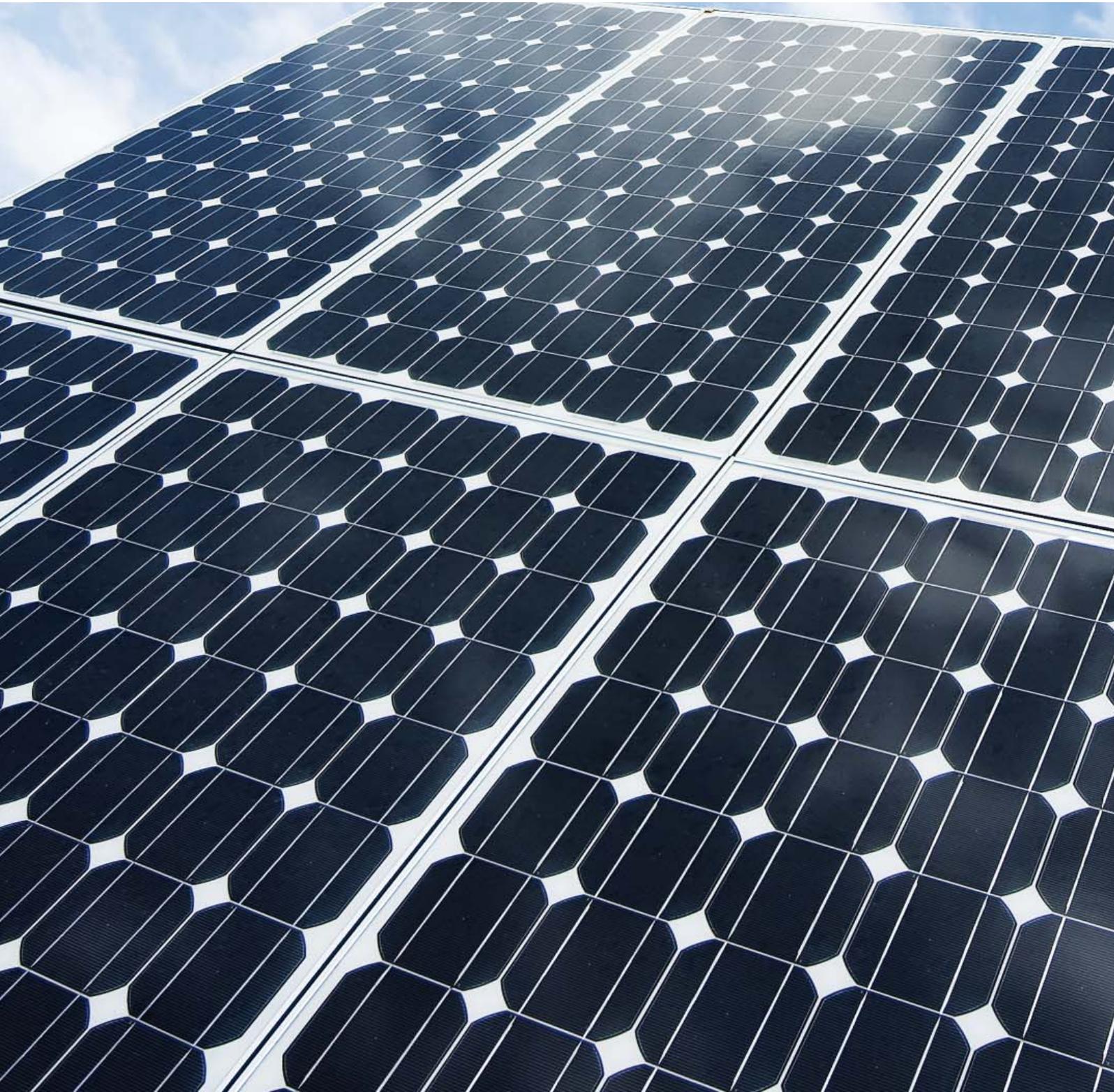


PHOTOVOLTAICS

Cleaning up green power
Grid compliance and reliability
for photovoltaic systems

SCHAFFNER

energy efficiency and reliability





SCHAFFNER GROUP

Schaffner is the international leader in the fields of electromagnetic compatibility and power quality, supplying components that support the efficient and reliable use of electric energy. Customers benefit from the technological know-how of the Schaffner Group in the development, manufacturing and marketing of high-performance products that offer optimized and fault-free operation and compliance with all major quality and performance standards. With its products and services, the Schaffner Group plays a key role in promoting technologies that support renewable energies, ensures the reliable functioning of electronic equipment and systems and meets the requirements for greater energy efficiency.

