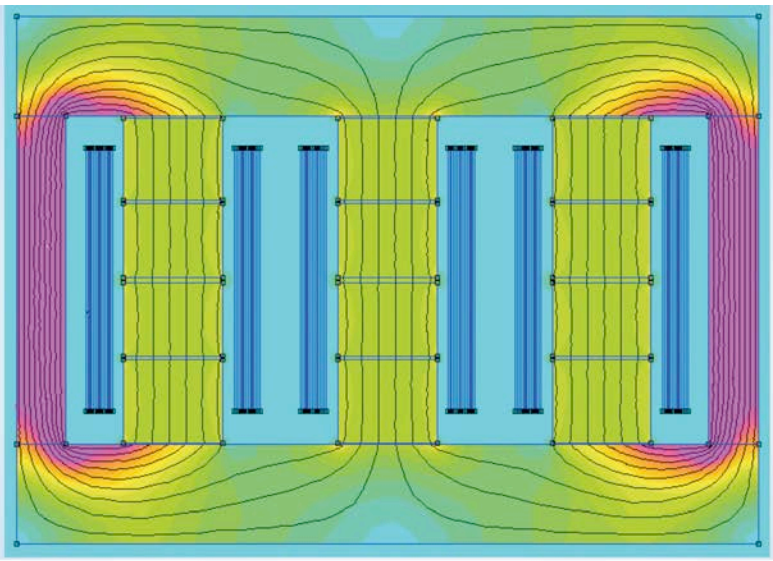
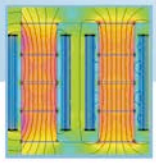
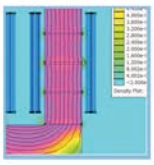
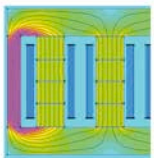








The use of 5-core chokes with common-mode noise

A comparison with alternative solutions

Pure|Power|Perfection

Contents

Contents

1. Introduction

In order to be able to transfer large loads using low voltage inverters, they are increasingly connected in parallel nowadays. Thus, the current load of the individual inverters is less, and it is also possible to use high switching frequencies that enable a sinusoidal current with a low THDI (Total Harmonic Distortion) to be produced from the start. At first, this may sound very good and advantageous. However, this also means that the downstream elements must meet specific requirements.

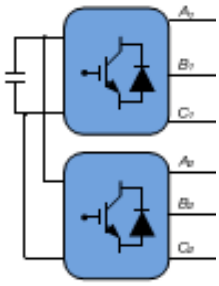


Fig. 1: When inverters are connected in parallel, there are compensating currents which flow between them and result in so-called common-mode interference

One of these is common-mode noise which can occur due to parallel connected inverters and the resulting fluctuating intermediate circuit voltages. For smooth operation, this must be filtered, because especially in applications where the load is connected in delta, the common-mode noise leads to an unbalanced power supply.

The solution is a current-compensated choke that has a high inductance for the currents from common-mode noise, thereby attenuating them. Finally, the parasitic currents are eliminated by connecting capacitors to earth downstream of the choke. At the same time the rated current for a current-compensated choke can flow through the choke virtually unhindered. However, this is undesirable when operating an inverter because the choke must also have a defined inductance in order to smooth out the rated current. Consequently, the choke must be designed so that both application cases can occur simultaneously. This document examines this topic in typical three-phase core sections.

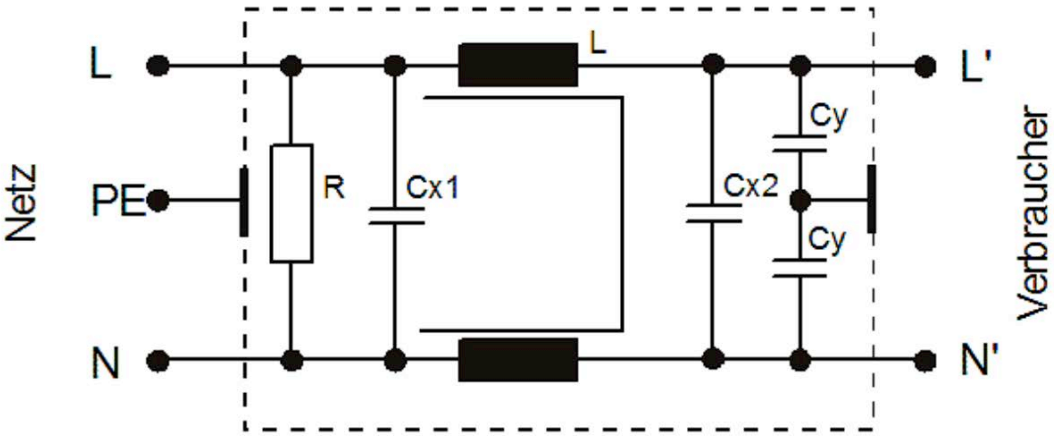


Fig. 2: Application example of a current-compensated radio frequency interference choke

2. Current-compensated choke

Here the supply and return conductor are wound around a common core, so that the rated current in the core is compensated and the effective inductance of this is very low. However, the high frequency, common-mode current has the same direction in both phases and is guided through the core.
This results in a much higher inductance for the interference current and this is attenuated. The choke core is designed for the common-mode current accordingly. The design is illustrated more clearly in Fig. 1.

