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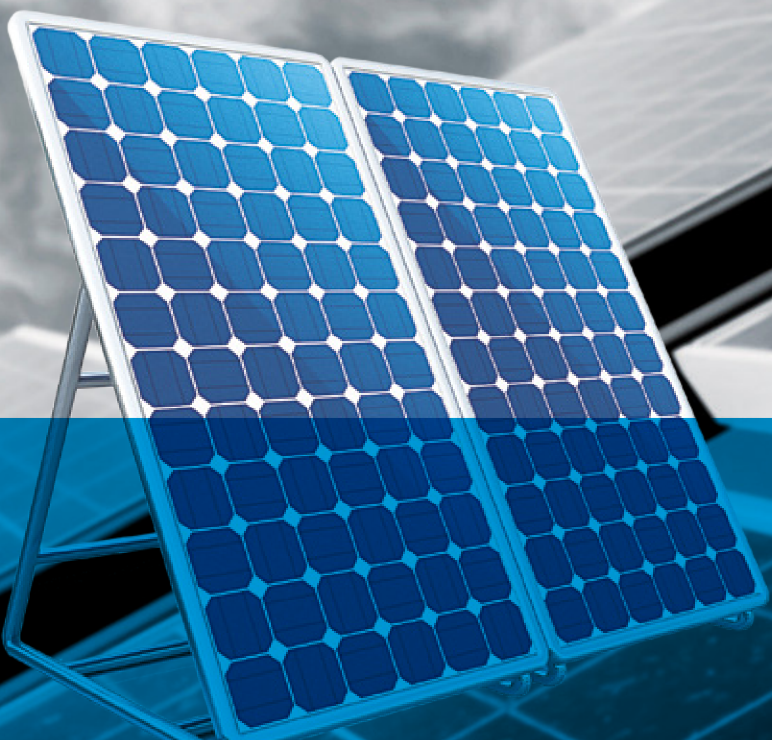


Ferrites in Renewable Energies: Solar Inverters

www.ferroxcube.com

Solar Inverters

- Reliability and efficiency are critical parameters on inverter design
- Optimum ferrite material selection for magnetic applications the design for cost saving, and performance improvement
- Support and flexibility to design custom product to customer requirements

Formerly, a Philips Components company we now belong to the Yageo Group, one of the world's strongest suppliers of passive components. As a leading supplier of ferrite components, FERROXCUBE has manufacturing operations, sales offices, and customer service centers all over the world.

We supply one of the broadest ranges of high-quality, innovative products and place strong emphasis on miniaturization of magnetic functions. Ferrite components and accessories from FERROXCUBE are used in a wide range of applications, from telecommunications and computing electronics through consumer electronic products to automotive.

Ferroxcube ferrites have achieved great penetration in renewable energies market thanks to its leadership in materials and shapes. The constant adaptation to the latest technologies is one of our main assets. Besides, we are working to offer outstanding solutions for the forthcoming development and expansion of renewable energy sources such as solar, wind power and smart grid.

