HARMONIC FILTER MODULE

RHF-AS/BS

Operating instructions

Power range 160 ... 800kW
Nominal voltage 400V, 460V
500V, 690V
We will be glad to receive any possible information which could help us improving this manual.
The e-mail address is the following: techdoc@gefran.com.
Before using the product, read the safety instruction section carefully.
Keep the manual in a safe place and available to engineering and installation personnel during the product functioning period.
Gefran S.p.A has the right to modify products, data and dimensions without notice.
The data can only be used for the product description and they can not be understood as legally stated properties.
All rights reserved
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**Operating instructions RHF**

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1 Important information

1.1 About the operating instructions

- These present operating instructions are the translation of the original instructions, which were composed in the official EU language German.

- These operating instructions shall ensure safe operation of and with the filter module RHF. They contain security advices which must be observed and information which is necessary for an undisturbed operation of the units and for the exploitation of all advantages of the system.

- All persons who work on and with the filter module RHF must have accessible the operating instructions, or the equal chapters of the operating instructions for other with this option equipped GEFRAN products available. All persons must follow the relevant notes and designations.

- The operating instructions must be complete and perfectly legible.

1.2 Uses terms and definitions

Filter module
For “Filter module RHF” the term “Filter module” is used in the following chapters, if the designation refers to all types (AS, BS).
For different characteristics, the complete marking (for example RHF-AS) is used.

Drive system control
For the frequency converter which is used together with the filter module, the term “Controller” is used.

Drive system
For a drive system with filter modules, controller and other components of the drive system in the following the term “Drive system” is used.
1.3 SI units and symbols

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Prefix</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{24}$</td>
<td>Yotta</td>
<td>$10^{-1}$</td>
<td>Deci</td>
</tr>
<tr>
<td>$10^{21}$</td>
<td>Zetta</td>
<td>$10^{-2}$</td>
<td>Centi</td>
</tr>
<tr>
<td>$10^{18}$</td>
<td>Exa</td>
<td>$10^{-3}$</td>
<td>Milli</td>
</tr>
<tr>
<td>$10^{15}$</td>
<td>Peta</td>
<td>$10^{-6}$</td>
<td>Micro</td>
</tr>
<tr>
<td>$10^{12}$</td>
<td>Tera</td>
<td>$10^{-9}$</td>
<td>Nano</td>
</tr>
<tr>
<td>$10^9$</td>
<td>Giga</td>
<td>$10^{-12}$</td>
<td>Pico</td>
</tr>
<tr>
<td>$10^6$</td>
<td>Mega</td>
<td>$10^{-15}$</td>
<td>Femto</td>
</tr>
<tr>
<td>$10^3$</td>
<td>Kilo</td>
<td>$10^{-18}$</td>
<td>Atto</td>
</tr>
<tr>
<td>$10^2$</td>
<td>Hecto</td>
<td>$10^{-21}$</td>
<td>Zepto</td>
</tr>
<tr>
<td>$10^1$</td>
<td>Deca</td>
<td>$10^{-24}$</td>
<td>Yocto</td>
</tr>
</tbody>
</table>

**Measure** | **Name**  |
---|---|
Ampere | A |
Speed | n |
Farad | F |
Frequency | f |
Degree Celsius | °C |
Gramm | g |
Henry | H |
Hertz | Hz |
Magnetic flux density | T |
Meter | m |
Minute | min |
Newton meter | Nm |
Second | s |
Thermodynamic temperature | K |
Volt | V |
Resistor, electrical | Ω |
Real power | W |
Efficiency factor | η |

**Measure** | **Name**  |
---|---|
Electromagnetic compatibility | EMV |
Direct current | DC |
Motor nominal frequency | $f_{MN}$ |
Motor power rating | $P_{MN}$ |
Motor nominal voltage | $U_{MN}$ |
Motor nominal current | $I_{MN}$ |
Nominal current RHF module | $I_{RMS}$ |
Power input current | $I_{FC,L}$ |
Revolutions per minute | min$^{-1}$ |
Alternating current | AC |
1.4 Unit designation

RHF - YY 30 - XXX - XX - XXX - X

- Version
- Fan supply
- Frequency
- Connection voltage e.g.: 400 (3 x 400V AC)
- Nominal current of the filter module

AS=with external L0, THDI ≤ 10%
(at $R_{SCE} \geq 66$, THD U ≤ 2%)
BS= with external L0, THDI ≤ 5%
(at $R_{SCE} \geq 66$, THD U ≤ 2%)

RHF=filter module

Example: Nameplate RHF-AS 980-400-50-230-A:

<table>
<thead>
<tr>
<th>Serien-Nr. / Serial no.</th>
<th>XXXXXXXXXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artikel-Nr. /Article no.</td>
<td>25050212</td>
</tr>
<tr>
<td>Type / Type:</td>
<td>RHF-AS 980-400-50-230-A</td>
</tr>
<tr>
<td>Spannung / Voltage</td>
<td>3 x 400 VAC/50Hz</td>
</tr>
<tr>
<td>$I_{eff}$</td>
<td>980A</td>
</tr>
<tr>
<td>$I_{eff, max.}$</td>
<td>1470 A</td>
</tr>
<tr>
<td>Gewicht / weight</td>
<td>580kg</td>
</tr>
<tr>
<td>Umgebungstem. / Ambient Temp.</td>
<td>Max 45°C</td>
</tr>
<tr>
<td>Schutzart / Protection</td>
<td>IP 20 (filter circuit) / IP 00 (choke)</td>
</tr>
</tbody>
</table>

