Hukseflux
Thermal Sensors

In-company workshop: solar radiation measurement

Experts from Hukseflux explain and discuss at your company recent developments in solar radiation measurement for PV system performance monitoring

An accurate measurement of solar radiation is the backbone of PV system performance assessment. In our in-company workshop, we present developments in PV system performance monitoring according to the IEC 61724-1 standard. You will also get the latest insights in instrument classification according to ISO 9060, recommended practices for use, maintenance, inspection and calibration according to ISO 9901 as well as an introduction to ASTM G213 on uncertainty evaluation. In many cases we can help save costs.

Figure 1 *Improving data availability and measurement uncertainty; heated versus unheated instruments*

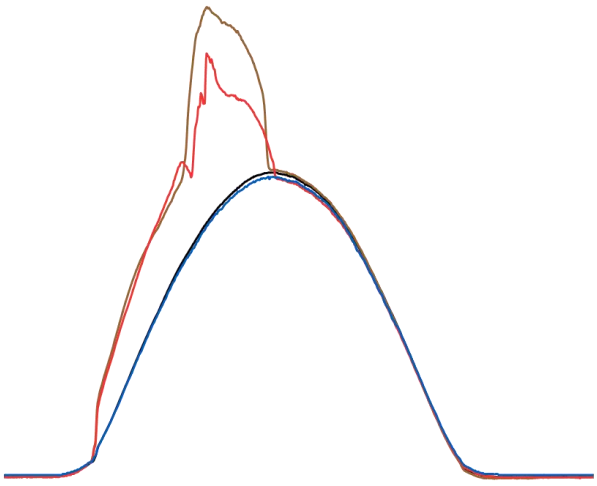


Figure 2 *Example of the effect of frost on the measurement; black and blue are reference measurements, brown and red are measurements made with pyranometers with frozen domes, like the one in front in Figure 1*

Objective of the workshop

The in-company workshop is offered to you free of charge by Hukseflux Thermal Sensors. We present the latest developments in solar radiation measurement and help you optimise system design, measurements and maintenance.

Management summary

Asset managers increasingly insist on having the highest accuracy monitoring systems according to the latest IEC 617240-1 standard for PV system performance monitoring. The standard requires instruments with the right paperwork (according to ISO and ASTM standards), dew and frost mitigation by heating, and regular (recorded) inspection and recalibration to act as proof of reliable performance.
Keeping IEC-grade monitoring records increases the PV power plant's value. This high-level quality assurance also proves its value when legal issues arise, for example in support of warranty claims.

The latest trends in PV monitoring are:

- measurements according to IEC 61724-1 Class A, including quality assurance: regular cleaning, inspection and re-calibration
- expected new IEC recommendations for monitoring of bifacial PV systems
- use of digital sensors for easy instrument exchange, and cost savings on cabling
- use of highest accuracy – Spectrally Flat Class A – instruments
- improvement of data availability by mitigation of dew and frost using ventilation and heating
- uncertainty evaluation according to ASTM G213

Each topic is discussed during the in-company workshop and (briefly) on the following pages.

Major updates of IEC 61724-1

The IEC 61724-1: *Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis* – has been updated in 2017. The new scope not only defines the measuring system components and procedures (as in the 2008 version), it now also aims to keep measurement errors within specified limits. It does so by establishing accuracy classes for monitoring systems.

The new standard includes:

- 3 accuracy classes, A, B and C, for monitoring systems, to be used in conformity declarations
- accuracy requirements for monitoring equipment per class
- required quality checks (i.e. calibration and maintenance) per class
- recommended minimum number of instruments used as a function of the PV system scale

