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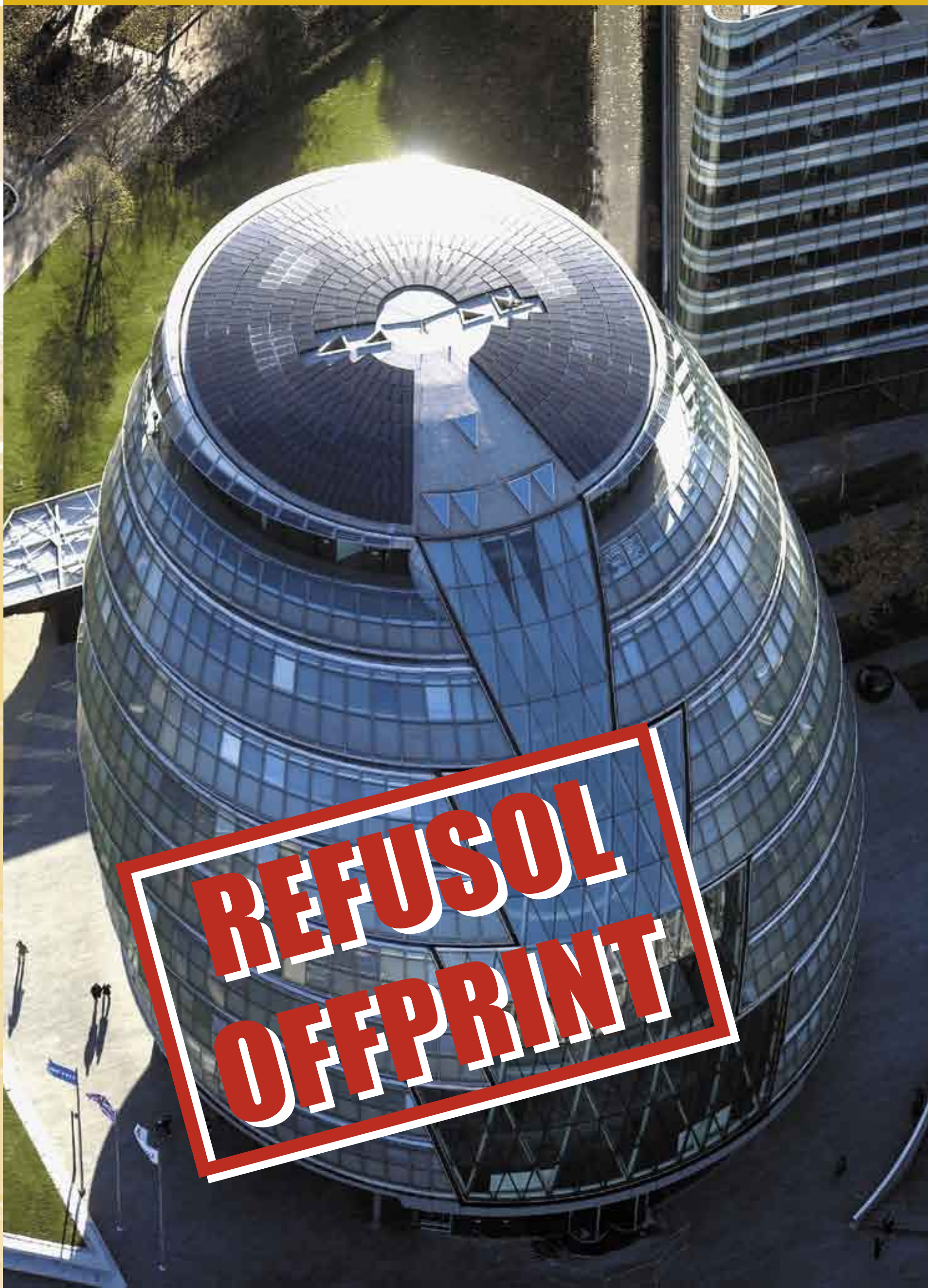
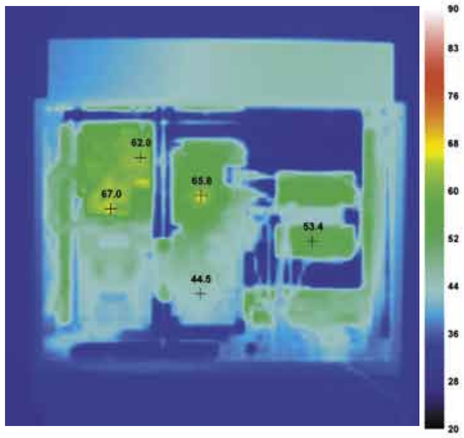


Solar architecture special

The beauty and problems of building-integrated PV

Reaching for the stars

Testing Refu Elektronik's Refusol 11 K inverter



photon-pictures.com (2)

Small, but (almost) unbelievably efficient: With a supremely compact construction, the Refusol 11 K achieves record-breaking efficiency levels. And there's no reason to worry about it overheating: thermographic imaging shows maximum component temperatures of less than 70 °C.

