SWEEP TIME, SPECTRAL MISMATCH AND LIGHT SOAKING IN THIN FILM MODULE MEASUREMENTS

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ABSTRACT: Measurements of thin film modules with a single flash inline simulator were compared to outdoor measurements with 6 different modules (2 a-Si, 2 CdTe and 2 CIGS). Outdoor measurements were done with voltage sweep times ranging from 0.5 to 25 ms. The performance of CdTe modules was measured before and after light soaking. Sweep time was not observed to have an effect on the measured performance with sweeps over 1 ms. Sweeps shorter than 1 ms can reduce the measured power particularly with a-Si modules. The differences with outdoor and indoor measurements were small implying the measurement is not sensitive to the used spectrum. The largest difference between indoor and outdoor performance was observed for triple junction a-Si.
Keywords: Thin Film, Performance, Module

1 INTRODUCTION

Testing module performance is essential for PV manufacturers to assure product quality. Solar simulators allow I-V performance testing of modules and cells to be directly integrated to the production line thus making the test procedure more efficient and effective. When measuring thin film modules there are three important questions that need to taken into consideration: Simulator voltage sweep rate, spectral mismatch and light soaking effects. These topics will be briefly reviewed here. Module performance was measured with varying sweep times from 0.5 to 30 ms and a comparison was made between indoor and outdoor measurements.

1.1 Voltage sweep rate

Fast sweeps can affect measurement results for high efficiency solar modules due to diffusion capacitance [1,2]. Sweep length effects for thin film devices have been studied by Willet [3], Friesen [4] and Virtuani [5].

Within the limits of measurement uncertainty sweep time has not been shown to affect measured performance of good quality thin film modules. In the study by Willet [3] poor quality modules were found to have a lower fill factor (FF) when measured by a flash simulator. However, measurement differences in modules having a FF of over 60% were negligible.

1.2 Spectral mismatch

The mismatch between the spectral responses of the modules as well as between the simulator and the AM1.5G spectra causes a difference in measured indoor and outdoor short-circuit currents. This can usually be corrected by the use of mismatch factor. However it is known that the fill factor of a module can also be dependent on the incident spectrum [6,7]. In this work the effect of spectrum is studied by comparing results obtained under AM1.5G outdoor contitions to indoor measurements using filtered Xe class A spectrum.

1.3 Light soaking

An increase in the open-circuit voltage and fill factor under illumination was first reported for CIS cells in 1986 [8]. A theoretical model was proposed to explain the phenomenon based on the tunneling of electrons trapped in deep states of CdS to holes in the CIS layer valence band. This suggested that the effect is present in other devices having a CdS layer, such as CdTe, and was later confirmed [9]. It was also showed that the increase in performance was caused indirectly by the forward bias voltage created in the cell under incident light [8,9]. The magnitude of the change in V_{OC} or FF reduces with improving device quality [2]. Light soaking has been shown to increase the performance of CIGS modules [5]. In this work CdTe modules were measured indoors, then light soaked under 200-500 W/m2 for several hours and measured again indoors.

2 EXPERIMENTAL

Indoor and outdoor experiments were done using 2 commercial a-Si and CdTe modules as well as 2 pilot CIGS mini-modules. Quicksun 540LA pulsed solar simulator was used for indoor measurements. It creates a linearly increasing voltage sweep during which the I-V curve of a module is measured. The monitor cells used to measure the incident irradiance on the module surface were specifically filtered to match the spectral responses of a-Si and CdTe.

Outdoor measurements were carried out during clear day conditions with an air mass close to AM1.5. A modified QuickSun electronics unit was used in the outdoor measurements. The modules were mounted on a base that allowed the position of the sun to be tracked to a few degrees of accuracy thus avoiding angle of incident effects.

Modules were first measured indoors, then taken outdoors and measured with a shutter to avoid excessive heating of modules. During this process the modules were only exposed to irradiation for a few seconds during a measurement.

