Driven by the accuracy requirements of the solar renewable energy industry, solar radiation measurement reaches the next level. Sensor technology is improving, user access to calibration is getting easier, practices for instrument maintenance and measurement uncertainty evaluation are now being standardised. Hukseflux Thermal Sensors, a technology leader in this field, is actively involved.

The weakest link

Until now, measurement of solar radiation has often been the weakest link in PV system performance assessment. The equipment used for this, pyranometers, is an optical instrument. Their measurement uncertainty under perfect conditions is in the 2 to 3% range. However, conditions at a solar power plant are frequently imperfect. A major error source is instrument fouling, for example by dew, frost, rain or dirt. The frequency of pyranometer maintenance is often low. To reduce the impact of fouling, cleaning is essential, but it may not be part of the standard maintenance program.

Recalibration, the most common way of verifying the true performance of the instrument, is seldom done. The overall result of this lack of cleaning and calibration is a much larger measurement uncertainty than that under perfect conditions; typically no better than 5%.

New standard practices: ASTM and IEC

In the past five years, the solar community has acknowledged that the low measurement accuracy of solar radiation deserves attention. In particular utility-scale PV systems, from 4 MW and up, are professionally monitored and treated as a financial asset.

Asset managers accurately monitor PV system performance to optimise day-to-day operations. The same monitoring data are needed in order to have a clear understanding of the present value of the asset.

The solar community has already been working on standard procedures for uncertainty evaluation. The Working ASTM standard “New Practice for Uncertainty Evaluation of Calibration and Measurements with Pyranometers and Pyrheliometers” is under ballot and is expected to be released soon.

Examples of the recommended procedures are already available, in the form of spreadsheets, via the main editors such as the National Renewable Energy Laboratory NREL in the USA and Hukseflux Thermal Sensors. See Figure 1 for an example of measurement uncertainty evaluation over the course of a day.

The IEC 61724-1 Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis – was updated in March 2017. The new 2017
version of the standard is fundamentally different from the 2008 version. The scope now not only defines the measuring system components and procedures, as in the earlier 2008 version, but it also aims to keep measurement errors within specified limits. It does so by establishing “accuracy classes” for monitoring systems.

The new IEC 61724-1:2017 standard includes:

- 3 accuracy classes, A, B and C, for monitoring systems, to be used in conformity declarations
- Accuracy requirements for monitoring equipment (electrical as well as solar radiation) per class
- Required quality checks (i.e. calibration and cleaning for pyranometers also) per class
- Recommended minimum number of solar radiation measurement instruments used as a function of the PV system scale

**Utility-scale PV system performance monitoring**

Utility-scale PV systems will be monitored using Class A or Class B monitoring according to IEC 61724-1. For example, the requirements for solar radiation measurement to comply with Class A are:

- Secondary standard pyranometers for Global Horizontal Irradiance (GHI) and Plane Of Array (POA) irradiance
- Instruments equipped with ventilation and heating against dew and frost
- Instruments cleaned daily
- Instruments calibrated yearly

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**Figure 1.** Uncertainty evaluation of the measurement of Global Horizontal Irradiance (GHI) on a sunny day, expressed in W/m². The maximum GHI value around solar noon is 1000 W/m². The different colours represent different error sources.

**Figure 2.** When pyranometer domes are covered with dew or frost, data is no longer reliable. New technology developments implemented in SR30 (sensor on the right in the image above) ensure data availability.

**Figure 3.** Illustration of the significance of data availability: irradiance readings on a clear sky day with freezing temperatures: new technology - heated model SR30 – pyranometer, traditional pyranometer heated and ventilated, traditional pyranometer unheated and unventilated. Data were taken 4 December 2016 at Cabauw, the Netherlands.
Class B requirements are somewhat less stringent. However, Class B also has requirements for ISO 9060 instrument class, as well as cleaning and calibration. The implementation of an IEC 61724-1 Class A or B monitoring system means that the measurement uncertainty will get quite close to the ideal situation.

- The accuracy loss due to fouling will get close to zero, and may otherwise be estimated from signal jumps in the irradiance after cleaning on a clear sunny day.
- The accuracy loss due to instrument non-stability also becomes negligible.

Why pyranometers must be heated: data availability

Pyranometers in general suffer from various measurement errors. Most obviously: their optics, glass domes, get dirty. This results in a badly defined condition. Measurements are no longer reliable. We then say that data are “not available”. See Figures 2 and 3 for examples of what happens.

In Figure 4 we see an example of the loss of data. Measuring with a traditional pyranometer, 10% of the data, as a percentage of total time, is unreliable. When instruments are ventilated and heated, as required in IEC 61724-1 Class A, the data reliability strongly improves.

New instrument development: Hukseflux pyranometer model SR30

New technology development was needed to overcome the drawbacks of traditional pyranometers. It started with the wish to match the performance of externally ventilated instruments, without the disadvantages of high power use. Remote status monitoring, an extra benefit for users, was on the research & development wish list too.

Hukseflux Thermal Sensors, a leading manufacturer of pyranometers, is with its focus on R&D and engineering improvements, at the forefront of these new technology developments.

SR30 pyranometer, released by Hukseflux in January 2017, is designed specifically to meet the needs of the PV industry. It is the first pyranometer to comply with the new IEC 61724-1 standard Class A requirements. SR30 measures solar radiation employing a state-of-the-art thermopile sensor with black coated surface and two domes. The outer pyranometer dome is heated by ventilating the area between the inner and outer dome using RVH™ – Recirculating Ventilation and Heating technology. RVH™, developed by Hukseflux, suppresses dew and frost deposition and is as effective as traditional ventilation systems, without the maintenance hassle and large footprint. See Figure 3 for the overall performance.

Domes free of dew and frost ensure high data availability. In addition to the highest measurement accuracy and data availability, SR30 pyranometer offers remote diagnostics, including instrument tilt, and low total cost of ownership.

Pyranometer maintenance: cleaning and calibration

Notwithstanding the performance improvements due to instrument heating and ventilation, pyranometers still need regular cleaning and calibration. The IEC standard contains requirements for both, again depending on the monitoring class. Calibration is now available at multiple locations around the world: the Hukseflux organisation can handle instrument calibrations of multiple brands in India, Japan, China, Brazil, USA, South Africa and the Netherlands. These facilities typically perform indoor calibration according to ISO 9847 and ASTM G207. A further reduction of turnaround time and logistics costs is high on the agenda.

What’s next?

There is significant progress: with standard practices of ASTM and IEC, instrument model SR30 bringing the price of ventilated and heated instruments down and a reduction of calibration costs by offering it closer to the customer.

PV system O&M and Asset managers expect measurements to be more accurate, reliable and at the same time more affordable. At Hukseflux, we do not see this as a contradiction; we do our best to make this possible. Pyranometers such as SR30 are proof of this.

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