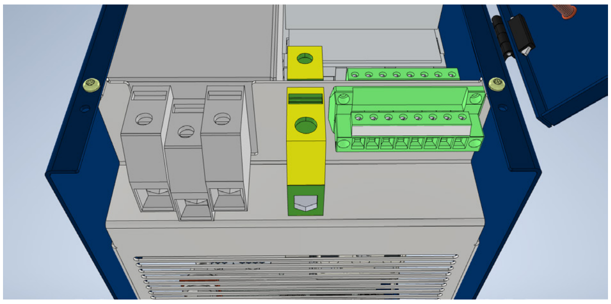
FE-SI Voltage-regulating filter

Active harmonic filter voltage-controlled



FE-SI, the latest development from FRANKE Elektrotechnik e.K., is setting new standards in power quality. The heart of the active-, rectifier is a modern and low-loss semiconductor technology based on silicon carbide (SiC).

The FE-SI product integrates the following functions.

1. damping function: elimination of resonances and broadband reduction of interference levels

2. filter function: targeted, discrete filtering of the 5th, 7th, 11th 13th, 17th, 19th, 23th and 25 th and higher harmonics

3. Reactive power compensation: low-loss and highly dynamic, capacitive and inductive

FE-SI is mainly used when filtering over a wide frequency range is required. The low-loss damping function eliminates in particular higherfrequency distortions of the mains voltage as well as oscillations in the mains. This can be, for example, a network resonance that cannot be eliminated with an or-dinary LC-circuit. The resonance point is merely shifted to a higher frequency with such a filter. Even conventional, currentcontrolled active filters cannot effectively counteract resonance-induced voltage levels. The FE-SI-active rectifier, on the other hand, simulates the behavior of a resistor for all fre-quencies except the fundamental.

This patented control method introduces damping into the power system and can thus eliminate resonances and reduce voltage levels over a wide frequency range. Compared to a real resistor, FE-SI does not convert the absorbed active power into dissipated power - i.e. heat. Instead, it is extracted from the harmonics and fed back into the network node in the form of fundamental active power. The patented control method thus effects a local energy recycling directly at the connection point.

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Introduction

Theoretically, AC voltage from the mains has a perfect sine wave. In practice, real loads cause deviations, called harmonic voltage distortions (harmonics), whose frequency are integer multiples of the fundamental frequency. In combination with the higher-frequency voltage distortions (supra-harmonics) that have been immensely stressing our grid in recent years, this can lead to an electrical super-disaster. The problem is that every self-controlled power converter installed in the grid feeds clock frequencies of its installed power electronics into the grid as supra-harmonic disturbances. In order to detect and stop this impending and unpredictable “grid infarction” at an early stage, the grid must be damped by an additionally introduced ohmic resistor, because the immensely increasing proportion of non-ohmic consumers in our grids also leads to increasingly pronounced interactions. Our broadband filter technology FR-SI provides a remedy here.

The FE-SI product integrates the following two functions

1. damping of power supply networks for broadband reduction of interference levels
2. low-loss and highly dynamic reactive current compensation (capacitive and inductive).

FE-SI is primarily used when broadband filtering over a wide frequency range is required. The FE-SI active rectifier simulates the behaviour of a resistor for all frequencies except the fundamental. This patented control method introduces damping into the power system and can thus eliminate resonances and reduce voltage levels over a broad band. Compared to a real resistor, FE-SI does not convert the absorbed active power into dissipated power – i.e. heat. Instead, it is extracted from the harmonics and fed back into the network node in the form of fundamental active power. The patented control method thus causes a local energy recycling directly at the grid node.