A global one-stop shop

EMC filters

- PCB filters
- IEC inlet filters
- Single-phase filters
- Three-phase filters
- Three-phase + neutral line filters
- Open frame filters

RFI suppression chokes

Feedthrough filters and capacitors

Automotive components

Customized solutions

Power Quality

- Line reactors
- dv/dt reactors and filters
- Sine wave filters
- Harmonic filters
- Regen reactors and filters
- Transformers

Customized solutions

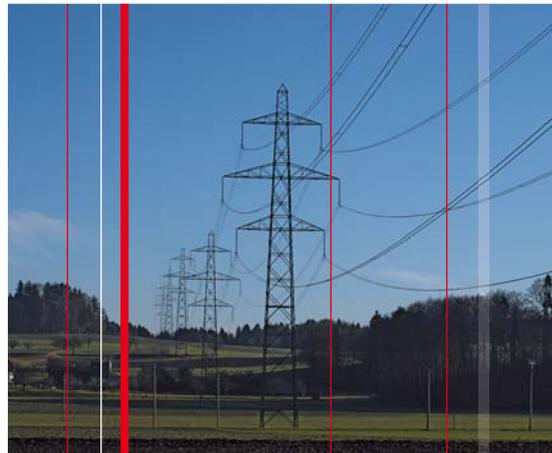


EMC and Power Quality for photovoltaic inverters and systems

Electricity is one of the key resources of the 21st century. Hardly any product can be manufactured and very few modern comforts can be enjoyed without a constant supply of clean electric power. Global warming, high oil prices, and the increasing demand for a more responsible use of fossil fuels encourage energy production from clean, sustainable, and renewable sources.

In recent years, renewable energy technologies have developed dramatically. Higher efficiency and government driven incentive programs around the globe make renewable energy sources a real alternative to traditional sources like coal or nuclear power.

Shaping up green power. Renewable energy sources deliver environmentally friendly sustainable power. This power is initially not always generated as AC current at 50 or 60Hz, as is delivered by the grid and required by most electric consumers. DC current, as generated for example by photovoltaic panels, must be transformed by a process called power conversion before it can be fed into the grid, using PV inverters.





Challenges associated with photovoltaic inverters

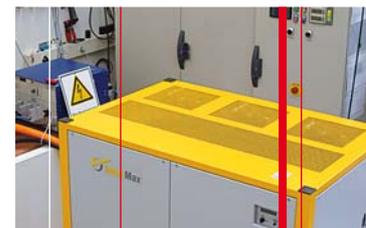
The currently used high-speed semiconductor switch-mode techniques, to achieve highest efficiency levels, unfortunately create a broad spectrum of interference, ranging from low frequency harmonics to conducted and radiated electromagnetic interference (EMI) emissions in the Megahertz range.

Such interferences must be eliminated for three reasons: Firstly, PV systems must meet Power Quality standards and adhere to local utility codes. Secondly, electric and electronic equipment in the vicinity or connected to the same branch of the grid must not be affected in their function and reliability. Thirdly, contractors need to be able to guarantee the quality and durability of the PV systems.

Shortcuts or detours. Sometimes, a minimum effort is being made to fulfill the essential interference regulations. This approach can reduce initial cost and time to market for the equipment manufacturer. However, once up and running, a system may not be compatible with nearby consumers. Any attempt to upgrade the PV system at this point will result in downtime and additional costs.

This can be avoided by looking at the whole spectrum of potential interference problems right from the beginning. Little additional effort may be needed to cover all potential problems. Even though some frequency ranges are not subjected to (inter)national rules and regulations, interference in their bands may still affect surrounding equipment and sensitive electronics.

Solutions for the PV industry. Schaffner has more than 40 years experience in tackling interference and compliance problems associated with many different power electronic devices used in renewable energy systems, particularly with PV inverters. And we are proud to support industry leaders in Europe, North America, and Asia/Pacific in developing highly reliable and compliant renewable energy systems.



