EFFECTS OF THE NEW STANDARD IEC 60904-3:2008 ON THE CALIBRATION RESULTS OF COMMON SOLAR CELL TYPES

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ABSTRACT: The spectral and total irradiances which have to be used for the characterization and calibration of solar cells under standard test conditions are defined in the IEC 60904-3 standard. Due to the recent changes made in IEC 60904-3:2008, the revised edition of IEC 60904-3:1989 [1], there is some confusion about the consequences of these modifications with respect to existing calibration data. This paper provides information about the impact on the efficiency (typically +0.75 % for c-Si) and the short circuit current (about +0.7 % for c-Si) due to the respective standard test conditions of different common types of solar cells and tries to give some reasons for the changes.

Keywords: Calibration, Spectral Responsivity, IEC Standard

1 REASONS FOR THE UPDATE

The spectral data given in IEC 60904-3 approximate a spectrum which is obtained when sunlight effectively passes the atmosphere 1.5 times, i.e. when the sun has a zenith angle of about 48.2°. The standard was updated with the intention of extending the spectral range deeper into the ultraviolet, to increase the resolution, to use more representative atmospheric conditions [2] and, last but not least, because the outdated software for the spectrum generation was not available anymore.

2 CALCULATIONS

The short circuit current I_{sc} of an illuminated solar cell can be calculated by the integral over the product of the absolute spectral irradiance $E_\lambda(\lambda)$ of the radiation source and the absolute spectral responsivity $s(\lambda)$ of the solar cell: $I_{SC} = \int E_\lambda(\lambda) \cdot s(\lambda)\, d\lambda$. Therefore, if the relative spectral responsivity of a solar cell is known, the relative deviation between the short circuit currents with respect to the old spectral irradiance $E_{\lambda,\,AM1.5:1989}(\lambda)$ and the new $E_{\lambda,\,AM1.5:2008}(\lambda)$ can be easily obtained (see Figs. 1, 2). The absolute spectral responsivities of the investigated solar cells were measured using the DSR method [3].

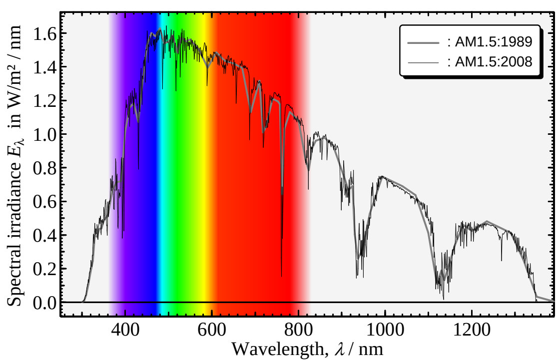

Fig. 1: Old and new AM1.5 spectrum. Only the wavelength range from 280 nm to 1320 nm is displayed. The spectrum is defined up to 4000 nm.

3 RESULTS

For some types of amorphous Si solar cells the short circuit current under standard test conditions I_{STC} decreases by 0.3 % due to the new spectrum. Most crystalline Si solar cells show an increase of about 0.7 % in the short circuit current. The $I_{STC:2008}$ value of CdTe and GaAs solar cells is 1 % higher than the respective $I_{STC:1989}$ value (see Fig. 3).

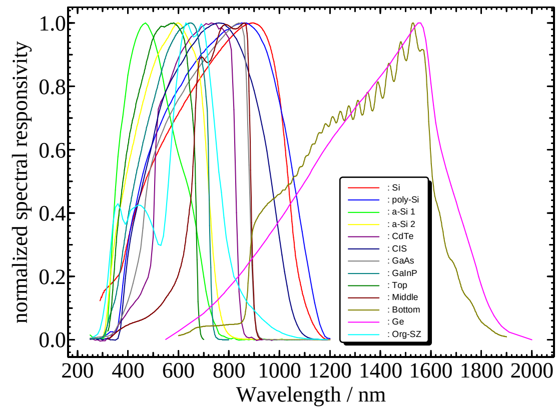

Fig. 2: Normalized spectral responsivities of various types of solar cells used for the calculations in Fig. 3.

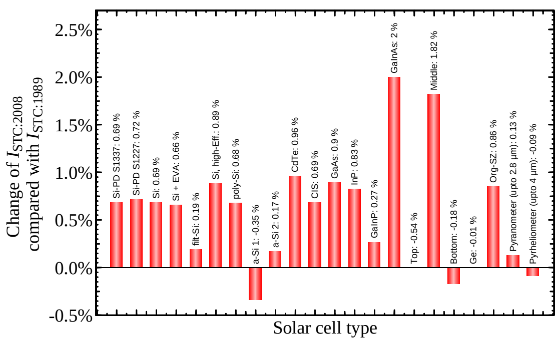

Fig. 3: Change of $I_{STC:2008}$ for different types of solar cells in comparison with $I_{STC:1989}$.

However, the amount of the increase in efficiency is not only affected by a change in the short-circuit current (which is supposed to be approximately linear with respect to the irradiance) but also in a change of the fill factor and the open circuit voltage. Therefore, the increase or even the decrease of the efficiency appears to be about 5 % larger than the increase or decrease of the short circuit current (see Fig. 4). Hence, a c-Si solar cell with an increase of 0.71 % in the short-circuit current has an increase of about 0.75 % in the efficiency and some high-efficiency solar cells show nearly 1 % increase. That means that a solar cell with a dedicated efficiency of 20 % according to the old standard will have a calculated efficiency of 20.20 % according to the new standard (and not 21 % of course).

