Module testing round robin results: Does CSIRO's PV lab really perform?

Christopher J Fell[1], Blago Mihaylov[1], Benjamin C Duck[1], Mauro Pravettoni[2]

[1]*CSIRO PV Performance Laboratory, 10 Murray Dwyer Cct, Mayfield West NSW 2308, Australia*

[2]*SERIS, National University of Singapore, 1 CleanTech Loop #06-01, Singapore*

Introduction

Between February 2018 and December 2019, the Solar Energy Research Institute of Singapore (SERIS) coordinated the largest and most comprehensive international PV module testing intercomparison ever attempted. The principal aim of the round-robin experiment was to assess the methodology proposed in the new IEC Technical Specification 60904-1-2 for bifacial modules. Bifacial modules are more challenging to measure than monofacial modules, due to (i) the need to restrict light from hitting the non-measured side, and (ii) the need to perform low-light measurements on the rear side, sometimes with the complication of a positioning offset due to the width of the frame. Two consignments of eight PV modules (2 monofacial and 6 bifacial) travelled the world for two years, visiting 26 of the world's most established PV module testing laboratories, each reporting up to 25 different performance parameters for each module. The outcomes are interesting not just as a trial of the method, but also to understand the level of measurement reproducibility that is achievable in PV module testing today.

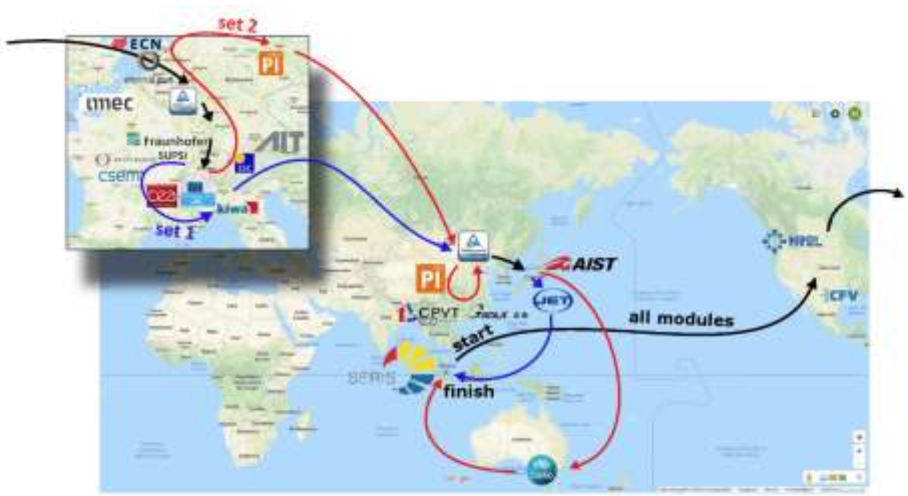

Figure 1. Shipping pathways for the international round-robin experiment

Bifacial methodology

The IEC TS 60904-1-2 technical specification describes three methods for measuring (rating) the output of a bifacial PV module, depending on whether the measurement system is: indoors with a single solar simulator ("single'sided"); indoors with two solar simulators facing each other ("double-sided"); or outdoors. CSIRO's measurements were all performed using the single-sided method. A summary of this method as it was applied at CSIRO follows:

1. Establish and verify a light-trapping scheme such that when one side of the module is illuminated, the other side receives no more than 3 Wm^{-2} at any time during the measurement. Front-side irradiances of up to 1200 Wm^{-2} are required, hence the trapping scheme must be effective to better

than 0.25% of the main-side irradiance. CSIRO's scheme reduced the top-side irradiance to values between 0.08% and 0.2% of the front side irradiance, depending on the module being measured. The specific rear-side light leakage was corrected-for in each final result.

