

Solar Power for Your Ham Station - It's Easier Than You Think

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Solar Power for Your Ham Station— It's Easier than You Think

I blame it all on my friend Gary Phillis, a solar physicist and my sounding board for anything I consider exotic. Gary was headed to the wilds for a week, far from any hookups for his camper. He didn't want to run his vehicle's engine every day just to recharge his battery for some evening lighting, so he bought a solar panel. That got me thinking. What could I do with a solar panel? I went with Gary to the alternative energy store and found a world I never knew existed! By the time we left, I had a solar panel and a reconditioned tractor battery in my trunk. Total cost? Less than \$300. I consider this purchase to be one of my better spur-of-the-moment decisions.

Sizing Your System

A solar-electric system¹—more properly, a photovoltaic (PV) system—works like the animals in the story of the hare and the tortoise. Your rig is the hare: It gulps power in short spurts and then idles along

at rest for lengthy periods. The solar panel is the tortoise—slowly but surely providing energy. The tortoise wins the race when the energy it supplies builds up faster than the hare depletes it.

My Amateur Radio operating habits are probably fairly typical. A week may find me at my HF rig two or three evenings for a couple hours, with perhaps another session on the weekend. I typically operate a mixture of CW and AMTOR or PACTOR, with a little SSB thrown in.

How much energy does this require? Because batteries are generally rated in ampere-hours rather than watt-hours, let's do the calculations in ampere-hours. My Yaesu FT-747's manual states the rig draws 19 A maximum at full power out (100 W). If I'm operating CW, I'll be sending half the time and receiving half the time. Furthermore, when I'm sending, the key is down only half the time, so really, even while I'm in the middle of a QSO, the rig's duty cycle is 25% or less. On receive, my

rig draws a measured 1.06 A. So, my rig's average current drain (which is what the battery cares about) is less than 6 A. Also, I'm not engaged in a QSO all the time—there's quite a bit of listening. Let's suppose I'm transmitting 75% of the time. So, for a two-hour session at the radio, my rig draws 6 A for 1.5 hours plus 1 A for another half hour. That's about 10 Ah. Multiply that by three sessions a week, that's 30 Ah. Assuming I could fully deplete that battery, I could operate for over seven weeks without recharging!

There's more. In full summer sunlight, my "32-W" solar panel produces a charging current of about 1.5 A. It does this from about 9 AM until about 5 PM during the summer months.² That's eight hours, or 12 Ah per day. Here in Boulder, Colorado, we get about three or four equivalent cloud-free days a week. That's a charge of 36 to 48 Ah per week, which leaves me with power to spare. Even in the winter, when charging time may last from 10 AM until

¹Notes appear on page 37.

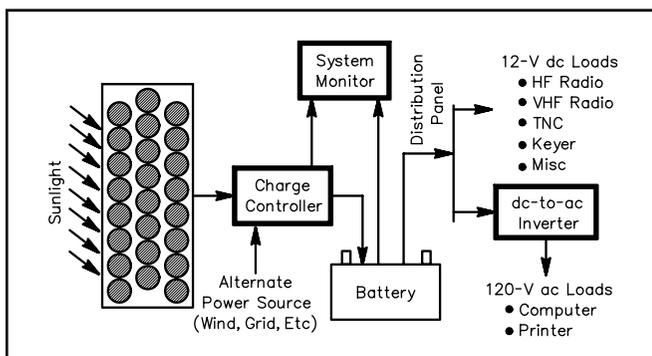


Figure 1—Solar electric system block diagram. A PV panel is only part of the system. The battery stores power for use when the sun isn't shining. A charge controller ensures the battery is not overcharged. The system monitor informs you of system operation and level of battery charge, and the distribution system puts the power where it is needed. An inverter can provide 120 V ac for loads requiring it.