Figure 1: The RHF nameplate
1.5 Legal regulations

<table>
<thead>
<tr>
<th>Marking</th>
<th>Name plate</th>
<th>CE-marking</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter modules RHF are clearly marked by the content of the name-plate</td>
<td>Conformable to EG directive “low-voltage”</td>
<td>ELTROPLAN-REVCON Edisonstraße 3 D-59199 Bönen</td>
<td></td>
</tr>
</tbody>
</table>

| Trade mark rights | The filter module RHF is protected in the Federal Republic of Germany by utility patents. Patent-Nr.: DE 3938654C1 und Patent-Nr.: 90123584.6-2207. Violation of this utility patent and the verbalized trade mark rights will be prosecuted criminally. |

<table>
<thead>
<tr>
<th>Intended use</th>
<th>Filter module RHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>• only to use under the terms of this operating instructions and the required operational conditions</td>
<td></td>
</tr>
<tr>
<td>• are components</td>
<td></td>
</tr>
<tr>
<td>‒ to reduce the harmonic distortions of the electrical network by specific B6 rectifiers and inverters</td>
<td></td>
</tr>
<tr>
<td>‒ to fit in a machine</td>
<td></td>
</tr>
<tr>
<td>‒ to assembly with other components to a machine together</td>
<td></td>
</tr>
<tr>
<td>• are electric equipment to assembly in a electrical enclosure or similar</td>
<td></td>
</tr>
<tr>
<td>• locked up operations rooms</td>
<td></td>
</tr>
<tr>
<td>• conform to the protection requirements of the EG directive “low-voltage”</td>
<td></td>
</tr>
<tr>
<td>• are no machines in terms of the EG directive “machines”</td>
<td></td>
</tr>
<tr>
<td>• are no household appliances, but components which are determined only for the further application in commercial use</td>
<td></td>
</tr>
<tr>
<td>Drive system with filter module RHF</td>
<td></td>
</tr>
<tr>
<td>• conform to the EG directive “Electromagnetic Compatibility”, if they are installed by the specifications of the CE-typical drive control system</td>
<td></td>
</tr>
<tr>
<td>• are applicable</td>
<td></td>
</tr>
<tr>
<td>‒ in the public electrical network and closed electrical networks.</td>
<td></td>
</tr>
<tr>
<td>‒ in the industrial sector and in living areas as well as in business units.</td>
<td></td>
</tr>
<tr>
<td>The responsibility for the compliancy of the EG directive with the machine application is one for the user.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Liability</th>
<th>The indicated information, technical data and notes in this operating instruction were updated at the time of the printing. No demands for changing a delivered filter module can be asserted by the information, figures and descriptions of these operating instructions.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The represented process engineering notes in this operating instructions and circuit details are suggestions, which transferability on the respective application must be verified. For the suitability of the specified procedures and circuit suggestions accepts the ELTROPLAN-REVCON GmbH no guarantee.</td>
</tr>
<tr>
<td></td>
<td>The data in these operating instructions describe the characteristic of the products without ensuring them.</td>
</tr>
<tr>
<td></td>
<td>No Liability will be taken over for damages and malfunctions which result by:</td>
</tr>
<tr>
<td></td>
<td>‒ disregard of the operating instructions</td>
</tr>
<tr>
<td></td>
<td>‒ arbitrary changes on the filter module</td>
</tr>
<tr>
<td></td>
<td>‒ operating errors</td>
</tr>
<tr>
<td></td>
<td>‒ improper works on and with the inverter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Disposal</th>
<th>Material</th>
<th>Recycling</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>•</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Plastic</td>
<td>•</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
1.6 Scope of supply

- 1 external choke
- 1-3 filter module RHF-R
- 1 operating instructions

- After receipt of the delivery verify immediately, if the scope of supply correspond to the shipping documents. We make no warranty for later complained defects

- Complain

- visible damages in transit immediately at the deliverer

- visible defects / incompleteness immediately at GEFRAN.
Safety instructions

2 Safety instructions

Safety- and application instructions
for propulsion converters
(in conformity with low-voltage directive 2014/35/EU)

1. General
During the operation filter modules can own according to their protection class live, blank and if necessary even movable parts, as well as hot surfaces. The hazard of severe person or property damage exists at not permissible removal of the required coverage, at inadmissible application, at false Installation or operation. Further information can be learned from the documentation. All works for transport for installation and commissioning as well as maintenance has to be done by specialized staff (IEC 60364 or CENELEC HD 384 or DIN VDE 0100 und IEC-Report 6064 or DIN VDE 0110 and observe national accident prevention regulations).

Specialized staffs in terms of these fundamental safety instructions are persons who are acquainted with installation, assembly, commissioning and operation of the product and who dispose through their work of the corresponding Qualifications.

2. Conventional application
Filter modules are components that are conventional for the installation in electrical systems or machines. At the installation in machines is the start-up of the filter modules (the start of the conventional operation) prohibited until it is determined that the machine complies with the regulations of the EG directive 2006/42/EG (Machine directive); EN 60294 is to observe.

The start-up (the start of the conventional operation) is only allowed under compliance of the EMC-directive. The filter modules comply with the requirement of the low-voltage directive 2006/95/EG. The technical Data and also the data of the connecting conditions have to be taken from the name-plate and the documentation and they have to be necessarily observed.

