Master's Thesis Engineering Technology 2021-2022

Accurate outdoor I-V and IAM characterization of PV modules using a dual-axis solar tracking setup

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Problems & objective

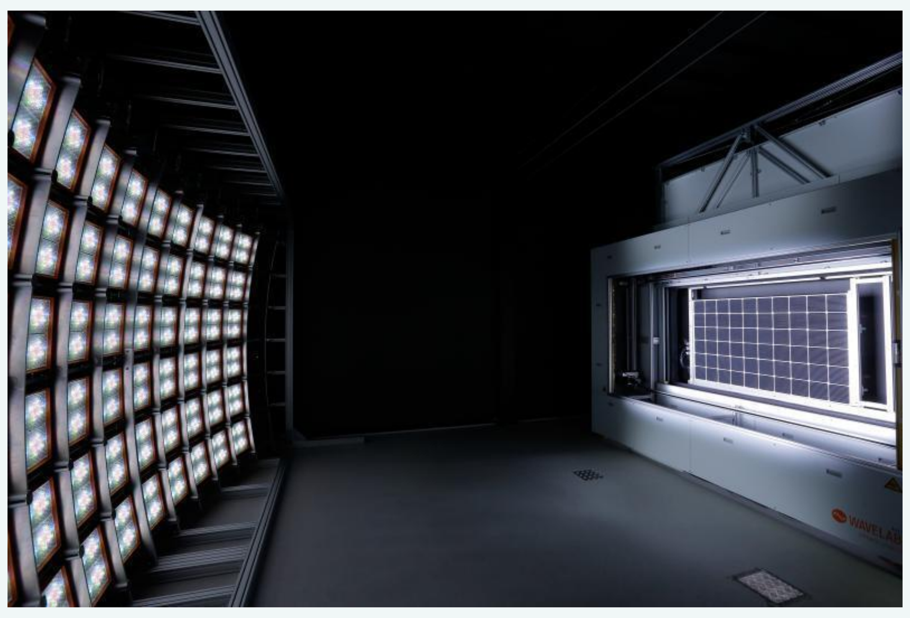

Fig. 1. Solar simulator at EnergyVille [1]

The research institute imo-imomec within EnergyVille in Genk currently characterizes PV modules using an indoor solar simulator, as shown in Figure 1. However, the used LED lights in this device can only approximate the required AM1.5G spectrum, which is visualized in Figure 2. Moreover, two steps occur in the horizontal part of the I-V curve due to a reduced light intensity at the edges of the module. Additionally, it is not possible to mount curved modules or turn modules away for incident angle modifier (IAM) characterization.

The objective of this master's thesis is to develop accurate and easy-to-use systems for performing outdoor I-V and IAM characterization using a recently developed dual-axis solar tracker.

