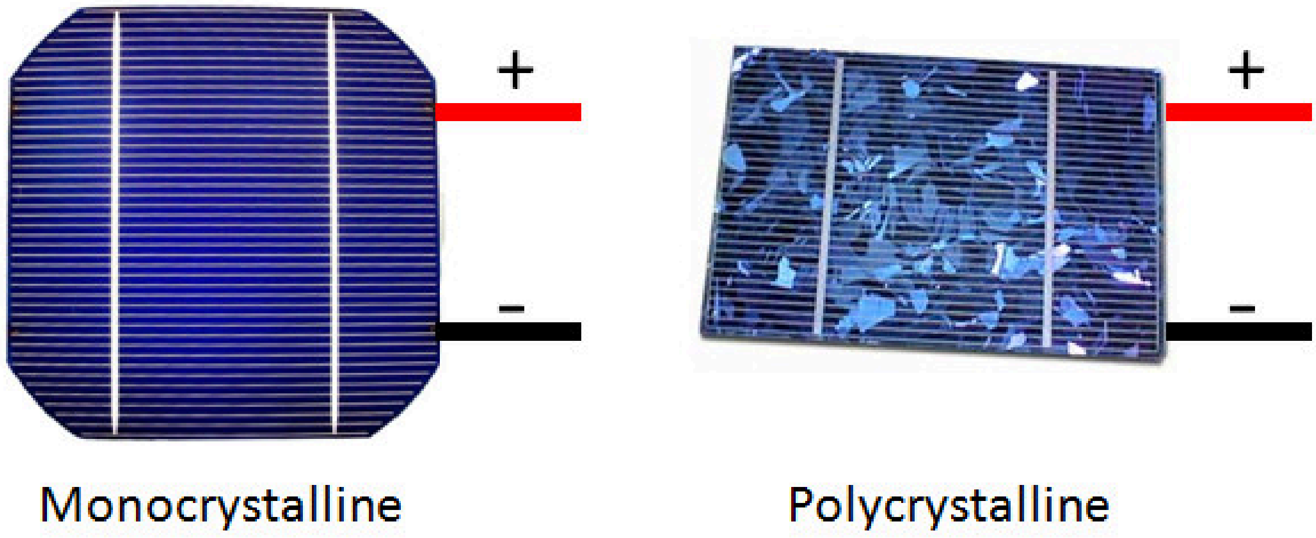
Introduction to Solar Photovoltaic Electric Power

Discovered in the 1880s, solar photovoltaic (PV) electric power is the conversion of sunlight into electricity. Modern PV cells are capable of converting up to 15% of the sun’s energy into DC electric power. Sunlight provides roughly 100 watts per square foot to the earth’s surface, so on a clear day a 1-square foot PV panel can produce about 15 watts. A 10 square foot panel therefore can produce about 150 watts in ideal conditions.

The Photovoltaic Cell

There are two main types of silicon cells commonly sold; monocrystalline and polycrystalline. Monocrystalline is slightly more efficient and therefore is slightly more expensive. Both types are very good.



Acts like a 0.5V battery
The current flow changes with the amount of sun hitting the cell

Open Circuit Voltage (Voc)	= ~ 0.625 Vdc
Maximum Power Voltage (Vmp)	= ~ 0.5 Vdc
Maximum Power Current (Imp)	= ~ 8.0 Amps
Maximum Short Circuit Current (Isc)	= ~ 8.5 Amps
Optimum Power = Vmp x Imp (Pmax)	= ~ 4 watts

The electrical terms shown above are important to understand. They are used to describe performance at the PV cell, PV panel, and PV system levels. The basic point however is to realize that a PV cell acts very much like a battery when the sun is shining on it. It has a fairly steady voltage (Vdc) but the current (Idc) varies based on the intensity of the light. Voltage and current are needed to produce power.

The Photovoltaic Panel

A PV panel is made up of a series of PV cells. The term “series” means that the cells are connected in a way that allows the voltage to increase at a desired operating level, much like connecting multiple batteries together for a radio. If you took apart a 9V battery you would see they are made up of six small 1.5V batteries wired in “series.” The same method is used for PV panels.