Almost a year ago, we presented the test results of SMA's Sunny Central 8000TL, which we baptized as »the editorial staff's personal favorite« (see PI 10/2007, p. 106). The device performed very well in PHOTON Lab – so well in fact that its scores soared far above those of its competitors. For a long time, our list started with the Sunny Central 8000TL – and then came all the rest. A month ago, our staff would hardly have thought it possible that less than a year later, a second device would hit the market with similarly impressive test results. But the inverter tested this month, from Refu Elektronik, located in Metzingen, Germany, not only matches SMA's inverter, it is even slightly better. The Refusol 11 K is now number 1 on PHOTON Lab's list of tested devices. The details are revealed in this test report. But, in a nutshell, the Refusol is a very good device, with very few flaws. It has a high efficiency and demonstrates extremely stable conversion performance. It's won the hearts of our editorial staff and we can only give it our highest recommendation.

The Refusol 11 K has been available for a year now. The inverter series is the first to be produced by German company Refu Elektronik. Founded in 1965, the company has made a name for itself in the drive and power electronics business. The company is active in the areas of textile, grid and energy technology, as well as traction drives and vacuum technology. In the last 12 months, the company added seven PV inverters to its product portfolio, five of which are large-scale devices housed in a cabinet.

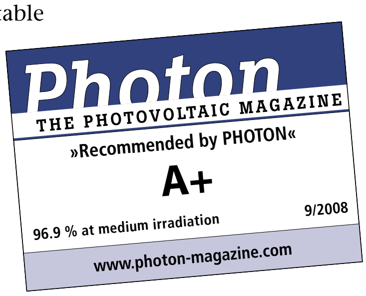
In July 2008, the company provided us with its Refusol 11 K central inverter, signing an agreement with PHOTON's Lab to test its product.

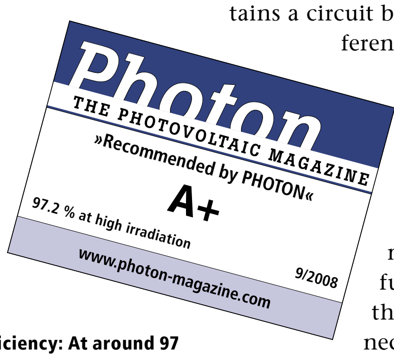
Construction

The device being tested is a member of the Refusol range, which consists of two devices, with AC nominal powers of 11 and 15 kW. The devices are three-phase inverters with built-in MPP trackers. All of the models in this family are designed without a transformer for grid disconnection. However, customers can purchase a 50 Hz transformer from Refu Elektronik and connect it to the inverter.

The test candidate has a clear, two-layer construction. The power element is mounted on a large circuit board located on the lower level. The power semiconductors are installed in four integrated semiconductor modules, which are directly soldered onto the power element circuit board. A large high-performance cooling element serves as the assembly platform, which holds the semiconductor module for cooling. The device is convection cooled, so it doesn't require an additional ventilator. Inside, the device uses a ventilator that prevents temperature layering and warm spots from developing. The fan has a life expectancy of 40,000 hours at 70 °C. The inverter housing is protected from dust thanks to its high protection type of IP 65 – this promises a long lifespan. In the event of failure, the fan can be disassembled and replaced with relatively little effort.

The device's second visible layer contains a circuit board with the DC-interference filter and switching-mode power supply component. An additional circuit board holds the device's control system. The boost converter and sinusoidal filter chokes are fused in the upper part of the housing. Cables connect them with the power element's circuit board. The display is connected to the control system with a cable, and then fixed to the back of

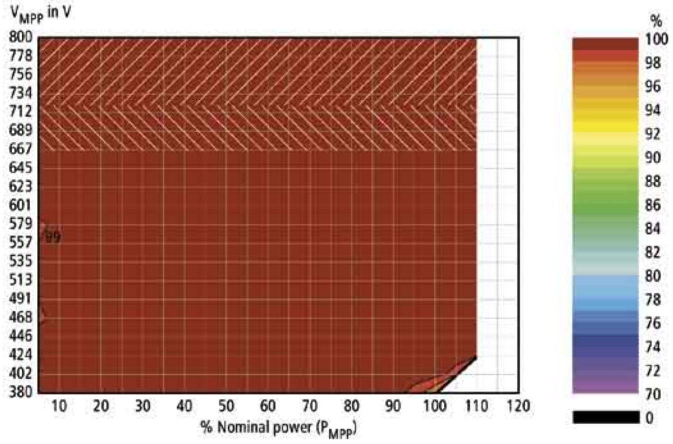




An excellent device with excellent efficiency: At around 97 percent for medium and high irradiation levels, the Refusol 11 K bests almost all of the devices tested by PHOTON Lab hitherto by at least 2 percentage points. Only SMA's SMC 8000TL rivals this inverter in the area of efficiency.

