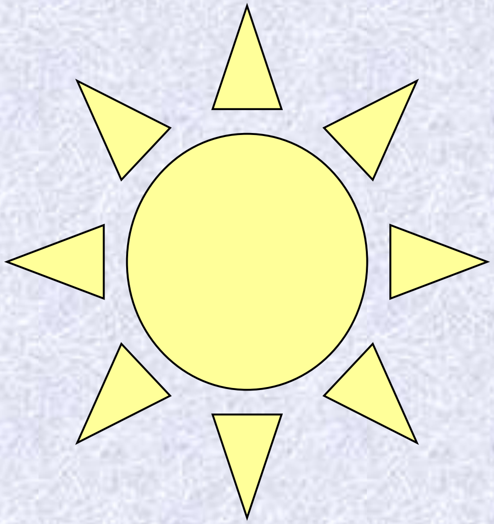
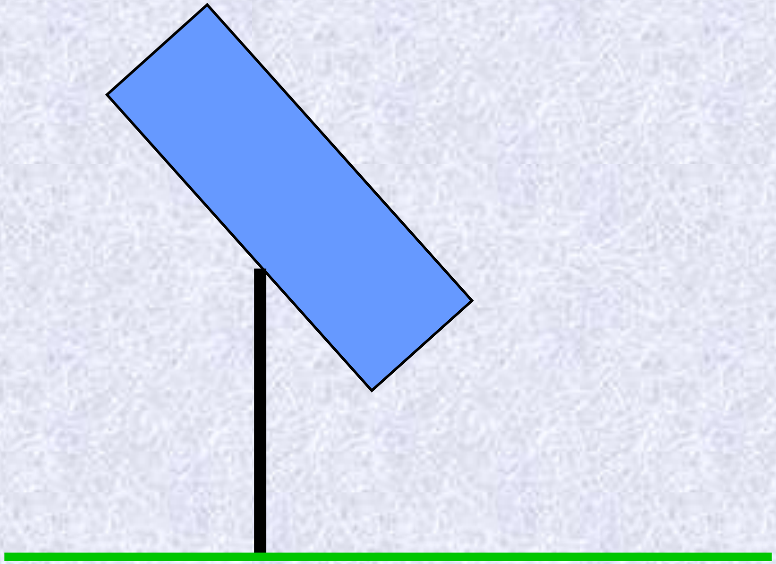


Designing a PV System



BP 0403

In practice, designing a PV system depends if it is off-grid or grid-tied.

Off-grid systems require a rigorous design, often with several iterations to optimize the number of modules, batteries, and stand-by generators, if necessary, to minimize system costs. Loads must be carefully calculated.

Grid-tied systems generally are sized by one of two methods:

a. How big of a system is possible with the available budget, i.e. budget constrained.

b. How big of a system is possible given a limited area, i.e. area constrained.

NOTE: Systems rarely are large enough to match the load. Approach (a) is generally used. Also, the PV industry is marketing pre-engineered packages of varying sizes.

Grid-Tied:
Design limited by budget

Grid-Tie Design

Assuming approach (a), i.e. the budget determines the system size, newly available internet based software may be used. Most of these are based on NREL's PVWATTS or the Clean Energy Calculator as well as pre-engineered systems.

Internet Sites based on Clean Power Estimator:

a. www.bpsolar.com
    - BP Solar Home Solutions, "Click Here" X 2
        - Solar Savings Estimator

b. www.kyocera.com
    - Tech Support
        - PV Calculator

c. www.uni-solar.com
    - Build Your Own Clean Energy System "ICON"

Internet Site for PVWATTS:

http://rredc.nrel.gov/codes_algs/PVWATTS/

Where pre-engineered systems are not available, the basic design procedure is to:

1. Choose an inverter(s) to match the desired Voltage and phases at the load (120/240/208/1 or 3 phase)
2. Choose a module to match the inverter specs (Internet Site for matching inverters and modules: www.sma-america.com String Sizing)
3. Decide if tracking desired
4. Determine system schematic
5. Determine mounting system (ground, roof, pole)
6. Size wiring and fusing per NEC
7. Size combiner box, DC and AC disconnects, etc.

