Solar irradiance beyond a shadow of a doubt

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Capturing accurate solar irradiance data is essential for many fields of use, including architecture and construction planning, meteorology and climate research, and of course, solar energy applications such as designing and optimizing Photovoltaic (PV) systems.

Traditionally, monofacial fixed-tilt PV modules facing the equator have been used in solar PV plants. In this application, it is critical to monitor global horizontal and plane of array irradiance to gauge and optimize the PV system energy yield. However, with the introduction of bifacial PV modules, system design decisions have grown increasingly challenging. Since bifacial modules may gather light from both sides, the amount of useful solar irradiance available to these panels depends on additional factors like ground albedo and panel height.

Furthermore, during overcast sky conditions, diffuse radiation becomes the primary source of light for a solar plant. In such cases, bifacial solar panels significantly outperform standard monofacial panels. Consequently, monitoring diffuse and ground-reflected irradiance accurately becomes increasingly important throughout the development and operation stages of a solar power project.

Pyranometers have been the go-to sensor used to measure solar irradiance and have been widely used for decades, but they are not without their limitations. While measuring the in-situ global or ground-reflected irradiance components using a pyranometer is relatively simple, quantifying the direct or diffuse irradiance components accurately can be challenging. The setup capable of providing in-situ Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI) data with the lowest uncertainty is comprised of one pyrheliometer for the direct, and a ball-shaded pyranometer for the diffuse measurement, assembled on a sun tracker.

While a solar tracker system has high accuracy, sometimes it introduces obstacles and drawbacks such as increased costs and maintenance requirements, not to mention the decreased accuracy when not properly maintained.

As an alternative to the use of sun trackers, various lower-cost solutions have been created to measure or infer the diffuse and direct solar radiation components. For instance, one could measure the DHI by utilizing a pyranometer and a static shading-ring. While accurate for measuring DHI, this approach increases maintenance efforts since the shading-ring must be adjusted on a weekly basis to account for the sun path variation.

A less maintenance-intensive approach can be taken by using the EKO MS-90 Plus+ system. Combining MS-90 tracker-less DNI sensor with a pyranometer measuring the Global Horizontal Irradiance (GHI) enables the estimation of DHI with reasonable accuracy.

At EKO, we wanted to offer a system able to provide highly accurate irradiance data with lower maintenance requirements and lower costs by exploring an automatic shading measurement procedure. For this purpose, we are developing another configuration; A pyranometer equipped with a rotating shadow band, or RSB.

The RSB concept consists of a curved band that rotates around a central axis in front of a sensor, orientated towards the equator. The band is positioned to create alternating periods of shade and sunlight, allowing one single sensor to measure both the global and diffuse irradiance components separately. Measuring solar irradiance components with an RSB system can help provide more consistent, accurate and comprehensive measurements, even in the presence of adverse conditions and cloud cover.

We previously introduced a rotating shadow band, the RSB-01, which can be used in combination with our spectroradiometers to measure the spectral irradiance components. Currently, we are in the process of developing a brand-new rotating shadow band for broadband irradiance measurements using our ISO 9060:2018 Class A pyranometer.

Until now, the RSB approach has only been successfully applied to broadband irradiance measurements with ISO9060:2018 Class C, non-spectrally flat, fast response silicon-based irradiance sensors. While the measurement approach benefits from these sensor's fast response time, the non-spectrally-flat response can yield large

Tracker-based Solar Monitoring Station

- Separate Instruments to Measure DHI, GHI, & DNI
- Highest Accuracy
- More Maintenance Required
- Higher Cost

MS-90 Plus+ System

- MS-90 Sensor for DNI, Pyranometer for GHI & inferred DHI
- Medium Accuracy
- Less Maintenance Required
- Lower Cost

Pyranometer + Shadow Ring System

- DHI measurement with static shading ring assembly
- High Accuracy
- Most Maintenance Required
- Lower Cost

Pyranometer + RSB System

- Shaded Pyranometer Measures GHI, DHI, and Determines DNI from measured components
- High Accuracy
- Least Maintenance Required
- Lowest Cost

measurement errors, specifically under cloudy sky conditions, which only through extensive characterization and correction can be minimized.

Of course, the accuracy and reliability of solar irradiance measurements are highly dependent on the quality of the instruments used. To ensure the highest level of accuracy, we're developing this rotating shadow band system to work with our Class A, spectrally flat, fast-response digital pyranometer, with integrated high-efficiency dome heating technology, the EKO MS-80SH.

Thermopile sensor based pyranometers have a flat spectral response which reduces measurement errors due to spectral mismatch effects under all-weather conditions. Still, thermopile devices are typically slow response devices as they operate based on the thermoelectric effect, where temperature changes produce a voltage potential.

The MS-80SH follows an innovative concept in solar radiation sensors, where a low mass, fast thermopile detector is integrated within the sensor body instead of the surface. This design enables rapid measurement rates, as well as improved long-term stability, and reduced thermal offsets.

