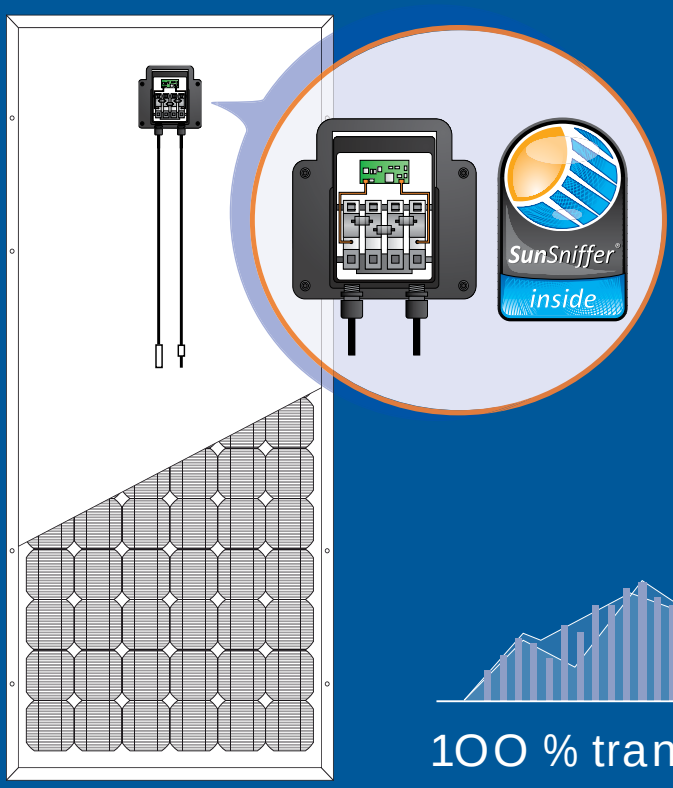
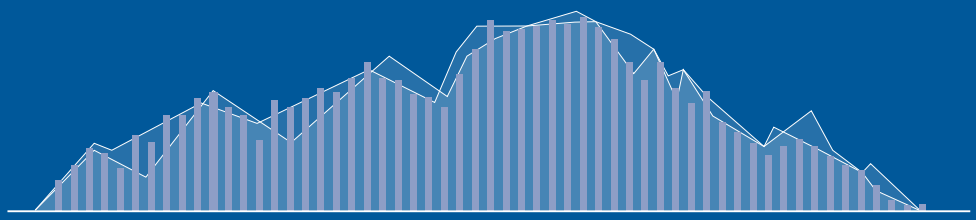
SunSniffer®

Secure your solar investment





100 % transparency = 100 % performance

SunSniffer: the **operating system** for PV plants,
monitoring and **analyzing with artificial intelligence**

www.sunsniffer.de

How to read this brochure:

Fast readers and managers will find condensed information in the main parts in the middle of the text. Those who are technically or scientifically minded will find links for more detailed information in the margins, along with interesting facts.

Is your plant producing as effectively as possible?

With a solar energy system, anybody can produce environmentally friendly electricity – that´s great! Things become a little more complicated when one of the modules is not working properly. Unfortunately, this can happen very easily for a number of reasons: diodes get broken, hail causes cell cracks, and potential induced degradation (PID) reduces performance continually without even being recognized.
But being aware of a problem, and then identifying it, is the precondition for a plant producing as much as it can. Because: **with no system in place to find the defects of your plant automatically, how can you know the plant is working properly all the time?**
... But monitoring systems are expensive... Really? Not with SunSniffer®.

SunSniffer® is an investment!

SunSniffer® not only monitors your plant, but also produces an ROI by itself. SunSniffer® is able to improve the performance of a plant so much that it virtually is an investment in itself - see ROI example calculation on page 5. **Plant owners and investors benefit from the fact that a plant is sustainably producing as much as it can, because every error can be eliminated at once.**
A problem might not reduce yield at a painful level from the beginning, but small issues **will** grow and **eventually every problem will have to be solved** - at the latest when losses have accumulated to a level it is no longer possible to ignore. We show you exactly, how much you lose - and what to do to fix it! All automated based on our German engineering skill using the latest artificial intelligence. You gain every minute from it!

*So why not **solving** the problem **right from the start**?*

According to diverse studies*, modules have replaced inverters as the most error-prone part of solar plants and are their main weak point - especially regarding their economic impact. Modules are the power production point, failures affect directly the power output. New module technologies with no long-term experiences in the field and further downward price spirals cry out for improved quality assurance.

But how? Well, it‘s easy:
By measuring the power of each module, especially the voltage!

Every module should have a similar voltage curve over the course of a day independent of irradiation. If this curve shows deviation we know there is a problem. SunSniffer® measures each module and deviations are calculated by artificial intelligence. If a critical level is reached, you will be notified - fully automatically. Then, just swap the module!

That‘s why plants with SunSniffer® are not just smart - they are intelligent! Fixing plants becomes a child‘s play!

Did you know...?

... that 48% of all particularly serious failures in PV plants relate to modules?

www.sunsniffer.de/knowledge/TUEV-Modules.pdf

Vaaßen, Willi: „Felderfahrungen mit PV-Modulen“, TÜV Rheinland, 2015.

