Pyranometers v. Reference Cells for PV Installations

Often we are asked, why use a pyranometer? Or, what is the benefit of a pyranometer over a reference cell? The following points give answers to these questions.

Reference cells have similar properties to PV panels, but even when properly calibrated, will have the same shortcomings in temperature, spectrum and degradation. Therefore they will not be able to give an accurate measurement of the available solar radiation under all conditions. Depending on the application and the type of energy calculation several differences can be noted.

Advantages of a pyranometer over a reference cell:

1. The pyranometer gives an independent, accurate reading of the total available solar radiation
2. The pyranometer are classified and calibrated to ISO standards
3. The response time of the pyranometer is longer than a PV cell
4. The pyranometer is PV cell type independent
5. A pyranometer can have a very small temperature coefficient
6. PV cells are specified at STC (Standard Test Conditions)
7. Reference cells (and PV panels) suffer more from pollution than pyranometers
8. Performance Ratio or Performance Index calculations are more accurate using a pyranometer

Explanations of the above advantages:

Advantage 1: Depending on the technology (amorphous silicon, thin film CdTe or triple-junction cells, etc) and the cell/panel 'window' material PV cells have different spectral responses. Due to the changing position of the sun (Air Mass), pollution, humidity, clouds, etc, the solar spectrum at ground level varies considerably. Pyranometers measure the total solar spectrum from 0.3 to 3 micrometers wavelength and give an integrated measurement of the total short-wave solar energy available under all conditions.

Advantage 2: Pyranometers have been the instruments used to measure solar radiation for over 80 years. The world-wide solar radiation database is founded on pyranometer measurements. Also the pyranometer calibration factor is very stable over time. Performance classifications are defined by ISO 9060 and the calibration methods by ISO 9847.

Advantage 3: The advantage here is that the pyranometer integrates over time, typically between 5 and 20 seconds. This means that sudden changes such as passing small clouds, birds and planes will not give transient spikes or dips in the data. A pyranometer will give a correct integrated values over a day when using sample intervals of 20 seconds or more.

Advantage 4: When different PV cell types are used in one plant, a separate reference cell for each type should be used, but only one pyranometer is required for monitoring all types.

Advantage 5: The temperature dependency of pyranometers can be as low as 1 % over a 70 °C temperature range (depending on type). This is much lower than that of PV panels and reference cells.

Advantage 6: Most panels and reference cells have performance are specified under Standard Test Conditions. These are conditions of +25 °C ambient temperature, 1000 W/m2 global solar irradiance, air mass 1.5 and no wind. The global radiation when under test is measured with a pyranometer. These conditions are far from realistic in the real world and an accurate measurement with a pyranometer shows the real performance.

Advantage 7: There is a conception that pyranometers need to be cleaned very frequently, and this is advised for optimum performance. However, reference cells with a flat surface suffer more from deposits than the hemi-spherical dome of a pyranometer.

Advantage 8: Performance Ratio (PR) or Performance Index (PI) calculations when based on accurate independent data from a pyranometer are more relevant than when based on a reference cell with lower accuracy and the same inherent flaws as the panel itself. A pyranometer (depending on the type) can measure with 1 % accuracy.

Reasons for measuring solar radiation

1. To select the most appropriate PV system, cell technology and fixed or tracking type.
2. To find optimal locations (solar prospecting)
3. To help investment decisions
4. To monitor system performance
5. To schedule maintenance
6. To maximize operating efficiency
7. For performance calculations

Points 1, 2 and 3 can be used to determine the optimal system and location of the power plant. Even relatively small changes in location of a few tens of kilometers can affect the annual energy available by several hundred kWh. Micro-climate and geographical effects due to mountains and valleys or shore-lines (for example cloud forming) can cause this. The calculated output based on accurate measurements and a selected PV technology can be used to facilitate project financing.

