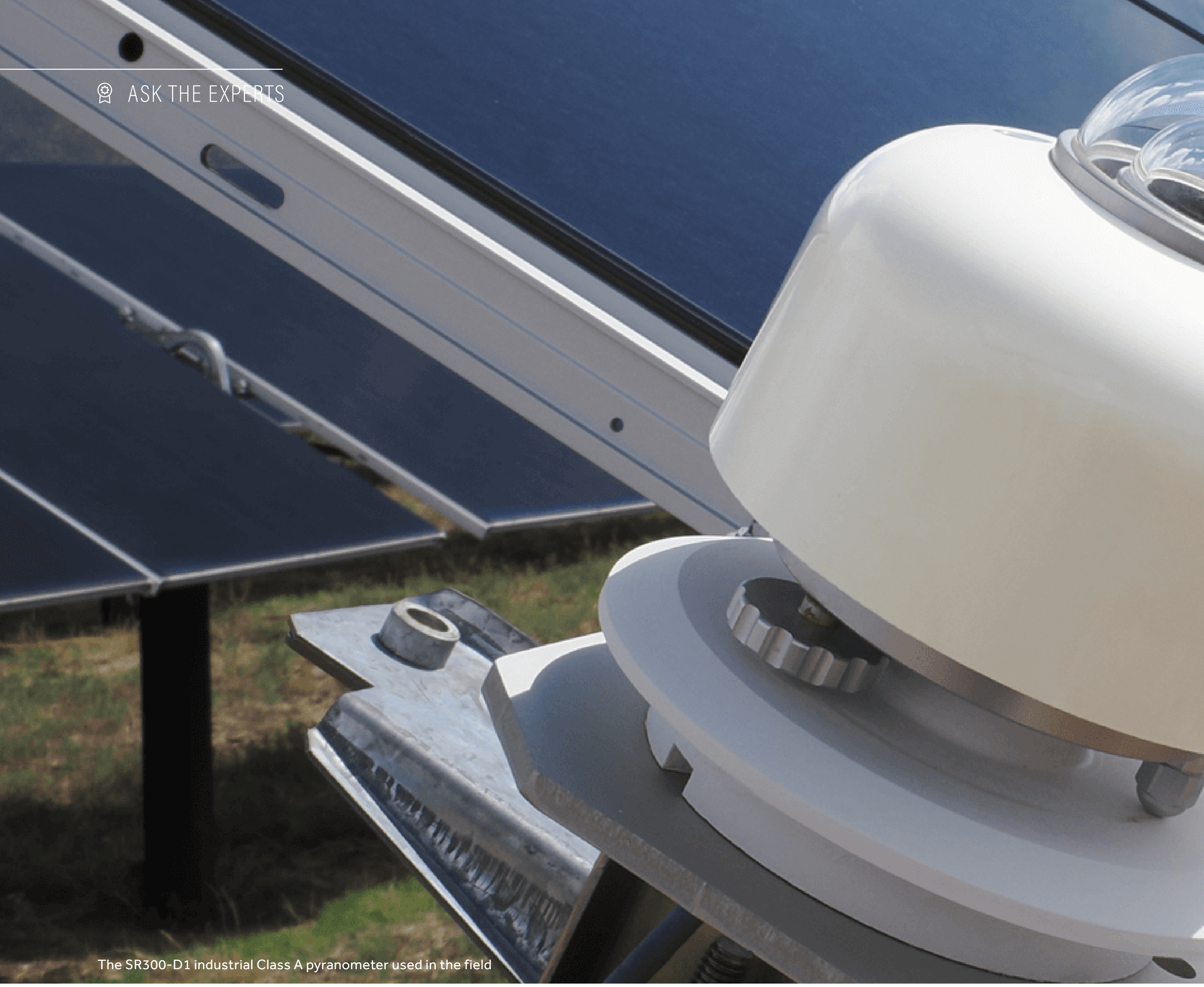


The SR300-D1 industrial Class A pyranometer used in the field

PV system Performance Ratio measurements: going beyond Class A standards

Hukx has earned a global reputation in solar radiation measurement, with its Class A instruments known for accuracy that goes beyond standard ISO benchmarks. The company has also developed a worldwide calibration network aimed at lowering long-term costs. In a recent study with Delft University of Technology, Hukx explored how measurement accuracy influences PV system Performance Ratio (PR). PES spoke with lead researcher Matthijs Ates to hear what they found.

PES: It's great to speak to you today Matthijs. Could you tell us more about your research and Hukx's motivations for initiating this study?