Other good websites and sources (not exhaustive):

- www.shell.com/solar (modules)
- www.evergreensolar.com
- www.firstsolar.com
- www.astropower.com
- www.solardepot.com (dealer)
- www.sunwize.com
- www.schottappliedpower.com
- www.xantrex.com (inverters)
- www.trojanbattery.com (typical batteries)

Other good sites (cont.):

- www.powerlight.com (BIPV)
- www.wattsun.com (trackers)
- www.unirac.com (frames)
- www.rooftrac.com
- www.powerpod.com (packaged remote power)
- www.eren.doe.gov/PV (U.S. Govt research)
- www.nrel.gov/photovoltaics
- www.ases.org (American Solar Energy Society)
- www.solarelectricpower.org (Solar Electric Power Association)
- www.seia.org (Solar Energy Industries Assoc)
- www.solarcooking.org (Solar Cooking – GREAT non-profit, socially responsible)

Other good sites (cont.):

- www.mrsolar (typical catalog)
- www.pvportal (International Info)
- www.solarpathfinder.com (Design tool)
- www.raydec.com/daystar
- www.solarenergy.org (education)
- www.the-mrea.org
- www.fsec.ucf.edu
- www.homepower.com (also magazine)

Other good sites (cont.):

www.dsireusa.org (State incentives)
www.irecusa.org (Interconnection by state)
www.energy.gov (Additional Govt sites)
www.eere.energy.gov
www.eere.energy.gov/femp.html/srg
www.eere.energy.gov/greenpower/

Note: Many of these websites have links to other good sources. Try navigating them………

Off-Grid Design

Off-Grid Design Example

Step 1: Determine the DC Load.

DC Device	Device Watts	X	Hours of Daily Use	=	DC Watt-Hrs per Day
Refrigerator	60		24		1,440
Lighting fixtures	150		4		600
Device A	12		8		96
	Total DC Watt-hrs/Day [A]				2,136

Step 2: Determine the AC Load, Convert to DC

AC Device	Device Watts	X	Hours of Daily Use	=	AC Watt-Hrs per Day
Device B	175		6		1,050
Pump	80		0.5		40
Television	175		2		350

Total AC Watt-hrs/Day 1,440

Divided by 0.85 (Inverter, losses)

Total DC Whrs/Day [B] 1,694

Step 3: Determine the Total System Load

Total DC Loads [A]	2,136
Total DC Loads [B]	1,694
Total System Load	3,830 Whrs/Day

Step 4: Determine Total DC Amp-hours/Day

Total System Load / System Nominal Voltage =
(3,830 Whrs/Day) / 12 Volts = 319 Amp-hrs/Day

Step 5: Determine Total Amp-hr/Day with Batteries

--See note on Step 11--

Total Amp-hrs/Day X 1.2(Losses and safety factor)
319 Amp-hrs/Day X 1.2 = 382.8 or 383 Amp-hrs/Day

Step 6: Determine Total PV Array Current

Total Daily Amp-hr requirement / Design Insolation*
383 Amp-hrs / 5.0 peak solar hrs = 76.6 Amps

* Insolation Based on Optimum Tilt for Season

Step 7: Select PV Module Type

For example, choose BP Solar-Solarex MSX-60 module:
Max Power = 60 W (STP)
Max Current = 3.56 Amps
Max Voltage = 16.8 Volts
Nominal Output Voltage 12 Volts

Step 8: Determine Number of Modules in Parallel

Total PV Array Current / (Module Operating Current) X (Module Derate Factor)

76.6 Amps / (3.56 Amps/Module)(0.90) = 23.90 modules

Use 24 Modules

Step 9: Determine Number of Modules in Series

System Nominal Voltage / Module Nominal Voltage

12 Volts / (12 Volts/module) = 1 Module

Step 10: Determine Total Number of Modules

Number of modules in parallel X Number of modules in Series

24 X 1 = 24 modules

Step 11: Determine Minimum Battery Capacity*

[Total Daily Amp-hr/Day with Batteries (Step 5) X Desired Reserve Time (Days)] / Percent of Usable Battery Capacity

(383 Amp-hrs/Day X 3 Days) / 0.80 = 1,436 Amp-hrs

Step 12: Choose a Battery

Use an Interstate U2S – 100 Flooded Lead Acid Battery
Nominal Voltage = 6 Volts
Rated Capacity = 220 Amp-hrs

*Note: This step may be done with Step 5 if it is desired to fully charge the batteries (with reserve time) in one day with the PV. This strategy will require **more** modules.