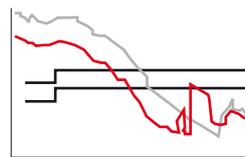
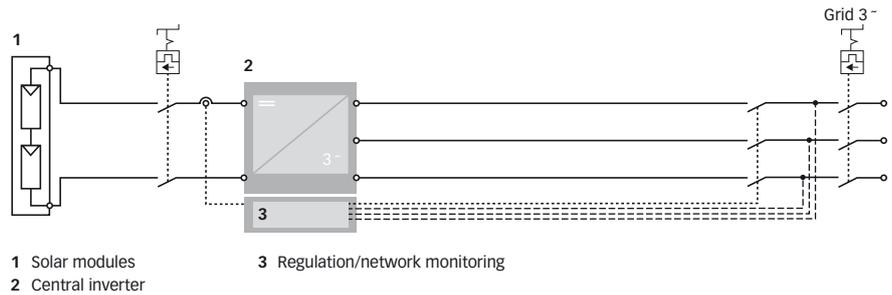
Benefits from engineered products. In addition to providing the broadest selection of off-the-shelf EMI and Power Quality components, Schaffner offers the full range of testing, engineering and custom design capabilities. Often these services are the key to the most cost-effective solution and the best match to system requirements.

Always near the customer. With five manufacturing sites in Europe and Asia as well as customer service and application centers in 15 locations around the globe, Schaffner is always in close contact with customers' design and application engineering centers.

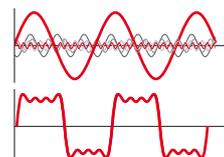


Grid interactive central three-phase PV inverters

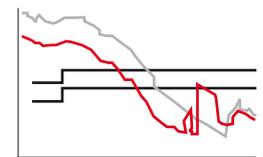
Every kind of switch-mode power converter produces a broadband interference spectrum and harmonics as a by-product of its operation. This also applies to PV inverters. Some or all of the adverse effects below can potentially occur:



EMI



Harmonics

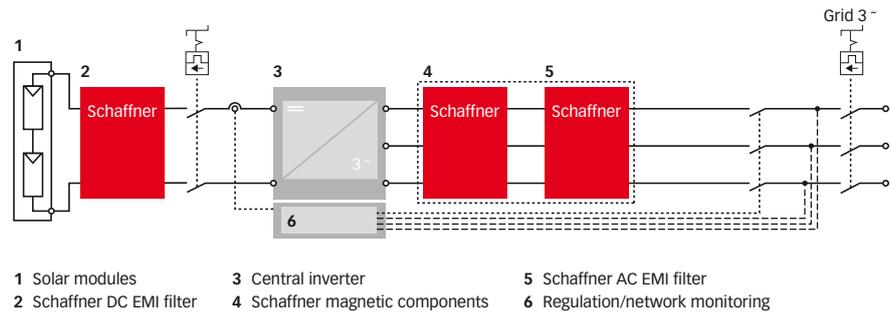


EMI

<p>DC side</p>	<ul style="list-style-type: none"> ■ Premature ageing of the solar panel due to superimposed high-frequency currents and leakage currents ■ EMI radiation off the solar panel beyond acceptable limits ■ Potentially negative influence on panel function and/or efficiency ■ Triggering malfunctions in nearby electronic equipment or within the system itself
<p>AC side</p>	<ul style="list-style-type: none"> ■ Noncompliance with electric utility codes ■ Noncompliance with national or international EMC and Power Quality standards ■ Triggering malfunctions in other grid-tied electric consumers