Points 4 to 7 are used for monitoring efficiency and other performance parameters during operation of the installed system. Many inverters for PV systems have an input for pyranometers as well as reference cells.

The most important points that affect the (expected) total system output are:
• Mismatch between STC specifications and actual installed output of PV cells
• Efficiency loss at low radiation values
• Shading
• Temperature
• Inverter efficiency
• Cable losses
• Dirt and precipitation on the panels

Other meteorological parameters such as wind, rain and temperature are often recorded for further analysis of the plant performance:
• Temperature of the PV panels gives an indication of their change in efficiency
• Wind and rain (cleaning of panel windows) together with radiation (change in efficiency) data can be used to schedule maintenance
• Wind speed is also used to prevent damage to moving panels by lowering or turning them when the wind load is too high

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Frequently asked questions and answers

Q1: How many pyranometers are required for larger installations?

A1: The answer is related to redundancy and mounting angles: For larger plants monitoring is important to prove system efficiency. Using more than one pyranometer reduces the chance of data loss in case of failures or maintenance. The two pyranometers (often meteo-masts combining solar radiation, wind speed, wind direction and and temperature) are located on two opposite sides of the plant. This gives an even more accurate measurement of the average conditions over that area. When different sections of the PV plant are operated at different angles at least one pyranometer per section should be used.

Q2: The directional response of my panel is different from that of the pyranometer.

A2: This is true but the largest difference is at low solar elevations (just after sunrise and before sunset), when the amount of solar energy is a small proportion of the daily total.

Q3: How do I mount my pyranometer?

A3: Pyranometers used to calculate the efficiency or Performance Ratio (PR) need to be mounted in the same plane as the panel or collector. This means that the leveling feet have to be removed. The bottom of the pyranometer housing is accurately parallel to the detector. Radiation measured in this way is called Global Tilted Radiation.

Global Radiation measured by a meteorological station is always done with a pyranometer mounted and leveled horizontally.

Q4: Where do I mount my pyranometer?

A4: When one pyranometer is used it can be mounted roughly in the centre of the site. With two pyranometers they are best mounted at two opposite sides of the power plant. Depending on the size and shape of the plant the locations should be as far away from each other as possible, or one to the North and one to the South. When the pyranometer is part of a meteo-station, care has to be taken that the mast does not shade the pyranometer or the panels.

In that case, locating it at the North side of the plant would be the best option, in the northern hemisphere, to avoid shadows. PV power plants near a shore-line or mountains need special attention. Clouds are created by humid air coming inland and mountains can block cloud movements. So here the pyranometers are best located with one near the shore or mountain and the other on the opposite side.

Q5: What is the best sample interval?

A5: To obtain a correct integrated value for solar irradiance over the day, small intervals are better. But because the pyranometer already integrates due to its response time, sampling times below 5 seconds are not necessary. Often sampling intervals are decided based on the data collection system and calculation and update speed of the performance algorithms used. When the pyarnometer is connected to a separate data logger, or a meteo-station, a sampling interval of 10 seconds and a storage interval of the integrated values of 1 minute can be used (1 minute averages).

Q6: What is the recalibration interval for a pyranometer?

A6: The recommended interval is 2 years. Within this period the initial accuracy is guaranteed. The change of sensitivity of a thermopile pyranometer such as the Kipp & Zonen CMP series is less than 1% per year, and is much less than that of a silicon reference sensor.

Q7: What maintenance is required for a pyranometer?

A7: Higher performance pyranometers (our CMP 6, CMP 11, CMP 21 and CMP 22) have a drying cartridge with a desiccant that changes colour when it needs to be replaced. This needs to be checked periodically and replaced when necessary. It will last at least 6 months. The CMP 3 is completely sealed and has no replaceable desiccant. Normally checking of the pyranometer desiccant and cleaning of the dome is combined with visits to the PV site for other inspections.

Much more information can be found on our website **www.kippzonen.com**, including all product brochures, instruction sheets and/or manuals, application information and guides.