Introduction

Enabling High-efficiency Renewable Energies

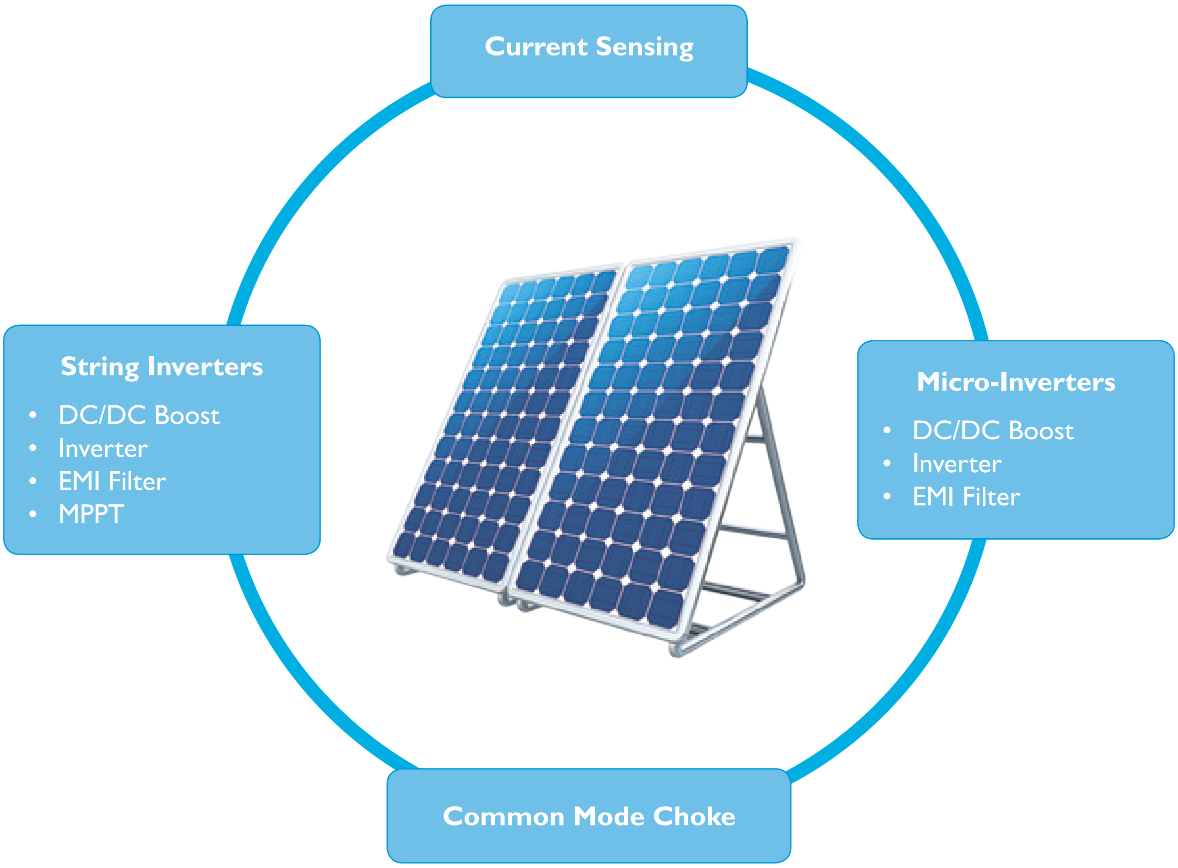
Power conversion from the generation source to the mains implies the use of different types of ferrites, especially in the case of solar inverters. Ferroxcube works to offer outstanding solutions for the forthcoming development and expansion of renewable energy installations such as solar and wind power, as well as hybrid technologies.

Ferroxcube ferrites have achieved great penetration in renewable energies market thanks to its leadership in materials and shapes. The constant adaption to the latest technologies is one of our main assets.

This application note shows what types of Ferroxcube materials and shapes are suitable for each part of the inverter, and highlights some of their features.

Requirements for Renewable Energy Applications

- Reliability and efficiency are critical parameters in inverter design
- Optimum ferrite material selection for magnetic applications in the design for cost saving, and performance improvement
- Support and flexibility in designing customized product to fulfill customer requirements

