

How to measure albedo for bifacial PV modules

Hukx is the market leader in albedometers for bifacial PV system performance monitoring.

Measuring the albedo of surfaces, or ground surface reflectance, is becoming increasingly important. Bifacial PV modules generate power from both the global solar radiation and the reflected solar radiation. Downfacing pyranometers can be used to make reflected radiation measurement, but it is essential to consider what the performance model requires as input: the ground surface property or reflected irradiance? This note provides guidance on instrument specifications, measurement location, and orientation.

Introduction

Albedo, also called solar reflectance, is defined as the ratio of reflected to global radiation. It is a dimensionless number less than 1 and a property of the ground surface.



Figure 1 In PV system performance monitoring, users typically employ Plane of Array (POA) on the right, Global Horizontal Irradiance (GHI) on the left, and increasingly also Reflected Irradiance (RI) in the middle.

An albedometer is an instrument that measures both global and reflected solar radiation and, by calculation, the solar albedo—or solar reflectance—for a particular

ground surface. An albedometer is composed of two pyranometers, both installed horizontally, with the downfacing one measuring reflected solar radiation.

In the open field, solar albedo depends on the directional distribution of incoming radiation and on surface properties at ground level. It is usually expressed as a single number, determined by taking an average over a day. Changes of albedo are typically slow and seasonal, except when it snows. Albedos of typical surfaces range from about 4% for fresh asphalt and 15% for green grass to 90% for fresh snow.

The classic application of albedometers is in meteorological energy balance studies, studying albedo variations of large areas over multiple years. With the rise in popularity of bifacial PV modules, there is an increased demand to measure the albedo at PV power plants. This is possible with pyranometers, but there are several considerations to keep in mind.

Use of albedo measurement in the PV performance model

The albedo measurement is used as input to the PV system performance model, which is defined and agreed upon between the stakeholders. Stakeholders should agree on the following:

- what “albedo” in a PV power plant means
- whether it should be continuously measured or not at all (since its contribution to the total yield may be small, the value of a highly accurate measurement may be questioned)
- and, if so, how should it be measured

Parameters in the performance model

Regarding the parameters used in the performance model:

- The primary input to a PV system remains Plane of Array (POA) radiation, either measured with a pyranometer facing up, mounted in the Plane of Array, or estimated from Global Horizontal Irradiance (GHI) with an upward facing horizontal pyranometer.
- With downfacing pyranometers, the Horizontal Reflected Irradiance (HRI) can be measured.
- It may be that the performance model asks for measurement of reflected radiation in the Plane of Array of the downfacing side of the bifacial panel, or Plane of Array Reflected Irradiance (POARI). Most performance models do not require this input, as this approach leads to confusion; many PV power plants do not have a single or uniform Plane of Array. Instead, many performance models expect the albedo of the ground surface only.
- Some performance models ask for distributed sensors among the panels or site surveys to get a better idea of spatial variability of the reflected irradiance or the local albedo. Quantifying this variability is a requirement of IEC for proper uncertainty evaluation of the performance test of bifacial PV systems (see site survey).

Reflected radiation between PV arrays

While albedo in the open field is simple to define as a property of the ground surface, in PV applications there are a few complicating factors:

- The amount of reflected solar radiation between PV arrays is dominated by the shading of the ground surface by the array panels, and secondly by the reflectance of the ground surface (albedo).
- Since shading dominates, albedo does not need to be known with high accuracy.
- The shading and ground surface properties are not homogeneous.
- For reflected yield calculation, conversion to panel backside in-plane irradiance is required.
- For reflected yield calculations, spectral corrections may be required, as the spectral content of reflected radiation is not the same as incoming radiation. Usually, this correction is treated as insignificant.

At a fundamental level, we can expect that reflected radiation below solar array structures, as a percentage of incoming GHI above the array, is highly variable:

- Reflected solar radiation below PV arrays varies spatially across a power plant. For example, in the middle of a row, the reflected irradiance will be different from that at the ends of a row due to different shading patterns or a different local horizon.
- Reflected radiation below PV arrays also varies over the day, depending on moving local shading patterns.
- Albedo of the ground surface may vary seasonally, depending on vegetation properties, shading patterns, and soil moisture content.

Common practice: performance model input

The complex nature of reflected radiation is the reason why most performance models suggest keeping it simple:

- Enter ground surface albedo as a single number.
- Account for seasonal variation by month.
- Calculate backside POA based on a GHI measurement and model calculations.
- Use reflected radiation measurements (because of their local nature) as model validation, not as critical input

One unobstructed reference station

Some performance models suggest using a measurement at a location away from the arrays, measuring HRI not suffering from any shadow effects, and determining the albedo as a ground surface property. The question then becomes: does this location have a representative ground surface?

At the array location, the reflected radiation measurement may be realistic, but there are also many local shadow effects, which gives a confusing impression of the ground surface albedo (unless the GHI is also measured below the array panels).

The unobstructed measurement has the advantage of simplicity. If representative, it serves as a check of the maximum albedo and as a point of reference for satellite observations. See also: site survey.