3. Transport, storage
Notes on transport, storage and appropriate handling must be observed
At non-observance any warranty expires. The power feedback unit has to be protected from inadmissible stress. Particularly at transport und handling no components must have to bent and / or insulation distances being changed. The touch of electric components and contacts is therefore to avoid. Electric components must not be mechanically damaged or destroyed. (Under conditions health hazards). At mechanical defects at electric and other components it is not allowed to start up the device, because a compliance of applied standards is not longer guaranteed.

4. Assembly
The Assembly and cooling of the devices must occur accordingly the instructions of the respective documentation. The filter modules have to be protected of not permissible stress. Particularly at transport und handling no components must have to bent and / or insulation distances being changed. The touch of electric components and contacts is therefore to avoid. Electric components must not be mechanically damaged or destroyed. (Under conditions health hazards). At mechanical defects at electric and other components it is not allowed to start up the device, because a compliance of applied standards is not longer guaranteed.

5. Electrical connection
At live-line working on filter modules apply national accident prevention regulations (VBG 4) must be observed. Before any installation- and connection works the system must be operated on dead voltage and accordingly must be secured. The electric installation must be performed according to the respective instructions (e.g. cable cross- section, fuses, connection to the protective conductor). At usage of the filter module with drive system control without a safe disconnect from the supplying circuit (according to VDE 0100) all control cables must be included in additional protective measures (e.g. double insulated or shielded, grounded and insulated).

Notes for the EMV-conform installation – like shielding, grounding, arrangements of filter modules and the installing of conductors – are located in the chapter “Installation of these operating instructions”. These notes must even be observed at CE-marked propulsion converters. The compliance of the required limit values by the EMV-legislation is up to the responsibility of the manufacturer of the system or the machine.

6. Operation
After disconnect of the filter modules of the supply voltage, it is not allowed to touch live-line device parts and line connections because possibly charged capacitors must not be touched immediately. During the operation all covers and doors must be closed.

7. Service and Maintenance
The operation of the manufacturer must be observed.

Observe also the product specific safety- and application notes of these operating instructions!
2.1 Layout of the safety instructions

All safety instructions are built uniformly:

- The pictogram marks the type of danger.
- The signal word marks the severity of danger.
- The legend marks the danger and gives notes, how to avoid the danger.

<table>
<thead>
<tr>
<th>Used pictograms</th>
<th>Signal words</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warning of injury to persons</strong></td>
<td>Imminent danger by current</td>
<td><strong>Danger!</strong></td>
</tr>
<tr>
<td></td>
<td>Warning of imminent danger</td>
<td><strong>Warning!</strong></td>
</tr>
<tr>
<td></td>
<td>Dangerous situation</td>
<td><strong>Caution!</strong></td>
</tr>
<tr>
<td></td>
<td>Warning of hot surface</td>
<td><strong>Warning!</strong></td>
</tr>
<tr>
<td><strong>Warning of property damages</strong></td>
<td>Harmful situation</td>
<td><strong>Stop!</strong></td>
</tr>
<tr>
<td><strong>Useful information and application notes</strong></td>
<td>Information</td>
<td><strong>Note!</strong></td>
</tr>
</tbody>
</table>

Table 1: Layout of the safety instructions
2.2 General safety guidelines

- These safety guidelines make no demand to be complete.
- In case of questions and problems please confer with a technician of our company.

- The filter module complies with the state of technology at date of delivery and is considered as reliable basically.

- The data of these operation instructions describe the characteristics of the products, without assuring them.

- The filter module may cause danger of risk for persons, the filter module itself and for other material assets, if

  - non qualified staff is working on and with the filter module

  - the filter module is used improperly

- The Filter modules must be planned and commissioned so that they fulfill their intended function in a proper installation, at intended use and at error-free operation and cause no danger for persons. This is valid even for their interaction with the complete plant.

- The represented procedural notes and circuit details in these operation instructions have to be understood analogously and have to be verified to assignability to the current application.

- Operate the drive system only at perfect status.

- Changes to or modifications of the filter module are fundamentally prohibited. They require in any event the confer with a technician of our company

- The granted guarantee from us expires, if the device is changed or (even partly) dismantled, or if it is deployed in contradiction to our instruction.

- The installer of the plant must know the technical rules and guidelines and is responsible for the correct selection and arrangement of the electrical equipment.

- The operation of the filter module is only permitted on standard conform grids of the electrical energy supply! Disregard can lead to reduction of the filter effect and possibly to destruction of the filter module.
Safety instructions

- According to the corresponding standards and guidelines is the operation even at for a short time overcompensated grids \((\cos \phi \leq 1)\) respectively at compensation plants without chokes is not permitted, because the otherwise caused by oscillation recurrent surges can damage all connected loads, particularly electronic equipment for example drive controller and power feedback units.

Stop!
An undisturbed and safe operation of the filter module is only to expect under the observance of the following connection instructions.