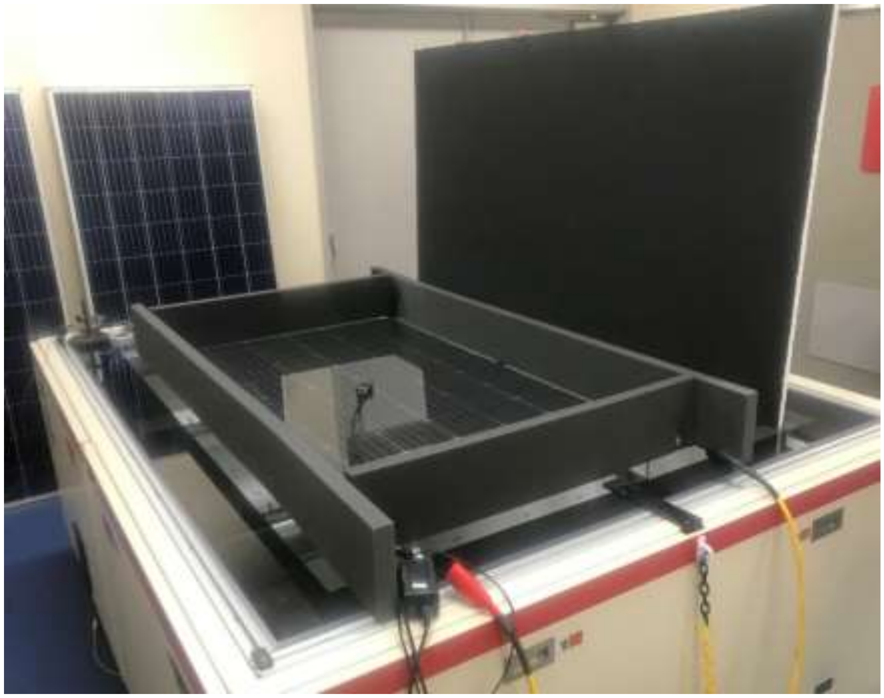

Figure 2. CSIRO's rear-side light trapping setup

2. For each side to be measured, and at each irradiance to be used, establish the spectral mismatch factor. Fourteen coupon modules were included with the shipment, allowing the lab to measure the spectral responsivity of both sides of each bifacial module, and the front side of both monofacial modules. These data are used along with measurements of the spectral irradiance of the solar simulator at each irradiance setpoint, to determine the spectral mismatch factor in advance. The irradiance setpoints are then adjusted specifically for every active module surface, to correct for spectral mismatch.

3. Establish the bifaciality coefficient, φ, of each module by measuring I-V curves of the front and the rear sides at Standard Test Conditions. The presence of the module frame and junction box mean that the rear side measurement is more complex than the front since the active surface of the module cannot be placed directly onto the simulator surface. For framed modules, the surface sits off the simulator by the width of the frame. For frameless modules, additional supports are required to avoid the module resting on the junction box. In both cases a correction is applied, to account for the variance in irradiance with height above the simulator surface. This effect is important for the Spire 5600SLP, which is a highly non-collimated light source. The variance with height was measured to be 0.0225 %/mm, resulting in a correction to the setpoint irradiance of, for example, 0.79% for a module with a 35mm frame.

4. On the rear side of each module, measure I-V curves at irradiances of 100 Wm^{-2} and 200 Wm^{-2}. CSIRO was not able to make the 100 Wm^{-2} measurement, due to a limitation of the solar simulator.

5. On the front side of each module, measure a series of I-V curves at various irradiances in the range 1000-1200 Wm^{-2}, then determine the slope of the relationship between each I-V parameter (I_{sc}, V_{oc} *and* P_{mp}) and the irradiance. Use this relationship to interpolate and report values for each I-V parameter at the following two irradiances: 1000+100φ, 1000+200φ.

Results

The results were presented to the participants in the form of a detailed, anonymised report in April 2020. A subset of the most experienced participant laboratories was deemed *Group 1*. Results from the Group 1 laboratories were used to establish an estimated ‘true’ value for each of the reported parameters, with a statistically determined uncertainty associated with each parameter. Reports were customised such that each participant could see the results for all participants but could not see which results corresponded to which lab, except for their own.

Two key metrics are used in the report, to represent the performance of each laboratory. The first is the z’-score, which indicates how far a measurement is away from the estimated true value, in units normalised to the uncertainty in the estimate of the true value. The second is the *En* number, which again indicates how far a measurement is away from the estimated true value, but this time in units normalised to that laboratory’s reported measurement uncertainty. *En* values >±1 indicate the laboratory has underestimated the measurement uncertainty. *En* values <~±0.2 indicate the laboratory has likely overestimated the measurement uncertainty.

CSIRO’s results for all measurements in terms of these parameters will be presented at the conference.