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HARMONY FARM SOLAR
presents

Grid-Tied Photovoltaic System Sizing

Solar Energy

The intensity (or power) of sunshine is called irradiance and is measured in watts per square meter (W/m2). The amount of solar radiant power that hits the earth's outer atmosphere is a nearly constant 1,360 W/m2. On a clear day, approximately 70% of this radiation makes it through to the earth's surface. The southwestern United States frequently exceeds 1,000 W/m2 at ground level. In some mountain areas, readings of over 1,200 W/m2 are common. Average values are generally lower elsewhere, but can reach instantaneous values as high as 1,500 W/m2 when puffy clouds are present to focus the sunshine. The amount of solar energy received on a given area over time is measured in kilowatt-hours per square meter (kWhr/m2) and is called insolation (one kilowatt equals 1,000 watts). Insolation (energy) differs from irradiance (power) because of the inclusion of time.

Solar Module Output Power

Photovoltaic (PV) modules (and systems) are called out and sized using wattage determined under Standard Test Conditions (STC). This is the manufacturer's specified nameplate wattage and represents module output as measured under very controlled factory conditions. Specifically, STC are 1,000 W/m2 solar irradiance and 25 deg.C module temperature. STC wattage provides a good relative comparison between module and system sizes, but not a good real world output measure.

PVUSA (an industry consortium) developed another set of solar module test conditions called PVUSA Test Conditions (PTC) to more closely reflect real world conditions. PTC are 1,000 W/m2 solar irradiance, 20 deg.C ambient temperature, and 1 m/s wind speed. PTC differs from STC in that its test conditions of ambient temperature and wind speed will result in a PV module temperature of about 50 deg.C, instead of the 25 deg.C for STC. Silicon photovoltaic cells produce less power at higher temperatures. Consequently, for crystalline silicon PV systems with a power degradation due to temperature of -0.5% per degree C (typical), the PV module PTC power rating is about 88% of the PV module nameplate (STC) rating.

System Output Power

Determining the AC power expected out of a PV system requires additional considerations. The DC wattage expected from the solar modules must be reduced further to estimate the actual AC power produced. Typical de-rating factors include:

- Module Production Tolerance	.95
- Dirt/Dust	.93
- Module mismatch	.98
- Wiring losses	.97
- Inverter conversion losses	.94

Combined with the 88% temperature de-rating factor discussed above, the total de-rating from the system nameplate wattage (STC) is approximately 70%. This means that in the real world, a 1,000 watt PV system would be expected to produce an average of 700 watts on a full sunny day.

System Energy Production

The actual annual energy production expected out of any photovoltaic system is a function of its expected output power in watts, as discussed above, and the amount of solar insolation available at the specific location. Solar insolation (energy) available is equivalent to "peak sun hours" which is defined as the equivalent number of hours per day with solar irradiance equaling 1,000 W/m2, that gives the same energy received from sunrise to sundown. For example; 5 peak sun hours means the energy received during total daylight hours equals the energy that would have been received had the sun shone for 5 hours with an irradiance of 1,000 W/m2.

To calculate estimated system energy production:

System STC (Watts) x Peak Sun Hours x System de-rating factor = Estimated Daily AC Output (Whr/day)

(Example: 3000W x 5.5 peak sun hours x .70 = 11,550 Whr/day = 11.6 kWhr/day)

System Sizing

Harmony Farm Solar sizes your system using your average kWhr/day electrical power usage. Dividing this by the "peak sun hours" per day measure appropriate to your location, gives a direct system STC kilowatt size. (Example: 15 kWhr/day ÷ 5 peak sun hrs./day = 3kW STC System). The "peak sun hours" used, in this case, is an adjusted value incorporating the de-rating factors previously discussed. For Sebastopol, we use 4.5 as a fully de-rated peak sun hour value.

Shading must also be considered. Due to the semi-conductive nature of silicon cells, small amounts of shade (fist sized) can completely disable the output of a module or even a string of modules (non-producing cells become non-conductive). PV systems with any shade will have production loss. Shade is quantified in terms of percent solar access. Shade measuring tools such as the Solar Pathfinder or Solmetric SunEye can be used to provide both monthly and annual solar access measurements. Shade adjustments are then applied to the proposed system size.

System sizing calculation example: 15 kWhr/day ÷ 4.5 peak sun hrs./day = 3.3kW STC System

Annual solar access: 90% => 3.3kW x 1.1 = 3.6kW STC System

There is no specific requirement that a system be sized to negate 100% of the owner's electricity consumption (although it is frequently the goal). Smaller systems, with lower up front costs, are sometimes desirable. These will eliminate the most expensive, top tier kilowatt-hours, and can pay for themselves very rapidly. For high-end electricity users, such a system can lower the cost of turning on a light in your house from $.36 a kWhr (Tier 5) to $.11 (Tier 1 under basic E-1 rates).

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