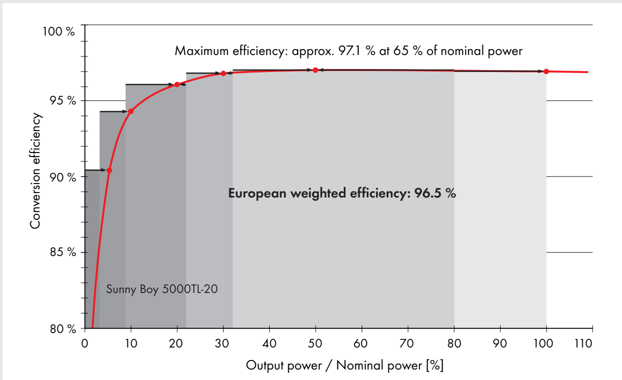
OptiTrac

A photovoltaic system rarely operates under constant ambient conditions because the sun's radiation values change based on the weather and the time of day. Since the solar inverter manages the output of the entire PV system, it must react immediately to these changes. This is the only way to continuously achieve the best possible energy production from the solar modules.

The dynamic reaction of the inverter is determined by maximum power point (MPP) tracking, which is the ongoing process of identifying the operating point at which the PV array achieves its maximum performance. The SMA development team has taken steps to improve this reliable electrical tracking process. The extensive capabilities of the company's solar testing center are able to replicate environmental conditions that can change frequently and suddenly. As a result, an MPP tracking procedure was developed to increase the energy production of the entire PV system.

The efficiencies of an inverter

A PV system's energy production depends heavily on the quality of the inverter used. Efficiency is a common metric that differentiates between high producing and low producing inverters. However, upon closer examination, this determination is far too simple. There are several types of efficiency that determine the energy production of a solar power system. We will describe the types of efficiency below.



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

Conversion Efficiencies

An inverter is often defined by its conversion efficiency. This efficiency indicates the percentage of power that is produced from the solar modules and can be fed into the public grid. Peak conversion efficiency is achieved under the most favorable operating conditions—ambient temperature, input voltage, and output power—for a given inverter. As a result, the CEC and Euro ETA weighted average efficiency ratings were developed to provide more meaningful measurements of conversion efficiency that better reflect the variable operating conditions experienced in typical PV system operation. 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.

The quality of the electronic components is the most significant factor in achieving leading conversion efficiency. Further developments, in which H5 topology can be considered the provisional high point, have resulted in the CEC rebate efficiency reaching a previously unattainable value exceeding 98.0 percent. In terms of the inverter's performance, the hardware is now highly developed.

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

MPP Tracking—the search for the optimum operating point

Typically we assume that the solar module's output increases with radiation. However, closer examination reveals that this is an important function of the inverter. A PV module directed at the sun 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 most efficiently (in other words, to travel as far as possible), the car must be driven at an optimum velocity where 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 will empty the tank, but it will also dramatically shorten the distance driven. An intelligent system control is required to set the optimum operating point.

To achieve maximum performance from the solar modules at all times, despite different radiation levels, cutting-edge inverters employ a procedure that measures the PV array's current potential at fixed intervals. This allows the array to operate as continuously as possible at its MPP.

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

MPP tracking is extremely reliable and is used by all well-known inverter manufacturers.

Tracking Efficiency Tested in the Laboratory

The tracking efficiency makes it possible to immediately assess how well the MPP tracking functions. Since current processes used with inverters are very sophisticated, laboratory tests conducted today often achieve values of more than 99 percent for the static tracking efficiency. As a result, the efficiency of these processes appears extraordinarily high and current procedures virtually disregard factors such as sudden weather changes and climate conditions.

Behavior During Weather Changes

Since the solar inverter rarely operates under constant ambient conditions, it is important that the inverter has 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. 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

Similar to the conversion efficiency, it makes sense to determine a dynamic tracking efficiency that accounts for the typical realistic operating conditions over a complete operational year. As is the case with the CEC rebate (conversion) efficiency, this efficiency corresponds to a weighted CEC rebate tracking efficiency.