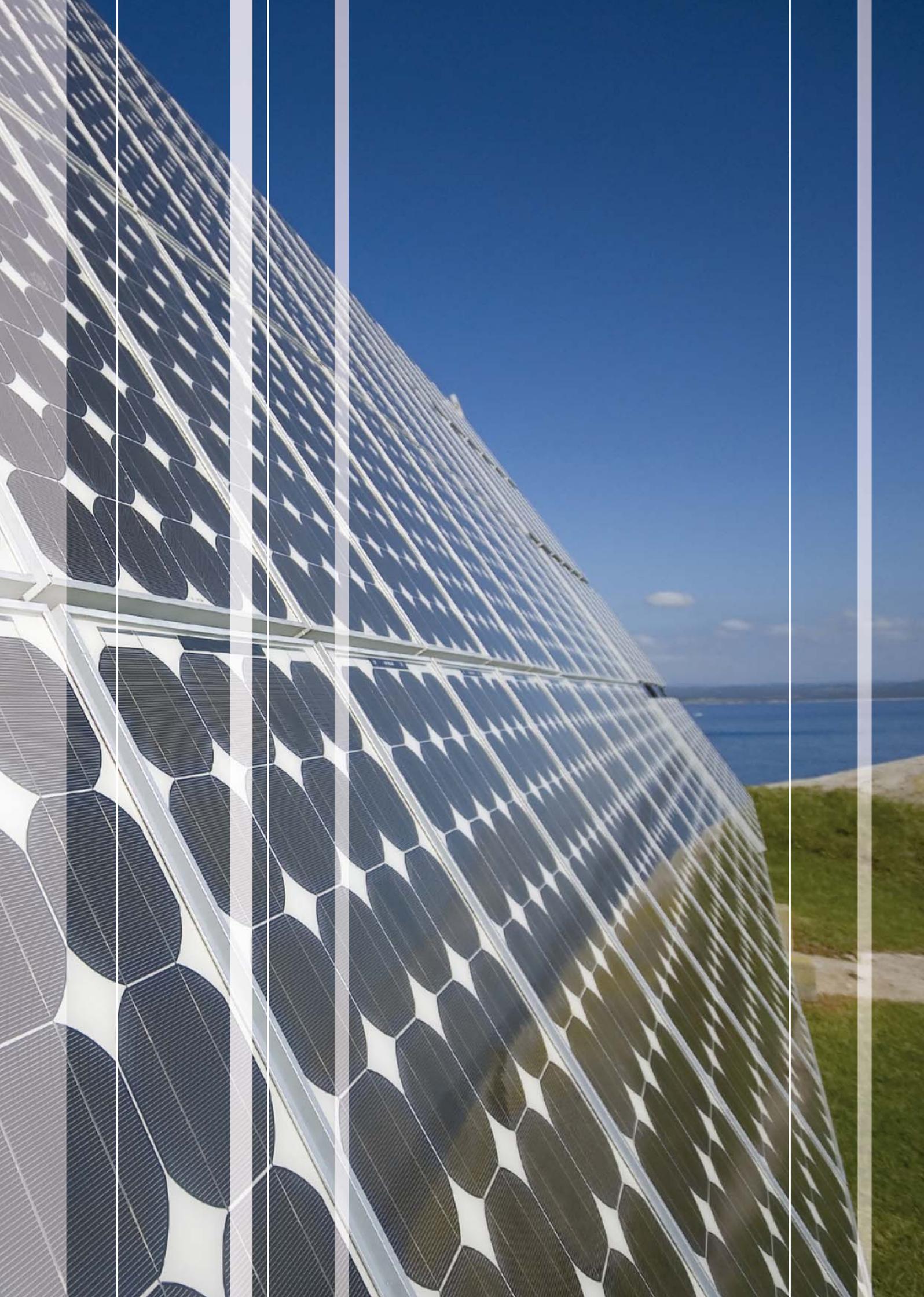


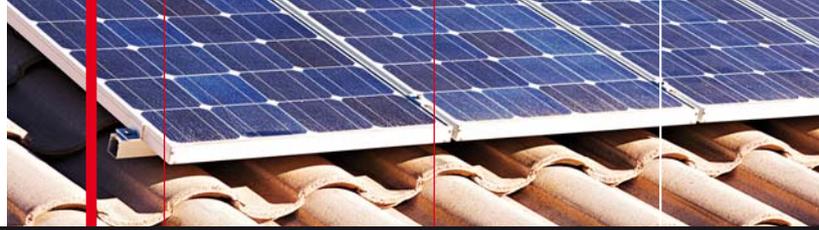
Manufacturers and users of PV inverters are not alone when confronting these challenges. Schaffner has already developed solution concepts for various problems. These concepts are successfully implemented in daily practice and resolve the issue of clean network connections for the user on a sustainable basis.



