Know Your System

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I've grown accustomed to using this column to discuss the growth of our off-grid renewable energy systems. The only problem with doing this is that our systems have been very boring lately—we've had no new additions this year. These large PV systems just smile at the sun and do their work, making more than 20 KWH of electricity per day.

Even though I'm not out there with a wrench making additions and troubleshooting problems, I still have daily involvement with the systems, beyond using the energy that they make—I read meters.

Reading Meters

Our systems, one 24 volt and the other 12 volt, are equipped with five different battery amp-hour meters. While only one meter per system would suffice, I enjoy comparing them and testing various models. Most of these meters are of older vintage—Cruising Equipment E-Meters, and older TriMetric meters. All are of the standard variety—reading battery voltage, net battery current, and battery amp-hours. They are all very accurate and read within 0.5 percent of each other.

The Bogart TriMetric battery system monitor.

By reading these meters, I have learned the behavior and effective use of our systems. I read them regularly and compulsively. The information from these meters allows me to see if the systems are performing at their full potential—this is the fast way to find minor problems before they become major problems. The information from these meters enables me to effectively operate our systems—many day-to-day energy decisions in an off-grid home depend on the systems' state of charge.

Battery Voltage

In the old days, we used battery voltage as a rough indicator of a system's state of charge. Happily, those days are gone. Now we use the amp-hour reading on the meter to determine the battery's state of charge.

But battery voltage still delivers essential information. During the day and while under charge, the battery voltage should remain at the PV regulator's set point. Any higher voltage indicates a regulator failure, or that the system's users forgot to switch the regulator to equalization mode. During the night, unduly low battery voltage can indicate that the batteries are nearing the end of their life, or that they haven't been sufficiently charged during the day.

I know what the voltage readings mean from experience, by constantly reading the meter and learning each system's voltage parameters. Your experience will be different—your battery is different and so is your usage. What *is* important is reading the meter and becoming familiar with the "normal" readings for your off-grid RE system.

Battery Current

Perhaps the most important thing to remember about the battery current (amperage) function in amp-hour meters is that it reads "net" battery current. Net battery current means the rate of charge either moving into or out of the battery at that instant. While this is an important function, it's good to remember that it does not indicate PV amperage being drawn by specific appliances or the source amperage. It is just the net amperage either going into or out of the battery.

The battery current reading is constantly changing. Appliances are turned on, some automatically, such as refrigerators, freezers, and pumps. When an appliance is started, either automatically or manually, the energy it consumes must come from somewhere—either the battery or the RE source, such as a PV array. This consumption is reflected, but not separately quantified, by the battery current reading in the amp-hour meter.

If the PV array is producing, an appliance's energy comes directly from the array. This means lower current available to recharge the battery, so the battery current reading of the meter decreases. At night (or when an energy source is not producing), an appliance's energy consumption is included in the negative battery current reading in the amp-hour meter.

Battery Amp-Hours

The amp-hour function of the meter is really just a bean counter, only it counts electrons. Every electron moving either into or out of the battery must pass through the shunt located at the battery. The amp-hour meter counts passing electrons and notes whether they are moving into or out of the battery.

When a battery is fully charged, the amp-hour meter reads zero. As the battery is discharged, each amp-hour removed from the battery is displayed as a negative number. For example, if a battery has been discharged 100 amp-hours, the meter will read -100. As the battery is charged, each amp-hour is added, as a positive number, to the total.

So if a battery that has been discharged 100 amp-hours is recharged with a current of 50 amps for one hour, the meter will add this amount to the total, which will then read -50. When the battery is once again fully recharged, the display will return to zero.

If the battery is overcharged (a modest daily overcharge is normal in RE systems), the number on the display will read positive. For example, if a battery is overcharged by 50 amp-hours during the day, the display will read 50. When the sun goes down and charging ceases, the display will once again return to zero as the battery goes into discharge mode.

The amp-hour function of the meter requires correct programming by the user. The user must input the voltage and charge amperage at which the battery is considered fully recharged, and the battery's capacity in amp-hours.