*See links:

- Solar Bankability project: *www.sunsniffer.de/knowledge/SBP-Financial.pdf*

- PV Tech: *www.sunsniffer.de/knowledge/PVT-Technical.pdf*

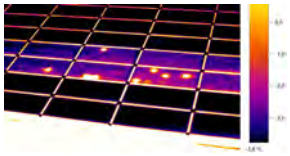
- International Energy Agency: *www.sunsniffer.de/knowledge/IEA-Task13.pdf*

Further information: *www.sunsniffer.de*

What can happen to modules?

PV plants face diverse problems during their lifetime: hot spots, defective diodes, PID, cell cracks, delamination, natural degradation, etc. ...

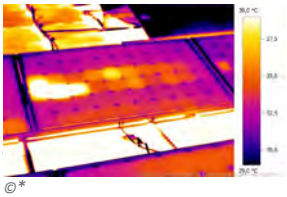
Here are the four biggest problems with PV modules and how we deal with them:



©*

Hot spots

Badly-soldered connections or structural defects in the cell cause selective heat productions at those spots. **Any hot spot is a power leakage**. SunSniffer detects those **defective** modules **automatically**! As we check the voltage curve every 30 seconds against a normalized one, we detect those deviations. Our **artificial intelligence** verifies these measurements and alerts only valid hot spots.



©*

Defective diodes

One defective diode reduces a module's voltage to 66%, two defective diodes down to 33%. This is not noticeable without measurement of the modules' voltages. Diode power loss is a very clear signature and **we easily detect defective diodes**!

©*

PID / LID

Potential or light induced degradation reduce the performance continually, without being noticed. And without constant voltage measurement in the module, PID recognition in the field is simply impossible. SunSniffer® measures constantly and **detects PID even in its beginning**.

Cell cracks

Hail can cause serious defects in cells. Cracks in a cell may be small, but can cause or accelerate degradation. The resulting power loss is diagnosed by us fully automatically. Insurance claims can be a very difficult process, but with SunSniffer it is very easy! **We document clearly if a module is starting to lose power from cell cracks and how much**.

Other problems will also be found because a defective module has a different power curve - which we measure precisely!

Thanks to SunSniffer®
every power reduction is recognized
and ***action can be taken immediately.***

Maximum power
thanks to SunSniffer®

→ See link:

Fraunhofer CSP/SunSniffer:
„New approach to LID..."
www.sunsniffer.de/knowledge/FCSP-LID.pdf

„Light-induced degradation newly addressed - predicting long-term yield loss of high-performance PV modules", Fraunhofer CSP, 2017.

→ See link:

TÜV Rheinland:
„Hail damages..."
www.sunsniffer.de/knowledge/TUEV-Hail.pdf

„PV module damage caused by hail impact and non-uniform snow load", TÜV Rheinland, 2016.

** Pictures provided by photovoltaikbuero Ternus und Diehl GbR.*

Can SunSniffer® deliver the same result as infrared thermography?

The common and well-proven way to inspect a PV plant for failures is infrared thermography. This method detects temperature differences. Overheating can point to errors, so this method can locate potential errors easily. Using drones for aerial inspection even accelerates and facilitates the examination of a plant.

IR images must be interpreted by experts, as overheating can also be caused by reflexions or bad ventilation. And the prerequisites, such as weather conditions, need to be suitable for taking IR images.

But: defects not only reveal themselves in changed temperature, but even more so in changed power – and even more precisely. Measuring the individual modules' power can determine exactly, which module has how much power loss and needs to be exchanged. As this process is automated, no expert interpretation is needed.

In a typical IR image all temperature differences are marked. But information on power losses is not available on IR.
Assuming that you are not an expert: Does it help you make decisions on warranty cases, for example? If you cannot see the degree of power loss? How much do such images support you in managing plant issues, without expert comments?

We measure the power of each module every 30 seconds, so power losses are recognized instantly. SunSniffer® does not need to rely on assessments, SunSniffer® measures! Our artificial intelligence analyses the data and clearly recognizes errors. Additionally, we offer precise instructions of what needs to be done - exchange the module, or change diodes,... But as we offer an integrated system, we even provide clear guidance through the respective repair processes, with clear instructions, and an App for on-site service including documentation functions.

Factors relevant	***IR***	***SunSniffer®***
Climate independant	*no*	*yes*
Automated interpretation	*no*	*yes*
Permanent analysis	*no*	*yes*
Power loss recognition	*no*	*yes*
Data/information history	*no*	*yes*
Integrated service guidance	*no*	*yes*
Warranty clarifications	*no*	*yes*

IR is a helpful tool if you do not have SunSniffer®. But if you have an option the answer is clear: SunSniffer® not only costs you less than all IR tests over the lifespan of your plant, it gives you automatic and instant results - all the time. So SunSniffer® delivers even better results than IR!

Check how IR reports look like:

www.sunsniffer.de/knowledge/IR-Report.pdf

Did you know that low performing modules are not limiting your string power?

See latest study of the Bavarian Center for Applied Energy Research (ZAE Bayern):

www.sunsniffer.de/knowledge/ZAE-Defect.pdf

„Defect Analysis of installed PV-Modules - IR-Thermography and In-String Power Measurement", ZAE Bayern, 2015.

Why SunSniffer® pays for itself

Make some calculations and you will see, SunSniffer® is an investment with its own interest rate. Even with conservative estimates SunSniffer® still makes the plant more profitable. So it actually IS an investment itself, as you can see in the brief example calculation below.