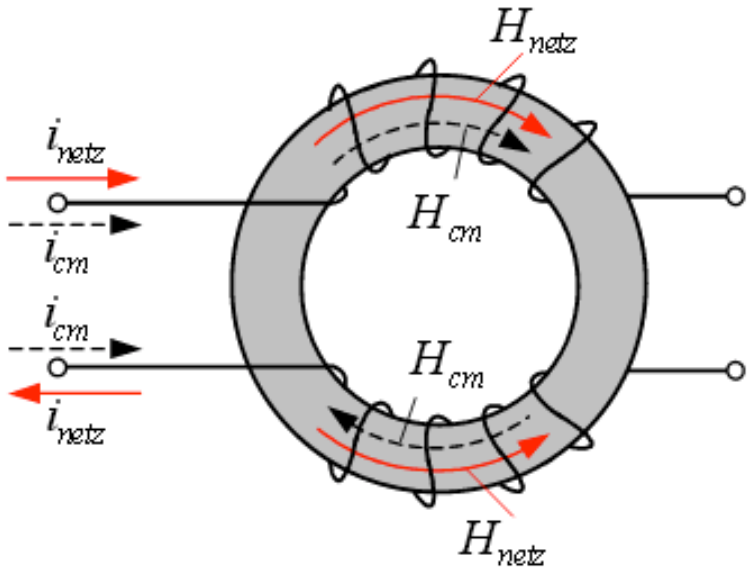


Fig. 3: Functional principle of the current-compensated choke

It is, of course, also possible to design the current-compensated choke for a three-phase mains system. In this case, the windings of the respective phase with the same winding direction are placed on a round core and connected accordingly.

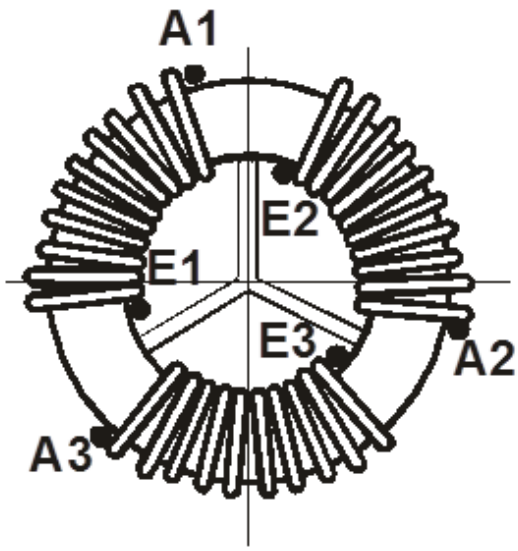


Fig. 4: Three-phase current-compensated choke

3. Common-mode noise for different core sections

When using inverters, chokes are often used to reduce the residual ripple of the rated current. Depending on the application, a specified inductance is required for this. In order to find the best solution for eliminating common mode noise during inverter operation, we will examine the following standard core sections of three-phase applications for their suitability and compare them with each other.

First, the problem of three single-phase chokes on one UI core is considered. This is followed by a 3-column core and finally a 5-column core.

In all cases, it must be ensured that as many magnetic field lines in the choke core as possible close. If these fields are leaked from the core and hit metals, they induce very high losses there. This effect can lead to the destruction of the component.

To better illustrate this, the common-mode noise and nominal operating conditions are considered separately. The pros and cons of each solution are mentioned in the appropriate section and evaluated in the conclusion.

3.1. Single-phase choke with UI core section

A simple and proven solution for controlling common-mode noise is to use a single-phase choke. Due to the design of the winding of these chokes, the core load is then indeed higher, but it cannot leak any field lines.

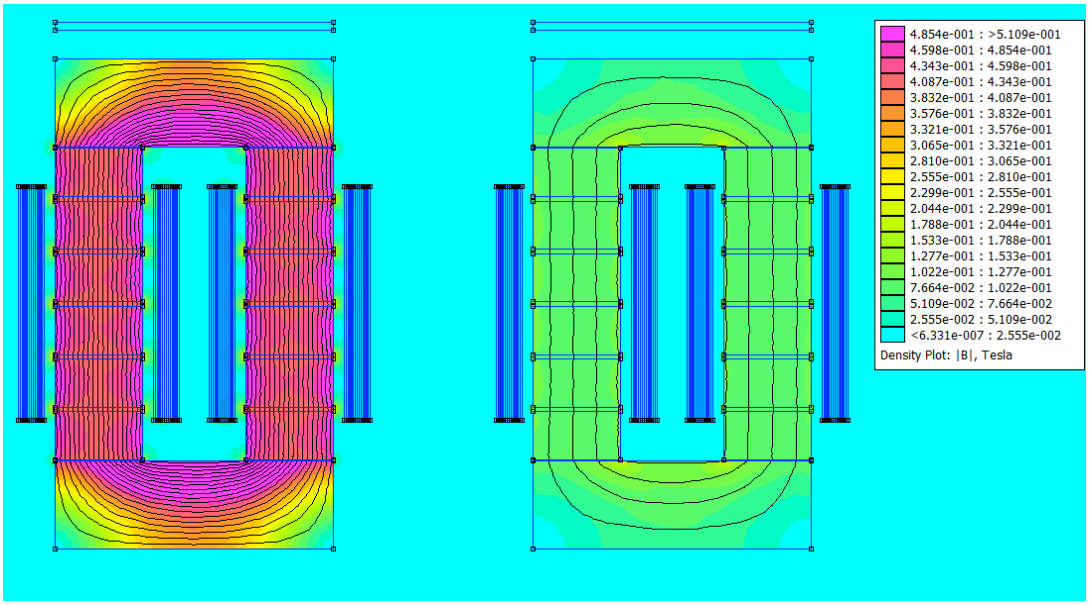


Fig. 5: Comparison of nominal operation (left) and common-mode noise (right) for a UI core

A disadvantage of this solution is that it requires the most space in comparison to the two following alternatives.

