
With so many thousands of solar PV modules installed in one place, it pays to know exactly what is going on at the string level. Monitoring, however, is the final step along a sophisticated process of testing and modeling.

# Fine-tuning the sun

**Utility-scale monitoring:** Every day large numbers of new PV panels are installed at large-scale sites around the world. Each panel helps bring about a cleaner energy future, but despite their durability, things can, and sometimes do, go wrong. But solar's maturation has nurtured a growing monitoring sector that can identify and understand faults, often before any ground is broken.

An oft-repeated benefit of solar PV is the rallying call: "It just works!" Power plant owners may have to wrestle with financials, logistics, suppliers and governments in order to get their solar park constructed and connected, but once the panels are in place and the cables are connected, most asset owners have generally been happy to sit back and let the sun take things from there.

From homeowners content with their rooftop arrays to global investors sowing their solar seed in many of the world's emerging markets, the notion that solar PV is a durable, low-maintenance source of energy and income has served the sector well during its dramatic growth over the past decade.

But as the solar industry has evolved beyond the niche and into the mainstream, attention has begun to turn towards maximizing performance, reducing downtime, upping the yield, maintaining standards and – increasingly – fulfilling expectations based on measured and predicted long-term performance at contract level.

The PV penny is dropping. In the sunny U.S. city of Tempe, Arizona, measurement and PV monitoring company Gantner Instruments owns an outdoor test facility (OTF) designed to measure the performance of all types of PV modules and weather sensors, delivering site-independent results that validate measured vs. predicted long-term performance of multiple Tier 1 technologies with a high resolution and calibrated long term data set since 2010.

The aim of the OTF is to provide investors, EPCs and asset owners with recommendations on what parameters and methods they should be using to ensure their utility-scale solar projects are maximized to their full financial and energy yield potential.

A growing awareness of the need for accurate PV testing and predictive modeling means that the Arizona site is certainly not the only such facility in the world, but it does boast a suite of features that makes it largely unique in the field of PV modeling, monitoring and outdoor testing. "Our Arizona test center has 98.5% uptime of data and is one of the leading test sites for PV in the world," Juergen Sutterlueti, head of Gantner Instruments' energy segment and business development, told **pv magazine**. "The facility measures IV curves every minute for 24 fixed PV modules and six modules on a 2D tracker. This allows us to perform all of the testing required for PV optimization, performance benchmarking, characterization and energy yield improvement."

Mention data and monitoring to non-specialists and eyes have a tendency to glaze over. Academics and researchers have long understood the value of accurate, independent and verifiable testing data for PV plants, and there is a growing acceptance within industry that such data holds a weight of value. Gantner's approach to this shifting attitude is manifold, but there are a couple of key themes that Sutterlueti believes are gaining a foothold in the wider scope of solar awareness – the need for simple, easily digestible data, and a growing preference for risk reduction.

## Put to the test

The one-second IV curve testing at Gantner's Arizona OTF enables normalized PV performance coefficients to be generated, separating sensor, electrical, thermal and seasonal or stability factors. This, Sutterlueti says, is unique.

"Our loss factor model (LFM) allows us to generate these separate factors in PV module performance. The results are independent of the site, and we have installed up to 30 different technologies to be tested there." Most other measurement sites use performance models that are either dimensioned coefficients (e.g. Isc amps or Roc Ohms) or use measurements that come out of optimizing a model to curve fit such as ideality factor or saturation current. The LFM is unique in characterizing the PV component with independent, normalized coefficients that show the power performance as having losses from identified sources, for example there may be 5% loss due to the Isc being below spec (and can be identified with soiling, spectral response, reflectivity etc.) and 10% loss due to a poorer than expected ROC which is related to the parasitic series resistance in a module mostly from tabbing material and sheet resistivity from the transparent conducting layers.

"Thin film devices such as CdTe, CIGS etc., for example, tend to have higher series resistance losses but often a better temperature coefficient (lower drop at higher temperatures) than crystalline silicon, and thin film modules' spectral response and behavior is different," said Sutterlueti.