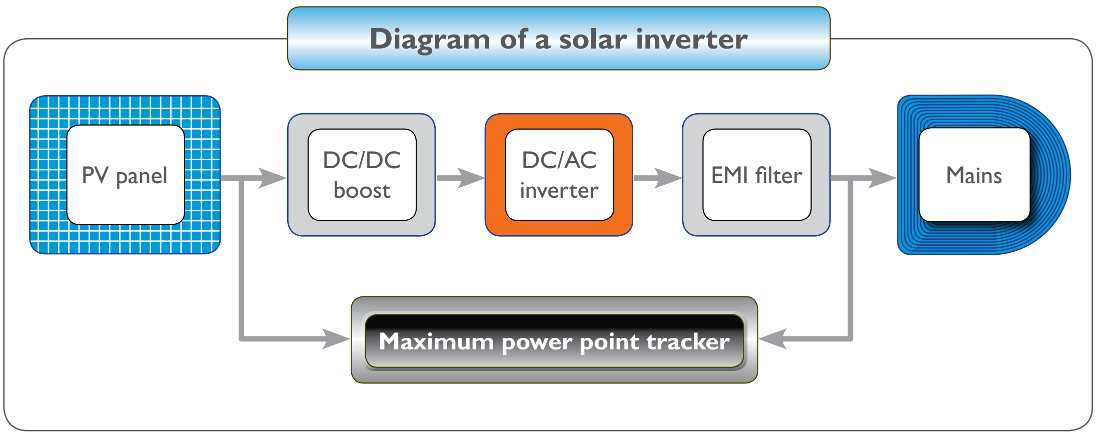


Applications

Solar Inverter Application Matrix	Function	Material Grade	Preferred Core Shape	Characteristics
String Inverter				
DC/DC boost	Boost inductor	3C95, 3C92, 3C90	Large E core Ferrite assembly	High saturation
	Transformer	3C95, 3C92	Large E core Ferrite assembly	Low loss
Inverter	Reactor	3C92, 3C90	Large E core Ferrite assembly	High saturation
EMI filter	Common mode choke	3E10, 3E27 4S2	Large toroid (> 42 mm)	High impedance
Maximum Power Point Tracker	Current sensor	3E10, 3E27	Gapped toroids, UU, custom	High perm., temp and B stable
Micro-Inverter				
DC/DC boost	Boost inductor	3C95, 3C92, 3C90, 3F36	Planar E, PQ, ETD	High saturation
	Transformer	3C95, 3C92, 3F36	Planar E, PQ, RM	Low loss
Inverter	Reactor	3C92, 3C90	Planar E, PQ, RM	High saturation
EMI filter	Common mode choke	3E10, 3E27, 4S2	Mid size toroids (14 to 25 mm)	High impedance

Ferrites in String Inverter

String inverters collect DC power from several solar panels (string of panels) and convert it to AC when transferring it to the grid. These inverters usually have the capability to drive several strings, adjusting the optimal conditions for each of the strings. The handling power varies from a few kilowatts (in domestic installations) to several hundreds on large scale plants.



There are several ferrite functions within the inverter: power conversion, EMI filtering and current sensing. The inverter can be split in 4 units:

• DC/DC converter :

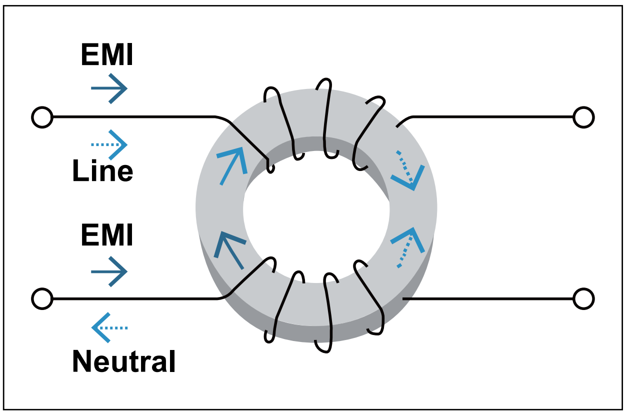
The DC/DC converter boosts the panel voltage up to a stable level high enough to let the inverter unit generate AC mains voltage. Preferred materials are 3C92 due to its high saturation flux (460 mT at 100°C), 3C95 with low loss over a wide temperature range and the cost competitive 3C90. Depending on the power, the shape can be a large E core, but also large assemblies with a distributed gap. In case galvanic isolation is needed, it is possible to implement a transformer.

• Inverter :

The inverter converts the DC power coming from the DC/DC boost to AC mains level voltage. An inductive reactor is used to smooth the wave generated by the switches. Again, a distributed airgap core made out of 3C92 with its high saturation is the preferred solution.

• EMI filtering :

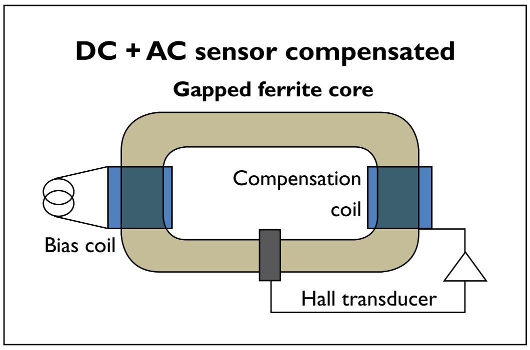
A common mode choke filters the line and neutral wire to supply a clean signal to the grid. This CMC consists of a current compensated magnetic circuit, in which the primary and the secondary are the line and neutral wire respectively. Optimal shapes for this function are toroids or any other closed magnetic circuit (without a gap). Feroxcube offers a wide range of toroid sizes. High permeability materials (3E10, 3E27) are optimal for EMI suppression at low frequency where the Electromagnetic Compatibility (EMC) regulations are more stringent. High frequency (up to 300 MHz) noise can be suppressed with 4S2 cores.



Typical shape starts at 42 mm diameter (for domestic inverters) growing to large toroids which can be even stacked in the high power systems.

