

# Top of the class

Steca's Stecagrid 3600 came up trumps in PHOTON Lab's test, even though the makers simply reorganized standard components

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## Highlights

- The single-phase Stecagrid 3600 inverter is transformerless and has a DC nominal power of 3,690 W
- The device's MPP range stretches from 350 to 600 V
- The maximum conversion efficiency came in at 98.6 percent, while the European efficiency reached 98.1 percent and the Californian efficiency is 98.2 percent
- The PHOTON efficiency at high irradiation came in at 97.8 percent, and the PHOTON efficiency at medium irradiation was recorded as 97.7 percent
- With truly excellent results, the inverter sets new standards for inverters in the lower power range

At the beginning of the year, Germany-based Steca Elektronik GmbH launched its new Coolcept topology in two compact inverters – and since then, PHOTON Laboratory has been eagerly waiting to put the inverters to the test. The single-phase, transformerless devices were reported as being able to attain European efficiencies of more than 98 percent thanks to a new design with symmetrically installed buck converters and the downstream pole-reversing circuits. Achieving that kind of efficiency would be sensational for an inverter in the power class under 4 kW.

But patience was required: it took until September for the manufacturer to provide PHOTON Lab with a series device that satisfied the conditions defined in the standard test agreement.

And it appears it was worth the wait: the Stecagrid 3600 did not disappoint. The single-phase device stormed to the top of the pack, taking the No. 1 spot in the rankings of all the inverters tested by PHOTON Lab so far. The excellent work achieved by the engineers is clear just by opening the housing: the device is extremely light, gets by without a massive, pricey cooling element and accommodates the complete power electronics on one single circuit board. With its technical values and production-friendly design, allowing a high degree of automation, this inverter sets new standards.

## Construction

The tested device is part of the Stecagrid range, with the subgroup comprised of two

transformerless devices with AC nominal powers of 3,000 and 3,600 W. The test candidate has a simple, compact design, and the entire electronics, including the control unit and the storage chokes, are housed on a single circuit board. Only the display is installed separately and is found on the front part of the housing, underneath the cover. The inverter does not have a separate cooling element; the power transistors are attached to the component side of the circuit board as surface-mounted devices (SMD) and emit heat onto larger copper surfaces. Cooling plates are soldered vertically onto these. A temperature-controlled fan then blows onto the eight plates in total, thereby dissipating the heat. Changing the fan is no easy task; should it malfunction, the task of replacing it should be left to an installer. The inverter's housing is comprised of three plastic segments: a rear section, the front part and a gray cover. The device corresponds to protection class IP 21, though the power electronics feature protection type IP 51. That means the inverter must be installed inside a building.

An automatic disconnect unit ensures safe operation by checking the grid for the correct voltage, frequency and impedance conditions. Furthermore, an insulation test is carried out on the solar generator, and the grid side is monitored for leakage current. The electrolytic capacitors in the power element, as well as those in the control electronics, have a temperature class of 125 °C and are therefore well-suited for dealing with ambient temperatures. Temperature-monitored varistors have been installed in the DC input, in addition to gas-filled surge arresters in the



▲ Simple and cost-efficient: The Stecagrid 3600 gets by without a heavy and expensive cooling element. Its plastic housing is also cheap to produce. The thermographic imaging reveals that this concept works. While temperatures of just under 70 °C are generated close to the two buck converters during operation, it is not harmful in regard to the service life of the components.

DC input and AC output. The solar generator is hooked up using a pair of MC4 connectors made by Multi-Contact AG, and connecting to the grid involves a three-pin plug from Wieland Electric GmbH. There is a mechanical DC disconnect next to the plugs on the bottom of the device. The inverter is able to communicate using monitoring devices such as Stecagrid Vision, Meteocontrol Weblog, Solar-Log or the Stecagrid monitor via an RS485 interface with two RJ45 sockets.

### Operation

At 9 kg, the Stecagrid 3600 is an absolute lightweight considering its DC nominal power. If the solar generator is correctly designed and the internal DC disconnect has been activated, the inverter requires around 79 seconds to complete diverse tests before connecting to the grid and starting work.

