ABOUT YOUR HOUSE

PHOTOVOLTAICS (PVs)

CE 43

Photovoltaic or PV systems are devices used to convert sunlight into electricity. Photovoltaic systems are a safe, reliable, low-maintenance source of solar electricity. They have a life expectancy exceeding 40 years. They produce no pollution or emissions, incur few operating costs, and are easy to install on most Canadian homes. With rising energy costs and concerns with respect to the reliability of continuous service delivery, the demand for PV systems is increasing.

PVs can be used effectively in most homes, alone or in combination with other systems. PVs are ideal for homes or cottages which are located some distance away from utility power lines. Power line extensions typically cost $5,000 to $10,000 per kilometer. These "off-grid" applications make up the majority of solar-electric installations in Canada. However, PV systems are being increasingly used to provide electricity for homes that are connected to utility power. Internationally, utility grid-connected PV systems represent the majority of installations, growing at a rate of over 30 per cent annually.

The basic building block of a solar-energy generating system is called the solar cell built into a PV module. PV modules are connected together into panels and arrays to meet various energy needs. Modules used for home power applications usually range between 75 to 120 watts, and measure about 0.6 m x 1.2 m (about 2 ft. x 4 ft.). Based on current module efficiencies, one square meter (10.7 ft.^{2}) of solar modules generates about 130 watts in bright sunshine. A 100-watt PV module generates an average of about 400 watt-hours per day or 100 kWh annually in most populated regions of Canada.

Photo 1: House with a building-integrated photovoltaic roof (BIPV)

Off-Grid and Grid-Connected PV Systems

Applications for PV systems fall into two main categories—off-grid and grid-connected. The "grid" refers to the local electric utility's infrastructure that supplies energy to homes and businesses. Each system type is unique and often uses slightly varying equipment.

Off-Grid PV Systems

Off-grid does not necessarily mean being a great distance away from power lines. Many homeowners already use solar-powered patio and garden lights. These solar lights are miniature versions of PV systems that power off-grid or autonomous homes. In this type of system, the solar modules charge a battery, which in turn operates the electrical loads. Since PV modules generate direct current or "DC" power, a power conditioner called an "inverter" is used to operate normal household

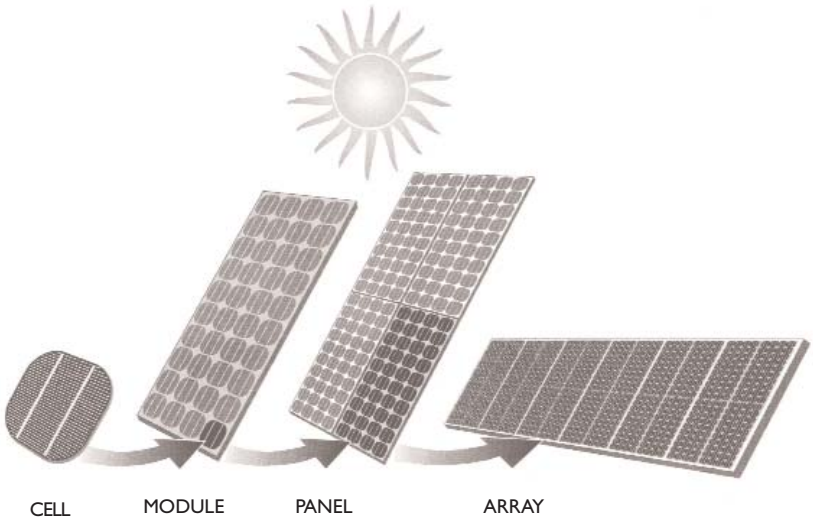

Figure 1: Components of a PV Array

electrical equipment that requires "AC", or alternating current power.

Another type of off-grid PV system directly connects the solar module to an electrical load. Examples of this type of system include attic-ventilation fans, and agricultural and livestock water pumps. Solar attic fans are often a cost-effective option for homeowners when a power vent is required and when it's costly to run a wire to the attic.

Off-grid homes rely on batteries to store the solar electricity for nighttime use and during periods of cloudy weather. In this type of application, the size of the solar array and the capacity of the battery bank are carefully sized to give optimum performance.

