Validation of Spectral Response Polychromatic Method Measurement of Full Size Photovoltaic Modules using Outdoor Measured Data

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Measurement of spectral response characteristic of large area PV module


Fig. 1(a) Spectral response measurement apparatus at TUV [1].

Continuous light source

Challenge(s):
- Achieving high irradiance uniformity of bias light illuminating all cells (apart from the target cell) in the string.
- Keeping temporal stability of light source.

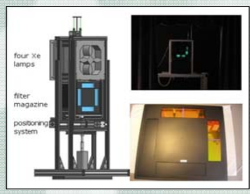

Fig. 1(b) Pulsed solar simulator used as a light source with narrowband filters (SUPSI) [2].

Pulsed light source

Challenge(s):
- Requires high power light source to enable monochromatic separation.
- Non-uniformity of monochromatic light on measurement plane.

Polychromatic measurement method of full size PV module

Polychromatic method is a filter-based measurement method using wavelength cut-off broadband filters that can be applied to measure spectral response characteristic of PV devices. The spectral response curve is determined by numerical modelling.

Spectral and current measurement

- Type of PV module measured is mono-crystalline silicon (mc-si) with dimensions 1.6m×0.8m.
- Light source used is the pulsed type simulator (Pasan 3b).
- A set of wavelength cut-off plastic sheet + visible band colour filters used to maximise spectral distribution variation.
- An Avantes spectrometer (290nm-1700nm) is used to measure the incident spectral irradiance.

Integration of measurement and numerical model

- Gaussian summation is used to model spectral response curve.
- Short-circuit current is modelled using incident spectral irradiance measurement and Gaussian function.
- Levenberg-Marquardt fitting tool is used to optimise variables of Gaussian summation while minimising error between measured and modelled short-circuit current.

$$SR_{mod} = \sum_{i=1}^{N} a_i \cdot exp\left[\frac{-(\lambda - b_i)^2}{2c_i^2}\right] \qquad I_{sc} = A \cdot \int_{\lambda_{min}}^{\lambda_{max}} SR_\lambda \times E_\lambda \cdot d_\lambda$$

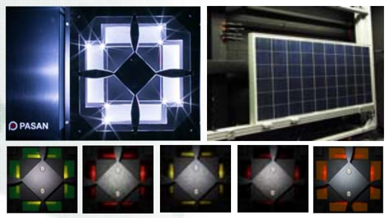

Fig. 2 (a) Image of light bulbs, measurement rig, and filters of the solar simulator used.

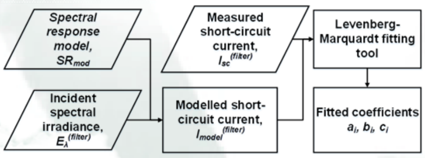

Fig. 2 (c) Simplified flow chart illustrating the process of the fitting algorithm.

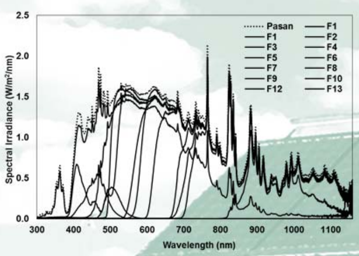

Fig. 2 (b) Spectral irradiance distributions used for spectral response determination, measured by Avantes spectrometer.

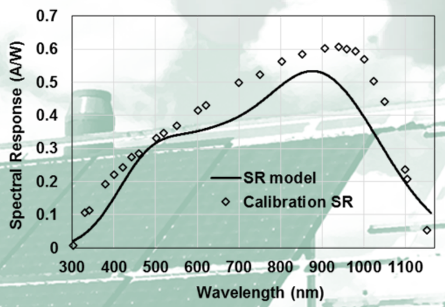

Fig. 2 (d) Spectral response model curve plotted using final determined fitted parameters.

Validation of spectral response curve model using outdoor data

Validation of the obtained spectral response curve for 1.6m×0.8m mono-crystalline silicon module is performed indirectly by means of short-circuit current comparison of the modelled and actual under different outdoor conditions.

- PV modules and detectors (spectrometers and pyranometers) are mounted on the rack with 35º inclination, facing south.

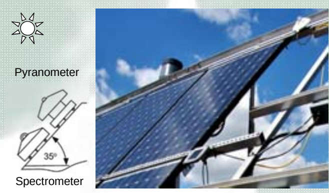

Fig. 3 (a) Outdoor PV performance and meteorological data monitoring system.

- Outdoor spectral distribution under different conditions are selected to model short-circuit current.

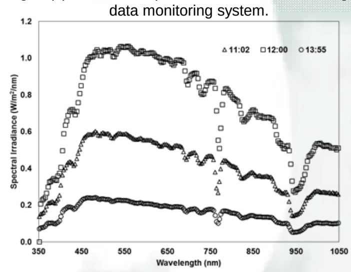

Fig.3 (b) Variation of spectral irradiance distribution measured by EKO MS700 at different conditions.

- Modelled and actual short-circuit current under respective outdoor condition are compared.

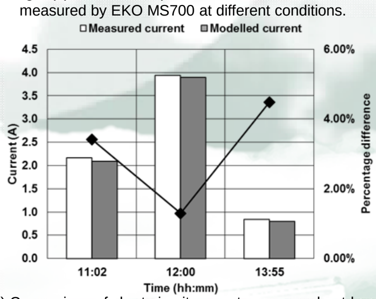

Fig.3 (c) Comparison of short-circuit currents measured outdoors and modelled using the polychromatic spectral response and measured spectral irradiance under different conditions.

Conclusions

- Determination of spectral response curve of 1.6m×0.8m mono-crystalline module is performed using polychromatic method.
- The validation of spectral response curve model is carried out by comparing the modelled short circuit current under different outdoor conditions to the respective actual short-circuit current. The overall difference between the two is below 5%.

References:
[1] "Study notes for Advanced Photovoltaics", 2014-2015, CREST2014.
[2] M. Pravettoni, A. Komlan, R. Galleano, H. Mullejans and E. D. Dunlop, "An Alternative Method for Spectral Response Measurements of Large-Area Thin Film Photovoltaic Modules," Prog. Photovolt: Res. Appl. 2012, pp. 416-422, 2011.

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