The display is situated under a plastic cover on the outside of the front section of the plastic housing. It has white backlighting, making it difficult to read. The languages available for selection are English, French, German, Italian and Spanish. With the help of four buttons, a great deal of current operating and yield data can be displayed, along with diverse status and error messages. In addition, the IV curves of the modules can be recorded at the touch of a button, allowing the solar generator's status to be shown graphically.

### Instruction manual

Installation and operating instructions in English, French, German, Italian and Spanish

are included with the inverter. The manuals are also available to download on the manufacturer's website. Along with general explanations, it also includes a description of how to install and connect the inverter, as well as details on operating characteristics, the menu structure and error messages.

### Circuit design

The Stecagrid 3600 is equipped with an MPP tracker; the manufacturer has labeled the unconventional circuit design as Coolcept. Energy from the PV generator first enters the power stage via an EMI filter. The power stage features two buck converters, which work as a tag-team. These units convert the output voltage of the module strings into the voltage required for the grid. The buck converters are connected in series, in parallel to the strings – and hence to the input voltage. On the input side and at the output of the buck converters, there is a capacitor half-bridge. The upper buck converter charges the upper capacitor of the half-bridge, while the lower converter feeds the lower capacitor. Therefore, each of the two buck converters are exposed to just half of the string voltage. If both buck converters are blocked, the capacitor voltage is zero. This is where the sine-wave modeling begins. If the lower buck converter is turned on and off, then, based on the ratio of time that takes, the output capacitor is charged with half of the input voltage. The metal-oxide-semiconductor field-effect transistors (MOSFETs) switch on and off 40,000 times a second. The ratio of time spent switching is pulse-width mod-

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Steca's Stecagrid 3600

**A**

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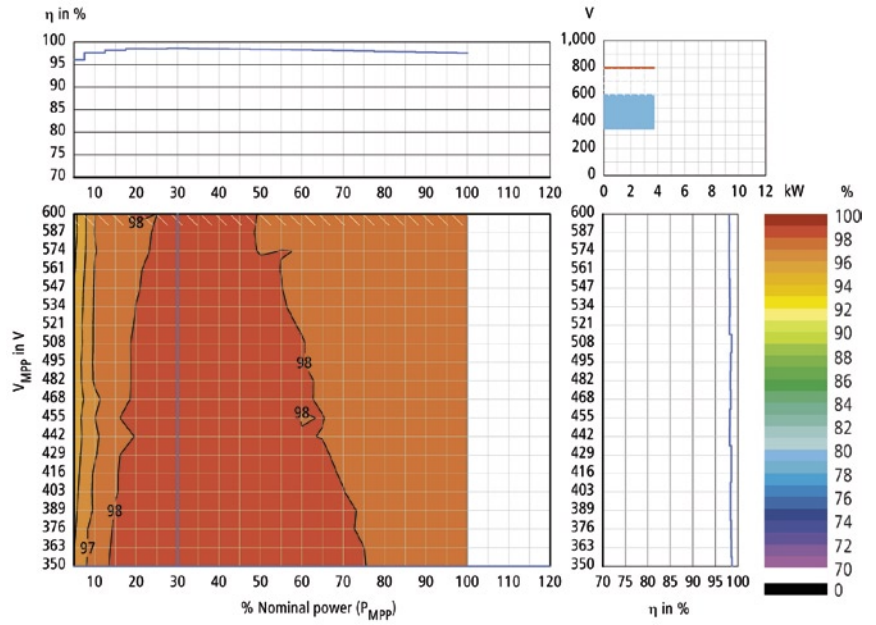
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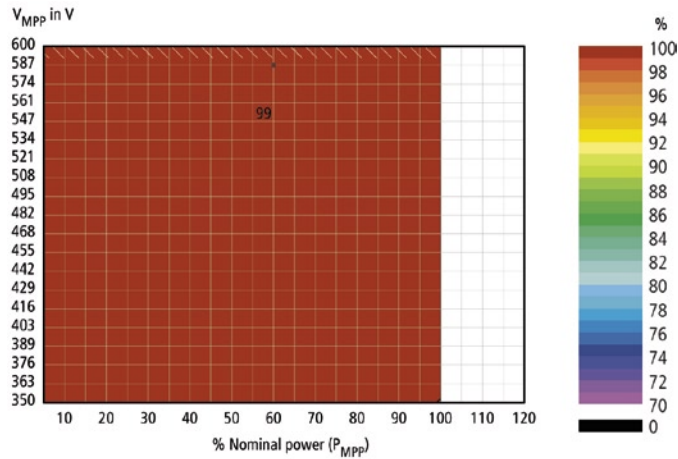
### Conversion efficiency

