Matching Your Load With Your PV System

After you have determined that PV represents the best way to meet your load, you need to size your system to effectively meet your daily load. In addition to bringing in an expert to help design your system, you should address the following questions to ensure you get the system you need.

- Does your load need to be met all day every day? Do you need to have an electrical storage system (batteries) for extended periods when the sun does not shine? For instance, if your load consists of a water pump that pumps water to a large storage tank, will you still have enough water if the sun does not shine for 4 days? If so, then maybe you won't need a battery system to store power. Store water instead.

- If you do need batteries, how many "days of autonomy" do you need? If the sun did not shine for an extended period, for how many days (days of autonomy) would your battery system need to run?

- Can your load be met with DC electricity (the type PV panels typically produce)? If so, your system won't need an inverter. Inverters are often an expensive component of PV systems. An inverter changes DC electricity (constant, one-direction current) to AC electricity (the current changes direction 60 times per second, well, technically 120 times per second, because it changes direction twice in each cycle). AC electricity is what you use at home for your TV, stereo, and computer.

- What type of system will you be operating? Small, simple systems will operate best (highest efficiency, lowest cost) if they use only DC electricity. However, certain loads (such as power for home appliances in a campground host's RV) may require AC electricity, necessitating an inverter and batteries.

When sizing your PV system, consider the highest load season. Often the highest load season will be during summer (campgrounds for instance), which is usually good for solar systems. Use the charts in appendix B to determine the average number of sun-hours per day you can expect at your location during your highest load season. If your load is year-round, consider all seasons and hours of sun per day.

Use PV sizing software or a worksheet to determine the full extent of your load. You can download Windows or Macintosh sizing software from the Center for Renewable Energy and Sustainable Technology's Web site *http://solstice.crest.org/cgi-bin/ssregister.pl* Determine if you need batteries for storage, a generator as a backup, DC or AC power, or both. Size your batteries according to your daily load and the number of days of autonomy you need. Size your PV system to meet your daily load with energy left over to charge your batteries.

Direct DC Systems

If you have a direct DC system (such as a water pump that only operates when the sun is shining), the motor can typically run at less than full sun, but it will not run as fast (Figure 4). DC motors often run at high voltages. For instance, the 10A SolarJack water pump runs at 90V. If the weather is partly cloudy, your array might be producing less than its normal current at a lower voltage. The result? Your pump does not run as fast as during full sun. So, if the pump would meet your load running full bore for 5 hours a day, it might not pump enough water on a day when it is running at less than full speed.

To compensate, you might add one or two panels to your array to help keep the voltage up to the motor's specifications.

AC Systems and Mixed AC/DC Systems

Your load will determine whether you should go with an AC or mixed AC/DC system. Consult your local PV dealer if you need AC power. You will need to add an inverter to your system. There

Figure 4—A photovoltaic-powered water pump installation at Wade Lake Campground on the Beaverhead National Forest in Montana.

were few insightful comments from the field in this area (since many systems were DC only), other than the suggestion to use a reliable inverter.

Everyone who had Trace Engineering's inverters spoke highly of them. In selecting an inverter, consider whether a backup generator may be needed in certain seasons or for certain loads. If so, select an inverter that is also a battery charger with a built-in transfer switch.

Batteries

If you need to meet your load even when the sun is not shining, batteries or a backup generator will be crucial for your system. Assuming you will be using batteries as your backup power, here are some ideas you will need to consider.

Battery Storage Ideas

***During the Season*—**Storing batteries while they're used in your system might not be as simple as it sounds**.** One or two batteries can be easily mounted on a roof or on a pole. When battery systems begin to include four or eight batteries, their weight requires them to be stored close to or in the ground.

Batteries can be stored inside the walk-in vault of composting or evaporative toilet systems. They should be enclosed in a ventilated box, well above the floor to avoid the danger of flooding.

Battery boxes stored in the ground have problems with flooding and rodents (a very serious issue with potential hantavirus infection) and they are dangerous for even routine battery maintenance (Figures 5 and 6). To check specific gravity or electrolyte levels you must routinely hunch over a battery pack, exposing your eyes and head to the area where hydrogen gas would escape and explode if ignited and to where sulfuric acid might splash. In addition you repeatedly risk injury in checking your system.