• Maximum Power Point Tracker:

The inverter adjusts continuously the working conditions of the DC/DC converter in such a way that the panels supply the maximum power. This is accomplished measuring the input and output current of the system. Hall effect sensors mounted on gapped ferrite cores provide an accurate and reliable current measurement. Using a bias coil and a compensation coil the current sensor gets its maximum accuracy, as linearity and thermal drifts are almost compensated.



Ferrites in Micro-inverters

Micro-inverters are installed in each panel to generate the maximum power from each of them. AC can be generated in the micro-inverter, or in a high power system for the complete installation. But in any case, basic operation of the unit is similar to what was described for string inverters.

Power handling is in the range of 300 watts. This implies:

- Higher switching frequencies are possible. Preferred materials will be 3C95 (<400 kHz) and 3F36 (>400 kHz) due to their optimal performance under a wide temperature range.
- Core size is smaller because of the lower power, but also because of the higher frequency. Typical sizes will be PQ32 or planar E38, but size of the core depends strongly on the switching frequency.

EMI suppression requires smaller toroid sizes than in string inverter. Commonly 14 mm to 25 mm toroids are optimal.

Preferred Materials

Power conversion materials: Low frequency

- Low frequency: <300 kHz
- Thermal stable: 3C95
- Optimized for 100C: 3C98
- High saturation: 3C92
- Cost effective: 3C90

Symbol	Conditions	Value				Unit
		3C90	3C92	3C95	3C98	
μi	25°C ,10 kHz , 0.25 mT	2300 ±20%	1500 ±20%	3000 ±20%	2500 ±20%	
μa	100°C, 25 kHz, 200 mT	≈ 5500	≈ 5000	≈ 5000	≈ 5500	
Bsat	25°C ,10 kHz ,1.2 kA/m	≈ 470	≈ 540	≈ 530	≈ 530	mT
	10°C ,10 kHz ,1.2 kA/m	≈ 380	≈ 460	≈ 410	≈ 440	
Pv	100°C, 100 kHz , 100 mT	≈ 80	≈ 50	≈ 40	≈ 35	kw/m^3
	100°C, 100 kHz , 200 mT	≈ 450	≈ 350	≈ 290	≈ 250	
ρ	25°C, DC	≈ 5	≈ 5	≈ 5	≈ 8	Ωm
T_c		≥ 220	≥ 280	≥ 215	≥ 230	°C
Density		≈ 4800	≈ 4800	≈ 4800	≈ 4850	kg/m^3

Power conversion materials: High frequency

- High frequency: >300 kHz
- Improved temperature performance

Symbol	Conditions	Value	Unit
		3F36	
μi	25°C ,10 kHz , 0.25 mT	1600 ±20%	
μa	100°C, 25 kHz, 200 mT	≈ 2400	
Bsat	25°C ,10 kHz ,1.2 kA/m	≈ 520	mT
	10°C ,10 kHz ,1.2 kA/m	≈ 420	
P_V	100°C, 500 kHz , 50 mT	≈ 90	kw/m^3
	25°C, 500 kHz , 100 mT		
	100°C, 500 kHz , 100 mT	≈ 700	
ρ	25°C, DC	≈ 8	Ωm
T_C		≥ 230	°C
Density		≈ 4750	kg/m^3

EMI suppression materials

- 4S2F: High frequency EMI suppression
- 3E27: High Tc, low frequency EMI suppression
- 3E10: Low frequency, high impedance EMI suppression

Symbol	Conditions		Value		Unit
		3E10	3E27	4S2	
μi	25 °C; ≤10 kHz, 0.25 mT	10000±20%	6000±20%	≈ 850	
Bsat	25 °C; 10 kHz, 1200 A/m	≈ 460	≈ 430	≈ 340	mT
	100 °C; 10 kHz, 1200 A/m	≈ 270	≈ 270	≈ 230	
tanδ/μi	25 °C; 30 kHz; 0.25 mT	$\leq 5 \times 10^{-6}$			
	25 °C; 100 kHz; 0.25 mT	$\leq 20 \times 10^{-6}$			
η_B	25 °C; 10 kHz; 1.5 to 3 mT	$\leq 0.5 \times 10^{-3}$	$\leq 5 \times 10^{-6}$		T^{-1}
ρ	DC; 25 °C	≈ 0.5	≈ 0.5	$\approx 10^5$	Ωm
T_C		≥130	≥150	≥125	°C
Density		≈ 5000	≈ 4800	≈ 5000	kg/m^3

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