Solar power

Every day, more and more people turn to the Sun as this seemingly limitless energy source that freely shines down upon us. Whether it’s by solar panels on our roofs or through a tiny film on a calculator, we’re taking advantage of technology that allows us to convert radiant energy into electrical energy. Let’s address exactly how that conversion takes place.

A solar cell starts out as two slices of ordinary silicon, a good insulator in its pure form, but made with an impurity mixed in, a process known as doping. One of the impurities is phosphorus, creating an n-type material, meaning the chemical bond between silicon and phosphorus results in an extra electron in the substance per phosphorus atom. The other impurity is boron, creating a p-type material, meaning the bond between silicon and boron results in a missing electron in the substance per boron atom.

These impurities turn the otherwise pure silicon insulators into fair conductors (called semiconductors), and are not all that remarkable by themselves. But bringing the two pieces of differently doped silicon in contact with each other produces an electronic arrangement such that electrons can flow through the two conductors, from the n-type side (cathode) through the border (called the P-N junction) between them, to the p-type side (anode), but not in the other direction, due to the polarized electric field created by the junction. This is known as a semiconductor diode.

So, a solar cell is not much more than an ordinary diode, but necessarily so, to favor a current flow in one direction, like a battery. Without this diode effect, the electrons would diffuse in both directions, neutralizing the current flow. (Also, keep in mind that the direction of current flow is the same as that for hole flow, and is opposite the direction of electron flow.)
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When sunlight strikes the n-type surface, the energy of the photons can be great enough to cause an electron in the phosphorus valence band to absorb the radiant energy and jump to the conduction band and become free to move about (the sunlight knocks it loose, to allow for electron flow). Because of the electric field imposed by the potential difference across the P-N junction, the freed electron rushes toward the p-type side (and holes toward the n-type side), where it accumulates with others, and presents an external charge pressure (voltage) to its external metallic electrodes, by electrons on one and holes on the other.

**Cross section of a solar cell**

This is known as a *photodiode*, or a *light-absorbing diode*, and the process described is known as the *photovoltaic effect*. If you then wire a closed resistive circuit across the electrodes of the two sides, a current will flow through the photodiode when it’s exposed to sunlight. Couple several solar cells together electrically to form a *solar panel* or solar module. A *solar array* is a set of solar panels you might find on a building. It’s important to note that, without
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the circuit to form an electrical path between the anode and cathode, there’s no place for the
electrons to go, and the solar cell will simply receive the light without performing any of the
conversion.

Efficiency

Capturing and converting more of the Sun’s rays is an ongoing development struggle, and
where much of the current research is focused. One problem is the unused light that’s reflect-
ed off the solar cell surface. Another is the heat generated by light absorption. It turns out that
some of the heat actually aids the conversion process, but the majority is wasted. So, just how
much radiant energy is converted to electrical energy? Depends on the solar cell technology.

At the time of this writing, about 10% of the solar market uses thin film solar cells, which are
less than 20% efficient, meaning for every five buckets of sunlight poured onto a thin film so-
lar cell, under one bucket of electricity will be pro-
duced. (I forget right off what the conversion fac-
tor is, from buckets to kWh, but I digress.) Over
50% of the current market uses polycrystalline
solar cells, which are about 20% efficient. About
33% of the current market uses monocristalline
cells, which are of slightly newer technology, and
about 23% efficient.

Power management

One of the primary problems encountered when
using solar panels is the wide range in voltage
presented by a solar cell, due primarily to the pro-
portion of sunlight exposure. Obviously, your
panel can produce more power when it’s exposed
to direct, bright sunlight, than during cloudy or
dimly lit hours. A device called a charge control-
er is essential to almost any solar-powered solution, and can provide a steady voltage over a
wide range of available light. More generally, the purpose of a charge controller is to manage
power in a solar setup.

Unlike with a solar-powered calculator, most solar solutions involve the storage of energy, to
allow a supplied device to continue running, even after dark. For this, you’ll need a battery,
and one that can be charged daily and withstand a fairly large amount of energy depletion
(more on this later). In spite of the battery variety available for solar power, a charge controller
can perform many necessary functions involved with energy storage.

A charge controller should be able to a) charge a battery while running a device, b) charge a
battery while running no device, c) sense the amount of stored energy currently in a battery
and adjust its supply to the battery as needed, and d) prevent depletion of the battery by the
solar cells during dimly lit moments. In general, there are two kinds of solar charge controllers
on the market today that perform these tasks: PWM (pulse-width modulation) controllers and
MPPT (maximum power point tracking) controllers.
PWM charge controllers are typically lower in cost than MPPT charge controllers, but they tend to incur heavy power losses when the solar panel output does not match the nominal battery voltage. MPPT charge controllers are typically much more expensive than PWM charge controllers, but incur very little power loss, whether or not the panel output matches the battery voltage, and can often make up for the cost difference in power savings. If you can afford one, I highly recommend using an MPPT-type charge controller for your solar needs.
Energy storage

Once you’ve successfully converted and controlled all that free solar energy, you’ll need to store it, to ensure that energy will be available to you after dark. As mentioned, this storage is normally available in the form of a battery, but not just any battery. Of course, the battery intended for solar energy storage needs to be rechargeable, but also deep-cycle, meaning it should be able to handle a large depletion of its stored energy without damage to the battery.