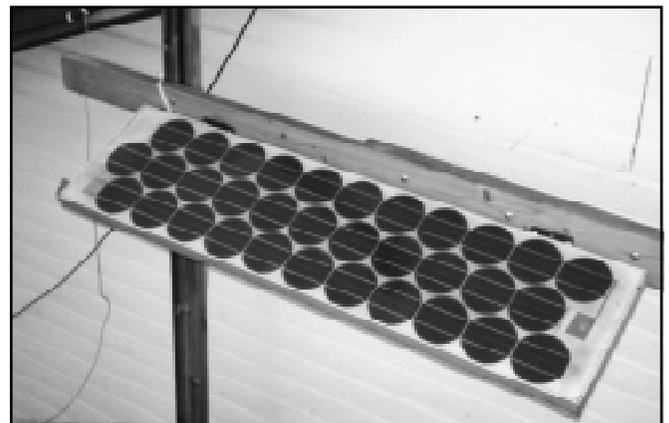


Figure 2—My Arco 32-W PV panel is mounted on a south-facing wall where nothing can obstruct the sunlight. For best performance, I adjust the arm beneath the panel to vary the tilt angle several times a year. The panel is attached to the horizontal 2 × 4 on hinges to permit easy repositioning.

3 PM, I still get 10 Ah a day, or 30 to 40 Ah per week. Lest you think I did my math wrong, solar panels produce more power when they're cold. In the winter, I get a charging current of 2 A or more in full sunlight.

Another example: Let's suppose you like to keep your 2-meter rig and a TNC on all the time to get your packet mail. Most of the time, the rig is in receive—in fact, the ampere-hours needed for transmit are negligible because the transmitter is on so seldom. My 2-meter rig draws about 0.5 A during receive. My PK-232, however, draws about 1 A. So, the combined drain is 1.5 A, 24 hours per day, or 36 Ah per day. Clearly, that's well within the capability of my battery. The problem is that during winter, my solar panel may provide an average of only 10 Ah per day. If I left my 2-meter packet station on all the time, I'd run down the battery. There are several alternatives, however: add more solar panels, use a TNC that draws less current, or leave the packet station on only during certain hours of the day.

How Much Does All this Cost?

The big cost drivers for a solar electric system are the PV panels and the battery. PV panels currently sell for \$5 to \$6 per watt. My 32-W panel (a used Arco unit) cost me \$179. A new 60-W panel may run around \$350. I've found my 32-W panel quite sufficient for my needs.

I paid \$75 for a reconditioned, 220-Ah D-8 tractor battery, which is probably overkill for my setup. A new, 110-Ah, deep-discharge battery costs around \$80 to \$100 at discount stores (such as WalMart).

Add in the cost of the wiring and distribution system and my solar system cost about twice as much as my Astron ac-operated power supply, but about what I would have paid for the transceiver's matching power supply. The cost difference between a PV system and a conventional power supply must be weighed against the advantages

of solar power—such as having an ever-present source of power—even when your local utility company goes off line. And, you can operate class 1E during Field Day, because your station is operating from “emergency power.”

Is solar power free? If you run the numbers—considering the need to replace the battery every several years—the capital costs of the PV panel and other system components, it's *not* free. In fact, in cost per kilowatt hour, there is no way solar electricity can compete with your local utility. What you get from a project like this is the sense of security that your station has virtually uninterrupted power, independence from the local utility and first-hand experience with alternative energy. Additionally, a very important part of your station—the power supply—is “yours” instead of something out of a box.

System Components

Figure 1 is a block diagram of a PV power system.

Photovoltaic Arrays

Figure 2 shows my Arco 32-W PV panel, which consists of 33 cells wired in series. A solar cell is actually a silicon diode. Photons striking the P-N junction create a voltage difference of approximately 0.5 V at the junction. This causes a current to flow, assuming there is a complete circuit. The amount of current is proportional to the area of the cell and the amount of light on the cell. Naturally, with pollution, haze, humidity and so on, a panel produces less power. If the sunlight is concentrated, the panel can produce more.

Figure 3 shows a typical voltage-versus-current curve for a solar panel in various amounts of sunlight. Given a constant load, the current produced by the array is a linear indicator of the amount of sunlight received. Cut the sunlight in half, and the current output is halved.

The rest of the story is not so linear. For a given amount of sunlight, there is a large region where the amount of current doesn't depend on the voltage across the array. Does this seem to violate Ohm's Law? It doesn't, if we think of the solar array as a current source.

By Ohm's Law, if the load resistance rises, the voltage across the load must rise. Thus, the power delivered by the array also rises. It reaches a point where the cells can't keep pushing current at the same rate, and eventually the amount of power will peak: This occurs on the knee of the curve and is called the *maximum power point*. The array rating (in watts) is the power at the maximum power point under a certain set of assumed light conditions.

