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Instrumentation for Outdoor Testing of Emerging PV Technology: Single Cells and Mini-Modules

2021-08-11

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Mini-modules for new technologies are emerging, but limited outdoor test equipment is available

- Encapsulated single-cells and mini-modules are frequently used to test new designs and materials.
- Mini-modules enable a larger number of prototypes to be manufactured quickly, allowing a larger sample size to be tested and improve the measurement statistics.
- More studies involving outdoor testing are needed to validate the performance of emerging PV technologies, but limited hardware is available for properly characterizing single-cells and mini-modules, especially outdoors.

Encapsulated mini-modules and single-cells are finding their place in outdoor testing.

Accurate and consistent I-V measurements of perovskite solar cells can be a major challenge due to metastability in the device's performance.

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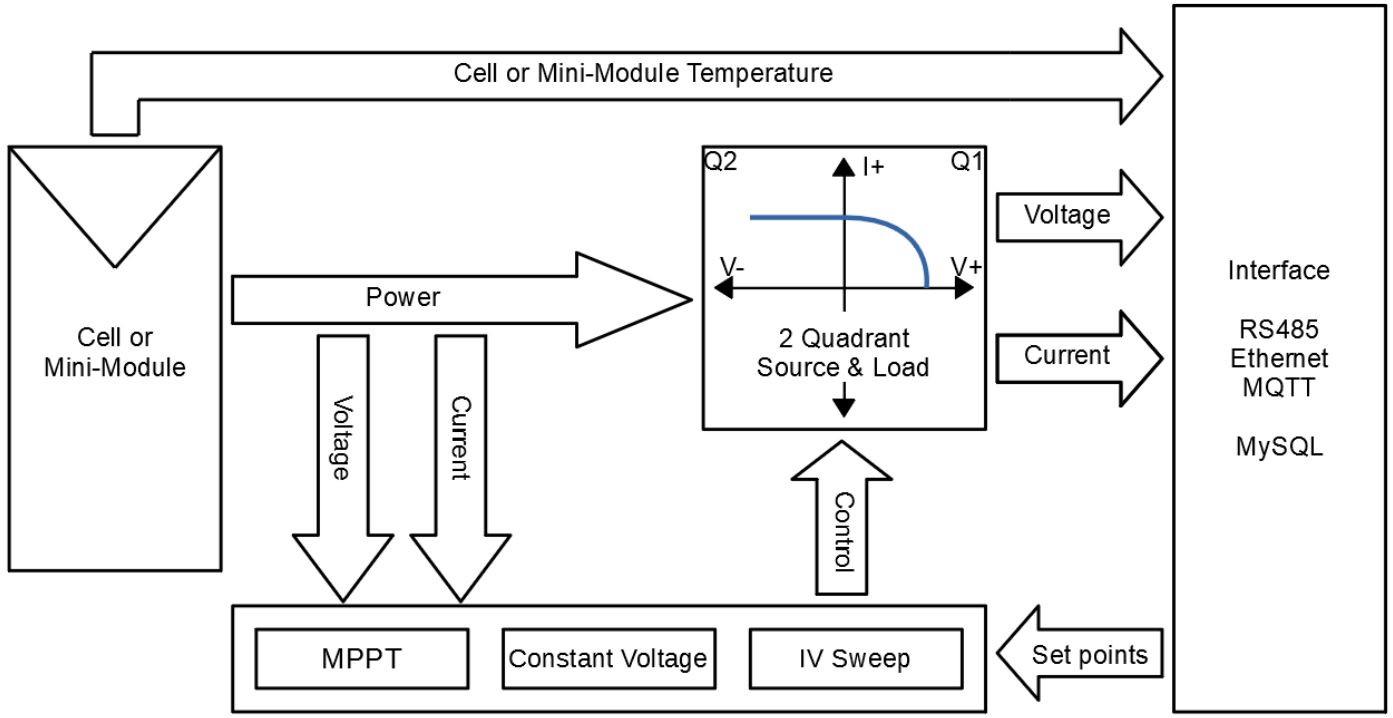
What type of equipment is needed to test these devices?

- A combination of tools and measurement techniques, such as MPPT, I-V sweeps, and constant voltage control can be used to provide a more complete performance picture.
- The ability to switch between different loading methods will enable rapid characterization of emerging PV technologies.
- Electronic loads [Keithley, etc.] exist that can be programmed to do this indoors, but they are expensive and not particularly suitable for outdoor use.



Block diagram visualizing how a two-quadrant source and load can be used to implement MPPT, constant voltage, and IV sweeps in one measurement/load unit.

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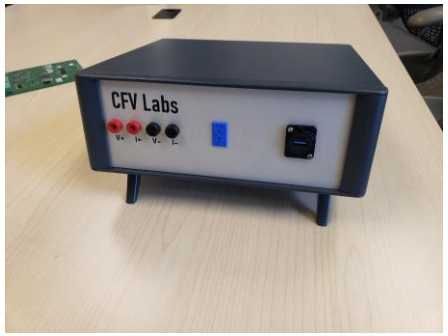
How is CFV Labs working to solve this problem?