In this example we assume the following:

- Plant size is 2 MW
- Yield per year is around 1,800 kWh/kWp
- Feed-in remuneration is $ 4.5 Cent per kWh
- O&M costs are around $ 8 per kWp on average
- SunSniffer hardware costs for that plant would be $ 42,385.
- A very conservative assumption of yield increase made by SunSniffer® would be 2%, and O&M cost reduction of 20%.

→ ***But even with this conservative estimate, the investment into SunSniffer® would pay off after 6.6 years in this case - the point when additional profit starts to accumulate.***

→ ***Assuming a lifespan of 20 years, due to SunSniffer® the plant produces more than $ 128,000 additional gain!***

→ ***Return on investment of SunSniffer® in this case is 15%!***
Real ROI is much higher on SunSniffer due to worst case estimates here.

- EXAMPLE -

Plant assumptions:	
Plant size (kWp):	2,000
Yield kWh/kWp/year:	1,800
Feed-in remuneration:	$ 0.045
Increase by SunSniffer®:	*2.0%*
Additional revenue by SunSniffer®/year:	*$ 3,240*
O&M assumptions:	
Costs O&M ø per kWp:	$ 8
Savings with SunSniffer®/year in %:	*20%*
Savings with SunSniffer®/year in $:	*$ 3,200*
Costs of SunSniffer® hardware:	*$ 42,385*
Additional gain with SunSniffer® in total/year:	*$ 6,440*
Additional gain with SunSniffer® after 20 years:	*$ 128,800*
Break even point, in years:	*6.6*
SunSniffer® ROI:	***15%***

At the 25th Fachsymposium Photovoltaische Solarenergie SunSniffer® was awarded 2nd place of the innovation competition 2010.

More detailed calculation:

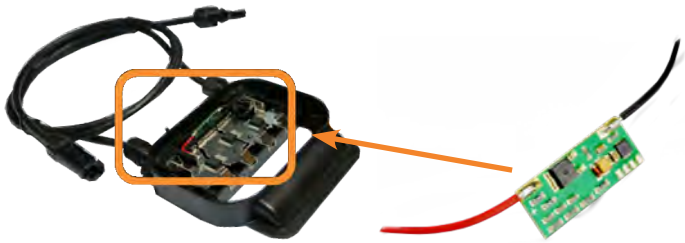
Contact us, we calculate your values with your own figures!

After 6 years using SunSniffer® in the field we see 7% yield increase on average compared to plants without SunSniffer®.

How to SunSniffer® a plant

New installations

Just ask for SunSniffer® enabled modules. Most manufacturers will offer this option on request. Ask us if you need support finding a manufacturer which already integrates SunSniffer®.



Existing plants

Retrofitting a plant is easy with our two options; both are compatible for modules of any manufacturer:

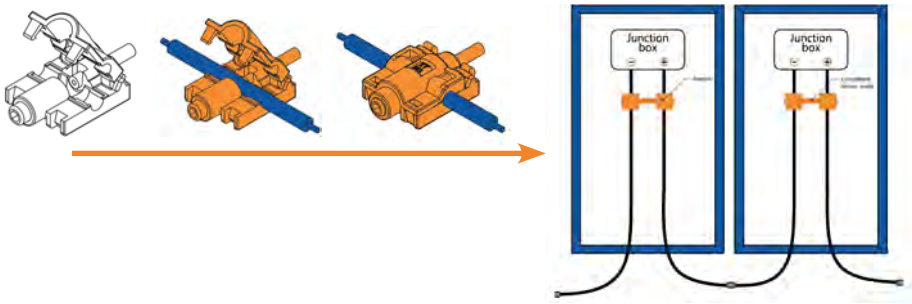
Link to Data sheet:

www.sunsniffer.de/components/hardware/retrofit-clip.pdf

- **SunSniffer® Upgrade Clip**

Our SunSniffer® Upgrade Clip is the fastest and most cost effective way to upgrade your existing PV plants with module level monitoring and analysis. Just crimp the sensor to the solar cable. It is that easy. The connection is waterproof and installation is made within seconds. Starts from less than 1 cent per Wp!

To mount the clip to the solar cable, just open the cover, clip it around the cable, close it, turn the screw, ready. Installed in 5 seconds:

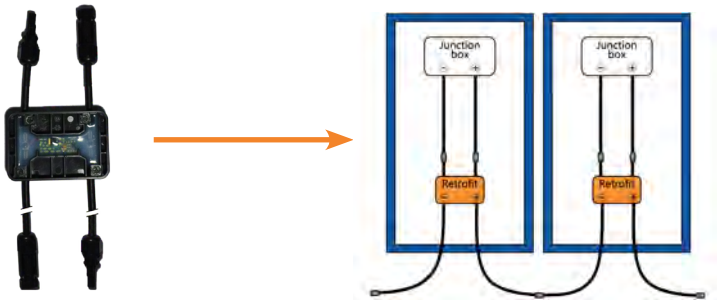


Link to Data sheet:

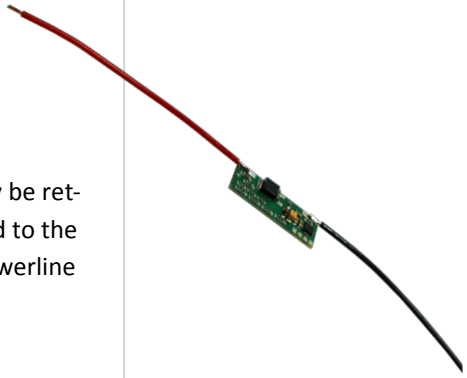
www.sunsniffer.de/components/hardware/retrofit-box.pdf

- **SunSniffer® Retrofit Box**

This version can be used by institutions in particular, as this Retrofit Box can be plugged in and out of PV modules and offers multiple usage, for example for testing purposes. This is how the Retrofit Box is plugged between modules:



That‘s how SunSniffer® components work



The SunSniffer® system consists of three hardware parts and the Webportal:

The SunSniffer® Sensor

The small sensor is integrated directly into the module‘s junction box or can easily be retrofitted. It measures voltage and temperature and sends the information attached to the module‘s serial number to the String Reader through the existing DC cable, via Powerline communication. Measurement accuracy is < 1%.

The SunSniffer® String Reader

The String Reader reads the module data from the strings and measures current and voltage with < 1% accuracy. For every string you need a String Reader which sends the read data via RS 485 to the Gateway.

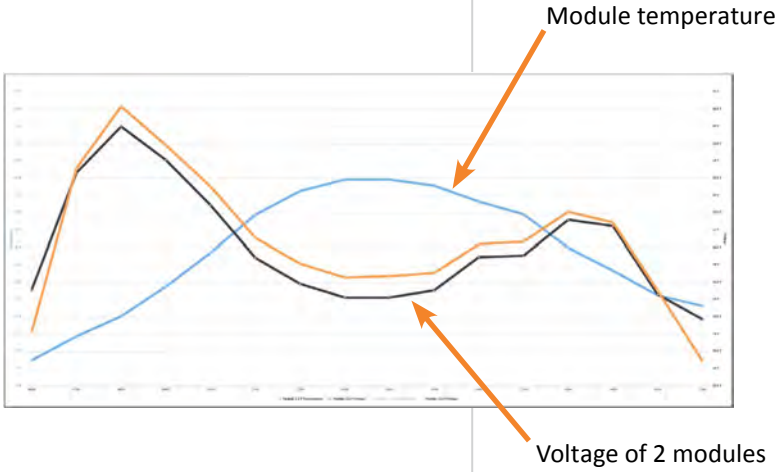
The SunSniffer® Gateway

The Gateway receives the data from every String Reader and sends via any desired internet router to the Webportal.

SunSniffer® measures voltage and temperature module-precise

Why voltage measurements?

All modules have the same consistant voltage curve consistant over the course of a day. Deviations from this specific value are clear indications of failures. Identifying the same characteristics enables precise error detection - and identification. In this curve you can see the voltage of two modules during one day in comparison, which are clearly similar. You can also see how the temperature on that day influenced the voltage: the warmer the modules, the lower the voltage.



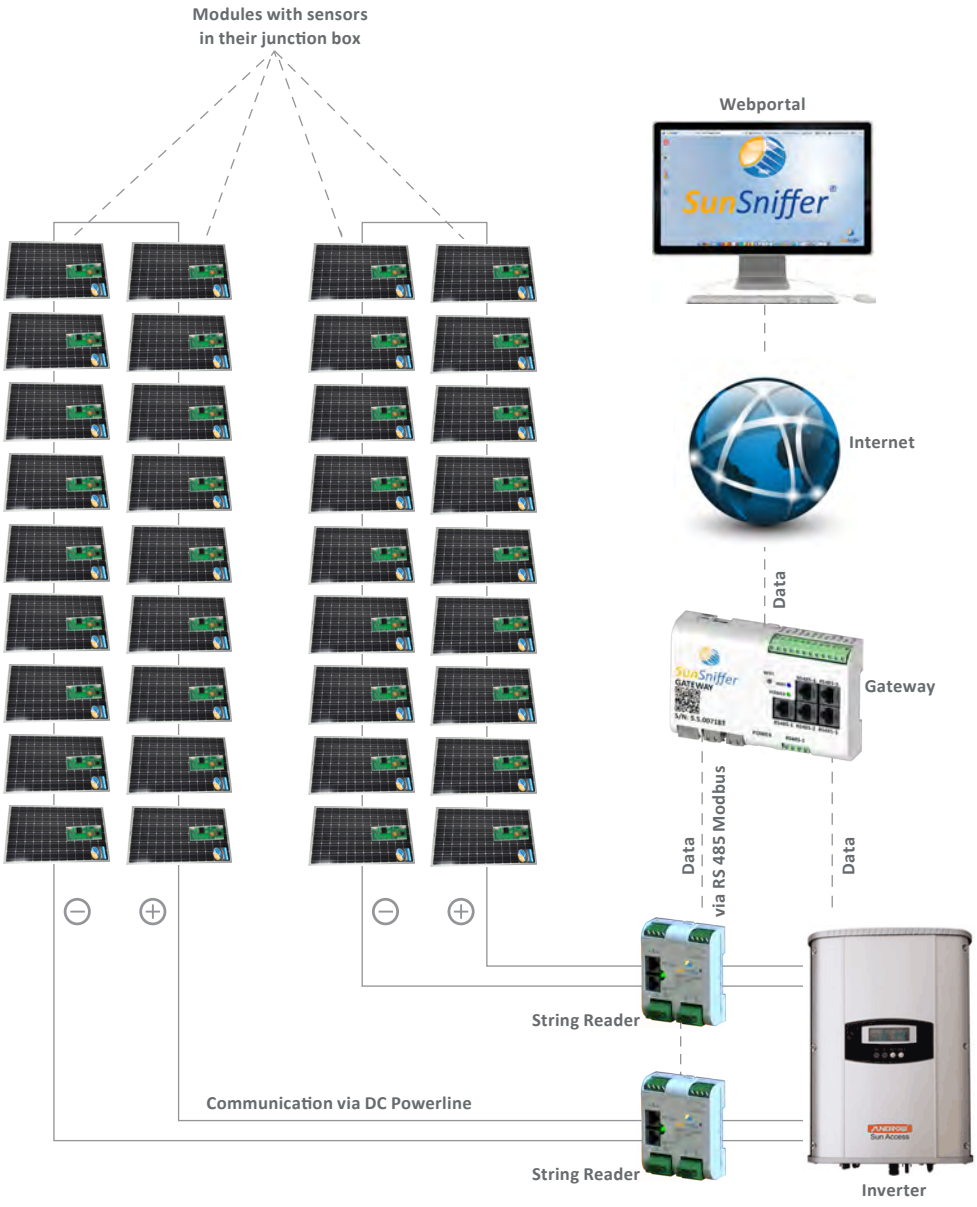
Why temperature measurements?