Advantages

- Very low losses due to the use of highly efficient silicon carbide semiconductor technology
- Broadband mains filter effect due to the combination of mains filter and damping resistor in one system
- No power loss due to local energy recycling at the grid hub
- Patented system

THE SCOPE

FE-SI is primarily used where classic passive and active filters reach their limits. Figure 1 shows a typical application. The voltage characteristic of frequency inverters characteristic of frequency converters (flat topping) are superimposed with higher-frequencyoscillations are superimposed. By combining broadband damping and discrete filtering, FE-SI reduces both low-frequency and higherfrequency oscillations and eliminates resonance-related interference levels. FE-SI can also reduce the effects of commutation dips (see Fig. 2).

Capacitances distributed in the network, e.g. long cables, input filters of converters or unchoked compensations, form a resonance together with the feeding transformer. If a resonance point exists, even a small current can lead to high interference voltage levels.

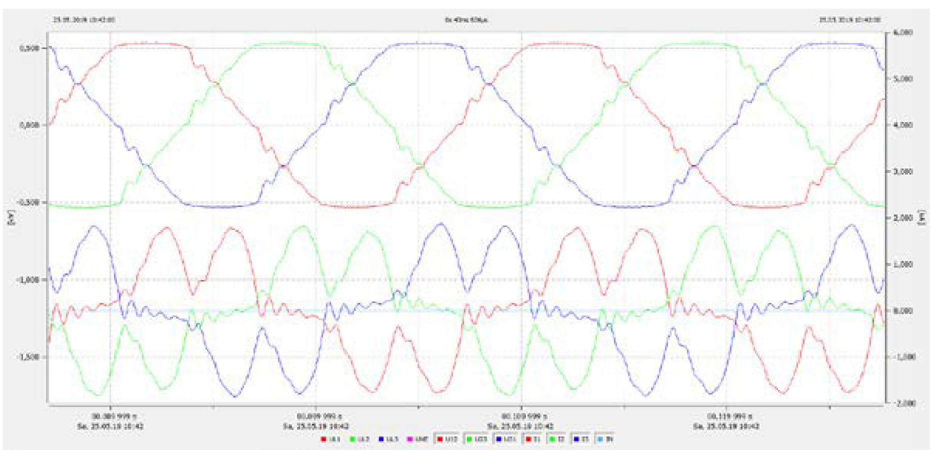


Fig. 1
Typical voltage and current characteristics in a large industrial printing plant

