Estimation of PV Array Power
Using the Daystar Solar Meter to Measure Irradiance

Do the following:

- Hold or place the Daystar solar meter in the same orientation as the PV array. Record the reading of irradiance (solar power) in Watts per square meter. **Note:** If possible, a PV array should be tested on a clear day around solar noon.

- Consult the PV module specification to determine the area of the PV array. This should be the "active area" of the PV cells excluding the frame of the PV modules. Calculate the active area in square meters.

- Multiply the irradiance reading and the active area to get total solar power striking the the array at that instant, the input power (Watts).

- Consult the PV module specifications to determine the conversion efficiency of the PV modules used in the array.

- Multiply the input power by the efficiency to estimate the power the array could produce under existing conditions.

- In most instances, this number will be greater than the output power because losses and temperature effects have not been considered.

The power produced by a PV array depends on characteristics of the PV modules used and the instantaneous climatological conditions. For most field testing, the measurable quantities are irradiance and temperature. Power is an instantaneous value; the PV array produces so many Watts (or kiloWatts) of power at a specific time depending on existing conditions. Power output will change continuously throughout the day. Energy includes a time factor and is measured in Watt-hours or kiloWatt-hours (kwH). This is what the PV array owner is interested in - energy production from the PV array over a period of

Terms

Irradiance	Sun's power per unit area, Watts/m^2
Insolation	Sun's energy per unit area, i.e. Watt-hours/m^2
Active Area	Area of PV material in the array, excluding module framing.
Efficiency	Efficiency of PV material converting solar power to dc power

time; a day, month or year. Testing a PV array will produce a “power snapshot”. Many such a snapshots, throughout the day (or month or year), would be required to estimate energy production; in other words integrate power over time. A comparison of output power to input power can indicate if all portions of the system are operating properly. Only power measurements are discussed here.

Determining the power output of a PV array is not a precise exercise. There are many variables that may affect the determination. Some factors are:

Measurement of solar irradiance
Reflectivity
Estimation of PV cell temperature
Efficiency of the inverter

Measuring solar irradiance – Solar power striking the earth is relatively constant (1366 Watts/m2) when measured above the earth’s atmosphere. Our atmosphere is an ever-changing system that reflects, scatters, and reduces the sun’s rays as they pass through. This makes any “measurement” an estimate; good only for a specific location at a specific time. Even the best instruments have an accuracy range of 2-3%. The Daystar solar meter is calibrated when pointed directly at the sun. We think the accuracy is 3% or better with that orientation.

Reflectivity – Many (most) PV arrays do not track the sun so reflection of incoming irradiance becomes an error source. This depends on many factors such as the module front cover material, dust on the modules, color of the surrounding surface, and primarily on the angle of the sun’s rays striking the array. The greater the angle between the perpendicular to the array and the normal to the sun, the greater the error. Daystar does not recommend testing an array when the angle is greater than 40 degrees.

PV cell temperature – All photovoltaic material is dependent on the temperature of the material where the conversion is taking place – and this value is not available to the person testing the installed system. The best estimate is gained by measuring the temperature at the back of the module. Generally, the output power will decrease as temperature increases. Most module manufacturers provide an estimate of this value on the PV module specification sheet. A rule-of-thumb is one half of one percent per degree Centigrade.

Inverter efficiency – Inverters convert dc power to ac power and there are losses in this process. Manufacturers specify the efficiency of their inverters and many provide a plot showing efficiency versus loading of the unit.

Example:

Your Daystar solar meter reads 650 Watts/m^2 when it is held in the plane of the PV array. Your PV array has 12 m^2 of active PV material.
Pi = 650 * 12 = 7800 Watts of solar power striking the PV array at that instant. The efficiency claimed for the PV modules is 13%. The power output, Po, for those conditions would be 1014 Watts.

<u>Correct for losses</u> – For a well-designed system, losses due to wiring, connections, diodes, etc., might be about 1 percent. This would drop the power to about 1000 W.

<u>Correct for temperature</u> – PV module manufacturers provide ratings for their modules operating at a stated temperature, often 25°C. The power output will be lower if your PV array is warmer than this temperature.
A rule of thumb for silicon PV cells is 0.5% per degree centigrade. Thus, if the module output is rated as 100 Watts at 25°C and you measure the temperature at the back of a module at 45°C, the output power would be 20° x 0.5% = 10% less. 900 Watts.

<u>Conversion losses</u> – Converting dc power to ac power causes losses of 3-10% depending on operating conditions for a typical inverter. Consult the specifications for any inverter used in the system and make a reduction for conversion losses.

Assume a 93% conversion efficiency for our example so the ac power output of the array could be estimated at 900 x 0.93 = 837 Watts ac.