Module temperatures vary within a plant by 15° Celsius due to variable cooling. Temperature has a significant effect on the performance of a module: 15° Celsius reflects a power difference of 6%. How do you know if your system is in perfect working order if it can vary within specification by that amount? Well - by measuring the temperature of each module and taking this into account of our plant performance calculations! Including module temperature measurements enables us to determine a precise PR - even for the shortest periods.

SunSniffer® connection and transmission scheme

Understand how SunSniffer® works

Visit:
videoen.sunsniffer.de



SunSniffer® powerline technology

Sensor and String Reader communicate via the DC cabling using a specifically developed transmission technology. An additional installation of communication cables for the modules is therefore not necessary.

The SunSniffer® Webportal

The Webportal analyzes the plant's data down to module level. **Error finding** - usually a time-consuming and expensive effort - **is fully automated**. Analysis is made by artificial intelligence and a simulation engine.
Our Webportal displays all plant data in an **easy-to-understand** way and **points directly to problems**. You can either **receive reports automatically** telling you when the plant has an issue to be solved. Or you can **log in and have all issues of all your assigned plants presented in a clear and prioritized fashion** - especially for plant owners with multiple plants or large farms.
Now you know certain things need to be fixed? We do not leave you alone at this point: you will receive clear and easy-to-understand **instructions at the push of a button**.

Did you know...?

...that modules are the weak point of a PV plant with most and gravest problems?

www.sunsniffer.de/knowledge/PVT-Technical.pdf

„Technical failures in PV projetcs", PV Tech, 2016.

Special functions of the Webportal:

Intelligent warning system

The warning system within the SunSniffer® Webportal recognizes performance variations of every component on a percentage basis. Besides this simple recognition it also **detects data patterns by automatic data analysis**. Thresholds are individually adjustable, for example can be set at 10% performance loss - so warnings will only be sent when the performance of a module drops below this value.

Yield gain and loss calculations

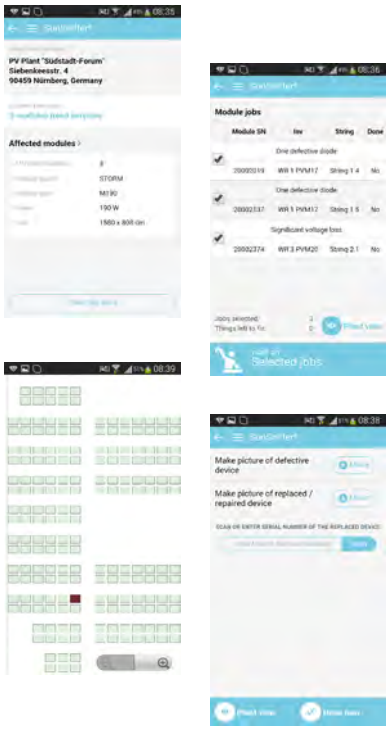
Of course all relevant data and values are shown. Furthermore, the SunSniffer® Webportal even **shows the additional gain obtained by an early module exchange**. And all modules with performance reductions are displayed together with the respective yield reductions. If it is economically viable to exchange an individual module, it will be automatically displayed.

Exact short-time Performance Ratio

By including the **measured module's temperature and the flasher data**, exact PR are determinable even for the shortest periods of time.

Warranty calculations

The Webportal **shows exactly the performance losses**, and therefore warranty claims are easy: sufficient way to prove in the field. Depending on the manufacturer the respective thresholds can be set.