At deviations of these guidelines in individual case malfunctions and damages could occur:

- Observe the grid voltage.
- Run power- and control lines separated (> 15cm)
- Use shielded / twisted control lines only
- Run the shielding riveted to PE!
- Ground the enclosure of drive, drive control, power feedback unit and filter module safe. Connect Shielding of power lines riveted and extensive (Remove the lacquer)!
- Ground the electrical enclosure or the plant to main ground star point sigmoid (necessarily avoid ground loops!)
- The filter module is only determined for a solid connection, because particularly at the application of interference filter leakage current of 3.5 mA appear. The protective earth conductor must average minimum 10 mm² copper, or one second conductor must be ran electrical parallel to Ground (grounded neutral point sigmoid).
Safety instructions

2.3 For the safety responsible persons

Operator

- Operator is every natural or legal person, which uses the drive system or in which order the drive system is used.
- The operator respectively his safety representative must assure:
  - That all relevant instructions, notes and laws will be abided
  - That only qualified staff works on and with the drive system
  - That the staff has the operating instructions at all respective works availably
  - That non qualified staff must not work on and with the drive system.

Qualified staff

Stop!
Qualified staff means persons, that are entitled (by the safety responsible) due to their training, experience, education, their knowledge in relevant norms, directives, accident directives and operation conditions to execute the necessary works and to recognize possible danger and to avoid it. (Definition of qualified staff IEC 364)
2.4 Specification of the used wires

- The used wires must conform to the required specification on site
- The regulations about the minimum cross-section of PE-conductors must be observed.

Connection:

- The connection has to be done by the terminals X4.1-X4.2-X4.3
- The temperature monitoring must be connected with the terminals A/B of the filter module with the pulse stop of the converter.

Stop!
If this connection is not made at all or at least analogously (for example via a PLC) the filter module may be damaged at constant overload operation.

Caution!
If this connection is not made at all or at least analogously (for example via a PLC) and the installation instructions (chapter 8) are not observed, this may lead to a thermal overload of the filter module and possibly to a smoke emission and/or a fire.

2.5 Remaining danger

Danger!
After switching off the electrical network, all connections could lead a dangerous contact voltage for up to 10 minutes!
Introduction

3 Introduction into the subject harmonics

3.1 The effect of harmonics in a power distribution system

In figure 2 a transformer is connected on the primary side to a common point of coupling PCC1 on the medium voltage supply. The transformer has an impedance $Z_T$ und supplies a number of loads. At a common coupling point PCCP2 all loads are connected. Each load is connected through wires that have the corresponding impedances $Z_1$, $Z_2$ und $Z_3$:

![Figure 2: The effects of harmonics](image)

Harmonic currents drawn by non-linear loads cause distortion of the voltage because of the voltage drop on the impedances of the distribution system. Higher impedances result in higher levels of voltage distortion. Current distortion relates to the device performance and it relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the load’s harmonic performance.
The configuration of the distribution system and the relevant impedances must be known to calculate the distortion in the PCC.

A commonly used term to describe the impedance of a grid is the short circuit ratio Rsce, defined as the ratio between the short circuit apparent power of the supply at the PCC \( S_{sc} \) and the rated apparent power of the load \( S_{equ} \).

\[
R_{SCE} = \frac{S_{SC}}{S_{equ}}
\]

with

\[
S_{SC} = \frac{U^2}{Z_{Netz}}
\]

and

\[
S_{equ} = U \times I_{equ}
\]

3.2 The negative effect of harmonics is twofold

- Harmonic currents contribute to system losses (power cable, transformer etc.)
- Harmonic voltage distortion causes disturbances to other loads and increase losses in other loads

3.3 Harmonic limitation standards and requirements

The requirements for harmonic limitation are:

- Application specific requirements
- Requirements from standards that have to be observed

The application specific requirements are related to a specific installation with technical reasons for limiting the harmonics.

For example: A 250kVA transformer is connected with two 110kW motors. One is connected direct and the other motor is supplied by a frequency converter. If the other motor should also be supplied by a frequency converter, the transformer will, in this case, sized too small. If the system should be retrofitted without changing the transformer, the harmonic distortion caused by two drives must be mitigated using RHF filters.
Introduction

There are various harmonic mitigation standards, regulations and recommendations. Different standards are applied in different geographical areas and industries. The following standards that are applicable will be specified:

- IEC/EN 61000-3-2
- IEC/EN 61000-3-12
- IEC/EN 61000-3-4
- IEC 61000-2-2
- IEC 61000-2-4
- IEEE 519
- G5/4

IEC 61000-3-2:
The scope of IEC 61000-3-2 is equipment connected to the public low-voltage distribution system with an input current up to and including 16 A per phase. Four emission classes are defined: Class A through D.

IEC 61000-3-12:
The scope of IEC 61000-3-12 is equipment connected to the public low-voltage distribution system having an input current between 16A and 75A. The emission limits are currently only for 230/400V 50Hz systems and limits for other systems will be added in the future. The emission limits that apply for drives are given in Table 4 in the standard. There are requirements for individual harmonics (5th, 7th, 11th, and 13th) and for THD and PWHD.
**IEC 61000-3-4:**
Limits, Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16A.
The IEC 61000-3-12 supersedes IEC 61000-3-4 for currents up to 75A. Therefore the scope of IEC 61000-3-4 is equipment with rated current greater than 75A connected to the public low voltage distribution system. It has the status of a Technical report and should not be seen as an international standard.
A three-stage assessment procedure is described for the connection of equipment to the public supply and equipment above 75A is limited to stage 3 connection based on the load's agreed power. The supply authority may accept the connection of the equipment on the basis of the agreed active power of the load's installation and local requirements of the power supply authority apply. The manufacturer shall provide individual harmonics and the values for THD and PWHD.