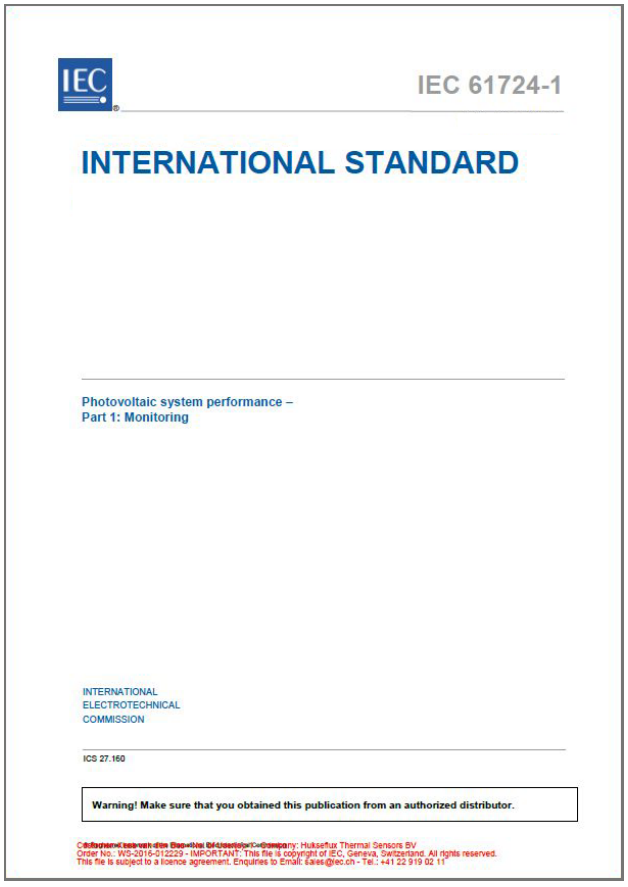


Figure 3 *Cover of the new IEC 61724-1 standard, published in February 2017*

A second update of IEC 61724-1 is on its way in 2020. This update will contain new recommendations for monitoring of bifacial PV systems.

From analogue to digital

While traditional pyranometers have analogue outputs, the latest pyranometer models communicate over RS-485.

Advantages:

- use of digital sensors for easy instrument exchange, exchangeable sensors
- no possibility to manipulate data
- on-board calibration history records

Potential disadvantages are:

- not all calibration laboratories can handle these digital sensors
- not all manufacturers allow access to the internal software to correct the sensitivity after recalibration. Hukseflux does!

Increasing instrument performance

Use of lower than Spectrally Flat Class A instruments and use of PV reference cells for POA is decreasing; these sensors are not sufficiently stable and not universally applicable with every cell type. This is now formally acknowledged in the latest IEC 61724-1 and ASTM 2848 standards.

Formalities: test certificates with every instrument

The approach of investors tends to get more formal. When auditing PV monitoring systems, investors ask for documented proof of performance verification during production as well as field maintenance records.
ASTM 2848-11, covering test methods for PV systems, states: "pyranometers are sensitive to both temperature and the angle of incidence of irradiance" and recommends: "that pyranometer responsivity be characterized to the extent practicable".

Focus on data availability

Dew, frost and snow deposition cause significant non-availability of data; as shown in Figure 2.
The latest trends to improve data availability are:

- ventilation of pyranometers
- heating of pyranometers

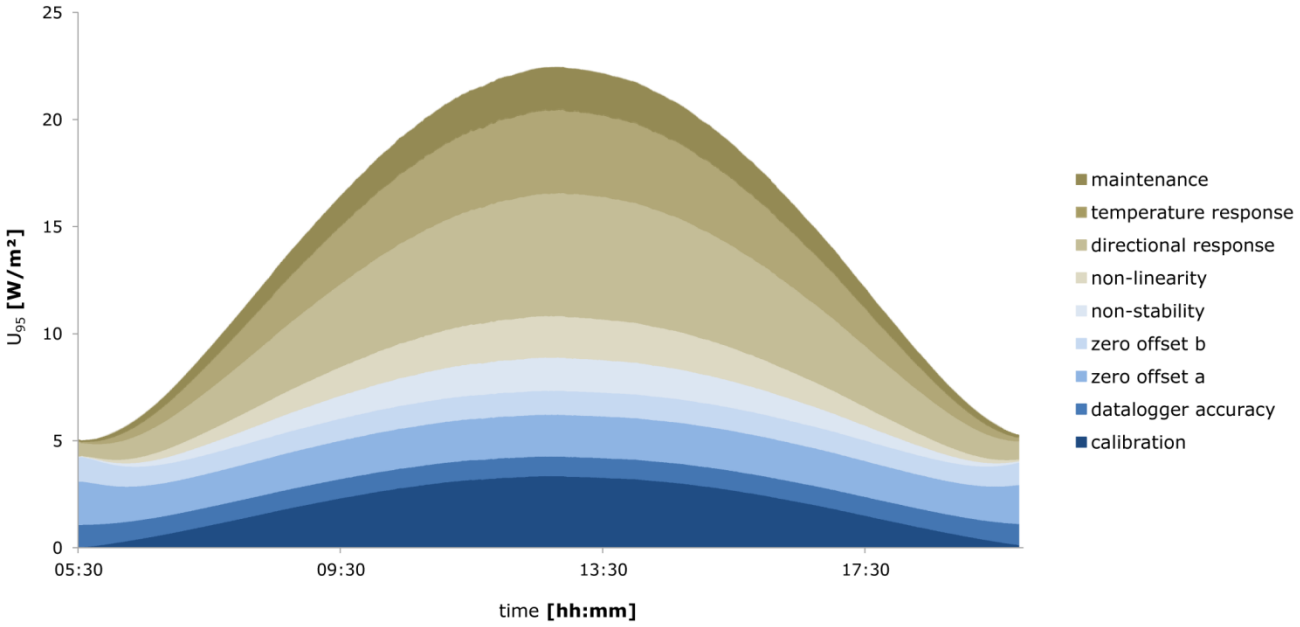
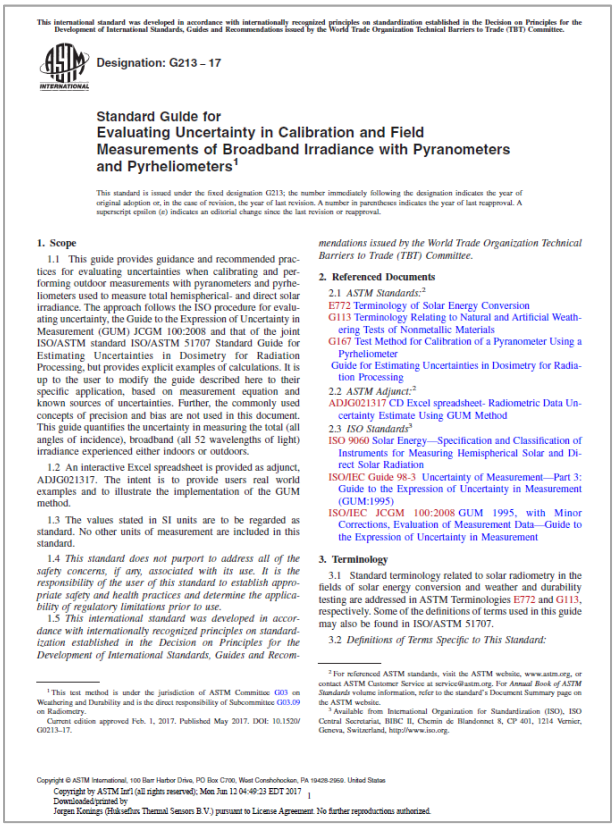


Figure 4 *Uncertainty evaluation according to the ASTM Guide G213 of a measurement of Global Horizontal Irradiance (GHI) on a sunny day, expressed in W/m². The maximum value around solar noon is 1000 W/m². The different colours represent different error sources*



This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: G213 – 17

Standard Guide for Evaluating Uncertainty in Calibration and Field Measurements of Broadband Irradiance with Pyranometers and Pyrheliometers[1]

This standard is issued under the fixed designation G213; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide provides guidance and recommended practices for evaluating uncertainties when calibrating and performing outdoor measurements with pyranometers and pyrheliometers used to measure total hemispherical- and direct solar irradiance. The approach follows the ISO procedure for evaluating uncertainty, the Guide to the Expression of Uncertainty in Measurement (GUM) JCGM 100:2008 and that of the joint ISO/ASTM standard ISO/ASTM 51707 Standard Guide for Estimating Uncertainties in Dosimetry for Radiation Processing, but provides explicit examples of calculations. It is up to the user to modify the guide described here to their specific application, based on measurement equation and known sources of uncertainties. Further, the commonly used concepts of precision and bias are not used in this document. This guide quantifies the uncertainty in measuring the total (all angles of incidence), broadband (all 52 wavelengths of light) irradiance experienced either indoors or outdoors.