3.2. Three-phase choke with 3UI-core section (3-column choke)

The 3UI core section is most commonly used in three-phase systems. Because of its design, very compact and affordable solutions can be implemented. Thanks to the rotating field of the electric currents in nominal operation, it is ensured that the field lines are guided into the core (see 4).

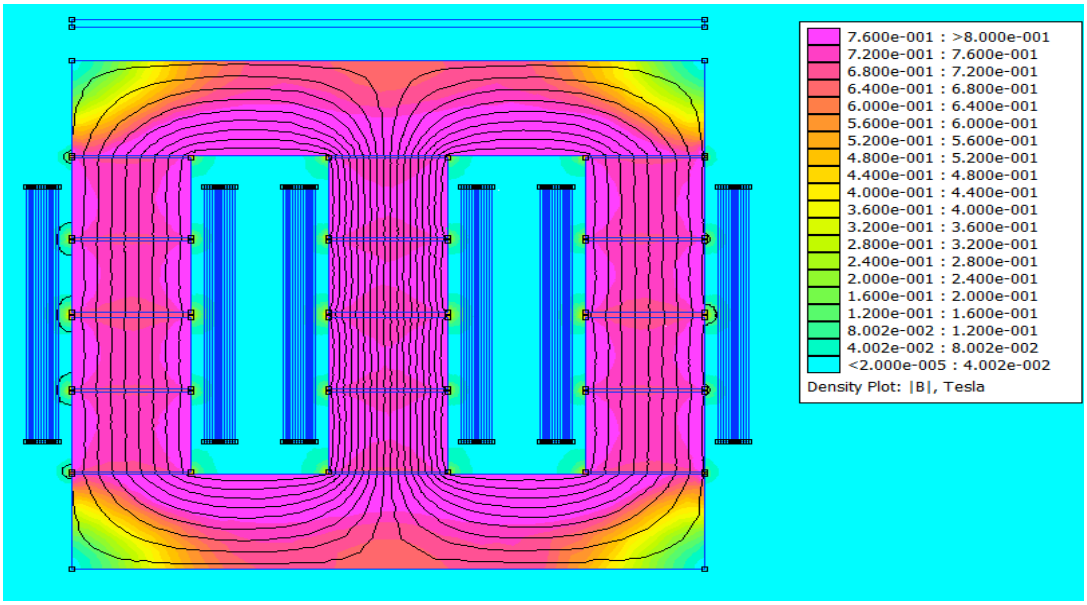


Fig. 6: 3-core choke in normal operation

The situation is different, however, if there is a common-mode noise whose phase position is the same in all three phases at any time. In this case, the entire core becomes a magnet, and the field lines, which were previously guided in the core leak out. This effect, which already occurs at low currents, is generally undesirable and must be avoided. The result is that magnetic field lines, which can lead to strong heating flow through the metallic parts outside the core (see Fig. 5). There, the eddy currents can cause the metallic parts, such as end plates, to heat up to the extent that damage to the whole component is inevitable.

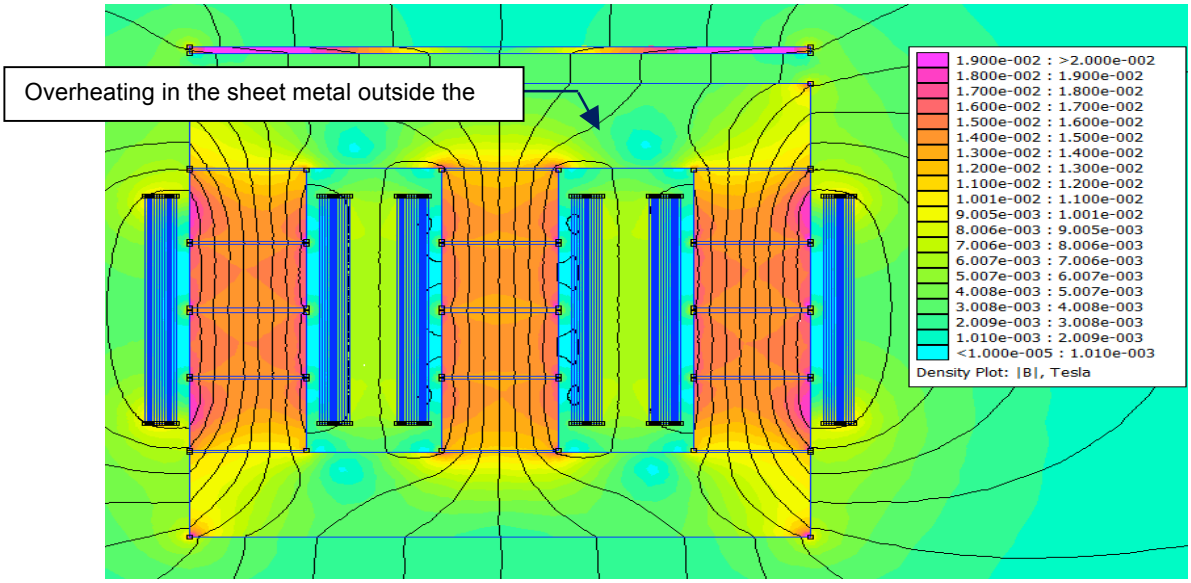


Fig. 7: 3-core choke with common-mode noise

The results clearly show that this core section is unsuitable for an application with common-mode noise.