Animals can wreak havoc with an underground battery box by eating wires, shorting out your system while shortening their lives. Yes, they can do it above ground, but they don't seem to do it as often. I have come across dead mice and marmots in these boxes (and plenty of live critters that got my attention). If you have to store your battery in the ground, consider pouring a concrete box. It will be more expensive, but will probably be a lot less hassle over the long run.

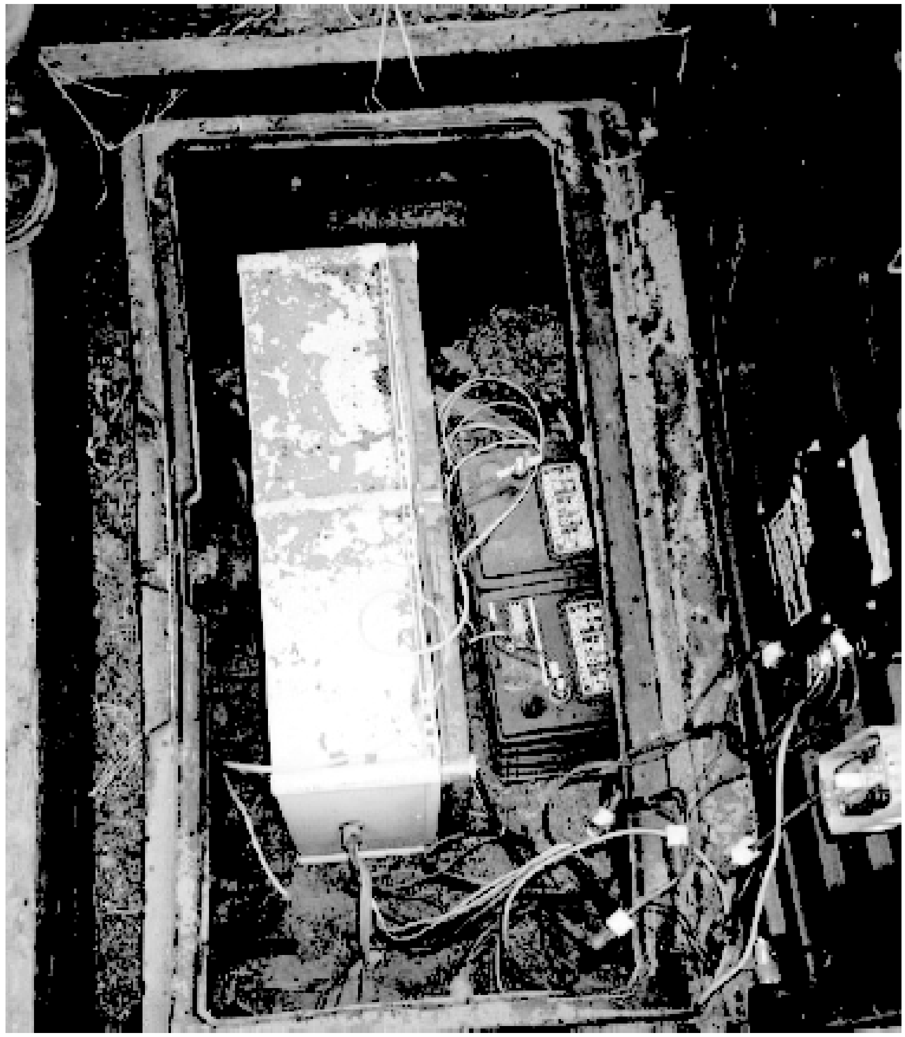

Figure 5–Storing batteries in the ground isn't recommended…

***Battery Box Insulation*—**Your battery box should be insulated to minimize temperature swings. Large temperature swings can affect a battery's performance and shorten its life. Lead acid batteries perform ideally at 77° F. At higher temperatures, batteries perform better, but they have a shorter life. At lower temperatures, batteries have a lower storage capacity. Remember, *an ounce of insulation now is worth a pound of batteries later!*

Insulation will help. But do not depend on insulation alone to keep the batteries from freezing. You may have to add more battery capacity to keep charge levels higher to prevent freezing. Discharged batteries contain mostly water and freeze at much higher temperatures than charged batteries that have a stronger acid solution.

