

Photovoltaic Applications

As energy demands around the world increase, the need for a renewable energy source that will not harm the environment has never been greater. Some projections indicate that the global energy demand will almost triple by 2050. Using photovoltaic (PV) cells is one way to meet the need, converting sunlight directly into electricity with no moving parts and no harmful pollution. Although more conventional sources of energy, such as fossil fuels, are still satisfying the majority of the world's energy demand, PV systems are used in a great variety of applications. These applications may be grouped into two categories: *utility interactive systems* and *stand-alone systems*.

Utility Interactive Applications

Since a PV system can only generate electricity when the sun is shining, some provision must be made to have electricity at night and during cloudy weather. It is often necessary to use a backup system to ensure that electricity will always be available no matter what the weather conditions. One way to back up a PV system is to connect the system to the utility grid through a high quality inverter (Figure 1). An inverter converts the direct current (DC) output from the PV cells to alternating current (AC) electricity that can power common household appliances or be sold back to the power company when more electricity is



Figure 2: Commercial PV system at EPA facility in Research Triangle Park, NC.

generated than is used. When connected to the grid in this way, the inverter must produce AC electricity such as is normally available from the power company. With a utility interactive system, when more electricity is needed than the PV system can generate, the necessary power is bought from the local power company.

Utility interactive systems are often used in homes or commercial buildings to offset electricity costs when the PV system is not large enough to satisfy all the energy

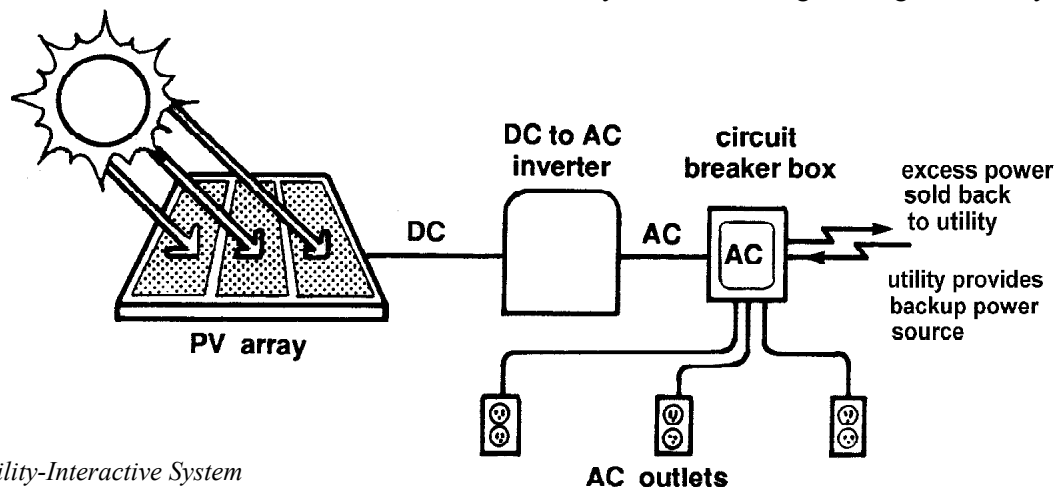


Figure 1: Utility-Interactive System

demands (Figure 2). These systems are especially attractive in displacing power bought from the utility during peak demand hours, which usually coincide with peak sunlight hours. Since most power companies incorporate a peak demand surcharge in their billing process for commercial customers, PV systems can significantly reduce electrical bills. A properly designed PV system with battery storage can be used to provide power during peak load periods, potentially leading to greater savings. An example of a residential utility interactive system is the PV system at the North Carolina State University Solar House.

Since the peak demand for electricity normally occurs during sunny periods, an increasing number of utility companies use large PV systems to supplement other systems of electrical generation. The unit costs of larger utility systems are lower because of the economies of scale that occur with larger systems.

Stand-Alone Systems

A far more common application of PV technology is found in stand-alone systems. A stand-alone system is one that does not have a utility connection. In many remote locations, the cost of running a line extension, at \$15,000 to \$20,000, or more, per mile, is uneconomical. Mobile applications also do not often have the luxury of being close to a power

line. With conventional fuel generators, the cost of fuel transport is often higher than the cost of the fuel itself. Conventional fuel generators also need significant maintenance, making PV systems the best and most cost effective solution in many instances.

The simplest stand-alone systems are direct systems, which use electricity as it is produced. Often, however, demand for electricity exists when the sun is not shining. In that case, a battery storage system is used. In these systems, the PV array charges the system's batteries during sunlight hours, and the batteries supply electricity at night and during cloudy periods. If necessary, stand-alone systems also may use conventional generators as backup systems. Both direct and battery storage systems can provide DC and AC power.

Some examples of the numerous applications of stand-alone PV systems include:

- **Lighting:** The availability of low power DC lighting, such as low pressure sodium and fluorescent lights, makes PV an ideal source for meeting remote or mobile lighting needs (Figure 3). Obviously, lighting demands are greatest at night, making battery storage essential. PV systems are currently used to provide lighting for billboards, highway information signs, public-use facilities, parking lots, marinas, homes, vacation cabins, piers, and caboose lighting for trains.
- **Communications:** Radio, television, and phone signals over long distances need to be amplified. Relay towers, often called repeater stations, perform this function. The best sites for repeater stations are usually at the highest possible elevation, where power lines are not commonly found and transport of conventional generator fuels would be difficult and costly. In addition, as the use of fiber optic cable spreads, photovoltaic repeater stations will be required. Coaxial cable can carry power to amplify the signal carried, but fiber optic cable does not have this capability. PV also is used on travelers' information transmitters, portable computer systems, cellular telephones, mobile radio systems, and emergency call boxes.
- **Remote Site Electrification:** Many residences and other structures are simply too far from the utility distribution network to establish a grid connection. Also, power is needed at construction sites before the connection has been installed. PV systems are an attractive way to provide electricity in these areas. Conventional generators or other renewable energy sources, such as wind or micro-hydroelectric generators, may be used in conjunction with the PV system to ensure uninterrupted power availability. Some examples of remote site electrification are for rural homes, visitor centers in parks, park ranger sites, vacation cabins, hunting lodges, remote farm workshops, village/



Figure 3: PV lighting at a park and ride facility in Raleigh, NC.



