SPECTRA OF THE MONTH

EVALUATING SOLAR SIMULATOR ACCURACY USING THE AVASPEC-SOLAR-MINI+

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INTRO

BACKGROUND OF APPLICATION

Solar energy is often considered one of the most promising avenues for renewable energy. It is more practical than geothermal and hydropower, less invasive than wind energy, and does not have the fear that surrounds nuclear energy, which is also only considered an "alternate" energy source rather than a renewable one. Indeed, many homeowners and businesses have opted to mount solar panels on their buildings to provide some level of energy self-sufficiency. That being said, there are still challenges that come with solar energy. Mainly, the high point of sunlight, and therefore energy collection, correlates with the low point in the day for energy use, which can overpower the electric grid without proper energy storage means. Solar panels must also be tested for efficacy in converting sunlight to energy, a process performed by their photovoltaic cells. To test this efficacy, companies will employ a device known as a solar simulator, a light source can mimic the output of the Sun in a factory environment. This may lead to a new question: how is the accuracy of solar simulators verified? This is done through spectroscopic measurements of multiple wavelength bands and measuring the output of these bands in terms of irradiance. The outputs of these bands are compared to known values of the Sun and given a letter grade based on how closely they correlate to the values of the Sun, with A+ being the most accurate and anything below a C being a failing grade. This measurement method is essential in differentiating between passable and exceptional solar simulators, which is key in creating instruments that can help push the solar energy industry forward.

FIGURE #1 Measurement setup showing the placement of the measurement end inside the solar simulator.

This experiment aims to measure the accuracy of a solar simulator from a local process control company called Sinton Instruments. To perform these measurements, we employed our new AvaSpec-Solar-Mini+, an Americas exclusive product that provides a compact, affordable option for measuring solar simulators based on the IEC 60904-9:2020 standard. Measurements were taken inside the solar simulator (Figure 1) and the accuracy was calculated using the local company's proprietary software.

DESCRIPTION OF SPECTROSCOPY SETUP

The setup for this experiment utilized our new AvaSpec-Solar-Mini+, available only in the Americas. This compact, all-in-one product utilizes two of our spectrometers to measure the full spectral range of the IEC 60904-9:2020 standard and an external trigger box to synchronize measurements. The spectrometers used in this system are our AvaSpec-NXS2048CL, more commonly known as the Nexos, and the AvaSpec-MiniNIR256-1.7. The Nexos is our next-generation photonics backbone spectrometer, designed to empower a wide range of applications in various industries. This device is built using our new semi-automated manufacturing technique that ensures higher levels of consistency and reproducibility unit-to-unit. The Nexos offers USB2.0 communication as well as RS232 and SPI communication protocols, a CMOS linear array detector, ultra-low stray light as low as 0.1%, and a signal/noise ratio of 375:1. Furthermore, this spectrometer can be customized with a wide range of gratings (13 total available) and the replaceable slit option is now standard for non-OEM units, which provides even more flexibility for a variety of application needs. The unit used in this experiment was optimized for the visible range, with a 300-1100 nm wavelength range and a 50-micron slit installed. The AvaSpec-MiniNIR246-1.7 is a compact near-infrared spectrometer based on a combination of our popular AvaSpec-NIR256-1.7-EVO and Mini-series. Like our other CompactLine spectrometers, this device is only the size of a deck of cards. It is USB powered, which, along with its size, makes it easy to integrate into other devices and handheld applications. The instrument used in this experiment had a 900-1700 nm wavelength range and a 50-micron slit installed. This unit measures the upper 1100-1200 nm range that cannot be reached by the CMOS detector of the Nexos and offers a more affordable solution compared to even a single AvaSpec-NIR256-1.7-HSC-EVO that would be needed for the updated IEC standard.

FIGURE #2 Experimental setup for solar simulator measurement: The spectrometers, AvaTrigger, and interface cable were housed in a custom enclosure. A custom fiber optic cable connected the spectrometers and AvaTrigger to the 90-degree cosine corrector and collimating lens, both mounted in a 3D-printed holder.