When looking at multi-junction solar cells, it must be taken into account that the junction with the smallest current limits the total current. Thus, as long as the middle cell limits the total current, an increase of the short-circuit current of up to 2 % could be possible. But if the triple junction solar cell matches the old spectrum perfectly or if the top cell limits the current this can result in a decrease of about 0.5 % due to the new spectrum. Hence, a slightly different design may be necessary to ideally match a multi-junction cell to the new theoretical spectrum of the IEC 60904-3 standard. Moreover, it has to be taken into account that other spectra are used for concentrator cells and space applications.

It must be noted that the total irradiance for the old and the new standard remains at 1000 W/m². But the spectral irradiance of the new spectrum increased slightly in comparison with the old spectrum in those wavelength ranges contributing especially to the current of c-Si solar cells, where other wavelength ranges are decreased (Figs. 5 and 6).

4 CONCLUSION

Due to the new AM1.5 spectrum, the efficiency according to the standard of the most common crystalline solar cells changed by about 0.75 %. However, the correct energy prediction of solar installations will not change, because it has to take into account the local climate conditions and not the standard test conditions. The efficiency according to standard test conditions is used only for the comparison of different types of solar cells. From this point of view, a great advantage of the DSR method used at PTB becomes obvious: Its results can be attuned to nearly any spectrum: AM1.5G, AM1.5D, AM0, the spectrum of lamps, etc..

5 REFERENCES

[1] IEC International Standard 60904-3 Ed. 2: "Photovoltaic Devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data ", Geneva 2008
[2] Gueymard, C. (1995). "SMARTS, A Simple Model of the Atmospheric Radiative Transfer of Sunshine: Algorithms and Performance Assessment." Professional Paper FSEC-PF-270-95. Florida Solar Energy Center, 1679 Clearlake Rd., Cocoa, FL 32922.

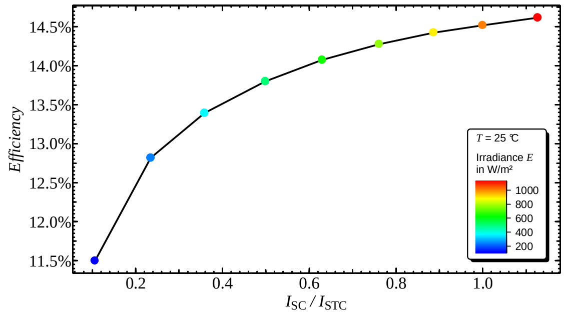

Fig. 4: Change of the efficiency in depending on the short circuit current, i.e. the irradiance. If the efficiency is calculated for a higher short circuit current, i.e. at a higher irradiance level, the efficiency increases, because not only the current increases with the irradiance but also the fill factor and the open circuit voltage. Therefore, an increase due to the new spectrum of about 0.71 % of the short circuit current of a typical crystalline solar cell results in an increase of about 0.75 % of its efficiency. The efficiency of high-efficiency solar cells can increase even up to about nearly 1 %.

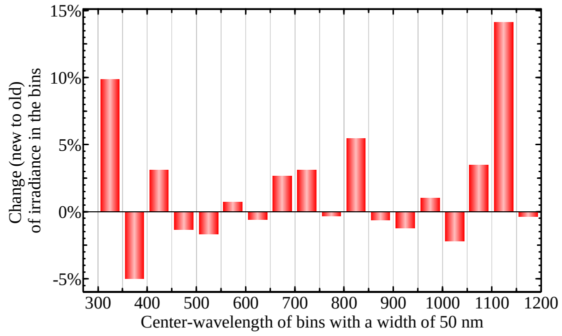

Fig. 5: Bar chart of the change of the irradiance in different wavelength ranges.

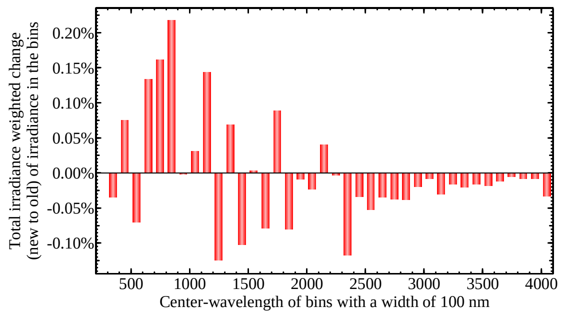

Fig. 6: Bar chart of the irradiance weighted change in different wavelength ranges. The highest increase of irradiance is in the wavelength range from 600 nm to 900 nm which is dominant for c-Si solar cells.

[3] S. Winter, T. Wittchen, J. Metzdorf: Primary Reference Cell Calibration at the PTB Based on an Improved DSR Facility; in “Proc. 16th European Photovoltaic Solar Energy Conf.”, ed. by H. Scherr, B. Mc/Velis, E. Palz, H. A. Ossenbrink, E. Dunlop, P. Helm (Glasgow 2000) James & James (Science Publ., London), 4 p., ISBN 1 902916 19 0