

## Solar PV systems

PV systems are most commonly used for stand-alone applications. They can be used to drive a load directly; water pumping is a good example - water is pumped during the hours of sunlight and stored for use; or a battery can be used to store power for use for lighting during the evening. If a battery charging system is used then electronic control apparatus will be needed to monitor the system. All the components other than the PV module are referred to as the balance-of-system (BOS) components. Below, in Figure 5, three possible configurations of stand-alone PV system are shown. Such systems can often be bought as kits and installed by semi-skilled labour.

For correct sizing of PV systems, the user needs to estimate the demand on the system, as well as acquiring information about the solar insolation in the area (approximations can be made if no data is readily available). It is normally assumed that for each Wp of rated power the module should provide 0.85 watt hours of energy for each kWhm<sup>-2</sup> per day of insolation. Therefore if we consider a module rated at 200 Wp and the insolation for our site is 5 kWhm<sup>-2</sup> per day (typical value for tropical regions), then our system will produce 850Wh per day (that is  $200 \times 0.85 \times 5 = 850$ ).

## Solar Basics

PV power generation systems are made up of interconnected components, each with a specific function. One of the major strengths of PV systems is modularity. As your needs grow, individual components can be replaced or added to provide increased capacity. Following is a brief overview of a typical PV system.

- ✓ **Solar Array** –The solar array consists of one or more PV modules which convert sunlight into electric energy. The modules are connected in series and/or parallel to provide the voltage and current levels to meet your needs. The array is usually mounted on a metal structure and tilted to face the sun.
- ✓ **Charge Controller** –Although charge controllers can be purchased with many optional features, their main function is to maintain the batteries at the proper charge level, and to protect them from overcharging.
- ✓ **Battery Bank** –The battery bank contains one or more deep-cycle batteries, connected in series and/or parallel depending on the voltage and current capacity needed. The batteries store the power produced by the solar array and discharge it when required.
- ✓ **Inverter** – An inverter is required when you want to power AC devices. The inverter converts the DC power from the solar array/batteries into AC power.
- ✓ **AC and DC Loads** –These are the appliances (such as lights or radios), and the components (such as water pumps and microwave repeaters), which consume the power generated by your PV array.
- ✓ **Balance of System** –These components provide the interconnections and standard safety features required for any electrical power system. These include: array combiner box, properly sized cabling, fuses, switches, circuit breakers and meters.

## Five Steps to Sizing a PV System

We have provided you with an easy-to-follow, step-by-step guide for sizing your photovoltaic (PV) system. Follow these five steps to determine your requirements and specify the components you will need.

### 1. Determine Your Power Consumption Demands

Make a list of the appliances and/or loads you are going to run from your PV system. Find out how much power each item consumes while operating. Most appliances have a label on the back which lists the wattage. Specification sheets, local appliance dealers, and the product manufacturers are other sources of information. Once you have the wattage ratings, fill out the load sizing worksheet.

### Load-Sizing Worksheet

List all of the electrical appliances to be powered by your PV system. Separate AC and DC devices and enter them in the appropriate table. Record the operating wattage of each item. Most appliances have a label on the back that lists the wattage. Local appliance dealers and the product manufacturers are other sources of this information. Specify the number of hours per day each item will be used. Multiply the first three columns to determine the watt-hour usage per day. Enter the number of days per week you will be using each item to determine the total watt-hours per week each appliance will require.

DC Appliance Watts X Qty X Hrs/Day = Wh/Day X Days/Wk = Wh/Wk

- A. \_\_\_\_\_
- B. \_\_\_\_\_
- C. \_\_\_\_\_
- D. \_\_\_\_\_
- E. \_\_\_\_\_

Total the numbers in the last column. This is your DC power requirement. Total \_\_\_\_\_

Multiply the total by 1.2 to compensate for system losses during battery charge/discharge cycle. DC WH/WK \_\_\_\_\_

### Load Sizing Worksheet

AC Appliance Watts X Qty X Hrs/Day = Wh/Day X Days/Wk = Wh/Wk

- A. \_\_\_\_\_
- B. \_\_\_\_\_
- C. \_\_\_\_\_
- D. \_\_\_\_\_
- E. \_\_\_\_\_

Total the numbers in the last column. This is your AC power requirement. Total \_\_\_\_\_

Multiply the total by 1.2 to compensate for system losses during battery charge/discharge cycle. AC WH/WK \_\_\_\_\_

1. Add AC WH/WK and DC WH/WK together. This is your total power requirement per week. Total \_\_\_\_\_
2. Enter the voltage of your battery bank (usually 12 or 24 volts) VOLTS \_\_\_\_\_
3. Divide line 1 by line 2. This is your amp-hour requirement per week. AH/WK \_\_\_\_\_
4. Divide line 3 by 7 days. This is your average amp-hour requirement per day that will be used to size your battery bank and your PV module array. AH/DAY \_\_\_\_\_

## 2. Optimize Your Power System Demands

At this point, it is important to examine your power consumption and reduce your power needs as much as possible. (This is true for any system, but it is especially important for home and cabin systems, because the cost savings can be substantial.) First identify large and/or variable loads (such as water pumps, outdoor lights, electric ranges, AC refrigerators, clothes washers, etc.) and try to eliminate the more examine alternatives such as propane or DC models.

The initial cost of DC appliances tends to be higher than AC, but you avoid losing energy in the DC to AC conversion process, and typically DC appliances are more efficient and last longer. Replace incandescent fixtures with fluorescent lights wherever possible.

Fluorescent lamps provide the same level of illumination at lower wattage levels. If there is a large load that you can not eliminate, consider using it only during peak sun hours or only during the summer. (In other words, be creative! ) Revise your Load Sizing Work sheet now with your optimized results.