Step 13: Determine Number of Batteries in Parallel

Required Battery Capacity (Step 11) / Capacity of Selected Battery

1,436 Amp-hrs / (220 Amp-hrs/Battery) = 6.5

Use 6 Batteries

Step 14: Determine Number of Batteries in Series

Nominal System Voltage / Nominal Battery Voltage

12 Volts / (6 Volts/Battery) = 2 Batteries

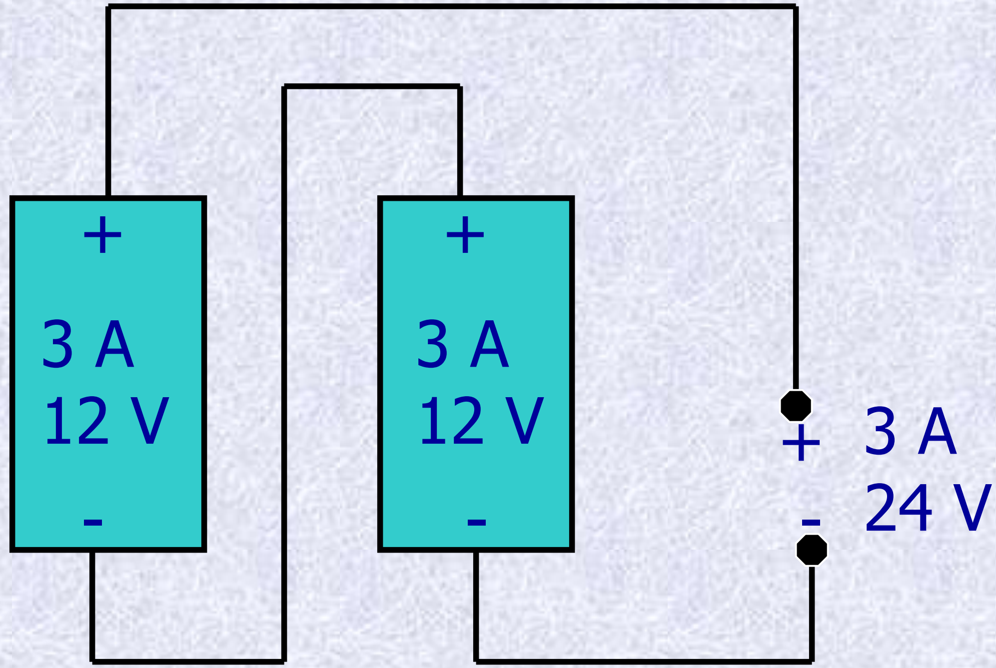
Step 15: Determine Total Number of Batteries

Number of Batteries in Parallel X Number of Batteries in Series

6 X 2 = 12 Batteries

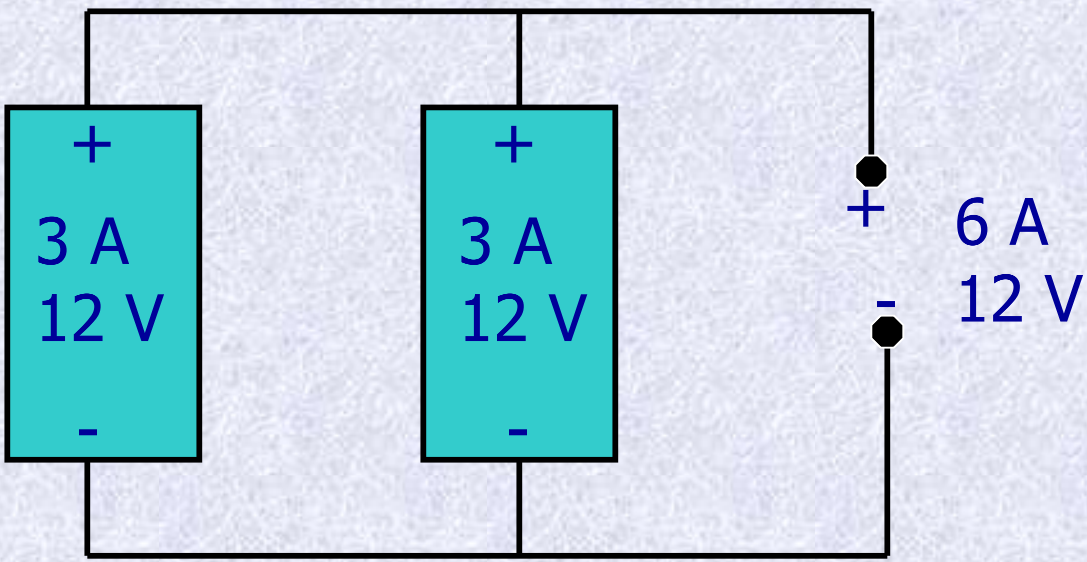
Series:

Voltage is additive



Parallel:

Current is additive



BP 0403

Step 16: Determine the need for a Standby Generator to reduce other Components (number of Modules and Batteries). Several iterations may be necessary to optimize costs.

Step 17: Complete Balance of System

a. Complete the design by specifying the:
- Charge Controller
- Inverter
- Wire Sizes (Battery will have larger gage due to higher currents)
- Fuses and Disconnects
- Standby Generator, if needed
- Battery Charger, if needed
- Transfer Switch, if needed.

Step 17 (Cont.):

b. Determine mounting method:
- Roof mount
- Ground mount with racks
- Ground mount with pole.

c. Assure proper grounding for safety.

d. Obtain permits as required.

The Elegance of Simplicity