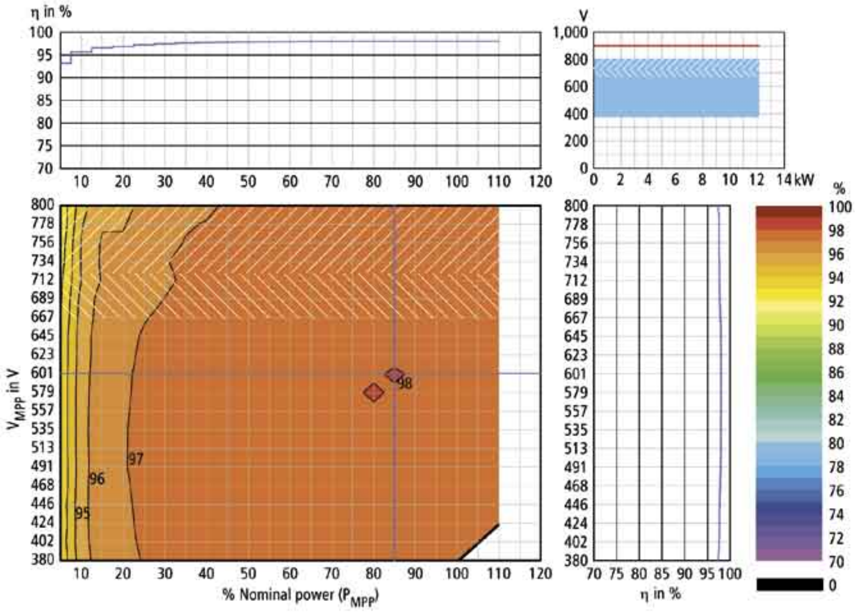
MPPT adjustment efficiency

The MPPT efficiency drops below 99 percent at three points. Otherwise it remains stable, just below the 100 percent mark – flawless tracking behavior.



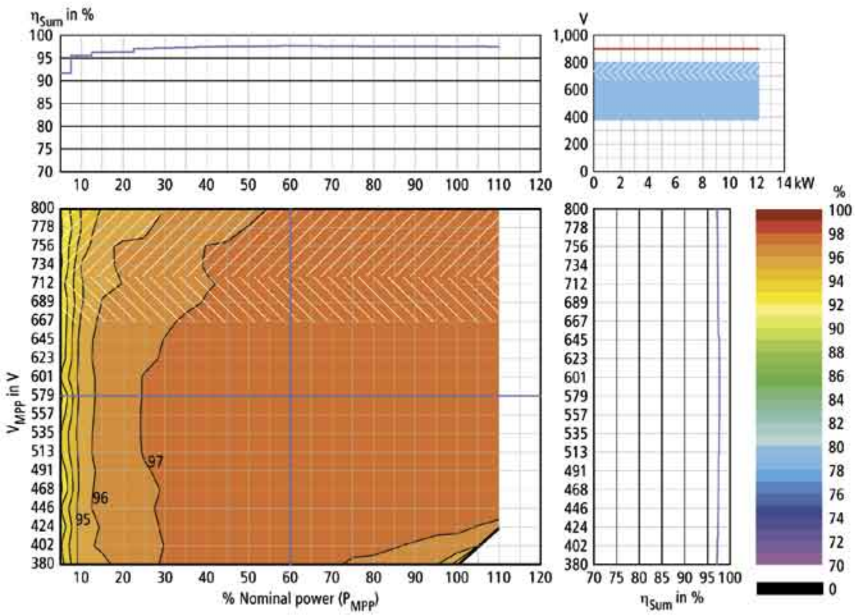
× Conversion efficiency

At two points, maximum efficiency reaches as high as 98 percent – that's unheard of up to now. Efficiency remains very stable over the entire nominal power range, decreasing only slightly. Hardly any of the other devices tested by PHOTON Lab exhibit such clean, stable operation. It's also worth repeating that the Refusol device has a wide voltage range.



= Overall efficiency

The diagram deviates only slightly from the diagram directly above. This is due to the inverter's excellent MPP tracking, which refuses to waste a single bit of energy produced by the generator. For the most part, the Refusol takes more then 97 percent of energy produced by the modules and feeds it into the grid or to consumers as alternating current.



the device's housing. It emerges through a hole in the cover. The housing consists of three aluminum components welded together and a cooling element, which serves as the assembly platform. The housing's IP 65 protection class ensures it's suited for installation outdoors.

To ensure safe operation, the device uses an automatic grid monitoring unit, which monitors the grid for proper voltage and frequency. The solar generator insulation test checks the resistance between the solar generator's connections and the ground. The device's status can be monitored using the display and four LEDs.

