

Challenges to measure IV and EL characteristics of solar modules in laboratories and production

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The global photovoltaic industry is going through a rapid transformation that affects all parts of the value chain. Producers face an ever-increasing demand for modules and have to scale their operations at a very high pace. The manufacturers' competition around offering the lowest levelized cost of electricity (LCOE) created a trend for larger modules, bifacial product variants, and the use of high-efficiency cells. Furthermore, producers increase their efforts to monitor and improve quality.

Simultaneously, the increasing demand for certifying module performance data drives the growth of independent laboratories and certification bodies to build and expand global service networks for module evaluation and testing.

Modern solar module designs require more sophisticated measurement techniques to capture IV characteristics and electroluminescence images accurately. The recent edition 3 of the IEC 60904-9 standard, reflects these new requirements by introducing a denser evaluation scheme for spatial uniformity to cater to modules with half-cut cells, and overall bigger sizes.

The standard for an improved evaluation of modules based on new cell technologies also requires testers to comply with adjusted spectral bands, within a broader

spectral range from 300 nm to 1200 nm. With edition 3, the industry now has an official definition of an A+ rating for the spectral, spatial, and temporal characteristics of test equipment.

Productivity and trust within the photovoltaics industry are based upon reliable measurement technology. As a recognized provider of measurement solutions, h.a.l.m. elektronik GmbH supports these values by offering a product portfolio for solar cell and module testing for manufacturers and laboratories alike.

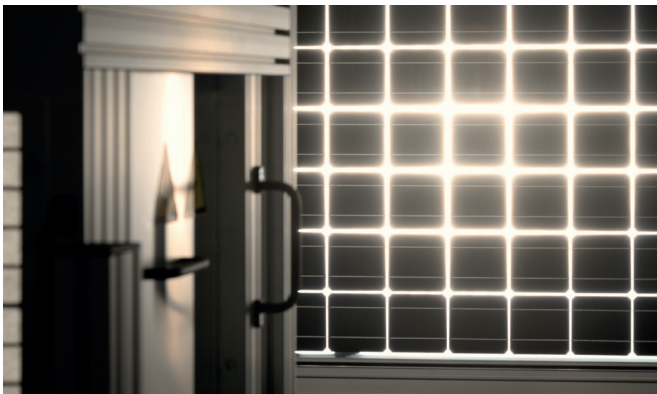
Measurement systems for laboratories

Wherever customers want to perform in-depth analyses of module performance, e.g. for R&D prototypes or certification of samples from production batches, h.a.l.m.'s

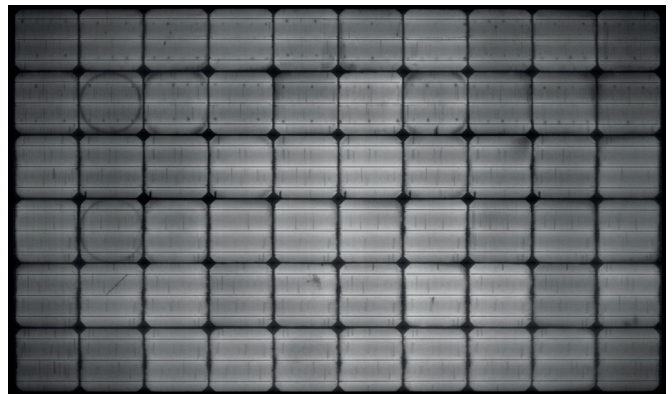
cetisPV-Moduletest3 and its variety of product options meet the above-mentioned challenges.

With a rating of A+A+A+ with respect to IEC 60904-9 Ed. 3, cetisPV-Moduletest3 caters to the highest needs on measurement accuracy. The optional cetisPV-XA enables a maximum module size of 2.60m by 1.60m and makes sure h.a.l.m.'s customers are fit for growing modules and choose a future-proof solution.