For homes that are off-grid, appliances that use a lot of electricity are usually taken off the PV system. House heating usually includes a combination of wood, propane and passive solar housing design, while water heating is often accomplished by using a combination of propane and solar domestic hot water heaters. High-efficiency refrigerators that can operate on solar are available; however, they tend to be expensive and many off-grid homeowners choose a propane refrigerator instead.

While a battery bank can store energy for short periods—typically three to seven days of "autonomous power"—there may be periods of cloudy weather when a back-up source is required. PV-hybrid systems combine a PV system with another power source such as an engine generator (gasoline, diesel or propane) or other renewable energy source such as a wind generator. This offers all the benefits of PV for low operation and maintenance costs, but also ensures a secure electricity supply. Hybrid systems can allow the size of the PV array and battery bank to be reduced, making the system more cost effective.

Grid-Connected PV Systems

The most popular type of grid-connected solar power is the "synchronous" system. The solar array is connected to a synchronous inverter that blends the PV-generated electricity with grid power, after which the combined electricity is fed into the house to run the domestic energy loads. When the solar array generates more power than is required, the excess is fed out into the grid where other utility customers use this solar-generated electricity. The inverter in this system is very different from the one in the off-grid system and must meet stringent utility guidelines.

The disadvantage of this system is that the inverter also shuts down in case of

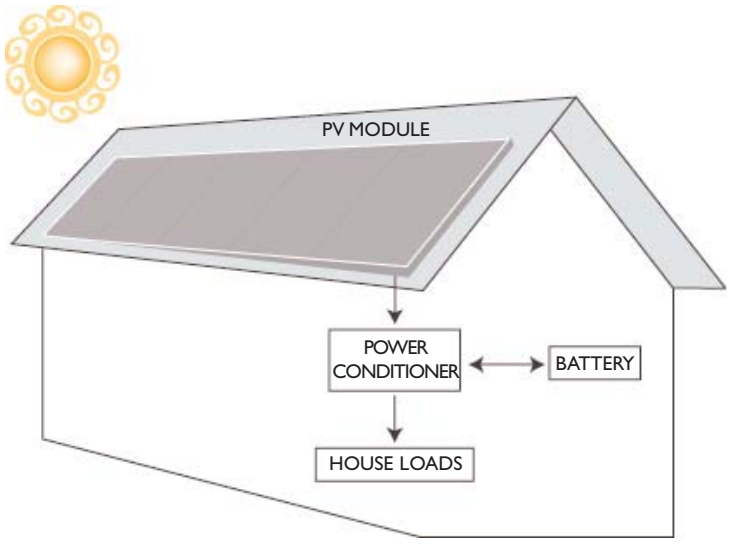

Figure 2: Off-grid PV system with battery backup

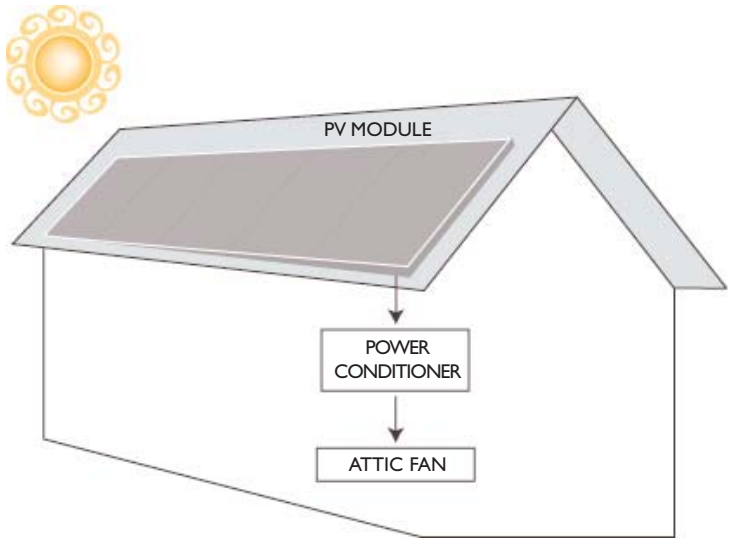

Figure 3: Off-grid PV system

power failure, for example during a lightning or ice storm. Thus, the PV system cannot provide electricity if the power goes out. This is a utility safety requirement to protect utility service employees that may be working on the power lines.