Special help for the service technician on-site:

The SunSniffer® App

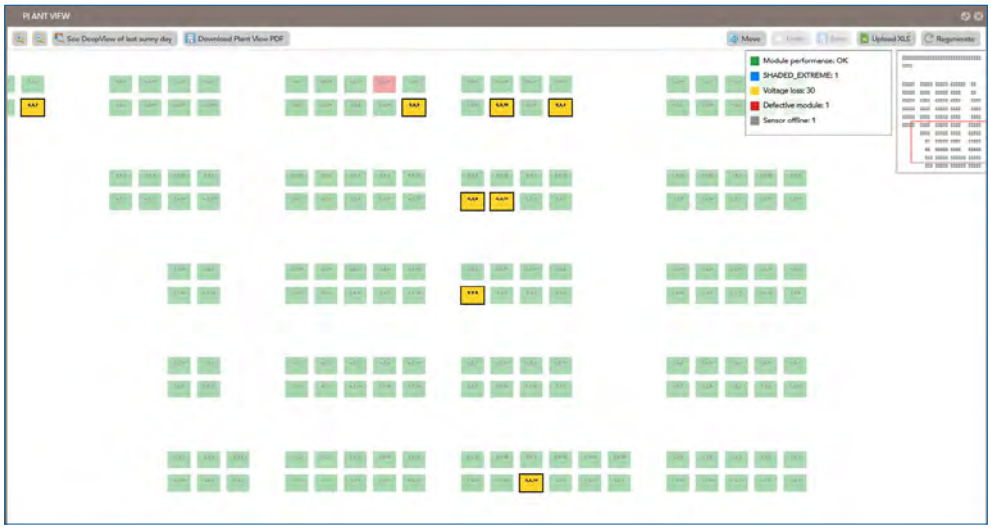
In the field the technician has the plant view for orientation purposes and find exactly the defective module. But not enough:
Our App guides him through the whole repair/exchange process, including documentation and picture storing. The the Webportal you can see instantly what has been done - instantly, but later on as well, as the whole plant's history will be saved.

This is how the SunSniffer® Webportal solves a problem

All measurements are analyzed in the Webportal, and the results are presented in a clear and comprehensive way. We do not only show you all plant's values down to each module, but display problems together with their cause and solution.

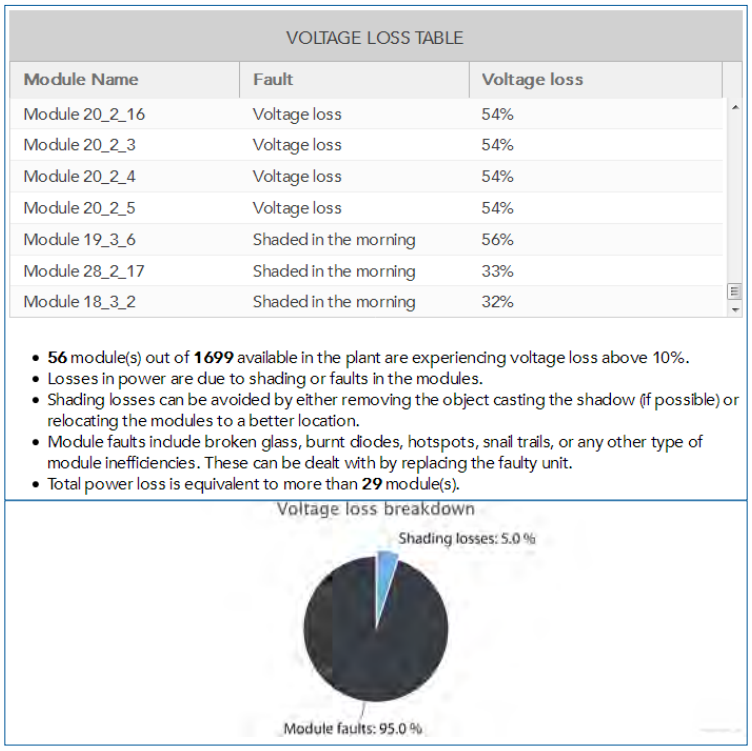
Here is an example of our Plant Maintenance functions. In four easy steps solving a plants problem: Fault Management gives you a clear overview of all issues and how to handle them, and even shows you their location.

1. Exact localization of every single module



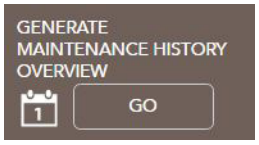
In the Plantview you can see all modules, where they are located and if they have a problem. Modules with voltage losses for example are marked yellow here. Now you know which modules have issues, but what exactly are the problems? See here:

2. Display of faulty modules



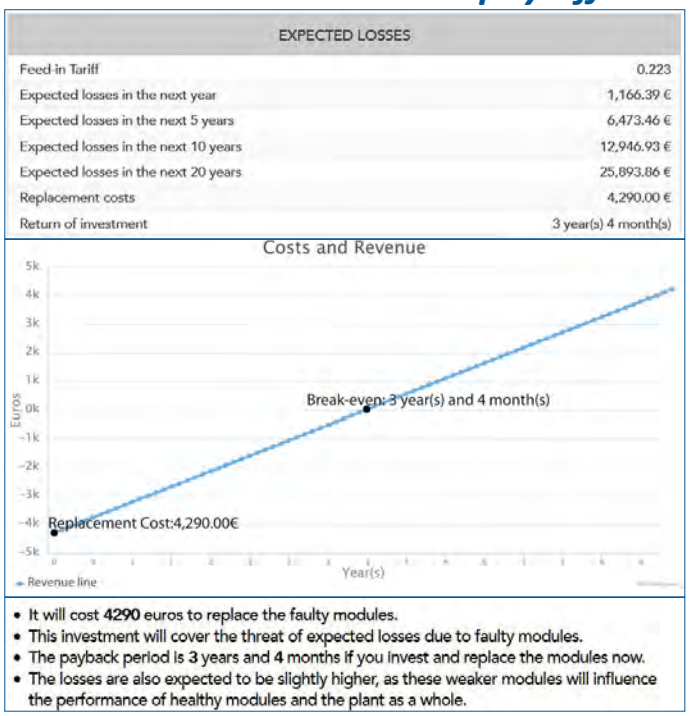
The Webportal gives you a list of all affected modules with their specific voltage losses.