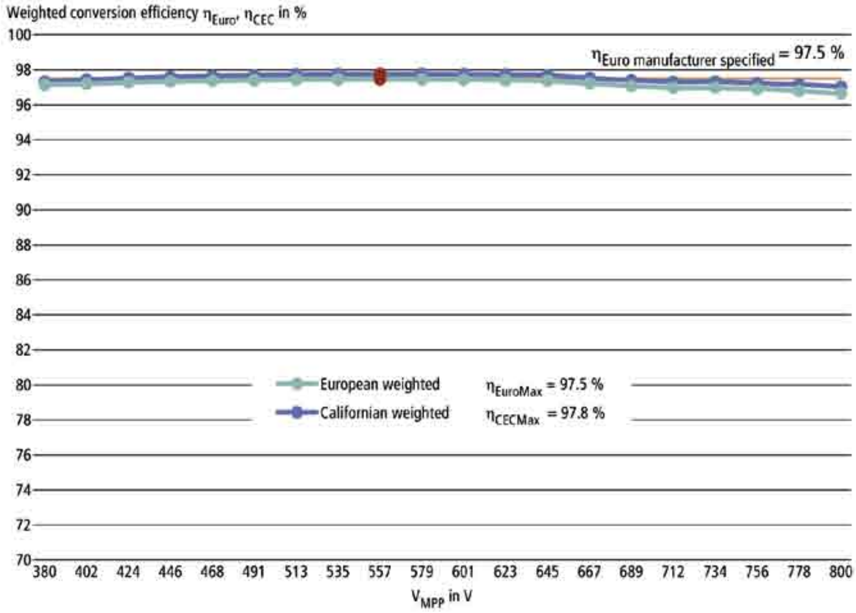
All in all, the device makes a good, well-rounded impression, and is rather light and small for a three-phase device in this power class. The configuration of components inside the device is clean and compact.

The electrolytic capacitors in the power element and in the control electronics have a 105 °C temperature class, which means they're well suited to handle the ambient temperature. The device is attached to the solar generator and the grid with connectors. Whereas customers can choose between different connector types for the DC connection, the unit uses one of Phoenix Contact's large, five-pin connectors for grid connection.

The inverter offers five possible methods for connectivity – via Ethernet, USB, RS485 port, a potential-free relay contact, and irradiation and temperature sensors. The device's Refuvis software allows users to communicate with the inverter via the USB or Ethernet ports. Moreover, the device contains an internal datalogger that can gather up to 40 measurements. The measurements must be individually activated and programmed.

The inverter offers the following two options: first, galvanic isolation by attaching a 50 Hz transformer, although this overall configuration reduces maximum efficiency to 96 percent. The second option is the use of various PV connectors.

Weighted conversion efficiency



This inverter doesn´t care if it´s installed in Central Europe or Southern Europe – it operates very well under various irradiation conditions, but shows even higher efficiency when working in areas with higher solar irradiation. Another bonus: the manufacturer´s specifications match perfectly with the measurements we took in PHOTON Lab – it´s easy to have trust in a company like that.

Operation

The device arrives at the customer's home well packaged and protected. The inverter can be installed on the wall using an aluminum wall bracket. Weighing 38 kg, the Refusol 11 K is a lightweight device.

As long as the solar generator is properly designed, and the internal DC disconnect is switched on, the inverter is ready for operation. During various tests, the device required around 70 seconds before connecting to the grid and starting work.

The display is mounted on the back of the front cover, through which it emerges. It can display graphics (maximum 8 rows), and the backlighting ensures good contrast and readability. Without the backlighting, the display is too dark. Currently, the display languages are German, English and Spanish. The display activates as soon as DC voltage is available. The backlighting switches off after a few minutes of not being used.

Users can navigate the extensive menu and set parameters using the four menu buttons and four arrow keys. In addition to various status and error messages, the display can show the following values: AC power, AC voltage, DC voltage and very extensive yield data. Thus, the most important measurements are at the user's disposal. Additional values can be obtained from the datalogger. However, the datalogger in this device failed to function properly. The display went dark and could no longer be operated when we tried to access it through the appropriate menu item.

Instruction manual

The device is accompanied by a preliminary instruction manual in German – portions of the manual are still a work in progress. It is also available in English and Spanish. The comprehensive manual covers, in addition to a few general explanations, installation, connection, description of operating behavior and use of the display. It also includes a comprehensive list of setting parameters and possible malfunction messages. The German and English instruction manuals can be downloaded from the manufacturer's website.

Circuit design

The three-phase inverter's circuitry essentially has two layers, but doesn't use a classic topology. First, energy from the solar generator reaches the power stage via an interference filter. The device has a split intermediate circuit capacitor, the center of which is connected with the grid's neutral wire. It possesses two, three-phase output bridges, which are connected in parallel on the output side. The first output bridge is directly connected to the DC input, in terms of voltage. The second bridge is supplied by two boost converters that are located in DC input's positive and negative conductors, and which feed the second split intermediate circuit capacitor. The sinusoidal wave modulation is distributed between these two output bridges, so that both of them only transmit a portion of the voltage boost to the output throttles to produce the sinusoidal current. This reduces the losses in the power transistors and output throttles. Furthermore, every output in each phase has a free-wheeling path, which prevents energy stored in the output throttle from flowing back into the intermediate circuit capacitor, which would cause greater losses. Although this variety of circuitry components makes the device's construction very elaborate, it has a high efficiency, good electromagnetic compatibility characteristics and a DC potential at the DC connecting terminal that is balanced with ground potential. This circuitry is patent-pending.

A successive filter smoothes the modules voltage blocks into sinusoidal voltage with a mains frequency of 50 Hz. An ENS disconnect unit separates the inverter from the grid as soon as grid voltage or grid frequency deviate from the designated limits, as well as if it detects residual current on the grid side. The insulation resistance is measured on the DC side. An output filter, installed directly in front of the grid clamp, eliminates any radio interference.