3.3. Three-phase choke with 5-column core

By examining the distribution of the field lines in nominal operation (6), we see that the field lines have the same course as the 3-column core. The effect of the additional columns is that, in the event of common-mode noise, a path with a lower magnetic resistance than the air resistance is available.

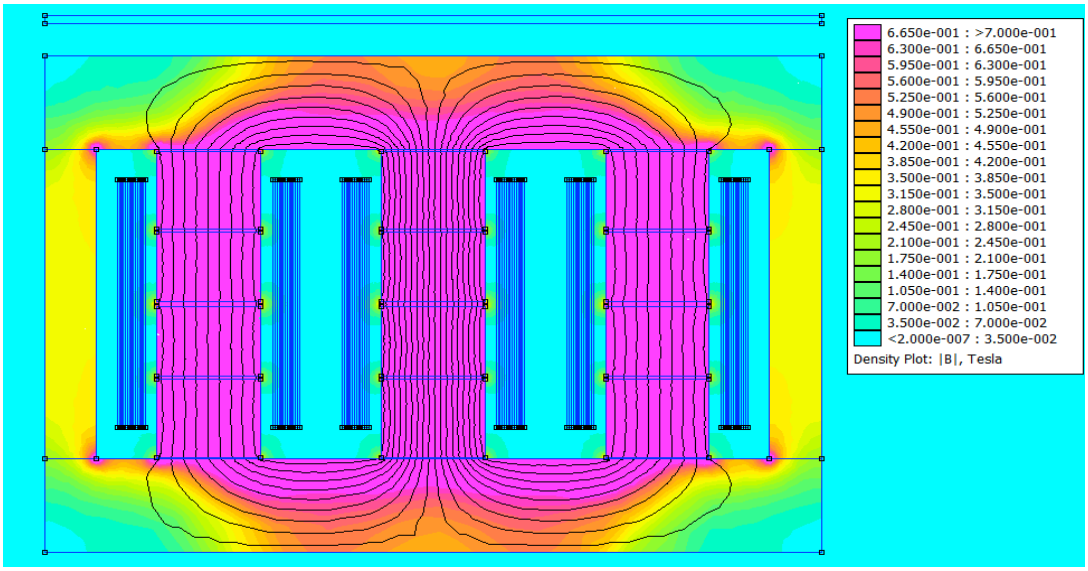


Fig. 8: 5-core choke in normal operation

The field lines therefore close into the choke core and do not leak to the outside. As a result, adjacent components cannot heat up.

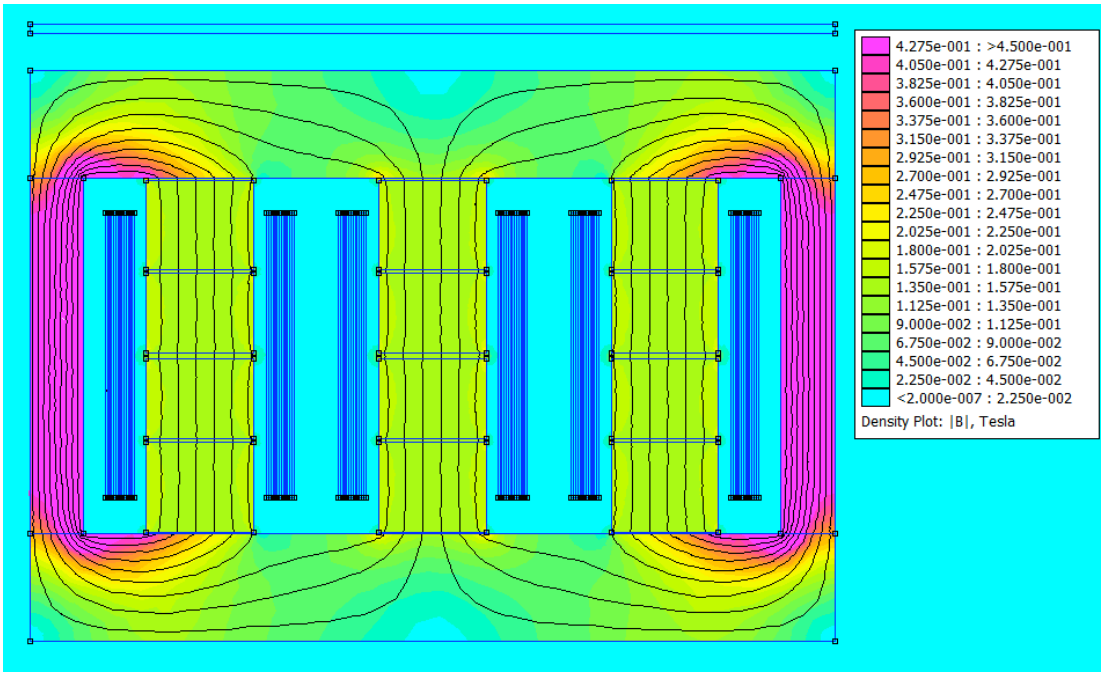


Fig. 9: 5-core choke with common-mode noise

The 5-column core therefore has both advantages of the previous core design. It is space-saving and lighter than three UI cores. The design is the same as the 3-column core, since the behaviour in nominal operation is identical.