Schaffner solutions for three-phase PV inverters

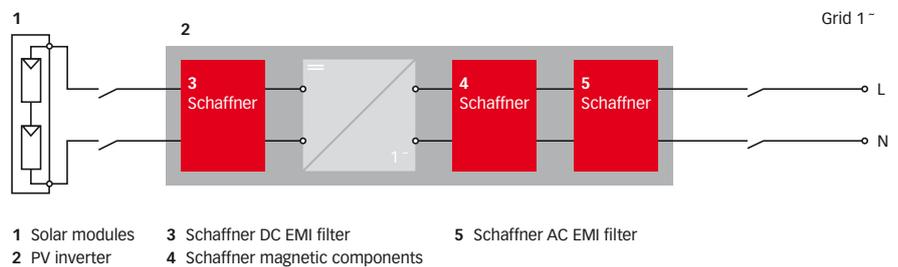
	Application	Products
<p>DC EMI filter</p> 	<p>DC filters are mainly used in latest generation transformerless inverters, where no galvanic separation is provided.</p> <ul style="list-style-type: none"> ■ De-coupling of solar panel and inverter ■ Reduction of conducted EMI towards the panel ■ Prevention of premature panel ageing ■ Prevention of radiation off the panel ■ Improvement of system reliability and efficiency 	<p>Custom designs with the following typical ratings.</p> <ul style="list-style-type: none"> ■ Voltage: Up to 1100VDC ■ Current: Up to 1500A ■ Ambient temp: Up to 70°C ■ Surge suppression on request ■ Approvals: UL, CSA, ENEC
<p>Magnetic components: Insulation transformer</p> 	<p>Used in traditional inverter concepts with galvanic separation or in combination with thin-film solar modules. Schaffner can uniquely combine the transformer and AC reactor into a single compact package.</p> <ul style="list-style-type: none"> ■ Combination of insulation, step-up, or step-down transformer and smoothing or filter reactor ■ Most mechanical and electric parameters are built to specification ■ Reduction in overall weight and volume ■ Reduction in wiring and installation time ■ Simplification of the power structure ■ Reduction in total cost of ownership 	<p>Custom designed to inverter requirements and specifications.</p> <ul style="list-style-type: none"> ■ Power: Up to 1000kVA ■ Primary: Up to 6000VAC ■ Secondary: To specification ■ Impedance: To specification ■ Insulation class: 200°C ■ Approvals: UL
<p>Magnetic components: AC reactor or sine wave filter</p> 	<p>AC reactors or sine wave filters help to smooth the inverter output signal towards the grid.</p> <ul style="list-style-type: none"> ■ De-coupling of PV inverter and grid ■ Signal smoothing towards the grid ■ Reduction of harmonics and LF interference ■ Fulfillment of utility codes 	<p>Custom designed to inverter requirements and specifications.</p> <ul style="list-style-type: none"> ■ Voltage: Up to 1000VAC ■ Current: Up to 1500A ■ Ambient temp: Up to 70°C ■ Approvals: UL
<p>AC EMI filter</p> 	<p>AC EMI filters should be used in all grid-tied inverter designs to protect the environment from electromagnetic pollution.</p> <ul style="list-style-type: none"> ■ Reduction of conducted EMI towards the grid ■ Fulfillment of international EMC/RFI regulations ■ Improvement of the reliability of nearby equipment 	<p>FN 3359 standard filters (also custom designs).</p> <ul style="list-style-type: none"> ■ Voltage: Up to 690VAC ■ Current: Up to 2500A ■ Ambient temp: 50°C ■ Surge suppression on request ■ Approvals: UL, CSA, ENEC





Grid interactive single-phase PV inverters/string inverters

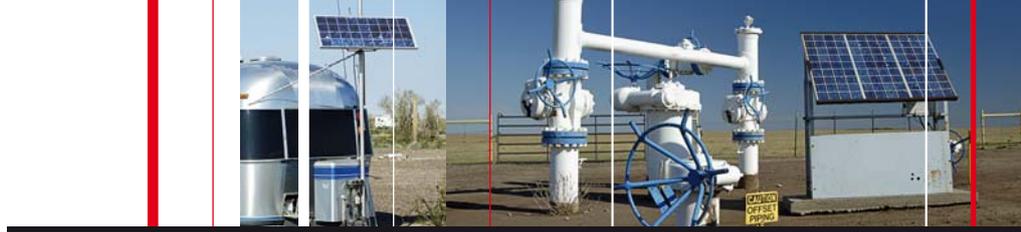
Grid interactive single-phase PV inverters are confronted with challenges that are similar to those described on the previous pages, but at lower power ratings and usually within much tighter space and cost constraints. Depending on the inverter concept and power rating, magnetics and filters can become board level components. Great care must be taken when replacing an enclosed filter with board level components in order to avoid unwanted magnetic and capacitive coupling.