It's also common to rate solar panels according to the open-circuit (no-load) voltage and the closed-circuit current (a load of zero ohms—a short circuit). In full-winter sun, my Arco panel has an open-circuit voltage of about 18 V and a short-circuit current of about 2.3 A. These ratings are the two endpoints of the voltage/current curve. You cannot multiply the two ratings to get the maximum power.

PV arrays are temperature sensitive. The hotter they get, the less current they produce.³ My panel produces around 2 A during the cold winter months and about 1.5 A (fully 25% less!) on a hot summer day.

To provide more current for battery charging, you can connect solar panels in parallel. Generally, there's no need to provide any kind of balancing network as long as the panels are reasonably similar in design. For very large systems, panels are wired in series-parallel and the system is run at 24, 48, or even 120 V, but such large systems do not concern us here.

Mount panels so they're completely exposed to sunlight. If a single cell doesn't receive sunlight, it becomes, in essence, reverse-biased and blocks an entire panel's output. Although some expensive panels

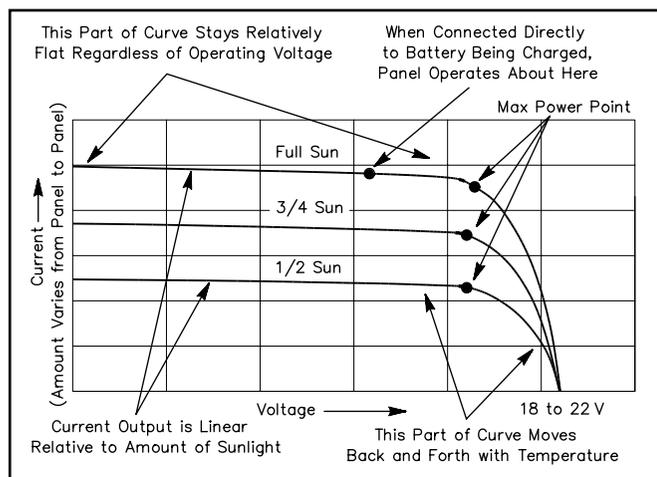


Figure 3—Solar panel operating characteristics. For a given amount of sunlight, a solar panel produces a nearly constant current across a wide voltage range. The amount of current is a fairly linear function of the amount of sunlight, so panels can charge batteries even on cloudy days.

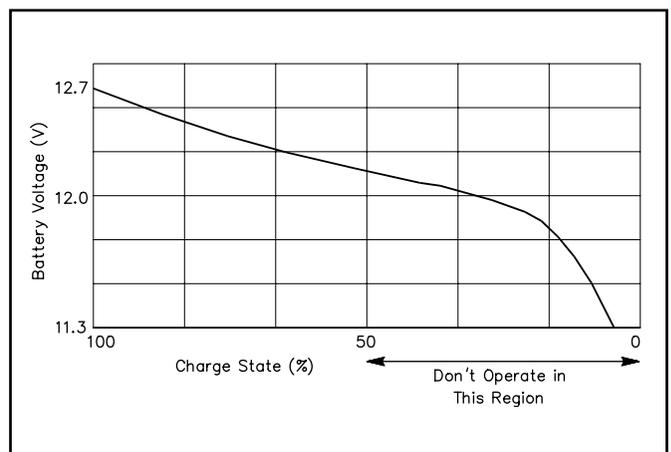


Figure 4—Battery voltage versus state of charge. A fully charged lead-acid battery has a potential of about 12.7 V. This voltage drops as the battery is discharged. It's good practice to keep a deep-discharge battery above 50% state of charge—it maintains the battery voltage above 12 V. This curve varies from battery to battery and according to temperature and rate of discharge.

have bypass diodes to get around this, it's best to mount each panel where it isn't partially shaded by trees or other objects.

Usually, panels are mounted facing due south. Tilt the panel so the noontime sun falls on it as directly as possible. This may mean changing the tilt angle a few times a year, as the sun is considerably higher in the summer than in the winter. If the panel is mounted where it's inconvenient to change the tilt angle, arrange it so that its angle from the horizontal is about equal to your latitude, which varies from about 30° in the southern US to about 50° in northern Canada.

