SOLAR ELECTRIC SYSTEM BASICS

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SOLAR ELECTRIC BACKGROUND

The most common method of producing electricity using solar energy is to use photovoltaic cells, often called solar cells. Solar cells produce an electrical current when exposed to sunlight. A typical solar cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a solar cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load.

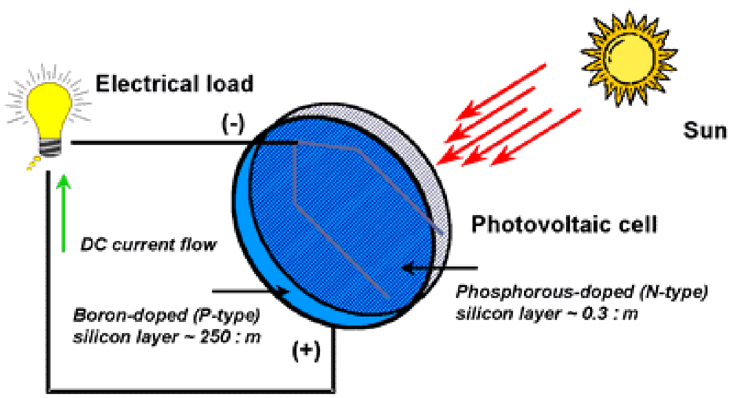

Diagram of a photovoltaic cell. *

SOLAR CELL TYPES

There are three common types of solar cells in use today.

Monocrystalline

Monocrystalline solar cells are made from single large crystals, cut from ingots. These cells are the most efficient, but also the most expensive. They generally perform somewhat better in low light conditions.

Polycrystalline

Polycrystalline solar cells are basically cast blocks of silicon which may contain many small crystals. They are sometimes called multicrystalline and are probably the most common type in use now. They are slightly less efficient than single crystal cells, but are generally considered to perform better than monocrystalline in partial shade conditions.

Amorphous

Amorphous, or "thin film" solar cells, are large plates, typically of stainless steel onto which silicon is spread directly. They cost less to produce, but are often much less efficient, which means larger panels are required the same power output obtained from monocrystalline or polycrystalline cells

SOLAR ELECTRIC SYSTEM COMPONENTS

(1) Solar Panel – Each individual solar cell produces about 0.5 – 0.6 volts of direct current ("DC"). Multiple solar cells are grouped together to form a solar panel. The voltage rating of a solar panel is determined by the number of individual solar cells wired together in series. For example, a panel composed of 32 solar cells would have a voltage of approximately 16 – 19 volts DC. The electric power (or wattage) of a solar panel depends both on the voltage (number of cells) and the size of each cell. The larger the cell size, the greater the current (measured in amperes) the cell can produce. Wattage of the panel is determined by multiplying the panel's voltage by its amperage.

(2) Solar Array -- To produce enough usable power, multiple solar panels are wired together to form a solar array. For example, ten 120-watt solar panels would form a 1,200-watt (1.2 KW) array.

(3) Inverter – Inverters convert the DC electrical current produced by a solar array into alternating current ("AC") that is utilized on the electrical grid and in most homes and business in the U.S. today. Modern inverters also perform a variety of safety and power conditioning functions and are sometimes called power conditioning units ("PCU"). Inverters designed to interface with the electrical grid will automatically and instantly shut down the solar should the grid lose power. Such inverters also match the AC frequency produced by the solar electric system with the 60 cycle ("Hz") frequency on the grid.

(4) Battery Bank – Of course, solar electric systems only produce power during sunlight conditions. Some type of electrical energy storage is required if the energy is to be used at some later period, i.e. at night or periods of low or no sun. Batteries remain the most common type of energy storage currently used in solar electric systems.

(5) Charge Controller – Charge controllers control the state of charge of the battery bank. Modern charge controllers also perform a variety of other functions designed to keep batteries at maximum state of charge, prevent batteries from being discharged too deeply, and prolonging battery life. Some modern inverters have a built-in charge controller.

BASIC SOLAR ELECTRIC SYSTEM TYPES

There are a wide variety of solar electric systems. In net metering applications, the two most common types are line tie (with direct grid connection) and line tie with battery backup.

Line Tie Systems (net metering only)

Line tie (Net metering only) systems consist of photovoltaic panels, the panel mounting system, inverter (line-tie only), AC & DC disconnects and related wiring.

Line tie systems are designed to operate in parallel with the electric utility grid. They are the simplest and least costly system. Other than the solar panels themselves, the primary component in grid-connected solar electric systems is the inverter. The inverter converts the DC power produced by the solar array into AC power consistent with the power quality requirements of the utility grid, such as maintaining a constant voltage and frequency. The inverter also will shut down the solar should the grid lose power. A bi-directional interface is made between the solar electric system AC output circuits and the electric utility grid, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the solar electric system to either supply on-site electrical loads or to back-feed the grid when the solar electric system output is greater than the on-site electrical load. At night and during other periods when the electrical loads are greater than the solar electric system output, the balance of power required by the loads is received from the electric utility grid.

Pictured above is one of the 10 net metering solar energy systems recently installed in the Ninth Ward in New Orleans by Sharp Solar. The 1.5 KW (1,500 watt) solar array is composed of eight separate solar panels.