The device converts energy with an efficiency of 98 percent or more over a very broad power spectrum. The maximum conversion efficiency can be found at 30 percent of nominal power and an MPP voltage of 350 V.



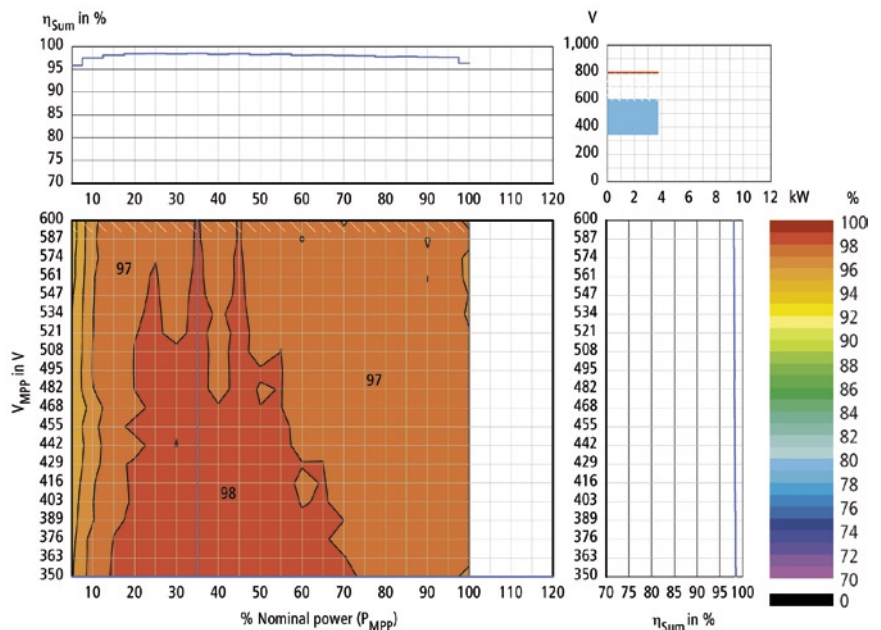
### × MPPT adjustment efficiency

A prime example for good MPP tracking: The adjustment efficiency is consistently at 99 percent or more over the entire power range.



### = Overall efficiency

The red plateau, which marks the area in which the overall efficiency is 98 percent or higher, is correspondingly broad. The values recorded at medium nominal powers, as well as at low and medium voltages, are particularly good. The maximum overall efficiency of 98.5 percent can be found at 35 percent of nominal power and an MPP voltage of 350 V.



ulated, whereby the slope and the shape of the increase in voltage is determined by the lower capacitor – forming the lower part of the sine wave. When the voltage at the capacitor reaches half the level of the grid voltage, the upper buck converter takes over. While the lower converter remains constantly connected, the upper one switches on and off – thereby modulating the sine wave. For the voltage to drop, creating the half-wave, the converters are connected in the exact opposite manner, thereby generating the second half-wave.

What is new about the Coolcept topology is that the buck converter can be decoupled or connected in a series, depending on requirements. In this way, the two components alternate so that one is always working, while the other has time to recover. This reduces the switching and conduction losses. The switching losses at half the input voltage are only half as large as the losses at full input voltage, which is shown in the device's high efficiency. By alternating synchronization and dividing the input voltage between the two buck converters, the power transistor warmth is also kept within limits, so the conduction losses from these components remain relatively low – a second reason for the high efficiency. In this way, the buck converters only create positive half-waves. To produce the negative half-waves, a pole-

reversing circuit is placed downstream – this works via a conventional H4 bridge, as is also used in conventional inverters, and each second half-wave is converted. The sine-wave filter smoothes the residual ripples.