There are basically 4 classes of PV panels

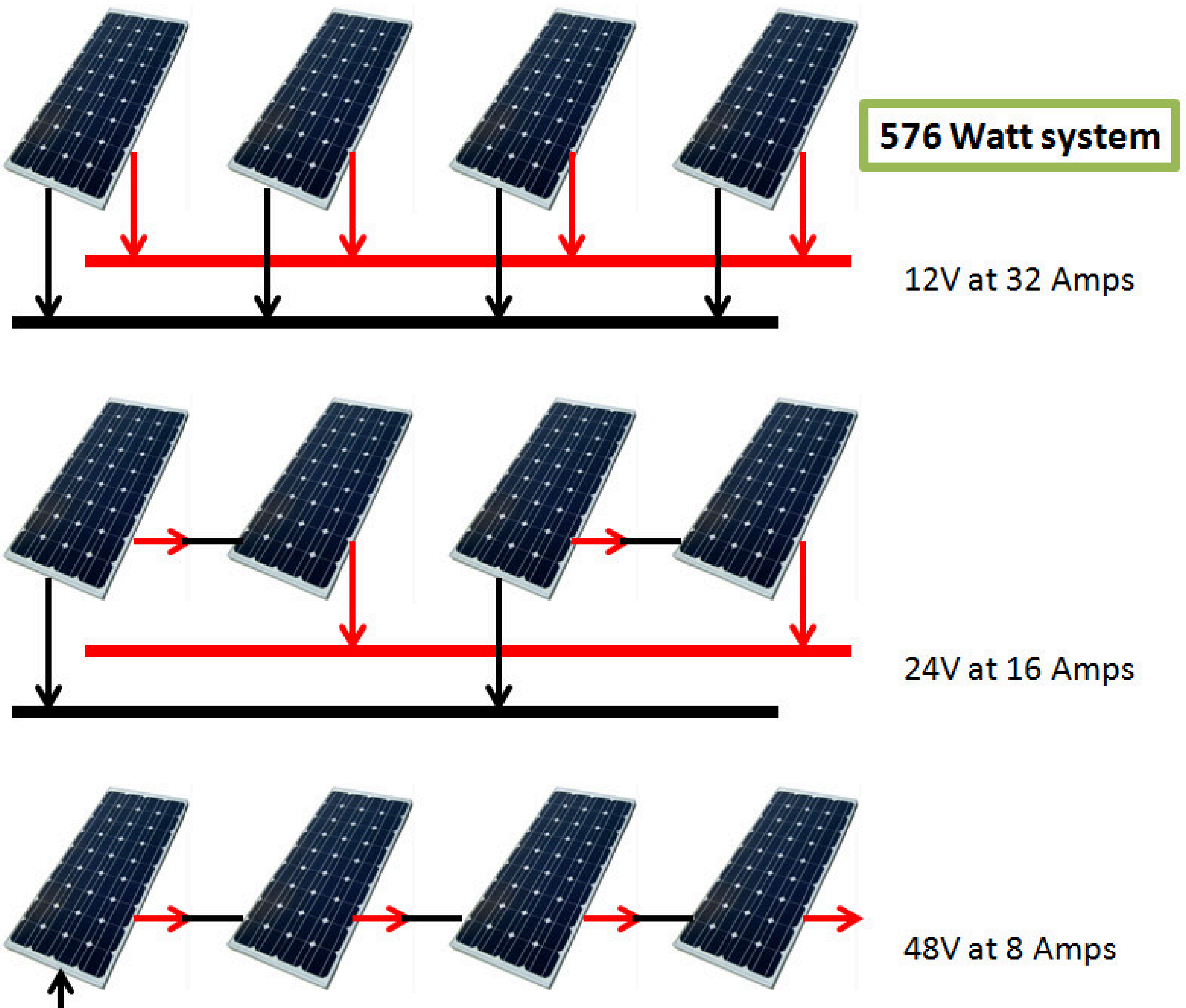
- Less than 12V – used for powering or charging small devices like radios and cell phones
- 12V panels/36 cells – used mainly to charge 12V battery systems (as above)
- 24V panels/72 cells – used mainly to charge 24V battery systems
- Greater that 24V – used for large battery systems and grid-tied systems

Modern PV panels use a standard connector called MC4. These are a 4th generation connector that allows easy interconnects between PV panels. There is a POSITIVE and a NEGATIVE connector, and lead for each from each panel. Hobbyists can buy MC4s and put them together themselves.