Matthijs Ates: We looked at how uncertainty in pyranometer measurements affects real-world uses of solar radiation data, particularly PV system Performance Ratio (PR) calculations. PR is based on measured solar irradiance, power output and module temperature, so any uncertainty in these inputs feeds directly into the final result.

We quantified the overall uncertainty in PR, identified the main contributing factors and examined how this uncertainty influences how PR is used in industry.

For a long time our focus has been on developing highly accurate instruments, often exceeding the Class A requirements set out in ISO 9060. This research was driven by a need to better understand how measurement uncertainty impacts downstream applications. We calculate the amount of error allowed starting from the defined specifications.

By taking this broader view, we can assess how sensor accuracy translates into real operational challenges for the PV sector and help inform discussions around the level of accuracy needed for modern PV systems.

PES: Can you share some results with us? How is measurement uncertainty in the Performance Ratio a practical issue?

MA: The Performance Ratio has multiple practical applications in the PV industry. It is used as a general performance indicator, but also as an instrument in determining the construction quality, degradation rate or financial value of a power plant. It is often included in contractual agreements related to these topics.

Uncertainty in measuring a power plant's PR will lead to uncertainty in PR applications. If you measure a PR of 90% with ± 5% uncertainty, which, in our opinion, is a high accuracy for this measurement, it means the actual PR is realistically somewhere from 85% to 95%.

This is a difference with significant financial consequences for the power plant owner and, potentially, for other parties involved in a power plant's lifecycle.

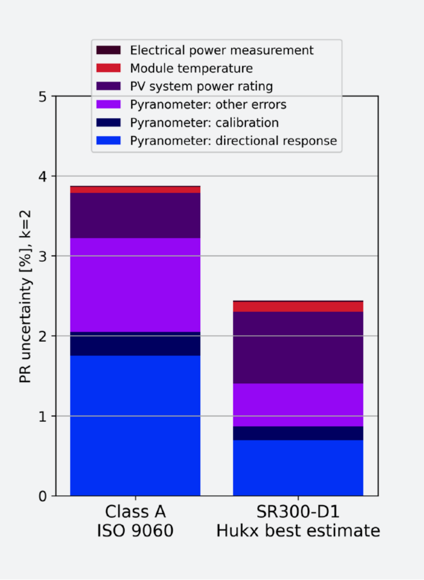
For example, engineering, procurement and construction (EPC) contracts often include a PR guarantee that a power plant must satisfy upon completion, with financial consequences if the threshold is not met. In this situation, measurement uncertainty in the PR directly leads to financial risks for both the power plant owner and the EPC contractor.

The analysis showed that the Value at Risk associated with performance-related liquidated damages increases linearly with PR measurement uncertainty. In other words, lower accuracy means more financial risk for the EPC. But also, more generally, lower accuracy means a higher risk of 'false acceptance' and 'false rejection'; basically, test results that are unfair and, in essence, incorrect.

We assessed the achievable accuracy of PR measurements under IEC 61724 monitoring requirements, comparing a standard ISO 9060 Class A pyranometer with a Hukx SR300-D1.

A system using a typical Class A pyranometer showed an uncertainty of around 3.5 to 4.0% in annual PR, whereas a system using the SR300-D1 reduced this to approximately 2.0 to 2.5%.

The relative difference is significant and translates into a financial risk difference of around 10 to 20% for EPC warranty provisions.



Performance Ratio measurement uncertainty for systems using a pyranometer with nameplate class A specifications (left) and an SR300-D1 (right)

Aside from acceptance testing, lower uncertainty also impacts other uses of the PR. It drastically increases the accuracy of performance loss rate calculations, supports more reliable plant valuations, enhances fault detection and enables more effective monitoring of O&M quality.

All in all, for both the asset owner and EPC, it is valuable to have accurate PR estimates.

PES: Based on your findings, what practical steps can asset owners and operators take to reduce measurement uncertainty and improve the reliability of performance data?

MA: Our calculations showed that solar irradiance measurement remains the most significant source of uncertainty in PR calculation. For a monitoring system of nameplate Class A accuracy specifications, we found that, under otherwise perfect conditions, approximately 75% of the uncertainty is attributable to the solar irradiance measurement. High-quality pyranometers are therefore crucial for accurate PV performance measurement.

Class A requirements serve as a baseline for monitoring. Going beyond this baseline directly increases data reliability and reduces financial risk.

Another important step is to recalibrate irradiance sensors, preferably every two years. Modern pyranometers are highly stable, but not impervious to physical damage to the dome or the circuit board. By regularly recalibrating sensors, you catch potential issues in a timely fashion and maintain trust in the data stream, reducing risk exposure.

