Explaining PV plant monitoring to IEC 61724-1

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Reliable measurement of solar irradiance, and other environmental parameters, is crucial to accurately calculating the performance ratio (PR) of a solar energy plant. IEC 61724, published in March 2017, is the latest and most comprehensive international standard to address these issues. But what does it mean?

IEC 61274-1 Photovoltaic system performance - Part 1: Monitoring also serves as the basis of two standards for performance analysis that rely upon the data collected, IEC TS 61724-2 and IEC TS 61724-3. Part 1 outlines equipment, methods, and terminology for the performance monitoring and analysis of solar energy PV plant systems; from irradiance

input to AC power output. It is applicable to fixed angle, single-axis tracking and dual-axis tracking conventional PV modules and to concentrator (CPV) systems. It does not currently cover bifacial installations.

For Classes C and B, it is acceptable to estimate some measurements from other nearby and reliable data sources, but these are rarely available. For Class A all parameters must be monitored at the site.

The types of sensors required for each monitoring system (station) depend largely upon the application. Measurement of Diffuse Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI) is included in the standard for specific purposes, but here we will concentrate on the measurement of Global Horizontal Irradiance (GHI) and Plane-of-Array irradiance (POA) and other key meteorological (weather) parameters.

Communication and Connection

The industry standard for data communication within PV plants is now 2-wire RS-485 with Modbus® RTU protocol, using individually addressable inverters and monitoring equipment on a small number of data bus loops. Distributed sensor power is 12 or 24 VDC.

Recent inverters, hubs and gateways often have no analog inputs. There may be no field data logging, all the devices connect back to the site supervisory control and data acquisition (SCADA) system for storage, analysis and visualization by the plant monitoring software and for remote access. Where a digital output is not available from a device, a 4-20 mA signal is usually preferred

Typical applications	Class C Basic Accuracy	Class B Medium Accuracy	Class A High Accuracy
Basic system performance assessment	X	X	X
Documentation of a performance guarantee		X	X
System losses analysis		X	X
Electricity network interaction assessment			X
Fault localization			X
PV technology assessment			X
Precise PV system degradation measurement			X
Maximum sampling interval for irradiance, temperature, wind, DC and AC electrical output	1 min	1 min	3 sec
Maximum sampling interval for soiling, rain, snow, and humidity	1 min	1 min	1 min
Maximum recording interval	60 min	15 min	1 min

IEC 61724-1 PV plant performance monitoring classifications

for use with the analog inputs of low-cost industrial data loggers.

Class C Monitoring System

- POA irradiance – any type of thermopile pyranometer, PV reference device or photodiode sensor; to be recalibrated as per the manufacturer's requirements.

- Ambient air temperature – for an indication of the effect on module efficiency, although it is much better to monitor the module temperature directly.

The efficiency of monocrystalline and polycrystalline silicon cells typically drops by around 0.5% per °C temperature rise, compared to the standard test condition of 25°C. At 45°C in the sunshine the output could be 10% lower. This is not a fault; it is a characteristic that needs to be measured accurately and taken account of in PR calculations.

This type of monitoring system is largely intended for commercial rooftop installations to give an idea of the PV installation efficiency where there are no significant performance-related financial and contractual implications.

Class C irradiance sensor with compliant module temperature sensor

Class B Monitoring System

- GHI and POA irradiance – ISO 9060:2018 Spectrally Flat Class B pyranometers or PV 'reference' devices with measurement uncertainty ≤ 8 % for hourly irradiance totals (photodiode sensors are not acceptable); to be recalibrated every 2 years.

Heating is required if condensation and/or frozen precipitation, including dew, will affect the irradiance measurement on more than 14 days per year. Ventilation of pyranometers is optional, but in many locations (particularly where cleaning is infrequent) soiling can be a significant issue. External ventilation units blow filtered clean air over the pyranometer dome to reduce the deposition of dirt, dust and other soiling contaminants and reduce the frequency of cleaning that is needed. They also include the option of heating the airflow to prevent dew forming on the dome, evaporate rain droplets and melt frost.

- PV module temperature – 6 sensors per system, distributed along the strings, for temperature correction of PR. As the number of modules in a string increases the loading along the string and the temperature of the cells varies. There are strict IEC guidelines regarding sensor position, thermal conductivity of the fixing and overall accuracy of the measurement.