System differentiates between shading and voltage losses! You can see at a glance if action is required and how serious it is.

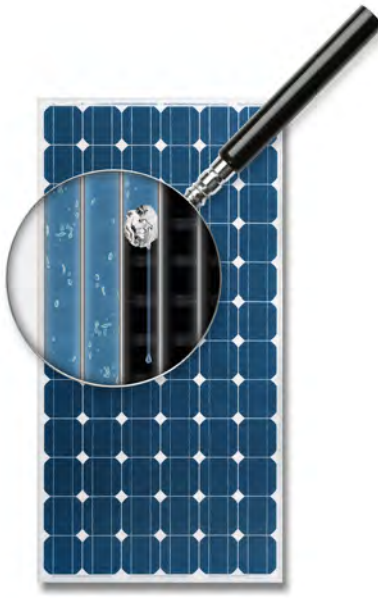


Defective modules are identified, our Intervention Assistant gives you clear advice of when a module swap is economically reasonable:

3. When does intervention pay off?

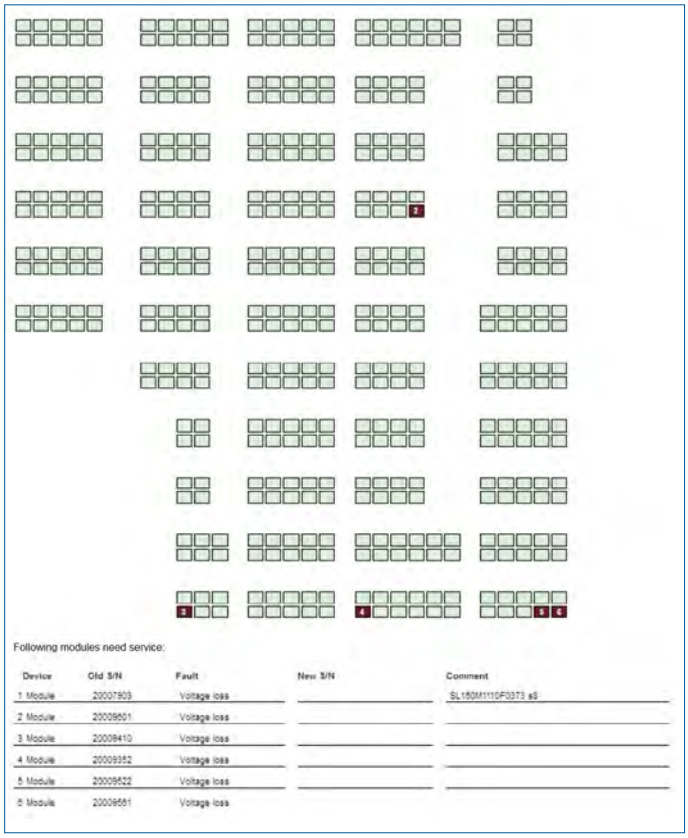


The SunSniffer® intervention calculator shows exactly which modules are defective and should be changed - and, how much this action would cost and how much yield would be wasted if not fixed. The settings can be adjusted individually. You see exactly, when the investment of new modules will pay off: the point, when additional profit starts to accumulate.



Perfect fault management even for non-technicians. Clear instructions and guided service, also via app. With SunSniffer service is child‘s play:

4. Maintenance Plan - for technicians on-site (or App)



Service engineers just need the printed maintenance plan: it will show exactly, which modules need service and what to do.

Or use the app, which will guide through the complete process step by step and instantly documents the service. In the Webportal every action is shown instantly. So every service step is being tracked and documented.

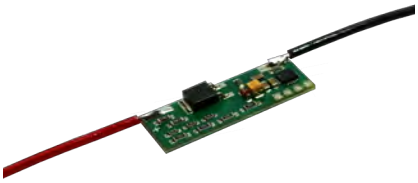
Want a demo account?

