Technology Brochure 7

OptiTrac

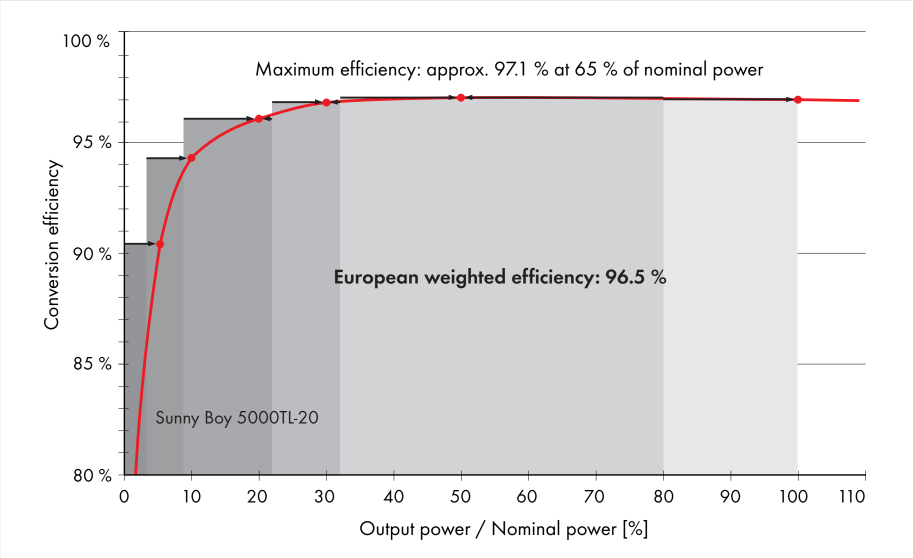
Optimized MPP tracking for a higher energy yield

Overview

A photovoltaic system is only rarely operated under constant ambient conditions, because the sun's radiation values are subject to changes related to the weather and the time of day. Since the solar inverter is responsible for managing the output of the entire PV system, it must react dynamically to these changes. This is the only way to constantly always achieve the best possible energy yield from the solar modules.

The dynamic reaction of the inverter is significantly determined by the MPP tracking: since MPP tracking is defined as the process of continually determining the operating point at which the PV generator achieves its maximum performance. The SMA development team has further improved this thoroughly proven electrical tracking process. The additional and extensive possibilities of the company's own solar testing center allow the replication of conditions which change frequently and suddenly in reality. As a result, an MPP tracking procedure was developed that increases the energy yield of the entire PV system and ensures a higher profit.

Photocase



The CEC rebate efficiency is the weighted average value of the conversion efficiency at six defined outputs between 5 % and 100 % nominal power.

SMA Test Center

The Efficiencies of an Inverter

A PV plant's yield depends heavily on the quality of the inverter used. Efficiency is commonly used as a characteristic for this purpose. However, upon closer examination, there are several types of efficiency that determine the energy yield of a solar power system. We will begin by describing the efficiency types below.

Conversion Efficiencies

An inverter is very often defined by its conversion efficiency. This efficiency indicates the percentage of the power that is produced from the solar modules that can be fed into the public grid. However, the best possible weather conditions for operating a solar power system are assumed when calculating the value. The CEC rebate efficiency, Euro ETA, is therefore a more meaningful measurement and better reflects the everyday partial load behavior. It is calculated from several efficiencies at different operating points that are weighted according to the frequency with which they occur at a specific location in Europe.

The quality of the electronic components is the most decisive factor for the conversion efficiency level. Continous further developments whose provisional high point can be considered the H5 topology, have resulted in the CEC rebate efficiency reaching a previously unattainable value of 97.7 %. Regarding the inverter's performance, the hardware is now at a very high level of development.

Intensive and comprehensive tests in the SMA testing center have demonstrated that further energy yield increases are obtainable, especially by optimizing the electrical tracking.

MPP Tracking – the Search for the Optimum Operating Point

That the solar module's output increases with the radiation is assumed, in most cases, as a matter of course; however, closer examination reveals that this is an important function of the inverter. A PV module directed at the sun at midday is comparable to an automobile that has a full tank of gas and is on the street with the engine running. To use the available energy very efficiently, in other words, to travel as far as possible, the car must be driven at an optimum velocity whose speed depends on the vehicle's rolling and wind resistance as well as the street's elevation profile. Operation at full throttle or in neutral indeed empties the tank, but it also dramatically shortens the distance driven. An intelligent system control is required to set the optimum operating point.