- Ambient air temperature – for historical trending analysis, the sensor must have a

Pyranometer measuring plane of array (POA) irradiance

ventilated solar radiation shield to prevent build-up of static air.

- Wind speed – affects surface cooling of the modules.

- Rainfall – to correlate with power generation loss due to water on the modules.

Class B is not likely to be popular because utility-scale PV plants often have significant contractual under-performance penalties. The uncertainty of the hourly irradiance totals will be around 6-8% and this is not good enough for meaningful PR calculations that will satisfy all stakeholders. It is unlikely that stakeholders will see a necessity to install 6 module temperature sensors per monitoring system.

Pyranometer with ventilation and heating unit

Class A monitoring system: GHI and POA pyranometers, weather station, soiling monitors

Class A Monitoring System

- GHI and POA irradiance – ISO 9060:2018 Spectrally Flat Class A pyranometers or PV reference devices with measurement uncertainty ≤ 3 % for hourly irradiance totals (these genuinely 'reference' cells typically cost more than an equivalent pyranometer); to be recalibrated every year.

Heating is required if condensation and/or frozen precipitation will affect the irradiance measurement on more than 7 days per year, ventilation of pyranometers is mandatory. In practice this means that heating and ventilation are always required. See the comments for Class B regarding the advantages of an external ventilation unit to reduce dome soiling.

- PV module temperature – 6 sensors per system, distributed along the strings, for temperature correction of PR; as described for Class B.

- Ambient air temperature – for historical trending analysis, the sensor must have a ventilated solar radiation shield.

- Wind speed – affects surface cooling of the modules.

- Wind direction – for historical trending analysis.

- Rainfall – to correlate with power generation loss due to water on the modules.

- Snow – to correlate with power generation loss if this is an issue at the location.

- Soiling ratio – if the power loss is > 2 %, to inform when module cleaning is advisable.

An all-in-one weather station with a single mounting and power/data connection is a convenient way to monitor all the meteorological parameters other than solar irradiance. Typically, these also monitor air pressure and relative humidity and calculate the dew-point, which is useful to correlate with reduced yield. The wind speed and direction sensor are ultrasonic with no moving parts.

Unlike a tipping bucket rain-gauge, a radar precipitation sensor does not need regular cleaning and outputs data in real time, to correlate with the power generated, and it can detect whether the precipitation is rain (liquid) or snow (solid).

A soiling monitor that can be mounted alongside PV modules or within an array gets dirty at the same rate as the surrounding modules. An optical soiling measurement technology monitors the loss of light transmitted through the glass and, for any type of module, the effect on power generation can be calculated from the manufacturer specifications. This type of soiling monitor requires no maintenance and is only cleaned at the same time as the modules around it.

Different areas of a large PV plant get dirty at different rates and multiple monitors can provide a soiling map of the plant. By comparing the opportunity cost of lost energy production with the cost of cleaning the O&M staff can decide when, and where, to clean modules on a site-specific basis.

The uncertainty of the hourly irradiance totals will be around 3 % (daily total typically within 2 %) which is very suitable for reliable plant PR calculations. Class A monitoring requires that the irradiance sensors are cleaned at least once per week and recalibrated every year and the air temperature and module temperature sensors are to be recalibrated every 2 years. There is a cost associated with this. Therefore, it is possible that a PV plant might be specified with Class A monitoring equipment but that the O&M procedures are not compliant.

Number of Plant Monitoring Systems

IEC 61724-1 refers to the designed AC power capacity of the plant for the recommended minimum number of monitoring systems, on the basis that all the PV modules are installed at the same orientation and that there is no redundancy or back-up monitoring.

Where sites have varying module angles, for example over hillsides or in valleys, there should be more POA pyranometers and soiling monitors; some orientations could be East and some West.

ISO 9060 – The Standard for Pyranometer Performance

ISO 9060 'Solar energy - Specification and classification of instruments for measuring hemispherical solar and direct solar radiation' defines what is a pyranometer, and what is a pyrheliometer for measuring DNI. IEC 61724-1 refers to ISO 9060:1990 because it was developed and published before the standard was updated in November 2018, which 'de facto' replaces the earlier edition.