Regular cleaning and inspection of pyranometers is equally important. Our uncertainty calculations are based on unsoiled instruments. Pyranometer soiling increases measurement uncertainty significantly and in an uncontrolled manner. This skews the data, leading to a structural overestimation of performance.

Similarly, sensor misalignment with the plane of array (POA) is another frequent cause of measurement errors that further distorts PR calculations.

Finally, keep in mind that you should critically assess both the data stream and the underlying expectations placed on it. Sometimes, discrepancies are not due to errors in measured data, but originate from the PV modeling framework that the data is compared to.

Matthijs Ates

PES: You mention that the Class A requirements should be seen as a baseline in practice. What differentiates high-end instruments within this class?

MA: Naturally, it is important to keep accuracy specifications in mind when discussing pyranometers. As I mentioned, our calculations show that there is a significant difference between the accuracy achieved using an SR300-D1 compared to using a nameplate class A instrument.

We found that the zero offset and directional response errors are the primary causes of measurement uncertainty in nameplate Class A pyranometers, while our analysis showed that the Hukx SR300-D1 performs very well in this regard. The SR300-D1 is also far more stable than what is prescribed by Class A requirements, which limits the growth of uncertainty over time significantly.

A cut through of the SR300-D1 industrial Class A pyranometer showing the different components inside the instrument

Hukx's affordable, worldwide pyranometer calibration services result in the lowest total cost of ownership

However, there are other important practical aspects when comparing pyranometers.

For instance, pyranometer circuit boards can be damaged by high-impulse currents and electrical spikes caused by switching or lightning strikes. Data from damaged instruments is no longer available, leading to gaps in the data stream as well as costly repairs.

All of our Class A industrial pyranometers come with integrated surge protection to mitigate these risks, and can optionally be connected to the SPD01, an external surge protection device that provides even greater electrical shielding and surge immunity.

Another important aspect is the total cost of ownership (TCO) of an instrument. Beyond the initial purchase, the TCO is also determined by recalibration costs and the associated transport costs. While it is therefore tempting to avoid recalibration, this can lead to problems going undetected and therefore to financial risk exposure, counteracting the saved costs.

Through our worldwide calibration and service network, Hukx performs expert calibration and repair services while ensuring low shipping costs and fast turnaround times, thereby providing the lowest total cost of ownership to the customers.

PES: How is the awareness in industry around the impact of measurement uncertainty? And how do you expect this to evolve in light of the challenges the PV sector is facing?

MA: There is growing awareness of the importance of effective monitoring. Many power plants underperform, and operators increasingly recognise that only high-accuracy, reliable PR measurements allow them to properly understand what's happening. At the same time, awareness of measurement uncertainty and its impact on performance monitoring is also increasing.

The industry is experiencing an uncertain economic environment and tightening margins, which is driving a stronger focus on asset optimization and accurate performance monitoring.

However, there is still a gap between recognizing the importance of measurement accuracy and understanding how it propagates into key indicators like the PR, which plays an increasingly important role in the modern PV industry. Seemingly small uncertainties can translate to significant financial exposure. Even if you don't explicitly account for measurement uncertainty, it still affects the outcomes you rely on.

During my thesis, I built both an Excel and a Python code to calculate PR uncertainty.[1]

High-quality measurement equipment is integral to maximizing asset utility, and I expect this awareness will grow further as the industry continues to adapt to the current challenges.

PES: Are you able to share any details about future development at Hukx?

MA: There are many interesting projects we are working on that will further advance the boundaries of solar irradiance measurement. There is still much to be done in solar PV monitoring.

Building on the insights from our recent research, we are continuing to improve the accuracy of our products through the most impactful avenues. We have plenty of ideas for the future of PV monitoring, and hope to further the understanding of this increasingly important field.

About the company

Hukx is a Dutch company specializing in manufacturing sensors and measuring systems. Established in 1993 as Hukseflux Thermal Sensors, it brings decades of experience under its new name, Hukx.

It is the leading innovator in solar radiation and heat flux sensor technology, proud to set the standard in high-accuracy measurement and to be working at the heart of the energy transition.

Customers are served through the headquarters in the Netherlands, and locally owned representative sales offices in the USA, Brazil, India, China, Southeast Asia and Japan.

Curious about Hukx's new instruments?

Take a look at Intersolar Europe from June 23rd to 25th in Messe München, Germany. Booth B4.309, Hall 4.

hukx.com

Reference

[1] Email: sales@hukx.com for a free copy with the user manuals