A typical OFF-GRID Solar Photovoltaic system

Let’s examine a case in which there are four 12V solar panels. There are three main configurations possible:

1. 12V system for 12V battery charging – Place all four panels in parallel
2. 24V system for 24V battery charging – Place two panels in series and connect this set in parallel with an identical second set of two panels in series
3. 48V system for 48V battery charging – Place all four panels in series



Note that for all three configurations the wattage is the same but the voltage and current are different. The choice of which voltage to operate at mainly involves the investment you will make in a DC-to-AC inverter. If you need a lot of power inverted, the higher voltage configurations are likely what you need as 12V inverters are limited in their wattage capability.

The other consideration is line losses. The higher the amps the more losses there will be, so operating at 24 or 48 volts is smart in order to minimize your line losses (This will be discussed in more detail later). The discussion will focus on a 24V system.

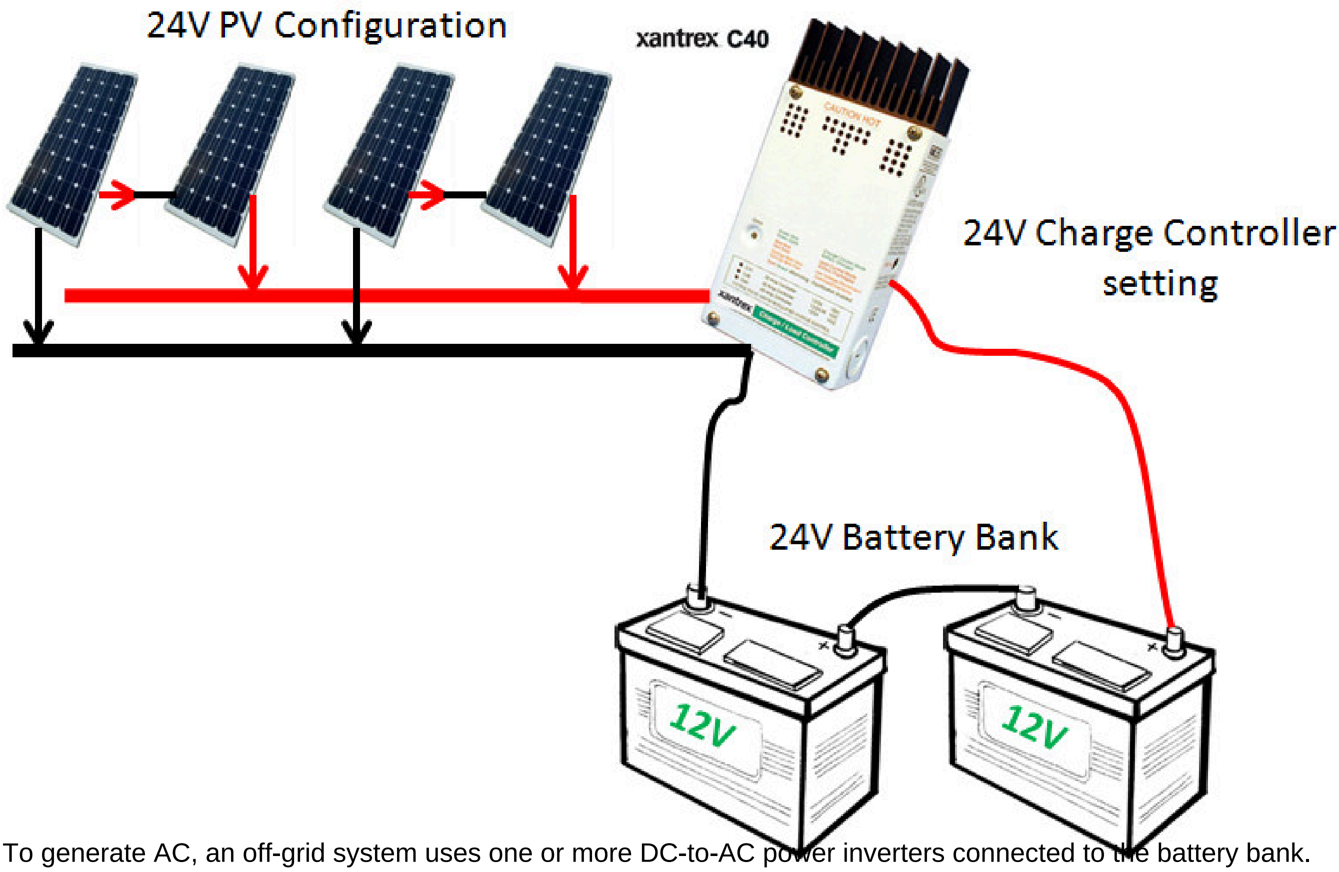
Next, we need a ***Charge Controller***. A charge controller's job is to charge the battery bank but not allow it to become overcharged. Overcharging a battery bank can result in damage to the battery bank as well as introduce a safety hazard.

