- Limit discharging the battery bank to 50 percent and then fully recharge.
- Always discharge a minimum of 5 percent.

- Avoid rapid charging and discharging of the battery bank.
- Never discharge a bank to below 10.5 volts DC.
- Consider a battery monitoring system that factors in the Peukert's exponent.
- Use accurate measuring devices when diagnosing battery-related symptoms.
- Always take measurements directly at the battery to determine the current state of charge, even if additional measurements must be taken at other locations in the system to complete a diagnosis of a specific problem.