Measurements

All of the following measurements are based on a grid voltage of 230 V.

For the MPP voltage range above 733 V, the simulator's open circuit voltage had to be limited, since this assumes a value of more than 900 V with an IV curve fill factor of 75 percent. The Refusol 11 K's maximum DC voltage is 900 V.

At lower powers, the unit stops feeding in three-phase, but adjusts to the lower power: to increase the partial load efficiency, one or two of the output bridge's phases are switched off. Thus, slight fluctuations in the input voltage can occur at this operating point on the input side.

At lower MPP voltages, the device switched off at the power stages around 5 and 15 percent on account of oscillation. The display presented an error message when shutting off.

When searching through the menu and selecting the datalogger option, the display went dark and could no longer be used, but the inverter continued to function normally.

Locating the MPP: At a predetermined IV curve with a nominal power and an MPP voltage of 601 V, the inverter needs around 70 seconds to connect to the grid. The DC and AC sides were switched off until the measurement process began. The inverter needed about 22 seconds to reach its MPP. The device needed 7 seconds to switch from 601 V to 579 V, and a switch to the next lower MPP range also required about 7 seconds.

MPP range: The MPP range stretches from 380 to 800 V, which gives this inverter an incredibly wide range. With today's fill factors, the maximum MPP voltage of 800 V is too close to the maximum input voltage of 900 V.

Conversion efficiency: Conversion efficiency is the relationship between P_{DC} and P_{AC}. To demonstrate the dependence of efficiency on input voltage V_{MPP} and the input power P_{DC}, the MPP voltage range was divided into 20 steps and the DC power range into 24 steps. The result is 480 different solar generator curves and a measurement cycle consisting of 480 individual measurements. Every curve has a fill factor of 75 percent. From this series of measurements, we gathered 480 efficiency values, which form the basis for the three-dimensional representation of efficiency dependencies (see graph, p. 89). The third dimension in this diagram is color. The color spectrum and its correlation to measurements are pictured next to the diagram. The power P_{MPP} is standardized according to the inverter's nominal input power P_{DCN} and is stated in percent of nominal power.

Both above and to the right of the diagram are cross-sections that are pictured in the three dimensional color diagram. These show the dependency of efficiency η on standardized power, and efficiency η on the voltage V_{MPP}. At the top right, the inverter's operating range is graded in relation to the MPP voltage range and the MPP power. The inverter can operate at 110 percent of nominal power in an MPP voltage range of 380 to 800 V. That's why the efficiency could be recorded in this area of the diagram.

In the three-dimensional color diagrams representing efficiency, one can see two-dimensional areas of the same color, so with the same efficiency. The area of maximum efficiency produces a large, uniform area across the entire voltage range, starting at an input power of around 25 percent.

At a maximum DC voltage of 900 V, one notices an area of hatching in the uppermost section of the diagram. This represents limitations on the MPP voltage range encountered when crystalline modules are used. Below that area is a section of hatching in the opposite direction. This area points out limitations when the device is used with thin-film modules, since the distance between the maximum MPP voltage and maximum DC voltage is simply too narrow.

The vertical cross-section at 85 percent of nominal power and the horizontal intersecting line at a V_{MPP} value of 601 V meet at the maximum efficiency of 98 percent. The maximum conversion efficiency varies by just 0.5 percentage points across the entire MPP voltage range.

The device's DC nominal power is P_{DCN} = 11,000 W. Our measurements matched exactly with the 98-percent maximum efficiency specified by the manufacturer. At lower powers, below 15 percent of nominal power, this device's efficiency drops by around 5 percentage points. The power factor cos φ at nominal power was about one.

Weighted conversion efficiency: Weighted conversion efficiency is given together with European and Californian weighting. The maximum European efficiency is achieved in a range of V_{MPP} = 491 to 645 V and is 97.5 percent, which precisely matches the manufacturer's specifications. The difference between the maximum efficiency and European efficiency is very small, just 0.5 percentage points. The Californian efficiency is even higher, 97.8 percent, and just 0.2 percentage points lower than the maximum conversion efficiency – it too reaches its maximum in a range between 491 and 645 V. The Californian efficiency is defined by the California Energy Commission (CEC).

MPPT adjustment efficiency: The comparison of specified DC power P_{MPP} with the inverter's actual DC power gives us an idea of an inverter's static MPP tracking capabilities – or how much of the available DC nominal power the inverter accepts. The MPPT adjustment efficiency is very high and consistent over the entire operating range. With predetermined power of between 5 and 110 percent of nominal power, the inverter's MPP power is more than 99 percent of available power over the entire voltage range.

DC current limitations begins to be noticeable when the inverter reaches the overload range at lower MPP voltages. The fluctuations of input voltage, mentioned above, result in slightly lower adjustment efficiencies at lower voltage levels for four voltage steps.