There are three basic charge controller types:

1. **Direct connect controllers** – Feed the raw current from the PV panels to the battery and simply disconnect the PV panels once the charge controller determines the battery bank is full. The main disadvantage of this type is that it limits the PV to operate at a voltage just a bit higher than the battery level rather than at the optimum voltage (Vmp) the panels are designed for. As a result, the panels only produce about 75% of what they are capable of. The main advantage is that they are low cost. A typical direct connect controller is the Coleman C40.
2. **Pulse Width Modulated (PWM) Controllers**– These vary greatly in capability, but generally they provide a degree of smart charging over what a direct charger provides. They still have the problem of not allowing

the maximum power the PV panels have available to be used. A typical PWM charge controller is the Xantrex C40.

3. **Maximum Power Point Tracking (MPPT)** – These units not only permit the PV panels to operate at maximum capability, but also manage the battery charging and maintenance processes more effectively. Typical MPPT charge controllers include: the Blue Sky Solar Boost, the Morningstar Tristar 60 MPPT, and the Outback Flexmax 60. Some advanced MPPT charge controllers also connect to the grid or to a generator to charge the battery bank if the batteries get too low due to weak sun or heavy battery use.



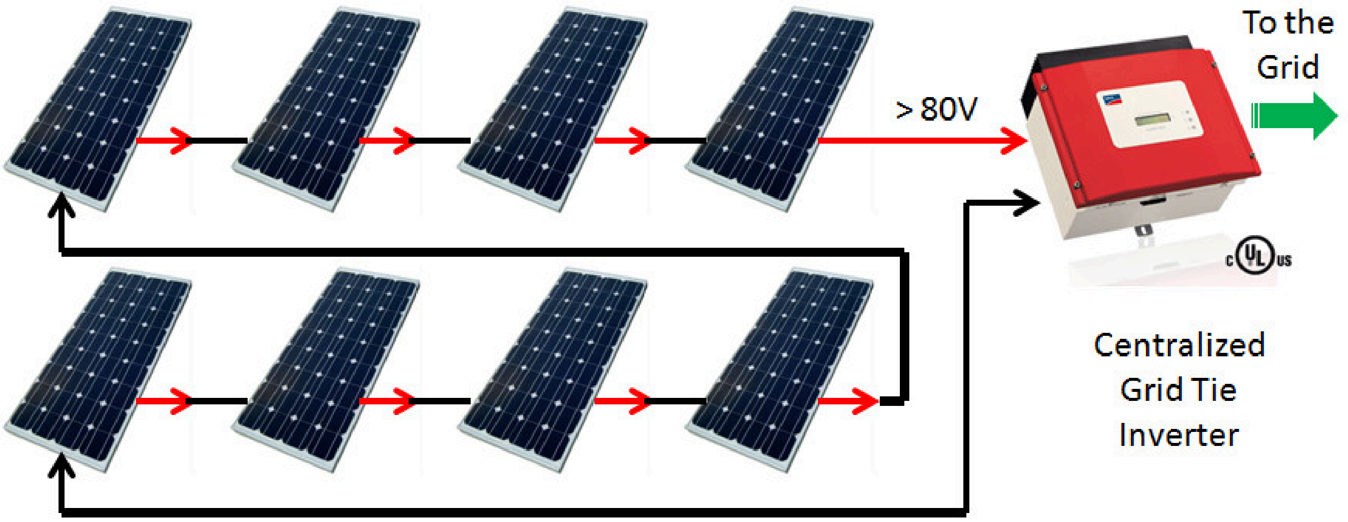
To generate AC, an off-grid system uses one or more DC-to-AC power inverters connected to the battery bank. These tend to be on all the time to run the home. Typical quality ones are from AIMS and XANTREX, which you can read about separately.