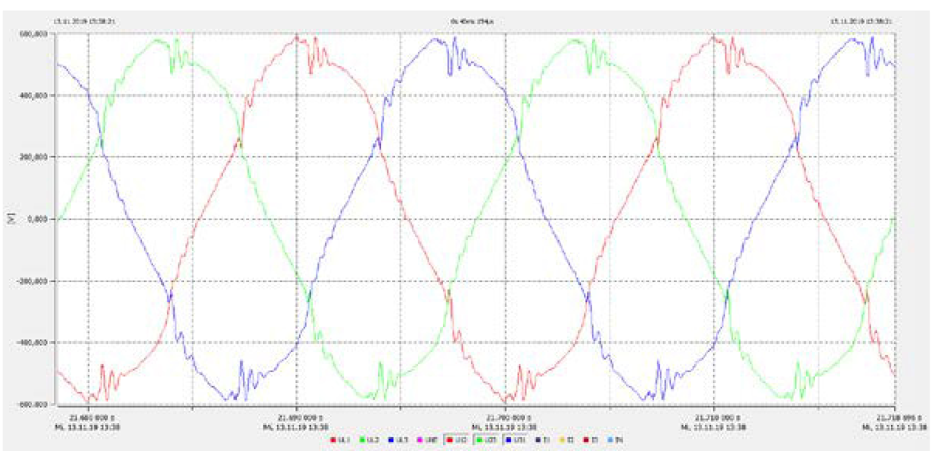
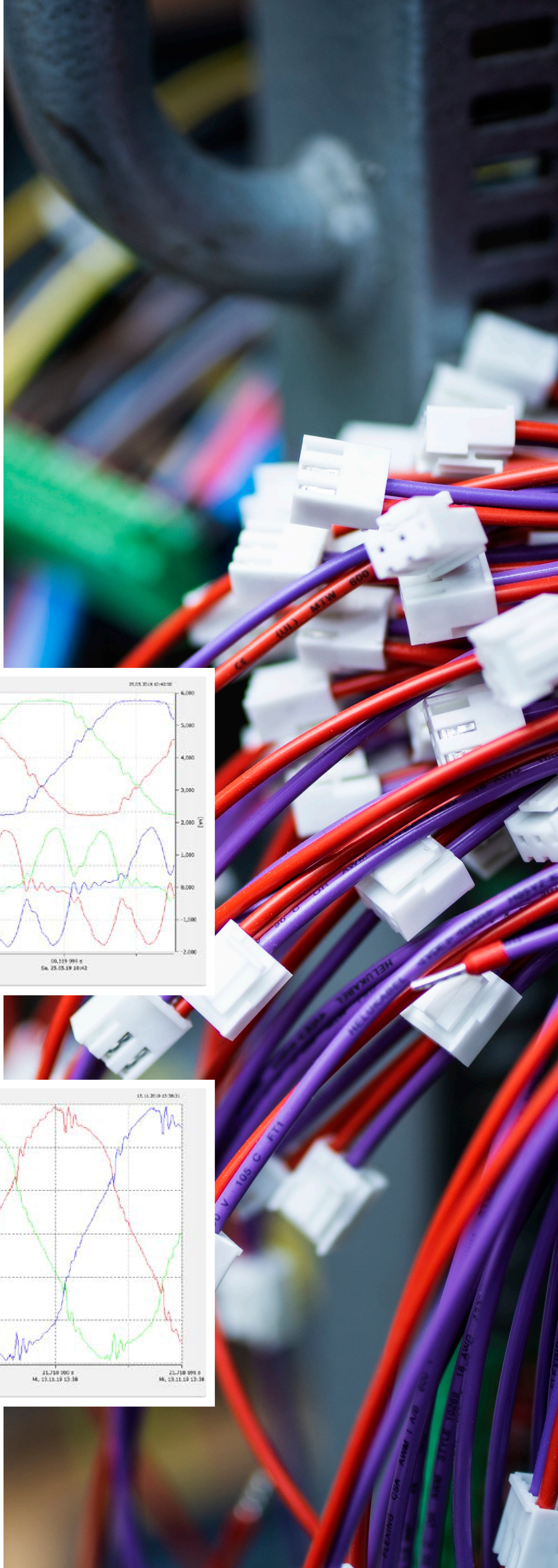
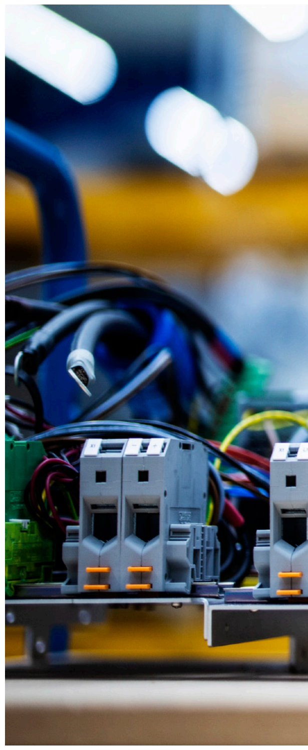