To always achieve the maximum performance from the solar modules despite different radiation levels, modern inverters employ a procedure that measures the PV generator's current achieved potential at fixed intervals, thus allowing the generator to be operated as continuously as possible at its MPP (Maximum Power Point).

During MPP tracking, the inverter's internal resistance undergoes minimal changes at specific time intervals, which simultaneously change both the voltage value as well as the current value of the generator. The change in both of these parameters directly affects the generator's output power. If this output power increases, the inverter retains the new voltage and current values. However, if the PV generator loses power, the inverter continues operating with the original values until the next measuring interval.

MPP tracking operates extremely reliably and is now used by all well-known inverter manufacturers.

Tracking Efficiency Tested in the Laboratory

The tracking efficiency allows the immediate assessment of how well the MPP tracking functions. Since the processes currently used with inverters are very sophisticated, laboratory tests conducted today often achieve values of over 99 % for the static tracking efficiency. Thus, the efficiency of these processes appears extraordinarily high. In fact, however, sudden weather changes, and with them the predominantly high dynamics of climatic conditions, remain virtually disregarded in the procedures used to date.

Behavior During Weather Changes

In practice, the solar inverter is only rarely operated under constant ambient conditions, because the sun's radiation values are subject to changes related to the weather and the time of day. As a result, it is important that the inverter should have an increased ability to adapt to the fluctuating output of the PV panel. To achieve a maximum energy yield, the inverter must have both a high conversion efficiency and an excellent tracking efficiency. In this context, the startup and shutdown efficiency, which respectively describe the inverter's behavior in the morning during startup and at night during shutdown, are also important factors.

The dynamic tracking efficiency

Similarly as with the conversion efficiency, it is therefore practical to determine a dynamic tracking efficiency that takes into account the typical realistic operating conditions over a complete operation year. As is the case with the CEC rebate (conversion) efficiency, this characteristic corresponds to a weighted CEC rebate tracking efficiency.

Total Efficiency

It is the weighted sum of these efficiency rates, taken together as a total efficiency rate, which first allows for a realistic representation of the output capability of an inverter. This is, at least, the claim of one of the pioneers of PV technology, Professor Heinrich Häberlin from the Berner Fachhochschule [1] (Bern University of Applied Sciences). Early on he had rated the devices tested according to their weighted European conversion rating and in so doing, attracted attention to the importance of observing the dynamic MPPT efficiency rating as part of the "total efficiency rating". Such a total efficiency rating allows the comparison between diverse inverter models for the first time, providing plant designers with additional decision-making security.
The simplified calculation of the total efficiency rating is suitable for this purpose:

$$\eta_{total} = \eta_{euro} * \eta_{tracking}$$

with

η_{euro} the weighted European conversion efficiency

$\eta_{tracking}$ the weighted European tracking efficiency

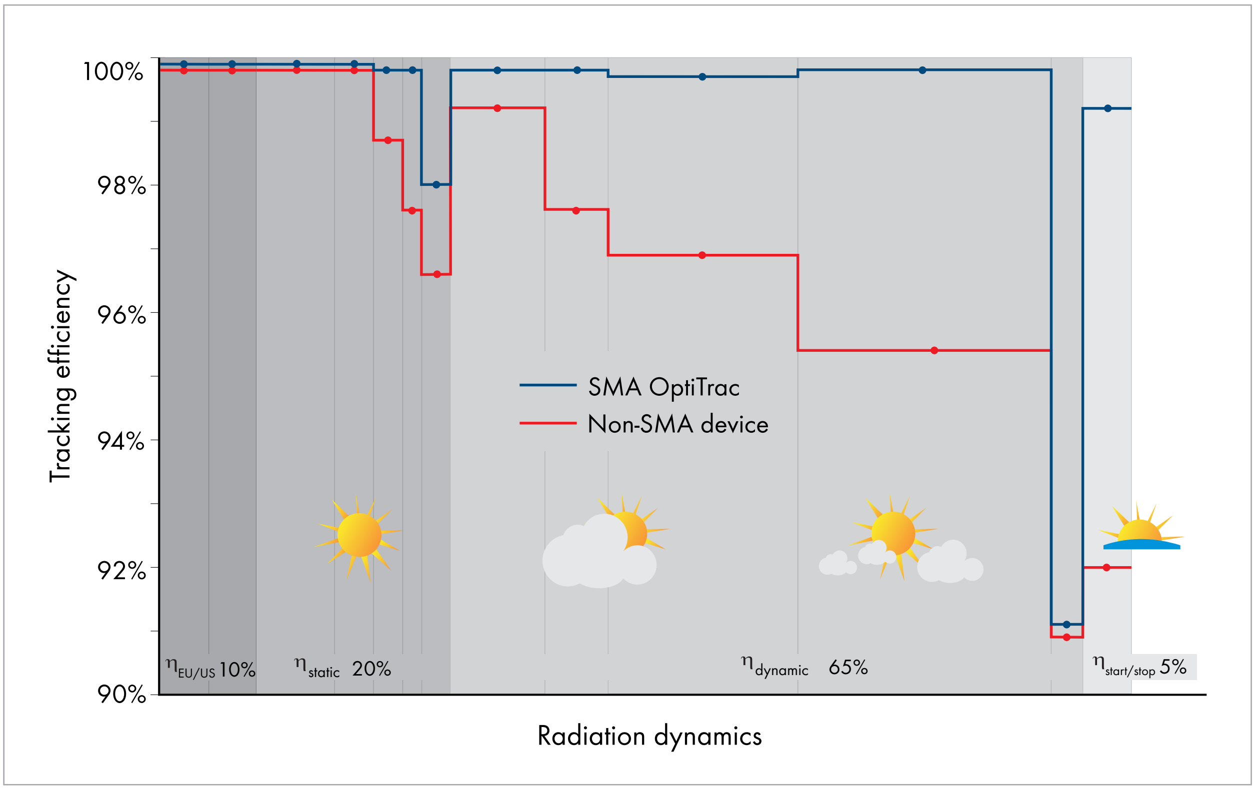
The new term of the radiation-dynamic tracking efficiency describes the process of finding and maintaining the MPP during real weather conditions over an operating year. In this case, similar to that of the CEC rebate conversion efficiency, a typical radiation level for central Europe must also be assumed. Just as the CEC rebate conversion efficiency is derived from the weighted average value of the conversion efficiency at six selected outputs, the radiation-dynamic tracking efficiency can be determined from the weighted average value of the tracking efficiency in 13 characteristic radiation situations.

However, the definition and reproducible replication of these operating conditions pose a great challenge and require a testing station that is far better equipped than a normal testing laboratory.

The innovative testing facilities at the SMA solar testing center, developed in-house over many years, make it possible for the first time to simulate realistically a PV generator under the most diverse weather conditions and the highly dynamic weather changes that often occur in the course of a day.

This has now also made it possible to determine the MPP-tracking quality of an inverter precisely and reproducibly. Therefore, SMA added the radiation-dynamic tracking efficiency analysis to its qualification standard in assessing inverters some years ago (see also "Weather at the touch of a button", page 11).

The benefits of this analysis are made obvious when comparing the operational behavior of two inverters or MPP trackers. If it is still difficult to differentiate both devices under laboratory conditions (Euro ETA and US ETA), the individual strengths and weaknesses are clearly demonstrated with the results of the remaining tests. The radiation conditions are divided into four groups: laboratory operation, static behavior, dynamic behavior and startup/shutdown behavior.



The quality of the MPP tracking depends very heavily on the radiation conditions. Many tracking procedures only provide excellent results during good weather.

MPP Tracking – the Search for the Optimum Operating Point

A New Procedure

Through significant refinements made in the electrical tracking, the SMA development team has managed, with OptiTrac, to improve further on the MPP tracking used to date, thereby achieving an increase in the total efficiency. This is extremely important for system operators, since this value directly affects the energy yield of the entire photovoltaic system.

The Inverter Reacts Faster

Equipped with SMA OptiTrac, the inverter reacts much more precisely to changes in radiation levels, so that the maximum energy available can be constantly fed into the grid. Thus, SMA OptiTrac significantly improves the dynamic behavior and increases the energy yield on intermittently cloudy days. This is very important mostly for systems in regions within central Europe, since the general weather conditions here are considerably more unstable.

Increased Yield

The yield was further increased by improving the startup behavior. The maximum power point is now reached much more quickly after sunrise and can also be maintained longer as night begins to fall. The OptiTrac procedure is not only suitable for use with crystalline PV modules, but it can also be used for operating thin-film modules in particular.