4. Comparison

The following table compares the common solutions in terms of material use and suitability for common-mode noise.

	3x1 phase choke	3-column core	5-column core
Core weight	High	Low	Medium
Space requirements	High	Low	Medium
Common mode suitability	Yes	No	Yes

5. Conclusion

Three-phase chokes with 3UI core section (3-column choke) are not suitable for operation with common-mode noise. Operating these chokes with common-mode noise leads to overheating and can cause destruction to the component.

Single-phase chokes or 5-core chokes are suitable for operating with common-mode noise.

The 5-core choke is a very good option for setting up the devices in both a space-saving and cost-effectively way, while also ensuring full functional capacity. The 5-core choke is space-saving and lighter than three single-phase chokes.

In addition, the 5-column-choke also has distinct advantages over the other two solutions in terms of field distribution in the core.

A typical application are multilevel inverters.

6. REO products

REO produces application-specific 5-core chokes in a wide variety of designs according to customer requirements, with or without liquid cooling. Here are some examples:

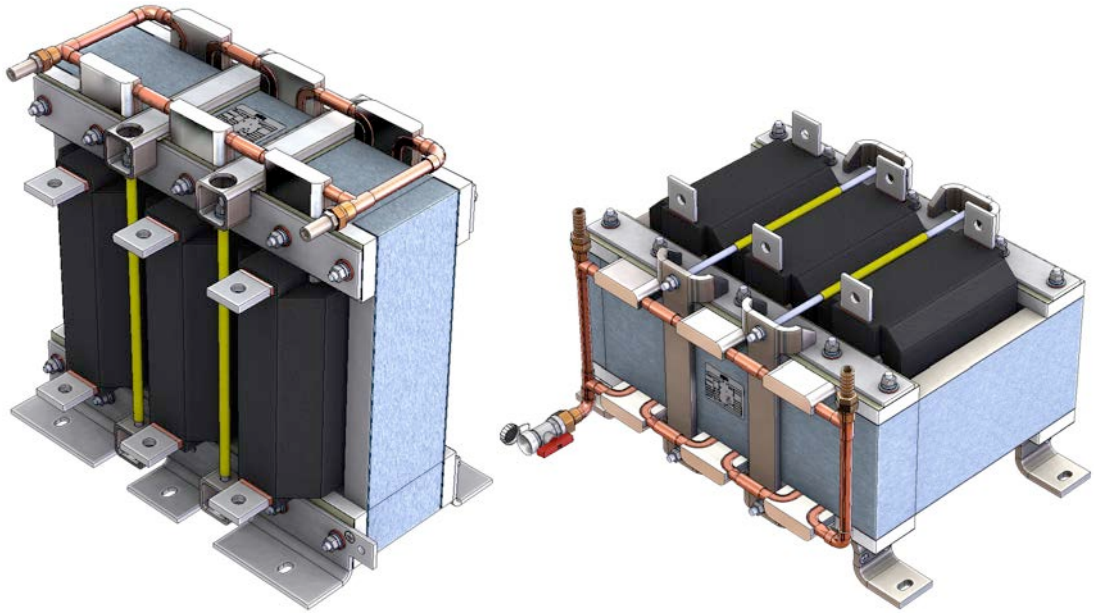


Fig. 10: Liquid-cooled 5-column choke in an upright or horizontal design

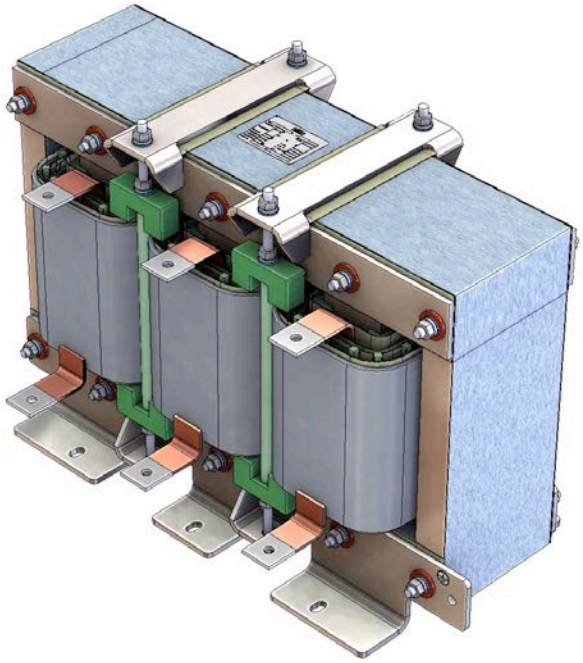


Fig. 11: Air cooled 5-column choke in the 0.18 mH and 250 A design

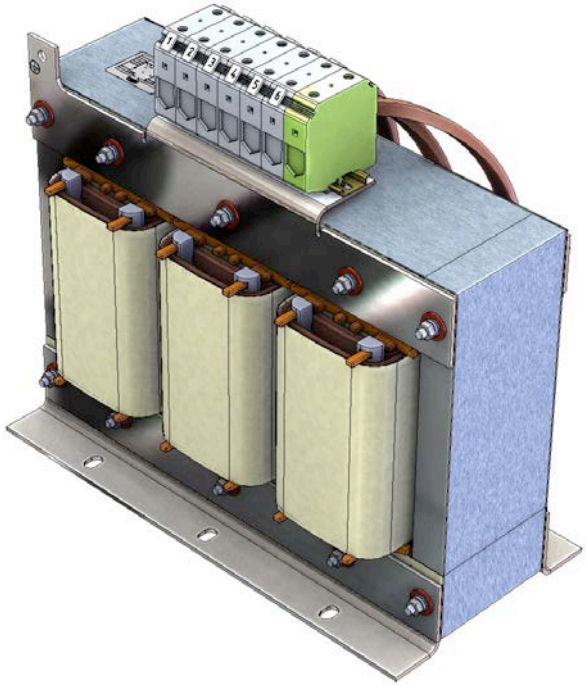


Fig. 12: Air cooled 5-column choke in the 1.2 mH and 160 A design

7. The REO-three-phase mains choke CNW MD 835/…

Dimension diagrams

Fig. 1

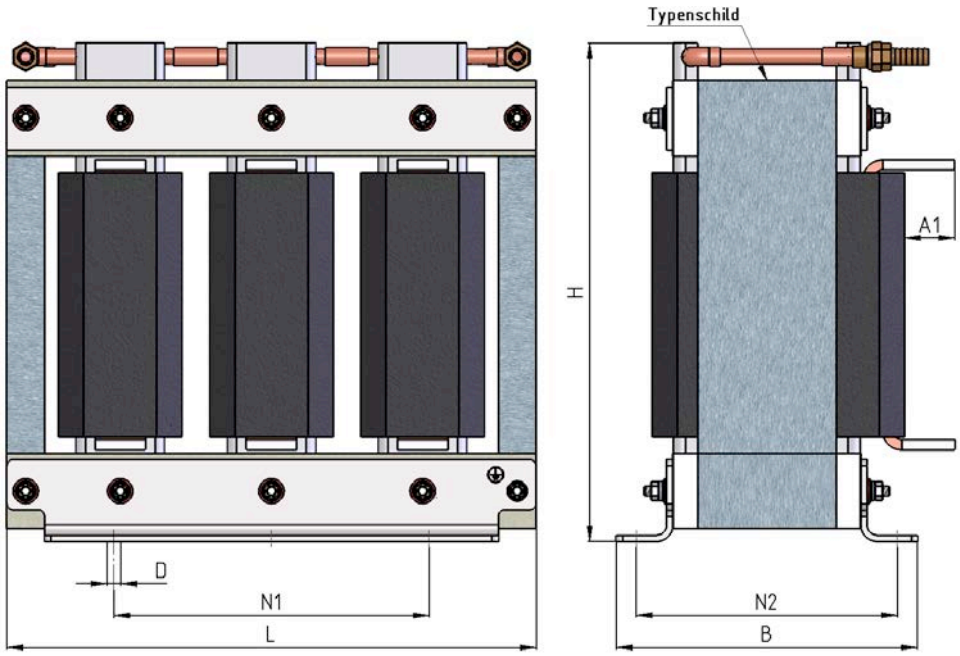
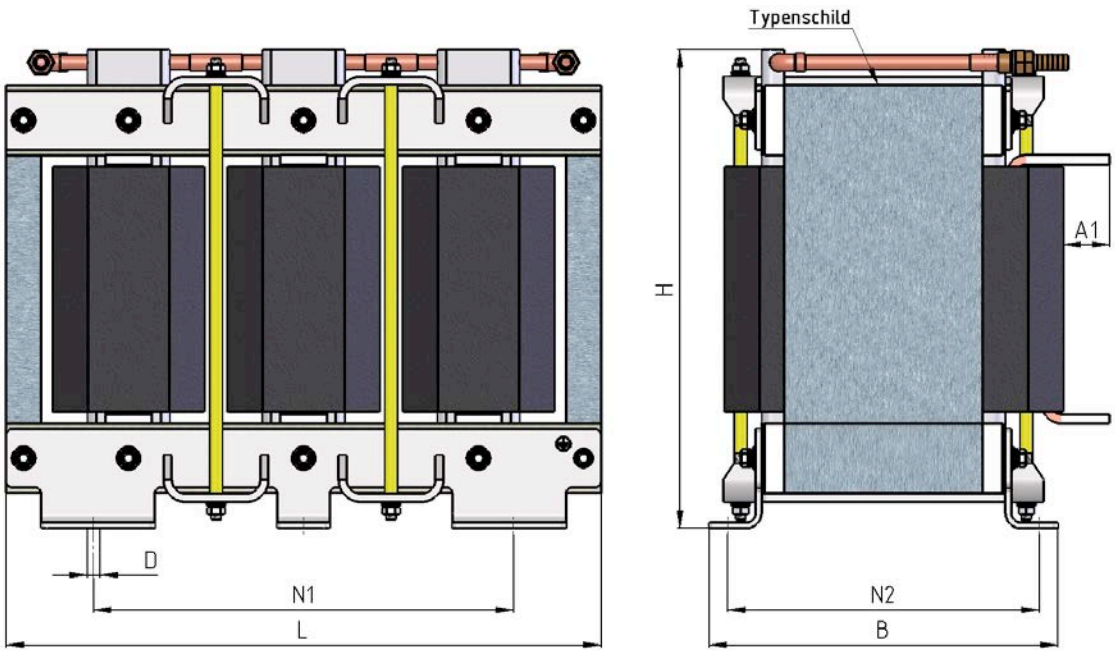


