Solar Industry®

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Standards For Simulators Can Vary Widely

The differences among the three standards used for evaluating solar cell performance might create confusion during testing.

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The efficiency of photovoltaic devices is continuously being improved as researchers explore various methods for formulating the materials and changing the cell structure to enhance the conversion of incident photons to electrons.

Researchers have developed standardized methods for defining the criteria for measuring solar cell performance. These tests typically utilize a light source to simulate the spectral content and intensity of irradiance and temporal stability. As solar simulators' technology evolves, the ability to tightly control their performance has improved.

Using standard methods to quantify performance consistency among solar simulator devices allows results comparability and traceability by minimizing error introduced by the light source. Variations in spectral match and/or uniformity from one simulator to the next can produce differences in apparent performance of a photovoltaic device.

With improvements in efficiency generally occurring as a fractional increase in efficiency, variations introduced by the light source can be significant. Performance consistency enables the precise comparison of performance data by researchers engaged in developing novel materials for photovoltaic devices.

Three different standards can be applied to quantifying the performance of a solar simulator: the International Electrotechnical Commission (IEC) 60904-9 Edition 2 (2007) Photovoltaic Devices - Part 9: Solar Simulator Performance Requirements; the JIS C 8912-1998, Solar Simulators for Crystalline Solar Cells and Modules; and the ASTM E 927-05 (2005) Specification for Solar Simulation for Terrestrial PV Testing.

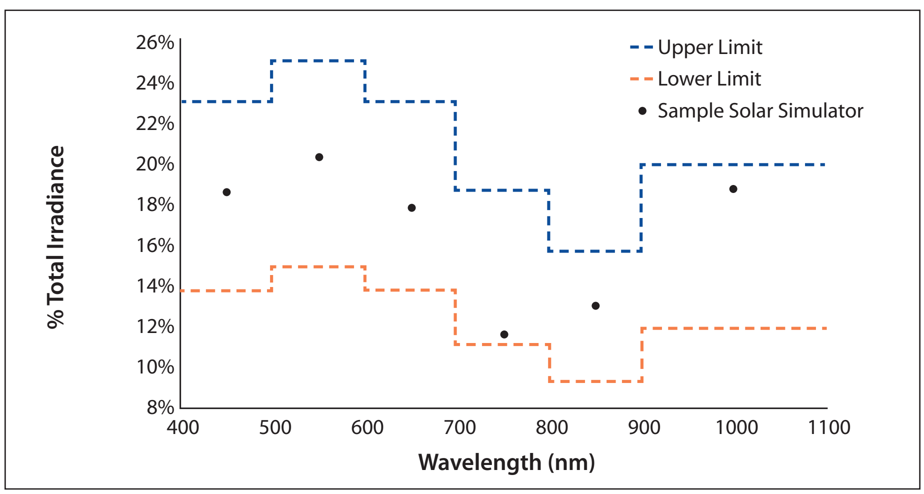
Although they are similar, these three standards differ significantly in some of their defined metrics to measure performance. As a consequence, confusion has emerged regarding the comparison of simulators that have been validated using these different methods.

In 2006, the IEC promulgated a new set of criteria for solar simulators as defined in the IEC 60904-9 Edition 2 (2007) Photovoltaic Devices - Part 9. The criteria for non-uniformity of irradiance of under 2% - and a definition for short-term and long-term temporal stability - became the most stringent of the three standards worldwide when it went into effect in 2007, replacing the first edition issued in 1995.

The current edition of IEC 60904 redefined the scheme for solar simulator classification, utilizing a reporting method that mandates individually reported categories for spectral match, non-uniformity of irradiance and temporal stability. The method characterizes a solar simulator by defining performance criteria in three classes (A, B or C) for each of the three categories.

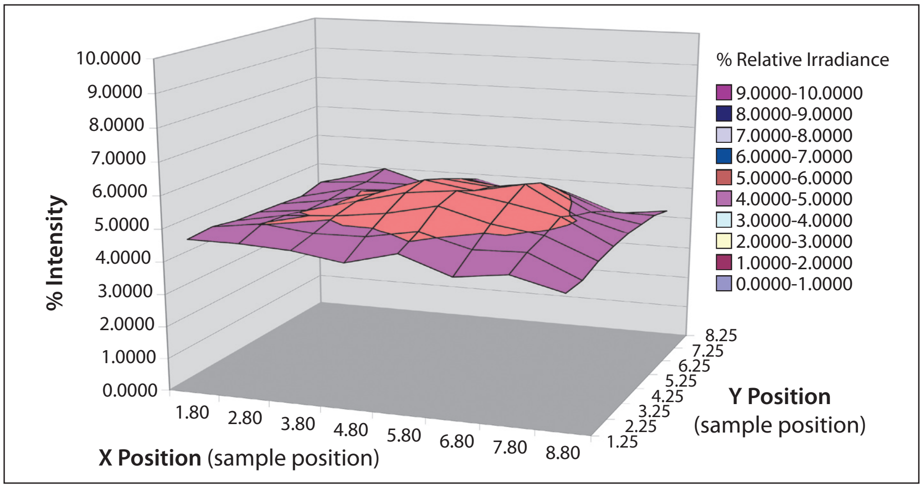
A comparison of the criteria for spectral match between the IEC 60904-9 Edition 2 (2007), the JIS C 8912-1998 and the ASTM E 927-05 (2005) methods shows almost no difference in the performance requirements.