Figure 2 2 x SR300 spectrally flat Class A (secondary standard) pyranometers connected to a fixture plus rod, together forming an albedometer. The downfacing pyranometer is equipped with a glare screen to block solar radiation entering the lower detector at low solar angles (150 ° instead of 180 ° full field of view angle).

IEC 61724-1:2021

This standard outlines requirements for measuring equipment (sensors), methods, and terminology for performance monitoring and analysis of photovoltaic (PV) systems. In addition, it serves as a basis for other standards that rely upon the data collected, such as 61724-2 and 61724-3.

The standard addresses sensors, installation, and accuracy for monitoring equipment, as well as measured parameter data acquisition and quality checks (i.e., system calibration and cleaning/maintenance), calculated parameters, and performance metrics.

With the widespread adoption of bifacial panels (which also generate power from rearside irradiance), reflected irradiance measurements often serve as input.

In case bifacial modules are used, the rear-side solar irradiance may be:

- directly measured, or
- estimated using an optical model based on GHI,

albedo, and, optionally, diffuse irradiance.

The contribution of reflected radiation to the system performance is typically small. For measurement of reflected radiation, lower accuracy Class C pyranometers may be used.

Recommendations in summary

A summary of Hukx's recommendations for albedo measurement with bifacials:

- Keep the albedo definition simple: most models assume it is a ground surface property with a seasonal (monthly) variability. Let the model take care of corrections for shading patterns and conversion to Plane of Array.
- Employ at least one instrument located away from the array to have one unobstructed reference albedo measurement. This assumes that the ground surface properties at the station are representative for those between the arrays.
- Keep logistics simple. Use the same instruments for POA, GHI, and RI measurements. These are typically spectrally flat Class A (secondary standard) pyranometers, which can also share the same calibration services.
- Use either 2 x single pyranometers or modular instruments consisting of 2 x pyranometer for easier servicing and recalibration.
- Consider performing surveys for site characterization in different seasons (also relative to the unobstructed reference station) to determine ground surface properties. This is required for uncertainty evaluation.
- As an alternative for surveys, consider using multiple instruments between the arrays to verify model calculations of reflected irradiance and assess its spatial variability. When using multiple instruments between rows, you may also employ lower accuracy (spectrally flat Class B or C) instruments. Typically, these instruments are installed horizontally facing down, though in some cases users choose to install in POA.
- Do not install pyranometers for RHI measurement below 1 m height; 1.5 m is a good and practical compromise.
- For personnel safety, electrically insulate the instrument body from PV array mounting frames.
- After snowfall, do not use the values measured by an unobstructed reference albedo measurement station. An unobstructed station will not have snow patterns representative of those between arrays.

Performance model, ratio and index

The new IEC 61724 Photovoltaic System Performance series of standards is the best available source that defines parameters such as "performance ratio" and "performance index." IEC uses the following definitions:

- performance model: a mathematical description of the electrical output of the PV system as a function of meteorological conditions, the system components, and the system design. This model is typically agreed upon in advance by the stakeholders of the test.
- predicted output: the output for a given period as calculated using the performance model based on historical weather data
- expected output: the output calculated using the performance model when entering measured weather data
- rating: performance as specified by the manufacturer, usually confirmed via the name-plate on the panel, or as agreed upon by a supplier, typically under reference conditions such as Standard Test Conditions (STC)
- performance ratio (PR): the ratio of measured output to expected output for a given reporting period, based on the system name-plate rating
- performance index: the ratio of measured output to expected output for a given reporting period, based on a more detailed model of system performance than the performance ratio

Site survey on a sunny day

To investigate the characteristics of the site, users may perform a site survey. During the survey, you can walk around with an albedometer and measure at different locations. Under stable solar conditions, you may also use a single pyranometer and invert it.

The purpose of such survey is to investigate:

- spatial variability of the (ground surface) albedo
- seasonal variability of the albedo
- correlation between a field station and the conditions at the arrays

At the location of all POA measurements, IEC 61724-3, clause 5 requires measurement of the local albedo to verify that it is representative of the albedo of the total power plant, fits the assumptions made in modeling, and to use the measurements in the uncertainty evaluation of the performance test.

Recommendations and boundary conditions for the survey are:

- Choose a sunny day, with limited cloud cover and solar elevations above 60 degrees.
- Focus on measuring the ground surface properties: measure above unshaded locations with a representative ground surface or vegetation.
- Measurements in shaded locations typically provide a signal level that is too low to make a good albedo estimate.
- In case there is seasonal vegetation, measure 2–4 times throughout the year.
- Use an albedometer, or under stable solar conditions, use a single pyranometer and invert it.

