How to measure albedo for bifacial PV

Hukseflux is a market leader in albedometers for bifacial PV system performance monitoring

The measurement of the albedo, or reflectance, of surfaces is gaining popularity. Bifacial PV modules generate power using both the global solar radiation and the reflected solar radiation. Downfacing pyranometers are suitable to make this measurement, but you must carefully consider what the performance model requires as an input; instrument specifications, location, and orientation.

Introduction

Albedo, also called solar reflectance, is defined as the ratio of the reflected to the global radiation. It is a dimensionless number smaller than 1.

Figure 1 *in PV system performance monitoring users typically employ Plane of Array (POA) Global Horizontal Irradiance (GHI) and increasingly also Reflected Irradiance (RI)*

An albedometer is an instrument that measures both global and reflected solar radiation and, by calculation, the solar albedo, or solar reflectance. It is composed of two pyranometers, both installed horizontally, the downfacing one measuring reflected solar radiation.

The solar albedo depends on the directional distribution of incoming radiation and on surface properties at ground level. 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 area's 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 a few things to keep in mind.

Recommendations in summary

A summary of recommendations for albedo measurement for bifacials:

- look at the requirements of your performance model
- employ at least one instrument located away from the array, so that you have one unobstructed reference albedo measurement.
- keep logistics simple; use the same instruments for POA, GHI and RHI measurements. These are typically spectrally flat Class A (secondary standard) pyranometers. You can then also use the same calibration services.
- use modular instruments consisting of 2 x pyranometer, this is easier for servicing and recalibration
- consider performing a survey for site characterisation (also relative to the unobstructed reference station)
- consider using multiple instruments between the arrays to get a better idea of spatial variability; when using multiple instruments, you may also employ lower accuracy (spectrally flat class B or C) instruments.
- do not install below 1 m height; 1.5 m is a good and practical compromise
- for personnel safety, electrically insulate instrument body from PV array mounting frames

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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** gives 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** is the output for a given period as calculated using the performance model based on historical weather data
- **expected output** is 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)** is the ratio of measured output to expected output for a given reporting period based on the system name-plate rating
- **performance index** is 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

Use of Albedo measurement: in performance model

The albedo measurement is used as input to the performance model. The performance model is agreed between the stakeholders. Stakeholders should at the same time agree how albedo is measured.

Expect high variability

At a fundamental level we can expect that reflected radiation below solar array structures, as a percentage of incoming global horizontal irradiance, is very variable;

- albedo below PV modules varies in space over a power plant, for example in the middle of a row the albedo will be different from that at the ends
- albedo below PV modules varies over the day depending on local shading patterns
- albedo below PV modules may vary seasonally depending on vegetation and shading patterns

Measurements required

When using bifacial modules, look at the requirements of your performance model:

- the primary measurement remains Plane of Array (POA) radiation, measured with a pyranometer facing up, mounted in the plane of array.
- in addition you measure Global Horizontal Irradiance (GHI) with an upward facing horizontal pyranometer.
- with downfacing pyranometers you measure horizontal reflected irradiance (HRI)
- 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 because this approach leads to confusion. Many performance models expect the horizontal albedo. This may also be easier when using one-axis trackers.
- some performance models ask for distributed sensors among the panels to get a better idea of spatial effects.

One unobstructed reference station

Some performance models use a measurement at a location away from the arrays, measuring HRI not suffering from any shadow effects. At the array location, the measurement may be realistic, but there also are many local shadow effects. The unobstructed measurement has the advantage of simplicity. It serves as a check of the maximum albedo and also as a point of reference for satellite observations. See also: site survey.

Site survey on a sunny day

In order to investigate the characteristics of the site, users may perform a site survey. During the survey you may 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 albedo
- seasonal variability of the albedo
- correlation between a field station and the conditions close to the array.