Schaffner solutions for single-phase PV inverters

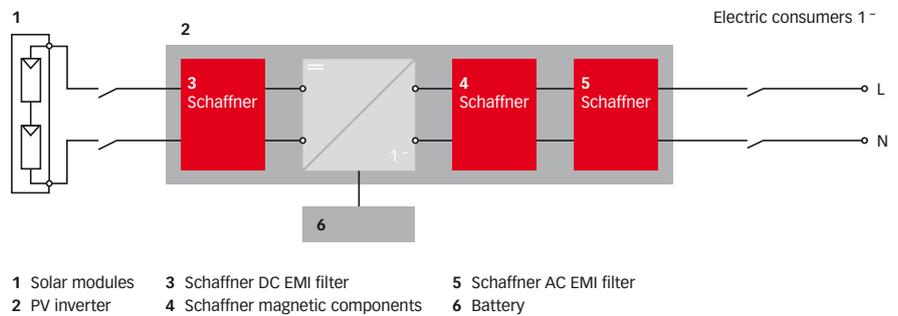
Application	Products	
<p>Single-phase AC EMI filters</p> 	<p>Single-phase AC EMI filters are an essential part of successful inverter design and application. They help to:</p> <ul style="list-style-type: none"> ■ Control conducted emissions ■ Meet international EMC/RFI standards ■ Help to achieve CE compliance 	<p>FN 2000 standard filters (also custom designs).</p> <ul style="list-style-type: none"> ■ Voltage: 250VAC ■ Current: Up to 60A ■ Various termination styles ■ Approvals: UL, CSA, ENEC
<p>DC EMI filters</p> 	<p>DC EMI filters protect the solar panel and support the PV system in meeting radiated emission standards.</p> <ul style="list-style-type: none"> ■ De-coupling of solar panel and inverter ■ Prevention of premature panel ageing ■ Prevention of radiation off the panel 	<p>Custom designs with the following typical ratings.</p> <ul style="list-style-type: none"> ■ Voltage: Up to 600VDC ■ Current: Up to 100A ■ Surge suppression on request ■ Approvals: UL, CSA, ENEC





Off-grid single-phase island inverters

Off-grid PV inverters represent a great power source in remote areas without access to a power grid. Without the interaction with a power grid, utility codes and Power Quality standards become less of an issue. However, since off-grid inverters supply very common electric and electronic consumers, and because the line impedance of the grid is entirely missing, the inverter output signal must be a pure sine wave, free of harmonics and high frequency components. This can only be achieved with appropriate filtering.



Schaffner solutions for off-grid PV inverters

	Application	Products
<p>Open frame filters</p> 	<p>Off-grid PV inverters are extremely compact, as are the required AC and DC filters. Open frame filters from Schaffner offer many benefits:</p> <ul style="list-style-type: none"> ■ Easy integration into the inverter ■ Space and cost savings compared to canned filters ■ Highly customizable 	<p>Built to inverter requirements, with the possibility of customization of:</p> <ul style="list-style-type: none"> ■ Size and shape ■ Electric ratings ■ Filter performance ■ Terminal style
<p>PCB filters</p> 	<p>EMI PCB filters allow fast integration directly on the inverter boards. They represent the most compact way of filtering for those who plan for international compliance already in the design phase.</p>	<p>FN 400 standard filters.</p> <ul style="list-style-type: none"> ■ Voltage: 250VAC ■ Current: Up to 10A ■ Approvals: UL, CSA, ENEC
<p>Discrete chokes</p> 	<p>In addition to complete filters, Schaffner also supplies board level RFI suppression chokes (common-mode chokes) to support PV inverter manufacturers who prefer to build their own board level filter circuits.</p>	<p>EV, EH, RN and RD standard chokes.</p> <ul style="list-style-type: none"> ■ Voltage: 250VAC ■ Current: Up to 16A ■ Inductance: Up to 100mH



Solutions beyond inverters

Photovoltaic tracking systems

Solar tracking systems are designed to extend the period of peak power generation of a PV system. By tracking the sun, more electricity can be harvested throughout the day, increasing the return on investment for owners who are feeding electricity back to the grid. The additional energy yield can be up to 25% greater than with fixed PV arrays. Simple 1-axis and more sophisticated 2-axis models are available. Some tracking systems feature intelligent controls involving sensitive electronics and an electric drive. EMI filters can make a significant contribution to the immunity of control electronics as well as to the reduction of conducted emissions by the drive.