An automatic circuit breaker disconnects the inverter from the grid in the event that the grid voltage, impedance or frequency deviate from predefined limits, as well as if residual current is detected on the AC side or insufficient insulation resistance is measured on the DC side. Islanding detection is carried out using a frequency-shift method, while any radio interference is eliminated by an output filter, which is located directly in front of the grid clamp.

### Measurements

The maximum DC voltage of the Stecagrid 3600 is 800 V, and the DC nominal power is 3,690 W. The maximum PV output that can be connected is also 3,690 W.

**Locating the MPP:** At a predetermined IV curve with nominal power and an MPP voltage of 468 V, the inverter requires around 79 seconds to connect to the grid. Both the DC and AC sides were switched off when measurements began. Another 10 seconds elapsed before the inverter reached its MPP. When switching from 468 V to 455 V, the inverter required around 8

seconds, and switching to the next-highest MPP range of 482 V also took around 8 seconds.

**MPP range:** The MPP range spans from 350 to 600 V, which is a normal range. The maximum MPP voltage of 600 V is at a comfortable distance from the maximum input voltage of 800 V.

**Conversion efficiency:** The inverter can operate at 100 percent of its nominal power within an MPP voltage range of 350 to 600 V. At a maximum DC voltage of 800 V, there is a very narrow area with hatching, indicating limitations when using thin-film modules due to the insufficient distance between the maximum MPP voltage and maximum DC voltage.

The color diagram reveals large areas with the same color, meaning they have the same efficiency. The area of maximum efficiency forms a large plateau at a very high level, spanning the entire MPP voltage range. The vertical line at 30 percent of nominal power and the horizontal line at an MPP voltage of 350 V meet at the maximum conversion efficiency of 98.6 percent – matching the manufacturer's specs exactly. The maximum conversion efficiency drops by around 0.6 percentage points toward high MPP voltages. At low powers of less than 15 percent, efficiency falls by about 2.6 to 3.3 percentage points. At nominal power, the power factor  $\cos \phi$  was about one.