The combination of the optional cetisPV-Therm-package and cetisPV-NDF enables labs to determine temperature coefficients and the power-rating matrix of IEC 61853-1 that are crucial to predict performance in the field. Due to the optimized airflow of the cetisPV-Therm-package, cetisPV-Moduletest3 offers a fast, automated temperature cycling from



h.a.l.m bifacial module: the projection flasher cetisPV-IUCT-M allows flexible integration into module lines with product sizes of up to 2.60m by 1.60m and offers the highest standard on light uniformity in production



Module-EL: the electroluminescence option for h.a.l.m.'s projection flasher systems allows detailed defect analysis and quality documentation for laboratories and production – without the need for an additional measurement station

15 °C to 75 °C that ensures a very homogeneous temperature distribution.

For the customer, this directly translates to a higher throughput of the semi-manual workflow. Additionally, h.a.l.m. offers a template function for automatically creating measurement reports in Word and PDF format to streamline the customer process.

As laboratories and R&D departments face a wide and evolving variety of modules and technologies, the measurement system demonstrates its quality by accurately measuring even challenging ones.

For bifacial modules, increasing the light intensity to up to 1200 W/m² allows testing according to the equivalent irradiance (GE) method. When measuring high-capacitance modules, such as heterojunction (HJT), IBC, and TOPCon, with a h.a.l.m. system, the advanced hysteresis function of h.a.l.m.'s proprietary PVControl software allows

precise measurement results within a mere 40 ms. The short flash avoids any temperature-changing effects that longer flashes could cause. Nevertheless, it is possible to use section measurements and flashes of up to 105 ms with optional power boosters for evaluation purposes.

Extending the system to perform full 3-quadrant measurements with h.a.l.m.'s cetisPV-EL3-M option increases the accuracy for determining the open-circuit voltage and hence the associated resistance parameters. cetisPV-EL3-M allows a higher voltage measurement range from -150 V to 300 V and is the recommended choice when customers offer a complete range of module inspection services.

Beyond the precise IV measurement, the electroluminescence option offers further possibilities to analyze and document module defects like cracks or connector issues.

When laboratories and industrial R&D departments are looking for the highest accuracy in module characterization, h.a.l.m.'s cetisPV-Moduletest3 is the optimal solution. cetisPV-Moduletest3 is widely used in labs worldwide, like those of globally operating certified bodies, independent test labs, renowned research institutions, and leading module manufacturers. With its modular design, customers will certainly find a configuration supporting and enhancing their unique value proposition.

Measurement systems in production

In a time of rapid business growth, module manufacturers look for a reliable supplier keeping their pace by delivering on high throughput, high uptime, low maintenance effort, and a long lifetime. With its strong foothold in cell testing systems, h.a.l.m. has proven its technological and organizational maturity. h.a.l.m. is the natural choice when manufacturers create a unified machinery landscape with a single point of contact for training and support. As a by-product,

module manufacturers choosing h.a.l.m. align with the test equipment of many independent test laboratories.

Testing in production is vital for continuously delivering quality, uninterrupted operation, and preventive risk management. Beyond testing the final module, module manufacturers should consider test stations for incoming cells and module tests at the pre-lamination stage. The upfront investment for such a dense control scheme may appear high, but the cost caused by scrap production and missed customer deadlines can quickly outweigh it.

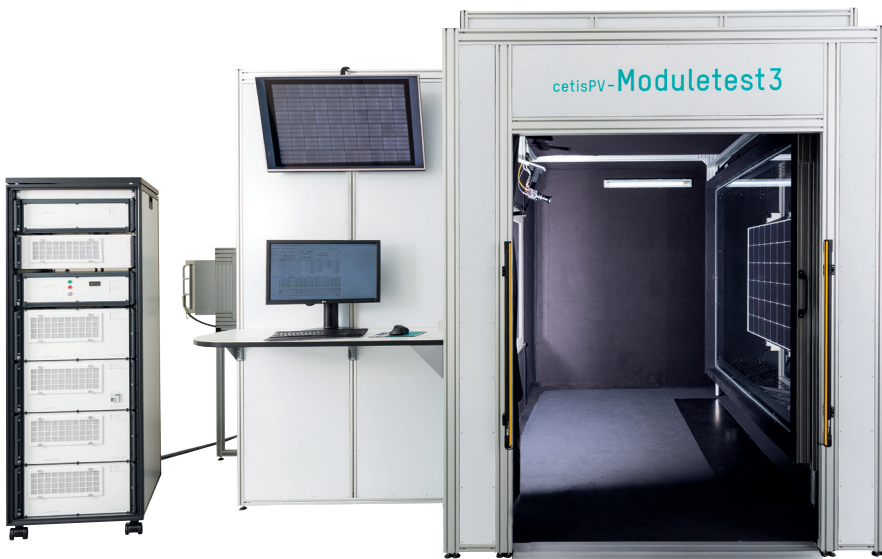
Manufacturers are especially at risk if production workflows with few control points allow large quantities of modules between potentially error-prone steps and product control. h.a.l.m.'s module testers are the perfect way to control production quality and quantify module characteristics. Within h.a.l.m.'s full-range portfolio, manufacturers can choose between two approaches for line integration.