**IEC 61000-2-2 and IEC 61000-2-4:** The IEC 61000-2-2 and IEC 61000-2-4 are standards that stipulate compatibility levels for low-frequency conducted disturbances in public low-voltage supply systems (IEC 61000-2-2) and industrial plants (IEC 61000-2-4).
These low-frequency disturbances include harmonics, but are not limited to harmonics.
The values prescribed in these standards should be taken into consideration when planning installations. In some situations the harmonic compatibility levels cannot be observed in installations with frequency converters and harmonic mitigation is needed.

**IEEE519:**
IEEE519 establishes goals for the design of electrical systems that include both linear and nonlinear loads. Waveform distortion goals are established and the interface between sources and loads is described as point of common coupling (PCC).
IEEE519 is a system standard that aims the control of the voltage distortion at the PCC to a THD of 5% and limits the maximum individual frequency voltage harmonic to 3%. The development of harmonic current limits aims the limitation of harmonic injection from individual customers so they will not cause unacceptable voltage distortion levels and the limitation of the overall harmonic distortion of the system voltage supplied by the utility.

The current distortion limits are given in Table 10.3 in the standard and depend on the ratio ISC/IL where ISC is the short circuit current at the utility PCC and IL is the maximum demand load current.

The limits are given for individual harmonics up to the 35th and total demand distortion (TDD). Please note that these limits apply at the PCC to the utility. While requiring individual loads to comply with these limits also ensures the compliance at the PCC, this is rarely the most economic solution, being unnecessarily expensive. The most effective way to meet the harmonic distortion requirements is to mitigate at the individual loads and measure at the PCC.

If in a specific application it is required that the individual drive should comply with the IEEE519 current distortion limits, an AHF can be employed to meet these limits.

**G5/4, Engineering recommendation, planning levels for harmonic voltage distortion and the connection of nonlinear equipment to transmission systems and distribution networks in the United Kingdom:**

G5/4 sets the Planning levels for harmonic voltage distortion to be used in the process of connecting non-linear equipment. A process for establishing individual customer emission-limits based on these planning levels is described.

G5/4 is a system level standard. For 400V the voltage THD planning level is 5% at the PCC. Limits for odd and even harmonics in 400V systems are given in Table 2 in the standard. An assessment procedure for the connection of non-linear equipment is described. The procedure follows three stages, aiming to balance the level of detail required by the assessment process with the degree of risk that the connection of particular equipment will result in unacceptable voltage harmonic distortion.

A RHF-filter should be employed to meet the requirements of G5/4.
3.4 Harmonic Mitigation

To mitigate the harmonics caused by the frequency converter 6-pulse rectifier several solutions exist and they all have their advantages and disadvantages. The choice of the right solution depends on several factors:

- The grid (background distortion, mains unbalance, resonance and type of supply – transformer / generator)
- Application (load profile, number of loads and load size)
- Local / national requirements/regulations (IEEE519, IEC, G5/4, etc.)
- Total cost of ownership (initial cost, efficiency, maintenance, etc.)

IEC standards are harmonized by various countries or supranational organizations. All above mentioned IEC standards are harmonized in the European Union with the prefix “EN”.

For example the European EN 61000-3-2 is the same as IEC 61000-3-2. The situation is similar in Australia and New Zealand, with the prefixes AS/NZS.

Harmonic solutions can be divided into two main categories: Passive and active were the passive solutions consist of capacitors, inductors or a combination of the two in different arrangements.

The simplest solution is to add inductors/reactors of typically 3% to 5% in front of the frequency converter. This added inductance reduces the amount of harmonic currents produced by the drive.

More advanced passive solutions combine capacitors and inductors in trap arrangement specially tuned to eliminate harmonics starting from e.g. the 5th harmonic.
4 Introduction into the subject filter modules

4.1 Function principle RHF

The RHF consists of a mains inductor $L_0$ and a two-stage absorption circuit with
the inductance $L_1$ and $L_2$ and the capacitors $C_1$ and $C_2$.

The absorption circuit eliminates harmonics starting at the fifth order and is spe-
cific for the designed supply frequency.

The filter performance in terms of THDI varies as a function of the load.

The RHF is available in two variants for two performance levels: RHF-BS with 5% THDI (total current harmonic distortion) and RHF-A with 10% THDI. The strategy be-
hind the two levels is to offer a performance similar to 12 pulse rectifiers with the RHF-
AS and a performance similar to 18 pulse rectifiers with RHF-B.

The filter performance in terms of THDI varies as a function of the load. At nominal
load the performance of the filter should be equal or better than 10% THDI for RHF-AS
and 5% THDI for RHF-BS.

At partial load the THDI has higher values. However, the absolute value of the har-
monic current is lower at partial loads, even if the THDI has a higher value. Conse-
quently, the negative effect of the harmonics at partial loads will be lower than at full
load. All THDI values are typical values and must be verified in accordance to chapter
3.1.
For example:
These diagrams are referring to standard type RHF.
The effect of the RHF-A is identical to the RHF-AS, the effect of the RHF-B, is identical to the RHF-BS.