Fig. 2
Commutation notches in an industrial battery factory



FE-SI-Voltage-regulating filter



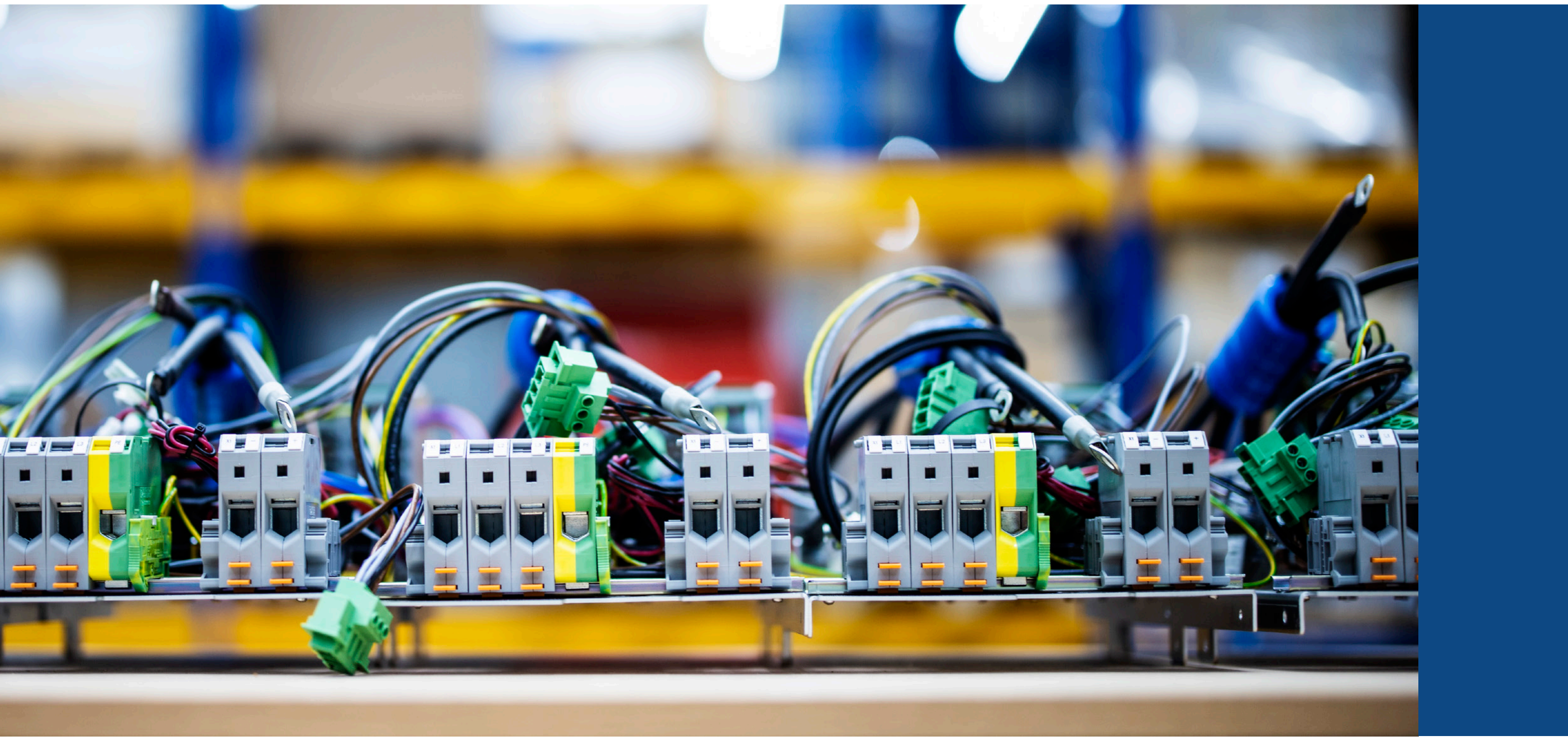
ADVANTAGES OF SILICONCARBIDE (SiC)

Silicon carbide is considered a wide bandgap semiconductor. This energy gap between valence and conduction band significantly determines the properties of the semiconductor material. SiC differs from silicon as follows:

Properties	SiC	compared to Si	Effects
Energy band-gap	3,26 eV	Triple	Higher Temperature working range
Electrical breakdown field strength	3 MV /cm	Tenfold	Smaller $R_{DS\,on}$ Lower conduction losses
Saturation drift	2 · 107 cm/s	Double	higher switching speed / lower switching losses
Thermal conductivity	4 . 5 W/cm · K	Triple	Excellent thermal Conductor