- We have successfully designed and built an all-in-one outdoor device that can perform these characterization methods and are currently testing it indoors for single cells and mini-modules under constant illumination.
- We can reproduce many emerging technology workflows with this device, a Modbus/USB interface and a Python scripted master control device:



Single-cell prototype hardware designed to test MPPT, constant voltage (CSFV, asymptotic IV) , and IV sweeping.

Test Mode	Parameter 1	Parameter 2	Parameter 3	Parameter 4
General	Digital Filtering	Voltage Range	Current Range	
IV Sweep	Number of Points	Sweep Time	Forward/ Reverse	Quadrant 2 Measurement
MPPT	Step Size	Update Interval	Simple Algorithm (P+O)	Complex Algorithm (Predictive, etc)
SCFV	Voltage Range, Number of Voltage Points	Current Measurement Interval	Stability Criteria, Regression Interval	Polynomial fit

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SCFV Asymptotic IV Curve Workflow per

Song, Friedman, Kopidakis 2021

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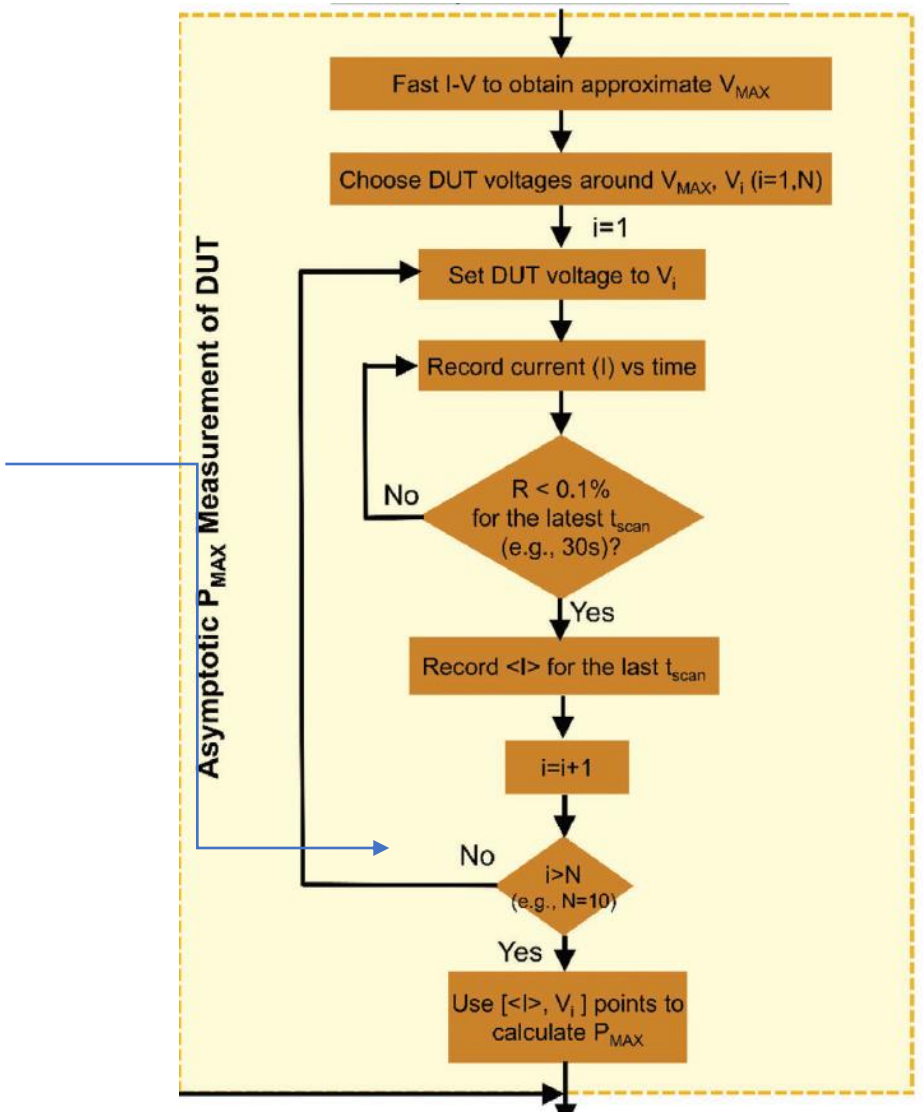
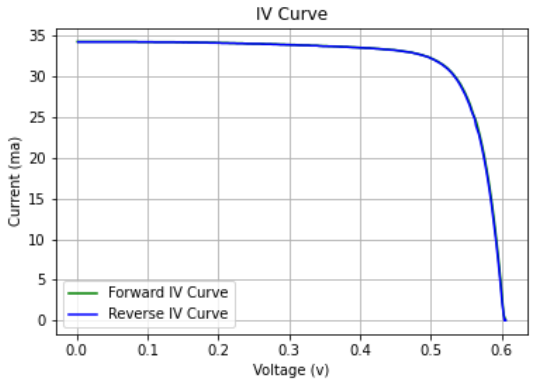
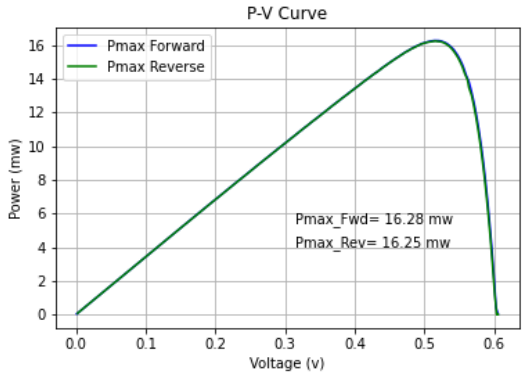
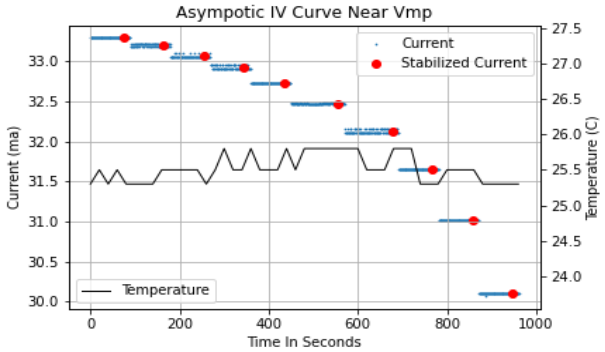