Fancy solar systems have mechanical trackers to point the array at the sun all day long. It's claimed the panels can capture as much as 50% more energy by doing so. This may be true in the summer, but during the winter the additional energy captured is much smaller, particularly at higher latitudes. For a small system powering a ham radio station, it's probably not worth adding a mechanical tracker unless you (unlike I) are mechanically inclined and like the challenge. To properly track the sun, two-axis tracking is required.

Batteries

The battery is the real heart of the system. Properly selected and treated, a battery can last a long time. Improperly treated, it will give you fits.

There are many types of batteries. For a typical installation, there really is only one choice: a lead-acid, deep-discharge battery. The reason? Cost. Oh, there are other choices—such as nickel-cadmium batteries—but their cost is outrageous for the ampere-hour capacity we need.

There are two types of lead-acid batteries. First, there's the battery you see at the auto-parts store: a liquid-electrolyte battery. The second is a fixed-electrolyte battery, such as a gel cell. The former is by far the least expensive, but if you can find a gel cell of appropriate capacity in good shape, it's the better choice simply from a maintenance point of view.

A typical automobile battery is a shallow-discharge battery. Its plate structure is designed to provide a veritable blast of current for a short period of time to start your car.

A deep-discharge battery has a different plate construction and can withstand up to 600 deep discharges, much deeper discharges than a typical automotive battery. However, it's still not good to completely discharge a deep-discharge battery. A rule of thumb is to keep a deep-discharge battery above 50% charge. Take this into account when sizing your system—those 48-hour contest periods should not discharge the battery below 50%! If your operating consumes 50 Ah before you pause to recharge, the rated battery capacity should be at least 100 Ah.

Why are batteries rated in ampere-hours rather than watt-hours? The answer lies in the way batteries work. If you charge a battery with 100 Ah, you can withdraw 100 Ah. How can this be? Is this a perfectly efficient device? No, it's not. The "amperes put in" are put there at a *higher voltage* than is present when the "amperes are taken out." In other words, you put in more power than you can take out. That's why it's convenient to do all the calculations in terms of ampere-hours rather than watt-hours.

State of Charge

A fully charged lead-acid battery that has rested for 24 to 48 hours shows a voltage of about 12.6 to 12.7 V. When the voltage drops to around 11.6 V, the battery is fully discharged (drawing it down any further can physically damage the battery). Thus, the voltage of a rested battery is a reliable indicator of the battery's state of charge. The relationship is not linear, however, as shown in Figure 4. If you never draw a battery below 50% charge, its voltage will stay above 12 V.

Another way to determine the state of charge of a liquid-electrolyte battery is to check the specific gravity of the electrolyte. This is done with a *hydrometer*, an inexpensive device you can get at an auto parts store. Be careful, though. You are working with sulfuric acid, which is caustic and poisonous. Wear goggles and gloves while checking a battery's specific gravity and follow the hydrometer instructions to the letter! (Keep a bucket of water nearby.—Ed.)

In a liquid-electrolyte battery, the electrolyte closest to the plate discharges before the rest does. This can lead to tempo-

rary voltage droop. After a while, the electrolyte mixes and the voltage rises. This is why a battery must be rested between discharging and charging to determine its true state of charge. Fixed-electrolyte batteries don't have this problem to the same degree, but will still droop some.

A 12-V battery kept above 50% charge delivers between 12 and 12.7 V. Most HF rigs are designed to operate with a nominal supply voltage of 13.8 V. Often the voltage to the final output stage is unregulated, so a lower power-supply voltage translates into lower output power. With my Yaesu FT-747, I see a 10% drop in output power, or about 90 W instead of the nominal 100 W. That's a small fraction of an S unit, not enough to bother with. However, you should check your rig's manual to make sure it will be happy with a 12-V supply. My Yaesu transceiver, rated at 12 to 15 V input, operates happily with my battery.

Lead-acid batteries have a fairly complex charge cycle; see Figure 5. The cycle can be divided into three phases. The first is the *bulk charge* phase. In this phase, as much current as the charger has to offer is given to the battery. This should not be more than about 20% of the ampere-hour rating of the battery (40 A for a 200-Ah battery, for example), but can be higher for a fixed-electrolyte battery, although I don't recommend it. The voltage across the battery rises as it absorbs charge. At about 80% of full charge, the voltage reaches 14.4 V for a liquid-electrolyte battery and 14.2 V for a fixed-electrolyte battery (this varies from manufacturer to manufacturer and among individual batteries). If your station equipment is turned on while the battery is being charged, it will be exposed to voltages as high as 14.4 V. Make sure your equipment is rated to handle this voltage.