A synchronous system with batteries allows the blending of a PV with grid power, but also offers the advantage of "islanding" in case of a power failure. A synchronous system automatically disconnects the utility power from the house and operates like an off-grid home during power failures. This system, however, is more costly and loses some of the efficiency advantages of a battery-less system.

Another type of grid-connected system is referred to as an interconnected, back-up or emergency power system. The operation of this type of system is similar to the UPS (Uninterruptible Power Supply) systems that are used to protect computers from power surges and outages. An off-grid type inverter is connected between the utility power and a sub-panel that runs critical loads into the house. When utility power is available, the inverter simply passes the utility electricity directly to the loads. However, when utility power fails, the inverter automatically turns on and supplies power to the loads from a battery bank. Once utility power is restored, the inverter turns into a battery charger to recharge the batteries. By adding PV modules to charge the batteries, the system can be run indefinitely. The homeowner has the option to manually turn off the utility power to the sub-panel during sunny periods when the batteries are charged, and to go partially "off-grid."

System Design Issues

The first step in evaluating the potential of solar electricity for your home is a site assessment. PV modules are extremely sensitive to shading. Ten per cent shading of a module can reduce power output by 100 per cent. Generally, a good site will be free from shade from 9 a.m. through to 3 p.m. Year-round systems must take into consideration that during the winter months the sun is lower in the sky and tall objects, such as trees, cast longer shadows. In most cases, the ideal location for a solar array is on the roof of the house. This alleviates most shading concerns, and its large, flat surface makes mounting relatively easy. It also can reduce snow buildup in front of the modules.

Properly aiming modules for direction and tilt will maximize the energy the solar array collects; however, small variations of up to 15° in direction or tilt will not significantly affect their

