Empowering PV performance evaluation under NOCT outdoor conditions

Words: Kees Hoogendijk, Technical Director, EKO Instruments Europe, B.V

As the demand for renewable energy continues to rise, the need for efficient and cost-effective photovoltaic (PV) technologies becomes increasingly pressing. Perovskite and bi-facial modules have gained significant attention due to their potential for high efficiency and versatility. However, to ensure their successful deployment on a global scale, it is imperative to conduct extensive onsite testing and research in diverse geographical regions, under varying environmental and atmospheric conditions.

Perovskite solar cells have shown remarkable progress in recent years, with their power conversion efficiencies rapidly approaching those of conventional silicon-based solar cells. These cells are composed of a hybrid organic-inorganic material with a unique crystalline structure, which offers the advantage of low-cost fabrication and the ability to be deposited on flexible substrates.

However, their long-term stability and performance under different climates and atmospheric conditions are yet to be fully understood. Onsite testing in various regions with distinct weather patterns, such as extreme heat, high humidity, or intense UV radiation, is crucial to evaluate their reliability and durability in real-world conditions.

Similarly, bi-facial solar panels have gained attention for their ability to absorb direct sunlight from above and also utilise reflected light from the ground, increasing their overall efficiency and maximizing energy generation. However, the performance of bi-facial modules can be influenced by factors such as ground albedo, shading, and temperature variations.

Thus, testing in different geographical locations with varying ground cover, such as deserts, grasslands, or urban areas, is necessary to assess the impact of these factors on the energy yield and to optimize the design and deployment of bi-facial systems.

Atmospheric conditions such as air pollution, dust, and cloud cover also play a significant role in the performance of both perovskite and bi-facial PV technologies. Regions all over the world experience diverse levels of air pollution and varying weather patterns. So again, testing in areas with high pollution levels, severe dust deposition, or frequent cloud cover is essential to understand how these environmental factors affect the efficiency and long-term stability of PV systems.

With these needs in mind, EKO Instruments has introduced a new comprehensive all-weather PV evaluation system, PV-Blocks. This unique and versatile solution enables researchers to combine a set of instruments to test, analyze, and verify the performance of the latest PV cell and module technologies outdoors. It can be used for small cells, PV modules, and complete strings. The system supports silicon, thin-film, perovskite, hybrid materials, organic PV, high-capacity, BIPV, bi-facial modules, and III/V solar materials.

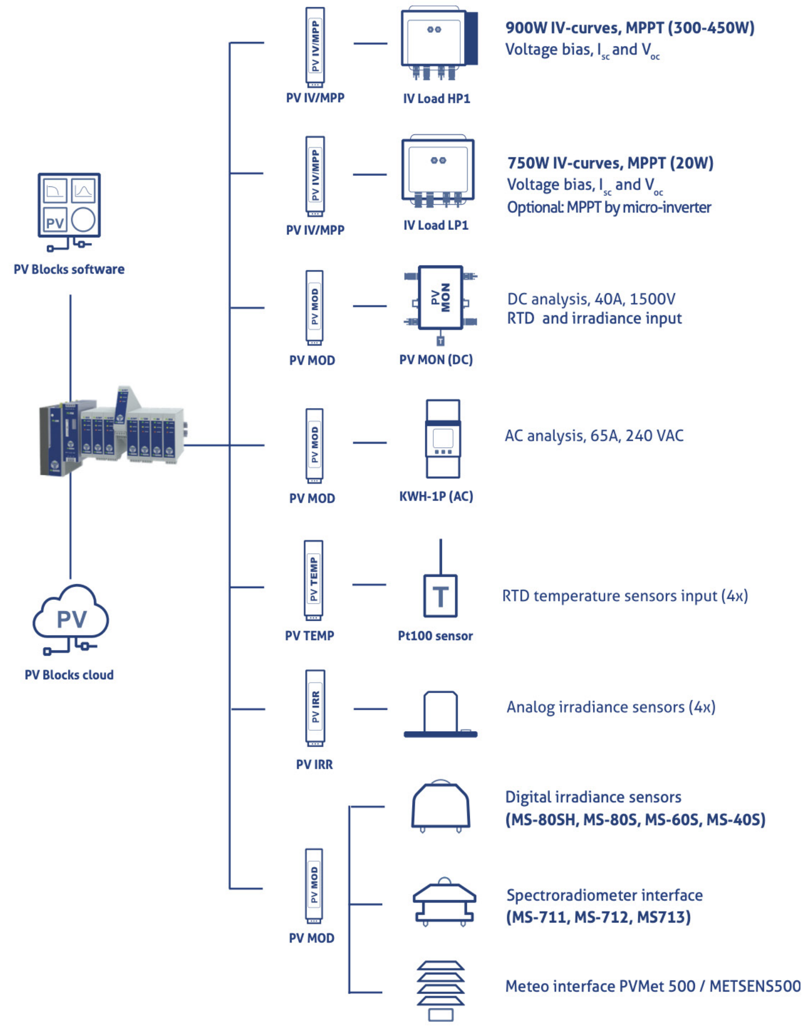
PV-Blocks are designed from the ground up, to solve the measurement challenges widely experienced by PV research meteorologists today. One single system can measure electrical power, irradiance, temperature, and spectrum while performing Maximum Power Point Tracking (MPPT) and trace IV curves. No multiplexing is used, as everything is synchronized to a one-minute heartbeat, and the all-weather calibrated IV-MPP load unit can be positioned near PV modules for easy installation and accurate measurements.