Fig. 2



Technical data CNW MD 835/…

Type	Nominal voltage [V]	Rated current [A]	Inductance per branch [mH]	Copper approx. [kg]	Weight approx. [kg]
CNW MC 835/450	500	450	0.028	22	80
CNW MC 835/650	500	600	0.042	5	115
CNW MC 835/700	500	700	0.02	5	125

Dimensions CNW MD 835/…

Type	Fig.	Dimensions							Connection
		L	B	H_{max}	N1	N2	Ø D	A1	
		[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	
CNW MC 835/450	1	450	200	345	270	170	13	45	30 x 4
CNW MC 835/600	1	420	240	395	250	210	13	45	40 x 5
CNW MC 835/700	2	425	265	420	260	220	13	45	40 x 8

8. Die REO three-phase mains choke CNW 915/…

Dimension diagrams

Fig. 1

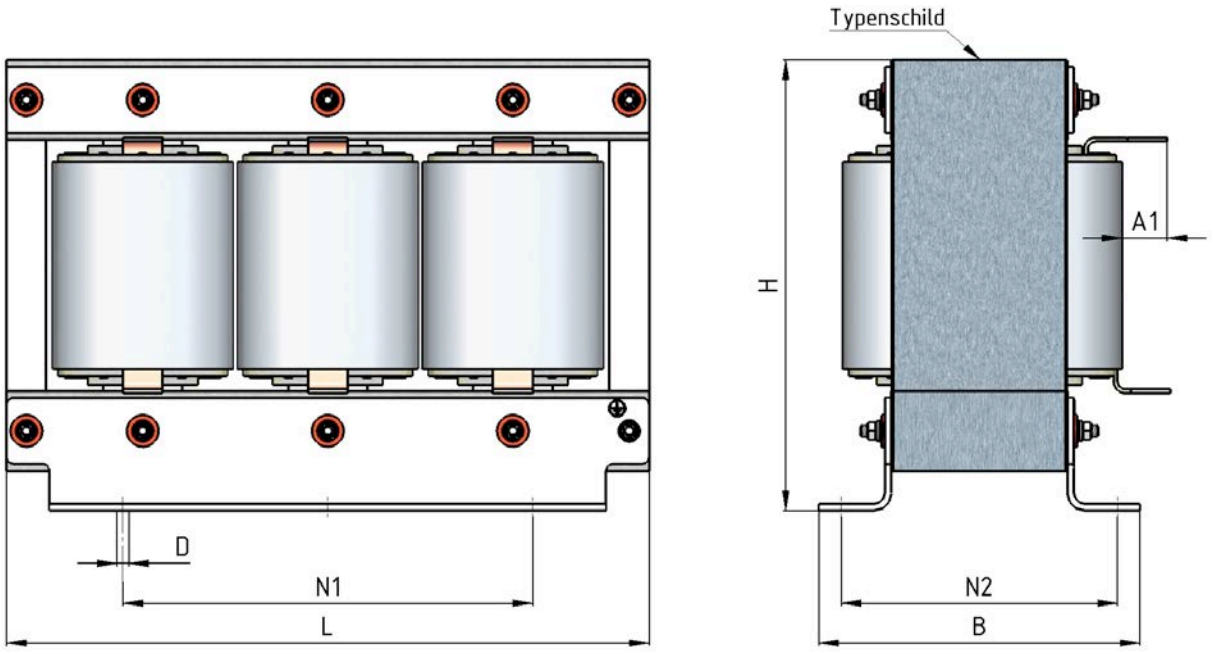
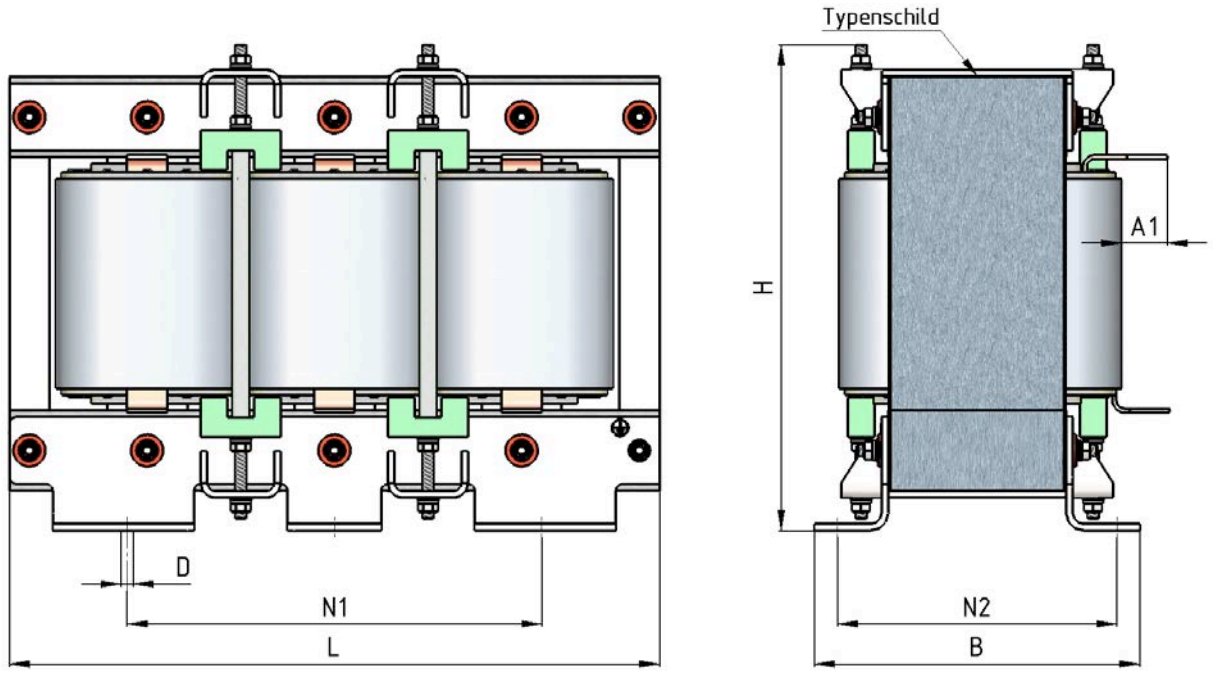