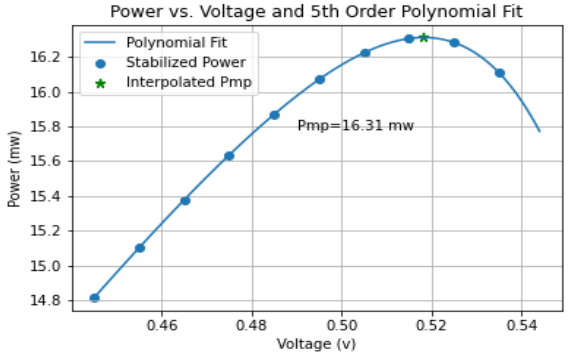
Example of a relatively complex indoor workflow: Asymptotic IV Curve/SCFV.

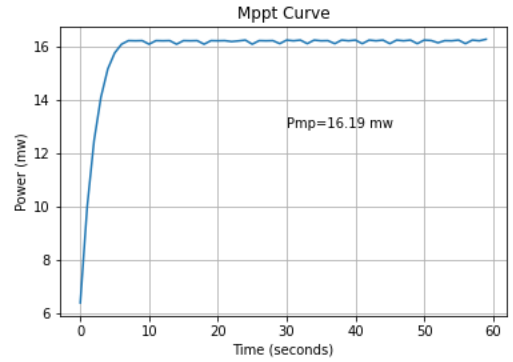
Sample Test Results for c-Si WPVS Reference Cell











C-Si Reference Cell – Measured at CFV Labs

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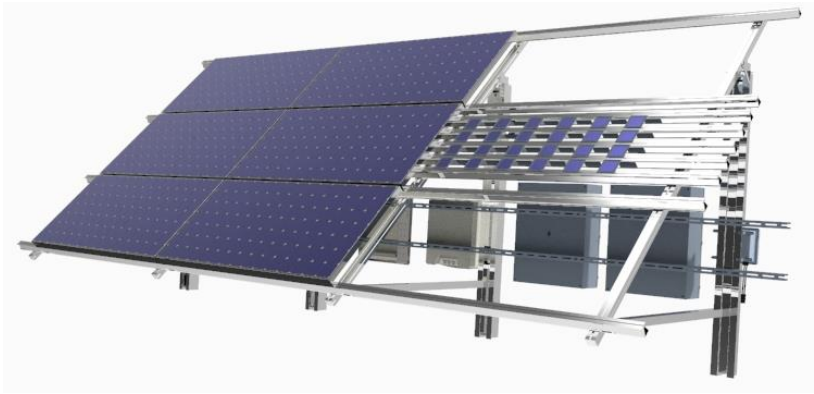
Moving the system outdoors

16 measurement/load channels per enclosure, integrated power supply, and computer will provide a complete testing unit.



CFV Labs outdoor test rack equipped with irradiance sensors, weather station, and electronic loads specifically designed for mini-modules and cells.

Specification	Parameter 1	Parameter 2	Parameter 3	Parameter 4
I,V Ranges	150ma/250ma/ 500ma/ 1A	3V/6V/12V/24V	16-bit A/D converter	Accuracy +/- .2% typical
Temperature Measurement	Type K-, J-, N-, T-, S-, R-, or E-thermocouple	18-bit A/D converter	0.05 °C resolution	+/- 1 °C accuracy typical
Card Interface	16 channels	Modbus	16 registers/ch.	115.2 kbps
Operational / Data Logging Options	Campbell – simple functionality	Raspberry Pi – complex functionality	Ethernet/Wi-Fi MQTT	NV data backup Battery backup

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CFV Outdoor Test Yard

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Contact Us for Questions or Project Inquires

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