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 modelling, and to use the measurement 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
- in case there is seasonal vegetation, measure at 2 to 4 moments in the year
- you may use an albedometer or under stable solar conditions you may use a single pyranometer and invert it

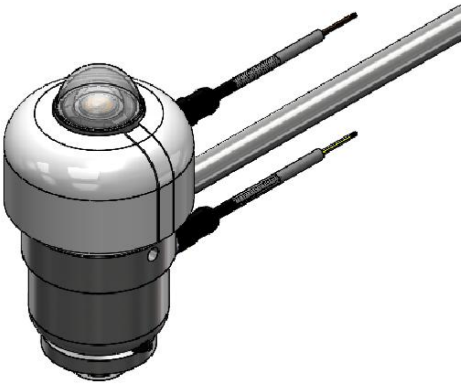

Figure 2 *2 x S320 secondary standard pyranometer connected to a fixture plus rod, together forming an albedometer. The downfacing pyranometer is equipped with a glare screen to block solar radiation entering the lower detector at low solar angles (150° instead of 180° full field of view angle).*

Figure 3 *the Tube mounts of SR30 and SR15 and SR05 can very well be used to measure global, reflected, and Plane Of Array irradiance. For downfacing instruments we typically do not use the sunscreen. See also Figure 1.*

Installation height

If the pyranometer is too low, it will measure in a small area only and its own shadow also becomes a source of error. If it is installed too high, you can no longer clean it. A 1.5 m installation height is a good compromise.

Recalibration

We recommend re-calibrating pyranometers every 2 years. Typical indoor calibration can efficiently be done with a standard model pyranometer housing an albedometer does not fit in. This is why we prefer albedometers constructed from 2 x standard pyranometer like in Figure 1.

Electrical insulation and protection

For personnel safety, we recommend to keep 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, for example using plastic mounting plates. Protect both sides, instrument and datalogger, 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, so 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 modelling.

Glare screen?

A glare screen limits the full field of view of the downfacing pyranometer to 150 ° (it is normally 180 °). This is useful for horizontal albedo measurements; in case you do not use a sunscreen, at sunrise and sunset the downfacing pyranometer may measure similar values as the upfacing pyranometer, suggesting albedo's larger than 1, which is physically not possible.
Nowadays this is usually solved 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 no longer good practice; you simply miss part of the incoming irradiance.

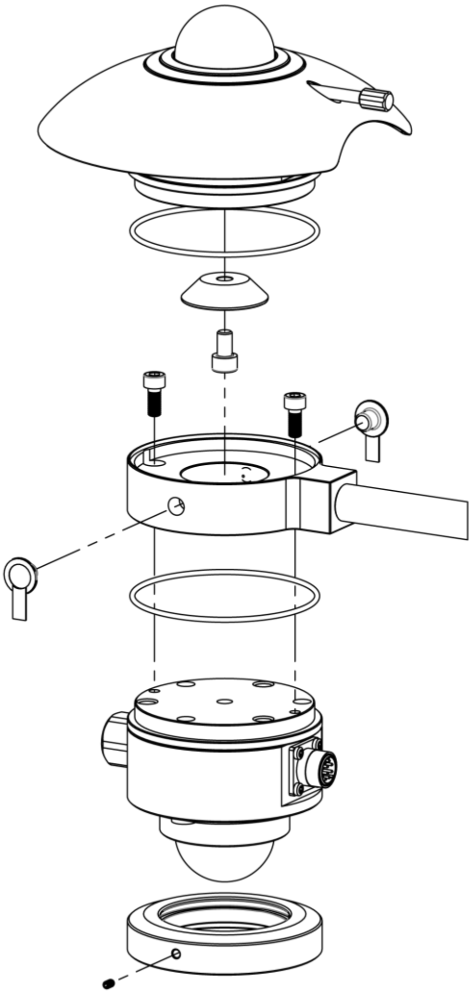

Figure 4 *how the albedometer of Figure 2 is constructed of 2 x pyranometer.*

What pyranometer to use

General recommendations for choice, calibration and cleaning of pyranometers of IEC 61724-1 are summarised in a separate note.

The Hukseflux pyranometer model SR30 is compatible with the requirements of Class A monitoring systems.

See also

SRA01, SRA20

About Hukseflux

Hukseflux Thermal Sensors offers measurement solutions for the most challenging applications. We design and supply sensors as well as test & measuring systems, and offer related services such as engineering and consultancy. Our main area of expertise is measurement of heat transfer and thermal quantities such as solar radiation, heat flux and thermal conductivity. Hukseflux is ISO 9001:2015 certified. Hukseflux sensors, systems and services are offered worldwide via our office in Delft, the Netherlands and local distributors.

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