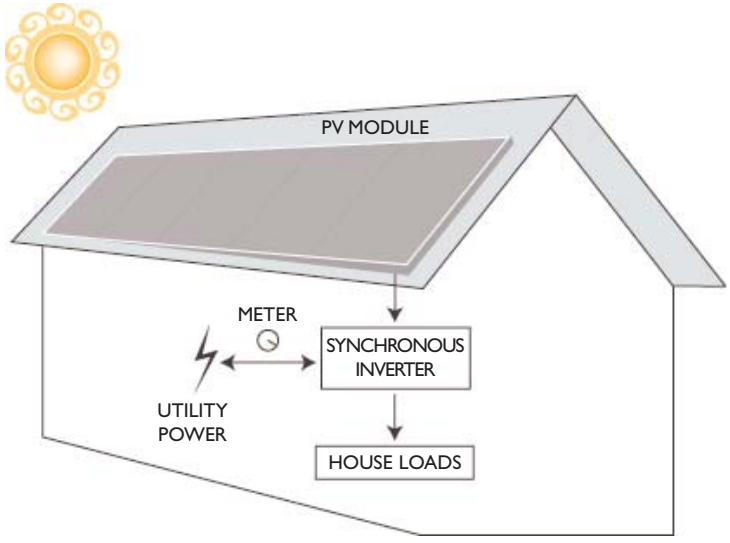

Figure 4: Grid-connected synchronous PV power system

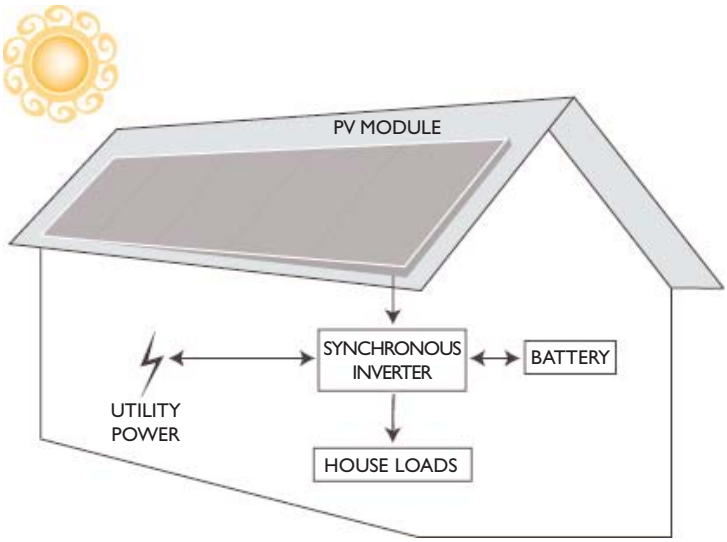

Figure 5: Grid-connected synchronous PV power system with battery backup

performance. Solar modules should face true south and be tilted so that they are perpendicular to the sun during the month of highest energy demand for off-grid applications. For grid-connected systems, a solar array tilted for maximizing energy generation during the summer will tend to supply the highest annual energy output. Installations further north will have a higher tilt angle than systems in southern Canada. For example, the optimum summer tilt in Toronto is 30°, while in Edmonton it is 40°.

Once it has been determined that solar-generated electrical energy is feasible, it is necessary to estimate the home's power and energy needs. This is a critical step for off-grid applications, as the homeowner will be relying on the solar system to provide all or most of the electricity. This step is less important for grid-connected systems as solar is being used to replace or supplement an existing source—the sizing in this case is often based on how large a system the homeowner can afford.

Energy efficiency and conservation are important measures when you generate your own electricity. It is far cheaper to save a kilowatt-hour than to produce one. Compact fluorescent lights and energy-efficient appliances will save significant sums of money when it comes to purchasing a PV system. While most homes in Canada use 20-30 kWh per day, energy-efficient homes often require only 8-12 kWh daily. A highly energy-efficient home may be able to be powered by a two-three kW solar array, while remote cottage systems typically range between 100 watts to 1.0 kW.

Adequate wall space is also required in the utility room or next to the load centre for the "solar power centre." Small systems may only require a 0.6 m x 0.9 m (2 ft. x 3 ft.) wall area, while larger systems may require a 1.21 m x 1.21 m (4 ft. x 4 ft.) space. If the system has batteries, then a separate battery enclosure will be necessary. Batteries should be kept in an insulated enclosure where the temperature is maintained between 18° to 22°C (64° to 72°F) year around. The batteries should be kept well away from open flames or sparks as they release small quantities of hydrogen when being charged. Battery enclosures should be vented to the outside with an up-sloping vent pipe so that the hydrogen can escape. For most home-sized battery banks, a 5 cm (2 in.) diameter vent is adequate.

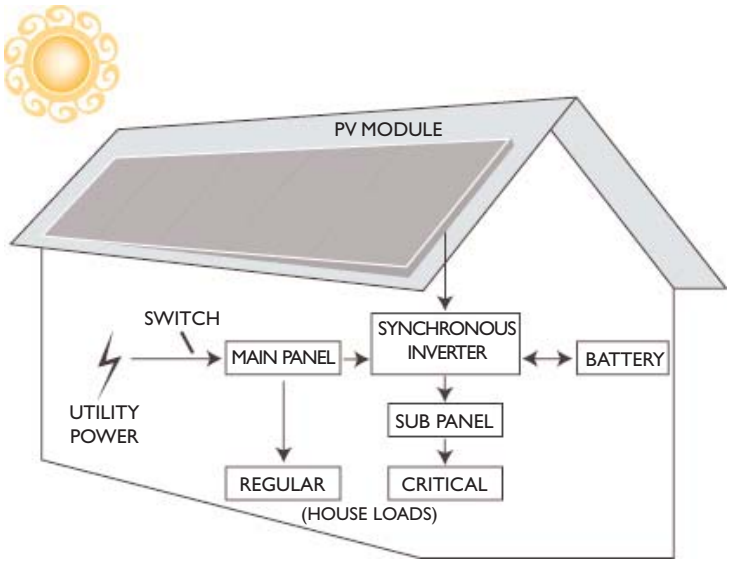

Figure 6: Grid-Interconnected PV power system with battery backup

Maximizing Performance and Assuring a Safe Installation

A PV system should be designed for maximum efficiency and cost-effectiveness. It is wise to consult a PV professional at the design stage as most dealers offer design and consultation services. Ensure that the dealer has proven experience in designing and installing the type of system you want. The Canadian Solar Industries Association (CanSIA) offers a PV Technicians certificate program, and graduates have good knowledge of the design, installation and operation of home-sized PV systems.