An 18.5kW drive is installed on a 400V/50Hz grid with a 35A RHF-A (type code RHF-A-35-400-50-20-A). The following values are measured for different load currents, using a harmonic analyzer:

<table>
<thead>
<tr>
<th>$I_n$ RMS [A]</th>
<th>$I_1$ RMS [A] Fundamental current 50 Hz</th>
<th>THDI [%]</th>
<th>Total harmonic current $I_h$ RMS [A]*</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.60</td>
<td>9.59</td>
<td>5.45</td>
<td>0.52</td>
</tr>
<tr>
<td>15.24</td>
<td>15.09</td>
<td>13.78</td>
<td>2.07</td>
</tr>
<tr>
<td>20.54</td>
<td>20.08</td>
<td>12.46</td>
<td>2.50</td>
</tr>
<tr>
<td>25.17</td>
<td>25.00</td>
<td>11.56</td>
<td>2.89</td>
</tr>
<tr>
<td>30.27</td>
<td>30.10</td>
<td>10.50</td>
<td>3.15</td>
</tr>
<tr>
<td>35.20</td>
<td>34.03</td>
<td>9.95</td>
<td>3.39</td>
</tr>
</tbody>
</table>

Table 2: Measurement RHF-A 35-400-50-20-A

* Calculated values

Table 3: Diagram RHF-A 35-400-50-20-A
It can be observed that at partial load 15A, the THDI is approximately 14%, compared to 10% at the nominal load of 34A. On the other hand, the total harmonic current is only 2.07A at 15A line current against 3.39A harmonic current at 34A line current. Therefore is the THDI only a relative indicator of the harmonic performance. The harmonic distortion of the voltage will be less at partial load than at nominal load. Factors such as background distortion and grid unbalance can affect the performance of RHF-filter. The specific figures are different from filter to filter and the graphs below show typical performance characteristics.

Background distortion: The design of the filters aims to achieve 10% respectively 5% THDI levels with a background distortion of THDU = 2%. Practical measurements on typical grid conditions in installations with frequency converters show that often the performance of the filter is slightly better with a 2% background distortion.

The complexity of the grid conditions and the different specific harmonics cannot allow a general rule about the performance on a distorted grid. Therefore the worst-case performance is chosen to consider characteristics with the background distortion:

Table 4: Diagram RHF-B
The Performance at 10% THDU has not been plotted. The filters have been tested and can operate at 10% THDU but the filter performance can no longer be guaranteed. The filter performance also deteriorates with the unbalance of the supply. The typical performance is shown in the graphs below:
Table 7: Diagram RHF-A
4.2 Harmonic line filter for frequency converters

Passive harmonic compensation of the input current of the frequency converter:

The harmonic line filter is used to reduce the circuit harmonic distortions of non linear loads, which are supplied with uncontrolled B6- bridge rectifiers, for example frequency converters. At the RHF it is about a passive filter module. It is not aligned to single frequencies how a absorption circuit, but works how a Band- stop filter that attenuates strong all low harmonic oscillations approx. until the fiftieth.

For comparison are in the following chart the circuit harmonic distortions of some potential circuits in principle represented by means of the THDI (total harmonic distortion of current) at the rated point of the rectifier:

<table>
<thead>
<tr>
<th>Rectifier without chokes</th>
<th>Rectifier with 4% chokes</th>
<th>Rectifier with RHF-AS</th>
<th>Rectifier with RHF-BS</th>
<th>Rectifier with RHF-AS and link choke</th>
<th>Rectifier with RHF-BS and link choke</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 80 %</td>
<td>~40 %</td>
<td>&lt; 16 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
<td>&lt; 5 %</td>
</tr>
</tbody>
</table>

The passive harmonic Rectifier RHF features an effective, inexpensive and very efficient ($\eta = 99.5\%$) means, to reduce network loads with harmonics.

Figure 4 shows the typical current waveform of a B6 bridge without RHF module:
Introduction

Figure 5 shows the typical current waveform of a B6 bridge with RHF module:

![Figure 5: The Current waveform with RHF module](image)

Figure 6 shows the Fourier analysis of the grid current by comparison:

![Figure 6: The Fourier analysis of the grid current](image)
5 EG- directives / Declaration of conformity

5.1 What is the purpose of EG-directives?

The EG-directives are composed by the European Council and are used as definitions of common technical requirements and certification procedures inside the European Community. At the moment there are 30 EG-directives for different sections. The standards are or will be converted by the respective member states in national laws. An in a member state issued certificate is automatically valid without more testing in all other member states.

The directive- texts restrict on the formulation of the essentially requirement. The technical details are or will be defined in European harmonized standards.

5.2 What is the meaning of the CE- marking?

After an already made Conformity valuation method the accordance with the requirements of the EG- directives will be confirmed by the mounting of a CE-marking. Within the EG consist for a CE-marked product no trade barriers.

Filter modules with CE-marking comply independently, exclusively the low voltage-standard. To the compliance with the EMC-standard recommendations will be pronounced (EMC standard 2004/108/EG).

5.3 EG-directive low voltage

Low voltage-directive (73/23/EWG)
Changed by: CE - directive (93/68/EWG)
CE - directive (2006/95/EG)

General:

- The low voltage-directive is valid for all electrical devices to use at a nominal voltage between 50V and 1000V alternating voltage and between 75V and 1500V direct voltage and at usual environmental condition. Expected is for example the usage of electrical devices in explosive atmosphere and electrical parts of person- and freight elevator.