Pictured from left to right are the following solar electric system components of a grid tie system. 1) solar array manual disconnect (code required), 2) inverter, 3) A/C manual disconnect (required by net metering regulations), 4) distribution panel and 5) utility meter.

The industry average installed cost of line-tie systems is $8 to $10 per watt. Using a cost of $8.50 per watt, a 1 kW (1,000 watt) system would cost $8,500 and a 10 kW (maximum residential size allowed by net metering regulations) would cost $85,000.

Line tie solar electric systems do not provide back up or emergency power to homes or offices since they have no energy storage and, as a safety feature, automatically shut down whenever power is lost on the electrical grid.

Line Tie (net metering) with Battery Backup Systems

Net metering with battery backup systems consists of photovoltaic panels, the panel mounting system, inverter (line-tie with battery backup), charge controller, energy storage (usually batteries), AC & DC disconnects and related wiring.

A line tie with battery backup system also provides emergency power through some type of energy storage. Batteries are typically used to provide such storage. The battery technology and the size of the battery bank vary greatly and are dependent on a number of factors including cost, size of the electrical load, the regularity of use and the design maximum duration of use. This type of system is popular for homeowners and small businesses that require a backup power supply for critical loads such as refrigeration, computers, lighting, and other necessities. Under normal circumstances, the system operates in grid-connected mode, serving the on-site loads or sending excess power back to the grid while keeping the battery bank fully charged. In the event the grid becomes de-energized, control circuitry in the inverter opens the connection with the utility through a bus transfer mechanism, and feeds the inverter from the battery to supply power to critical loads only. In this configuration, the critical loads must be supplied from a dedicated sub panel so as to insure that only the critical load is served and battery capacity is not wasted on non-critical loads.

The cost of line tie systems with battery backup vary greatly depending on the battery technology and size of battery bank installed. As a general rule, the addition of a battery bank and charge controller to a line tie system will increase system cost by $2 to $10 per watt. Thus, the 10 kW, $85,000 line tie system described above could double in cost by adding battery backup. The addition of a battery bank will also affect long-term economics since a battery requires on-going maintenance and occasion replacement.


Typical residential battery bank.

Typical small commercial battery bank.

Stand Alone Alternating Current (AC) Systems

Stand alone AC systems consist of photovoltaic panels, a panel mounting system, inverter (not able to tie to electrical grid), charge controller, energy storage (usually batteries), AC & DC disconnects and related wiring. Often times, the system includes a small gas or diesel generator for extended no-sun periods or to recharge the batteries when they fall below a 60 to 80 percent depth of discharge, at which time they can be damaged.

Stand alone systems are used in remote areas where the electric grid is either non-existent or to expensive to maintain. Stand alone systems are not typically designed to handle major air conditioning loads and require that the home be very energy efficient. Stand alone systems are comparably priced with line tie with battery backup systems.

Stand Alone Direct Current (DC) Systems

Stand alone DC systems consist of photovoltaic panels, a panel mounting system, charge controller, energy storage (usually batteries), DC disconnects and related wiring. Often times, the system includes a small gas or diesel generator for extended no-sun periods or to recharge the batteries when they fall below a 60 to 80 percent depth of discharge, at which time they can be damaged.

Stand along DC systems are the cheapest and most simple systems as they require no inverter and often have small photovoltaic arrays. They are often used on locations that have only occasional use. Such systems frequently use a small photovoltaic array to charge a large battery bank. During periods of infrequent use, the majority of the power is provided by the battery bank.

In these systems, the majority of household appliances are DC. There are currently many energy efficient DC appliances available at moderate costs.

SOLAR ELECTRIC SYSTEM OUTPUT

The average annual output in kWh that can be expected from a 1 kW (1,000 watt) fixed-axis solar electric system in South Louisiana is 1,314 kWh/year or 109.5 kWh/month. Larger systems are simply multiples of this. For example, a 10 kW (10,000 watt) system would produce 13,140 kWh/year or 1,095 kWh/month. This is based on the following assumptions:

(1) An average insolation (i.e., solar radiation reaching Earth) is 4.5 sun hours per day. A sun hour is the equivalent of one hour at a solar intensity of 1,000 watts per square meter. For example, 6 hours at 500 watts/m^2 is equal to 3 sun hours. Average insolation values for South Louisiana range from 4.0 to 4.9 sun hours per day.

(2) A realistic output for a solar panel is about 80% of its nameplate rating. Solar panels are rated at a specific temperature, a solar intensity of 1,000 watts/m^2 and a solar angle of incidence of 90 degrees. As temperature increases and incidence angle varies from 90 degrees, the output of the panel decreases. For example, a solar panel with a nameplate rating of 1,000 watts that is installed in a fixed axis rooftop array can be expected to actually produce about 800 watts (80% of nameplate). Additionally, inverter efficiency is always less than 100 percent. Fixed axis arrays generally operate at 70 to 80 percent of nameplate.

Thus, the calculation is the following. A 1,000-watt panel at 80% receiving 4.5 sun hours per day X 365 days/year will yield 1,314,000 watt-hours per year or 1,314 kWh per year.

To calculate average kWh per month, simply divide the 1,314 kWH/year by 12 months to obtain 109.5 kWh per month.