A good dealer will ask questions about power consumption, lifestyle and needs, and may wish to inspect the site before designing a PV system. Ask about component warranties and whether the dealer will guarantee the system. Enquire about where the products need to be sent for warranty service, and who pays for shipping costs. An inverter that fails and needs to be shipped across the country for repairs could mean that you'll be without solar power for a lengthy period—many professional dealers supply "loaners" while equipment is in for repairs.

The Canadian Electrical Code and its provincial equivalents govern installations of electric systems. In most cases equipment must be installed by a provincially certified electrician. However, many electricians are not yet familiar with the design features of solar electricity; and, while they will be able to install the system to meet the existing codes, they may be unable to maximize the PV system performance. In some jurisdictions, local electrical inspectors will allow the installation of DC equipment such as solar modules controls and batteries by non-certified electrical installers. Check if the solar dealer has an electrician on staff or subcontracts. If contracting an electrician directly, ensure that they are familiar with the design issues of PV.

To ensure that electrical systems, including PV systems, comply with the Electrical Code, the system must be inspected by the provincial Electrical Safety Authority (ESA)—your utility can supply local contact information. By having an electrical inspection done you are transferring the safety liability to the ESA and ensuring that your insurer will cover potential home liability claims.

Selection of Equipment

While safe installations of electrical systems are covered under the Canadian Electrical Code, the Canadian Standards Association (CSA) governs product safety. CSA has standards for all electrical components including solar equipment and all electrical equipment must carry an approval label. Products that are purchased outside of Canada may not have undergone the testing process that the same product goes through when brought in by a solar distributor. Furthermore, the solar industry in Canada is not large, and several small manufacturers and importers cannot afford the cost of CSA testing. Discuss this with your solar dealer and electrical inspector before proceeding to install these products—often a "Special Inspection" or extra safety measures will satisfy the requirements of your inspector.

It is important to remember that PV systems are modular, and systems can be expanded as energy needs grow or as budget allows. It is wise to anticipate future needs by purchasing larger or over-sizing wires, switch gear and controls, so that these components will not have to be replaced.

PV components have no moving parts—which keeps maintenance requirements to a minimum. Solar modules are typically warranted for 20 to 25 years, and have life expectancies exceeding 40 years. The majority of the other electronic components, such as controls and inverters, will generally last ten or more years if their ratings are not exceeded. Batteries, which are required for most off-grid applications, are the "weak-link" in the PV system. They will typically need replacement every five to ten years.

PV on the Local Utility Grid

It is difficult to justify the cost of a solar grid-connected system under the present economic situation in Canada. Nevertheless, there is a wide variety of reasons why homeowners are considering generating some portion—if not all—of their energy requirements using PV systems. PV systems provide a buffer from rising energy prices, and the presence of an on-site battery system can supply electricity during utility power outages. Solar power can also help make a difference in the way that we address our responsibilities for climate change. Finally, solar systems may be the next "status symbol," if trends appearing in Japan and Europe emerge in North America.

Utilities and their regulators in Canada are only beginning to address the issues of on-site generation where individual homeowners are their own power suppliers. Discuss the status of regulations in your utility area with your local solar supplier—in some cases utilities have not yet set up a

single point of contact for this new breed of customers, and working through the bureaucracy can sometimes seem daunting.

For grid-connected systems, on days where excess electricity is produced, it is possible to feed the electricity back to the utility through your electric meter. This is known as "net-metering." However net-metering is not yet common practice in Canada. Contact your local utility for more information on local policies and procedures. Currently most standard electric meters have not been approved for net-metering applications in Canada. A more expensive electronic meter that is approved may need to be purchased. Instead of using only one meter, a second one may be required to record how much solar energy is fed into the grid. This amount would be used to reduce your electrical bill—this is referred to as "net-billing."