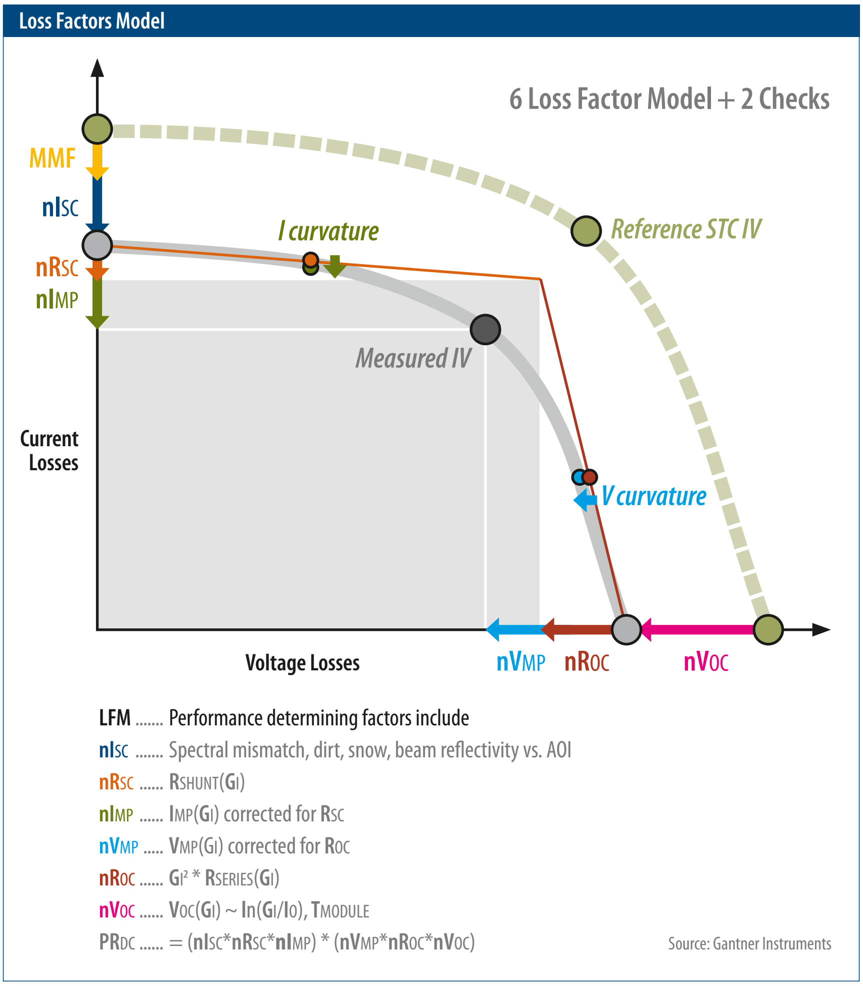
Armed with this data, Gantner can identify where losses are occurring and allocate them exactly to a physical parameter on the system. Allocating losses is, however, merely a first step in identifying where there might be a weakness in a module and, therefore, an entire power plant.

"The real benefit comes when you can understand these losses and are able to use this know-how to elevate performance in real time, deliver power prediction or identify responsible loss stages," he adds.

Such depth of data, so early on in the PV chain, is invaluable to large-scale solar investors or developers eager to model in advance exactly how a power plant may perform in any identified location and with the identified technology.

### AT A GLANCE

- PV project investments require continuous, accurate and traceable plant monitoring data to determine actual vs. design performance and fulfill owner/investor expectations.
- For many years, monitoring and modeling of PV performance was often overlooked by asset owners focused too much on the 'before' phase, rather than the 'after' phase
- Gantner Instruments' outdoor test facility in Arizona delivers conditions that can identify plant performance issues prior to installation, thus offering valuable savings on LCOE, installation time and O&M.
- Expert analysis and interpretation of such high-level data is also imperative, and offered by the Gantner Instruments webportal to ensure asset owners are provided with a powerful overview of how their plant is performing.
- As the solar sector expands, demand for such monitoring, predictive analysis and focus on what is relevant in terms of financial performance and kWh is set to grow globally.



Graphic: pv magazine/Harald Schütt

Accurate and independent module testing, such as that provided at the Gantner outdoor test facility in Arizona, can help to deliver lower LCOE and ensure asset owners are hitting their financial KPIs.