Dampingeffect

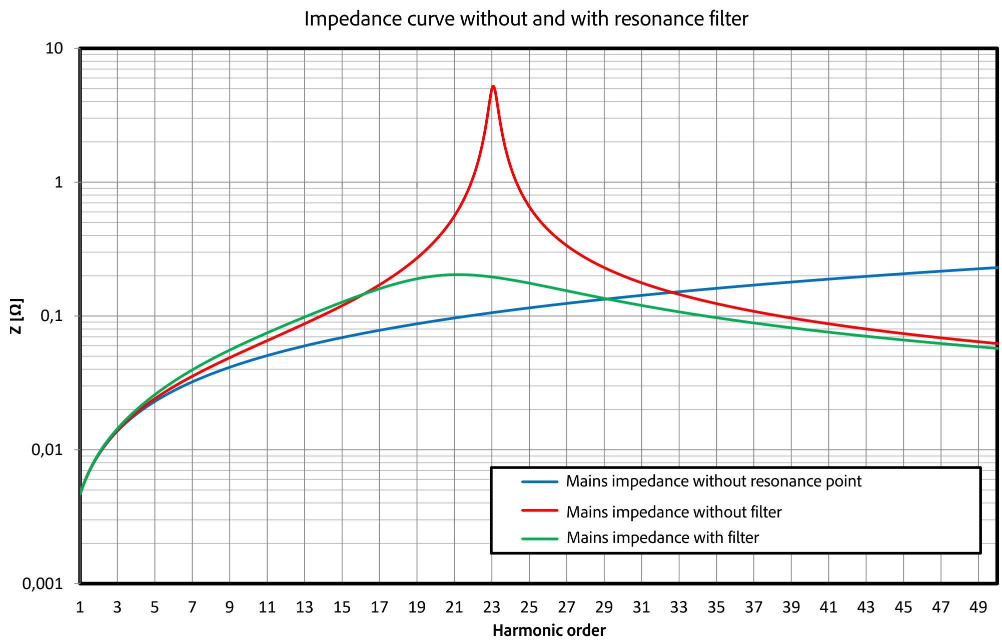
The unique damping function of FE-SI simulates the behaviour of a resistor and thus damps resonance-related increases in the network impedance effectively and in a loss-optimized manner, as shown in Figure 4. The red curve shows the impedance of a network (from the perspective of low-voltage distribution) with a 1 MVA transformer and a capacitance of 350 µF. The green curve shows the same network after adding a FE-SI filter with a simulated resistance of 300 mΩ.



LOCAL ENERGY RECYCLING FUNCTION

Via the patented control algorithm, a filter current is fed into the network at the connection point, which extracts active power from the harmonics and feeds it back into the network in the form of the fundamental (as fundamental active power). The recovered harmonic power can be calculated as follows:
$P_{FE\text{-}SI} = \sqrt{3} \cdot THD_U \cdot U \cdot I_{FE\text{-}SI}$

For a 400 V grid with a typical THDU (Total Harmonic Distorti on / harmonic distortion, in this case of voltage U) of about 5%, the use of a 120 A FE-SI results in about 4.2 kW of recycled harmonic active power. Less the losses of 1 kW, 3.2 kW can be fed back into the grid with the fundamental frequency.