Overall efficiency: The overall efficiency is calculated by PHOTON Lab and is the product of the conversion efficiency and the MPPT adjustment efficiency for all 480 measurements. As with the graph of conversion efficiency, cross-sections through the three-dimensional color diagram, at the right and at the top, show the dependencies of overall efficiency on standardized power, and overall efficiency on voltage V_{MPP}. At the top right, there is a graph of the inverter's operating points in relation to the MPP voltage range and MPP power.

In the three-dimensional colored diagram, the areas of identical color represent the value of a specific efficiency. The range of maximum overall efficiency stretches across the entire voltage range starting with powers of more than 30 percent. Only at higher voltages, and at lower voltages with higher powers, does the range narrow slightly.

As in the conversion efficiency diagram, there is an upper area of hatching at a maximum DC voltage of 900 V. This points to the limitations on the MPP voltage range when used with crystalline modules. There's also another area with hatching in the opposite direction that underscores the inverter's limitations when used with thin-film modules, on account of the narrow voltage gap between the maximum MPP voltage and maximum DC voltage.

The vertical cross-section at 60 percent of nominal power and the horizontal cross-section at V_{MPP} = 579 V run through the overall maximum efficiency of 97.7 percent.

Course of overall efficiencies, average overall efficiency and PHOTON efficiency: In the diagram, the overall efficiency gradient for the minimal and the maximum MPP voltage can be found displaying each of the maximum values. The average overall efficiency gradient is attained by averaging all overall efficiency results. That's followed by averaging all overall efficiency results across all voltage levels at a particular power level. This produces a two-dimensional curve.

The analysis covers the entire V_{MPP} range given by the manufacturer – including the hatched areas. The average is formed for the power levels between 5 and 100 percent of nominal power. The PHOTON efficiency is then determined based on the values calculated for the average overall efficiency. This device's PHOTON efficiency at medium irradiation is 96.9 percent and 97.2 percent at higher irradiation.

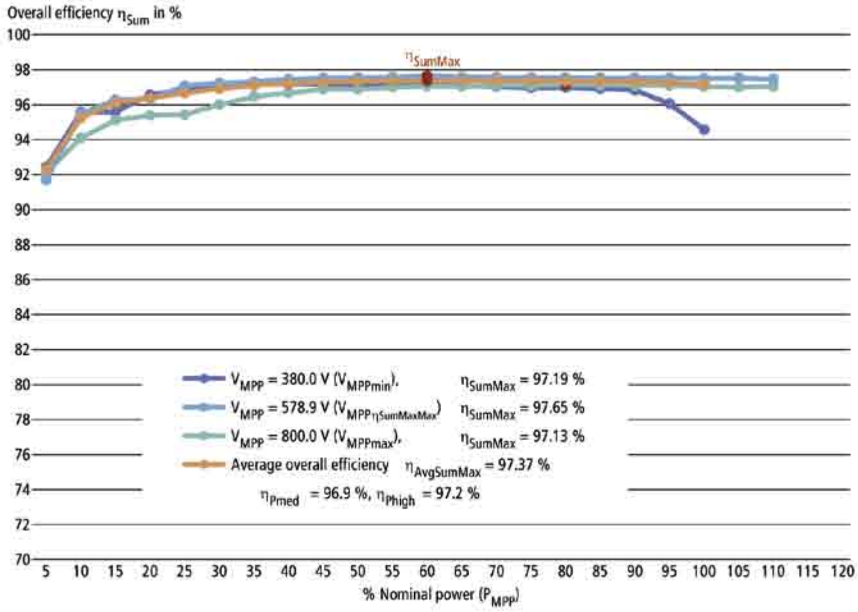
Feed-in at nominal power: The inverter feeds in 100 percent of nominal power over an input voltage range of between 380 and 800 V at an ambient temperature of 25 °C.

Displayed output power: In another series of tests the inverter was fed with different powers between 5 and 110 percent of the nominal power while keeping a constant MPP voltage of 601 V, so in the medium range. Measurements were taken for the inverter's output power – figures displayed by the inverter and by a power analyzer were compared.

The output power measured and displayed by the inverter differed at lower powers by 1 percent from the power analyzer's measurements. At 15 percent of nominal power, the error range decreased, and the value displayed by the inverter was only 0.9 percent less than that of the power analyzer. Thus the display's accuracy is equivalent to that of a class B meter (formerly known as precision class 1).