There are other battery factors to consider, such as nominal (the named) voltage, capacity (number of Ah), content (lead-acid, lithium, AGM, etc.), depth-of-discharge, and more, but we’ll save our exploration into these different parameters for another article. Meanwhile, let’s agree on a few battery semantics, to make sure you and I are speaking the same language.

First, the word charge is a little confusing. When we use it as a verb, as in, “I want to charge my battery,” or “My battery is fully charged,” that’s appropriate, because it means store energy in, or in other words, energize. But using it as a noun is where it gets confusing, as in “My battery stores charge,” or “The controller sends charge to my battery.” This is because, as long as your battery doesn’t gain or lose any chemicals, it will always contain the same amount of charge, whether it’s fully energized or completely dead.

Second, batteries work by chemical reaction, so that one chemical reacts with a metal (called the anode, or negative “−” terminal), and produces electrons as a reaction by-product. If there’s no place for the electrons to go, the reaction can only take place up to a point of equilibrium. Meanwhile, another chemical reacts with another metal (called the cathode, or positive “+” terminal), and requires electrons for its reaction to complete. If nothing provides electrons to complete the reaction, the reaction cannot take place there, until the electrons are provided.

Third, if we now compare the amount of potential (possible) electron stream available at the anode, with the amount of potential electron stream needed at the cathode, we call the difference between the two potentials voltage. Indeed, it’s more technically accurate for us to say that the battery stores potential energy, rather than saying that it stores electrical energy. However, in the interest of brevity, I’ll just say that the battery stores energy, and you’ll know what I mean. (Also, I’ll not attempt to distinguish between a battery and a cell here.)

Using the battery

If we provide a pathway (wire, circuit, etc.) for the electrons in the anode reaction to flow to the cathode reaction, both reactions can readily take place, and we now have direct current (DC) flow though the pathway, from the cathode side, through the pathway, and into the anode side. If the battery chemical reactions are reversible, we call that a rechargeable battery; if they are not reversible, it’s a one-life, non-rechargeable battery, to be discarded after most of the chemicals have reacted to present an acceptable voltage level.
Now, let’s replace the pathway with our solar cell, the subject of this article. If we connect the solar cell anode with the rechargeable battery anode (and therefore, cathode to cathode), and the potential (voltage) presented by the solar cell is greater than that of the battery, then expose the solar cell to sunlight, current will flow out the cathode of the solar cell and into the cathode of the battery, reversing the chemical reactions and effectively recharging the battery. But that flow needs to be carefully controlled; hence, the need for the charge controller.

Calculating solar power needs

Knowing just how much solar power you’ll need will require some fair estimation, and might even include some predictions of your future needs. On one hand, you can power your entire home with a large solar array and a battery bank to match. On the other hand, since this newsletter is geared toward amateur radio, let’s concentrate on that one aspect. To illustrate how to calculate your needs, I’ll present two radio-related situations, mobile and portable HF, including an inefficient inverter for a laptop.

Electrical needs common to both

- laptop (Chromebook charger and inverter = 6.6 A » 6.6 Ah)
- cell phone charger (12 V to USB = 3 A » 3 Ah)
- lighting (PWRbrite LED Light Strip = 0.2 A » 0.2 Ah)

Common hourly energy draw = 9.8 Ah

Mobile solar solution

- mobile radio (Yaesu FT-8800R = 9 A, but at 50% duty cycle » 4.5 Ah)

Total mobile hourly energy draw = 9.8 Ah + 4.5 Ah = 14.3 Ah

Portable HF solar solution

- portable HF radio (Yaesu FT-891 = 23 A, but at 50% duty cycle » 11.5 Ah)
- tuner (LDG AT-100Pro II = 0.5 A » 0.5 Ah)

Total portable HF hourly energy draw = 9.8 Ah + 11.5 Ah + 0.5 Ah = 21.8 Ah

21.8 Ah x 12 V = 261.6 Wh, which is the amount of energy you’ll need, to run your portable HF station. Assuming an 80% efficient solar solution, you’ll need a 261.6 Wh / 0.80 = 327 W solar panel charging your battery for an hour, or a 100 W panel for about 3½ hours. A 100 Ah deep-cycle battery will easily take care of these needs. If you talk less on the air (say, 25% duty cycle), you can lower those amounts to 2½ hours with the same panel into a 50 Ah battery.

Summary

The discussion about solar power is not a trivial one, and involves some understanding of not only how to convert radiant energy into electrical energy, but how to control it and store it. Similarly, figuring out just what it’s going to take, to supply your solar needs, is also a little involved, but practical if you keep inefficiencies in mind. One final word about charge controllers: some of them tend to generate radio noise (“hash”), so keep that in mind too.

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