The light source used for this experiment was the solar simulator itself. The specific unit used for this measurement was the Sinton Instruments FCT-650. Per their website, this product has been designed to have the highest possible accuracy for measuring high-efficiency solar cells by using a patented voltage modulation technique to neutralize the capacitive effects in I-V measurements.

Other accessories included in the AvaSpec-Solar-Mini+ system are our AvaTrigger external trigger box, a 90-degree cosine corrector, a 90-degree collimating lens, a custom trifurcated-to-bifurcated fiber optic cable to connect the two spectrometer channels to the cosine corrector and the AvaTrigger to the collimating lens, a custom interface cable to connect the AvaTrigger to both spectrometers and synchronize their measurements, and a custom housing to hold all the instruments.

DESCRIPTION OF METHODOLOGY

The solar simulator for this experiment was measured at Sinton Instruments. To prepare the AvaSpec-Solar-Mini+ system, both spectrometers underwent ISO 17025:2017-certified irradiance calibration by a third party using the 90-degree cosine corrector to ensure accuracy. Fibers were kept attached throughout. During measurement, the 90-degree cosine corrector and collimating lens were mounted in a 3D-printed holder within the simulator housing beneath the flash lamp. The AvaTrigger, set to “opto” mode, triggered the dual-channel spectrometer with each optical flash.

For data analysis, we utilized proprietary software provided to us by Sinton Instruments that can be included with their systems. This software automatically reads in the irradiance calibrations stored on the spectrometers’ on-board settings and allows the user to adjust the integration time, the number of scans to take, and the number of scans to average, among many parameters. This software package also includes multiple standard measurements to compare against and multiple classification standards to grade the measured spectrum. For this experiment, we used an integration time of approximately 210 microseconds, which can be adjusted to increase or decrease the amount of light being measured at one time and affects the overall magnitude of the reported spectrum. We set averaging to 1, meaning each measurement corresponded to one scan. While higher averages are usually preferred, using an average of 1 ensures that each measurement corresponds to a flash of the solar simulator lamp. Measurements were compared to the AM 1.5 – Global (IEC 60904-3:2019) Sun standard that is available in the Sinton Instruments software.