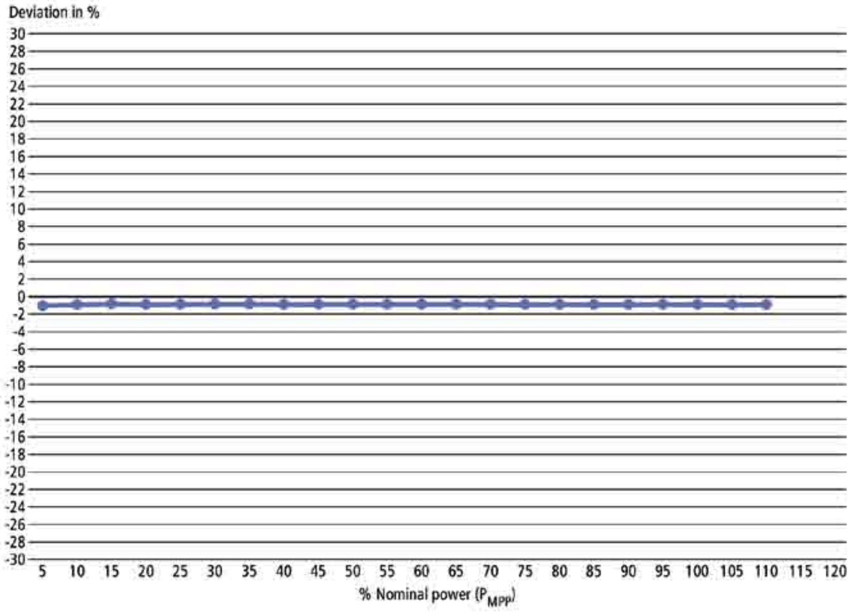
Operation at high temperatures: If the ambient temperature is increased, the inverter feeds 100 percent of its nominal power into the grid until the ambient temperature reaches around 55 °C. Once that temperature is reached, the inverter's power decreases. The selected operating point was P_{DC} = 11,000 W and the V_{MPP} = 601 V. Efficiency dropped by 0.15 percent over this temperature range. Because of its IP 65 protection class and its very wide temperature range (-20 to 55 °C), this inverter can be installed, without restriction, under a roof or even outdoors. However, one should keep in mind that power decreases when the ambient temperature is above 55 °C.

Efficiencies at different V_{MPP} voltages



No fluctuation, no outlying values – the Refusol has a completely stable mode of operation. It's barely worth even mentioning the slight efficiency drop at lower nominal powers.

Accurancy of inverter display



As precise as a meter: At the very most, the inverter displays 1 percent lower output power than what was measured by PHOTON Lab.

Overload behavior: If you offer the Refusol 11 K an overload of 1.3 times its nominal input power, so 14,300 W, at a V_{MPP} = 601 V at an ambient temperature of 28 °C, the device limits DC power to around 12,315 W. This is equal to an overload of 11.9 percent at a DC nominal power of 11,000 W. When these power limits go into effect, the device moves the operating point on the IV curve towards a higher input voltage. The DC voltage adjusts itself to a value of around 660 V.

Own consumption and night consumption: The inverter's own consumption in its tested construction is around 0.6 W on the AC side – the manufacturer doesn't provide any specifications here – and 29 W on the DC side. At night, the inverter consumes around 0.6 W of real power from the grid. The manufacturer lists this value as 0.2 W.

Thermography: Thermographic images show the inverter from above while it is operating at nominal power with an ambient temperature of 29 °C. It shows component temperatures on the circuit board of up to 67 °C. Still, these measurements only refer to the visible components, since the device is constructed in several layers.

As the image shows, the surface temperature of transistors in the switching-mode power supply area was 67 °C. The circuit board surface area, below which the processor is attached, showed a surface temperature of 65.8 °C. Only a small portion of the power element under the ventilator could be observed, but it didn't exhibit anything unusual. For instance, one could see an electrolytic capacitor, the temperature of which was still in the green portion of the temperature spectrum.

Nevertheless, we took a second thermographic image of the power element circuit board at an ambient temperature of 29 °C and nominal power. We have not included it here, since all of the components remained within an acceptable temperature range. However, it took 20 seconds before the image could be taken, since a few fasteners and cables had to be removed in order to fold the upper mounting level to the side. The surface temperature of the grid relay was a harmless 60.9 °C and the electrolytic capacitors were 56 °C.

Manufacturer's response

»As far as we can tell from the measurements, PHOTON Lab's data is within the range of measuring tolerance when compared to the measurements we've made, both internally and externally. The product documentation, as well as the display, will be available in Flemish, French and Italian by the end of the year.

The observation that lower DC input voltages around 400 V can disrupt the I-converter can be explained by a safety function, newly implemented in May 2008, that monitors the measuring systems inside the device. Unfortunately, this was only discovered once the device was in the field, since the device is too sensitive for particularly low input voltages below 400 V. Generally, systems that work with higher DC nominal voltages are not affected by this behavior. This problem will be corrected when the updated software is released in September 2008. In this case, the software update will be provided at no charge to our customers.

The fact that the display panel shuts off is due to a bad batch, so bad hardware configuration. It's a minor flaw, since the inverter continues to function regardless. Nevertheless, we intend to improve the display's functionality with a firmware update. We guarantee that by September 2008, when the new software is released, the inverter display won't shut off when operators use the menu.

The operating points at 5 and 15 percent of nominal power are almost exactly at the point of module switching in our high efficiency, three-phase partial load feed-in process. This can lead to minimal alterations in the adjustment efficiency, but exclusively at the direct change-over point (as the simulations from your constant test environment prove) – under operational conditions, this won't have a demonstrable, relevant effect on yield.«

Summary

Superb efficiency, compact construction unlike any other inverter in this power class and unusually stable operation: Refu Elektronik's Refusol 11 K is an excellent device. Considering all of the product's good qualities, one thing shouldn't be forgotten: this inverter is the first ever developed by Refu Elektronik. The company's successful debut on the PV market leaves one wondering what else Refu Elektronik has to offer in its new field of business, and we are awaiting the company's successive products with great anticipation.