**GPPV**

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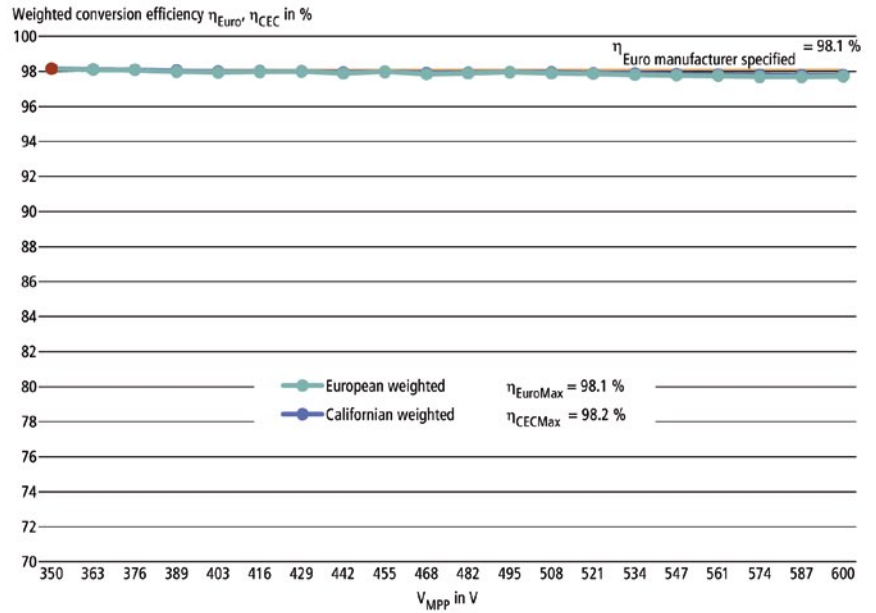
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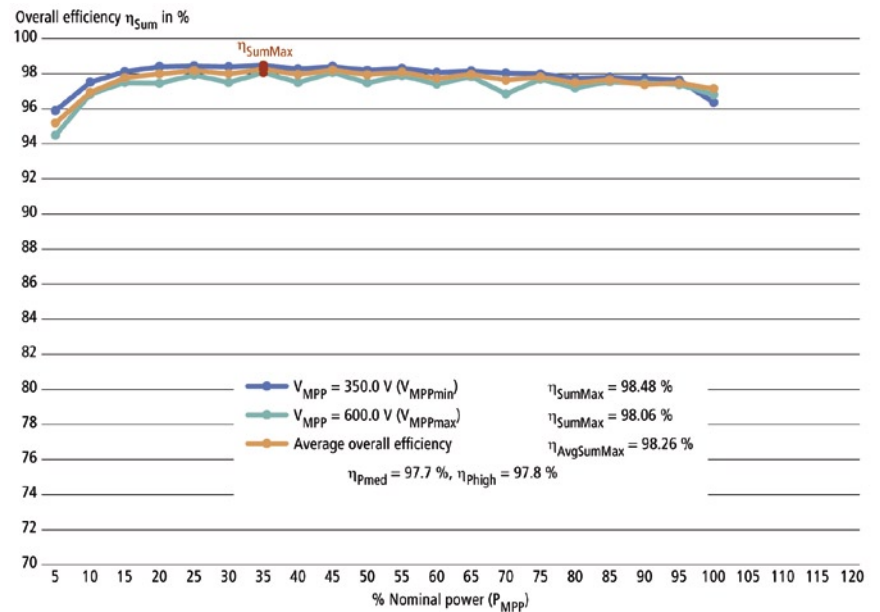
## Weighted conversion efficiency

Regardless of whether the conversion efficiency is assessed according to European or Californian weighting, it remains excellent. The respective maximums can be found at the lowest MPP voltages.



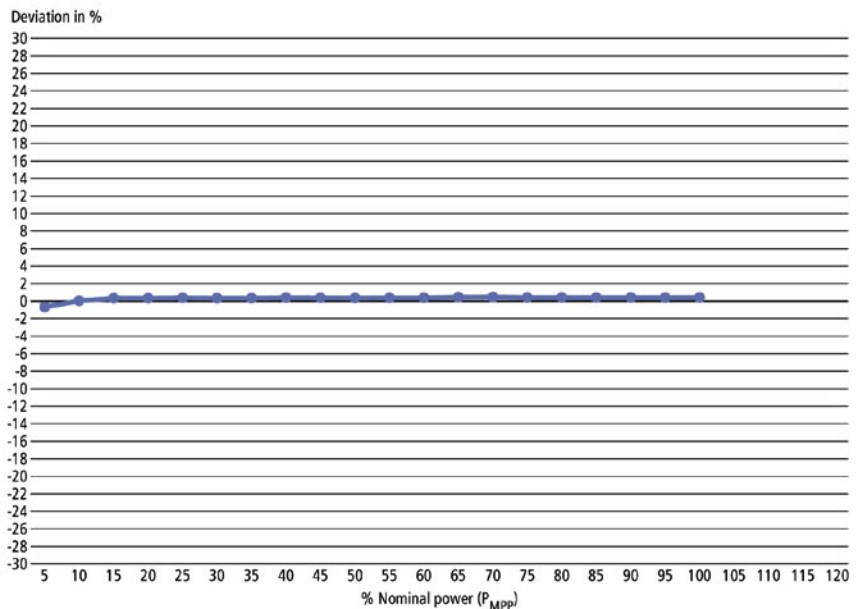
## Overall efficiency at different V<sub>MPP</sub> voltages

Slip-up: This is the only diagram that indicates there is a minor problem. At high MPP voltages of 600 V, in particular, a zigzag-shaped curve can be detected, which points toward conversion losses. The manufacturer believes that unfavorable spots on the IV curve are responsible for this. However, there is nothing to doubt about the outstanding PHOTON efficiency of 97.7 percent at medium irradiation.