Total Efficiency

The weighted sum of these efficiency rates, taken together as a total efficiency rate, allows for a realistic representation of the output capacity 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 rated the devices tested according to their weighted European conversion rating and in doing so, drew 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:

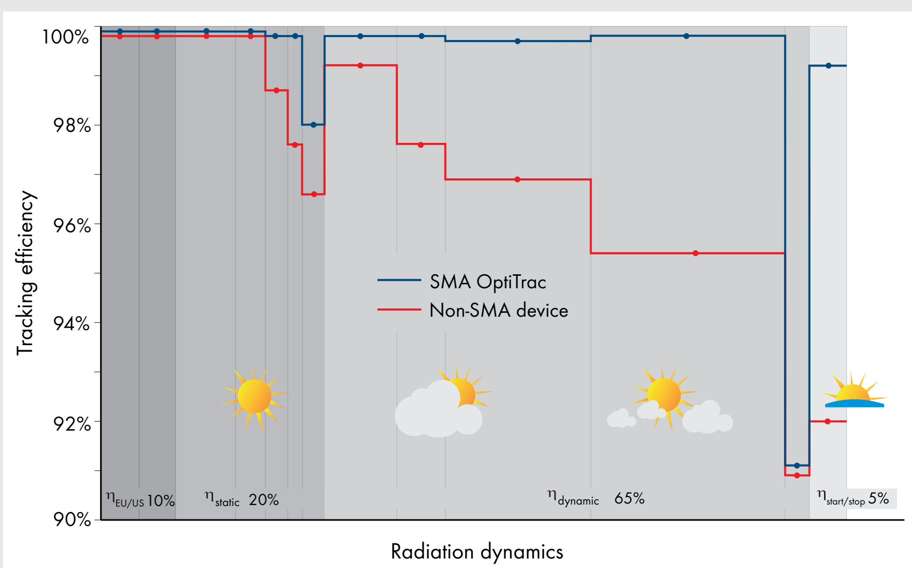
$$\eta total = \eta euro * \eta tracking$$

with

$\eta euro$	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 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, made it possible – for the first time – to realistically simulate a PV array under the most diverse weather conditions and changes that often occur in the course of a day. This also made it possible to precisely determine the MPP-tracking quality of an inverter, which led SMA to add the radiation-dynamic tracking efficiency analysis to its qualification standard in assessing inverters some years ago (see Weather at the touch of a button, page 7).



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

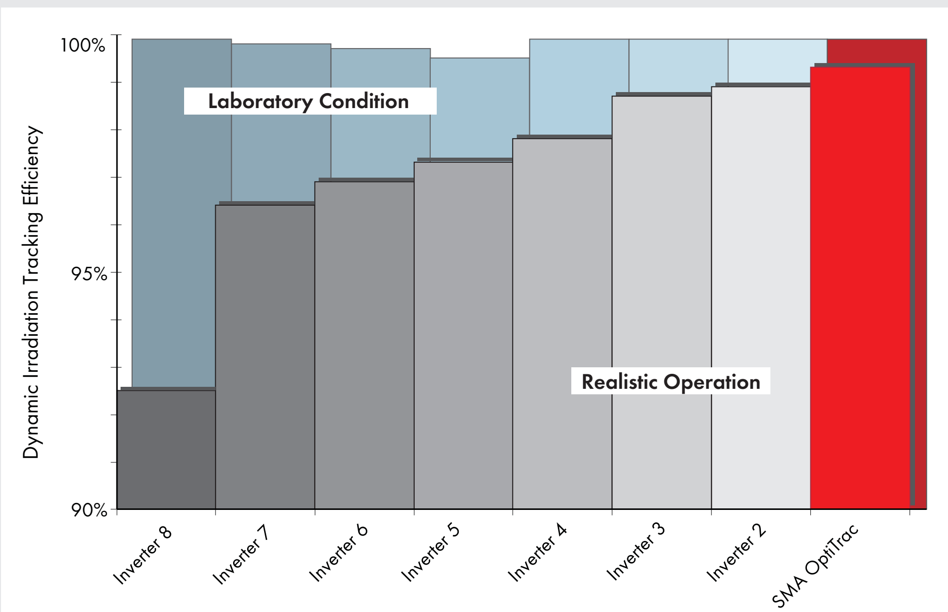
The benefits of this analysis become apparent when comparing the operational behavior of two inverters or MPP trackers. If it is still difficult to differentiate between devices under laboratory conditions (Euro ETA and US ETA), the individual strengths and weaknesses are clearly demonstrated with the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