Innovations Pay off

More Yield

With regard to the system operators' profit, the magnitude of the increase in yield which the new procedure allows is especially important. In addition, the effectiveness of OptiTrac can be expressed quantitatively: the irradiation-dynamic efficiency tracking described above shows the proportion of the PV generator's energy which is really converted. The higher this value is, the higher is the attainable annual yield of an inverter.

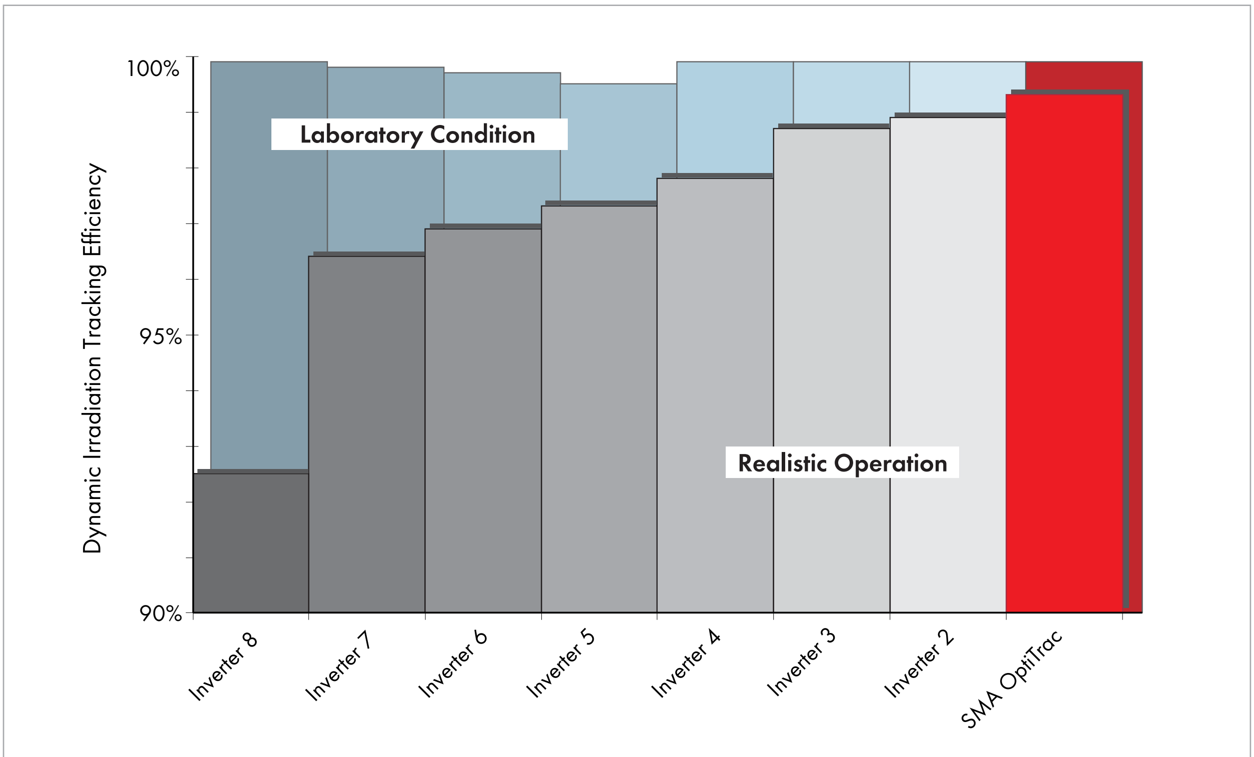
Increased Profits

Extensive tests and field trials have demonstrated that the energy yield of a PV system can be increased by up to 1.5 % per year by using the SMA OptiTrac. For system operators, this means pure cash. To ensure that all photovoltaic investors get something out of the new SMA accomplishment, OptiTrac will gradually become available for all new Sunny Boy, Sunny Mini Central and Sunny Central inverters.

More information

[1] H. Häberlin et al.: „Totaler Wirkungsgrad – ein neuer Begriff zur besseren Charakterisierung von Netzverbundwechselrichtern." 20. Symposium Photovoltaische Solarenergie, Staffelstein, 2005.