Fig. 2



Technical data CNW 915/…

For Europe:

- Frequency: 50 Hz
- Short circuit voltage Uk: 8.7% (at 400V)
- Voltage drop: 20 V/branch

Type	Nominal voltage [V]	Rated current [A]	Inductance per branch [mH]	Copper approx. [kg]	Weight approx. [kg]
CNW 915/200	500	200	0.32	2	116
CNW 915/400	500	400	0.16	4	212
CNW 915/700	500	700	0.095	9	329
CNW 915/900	500	900	0.07	17	377
CNW 915/1200	500	1200	0.055	18	496

Dimensions CNW 915/…

Type	Fig.	L [mm]	B [mm]	H_{max} [mm]	N1 [mm]	N2 [mm]	Ø D [mm]	A1 [mm]	Anschluss
CNW 915/200	1	490	200	370	300	170	13	40	30 x 4
CNW 915/400	2	560	250	480	330	210	13	40	40 x 5
CNW 915/700	2	630	270	630	370	230	13	40	40 x 8
CNW 915/900	2	630	290	630	370	250	13	80	60 x 10
CNW 915/1200	2	700	310	690	410	270	13	80	60 x 10

REO INDUCTIVE COMPONENTS AG
Brühler Straße 100 · D-42657 Solingen
Tel.: +49 (0)212 8804 0 · Fax: +49 (0)212 8804 188

Email: info@reo.de
Internet: www.reo.de

China
REO Shanghai Inductive Components Co., Ltd
No. 536 ShangFeng Road · Pudong, 201201 Shanghai · China
Tel.: +86 (0)21 5858 0686 · Fax: +86 (0)21 5858 0289
Email: info@reo.cn · Internet: www.reo.cn

France
REO VARIAC S.A.R.L.
ZAC Du Clos aux Pois 1 · 6/8 rue de la Closerie-LISSES· F-91048 Evry Cédex
Tel.: +33 (0)1 6911 1898 · Fax: +33 (0)1 6911 0918
Email: reovariac@reo.fr · Internet: www.reo.fr

Great Britain
REO (UK) Ltd.
Units 2-4 Callow Hill Road · Craven Arms · Shropshire SY7 8NT · UK
Tel.: +44 (0)1588 673 411 · Fax: +44 (0)1588 672 718
Email: main@reo.co.uk · Internet: www.reo.co.uk

India
REO GPD INDUCTIVE COMPONENTS PVT. LTD
2/202 Luna Road · Village Luna · Taluka Padra
Vadodara - 391440 · India
Tel.: +91 (2662) 221723
Email: info@reogpd.com · Internet: www.reo-ag.in

Italy
REO ITALIA S.r.l.
Via Treponti, 29 · I-25086 Rezzato (BS)
Tel.: +39 030 279 3883 · Fax: +39 030 279 0600
Email: info@reoitalia.it · Internet: www.reoitalia.it

Poland
REO CROMA Sp.zo.o
ul. Pozaryskiego 28, bud 20 · PL-04-703 Warszawa
Tel.: +48 (0)22 812 3066 · Fax: +48 (0)22 815 6906
Email: croma@croma.com.pl · Internet: www.croma.com.pl

Spain
REO ESPAÑA 2002 S.A.
C/Manuel Ventura i Campeny 21B · local 9 · E-08339 Vilassar de Dalt (Barcelona)
Tel.: +34 937 509 994 · Fax: +34 937 509 995
Email: info@reospain.com · Internet: www.reospain.com

Switzerland
REO ELEKTRONIK AG
Im Halbiacker 5a · CH-8352 Elsau
Tel.: +41 (0)52 363 2820 · Fax: +41 (0)52 363 1241
Email: info@reo.ch · Internet: www.reo.ch

Turkey
REOTURKEY ELEKTRONİK San. ve Tic. Ltd. Şti.
Halil Rıfatpasa Mah. · Darülceze CD Perpa Tic Merkezi
B Blok Kat 8 No:1095 · TR-34384 Sisli – Istanbul
Tel.: +90 (0)212 2215 118 · Fax: +90 (0)212 2215 119
Email: info@reo-turkey.com · Internet: www.reo-turkey.com

USA
REO-USA, Inc.
8450 E. 47th St · USA-Indianapolis, IN 46226
Tel.: +1 317 8991 395 · Fax: +1 317 8991 396
Email: info@reo-usa.com · Internet: www.reo-usa.com

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