The characteristics of the MS-80SH pyranometer' flat spectral response and fast

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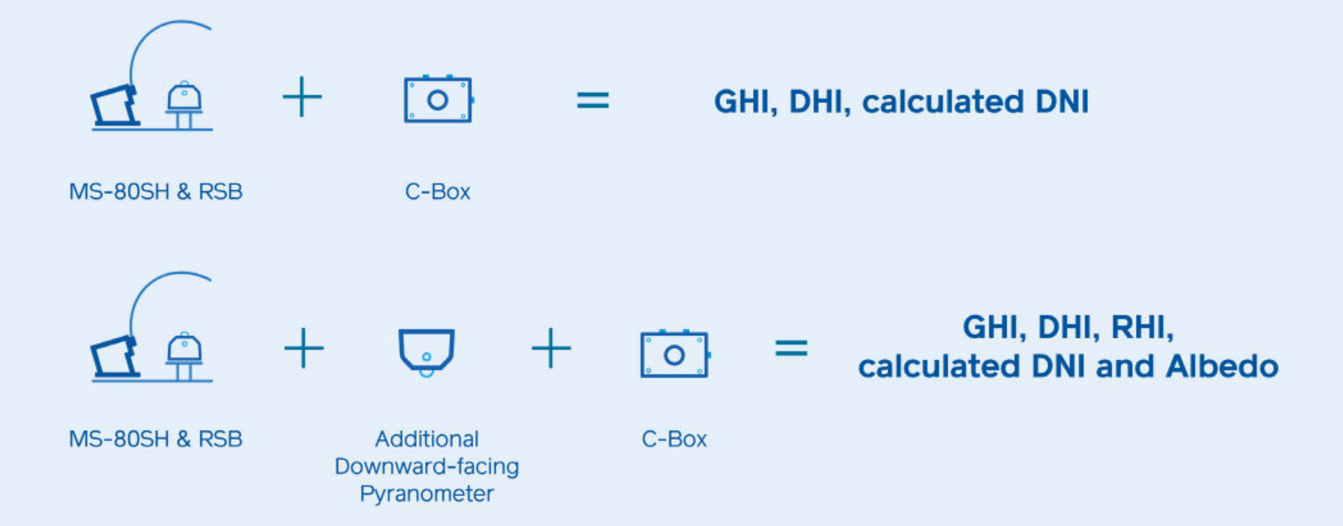

<0.5 second response time allows for unprecedented accurate irradiance measurements under highly variable irradiance conditions. Furthermore, these unique features allow for the coupling of thermopile technology with the RSB concept for precise irradiance measurements.

The new RSB we are developing utilizes a motorized rotating band which periodically shades and un-shades a single stationary pyranometer. This allows for the measurement of both the GHI and DHI, while determining the DNI from the measured components. It minimizes the number of sensors required for the measurement of the irradiance components, as well as the maintenance costs associated with routine cleaning and calibration.

Furthermore, this solution can provide a major benefit in terms of compliance with the updated IEC 61724-1 guidelines, as carrying out both GHI and DHI measurements are the criteria to fulfill the standard best practices when monitoring bifacial photovoltaic modules. Besides, using an ISO 9060 Class A pyranometer simplifies calibrations by allowing users to apply ISO 9847 standardized calibration procedures, potentially lowering calibration uncertainty and associated costs.

The entire solar measurement solution consists of the new rotating shadow band we're calling 'RSB-02' (working title), the MS-80SH, a control unit (C-Box), and a base installation plate equipped with three adjustable nuts to facilitate manual leveling. The C-Box operates the 'RSB-02' and samples the MS-80SH's digital signals, while the integrated C-Box GPS receiver determines the sun's position and positions the RSB band accordingly.

This allows for GHI and DHI measurements while calculating the DNI. An additional feature of the solution is the option to include an extra pyranometer to measure the reflected horizontal irradiance (RHI) and determine the albedo through the C-Box.

The solar measurement system is designed for easy integration with modern digital data acquisition systems. By utilizing Modbus RTU output, the system allows for seamless connection to a wide range of devices, including data loggers and SCADA systems. This ensures that the data can be easily accessed and utilized for a variety of applications, from research studies to real-time monitoring and control of solar energy systems.

Another advantage of this RSB system is its versatility and adaptability to different environments and weather conditions. Its durability and resistance to environmental factors makes it ideal for use in a wide range of locations and climates, even remote locations where frequent maintenance is difficult.

As the demand for solar energy projects continues to grow exponentially worldwide, so too will the need for accurate solar irradiance measurements. Together with our award-winning MS-80SH Pyranometer, this RSB system can provide that necessary data in a compact, easy-to-maintain form factor.

We're excited to bring this new solution to industry professionals around the world in the near future, and we'll be giving an exclusive first-look at the upcoming Intersolar Europe Exhibition in Munich, Germany this June. Visit Booth B4.111, and be one of the first to see this new system in-person. We'll also be presenting the results of the validation of this system at the 40^{th} European Photovoltaic Solar Energy Conference & Exhibition (EU PVSEC 2023).

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