A good controller (such as the Trace C-40) can be wired with a temperature sensor in your battery bank. The main purpose of the charge controller is to prevent them from overcharging, which also may keep the batteries from

Figure 5–Storing batteries in the ground isn't recommended…

overheating. The controller can adjust the charging voltage to maintain the temperature below 80° F or so. Such a system can be a worthwhile investment for maximizing the return from your batteries.

***Off-Season Battery Storage*—**If your PV system won't be in use during the off-season, battery storage is often a critical issue. At the end of the season, bring your batteries in to be fully charged. Do not let the batteries freeze or fully discharge over the winter.

Battery Configuration and Maintenance

Use batteries designed for PV systems. Trojan (L-16) and DEKA (solar battery) are two of the "workhorses" in the PV industry. Batteries come in various voltage and amp-hour sizes. Using 6V batteries gives solid performance and maximum flexibility in system design. Two 6V batteries wired in series gives you the equivalent of a 12V battery.

When wiring batteries in series, you add the voltages of each battery to find the system voltage (6V + 6V + 6V + 6V = 24V system). The system amperage remains the same as in each battery. When you wire batteries in parallel, you add the amperages of the batteries to find system amperage (3A + 3A + 3A + 3A = 12A). The system voltage remains the same as in each battery.

Failure to properly maintain batteries may shorten battery life, lead to system failures, and cost money.

One of the simplest ways to reduce battery maintenance problems is to use "gel-cell" or "valve-regulated" batteries. These are deep-cycle batteries that are "sealed." You don't have to worry as much about these batteries giving off highly explosive hydrogen gas as they reach full charge, about checking their electrolyte levels, or about measuring the specific gravity of the electrolytes. These batteries can even be stored on their side. However, they must still have adequate ventilation. They have a vent to release small amounts of hydrogen gas that are formed as they reach full charge. More importantly, the charge rate on these batteries must be controlled to lower voltage to prevent gassing. Gassing in a gel cell can ruin the battery by injecting hydrogen into the gel and severely reducing the battery capacity. Keep the charge rate on gel cells at or below 14.1 volts. By contrast, wet lead-acid batteries are regularly charged up to 14.8 volts, and are equalized at 15 volts. Gel cells generally should not be equalized.

Purchase gel-cell batteries if you can. If you can't get the gel-cell batteries, purchase heavy-duty, deep-cycle, lead-acid batteries. If you use lead-acid batteries, adequate ventilation becomes even more important. They will "gas" as they reach a state of full charge. Great care should be taken when opening the battery box. Never smoke or allow any flames or sparks near your battery system.

If you get deep-cycle, lead-acid batteries, commit yourself to monthly battery inspections to ensure long battery life with full capacity. Otherwise, you may find yourself wishing you had gotten the valve-regulated, gel-cell batteries. When inspecting the batteries, check their electrolyte levels. If you need to add water, be sure to use distilled water.

One way to reduce maintenance of the deep-cycle, lead-acid batteries is to install "Hydro-caps." These caps take most of the hydrogen and oxygen that is released during gassing and return it to the battery cell. You will not have to refill the electrolyte as frequently. People in the field have suggested they can go 2 to 3 months between battery checks when using Hydro-caps.

Battery Matching and Equalizing

If you find a battery that does not get up to full charge repeatedly, it may need to be replaced. Full charge varies according to battery make, but it is about 7.1V for a 6V battery or about 14.4 for a 12V battery. If the full-charge voltage of your new battery varies from your old ones by more than about 0.2V, you will reduce overall battery system life and capacity. Try to match batteries in each system as much as possible.

Batteries should be periodically topped off or fully charged–known as “equalizing.” Equalizing your batteries can help prevent sulphation on the battery plates–important for maintaining full storage capacity in your batteries. The final stages of equalizing involves trickle charging your batteries. A good controller (Trace C-40) can do this automatically for you, making it well worth the investment. If your controller doesn’t do this automatically and you don’t do it periodically, you will shorten the life of your battery bank. Gel cells generally should not be equalized. See the list of sources for additional information to learn more about gel cells and equalization.