Best Practices: Solar Irradiance Measurements with Rotating Shadowband Irradiometers

Large-scale solar thermal projects, such as those producing industrial process heat for mining areas in Chile or district heating in Denmark, require diligent solar resource assessments. Unfortunately, high accuracy irradiance data are scarcely available in many regions, which are attractive for solar energy applications. This holds especially true for solar thermal technologies using concentrating collectors to produce high temperatures. For these systems, the focus of the resource assessment lies on direct normal, or beam irradiance (DNI). Satellite data can only be used in combination with ground data to estimate inter-annual variability and long-term mean values. Hence, new ground measurements have to be collected for projects using concentrating collectors, such as high temperature process heat or district heating systems.

Ground measurement data usually show significantly higher accuracies than satellite derived irradiance data, when general guidelines regarding site selection and preparation, instrument selection and maintenance and data quality monitoring are respected. Best practices for Rotating Shadowband Irradiometers (RSIs), developed within the framework of IEA SHC Task 46: Solar Resource Assessment and Forecasting, are presented in the recently published report, Best Practices for Solar Irradiance Measurements with Rotating Shadowband Irradiometers

▲ Figure 1. Rotating Shadowband Irradiometer (RSI) in normal position (left) and during rotation (right).

A continuously rotating RSI consists of a horizontally mounted solid-state pyranometer in combination with a shadowband. The shadowband is mounted below the sensor at an angle of (approximately) 45° and rotates around the sensor continuously at approximately once per minute (see Figure 1). This way the shadowband once casts a shadow on the sensor during the rotation, blocking out the sun for a short moment, which provides briefly a measure of the diffuse horizontal irradiance (DHI).

Before this shadow is cast the pyranometer measures global horizontal irradiance (GHI). The irradiance measured over time during the rotation results in a typical measurement curve, which is analyzed to determine the diffuse horizontal irradiance (DHI). In the moment when the center of the shadow falls on the center of the sensor it basically only detects DHI. Subsequently, direct normal irradiance (DNI) is calculated by the datalogger using GHI, DHI and the actual sun height angle by known time and coordinates of the location.

Appropriate irradiance sensors for ground measurements must be selected in consideration of general surrounding conditions for equipment and maintenance to gain and maintain the necessary accuracy over the entire operation period. Thermopile instruments like pyrheliometers as specified in ISO standard 9060 [ISO9060, 1990] are severely affected by soiling [Pape, 2009] and also require expensive and maintenance-intensive support devices such as solar trackers. Thus, the uncertainty of resource assessment with pyrheliometers

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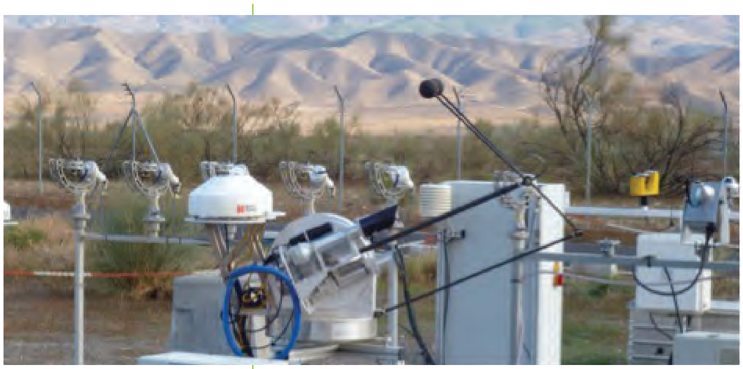
depends heavily on the maintenance personnel and cannot be determined accurately in many cases. The initially lower accuracy of RSIs, which can yield deviations of 5 to 10 % and more, is notably improved with proper calibration of the sensors and corrections of the systematic deviations of its response. The main causes of the systematic deviations are the limited spectral sensitivity and temperature dependence of the solid-state pyranometer commonly used in most RSIs. Several sets of correction functions exist and are documented in scientific publications and in the report.



▲ **Figure 2. Solar tracker with reference radiometers for RSI calibration at Plataforma Solar de Almeria.**

Besides the systematic deviations of the sensor response, a significant contribution to the measurement inaccuracy originates from the sensor calibration at the manufacturer, where no corrections are applied. For proper calibration however, the proposed corrections still need to be considered in the calibration procedure. While well documented standards exist for the calibration of pyrheliometers and pyranometers ([ISO9059, 1990], [ISO9846, 1993], [ISO9847, 1992]) they cannot be applied to RSIs and no corresponding standards exist for RSIs. Different RSI calibration methods exist and are compared in the report (Figure 2). Application of two or more calibration factors for the different irradiance components (GHI, DHI and DNI) respectively yields noticeable higher accuracy than the application of only one calibration factor derived from GHI measurements.

The IEA SHC Task 46 report contains RSI specific best practices for the following tasks:

- Requirements on the selection of a location for a measurement station
- Installation, operation and maintenance of a measurement station, including the case of remote sites
- Documentation and quality control of the measurements
- Correction of systematic errors & instrument calibration
- Also the performance and accuracy of RSIs are described.

RSIs have proven to be appropriate instruments for diligent solar resource assessments for large-scale solar thermal projects, especially for those using concentrating collectors. Due to their lower maintenance requirements, lower soiling susceptibility, lower power demand, and comparatively lower cost, RSIs show significant advantages over thermopile sensors when operated under the measurement conditions of remote weather stations. For properly calibrated RSIs that use correction functions for systematic effects, uncertainties of below 3% for 10 min DNI averages and below 2% for yearly DNI sums have been found in various studies. Thus, RSI's offer a low-cost solution for obtaining accurate DNI data for the proper sizing of solar systems using concentrating collectors.

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