At this point, an ideal charger switches to the *absorption phase*. The voltage is held at 14.4 V (14.2 V if it's a gel cell) and current is supplied to the battery. The amount of current gradually falls off until it has reached 3 to 5% of the ampere-hour rating. This brings a battery up to about 90% of full charge.

The ideal charger then switches to *trickle charge*. The battery is allowed to

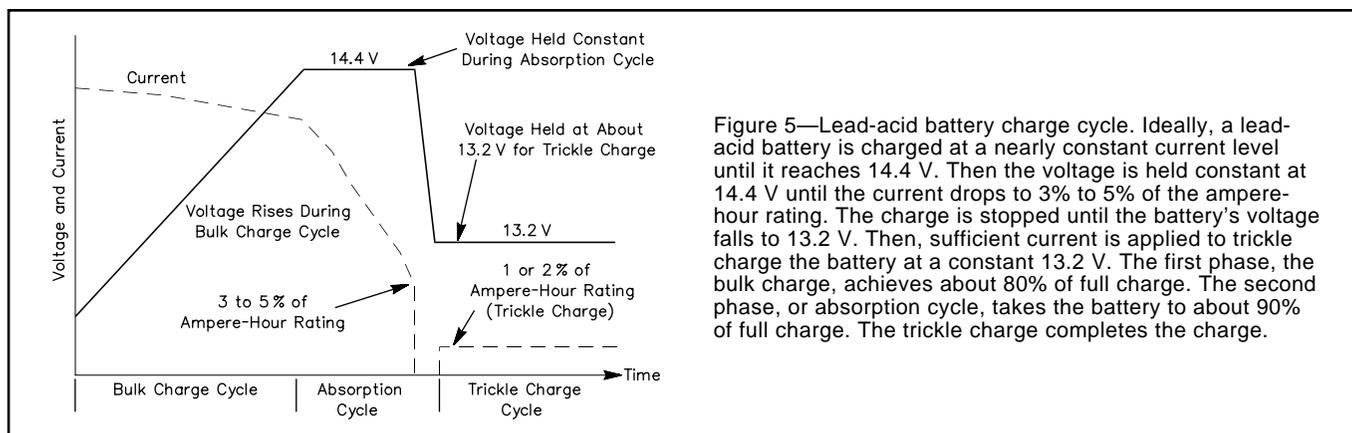


Figure 5—Lead-acid battery charge cycle. Ideally, a lead-acid battery is charged at a nearly constant current level until it reaches 14.4 V. Then the voltage is held constant at 14.4 V until the current drops to 3% to 5% of the ampere-hour rating. The charge is stopped until the battery's voltage falls to 13.2 V. Then, sufficient current is applied to trickle charge the battery at a constant 13.2 V. The first phase, the bulk charge, achieves about 80% of full charge. The second phase, or absorption cycle, takes the battery to about 90% of full charge. The trickle charge completes the charge.

PV Equipment and Information Sources

Inquire locally. Check the Yellow Pages under *Solar or Electrical Contractors*. *Home Power* magazine (see **Information Sources**) carries ads for mail-order houses specializing in alternative energy. Here are a few you can investigate:

Jade Mountain, PO Box 4616, Boulder, CO 80306, tel 800-442-1972, offers solar panels, books, balance of system components, a wide array of high-efficiency lighting; catalog available.

RMS Electric, 2560 28th Street, Boulder, CO 80301, tel 303-444-5909, specializes in system design and installation, but sells individual panels and balance of system components. Be sure to tell them you're a ham when you call—they've been known to become somewhat more flexible on price when dealing with hams. These are the folks who supplied our local club with a large solar array to power our Field-Day site for the past two years!

Siemens Solar Industries, PO Box 6032, Camarillo, CA 93011-6032, tel 800-94-SOLAR. Siemens manufactures solar arrays and they can direct you to a dealer.

Solar Depot, 61 Paul Dr, San Rafael, CA, tel 415-499-1333—solar modules, balance of system components; catalog available.

Sunlight Energy Systems, 2225 Mayflower NW, Massillon, OH 44647, tel 216-832-3114; fax 216-832-4161, system components, charge controllers.