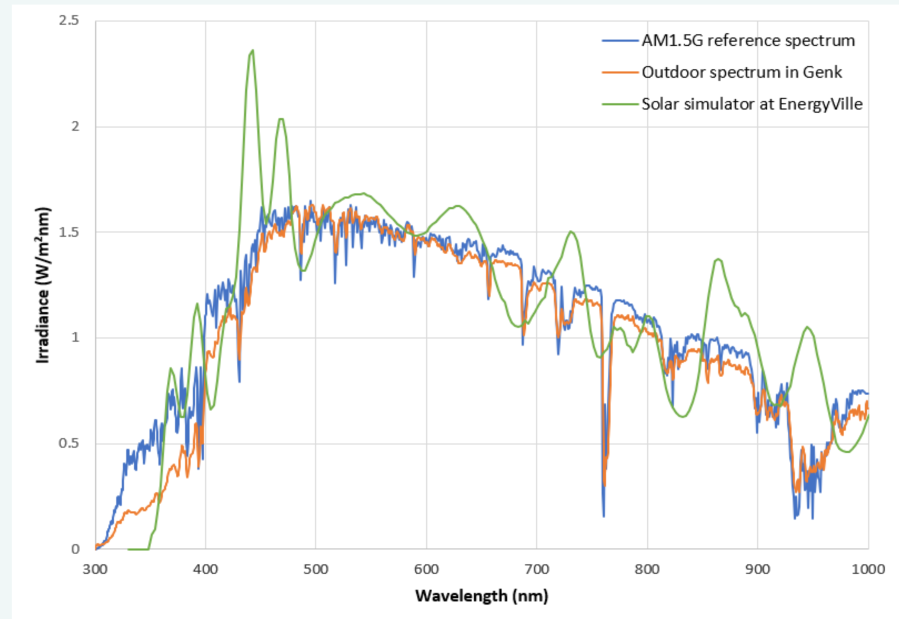

Fig. 2. Comparison of indoor, outdoor and reference spectra

I-V characterization

Materials & methods

Outdoor **I-V characterization** of PV modules was done by measuring the **I-V curve**, **irradiance** and **temperature** simultaneously using a LabVIEW program. The measurement setup is visualized in Figure 3. To measure the I-V curve of the module under test (MUT), an MB Technologies **source measurement unit (SMU)** was used. The irradiance was determined using a **PV module irradiance sensor (PVMS)** and a multimeter with 5 mΩ calibration resistors. To measure the temperatures of the MUT and PVMS, **thermocouples** and a Pico TC-08 datalogger were used. The MUT and the PVMS are mounted on the solar tracker which is directed towards the sun during the measurement.

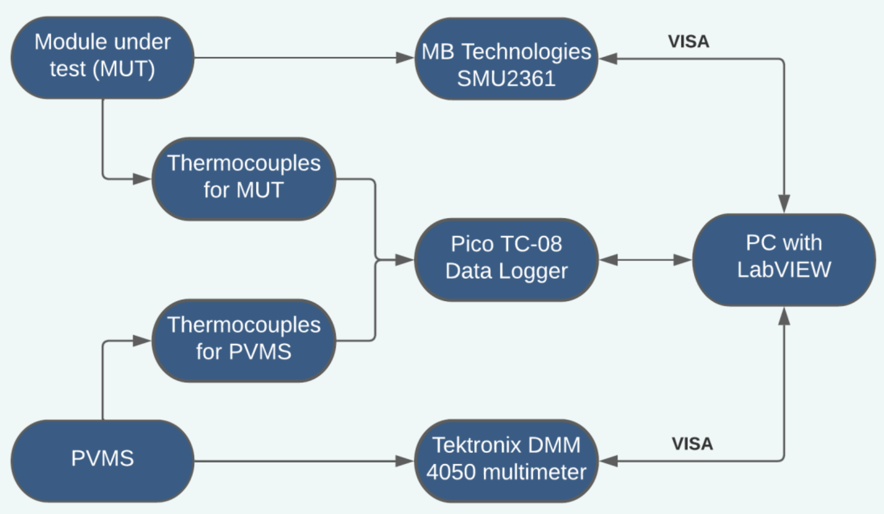

Fig. 3. Outdoor I-V characterization measurement setup

The **obtained I-V curve** must be **corrected to standard test conditions (STC)** by using the acquired irradiance and temperature data. For this purpose, a **Python program** was developed. The program calculates and plots the corrected I-V curve, following the IEC 60891 guidelines.

Results & conclusion

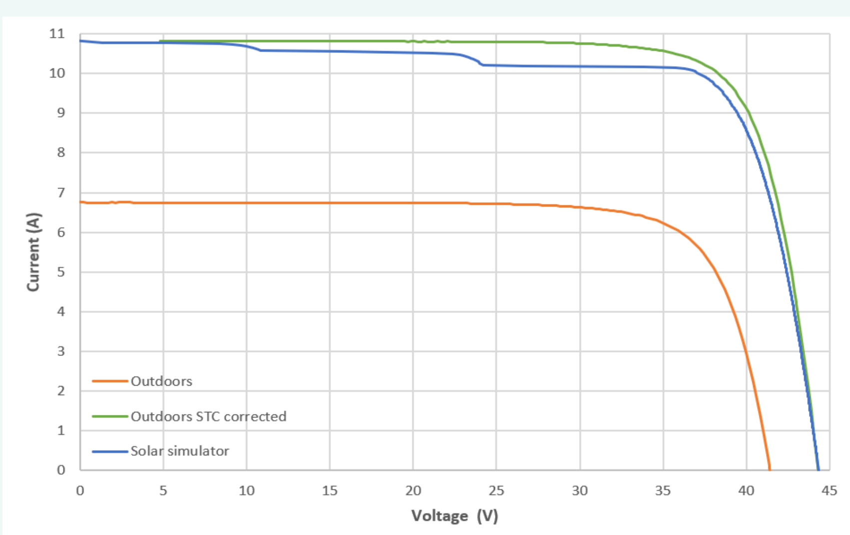

Fig. 4. Indoor, outdoor and STC corrected outdoor I-V curves

Figure 4 shows the I-V curve of a PV module measured outdoors and corrected to STC in comparison to the I-V curve measured indoors using the solar simulator.

