Resources

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To design a safe, cost effective, durable, and reliable photovoltaic power system, you need a number of resources. In this column, I will discuss some of the print and Web resources I use in PV system design and installation, what they contain, and where they may be obtained.

Design Information

How much sun? The first thing you should do when designing a system is to determine the solar resource available in the particular location. The amount of solar energy available will have a direct bearing on the system size and cost for any specific size of load. Local airports that have weather stations may have records of the solar resource. Newspapers sometimes publish and even record the daily solar radiation.

Lacking those local sources, the next best source of solar radiation data is the National Renewable Energy Laboratory solar radiation Web site, http://rredc.nrel.gov/solar. Solar radiation data in formats used for PV systems (KWH/m^2) is found at http://rredc.nrel.gov/solar/old_data/nsrdb/redbook. Solar radiation data for solar thermal heating systems (BTU/$foot^2$/day) is found at http://rredc.nrel.gov/solar/old_data/nsrdb/bluebook. The 30-year averages of monthly data are most useful. These spreadsheets show not only the solar radiation, but also the temperature averages and extremes, which can be used in code and performance calculations.

In many cases, the local microclimate where the PV system is being installed may differ from the climate at the nearest weather station. Elevation differences may affect temperatures. Fog, smoke, or blowing dust may reduce the solar insolation. Nearby mountains may cause shading part of the day.

A site survey should be conducted using one of the sun-angle charts (available from vendors advertising in *Home Power*) to determine if there is any significant shading. I have seen people attempt PV installations on 1/4 acre homesteads surrounded by 90 foot tall pine trees. This may not work well, unless the pole mount system is very high.

When you are designing your system, make sure you check for state and local incentives. A minor change to your system could determine your eligibility for substantial financial help. Check this Web site for a state-by-state summary of the various rebates and other financial incentives for PV: www.dsireusa.org.

Handbook

Stand-Alone PV Systems: A Handbook of Recommended Design Practices from Sandia National Laboratories shows you how to properly use the solar resource data to size a PV system. Although the title implies designing a stand-alone PV system, many of the techniques and methods presented are also applicable to utility-interactive (U-I) systems and U-I systems with battery backup. The book can be ordered from the Sandia Web site. The site includes information on both utility-interactive and stand-alone systems, as well as technical papers related to the testing of PV systems and modules. All are available at no cost.

Bill Brooks and the other engineers at Endecon Engineering produced a good book, *A Guide to Photovoltaic (PV) Power Systems Design and Installation*, for the California Energy Commission that covers designing utility-interactive PV systems. It can be downloaded in PDF format from the CEC Web site: www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF

Several of the PV module manufacturers and the larger PV distributors that advertise in *Home Power* also have software, spreadsheets, and other design tools.

Loads: Stand-Alone & Utility Interactive

Previous articles in *Home Power* have discussed how to estimate loads. Some *HP* advertisers market small, plug-in power meters that can be connected to appliances for a week or so to monitor and record the actual energy used. This energy use can be used to refine any energy use estimates from the nameplate ratings found on electrical devices.

Code Information

As you might expect, I consider the *National Electrical Code* and the *National Electrical Code Handbook* as absolute musts for anyone designing and installing PV systems. Familiarity with the code at the design stage will allow many potential installation, safety, and durability problems to be avoided or at the very least minimized. These books are available from most electrical supply houses and the National Fire Protection Association (NFPA).

The first four chapters of the *NEC* contain general information, and subsequent chapters modify that material for specific applications. Article 690 in Chapter 6

covers the specifics for PV system installations. Chapter 9 contains tables that define conductor parameters (resistance for voltage-drop calculations, and conduit fill tables, for example). These sections of the code are a must, and depending on the particular application, other sections may also apply.

All of my past *Code Corner* columns as well as the *Photovoltaic Power Systems and The National Electrical Code: Suggested Practices* manual can be found on the Southwest Technology Development Institute (SWTDI) Web site. A print copy of the manual can also be ordered from Sandia on their Web site.

The Florida Solar Energy Center (sister organization to SWTDI) has significant amounts of information about installing and inspecting PV systems on their Web site: www.fsec.ucf.edu/PVT/Education/training/inspgcps/handbook/index.htm

The IAEI Ferms Fast Finder is a large, spiral-bound manual published by the International Association of Electrical Inspectors (IAEI). It indexes and cross references nearly every term used in the code. It also provides substantial amounts of supplementary information useful to people installing electrical systems. Local electrical codes may differ or supplement the *NEC*, so they and the local building codes should also be reviewed.

Grounding

The IAEI Soares Book on Grounding is the definitive source for information on grounding electrical systems. It covers all the grounding methods and techniques found in the *NEC*, and it is profusely illustrated.

For those wishing to debate whether or not PV systems should be grounded, this book is a must because it summarizes many of the arguments that were put forth around 1900 when the grounding requirements for the U.S. electrical system were formulated. As the saying goes: "Those who do not read or understand history are doomed to repeat it."

Get Educated

The well-read PV system designer, integrator, or installer is in a better position to understand the physics of PV systems, and the safety, performance, and durability requirements than a person who does not read, study, and understand. The material is readily available, much of it is free, and the cost of documents that are not free is a very small percentage of the cost of a PV system—particularly one that doesn't work as expected.

In the next *Code Corner,* I will show all of the calculations required by the *NEC* for an example stand-alone PV system.

Grounding Correction

In the *Code Corner* for *HP90,* I offered some possible methods of grounding the DC side of a utility-interactive PV system. Further research into the *NEC* grounding requirements has shown that those methods may not meet *NEC* requirements. To properly ground the DC portion of a utility-interactive PV system, two methods are available.

In the first method, a grounding-electrode conductor is run from the identified DC grounding point (usually in the utility-interactive inverter) to a separate (from any AC grounding electrode) DC grounding electrode. *NEC* Section 250.166 determines the size of the DC grounding-electrode conductor. The smallest allowable size is #6 (13 mm^2) when a "made" ground rod is being used. This DC grounding electrode must be bonded to the AC grounding electrode to make a grounding electrode system per *NEC* Section 250.52 and 250.53. The bonding conductor can be no smaller than the largest grounding electrode conductor, either AC or DC.

The second method does not require a separate DC grounding electrode. The DC grounding electrode conductor is routed and connected to the AC grounding electrode. The size is as described above.

Questions or Comments? If you have questions about the *NEC,* or the implementation of PV systems that follow the requirements of the *NEC,* feel free to call, fax, e-mail, or write. Sandia National Laboratories sponsors my activities in this area as a support function to the PV industry. This work was supported by the United States Department of Energy under Contract DE-FC04-00AL66794. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

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The 2002 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Dr., Avon, MA 02322 • 800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301
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