[2] R. Bründlinger et al.: „99,9 % MPP-Tracking Performance – nur die ‚halbe Wahrheit'?"; 23. Symposium Photovoltaische Solarenergie, Staffelstein, 2008

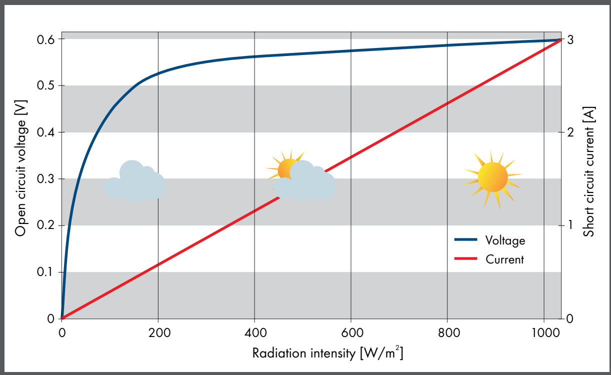


Measurement of the tracking efficiency under laboratory conditions is carried out quite easily, but it provides no information on the tracking behavior under real radiation conditions. Differences between the devices can only be clearly distinguished once the measurement results of the radiation-dynamic tracking efficiency are available.

The weather-sensitive solar cell

Solar radiation

The electrical parameters of current, voltage and output of a solar cell depend on solar radiation. As a result, a solar cell provides the current I that is proportional to the solar radiation: the higher the radiation level, the higher the current. For the most part, the voltage U is constant at higher radiation levels; however, it quickly drops at low radiation levels.

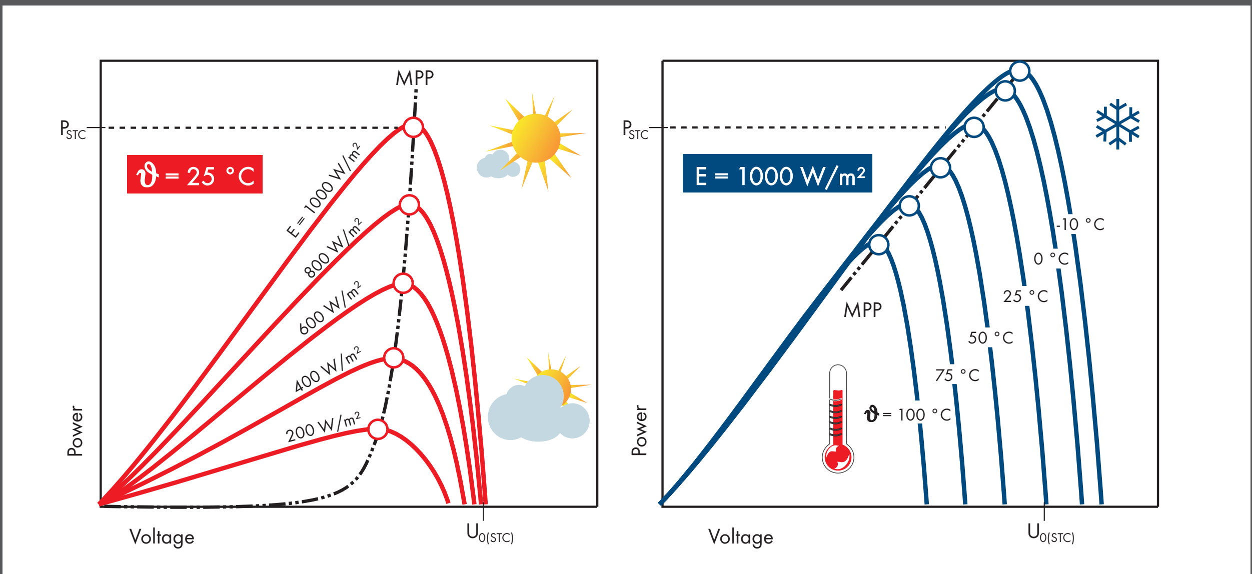


The dependence of the open circuit voltage and short-circuit current of a crystalline silicon cell on the radtiation level.

Cell temperature

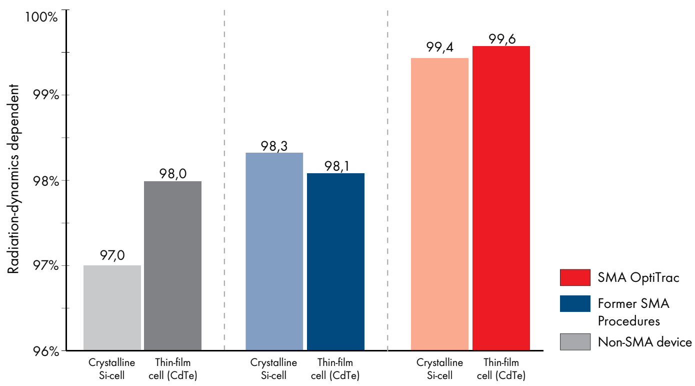
The electrical parameters also depend on the temperature. To achieve comparability, they are commonly specified under standard test conditions (STC). In this case, a radiation level of 1000 watts per square meter, a cell temperature of 25 °C and an air mass index of 1.5 are assumed.