## Accuracy of inverter display

Another picture-perfect curve: The Stecagrid 3600's display can be relied on to reflect the actual output power exactly.



**MPPT adjustment efficiency:** The MPPT adjustment efficiency is very consistent and high across the entire operating range.

**Overall efficiency:** In the three-dimensional color diagram, the extensive areas with the same color indicate uniform efficiency. The area of maximum efficiency can be found at low and medium voltages, and medium powers. The vertical line at 35 percent of nominal power and the horizontal line at an MPP voltage of 350 V meet at the maximum overall efficiency of 98.5 percent.

**Weighted conversion efficiency:** The European efficiency is recorded at low voltages; at 98.1 percent, it matches the manufacturer's specs exactly. The difference between the maximum conversion efficiency and maximum European efficiency is just 0.5 percent. The Californian efficiency is a little higher at 98.2 percent and is also found at low MPP voltages.

**Course of overall efficiencies, average overall efficiency and PHOTON efficiency:** When the overall efficiency curves were recorded by PHOTON Lab, one palpable weakness that leads to conversion losses became evident. At high MPP voltages of 600 V, this issue can be seen by the zigzag shape of the corresponding curve. This phenomenon is related to the fact that the inverter runs through the entire IV curve rather frequently and relatively slowly

when searching for the optimal MPP. That results in some time spent operating outside of the optimal range. The manufacturer has acknowledged the problem and is looking for a solution (see box, p. 138).

Despite this weakness, the PHOTON efficiency at medium irradiation reaches a very respectable 97.7 percent, and the PHOTON efficiency at high irradiation amounts to 97.8 percent.

**Feed-in at nominal power:** The inverter feeds 100 percent of its nominal power into the grid over the entire input voltage range of 350 to 600 V at an ambient temperature of 25 °C.

**Displayed output power:** At a constant MPP voltage of 468 V, which is in the medium range, the Stecagrid 3600 was fed with different powers ranging from 5 to 100 percent of its nominal power. The output power measured and displayed by the inverter during the test deviated by -0.7 percent from the values measured by the power analyzer at very low powers. At 10 percent of nominal power and above, the error rate is less than 0.5 percent, meaning the display's accuracy is equivalent to that of a class B meter (previously known as precision class 1).

**Operation at high temperatures:** The inverter feeds 100 percent of its nominal power into the grid up to an ambient temperature of around 52 °C. When it reaches this temperature, the device reduces its power – the oper-

ating point selected was 3,690 W and an MPP voltage of 468 V. The efficiency fell by around 0.6 percentage points over this temperature range. The wide temperature range of -15 to 60 °C, combined with protection type IP 51 for the power element and IP 21 for the device overall, allow the inverter to be installed in a location protected from moisture, and it may also be installed under the roof. However, power reductions above an ambient temperature of 52 °C must be taken into consideration.

**Overload behavior:** If the Stecagrid 3600 is presented with 1.3 times its nominal input power – so 4,797 W – at an MPP voltage of 468 V and an ambient temperature of 25 °C, the device limits DC power to around 3,736 W. This is equivalent to an overload of 1.2 percent, meaning the device does not really feature an overload range. When power limitations take effect, the inverter shifts the operating point on the IV curve toward higher input voltages. The DC voltage adjusts itself to a value of around 523 V.

**Own consumption and night consumption:** The device's own consumption in its tested state came in at around 3.7 W on the AC side (the manufacturer specifies less than 8 W) and 6 W on the DC side. At night, the inverter draws around 0.6 W of real power from the grid. The manufacturer specifies less than 0.9 W in this case.