Figure 1: Class A Simulator Spectral Match



Source: Newport Corp.

Figure 2: Uniformity Analysis



Source: Newport Corp.

Class A performance is defined as a percentage of irradiance for a defined wavelength range (bin) with a +/- 25% tolerance. This definition is shown graphically in Figure 1. Most manufacturers have developed proprietary filter designs that maintain spectral match over a specified lamp lifetime, taking into account lamp aging.

Although the temporal-stability requirements are different among these three methods, manufacturers have addressed temporal-stability issues with several effective techniques. These methods include dual lamp designs, custom xenon arc lamps and photo feedback systems. All of these techniques help ensure that temporal stability can be controlled adequately to meet the most stringent requirements.

Independent of the standard used for evaluation, uniformity of irradiance is probably the most important criterion if the goal of solar cell measurement is to compare IV performance on a given solar simulator.

Even when done on a particular simulator, non-uniformity can create hot spots in which the irradiance may not be at the one-sun ideal at AM1.5 Global. Class A uniformity assures consistent results, regardless of position in the test area, in cases where the sample cell is smaller than the total test area.

It is important to note that none of the methods allows definition of a subset of the test area. For example, a smaller area cannot be designated as "Class A in this area only" but not other areas. The entire area must be tested, and only one classification applies.

The biggest disconnect between the methods is in the requirements for non-uniformity of irradiance and the methods defined for its measurement. The method defined by IEC 60904-9 Edition 2 (2007) is the most difficult to meet, with a requirement of less than 2% non-uniformity over the entire area of illumination using a method requiring that the entire area be measured.

The IEC method takes the designated test area and requires it to be divided into 64 equally sized test positions, and further requires the detector used be sized no larger than 1/64 of the designated test area, up to a maximum of 400 cm^2 for large-area simulators.

The JIS method does not require that the entire area be subdivided and measured in a fashion similar to that of the ASTM and IEC methods, but rather, supplies a grid that is defined differently if the irradiated plane is circular or square type with fixed test points.

In addition, the detector area is defined as 2 cm^2, or 4% of the irradiated area (whichever is smaller). The maximum non-uniformity of irradiance is defined as +/- 2%. For purposes of this discussion, it is assumed that the IEC standard is more stringent for non-uniformity of irradiance.

Effects of multiple standards

ASTM E 927-05 (2005) calls out a minimum of 36 evenly spaced test positions, with the test device having an area no larger than the area of an individual test position. Non-uniformity must be 2% or less for Class A designation using this method, too.

This means that the area of the detection device can be as much as 56% larger in the ASTM method than the area called out in the IEC method. This larger area increases the averaging factor for the measurement.

ASTM acknowledges this fact by recommending that more than 36 measurements be taken. As a result, when the minimum number of samples is taken using the largest permissible area, the measurement is less sensitive than the IEC method.

Therefore, a Class A uniformity designation using ASTM guidelines has more non-uniformity than an IEC Class A uniformity measurement, even though the criteria are the same.

A consequence of the use of multiple standards with varying measurement criteria is that it is impossible to completely understand the performance of a solar simulator simply by looking at the class designation for spectral match, non-uniformity of irradiance and temporal stability.

The researcher must dig deeper into how the tests are performed to ensure complete compliance to the standard. The class designation must be considered in a critical way, and the limits of each classification should be understood.

When a standard is referenced, which standard is being used? If a simulator is Class A uniformity, was it tested according to ASTM, IEC or JIS? Simply knowing the standard is not the entire story.

In addition, the researcher must consider the area of the detector used. The smaller the detector, the less averaging is done, which means finer detail. However, if a smaller detector is used, the number of sample points should be increased to ensure the entire test area is measured.

The researcher should also consider how many data points were taken. If the numbers of sample points are not increased, the detector can be repositioned to achieve the best data within that "test block."

Finally, take into account whether the designation applies to the whole field or to a sub-section. There is no sub-section within the test area. If a researcher is testing an area that is 300 mm x 300 mm, the designation of uniformity applies to the entire test area.

The researcher must also check to ensure that the tests being done comply with the current standard requirements. It cannot be assumed that the current standard is being followed. The 1995 edition of the IEC standard is superseded by the 2007 edition.

When a researcher is comparing simulator performance, is comparing an ASTM Class AAA to a IEC Class AAA simulator comparing apples to apples? The IEC standard is more stringent, and the test method is less subject to interpretation.

A Class AAA ASTM designation may actually be only Class ABA if tested using the IEC method, due to differences in the test method.

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