Information Sources

Steven J. Strong with William G. Scheller, *The Solar Electric House*, Sustainability Press, Still River, MA 01467-0143; ISBN 0-9637383-2-1; price: \$21.95. A thorough discussion of sizing and using solar electric systems. Description of "balance of system" (the rest of the system besides the solar panels), components and use.

Richard J. Komp, *Practical Photovoltaics: Electricity from Solar Cells*, second edition, Aatec Publications, PO Box 7119, Ann Arbor, Michigan 48107, ISBN 0-937948-06-3. Rather detailed description of how solar cells operate. Overview of batteries and balance of system components. Description of how to save money by assembling your own panels from individual cells. Price: \$18.

Kevin Jeffrey, *Independent Energy Guide: Electrical Power for Home, Boat & RV*, Orwell Cove Press, distributed by Chelsea Green Publishing, PO Box 428, White River Junction, VT 05001, tel 800-639-4099; price: \$19.95. Aimed primarily at boat owners, nevertheless gives thorough discussion of solar electric panel options, wind electricity generation, chargers and batteries. Most of the examples are boat-oriented.

David Smead and Ruth Ishihara, *Living on 12 Volts with Ample Power*, RIDES Publishing Company, 2442 NW Market Street No. 43, Seattle, WA 98107; price: \$25. Ample Power is the name of a company with whom the authors are associated. Ample Power makes balance-of-system components. Very thorough discussion of batteries. Light discussion of solar panels. Good discussion of balance-of-system components. Concludes with a very lengthy discussion of energy efficient refrigeration systems and how to engineer them and build them yourself. Most of the examples are boat-oriented.

John Schaeffer & The Real Goods Staff, *Real Goods Solar Living Source Book*, 8th edition, Chelsea Green Publishing Company, PO Box 428, White River Junction, VT 05001; price: \$23. Part catalog for Real Goods, part explanation. Very comprehensive listing of all products available.

Home Power: The Hands-on Journal of Home-made Power, PO Box 520, Ashland, OR 97520, tel 800-707-6585. A bimonthly subscription costs \$22.50 per year. Aimed at the do-it-yourself enthusiast. Covers all forms of alternative energy, but primarily solar PVs. —David C. Casler, KEØOG

rest, which lets the voltage fall. Then the charger supplies enough current to hold the voltage at 13.2 V. This current is usually about 2 or 3% of the ampere-hour rating, but can be less. The voltage is held at this rate indefinitely. Over a period of hours, the battery reaches 100% charge. By keeping the battery on trickle charge, any long-term losses are made up.

On the one hand, floating a battery across a 13.8-V power supply never fully charges the battery. On the other hand, the voltage is too high for a trickle charge. Also, battery chargers that perform all three charging phases are rare, expensive and somewhat balky. *Two phase* (bulk and absorption) chargers are more readily available, but they take a battery to only 90% of a full charge. So, if you want to keep a battery above 50%

charge, you have only 40% of the ampere-hour rating available for use.

A more important point is that a solar panel is not a steady source of current for charging. You may be only halfway up the bulk charge curve when the sun goes down. Thus charging from a solar system is a bit of a compromise.

Maintenance

Batteries, particularly liquid-electrolyte types, require maintenance. Don't let the electrolyte level fall below the top of the plates—permanent damage results, which reduces the battery's capacity. Never add anything but *distilled* water. Be careful when adding water to the battery—wear goggles! Keep the battery top and its terminals clean. Charging a battery produces

hydrogen gas, which is explosive—keep the battery in a well-ventilated place away from open flame (for example, a water heater). Keep your battery warm—don't let it freeze or get too cold (or too hot). Fixed-electrolyte batteries don't require nearly this level of maintenance, nor do they produce very much hydrogen gas. Further, fixed-electrolyte batteries don't require periodic equalization charging—a special procedure that can restore lost capacity that is a bit too complicated to go into here.

Make sure your battery is mounted so that the terminals will *never* be short circuited. Batteries store enormous amounts of energy. My D-8 tractor battery can supply *1100 A* for short periods! This would turn a crescent wrench into molten metal. Be careful!

Charge Controllers

The charge controller ensures that the battery gets charged, but not overcharged. Commercial charge controllers are available in a variety of price ranges. As mentioned earlier, the most expensive charge controllers perform all three charge phases. More commonly, a charge controller performs the bulk charging phase by simply cutting off charging when the battery voltage reaches 14.4 V. Then, the battery voltage immediately starts to fall. When it reaches a certain set point, the solar array is reconnected and the voltage is allowed to rise to 14.4 V again. This repeats indefinitely.