Another key feature of PV-Blocks is its modularity. Systems can be configured and expanded to meet any project requirement, making them uniquely capable of monitoring all environmental and atmospheric parameters simultaneously under present conditions. They can also be triggered to capture exceptional atmospheric events such as over-irradiance.

Both analogue and digital irradiance sensors can be connected to the system, and most digital sensors from EKO Instruments are supported, including our ISO 9060 Class A MS-80 series pyranometers / MS-711N and/or MS-712 spectroradiometers, and latest digital RR-series reference cells.

The RR-series offers a unique range of new reference cells that can be used to measure irradiance for various PV-Blocks applications. As well as the sensitivity, the External Quantum Efficiency (EQE) of each device is given, allowing for precise spectral mismatch corrections when monitoring PV-Modules. The sensor contains a stable encapsulated silicon solar cell with an area of 20 x 20 mm, and the solar cell is calibrated for the AM1.5G spectrum. This allows for the determination of the Performance Ratio (PR) of PV cells and modules of any type, not limited to silicon.

The PV-Blocks system is also fully autonomous. Once it has been configured according to the user's requirements, it can run for years without intervention. This is achieved by using a high-quality industrial heavy-duty computer. Even though the measured data is stored safely on the system locally, each PV-Blocks system is delivered with an extensive toolkit to enable data analysis and retrieval by the user. There is



a Command Line Interface (CLI) for Linux, Windows, and OSX, and an Application Programming Interface (API) available, to use a programming language of one's choice.

Every research project is unique and user demands can vary greatly based on research goals and test locations, so the system can be built and pre-configured according to the user's needs and future requests.

Beyond the factory tests conducted under Standard Test Conditions (STC), testing solar cells and PV modules under Nominal Operating Cell Temperature (NOCT) conditions outdoors is important to assess their performance and efficiency in real-world operating conditions.

NOCT conditions simulate the average temperature and solar radiation levels experienced by the modules during normal operation. By subjecting solar cells and modules to NOCT testing, researchers can evaluate their thermal behavior, power output, and degradation rates under typical environmental conditions. This testing provides valuable data for system design, performance modeling, and identifying any issues or limitations that may arise in different geographic regions and climates, ensuring the reliable and optimal operation of solar PV installations.

I/V current-voltage measurements are needed to accurately determine the true performance of a PV module outdoors as well. These measurements provide vital information about the electrical characteristics of the module, including its open-circuit voltage, short-circuit current, maximum power point, and efficiency. By conducting I/V measurements, researchers can assess the module's performance under real-world conditions, taking into account factors such as temperature, shading, and variations in solar irradiance. This data helps in evaluating the module's energy production, identifying any performance issues or degradation over time, and optimizing the system design and operation to maximize the overall energy yield of the PV installation.

In between the I/V measurements, Maximum Power Point Tracking (MPPT) is crucial for PV modules because it enables them to operate at their peak efficiency and maximize power output. PV modules exhibit a non-linear relationship between voltage and current, and the Maximum Power Point (MPP) corresponds to the optimal voltage and current combination for maximum power generation.

MPPT algorithms dynamically adjust the operating voltage of the PV module to continuously track and maintain the MPP, even under changing environmental conditions like temperature, shading, or varying solar irradiance. By employing MPPT, PV modules can extract the maximum available power from the solar resource, ensuring optimal energy production, improving system efficiency, and maximizing the return on investment for solar installations. The PV-Blocks system is capable of MPPT for off-grid systems. In the case of a grid-connected PV module, the MPP data can be obtained through the PV-Blocks measurement unit and μ-interverter.

For decades, EKO Instruments has been offering industry-leading solar sensors and PV evaluation systems. With the new PV-Blocks system, we can add another chapter that is perfectly aligned with our vast range of solar sensors and I/V measurement solutions for critical testing of the latest PV technologies. Soon we expect to introduce a new PV-Block component for Maximum Power Point (MPP) string monitoring, called 'PV-Mon'.

The device not only works in 1500V systems and can be used as part of a PV-Blocks system, it can also be used in combination with an existing PV-Monitoring solution for independent monitoring of the PV string DC parameters. We believe that PV-Blocks can greatly contribute to a better understanding of the true performance of PV modules under real conditions, and look forward to seeing the impact of the powerful insights these systems provide for metrologists and solar energy industry professionals around the world.

www.eko-instruments.com/eu/categories/products/iv-measurement-instruments/pv-blocks