1.2 An interactive Excel spreadsheet is provided as adjunct, ADJG021317. The intent is to provide users real world examples and to illustrate the implementation of the GUM method.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
E772 Terminology of Solar Energy Conversion
G113 Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials
G167 Test Method for Calibration of a Pyranometer Using a Pyrheliometer
Guide for Estimating Uncertainties in Dosimetry for Radiation Processing

2.2 *ASTM Adjunct:*[2]
ADJG021317 CD Excel spreadsheet- Radiometric Data Uncertainty Estimate Using GUM Method

2.3 *ISO Standards*[3]
ISO 9060 Solar Energy—Specification and Classification of Instruments for Measuring Hemispherical Solar and Direct Solar Radiation
ISO/IEC Guide 98-3 Uncertainty of Measurement—Part 3: Guide to the Expression of Uncertainty in Measurement (GUM:1995)
ISO/IEC JCGM 100:2008 GUM 1995, with Minor Corrections, Evaluation of Measurement Data—Guide to the Expression of Uncertainty in Measurement

3. Terminology

3.1 Standard terminology related to solar radiometry in the fields of solar energy conversion and weather and durability testing are addressed in ASTM Terminologies E772 and G113, respectively. Some of the definitions of terms used in this guide may also be found in ISO/ASTM 51707.

3.2 *Definitions of Terms Specific to This Standard:*

[1] This test method is under the jurisdiction of ASTM Committee G03 on Weathering and Durability and is the direct responsibility of Subcommittee G03.09 on Radiometry.
Current edition approved Feb. 1, 2017. Published May 2017. DOI: 10.1520/G0213-17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

Figure 5 *Cover of the new ASTM G213-17 standard, published in June 2017*

NEW: uncertainty evaluation / data analysis using ASTM G213

Measurement accuracy does not only depend on instrument properties, but also on measurement conditions:

- a very accurate instrument, like the secondary standard class sensors mostly used in the PV industry, will quickly underperform without a regular schedule of maintenance and calibration.
- assessment of data availability and rejection of data are integral parts of the evaluation of the measurement. Data is eventually presented including a measurement uncertainty.

ASTM International has released the G213-17 "Standard Guide for Evaluating Uncertainty in Calibration and Field Measurements of Broadband Irradiance with Pyranometers and Pyrheliometers". It provides guidance and recommended practices for evaluating uncertainties when calibrating and performing outdoor measurements with pyranometers and pyrheliometers. In conformity declarations, providers can now refer to this standard.

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Figure 6 *Individual testing of every instrument; Hukseflux performs individual testing of temperature response and directional response of all Class A instruments*

NEW: pyranometer recommended practice for field use ISO TR 9901

ISO TR 9901 is under revision: get a preview!

Hands-on with the sensors

During the workshop, several sensors can be demonstrated. Users will be able to find out for themselves how easy their use is.

Saving costs on system and maintenance

You can save costs in many ways, for example by paying attention to the design; we can assist in optimising power supply cabling, dew and frost mitigation, and measures to improve electromagnetic immunity. We can also assist to save costs of calibration.

Measurement versus model

Modellers increasingly use virtual representations or "digital twins" in system analysis. Show us what your digital twin needs as input, so that we can optimise.

Cost of ownership

Asset managers increasingly accept the need for regular recalibration of the PV plant monitoring systems. Calibration of Class A pyranometers is not easy, and can only be performed by a limited number of organisations.
For pyranometers under a professional maintenance regime, the cost of ownership over the instrument lifetime will be not only be determined by costs of purchase but also by maintenance costs.

The role of monitoring parties

Asset managers increasingly separate the responsibilities for PV plant operation and performance monitoring. The role of the monitoring party will, in our opinion, concentrate on the analysis and quality assurance of the data, including instrument maintenance and calibration. A major challenge is to perform maintenance and recalibration of pyranometers efficiently.

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. With our laboratory facilities, we provide testing services including material characterisation and calibration. Our main area of expertise is measurement of heat transfer and thermal quantities such as solar radiation, heat flux and thermal conductivity. Hukseflux sensors, systems and services are offered worldwide via our office in Delft, the Netherlands and local distributors.

Interested in having this workshop at your company?

E-mail us at: info@hukseflux.com