The PV generator only provides its maximum output at a specific point called the maximum power point (MPP). The maximum output is primarily influenced by the current radiation level and the cell temperature.



The power curves – influence of the solar radiation and the dependence on the cell temperature.

Solar cells



Sound MPP tracking exhibits virtually no difference when operated with different cell technologies.

Cell Material

The material of the solar cells has a large impact on the electrical characteristics of the module and thus on the location and surroundings of the MPP as well. In particular, the power curve for thin-film modules (amorphous silicon (a-Si), cadmium telluride (CdTe)) is much flatter over the generator voltage and determining the MPP is correspondingly more complicated than with crystalline PV modules.

The MPP tracking procedure of SMA inverters has always been suitable for both crystalline modules as well as thin-film modules. In contrast, some competitive devices require different procedures to achieve similar results.

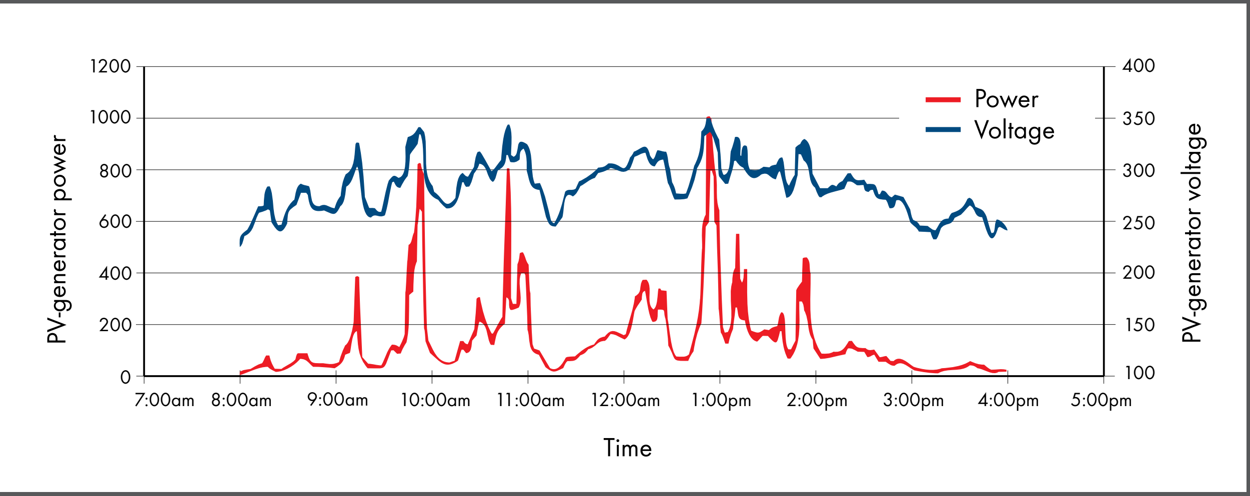
Weather at the Touch of a Button: The SMA Solar Testing Center

The influencing variables specified here affect the circumstances surrounding the MPP in completely different ways and almost all of them are related to the current weather conditions. Weather reports in Germany over many years have clearly demonstrated that only one third of the days in a year have consistent weather conditions for the entire day. The remaining two thirds of the year have different levels of cloud cover.

The SMA Solar Testing Center

Up until now, many inverter manufacturers did not focus much attention on this dynamic behavior. This is primarily due to the technical requirements that must be met for developing reproducible testing and measuring procedures. SMA commissioned a new testing laboratory at its headquarters in Niestetal, Germany in 2006. This laboratory allows high-precision measurements and precisely simulates reproducible radiation conditions.

Standard values, such as hopping or sinusoidal responses as well as exact daily variations in the radiation level can be replicated. It is now possible to simulate a variety of operations and weather situations to further optimize the inverter's properties. SMA uses this laboratory, which is unique in the industry, primarily to test SMA's own inverters, and those of other manufacturers, for their behavior under adverse weather conditions.



Present output and the course of ideal MPP voltage on day with inconsistent weather conditions in Kassel.

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