The **I-V curve at STC** can be determined with **equal accuracy** on a clear sky day, **without the two steps** that occur indoors.

IAM characterization

Materials & methods

The **incidence angle modifier (IAM)** indicates the short-circuit current (I_{SC}) losses at a given angle of incidence (AOI) due to the optical properties of the PV module compared to the I_{SC} under direct normal irradiance.

IAM characterization was done by using a **novel approach** that only requires a reference PV module with an already known IAM curve to be turned away 0°-90° from the sun together with the MUT. A **Python program** was developed to process the data and calculate the IAM of the MUT.

Additionally, two **in-house reference PV modules were created**. This was done by placing them on a stepper motor controlled rotatable axle in a **1.2 m long, diffuse light blocking tube** mounted on the solar tracker. By turning away the module 0°-90° from the sun, while measuring the I_{SC} and AOI for each step, the IAM can be calculated for each step. Figure 5 shows the lower part of the tube and Figure 6 shows the inside of the tube while it is mounted on the solar tracker.

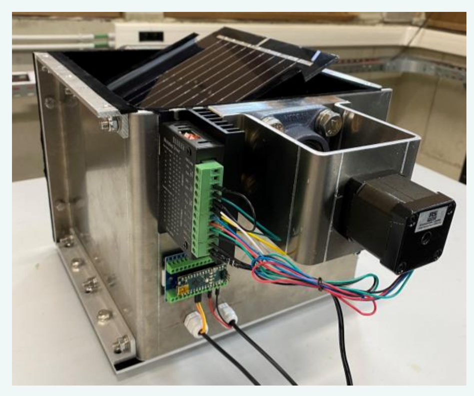

Fig. 5. Lower part of the tube

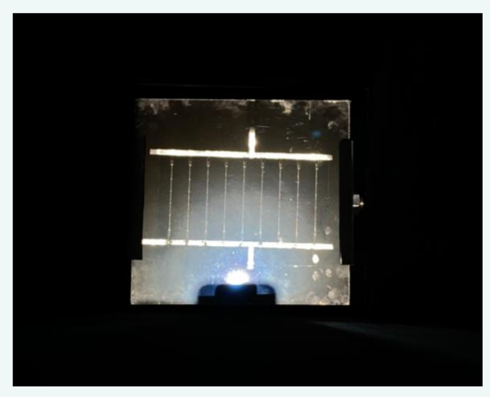

Fig. 6. View inside the tube mounted on the solar tracker

Results & conclusion

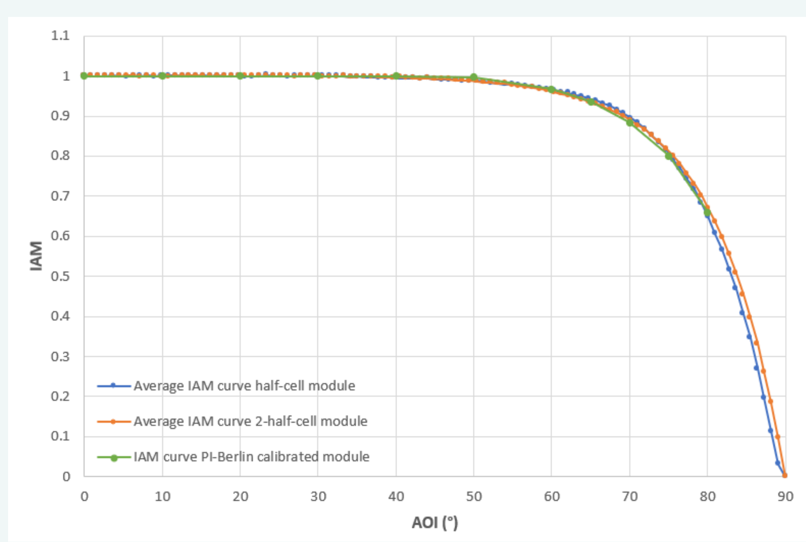

Fig. 7. IAM curves of the in-house and PI-Berlin reference PV modules

Figure 7 shows the IAM curves of the in-house and PI-Berlin calibrated reference PV modules.

It is clearly visible that the IAM curves of the **in-house modules are more detailed** than the curve of the PI-Berlin module.

The in-house modules enable the **IAM curve of the MUT** to be determined with an **angular resolution of 0.9°**.

Supervisors / Co-supervisors / Advisors

Prof. dr. ir. Michaël Daenen
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[1] EnergyVille, "Zonne Energie." [online] https://www.energyville.be/onderzoek/zonne-energie. [Accessed 6 December 2021].

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