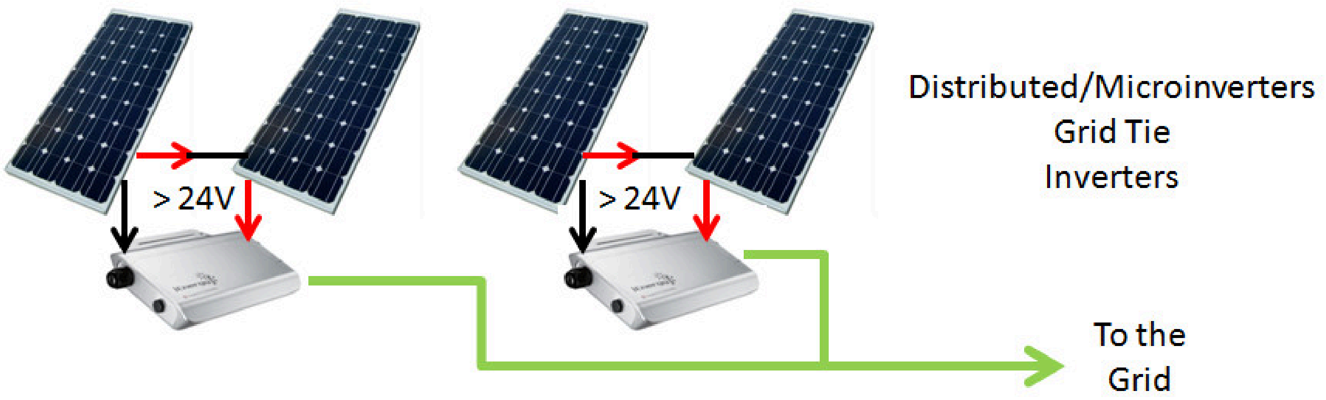
A typical ON-GRID Solar PV system

The goal of an ON-GRID PV system is to slow down, stop, or reverse the utility meter by feeding all of the PV watts through a device called a Grid Tie Inverter (GTI). There are mainly 2 types of GTIs:

1. Centralized – One unit that grid ties the power from an entire PV array.
2. Distributed (microinverters) – One unit per PV panel or pair of PV panels.

Because we are feeding high voltage AC into the grid, it is important to use an Underwriters Laboratories (UL) certified unit. These can be expensive, but are required by local building codes.





The main advantage of the centralized system is the ability to add panels more economically. The disadvantage is that if any one panel is weak or shaded it will significantly reduce the power sent to the grid.

The main advantage of the distributed/microinverter system is that each panel or pair of panels are managed independently, and are not impacted by shading that might be happening with other panels. The disadvantage is that a single microinverter can cost the same as a PV panel making the overall cost higher.

Hybrid ON/Off-GRID Solar PV system

A hybrid system involves a combination of the two systems described above. The goal of a Hybrid system is to keep a bank of batteries fully charged for use as back-up power in case a grid power outage occurs, while also feeding the grid in normal conditions to lower the overall energy costs for the home. This type system will not be described here.

Introduction Summary

The above information and diagrams describe the very basic aspects and layouts of PV systems. There are many details that need to be understood as well as many more components that are required in order to make a safe and complete system. The following sections will address many of these areas.

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