The 1990 version specifies pyranometer performance in order of improving performance as:

Second Class → First Class → Secondary Standard

Radiation from 350 to 1500 nm is the critical wavelength range for photo-voltaic materials

Plant capacity (AC)	Number of monitoring systems
< 5 MW	1
≥ 5 MW to < 40 MW	2
≥ 40 MW to < 100 MW	3
≥ 100 MW to < 200 MW	4
≥ 200 MW to < 300 MW	5
≥ 300 MW to < 500 MW	6
≥ 500 MW to < 750 MW	7
≥ 750 MW	8

IEC 61724-1 minimum number of monitoring systems by plant capacity

and the standard requires that pyranometers respond evenly over this range and are 'spectrally flat'. For this reason, it does not allow 'photoelectric' sensors, such as silicon cells and photodiodes, because of their restricted and uneven spectral response.

The most noticeable change in ISO 9060:2018 is the classification names:

Class C → Class B → Class A

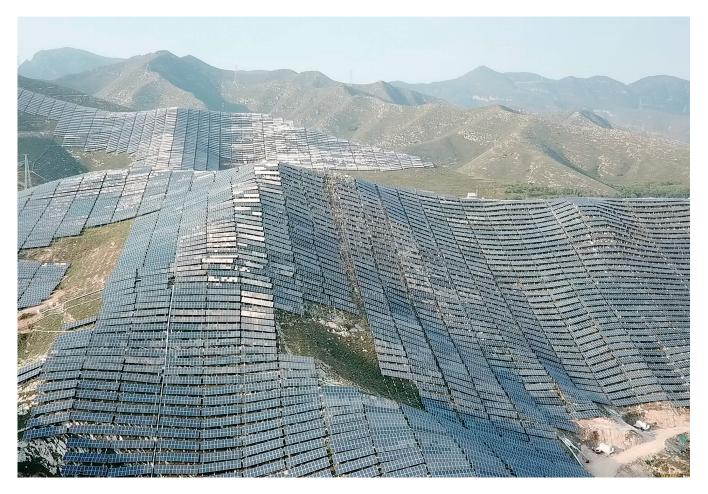The standard now allows photoelectric sensors. If a pyranometer meets the 1990 criteria for Secondary Standard, it is now termed Spectrally Flat. If the 95 % response time is less than 0.5 second, it is Fast Response. Fast Response Class C is typical for the analog output of a photodiode sensor without amplification.

Radiometers with RS-485 Modbus® RTU serial data communication usually update values in the output registers every second and therefore are not 'fast response'. This is also true of most amplified analog pyranometer outputs due to noise reduction filters.

ISO 9060:2018	Class C	Spectrally Flat Class C	Spectrally Flat Class B	Spectrally Flat Class A
ISO 9060:1990	Not Allowed	Second Class	First Class	Secondary Standard
Performance	Lower	→	→	Higher
Passive pyranometers	SP Lite2 (Fast Response)	CM4 CMP3	CMP6	CMP10 CMP11 CMP21 CMP22
Smart pyranometers	RT1	SMP3	SMP6	SMP10 SMP11 SMP21 SMP22

Kipp & Zonen pyranometer ISO 9060:1990 and 2018 classifications

'By comparing the opportunity cost of lost energy production with the cost of cleaning the O&M staff can decide when, and where, to clean modules on a site-specific basis.'

Different module orientations require extra POA pyranometers

ISO 9060:2018 states that the new classifications are 'roughly corresponding' to the classes from 1990 and there are some significant differences in the way that specifications are defined. However, in general, a pyranometer that met the 1990 Secondary Standard requirement should meet the 2018 Spectrally Flat Class A requirements.

Note that Class A pyranometers must be individually tested for temperature response and directional response (cosine error) to demonstrate that it meets the requirements of the standard. This means that if a Secondary Standard pyranometer did not have these individual tests carried out, and it met the new limits, it cannot be 'updated' to Class A without the additional testing being carried out.

Many people involved in the solar energy sector have heard about this standard but do not appreciate what it covers. We strongly recommend purchase of the document from the IEC Webstore at https://webstore.iec.ch/publication/33622.

www.kippzonen.com

This article is an excerpt from 'Solar Energy International Standards', a whitepaper produced by Kipp & Zonen to explain the standards most frequently used in solar energy: ISO 9060, IEC 61274-1, ISO 9846/9847 and ISO/IEC 17025. You can download it at www.kippzonen.com/standards