This first device makes an overall very good and well rounded impression, and for a three-phase device at this power, it's very light and compact. The internal construction is well arranged, tidy and compact. The power element's innovative topology makes it possible to balance the DC connection's potential with the ground wire and achieve a very high efficiency. But, in exchange, the device doesn't operate quietly – the chokes are responsible for the noise.

The maximum conversion efficiency is 98 percent. We've never had an outcome like this in PHOTON Lab before. The record holder until now was SMA's SMC 8000TL with 97.96 percent, which by and large demonstrates similarly very good characteristics. The Refusol device functions very consistently across the entire voltage and power range. This can also be discerned in the European and Californian efficiency, both of which are calculated by the accumulation of conversion efficiencies for various voltages and powers: the European efficiency is just 0.5 percentage points and the Californian efficiency is 0.2 percentage points below the maximum conversion efficiency. The device's efficiency benefits from the very consistent and high MPPT adjustment efficiency. Thus, the Refusol 11 K has a PHOTON efficiency of 96.9 percent for medium irradiation, which means the device, like the above-mentioned inverter from SMA, received a grade of »A+.« With a PHOTON efficiency for high irradiation of 97.2 percent, the device even performs slightly better than SMA's product and therefore received a grade of »A+« again.

The Refusol offers another advantage: its very wide MPP voltage range, which stretches from 380 to 800 V. That's unusual, but here too is one of the device's weaknesses: the range is so wide that it can actually restrict the types of modules with which it can be used. This is underscored by the two hatched areas in the color diagrams. Hence, when designing the PV system's MPP, you can select from the entire MPP voltage range of up to around 720 V.

The inverter has an overload capability of 110 percent. The inverter's displayed output power is very accurate and beats all comparisons. The device's temperature range is very wide. Power restrictions only occur at a temperature of 55 °C. The inverter's conversion efficiency has a very low temperature dependency of -0.15 percent.

Despite a few flaws, of which the manufacturer is aware, the inverter is truly a quality device – it's the kind of inverter PHOTON's staff would like to see more often.

Heinz Neuenstein, Ines Rutschmann

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Inverter test results 2007-08

Inverter	Observed voltage range	Medium irradiation			High irradiation			PI issue
		$etaP_{med}$	Grade	Position	$etaP_{high}$	Grade	Position	
Refusol's 11 K	380 - 800 V	96.9 %	A+	1	97.2 %	A+	1	9/2008
SMA's SMC 8000 TL	335 - 487 V	96.9 %	A+	1	97.0 %	A+	2	10/2007
Sunways´ AT 4500	250 - 600 V	94.6 %	B	3	94.8 %	B	5	7/2008
Fronius` IG Plus 50	230 - 500 V	94.5 %	B	4	94.8 %	B	5	8/2008
Phoenixtec's PVG 2800 (updated model)	250 - 450 V	94.4 %	B	5	95.1 %	A	3	5/2008
Conergy's IPG 5000 vision	301 - 706 V	94.0 %	B	6	94.7 %	B	7	7/2007
Delta Energy Systems´ SI 3300	150 - 435 V	93.9 %	B	7	94.7 %	B	7	5/2008
Mitsubishi's PV-PNS06ATL-GER	260 - 650 V	93.9 %	B	7	94.6 %	B	9	6/2008
Sputnik's SolarMax 2000C[*1]	165 - 515 V	93.8 %	B	9	93.1 %	C	16	4/2007
Sunways´ NT 2600 (lower range)	350 - 623 V	93.8 %	B	9	95.1 %	A	3	11/2007
Ingeteam's Ingecon Sun 3.3 TL	159 - 414 V	93.4 %	C	11	94.3 %	B	10	8/2007
SMA's SB 3800	208 - 395 V	93.2 %	C	12	93.6 %	B	13	2/2007
Diehl Ako's Platinum 4600S	320 - 628 V	92.9 %	C	13	93.3 %	C	15	4/2008
Kaco's Powador 3501xi	350 - 597 V	92.6 %	C	14	92.9 %	C	17	6/2007
Kaco's Powador 2500xi	350 - 597 V	92.5 %	C	15	93.4 %	C	14	12/2007
Sunways´ NT 2600 (upper range)	476 - 749 V	92.3 %	C	16	93.9 %	B	11	11/2007
Mastervolt's QS 2000[*1]	212 - 366 V	92.3 %	C	16	92.7 %	C	18	1/2008
Riello's HP 4065REL-D	255 - 435 V	91.7 %	D	18	93.9 %	B	11	9/2007
Fronius´ IG 30	150 - 397 V	91.4 %	D	19	92.2 %	C	19	1/2007
Siemens´ Sitop solar 1100 Master[*1]	200 - 552 V	90.2 %	D	20	91.7 %	D	20	5/2007
Phoenixtec's PVG 2800 (original model)[*1]	255 - 435 V	78.4 %	E	21	85.8 %	E	21	2/2008

[*1] device no longer being produced, only leftover stock available