Schaffner solutions for PV tracking systems

	Application	Products
<p>Single-phase EMI filters</p> 	<p>Single-phase EMI filters protect the power supply and control electronics of PV trackers from conducted high frequency interference that can potentially compromise the proper functioning and reliability.</p>	<p>FN 2000 standard filters.</p> <ul style="list-style-type: none"> <li>■ Voltage: 250VAC <li>■ Current: Up to 60A
<p>Three-phase EMI filters</p> 	<p>Three-phase EMI filters are used for PV trackers that are hooked up with a three-phase supply. They offer the same benefits as the single-phase EMI filters.</p>	<p>FN 3258 standard filters.</p> <ul style="list-style-type: none"> <li>■ Voltage: Up to 520VAC <li>■ Current: Up to 180A



Solutions beyond inverters

Photovoltaic manufacturing equipment

The manufacturing of high quality solar cells and modules involves many special processes and precision machinery. Interferences from within the machine or from the grid can cause production downtime and waste material. Schaffner filters can help to increase the reliability and availability of mission critical process automation equipment and machinery.

Note: For more details, please see the Schaffner documentation dedicated to the machinery market.

Schaffner solutions for PV manufacturing equipment

	Application	Products
<p>EMI filters</p> 	<p>Schaffner EMI filters help to increase the reliability of manufacturing equipment and get them in line with EMC requirements. Typically, three-phase four-wire filters including neutral line filtering are most efficient in machine design.</p>	<p>FN 3256 and FN 3280 standard filters.</p> <ul style="list-style-type: none"> ■ Voltage: Up to 520VAC ■ Current: Up to 200A ■ Different performance levels
<p>Harmonic filters</p> 	<p>Schaffner ECOSine™ harmonic filters reduce the total harmonic distortion (THID) in PV manufacturing equipment that uses six-pulse rectifiers and motor drives. They help to comply with IEEE 519 and support a more efficient use of electric power.</p>	<p>FN 3410 and FN 3412 standard filters.</p> <ul style="list-style-type: none"> ■ 50Hz filters: Up to 160kW ■ 60Hz filters: Up to 250HP ■ THID: <5%
<p>EMI output filters</p> 	<p>Schaffner EMI output filters are installed between drive and motor. They increase the operating life of electric motors, reduce conducted emissions along the motor cables and allow the use of unshielded cables. They can significantly increase the reliability of sensitive PV module or polysilicon manufacturing equipment.</p>	<p>FN 530 standard output filters.</p> <ul style="list-style-type: none"> ■ Voltage: Up to 500VAC ■ Current: Up 16A ■ Residual ripple: <5%



Worldwide presence, global experience, unique proximity to customers

Schaffner is in a unique position to support the PV industry with AC filters, DC filters, harmonic filters, and magnetic components, such as high efficiency transformers and reactors. We have been working with PV engineers for many years and gained valuable experience in making PV inverters and PV systems grid compliant and highly reliable.

In addition to offering the most comprehensive range of EMI filters, Power Quality products, and magnetic components, Schaffner supports design and application engineers with engineering advice, testing, trouble-shooting, and custom product design.

With 15 customer service and application centers around the world, Schaffner is always close to the customer. Our own manufacturing plants in Switzerland, Germany, Hungary, Thailand, and China allow us to build both highly specialized parts as well as high volume commodities. Being the largest EMI filter manufacturer in the world, our global procurement network ensures the lowest raw material costs in times of soaring copper and steel prices, savings that we pass on to our customers.

Please feel free to contact your local Schaffner partner any time to discuss how we can support you in dealing with your individual challenges in the dynamic PV marketplace.





energy efficiency and reliability

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