The full-charge voltage is set at slightly less than the controller's bulk voltage setting. If the full voltage setting of the meter is set higher than the system's PV controller, the meter will never recognize the battery as fully recharged. I program my meters to recognize the battery as fully recharged at 0.1 VDC less than the setting on the PV regulators.

The full-charge setting for current (amperage) is a bit more difficult. This setting is the current level *below* which the battery is considered fully recharged. As the battery is recharged, the system's regulators hold the voltage constant, and as a result, the amperage into the battery decreases. The number is programmed into the meter as a percentage of battery capacity. The number usually used is between 2 and 4 percent.

For example, my 24-volt battery has a capacity of 1,640 amp-hours. I set the meter for 3 percent. Multiplying 1,640 amp-hours times 3 percent equals 49.2 amps. So when the system reaches full voltage (29.2 VDC for our system) and the current to the battery reaches 49 amps, the meter considers the battery full.

The battery amp-hour meter is smart. It knows that no battery is 100 percent efficient, so it scales, with an efficiency factor, the incoming amp-hours on the charge side. And the meter determines battery efficiency based on the last three charge–discharge cycles, so the efficiency factor changes with battery use and age. The meter considers a charge–discharge cycle to be at least 10 percent of the battery's programmed capacity. Cycles that empty the battery less than 10 percent are not counted in this process.

The new Xantrex XBM battery monitor.

Modern battery amp-hour meters will also read the battery's state of charge as a percentage of battery capacity, for example, 92 percent. If you are not comfortable with the concept of amp-hours, set the meter to read percentage of battery capacity.

Knowledge Is Power

Your battery amp-hour meter should be mounted where you can look at it many times per day. Don't hide it in the power room! Put it on the wall in the kitchen or the living room—someplace where it's always in your face. Distance to the battery is not a problem. I mounted our meters in my office, more than 120 feet (37 m) from the batteries. It's possible to go 500 feet (150 m) or more with some meters.

Check the meter often. Only by becoming familiar with the readings will you learn how your system performs and how best to use the energy it produces. I start my day, within minutes of getting up, by reading the meters. I want to see how many amp-hours were withdrawn from the systems overnight.

Normal consumption from our 24-volt system is between 150 and 210 amp-hours, while the 12-volt system uses about 130 amp-hours. Overnight consumption depends on how much time we stay up watching television and running the lights. Hotter weather means more overnight consumption because our two refrigerators run more to compensate for the heat.

Overnight consumption that is far higher than normal deserves investigation. One time, I located a faulty solar hot water controller that was running the pump all night instead of shutting it off. I noticed the higher consumption and went around at night to see what was using energy when it should have been off.

During the day, I watch the amp-hours count back to zero, indicating that the batteries are refilling. I also check the amperage in each system to make sure that the PV charge rate is what I'd expect. I know from experience the consumption of the usual appliances that are on during the day, and there are many—three solar hot water pumps, three computers, a StarBand satellite communication system, a laser printer, and refrigerators, to name a few.

I also try to notice when our systems become fully recharged. When this happens, it's time to use energy for a number of chores—pumping water (an 800-watt load that takes one or two hours), washing clothes in the washer (a load that takes 90 minutes and consumes about 150 watt-hours), vacuuming the house (a big load at 1,350 watts for an hour or two), and other energy intensive jobs that can be done when we decide to do them.

We wait to do these jobs until the system is fully recharged, using the energy directly from the arrays. This means better efficiency, since we don't have to retrieve the energy from the battery, which also extends the battery's useful life.

At the end of the day, I check the meters to see how many overcharge amp-hours we have accumulated. Ideally, I'd like to see 2 to 4 percent overcharge, but that doesn't happen many days. Having the batteries fully recharged at the end of every day makes them last far longer, and they run more efficiently.

Once every week or so, I delve into the historical data contained within the amp-hour meters. Different meter models track and display different historical data. On my meters, I check things like charge efficiency, deepest depth of discharge, and average depth of discharge. This information helps me keep the systems in peak condition.

Meter watching is only effective if it's done all the time. Only checking the meters when the system fails is less than informative since you don't have the background to determine what is normal and what is not. So if you have a battery-based system, install and read a battery amp-hour meter regularly. The familiarity with its information will enable you to more effectively use your system, and to find problems before they become critical.

Access

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