Please go to:
webportal.sunsniffer.de

Technical data

SunSniffer® Sensor - Link to Data Sheet

Monitoring chip for integration into the junction box



Allowed ambient temperature	-40 to +90°C
Working voltage range	5 - 45 V
Absolute measuring tolerance voltage	< 1,0 %
Absolute measuring tolerance temp.	-/+ 2°C
Energy consumption	< 0,1 %
Warranty	20 years

SunSniffer® String Reader - Link to Data Sheet

Connection for strings	DC cable, up to 12mm²
Interface for Gateway	RS485
Max. number of modules per string	30
Max. voltage in the string	1000 V DC, optional 1500 V
Max. current per string	10 A
Absolute measuring tolerance current	1 % absolut
Energy consumption	0.5 W (operating) otherwise 0 W

SunSniffer® Gateway <10kWp - Link to Data Sheet

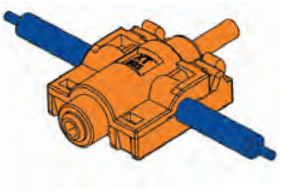
Interface for String Reader	RS485
Max. cable lenght	1000 m
Interface internet	Ethernet RJ45
Max. number of String Reader	5
Max. number of inverters	2
Energy consumption	< 5 W input supply
Memory card	4 GB

SunSniffer® Gateway - Link to Data Sheet

Interface for String Reader	RS485
Max. cable lenght	1000 m
Interface internet	Ethernet RJ45
Max. number of String Reader	150
Max. number of inverters	30
Energy consumption	< 5 W input supply
Memory card	4 GB

SunSniffer® Upgrade Clip - *Link to Data Sheet*

Allowed ambient temperature	-40 to +90°C
Absolute measuring tolerance voltage	< 1.0 %
Absolute measuring tolerance temp.	-/+ 2°C
Energy consumption	< 0.1 %
Protection class	IP67

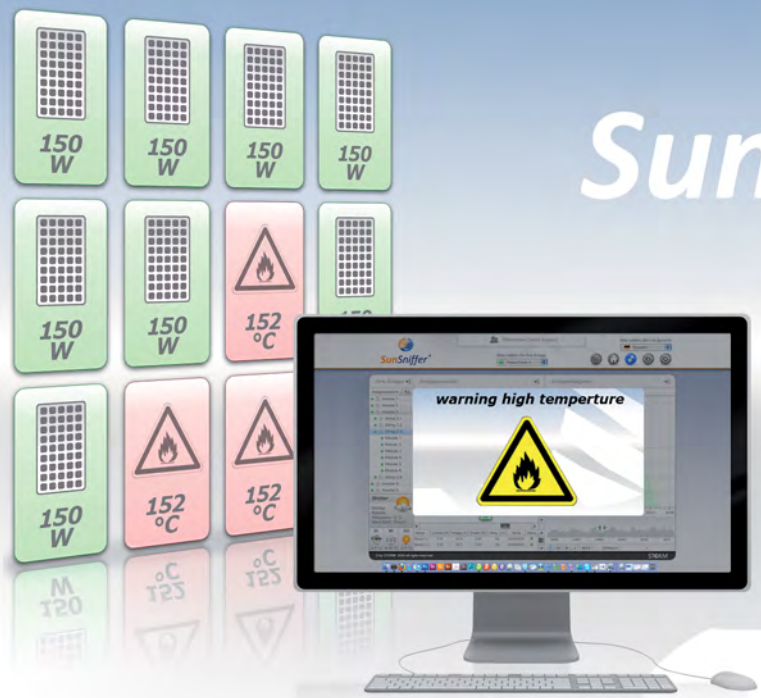


SunSniffer® Retrofit Box - *Link to Data Sheet*

Allowed ambient temperature	-40 to +90°C
Absolute measuring tolerance voltage	< 1.0 %
Absolute measuring tolerance temp.	-/+ 2°C
Energy consumption	< 0.1 %
Protection class	IP67
Max. number of inverters	MC4 compatible
Cable lenght	2 x 5 cm - 2 x 90 cm

SunSniffer® Rapid Shutdown Sensor - *Link to Data Sheet*

Allowed ambient temperature	-40 to +85°C
Absolute measuring tolerance voltage	< 1,0 %
Absolute measuring tolerance temp.	-/+ 2°C
Energy consumption	< 0,1 %
Warranty	20 years



Did you know...?

... that most PV plants work, but operators do not know how good really and lots of yield goes to waste?

www.sunsniffer.de/knowledge/IEA-Task13.pdf

International Energy Agency - Photovoltaic Power Systems Programme: Task 13 (IEA-PVPS T13), 2015.

SunSniffer® Rapid Shutdown

SunSniffer® Rapid Shutdown de-energizes the plant in case of fire

Using SunSniffer® Rapid Shutdown allows an emergency shutdown of each individual module. This will be binding standard in USA from 2019 according to NEC 2017, but SunSniffer® fulfils the criteria of these specifications already today.

Benefits

- Fires can be extinguished without any precautionary measures and without putting the fire fighters at risk
- Cost-effective solution directly in the junction box; standard certified junction boxes are available for a quick integration by module manufacturers
- Profitability of the plants remains guaranteed
- No additional cabling

... together with all benefits of the innovative SunSniffer® monitoring and analysis system.

That's how SunSniffer® Rapid Shutdown works

SunSniffer® Rapid Shutdown is an optional extension of the SunSniffer® Monitoring System. Switching off is performed by the SunSniffer® Rapid Shutdown sensor. The sensor is integrated in the junction box of the module. In case of emergency the electrical current is cut off at its origin.

The SunSniffer® Gateway continuously sends the signal ‚permission to operate' to the SunSniffer® sensors. 10 seconds after absence of this signal, the system switches to shutdown mode and de-energizes the complete system to risk free voltage for maximum safety.

Nonetheless, the sensors are able to provide enough standby power for powering up the system again and prevent it from deadlock. Transmission of the signal is carried through the normal DC cabling, additional cabling serving as communication lines is not necessary.

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