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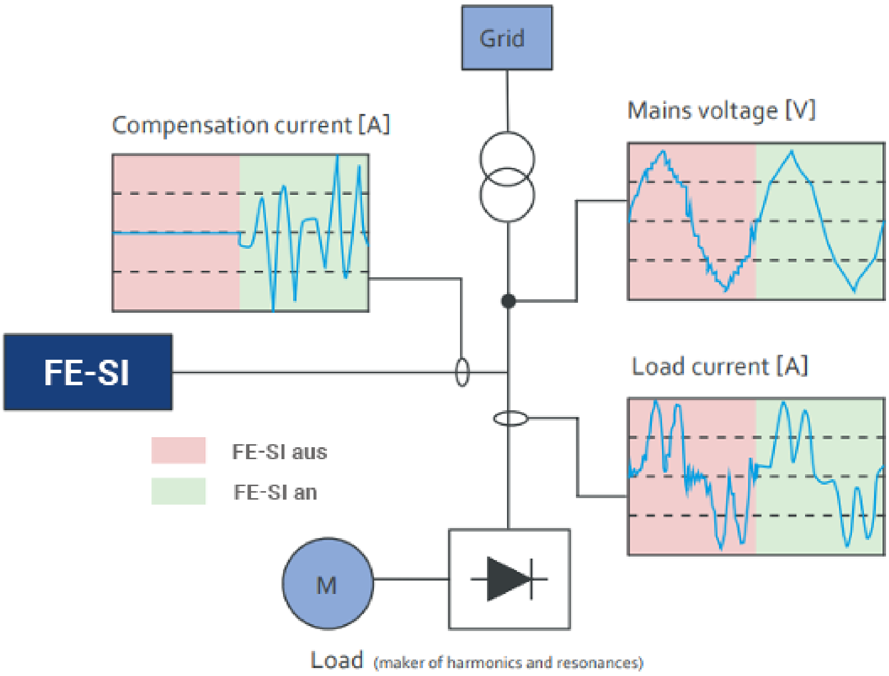
OPERATING PRINCIPLE



Damping function: FE-SI records the mains voltage via an integrated measuring device and uses it to calculate the harmonic voltage. Using this harmonic voltage and the simulated FE-SI resistance is then used to determine the current that the system must generate in order to achieve the same effect in the effect as a real resistor in the network.

Exactly this current is then fed into the grid by FE-SI. The filter is therefore able to actively simulate a passive damping resistor. FE-SI not only filters not only filters discrete harmonic orders, but also has a broadband effect on all frequencies. The network is thus damped, resonances and interference levels in the voltage are reduced. In addition voltage distortions are also smoothed out due to this property, not directly caused by a current, such as switching operations or commutation. Switching operations or commutation dips. As this is a purely voltage-controlled filter, no current transformers are required for filter operation. required for filter operation. These are only required if additional dynamically controlled reactive current is to be provided.

TECHNICAL DATA – FE-SI Voltage-regulating filter

Rated voltage	400 V	
Rated frequency	50 Hz	
Filter current	120 A	
Rated Power	83 kVA	
Peak current	400 A	
Crest factor	3,3	
Functions	Damping of resonances, commutation notches and transients Reduction of THD_U Discrete filtering of typical harmonics: - H5, H7, H11, H13, H17, H19, H23, H25 Reactive Power Compensation (cap & ind) Local Recycling of Harmonic Power	
	Active filter	**Reactive power operation**
Efficiency *over the entire load range*	>98%	>99%
Power losses *Maximum losses for cooling design*	< 1660 W	< 830 W
Topology	2-level active rectifier	
Semiconductors	Silicon carbide (MOSFETs)	
DC-Link	Film capacitors	
Switching frequency	20 kHz	
Reaction time	< 50 µs	
Ambient temperature	0 °C (min.), 40 °C (max.)	
Noise Level	< 67 dB(A)	
Cooling mode	forced air cooling	
Protection class	IP20	
Dimensions	228 mm x 450 mm x 1512 mm	
Weight	100 Kg	
Color	RAL 5017	
Type of mains	3 Phases + PE, without N conductor (TN-/TT-Netz)	
Cable infeed	from bottom	
Interfaces	Web server Modbus (TCP/IP) HTTP API- endpoint	
On-site fuse protection	160 A gG	
Connection cross-section	3 x 50 mm² + 1x 35 mm² (NSHXAFÖ)	
optional	with internal fuse protection 160 A gG on-site fuse protection 200 A gG	