In another set of outdoor measurements the modules were measured with different voltage sweep times ranging from 0.5 to 25 ms. Sweep time was varied in a random manner from faster to slower and vice versa in order to avoid any systematic errors caused by other factors such as rising module temperature.

The effects of light soaking on CdTe modules were studied by first measuring the modules indoors and then letting them stay outdoors on a sunny day for several hours. Change in the performance of the modules was then monitored indoors until their output stabilized. Measurements had to be started immediately after the modules were brought indoors because the effects of light soaking are mostly reversible. Module temperatures after light soaking were over 60 °C and special attention was paid to temperature corrections.

3 RESULTS

3.1 Sweep time

The measured power of four different modules with sweep times from 0.5 to 25 ms are shown in Fig. 1. The values at y-axes are normalized to those measured with 1.7 ms sweep time. Module short-circuit currents are calibrated to match. No effect on measured power was observed with sweep times over 1 ms with any of the modules. The decrease of the measured power with sweeps under 1 ms is mostly accompanied by a decreasing fill factor while open-circuit voltage is not affected.

3.2 Indoor-outdoor comparison

The comparison of module performance outdoors and indoors, when short-circuit currents are calibrated to outdoor values, is presented in Table 3. The differences in indoor and outdoor measurements in most performance parameters were small considering the measurement uncertainty of 1%. Only the triple junction a-Si module measured clearly lower power indoors.

Some of the I-V curves taken from the measurements are drawn in Fig.2 showing the similarity between indoor and outdoor measurements. This suggests that using an A class filtered Xe spectrum with thin film modules will only have a small effect when considering CdTe and CIGS modules. It is so far not known whether the used spectrum has caused the difference with the triple junction a-Si module.

Table I: The performance parameters of indoor measurement with respect to corresponding outdoor measurements. Currents were calibrated equal.

	Power	Voc	FF
CIGS 1	**-1.0%**	**-1.2%**	**+0.2%**
CIGS 2	**+1.1%**	**+0.5%**	**+0.6%**
CdTe 1	**-0.4%**	**-0.5%**	**+0.1%**
CdTe 2	**+1.3%**	**+0.1%**	**+1.2%**
a-Si 1	**-1.3%**	**-0.3%**	**-1.0%**
a-Si 2	**-3.4%**	**+0.2%**	**-3.6%**

3.3 Light soaking

The maximum power of both CdTe modules increased during the light soaking period by 2-5%. The relaxation of the effect was close to linear with respect to time taking an hour to two hours to return to original state.

4 CONCLUSIONS

Based on the samples measured using sweep times longer than 1 ms and filtered Xe spectrum do not present a problem for measuring most thin film modules.

In the future similar studies should be repeated with larger amount of samples from varying manufacturers. The behaviour of a-Si devices under Xe spectrum should also be studied for better understanding of the differences discovered in this work.