If your utility is progressive they may offer "time-of-day" billing. The cost of supplying electricity is significantly lower during off-peak times, typically during the night, and time-of-day customers are billed at the true cost of electricity at the time they actually use the electricity. The economics of solar power changes significantly when time-of-day billing is applied along with net-metering. Most solar systems generate excess electricity during peak-times—when electrical generation costs can be four times or more the average cost. Currently there are no utilities in Canada that are offering both time-of-day and net-metering billing at the same time—but this may be changing.

Integrating PV into New House Construction

If you are in the process of designing a new house or doing major renovations, you may want to consider installing a PV system, or at least consider preparing your house to be "solar ready." You have an opportunity for substantially reducing costs and increasing system performance. While you may not yet be ready to invest in a solar electric system, electricity prices will likely continue to rise while concerns about the reliability of utility supply and the environment combined with decreasing costs of PV systems will make solar electricity much more viable in Canada in the near future. Preparing your house to be solar ready now, may save thousands of dollars in the near future. While doing this preparation work you may also wish to consider making your home "solar ready" for a solar domestic hot water system.

Photo 2: Attic space with BIPV roof

Orienting the house on the building lot to maximize its solar exposure and installing a roof with the correct solar pitch can maximize the performance of the PV array. Landscaping features such as trees should be considered when preparing the site—removing trees or moving the house site slightly can make a significant difference in available solar radiation. Remember that trees can grow a couple of feet per year—planting deciduous trees is preferable on the south side as they lose their leaves in winter.

Wires should be installed before interior walls are enclosed as this will reduce installation time and hide unsightly conduit. Conduit-runs through walls, for battery enclosure cables, battery vents, etc., should be done at the time of construction. It is far less expensive to put conduit in place when installing the foundation walls than to have to drill holes later.

As solar systems generate low-voltage DC power—typically 12 to 48 volts—the system wires are generally larger than normal house wiring. Minimizing distances of wire runs is an effective method of reducing costs and increasing system efficiency.

Special PV systems called Building Integrated Photovoltaic (BIPV) modules can be integrated into the house roof at the time of construction. BIPVs can be an effective method of reducing the costs of solar power as they displace other building costs such as roofing shingles or metal roofing, and do not require special roof mounting hardware.

If you are constructing a building on a large lot, then consider the construction of a "power shed." Power sheds integrate all the components of a PV system into a small building—the roof can be pointed due south with the correct tilt, while the batteries, power centre and back-up generator can be installed directly underneath. A single AC cable is then run to the distribution panel in the house. A power shed has the advantage of maximizing performance, reducing wire distances and isolating the system and batteries away from the main house.

Photovoltaics in Northern Climates

In the northern areas of Canada, there is a limited supply of viable energy sources. Traditionally, electricity in the North has been provided by very costly diesel generation, which involves high fuel transportation costs and, if a spill occurs, it can be devastating to the local environment. In these areas, PV has a great deal of potential. However, PV systems in northern locations must be technologically adaptable to withstand extreme weather conditions and to provide electricity when there are large seasonal fluctuations in solar radiation.

Final Thoughts on PVs

Photovoltaics are a unique energy source. PV systems can be used to produce on-site electricity without the need of a fuel source or connection to a central supply. For off-grid applications it is possible to start with a simple system to meet basic needs and expand as budget and/or energy demands warrant. For grid-connected systems the size of the installation does not relate directly to energy needs but rather to the way that the homeowner values the non-financial benefits of solar. The self-sufficiency inherent in PV systems is attractive to many homeowners.

Homeowners who remain connected to the local utility grid do not need extensive PV systems. Solar-powered garden lights and solar attic vents are a good start and meet specific needs, while a small emergency back-up system can provide a secure supply of electricity for furnace blowers, well pumps and basic lighting. PV systems can be upgraded as finances permit provided that such allowances are built into the initial design.

Resources

Further Reading

Photovoltaic Systems – A Buyer's Guide

This booklet is published by Natural Resources Canada (NRCan) and contains much of the information that a homeowner needs when considering to purchase a solar electric system, including system design, component selection and energy load analysis. It is available at no charge from NRCan and can be downloaded or ordered from their website at
www.canren.gc.ca/prod_serv

Photovoltaics for Buildings: Opportunities for Canada

Natural Resources Canada, CANMET Energy Technology Centre – Varennes, 2001.

Sources of Information

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