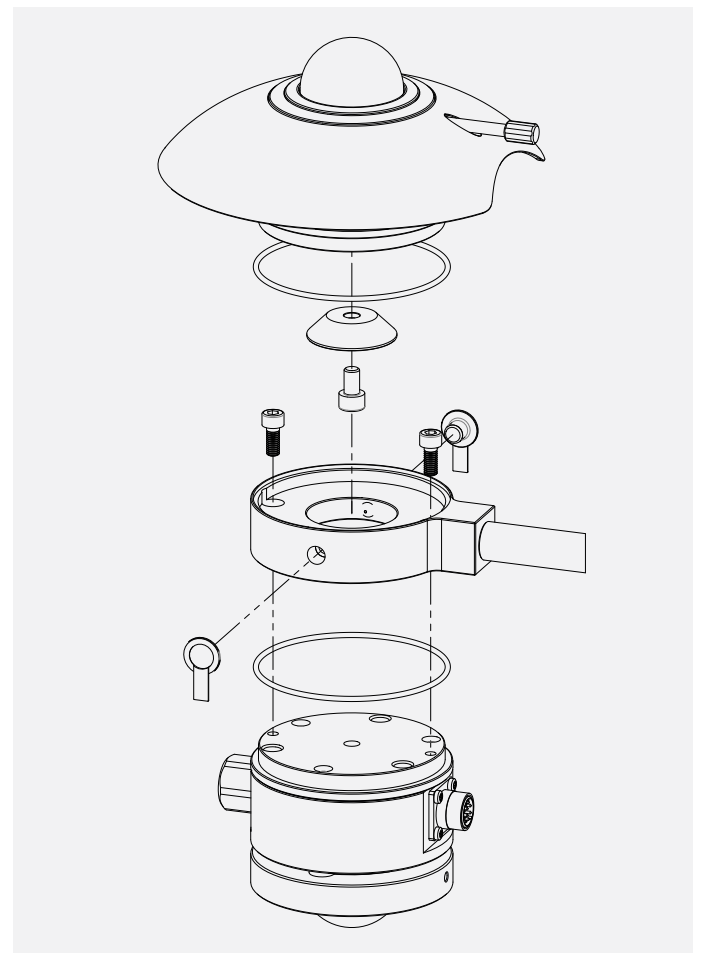


Figure 3 How the albedometer of Figure 2 is constructed of 2 x pyranometers.

Installation height

If the pyranometer is too close to the ground surface, it will only measure in a small area and its own shadow will become a source of error. If it is installed too high, inspection and cleaning becomes difficult. A 1.5 m installation height is a good compromise.

Recalibration

We recommend recalibrating pyranometers every 2 years. Typical indoor calibration can be done efficiently with a standard model pyranometer housing. A complete albedometer does not fit in, which is why we prefer albedometers constructed from 2 x standard pyranometer, as shown in Figures 1, 2, 3, and 4.

Electrical insulation and protection

For personnel safety, we recommend keeping pyranometers away from the PV array mounting frame. In case connection is unavoidable, for example when used with 1-axis trackers, make sure the connection is electrically insulating, such as using plastic mounting plates. Protect both sides, instrument and data logger, against electrical surges

In Plane of Array or not?

A pyranometer measures irradiance in the plane of its sensor surface. To directly measure the usable irradiance for the PV panel backside, the pyranometer must be aligned with the PV panel backside—in Plane of Array. However, most performance models assume you measure the horizontal albedo. The model later corrects to Plane of Array, using at least a view factor and sometimes more advanced modeling.

Glare screen?

A glare screen limits the full field of view of the downfacing pyranometer to 150° (normally 180°). This is useful for horizontal albedo measurements. In case you do not use a sun screen, at sunrise and sunset the downfacing pyranometer may measure similar values as the upfacing pyranometer, suggesting albedos larger than 1, which is physically impossible.

Using a glare screen is not a requirement. Nowadays, measurements suffering from glare-related errors are eliminated from the dataset by software limiting the measurement of the downfacing sensor to solar elevations > 10°.

When measuring reflected radiation in Plane of Array (POARI), using a glare screen is not good practice; you simply miss part of the incoming irradiance.

What pyranometer to use?

General recommendations for [choice, calibration, and cleaning of pyranometers of IEC 61724-1 are summarized in a separate note.](#)

Hukx pyranometer model [SR30](#) is compatible with the requirements of Class A monitoring systems.



Figure 4 The tube mounts of SR30, SR15, and SR05 can be used to measure global, reflected, and Plane Of Array irradiance. For downfacing instruments, we typically do not use the sun screen. See also Figure 1.

See also

- [SRA01](#) and [SRA30-M2-D1](#) albedometers
- [AMF](#) and [ALF](#) mounting and leveling kits

About Hukx

Hukx is the leading innovator in solar radiation and heat flux sensor technology. We are proud to set the standard in high-accuracy measurement, and to be working at the heart of the energy transition.

Customers worldwide rely on our bestselling pyranometers and heat flux sensors. From sensor design and selection to supply and recalibration, we support you across the entire lifecycle.

Hukx is headquartered in the Netherlands, with locally owned representative sales offices in the USA, Brazil, India, China, Southeast Asia, and Japan.

Let us help you select the best sensor for your application. Get in touch with our experts today via: info@hukx.com

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