## 3. Size Your Battery Bank

Read “Characteristics of Batteries” and then choose the appropriate battery for your needs. Fill out the Battery Sizing Worksheet.

### Characteristics of Batteries

#### Sizing Your Battery Bank

The first decision you need to make is how much storage you would like your battery bank to provide. Often this is expressed as “days of autonomy,” because it is based on the number of days you expect your system to provide power without receiving an input charge from the solar array. In addition to the days of autonomy, you should also consider your usage pattern and the criticality of your application. If you are installing a system for a weekend home, you might want to consider a larger battery bank, because your system will have all week to charge and store energy. Alternatively, if you are adding a PV array as a supplement to a generator-based system, your battery bank can be slightly undersized since the generator can be operated if needed for recharging.

#### Temperature Effects

Batteries are sensitive to temperature extremes, and you cannot take as much energy out of a cold battery as a warm one. Use the chart on the Battery-Sizing Worksheet to correct for temperature effects. Although you can get more than rated capacity from a hot battery, operation at hot temperatures will shorten battery life.

Try to keep your batteries near room temperature. Charge controllers can be purchased with a temperature compensation option to optimize the charging cycle at various temperatures and lengthen your battery life.

#### Depth of Discharge

Depth of Discharge is the percentage of the rated battery capacity that is withdrawn from the battery. The capability of a battery to withstand discharge depends on its construction. Two terms, shallow-cycle and deep-cycle, are commonly used to describe batteries. Shallow-cycle batteries are lighter, less expensive and have a short lifetime. For this reason, we do not sell shallow-cycle batteries. Deep-cycle batteries should always be used for stand-alone PV systems. These units have thicker plates and most will withstand daily discharges up to 80% of their rated capacity. Most deep-cycle batteries are flooded electrolyte which means the plates are covered with the electrolyte and the level of fluid must be monitored and distilled water added periodically to keep the plates fully covered. We also offer sealed, lead-acid batteries that do not require liquid refills. There are other types of deep-cycle batteries such as nickel cadmium used in special applications. The maximum depth of discharge value used for sizing should be the worst case discharge that the battery will experience. The system control should be set to prevent discharge below this level.

#### Rated Battery Capacity

The ampere-hour capacity of a battery is usually specified together with some standard hour reference such as ten or twenty hours. For example, suppose the battery is rated at 100 ampere-hours and a 20-hour reference is specified. This means the battery is fully charged and will deliver a current of 5 amperes for 20 hours. If the discharge current is lower, for example 4.5 amperes, then the capacity will go to 110 ampere-hours. The relationship between the capacity of a battery and the load current can be found in the manufacturer’s literature.

#### Battery Life

The lifetime of any battery is difficult to predict, because it is dependent on a number of factors such as charge and discharge rate, depth of discharge, number of cycles and operating temperature extremes. It would be unusual for a lead-acid battery to last longer than fifteen years in a PV system but many last for five to eight years.

#### Maintenance

Batteries require periodic maintenance. Even the sealed battery should be checked to make sure connections are tight and there is no indication of overcharging. For flooded batteries, the electrolyte level should be maintained well above the plates and the voltage and specific gravity of the cells should be checked for consistent values. Wide variations between

readings may indicate cell problems. The specific gravity of the cells should be checked with a hydrometer particularly before the on set of winter .In cold environments ,the electrolyte in lead-acid batteries may freeze. The freezing temperature is a function of a battery state of charge .When a battery is completely discharged, the electrolyte becomes water and the battery may freeze.

**Battery Sizing Worksheet**

1. Enter your daily amp-hour requirement. (From the Load Sizing Worksheet, line4) AH/Day

2. Enter the maximum number of consecutive cloudy weather days expected in your area, or the number of days of autonomy you would like your system to support.

3. Multiply the amp-hour requirement by the number of days. This is the amount of amp-hours your system will need to store. AH

4. Enter the depth of discharge for the battery you have chosen. This provides a safety factor so that you can avoid over-draining your battery bank.(Example: If the discharge limit is 20%, use 0.2.) This number should not exceed 0.8.

5. Divide line 3 by line 4. AH

6. Select the multiplier below that corresponds to the average wintertime ambient temperature your battery bank will experience. Ambient Temperature Multiplier  
 80F 26.7C 1.0070F 21.2C 1.0460F 15.6C 1.1150F 10.0C 1.1940F 4.4C 1.3030F -1.1C 1.4020F -6.7C 1.59

7. Multiply line 5 by line 6. This calculation ensures that your battery bank will have enough capacity to overcome cold weather effects. This number represents the total battery capacity you will need. AH

8. Enter the amp-hour rating for the battery you have chosen.

9. Divide the total battery capacity by the battery amp-hour rating and round off to the next highest number. This is the number of batteries wired in parallel required.

10. Divide the nominal system voltage (12V, 24V or 48V) by the battery voltage and round off to the next highest number. This is the number of batteries wired in series.

11. Multiply line 9 by line 10. This is the total number of batteries required.

## 5. Size Your Array

1. Enter your daily amp-hour requirement (from your Load Sizing Worksheet, line 4) AH/Day
2. Enter the sun-hours per day for your area. Refer to chart. H/Day
3. Divide line 1 by line 2. This is the total amperage required from your solar array.
4. Enter the peak amperage of the solar module you have selected Peak A
5. Divide line 3 by line 4. This is the number of solar modules needed in parallel.
6. Select the required modules in series from the following chart.

Battery Bank Voltage No. of Modules in Series 12V 1 24V 2 48V 4

1. Multiply line 5 by line 6 to find the total number of modules needed in your array. Total \_\_\_\_\_
2. Enter the nominal power rating (in watts) of the module you have chosen. W \_\_\_\_\_
3. Multiply line 7 by line 8. This is the nominal power output of your system. W \_\_\_\_\_