Another function performed by the charge controller is reverse-current protection. At night, the PV panel is simply a set of leaky, reverse-biased silicon diodes sitting in the dark. Therefore, it's common practice to put a "real" diode on the output lead of the array to prevent reverse current flow. Size this diode to handle the load. The voltage drop across a silicon diode is about 0.7 V. At 10 A, that's 7 W lost in the diode. Most charge controllers incorporate a diode, but if you design your own, include a reverse-current blocking diode or equivalent.⁴

I have no charge controller—just a reverse current diode. Why? Because my panel provides only about 2 A, which is less than 1% of the ampere-hour capacity of my battery. In other words, the system is always trickle charging. Experts would frown on my system—the array is undersized for my battery. I'm contemplating adding another panel and then putting my computer on the system full time.

We've treated solar panels as current sources so far. My panel provides around 1.5 to 2 A regardless of whether the battery voltage is 12.5 V or 14.4 V. Clearly it is providing more total power at 14.4 V. Actually, it could go up to 16 V or more and maintain 1.5 to 2 A. Wouldn't it be nice to operate the panel at 16 V? Wouldn't it be nice to have a transformer that would convert that to whatever voltage the battery wanted and boost the current accordingly?

But this is dc, you say; transformers only operate on ac. Well, that's true, but a dc-

to-dc converter performs the same function, albeit with many more components. Sophisticated charge controllers incorporate dc-to-dc converters, and are called "max power trackers." They employ sophisticated algorithms to determine the max power point (voltage and current) of the array at any given time (it varies with the amount of sunlight in a non-linear fashion) and offer a load to the panel that is equal to the max power voltage divided by the max power current. The algorithm then determines the battery voltage and adjusts the dc-to-dc converter to offer a current to the battery such that the power offered to the battery equals the power output of the array minus the dc-to-dc converter losses. The algorithm constantly adjusts the system for varying sunlight conditions and changing battery voltage.

This sounds complicated (and it is), but it can significantly increase the efficiency of the total system, providing more total energy to the loads at a cost below that of providing additional PV panels. For our simple system, we treat the panels as current sources and ignore the resulting inefficiencies.

Power Distribution

Commercial line voltage is easy to distribute because I^2R losses are negligible with properly sized wiring. When the voltage drops to 12 V, the current goes up accordingly and the wiring size must be increased to keep down losses. Wiring runs must be kept short and the wire size kept large.

I put my battery close enough to my operating location to connect the transceiver's dc power cord directly to the battery. I run a single #14 cable the same distance to power the other 12-V equipment in my shack, all of which draws far less than the Yaesu transceiver.

I cannot overemphasize the need for safety! Fuse all leads to and from the battery. I use in-line auto-type fuse holders. Make sure wires are of adequate size to handle the current loads. Any permanently installed wiring must conform to local building codes. If your installation grows beyond the simple, consult with a licensed electrician to see if you need to be doing something you may not have thought of.

At first, I hardwired everything. Needless to say, I soon found the error of my ways. The standard connector used by the alternative energy community for 12-V operation is the cigarette lighter plug/socket combination. These are available at Radio Shack and at RV stores as well as alternative-energy houses. Many hams have standardized on Molex connectors.⁵ Pick a system and stick with it. High-current devices such as your HF rig should be wired directly to the battery, however, with a fuse in both leads to avoid losses from undersized connectors.

The length of your dc wiring lines can approach a quarter wavelength at some frequency. The line most likely to do this is the

one from the PV panel to the charge controller. Lines this long make great antennas and can cause RFI problems. Install bypass capacitors and ferrite cores as needed and make sure the system is at RF ground.

Other System Components

There are a number of other components in a typical solar-power system. These include various monitoring circuits, inverters, lights and anything you can think of that might use 12 V.