TEST DATA AND RESULTS

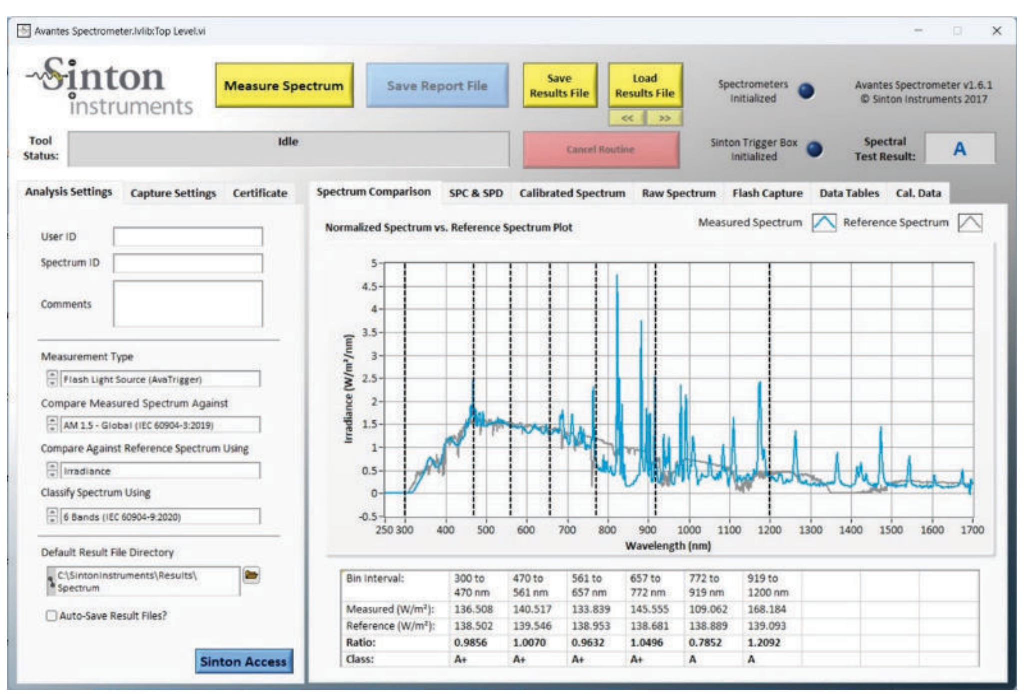

FIGURE #3 Irradiance spectrum of the solar simulator (blue) compared to a Sun standard measurement (grey). Grades for each wavelength band are shown in bottom table, and overall grade is shown in top-right corner.

ANALYSIS

Multiple measurements of the solar simulator were taken, with the one presented (Figure 3) being a measurement after multiple warm-up flashes from the lamp. The classification standard applied to the measurement was the most recent IEC 60904-9:2020 standard. The wavelength bands for this standard are 300-470 nm, 470-561 nm. 561-657 nm, 657-772 nm, 772-919nm, and 919-1200 nm. The measured irradiance for each band was compared to the reference irradiance values and given a letter grade based on the IEC 60904-9:2020 standard. Among other quantities, the percent match of the irradiance in each band is used for this grading scale, with +/-12.5% being A+, +/-25% being A, +/-40% being B, and +100/-60% being C. Other considerations for grading are spatial non-uniformity and short- and long-term temporal instability. For this analysis, we will focus on the percent match of total irradiance of each spectral band.

For the 300-470 nm band, the ratio of measured to reference irradiance was 0.9856, which gives this band an A+ grade. For the 470-561 nm band, the ratio of measured to reference irradiance was 1.0070, which also gives this band an A+ grade. For the 561-657 nm band, the ratio of measured to reference irradiance was 0.9632, which gives this band yet another A+ grade. The 657-772 nm band had a ratio of measured to reference irradiance of 1.0496, giving this band an A+ grade. The last two bands, 772-919 nm and 919-1200 nm, had measured-to-reference irradiance ratios of 0.7852 and 1.2092, respectively, giving both of these bands a grade of A. While it might be assumed the overall spectral grade would be an average of the grades of each band, it is actually just the lowest letter grade to ensure a deficiency in one band is not masked by averaging with the remaining bands. Because of this, the overall grade for this system is an A. It should be noted that previous visits and measurements with this company have seen A+ grades across all spectral bands. This slight drop may be attributed to not allowing sufficient warm-up time for the flash lamp or performing measurements on a test solar simulator system that has been extensively used. Regardless, the presented data still demonstrates an exceptional solar simulator that has an excellent spectral match in the lower four wavelength bands with less than 5% deviation compared to the reference irradiance values.

CONCLUSION

In conclusion, the present experiment highlights our ability to accurately measure solar simulators with our new, exclusive AvaSpec-Solar-Mini+ system, while also featuring an exceptional solar simulator available from another local company. The solar simulator showed close spectral matches in the upper two wavelength bands and nearly identical irradiance values in the lower four wavelength bands. The spectrometers at the heart of the AvaSpec-Solar-Mini+, ehe AvaSpec-NXS2048CL and AvaSpec-MiniNIR256-1.7 are highly versatile, compact devices that are ideal products for OEM applications or for any instances where a smaller instrument is preferred, such as the bundle provided in the AvaSpec-Solar-Mini+ system. The custom housing and interface cable of the AvaSpec-Solar-Mini+ highlights the capabilities of our engineering team to provide tailored assemblies and solutions for customer needs. Please contact Avantes for more information on the configuration that is best suited for your data collection.

CONTACT

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