A New Procedure

Through significant modifications made in electrical tracking, the SMA development team has managed, with OptiTrac, to further improve the MPP tracking used to date. This achieves greater total efficiency, which is extremely important for system operators since this value directly affects the energy production of the entire photovoltaic system.

The SMA Inverter Reacts Faster

When equipped with SMA OptiTrac, the inverter reacts to changes in radiation levels with greater precision so that the maximum energy available can continue to feed into the grid. SMA OptiTrac significantly improves dynamic behavior and increases the energy production on intermittently cloudy days. This is primarily important for systems in regions where the general weather conditions are unstable.



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.

Increased Energy Production

The energy production was further increased by improving the startup behavior. The MPP 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.

Innovations pay off with increased production

More Energy Production

With regard to the system operators' profit, the amount of increased energy production that 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 array's energy that is actually converted. The higher the value, the higher the attainable annual energy production of an inverter will be.

Increased Profits

Extensive tests and field trials have demonstrated that the energy production of a PV system can be increased by up to 1.5 percent per year using SMA OptiTrac, which translates to cost savings for operators and increased returns for investors.

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 but drops quickly at low radiation levels.

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, we assume a radiation level of 1,000 watts per square meter, a cell temperature of 25 °C and an air mass index of 1.5. The PV array only provides its maximum output at its MPP. The maximum output is primarily influenced by the current radiation level and the cell temperature.

Cell Material

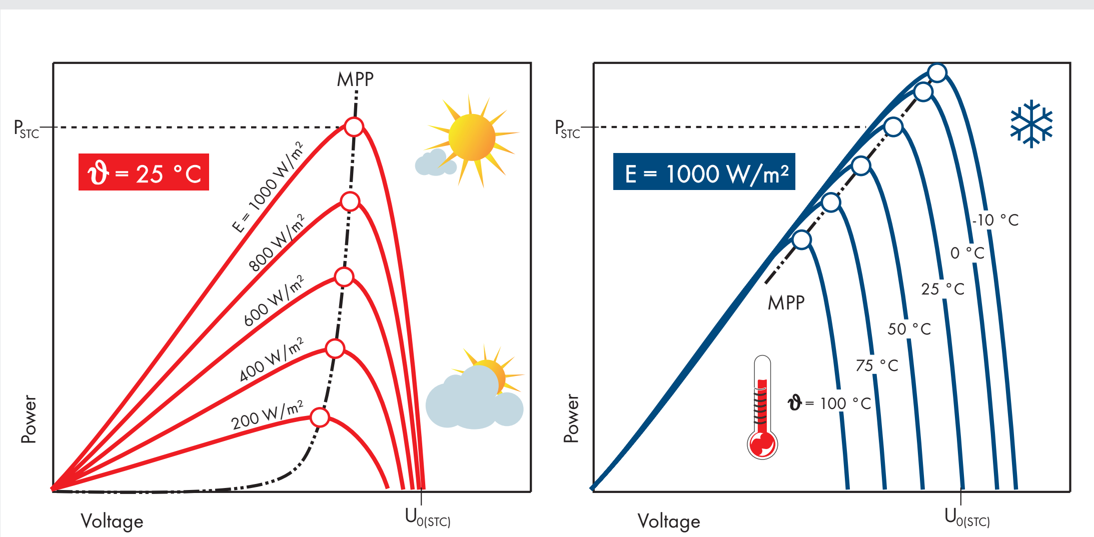
The material of the solar cells has a large impact on the electrical characteristics of the module and thus on the location and surroundings of the MPP. In particular, the power curve for thin-film modules (amorphous silicon (a-Si), cadmium telluride (CdTe)) is much flatter over the array voltage and makes it more difficult to determine the MPP than with crystalline PV modules. The SMA MPP tracking procedure has always been suitable for both crystalline modules as well as thin-film modules. To compare, some competitive devices require different procedures to achieve similar results.