You can monitor a number of things, but these three are important: You want to know that the charging system is working, the rate of charge and the battery's state of charge. I measure the solar array charging current with an analog ammeter made from a milliammeter and a shunt made from an almost 6-foot length (5.95 feet) of #14 wire (see the *Handbook* for a description of how to calculate shunt resistance). I measure the battery's state of charge with an expanded-range voltmeter⁶ made from a 0 to 1 milliammeter, a 10-V Zener diode and a couple of resistors. The total cost for these items (made from scrounged parts) is about \$5. More-sophisticated charge controllers (some costing hundreds of dollars) calculate the total ampere-hours of charge or discharge. These systems employ microprocessors to repeatedly and frequently measure current and integrate it over time. I'd rather put that money into another 2-meter rig.

Another helpful accessory in a 12-V system is an inverter. An inverter converts 12 V dc to 120 V ac. There are several types of inverters, varying in price and sophistication. Radio Shack sells a simple, modified-sine-wave inverter rated at 140 W (enough to power my computer) for about \$100 (RS 22-132). True sine-wave inverters can be very expensive and are found in larger systems designed to power entire houses. Square-wave inverters are generally inefficient because lots of the power goes into harmonics. I don't use my inverter much because it gobbles energy (over 10 A for a 120-W load), which my solar panel takes too long to replace—but the inverter's nice to have around in case of emergency.

My system produces more power than I use, so I have some compact fluorescent lamps with 12-V dc ballasts.⁷ I use one lamp in the bedroom for evening reading. Another provides light at my desk. Although far more expensive than a 12-V dc incandescent light bulb, they produce *four times* as much light per watt and can last *ten times* as long. I'm writing this article by the light of a 13-W compact fluorescent lamp, which is as bright as a 60-W incandescent bulb. Regardless of what type of bulb you favor, you can do only so much operating in the dark. You may want to include some 12-V light source in your system to use when utility power is unavailable.

Lights can be your largest power drain if you aren't careful. My compact fluorescent draws only about 1 A. But left on all day, that's 24 Ah gone from the battery!

Where to Get the Components

All the components of a solar-powered ham station are universally available except for the solar panels and the charge controllers—these are available from alternative energy suppliers across the country. Check the Yellow Pages under *Solar* or *Electricians*. Many will ship by mail or UPS. Call around, as prices vary quite a bit. The sidebar lists some suppliers. As usual, be ready to negotiate. Tell the store personnel what you're trying to do and get advice. Try to arrange a way to return the equipment should you find a problem.

Obtain your battery locally. Shy away from used batteries, especially if you don't know the battery's history. Avoid batteries removed from long-term service because they're near their end of life. A new deep-discharge (sometimes called "marine deep cycle") battery from an outlet such as WalMart should do fine and last two or three years. Alternative energy aficionados may scorn these as cheap and unreliable, but for hobby service, they should be more than adequate. "Good" batteries (as defined by the cognoscenti) are extremely expensive and offer far more "reliability" than we hams need.

There are dozens of books (and at least one magazine, *Home Power*) devoted to the subject of alternative energy. See the sidebar "PV Equipment and Information Sources" for a short list.

Summary

This project started out as a lark and turned into a mini hobby of its own. I never thought it would provide such a reliable source of power, but I may actually sell that old Astron power supply. I can operate as much HF as I want (and VHF too). I'm thinking of enlarging the system to encompass my computer full time so I can be truly "off the grid" for AMTOR and PACTOR.

Notes

¹See Michael Bryce, WB8VGE, "Off the Grid and on the Sun," *QST*, Dec 1992, pp 45-51. —Ed.

²According to the National Renewal Energy Laboratories (NREL), on average, you can expect an average of 5.8 hours per day per year.

³The temperature rise causes the panel voltage to drop and reduce the amount of current flowing to the battery.

⁴Mike Bryce, WB8VGE, "The SunSwitch," *QST*, Oct 1993, pp 24-27. See also *The 1996 ARRL Handbook*, pages 11.34-11.37.

⁵The ARRL-recommended 12-V power connector is the Molex Series 1545 connector. See *The 1996 ARRL Handbook*, p 22.6.

⁶John Grebenkemper, K16WX, "Expanded-Range DC and AC Voltmeters," *QST*, Technical Correspondence, May 1993, pp 77-78; Feedback, *QST*, Aug 1993, p 69.

⁷I obtained the 12-V ballasts from Jade Mountain (see the sidebar "PV Equipment and Information Sources"). I recommend getting such ballasts and lights from solar-equipment suppliers. The lighting equipment is more reliable and produces brighter lighting than the cheaper camping fluorescents.

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