Figure 4: PV powered fly zapper at the Center for Environmental Farming Systems in Goldsboro, NC.

island electrification, clinics and remote research facilities, highway rest stops, public beach facilities, campgrounds, and military test areas. Figure 4 shows a PV powered fly zapper used to kill hornflies at a remote research location.

- **Remote Monitoring:** Often monitoring for scientific research or other purposes must take place at temporary sites far from conventional power sources. PV systems can be effectively used as a power source to monitor meteorological information, highway/traffic conditions, structural conditions, seismic recording, irrigation control, and scientific research in remote locations.
- **Signs and Signals:** Devices such as navigational beacons, audible warning signs such as sirens, highway warning signs, railroad signals, aircraft warning beacons, buoys and lighthouses are generally remote or even impossible to connect to the utility grid. PV systems provide reliable power for these critical applications.
- **Water Pumping and Control:** PV is an ideal candidate for water pumping applications. Many water pumping needs, such as livestock watering, are greatest during the sunniest hours of the day. These systems may be either direct systems, operating the pump only when the sunlight is sufficient, or they may pump water to an elevated storage tower during sunny hours to provide available water at any time. Either system avoids the use of batteries, resulting in a decrease in initial cost and reducing maintenance needs. PV powered water pumping is used to provide water for campgrounds, irrigation, remote village water supplies, and livestock watering.
- **Charging Vehicle Batteries:** PV systems may be used to directly charge vehicle batteries, or to provide a “trickle charge” for maintaining a high battery state of charge on little-used vehicles, such as fire-fighting and snow removal equipment and agricultural machines such as tractors or harvesters. Direct charging is useful for boats and recreational vehicles. Solar stations may be dedicated to charging electric vehicles also (Figure 5).

- **Disaster Relief Applications:** Natural disasters such as hurricanes, floods, tornadoes, and earthquakes often destroy electric generating facilities and distribution systems. In situations where the power will be out for a long period of time and the affected area is relatively large, portable PV systems are very useful for providing street and personal lighting and power for communications equipment, warning and message signs, water purification, refrigeration of medical supplies and food, and pumping water. When makeshift shelters or medical clinics are necessary, PV supplied electricity is often a better choice than conventional fuel generators. PV systems have little noise, avoid problems with fuel transport, provide a non-polluting operation, and are more suitable for continuous operation.

- **Cathodic Protection:** Metallic structures exposed to soils and water naturally experience corrosion due to electrolytic action. This corrosion occurs because the metals lose ions when exposed to an electrolyte. A voltage may be applied that will prevent the ion loss from the metal, preventing corrosion. This method of protection is called cathodic protection. Only a small DC voltage is necessary to protect the metals. If utility power is used, the voltage must be lowered and the power must be converted from AC to DC. PV systems are capable of producing the low voltage DC power directly, resulting in a much more efficient use of energy. Cathodic protection is used on pipes, tanks, wellheads, wharves, bridges, and buildings.

- **Refrigeration:** PV systems are excellent for remote or mobile storage of medicines and vaccines.

- **Consumer Products:** Photovoltaic technology is used on a variety of commercially available and successful consumer products. For example, PV is used to power small DC appliances for recreational vehicles. Other examples include watches, lanterns, calculators, radios, televisions, flashlights, outdoor lights, security systems, gate openers, golf carts, and fans.



Figure 5: Electric vehicle with PV charging station at Topsail High School in Hampstead, NC.

Conclusion

Recent innovations have enhanced even further the attractiveness of using photovoltaic systems to satisfy energy needs. For example, instead of mounting PV modules on separate support structures, they may be mounted on buildings or integrated into the building structure. Building-integrated PV systems do not require additional space and offset construction costs by replacing conventional building materials. Another innovation is to use the heat collected by PV modules for space heating or hot water heating. The PV modules then serve a dual function as photovoltaic modules and heat collectors in an active solar system. In this way, more of the sun's energy is converted to a usable form.

As the technology improves and is applied in even more innovative ways, photovoltaics promise to cleanly provide a significant portion of the world's electricity. The cost of PV systems has steadily fallen and continues to do so. Their use will dramatically increase as they become more cost competitive with conventional forms of electrical generation. PV systems are already the best choice in hundreds of important applications.

This publication is available for download and printing from the list of information factsheets on the NC Solar Center's web-site at www.ncsc.ncsu.edu. To reduce paper waste, this publication was not mass reproduced in hardcopy. Printed copies can be mailed to those who do not have access to the Internet.



North Carolina Solar Center

Box 7401, NCSU, Raleigh, N.C. 27695-7401
Phone: (919) 515-3480, Toll free in N.C.: 1-800-33-NC SUN
Fax: (919) 515-5778
E-mail: ncsun@ncsu.edu
Web: www.ncsc.ncsu.edu



State Energy Office, NC Department of Administration

1340 Mail Service Center, Raleigh, NC 27699-1340
Phone: (919) 733-2230, Fax: (919) 733-2953
Toll free in N.C.: 1-800-662-7131
E-mail: Doa.Energy@ncmail.net
Web: www.energync.net

The NC Solar Center is sponsored by the State Energy Office, NC Department of Administration, and the US Department of Energy, with state Energy Program funds, in cooperation with North Carolina State University.