- Protection target of the low voltage-directive is to put only such electrical devices on the market, which do not endanger the safety of humans or animals and the conservation of material assets.
EG-declaration of conformity

in terms of the EG-directive low voltage (73/23/EWG)

Changed by:         CE - directive (93/68/EWG)
CE - directive (2006/95/EG)

The filter modules RHF were developed, designed and manufactured in accordance to the above named EG- directive in exclusive accountability by

ELTROPLAN-REVCON Elektrotechnische Anlagen GmbH,
Edisonstraße 3, D-59199 Bönen

Considered standards:

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN VDE 0160 5.88 +A1 / 4.89 +A2 / 10.88</td>
<td>Electronic equipment for use in power installations</td>
</tr>
<tr>
<td>PRDIN EN 50178</td>
<td>Adjustable speed electrical power drive systems</td>
</tr>
<tr>
<td>Classification VDE 0160 / 11.94</td>
<td></td>
</tr>
<tr>
<td>IEC 61800-3:2004 / EN 61800-3:2004</td>
<td></td>
</tr>
<tr>
<td>DIN VDE 0100</td>
<td>Low-voltage electrical installations</td>
</tr>
<tr>
<td>EN 60529</td>
<td>International protection rating</td>
</tr>
</tbody>
</table>

Table 8: Considered standards

5.4 EG-directive Electromagnetic compatibility

EMC directive (89/336/EWG)
Replaced by: EMC-directive (2004/108/EG)

General:

The objective target describes article 4 (2004/108/EG), as follows:

_The... designated devices must be so manufactured, that_

(a) _an intended operation of radio- and telecommunication devices and other devices is possible and_

(b) _the devices have an adequate stability against electromagnetically disturbances, so that an intended operation is possible._
EG-declaration by the manufacturer

in terms of the EG-standard EMC (2004/108/EG)

The listed products are in terms of the EMC no independently recoverable products, this means only after integration in the overall system would they be rateable regarding to EMC. The rating became detected for typical plant constructions, but not for the several products.

ELTROPLAN-REVCON Elektrotechnische Anlagen GmbH,
Edisonstraße 3, D-59199 Bönen

5.5 EG-directive on machinery

Machine directive (98/37/EG)
Changed by: Modification directive (2006/42/EG)

General:

_Machinery means an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort, consisting of linked parts or components, at least one of which moves, and which are joined together for a specific application._

EG-declaration by the manufacturer

in terms of the EG-directive machines (2006/42/EG)

The filter modules RHF were developed, designed and manufactured in accordance to the above named EG-directive in exclusive accountability by

ELTROPLAN-REVCON Elektrotechnische Anlagen GmbH,
Edisonstraße 3, D-59199 Bönen

The operation of the filter module RHF is prohibited as long as it is determined, that the machine, in which it should be installed, conforms to the regulations of the EG-directive machines.
## 5.6 Standards and permission

<table>
<thead>
<tr>
<th>Standard</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC/EN 61000-3-2</td>
<td>RHF</td>
</tr>
<tr>
<td>IEC/EN 61000-3-12</td>
<td>RHF</td>
</tr>
<tr>
<td>IEC/EN 61000-3-4</td>
<td>RHF</td>
</tr>
<tr>
<td>IEC/EN 61000-2-2</td>
<td>RHF</td>
</tr>
<tr>
<td>IEC/EN 61000-2-4</td>
<td>RHF</td>
</tr>
<tr>
<td>IEEE 519</td>
<td>RHF</td>
</tr>
<tr>
<td>G5/4</td>
<td>RHF</td>
</tr>
<tr>
<td>Power Conversion Equipment - UL 508C</td>
<td>RHF (460V, 600V)</td>
</tr>
<tr>
<td>Industrial Control Equipment - CSA-C22.2 No. 14</td>
<td>RHF (460V, 600V)</td>
</tr>
</tbody>
</table>

*Table 9: Standards and permission*
6 Selection of the right filter module and technical data

To reach the optimum performance of the filter module, it is essential to size the filter in order to reach the nominal current. Oversizing the RHF will lead to lower performance. The RHF modules are sized by their input current $I_{RHF}$.

This is the input current of the RHF, not to be mixed up with the classification of the frequency converter which is the drive output (motor) current. Due to the power factor of the motor, the motor current is usually higher than the RHF input current!

6.1 Motor correlation table

The RHF filter must be sized based on the RHF input current, which results from the motor power.

This current must be calculated appropriate in accordance to chapter 6.2 “Calculation”. These tables show typical motor RHF setups.

<table>
<thead>
<tr>
<th>Typical motor [kW]</th>
<th>Current at 400V [A]</th>
<th>RHF type</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td>261</td>
<td>RHF-AS/BS 252-400-50-230-A</td>
</tr>
<tr>
<td>185</td>
<td>302</td>
<td>RHF-AS/BS 304-400-50-230-A</td>
</tr>
<tr>
<td>200</td>
<td>327</td>
<td>RHF-AS/BS 325-400-50-230-A</td>
</tr>
<tr>
<td>220</td>
<td>359</td>
<td>RHF-AS/BS 380-400-50-230-A</td>
</tr>
<tr>
<td>250</td>
<td>408</td>
<td>RHF-AS/BS 433-400-50-230-A</td>
</tr>
<tr>
<td>280</td>
<td>457</td>
<td>RHF-AS/BS 480-400-50-230-A</td>
</tr>
<tr>
<td>315</td>
<td>515</td>
<td>RHF-AS/BS 550-400-50-230-A</td>
</tr>
<tr>
<td>355</td>
<td>580</td>
<td>RHF-AS/BS 600-400-50-230-A</td>
</tr>
<tr>
<td>400</td>
<td>653</td>
<td>RHF-AS/BS 650-400-50-230-A</td>
</tr>
<tr>
<td>450</td>
<td>735</td>
<td>RHF-AS/BS 750-400-50-230-A</td>
</tr>
<tr>
<td>500</td>
<td>817</td>
<td>RHF-AS/BS 850-400-50-230-A</td>
</tr>
<tr>
<td>560</td>
<td>915</td>
<td>RHF-AS/BS 980-400-50-230-A</td>
</tr>
<tr>
<td>630</td>
<td>1029</td>
<td>RHF-AS/BS 1090-400-50-230-A</td>
</tr>
<tr>
<td>710</td>
<td>1160</td>
<td>RHF-AS/BS 1200-400-50-230-A</td>
</tr>
<tr>
<td>800</td>
<td>1307</td>
<td>RHF-AS/BS 1300-400-50-230-A</td>
</tr>
</tbody>
</table>