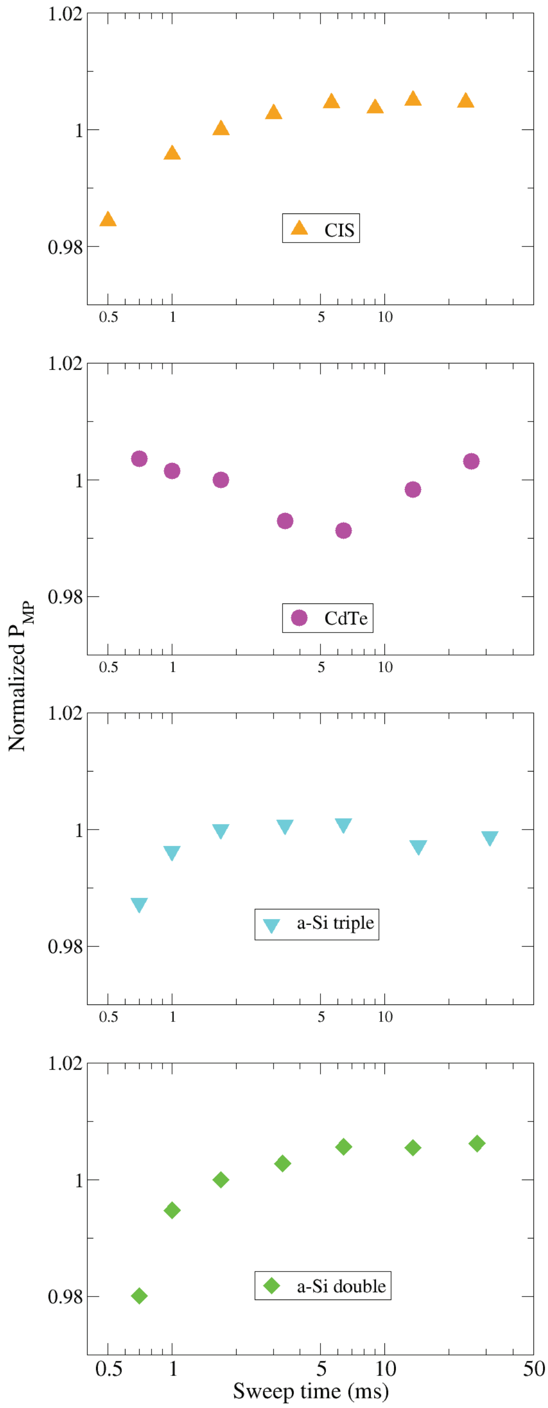

Figure 1. The normalized maximum power of four modules with different sweep times outdoors.

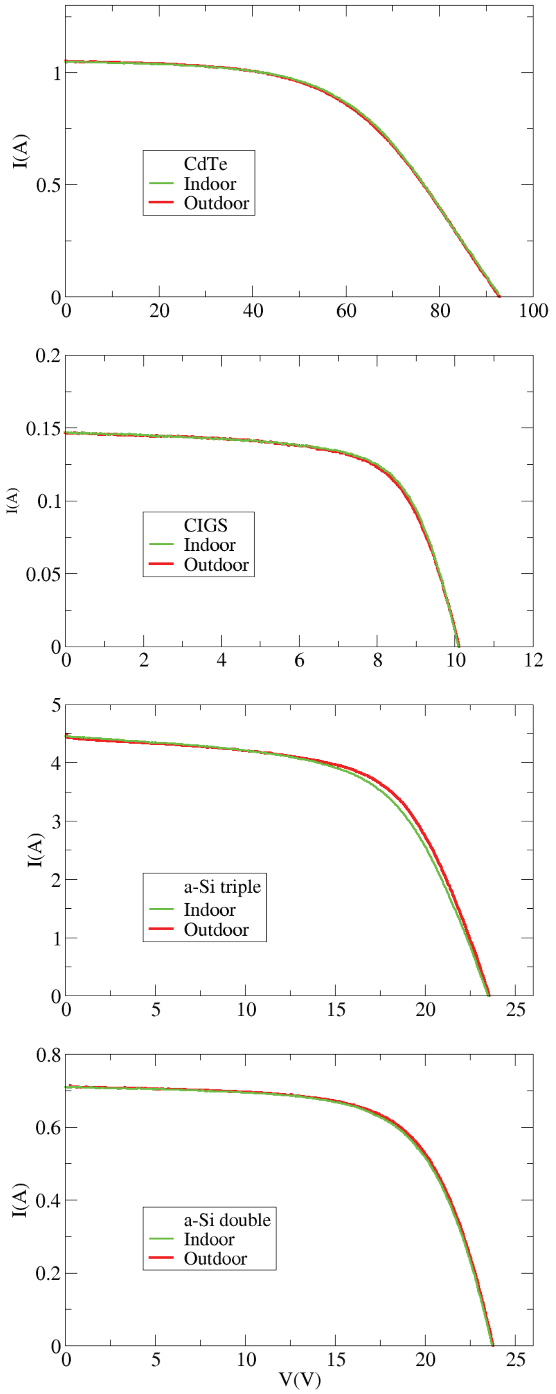

Figure 2. The I-V curves of four modules measured indoors and outdoors.

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