Weather at the touch of a button: The SMA Solar Testing Center

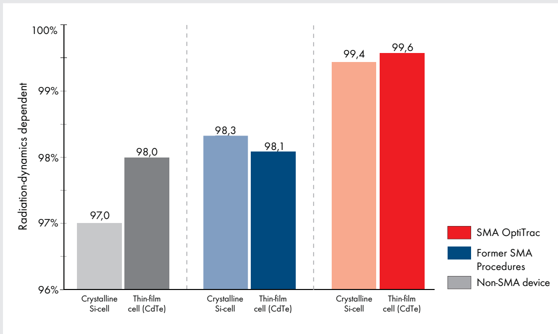
The influencing variables specified here affect the circumstances surrounding the MPP in completely different ways, mostly related to current weather conditions. As an example, weather reports in solar market pioneer Germany have clearly demonstrated that only one-third of the days in a year have consistent weather conditions for the entire day. The remaining two-thirds of the year have different levels of cloud cover.

The SMA Solar Testing Center

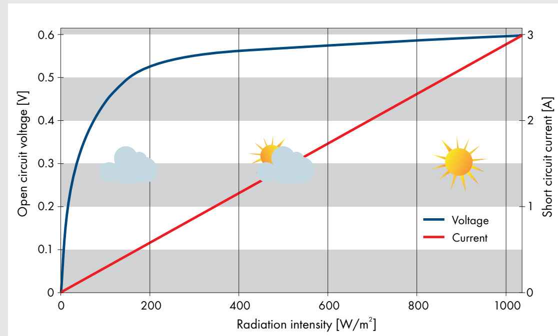
Up until now, many inverter manufacturers did not pay much attention to this dynamic behavior. This is primarily due to the technical requirements that must be met for developing reproducible testing and measuring procedures. SMA has long been on the forefront of this effort and commissioned a ground breaking testing laboratory at its headquarters in Niestetal, Germany, in 2006. This laboratory allows high precision measurements and simulates exact radiation conditions.



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

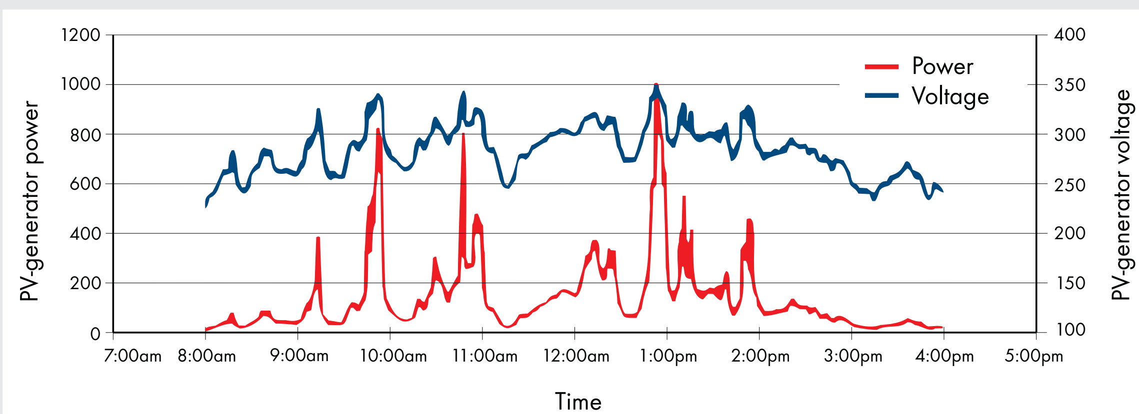


Sound MPP tracking exhibits virtually no difference when operated with different cell technologies.



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

Standard values, such as hopping or sinusoidal responses as well as exact daily variations in the radiation level, can be replicated. It is 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 its 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, Germany.

More Information

[1] H. Häberlin et al.: „Totaler Wirkungsgrad – ein neuer Begriff zur besseren Charakterisierung von Netzverbundwechselrich-tern." 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

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