Due to their compact footprint, table flashers have become a common choice for module inspection in production environments. cetisPV-IUCT-Q-L is h.a.l.m.'s most recent innovation in this segment and allows measuring modules of up to 2.30m by 1.40m with a class AAA rating. cetisPV-IUCT-Q-L integrates easily into existing or planned production lines with its low required transportation height.

It does not require additional housing due to the modules' sunny side down orientation. With a maximum throughput of 200 modules per hour, cetisPV-IUCT-Q-L is ready to handle demanding high-volume production requirements. Both the sealed design that impedes dust ingress as well as the easily accessible flash tubes with a long lifetime support manufacturers to meet high standards for availability KPIs constantly. Furthermore, customers can order cetisPV-IUCT-Q-L with an optional motorized transportation system.



Damian Koesters



Moduletest3: by combining the qualities of a projection flasher system with a large variety of options, cetisPV-Moduletest3 enables laboratories, test facilities and R&D departments to characterize almost every aspect of modules of up to 2.60m by 1.60m

Alternatively, module inspection in production environments can be performed using projection flashers like h.a.l.m.'s cetisPV-IUCT-M. Even though customers could regard their larger footprint with the necessary projection distance (of 3.5m to 4m) as a disadvantage, the greater maximum module size and the resulting light field quality reflected by a class A+A+A+ rating can easily make up for that. When assembled in a vertical tower or a horizontal tunnel layout, cetisPV-IUCT-M inspects modules of up to 2.60m by 1.60m and allows long-term reliable

planning regardless of changing module product roadmaps.

Based on a maximum throughput of 200 modules per hour, cetisPV-IUCT-M is thus ready to fulfill ambitious goals to increase productivity. The possibility to integrate h.a.l.m.'s electroluminescence option for defect inspection and quality documentation is yet another advantage as it is fully integrated within the flasher and needs no additional measurement time or an additional measurement station.

Customers find an optimal solution for a seamless line integration cetisPV-IUCT-M together with h.a.l.m.'s professional project management. Detailed technical consulting in all project phases makes cetisPV-IUCT-M a future-proof choice in expanding production environments.

h.a.l.m.'s PVControl software allows manufacturers to configure effective measurement schemes to ensure superior product quality. Customers with heterojunction modules or other high-capacitive technologies greatly profit from h.a.l.m.'s single flash advanced hysteresis that accurately measures steady-state IV curves while reducing the required flash length.

Independent of whether customers decide for a projective or a table flasher system, module testers designed by h.a.l.m. are an asset for every manufacturer. With their tight integration supporting the production process, h.a.l.m. testers give manufacturers a competitive advantage.

Summary

For both manufacturers and labs, h.a.l.m. offers high-end test equipment to the global PV industry. h.a.l.m.'s portfolio offers solutions for cell and module characterization based on its highly accurate IV measurement technology and complementing inspection methods. With a strong focus on innovation and a strong team of project managers and service technicians supporting our customers from our locations in Suzhou (China) and Frankfurt (Germany), h.a.l.m. is the established partner of many recognized photovoltaics brands.

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IUCT-Q-L: with its compact footprint, cetisPV-IUCT-Q-L is easy to integrate for module manufacturers and offers high throughput with up to 200 modules per hour