This is not retroactive monitoring; this is ahead-of-the-game predictive analysis that proves invaluable in providing comprehensive financial KPIs for investors, thereby reducing risk for power plant owners and operators.

## Let's go outside

Delivering to power plant owners a comprehensive overview of how a PV system is likely to perform requires understanding of the influences that can affect a module, and also a grasp of context. Set against empirical data and previous accurate modeling, successful analysis requires an identification of what is relevant in terms of financial return and kWh output.

At the Arizona OTF, Gantner has developed an optimized method to characterize the performance of different module types under all weather conditions and on fixed or tracked installations.

The Tempe location was identified as the ideal place in the world for solar testing. "The lengthy sun hours means that there is a lot of UV stress to the material, but Arizona offers more than just sun – you have clear bright skies, temperature variables, rain and once even snow, so you can also test soiling impact," said Sutterlueti. "But you still need a site that has enough sun hours, and Arizona has that in abundance."

As well as demonstrating to solar clients the efficacy of module testing, the facility has also pioneered a growing trend and acceptance of how longer data sets can deliver better yield for asset owners. Gantner Instruments has identified a growing appetite for this approach as they also install test setups worldwide.

"People observe issues in the field, and they do not find the root causes for problems in the conventional ways," he said. "If you want to test in the right way, you have to consider several different parameters, and you have to separate these too. It is not enough just to say that the performance ratio e.g. will be 80%. You also have to identify how you came to this conclusion and what is the impact of irradiance and temperature. And this has to be done in the real world. This is what we do in Arizona, and implement it into the Gantner-webportal."

The results offered by the OTF are verified as site-independent, meaning that the testing and modeling can be applied to power plants the world over with no compromise on accuracy. The site's one-minute IV curve data is checked alongside existing site calculations and actual meteorological measurements and measured PV performance, and any differences in yield or general behavior are easily identified. This is what Gantner calls the loss factor model (LFM), developed in cooperation with SRCL.

"To understand PV performance exactly, you have to identify where the uncertainty comes from," explains Sutterlueti. "Of course it helps to monitor irradiation sensors, but you also have to understand what kind of PV module quality you installed, and how accurate the labeling of the PV module is. At the Arizona site we can deliver and analyze these effects, which allow us to use the right sensors and the right module power or efficiency for any intepretation."

At utility scale, such accuracy can prove vital to a plant's performance. And in order to optimize, identification of weakness is key. "Optimization is only possible if there is weakness present. When you design everything right from the beginning, you get a good performance. But if you design a power plant without all the know-how, then you will lose something in the performance, meaning there is potential to improve this later on."

Additional hardware changes or site re-designs cost time and money. So, Sutterlueti adds, it is far more effective to achieve optimum performance during the modeling and planning stage.

## Testing to reduce LCOE

Every solar site owner across the world seeks a lowered levelized cost of electricity (LCOE). Tumbling module, inverter and balance of system (BoS) costs have helped solar PV's LCOE come much closer to grid parity than ever before, but there remain a handful of cost-intensive outliers that increase the bottom line, particularly for utility-scale solar plants.

The economies of scale that make larger sites more viable also mean that accurate information input is often harder to come by. Gantner's OTF generates a loss factor concept method that validates the highly accurate data acquired, and transfers that data to utility scale.

This accurate, traceable data – which delivers predictive results for all types of sites – is unique, Sutterlueti says. "When you have this ability in combination with the advanced monitoring concept, then you can see the performance of each component in real time. I have yet to see other institutes or sites offering this capability. This is made possible because Gantner has PV performance understanding, and the utility-scale approach means more accurate data logging and the ability to do so in real time."

When the modeling methods performed onsite in Arizona are taken to utility-scale, the process yields much more data. This, says Sutterlueti, is where the industry is heading: towards greater transparency regarding power plant performance, and independent results that are unbiased. "You can do a lot with just simple data," he adds. "You don't need reams of intense data. But it has to be physically meaningful and accurate. Correlation does not imply causation, and so what Gantner tries to do is bring physics into the analysis for high quality PV performance understanding."

## Meaningful modeling

There are people in this world who simply need to glance at a chart, a graph or a dataset to be able to decipher its meaning and extract value from it. The peaks