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## Manufacturer's response

The results of PHOTON Lab's measurements carried out on the Stecagrid 3600 correlate with our own. We noticed very minor deviations from our own results when it came to conversion efficiency and MPPT adjustment efficiency, but the differences were within measurement tolerance limits. As a general rule, the Stecagrid 3600 goes through the module IV curve in a defined range at regular intervals. This allows it to establish whether there are several maximums. The function means that the inverter is able to find the best operating points when shading becomes an issue. As a result of the conversion losses determined by PHOTON Lab, we are now endeavoring to optimize this function. To date, the inverter only complies with the requirements in the German low-voltage directive for systems up to 3.68 kW. By the end of the year, we will implement the requirements for systems up to 13.8 kW. The device adheres to the temporary provisions for frequency-dependent active power control. The Stecagrid 3600 does not feature galvanic isolation; the transformerless principle does not allow the negative or positive pole at the inverter input to be grounded. As a result, only thin-film modules that do not require this kind of grounding can be used. Currently, the Stecagrid 3600 has approval from First Solar Inc. An overview of approvals from other manufacturers of thin-film modules can be found on our website: [http://www.stecasolar.de/index.php?Module\\_compatibility\\_matrix](http://www.stecasolar.de/index.php?Module_compatibility_matrix).

**Thermography:** The thermographic image shows the inverter from above while it is operating at nominal power and an ambient temperature of 24.6 °C. As the circuit board is installed upside down, surface temperatures were recorded on the back side. The highest temperature measured was 69.6 °C – and that was found in the area in which the power transistors of both buck converters are located.

### Summary

PHOTON Lab's staff was impressed by this inverter. The Stecagrid 3600 hits the top of the ranks thanks to its innovative topology. To date, no serially produced inverter has performed better on PHOTON Lab's test bench (see table, p. 150). Even its modest shortcomings could not tarnish the overall impression. Furthermore, the chances are good that Steca's engineers will be quick to optimize the unit. The production-friendly design is one of its most striking features, which has largely allowed the company to automate the production process, promising considerable advantages in terms of cost in comparison to its competitors.

The test candidate's design is very simple and compact, featuring a clear layout and accommodating the entire electronics, including the control unit and storage chokes, on one single circuit board. The Stecagrid 3600 makes a good, high-quality impression, and, because a cooling element has been dispensed with, it is also very light. The maximum conversion efficiency comes in at 98.6 percent and is achieved at the lowest possible voltages. Toward higher voltages, the conversion efficiency drops by 0.6 percentage points and by around 0.9 percentage points at higher powers. Due to this highly homogenous conversion efficiency, the maximum European efficiency is only 0.5 percentage points below the maximum conversion efficiency, and the maximum Californian efficiency is only 0.4 percentage points less.

The very consistent, high MPPT adjustment efficiency results in the overall efficiency curve being just slightly lower than that of conversion

efficiency. The MPP voltage range is normal and only has limitations in the upper section in combination with thin-film modules. The distance between the maximum DC voltage and maximum MPP voltage is pleasingly large.

The fluctuation of the overall efficiency amounts to between 0.5 and 2.5 percentage points over the MPP voltage range. As a result, the PHOTON efficiency at medium irradiation is a very good 97.7 percent. The PHOTON efficiency at high irradiation is somewhat higher still, at 97.8 percent. When configuring the optimal operating point of a PV system, the entire MPP voltage range can be selected when crystalline modules are used.

The inverter does not feature an overload range. Its power display is very accurate and stands up to any comparison. The temperature range of the device is very large, though power was throttled above an ambient temperature of 52 °C. The temperature dependency of the conversion efficiency amounts to -0.6 percentage points. Although the inverter's efficiency development is not quite as homogenous as the best devices previously tested by PHOTON Lab due to its shortcomings in MPP tracking, the Stecagrid 3600 is the new frontrunner. The maximum conversion efficiency has advanced to previously unattained levels. The fact that the Stecagrid 3600 can be lauded as the new champion is all the more remarkable because it belies the old rule of thumb that only significantly more powerful, three-phase devices can achieve peak performances. With its Coolcept topology, the engineers at Steca are setting new standards in several areas. Anyone looking for an inverter for a small PV system should not overlook the Stecagrid 3600. ●

### Further information

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