Table 10: Allocation typical motor 400V
### Technical data and dimension diagrams

<table>
<thead>
<tr>
<th>Typical motor [kW]</th>
<th>Current at 690V [A]</th>
<th>RHF type</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>189</td>
<td>RHF-AS/BS 197-690-50-230-A</td>
</tr>
<tr>
<td>250</td>
<td>237</td>
<td>RHF-AS/BS 240-690-50-230-A</td>
</tr>
<tr>
<td>280</td>
<td>265</td>
<td>RHF-AS/BS 296-690-50-230-A</td>
</tr>
<tr>
<td>315</td>
<td>298</td>
<td>RHF-AS/BS 296-690-50-230-A</td>
</tr>
<tr>
<td>355</td>
<td>336</td>
<td>RHF-AS/BS 366-690-50-230-A</td>
</tr>
<tr>
<td>400</td>
<td>379</td>
<td>RHF-AS/BS 395-690-50-230-A</td>
</tr>
<tr>
<td>450</td>
<td>426</td>
<td>RHF-AS/BS 430-690-50-230-A</td>
</tr>
<tr>
<td>500</td>
<td>474</td>
<td>RHF-AS/BS 480-690-50-230-A</td>
</tr>
<tr>
<td>560</td>
<td>530</td>
<td>RHF-AS/BS 550-690-50-230-A</td>
</tr>
<tr>
<td>630</td>
<td>597</td>
<td>RHF-AS/BS 600-690-50-230-A</td>
</tr>
<tr>
<td>710</td>
<td>672</td>
<td>RHF-AS/BS 680-690-50-230-A</td>
</tr>
<tr>
<td>800</td>
<td>758</td>
<td>RHF-AS/BS 760-690-50-230-A</td>
</tr>
</tbody>
</table>

Table 11: Allocation typical motor 690V

#### 6.2 Calculation

The line input current $I_{RHF}$ can be calculated based on the nominal motor current $I_{M,N}$ and the $\cos(\varphi)$ (power factor). These values can usually be found on the name plate of the motor.

In the case that the nominal motor voltage, $U_{M,N}$ is unequal to the actual line voltage $U_L$, the calculated current $I_{RHF}$ must be corrected with the ratio between these voltages and with the following equation:

The equation is:

$$I_{RHF} = I_{M,N} \cdot \frac{\cos \varphi \cdot \eta_{FC} \cdot \eta_{RHF}}{U_{M,N} \cdot \eta_{RHF}} \cdot \frac{U_{M,N}}{U_L}$$

The efficiency $\eta_{RHF}$ can be considered as 99.5% for all RHF modules.

The nominal current of the chosen RHF filter ($I_{RHF,Nominal}$), must be equal or higher than the calculated input current ($I_{RHF}$)

$$I_{RHF,Nominal} \geq I_{RHF}$$

Do not oversize the RHF. The best harmonic performance is obtained at nominal filter load. Using an oversized filter will most likely result in worse THDI performance.
If several frequency converters are operated on the same filter module, the RHF filter module must be dimensioned with the sum of the calculated line input currents.

Stop!
If the RHF module is sized for a specified load and the motor is exchanged or modified afterwards, the current must be calculated again to prevent an overload of the filter module.

6.3 Worked sample
The following data are known:

<table>
<thead>
<tr>
<th>System line voltage</th>
<th>U_L</th>
<th>400 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor power nameplate</td>
<td>P_M</td>
<td>500 kW</td>
</tr>
<tr>
<td>Efficiency of the motor</td>
<td>( \eta_M )</td>
<td>0.92</td>
</tr>
<tr>
<td>Efficiency of the frequency converter</td>
<td>( \eta_{FC} )</td>
<td>0.975</td>
</tr>
<tr>
<td>Efficiency of the RHF module</td>
<td>( \eta_{RHF} )</td>
<td>0.995</td>
</tr>
</tbody>
</table>

The RHF input current \( I_{RHF} \) can be calculated by the following equation:

\[
I_{RHF} = \frac{P_M}{U_L \times \sqrt{3} \times \eta_M \times \eta_{FC} \times \eta_{RHF}}
\]

\[
I_{RMS} = \frac{500 \text{ kW}}{400 \text{ V} \times \sqrt{3} \times 0.92 \times 0.975 \times 0.995}
\]

\[
I_{RHF} = 809 \text{ A}
\]

In this case 850A filter must be chosen.

Note!
The true nominal current depends on the actual load therefore it is lower than the nominal Data most often.
6.4 Characteristics

- Small compact size
- Reduction of the THDI to ≤ 10% (5%) at type RHF-AS (RHF-BS)
- Power range 160kW to 800kW
- Higher power ratings true paralleling filters
- High Efficiency, typically 99.5%
- User-friendly commissioning, because no programming or setting necessary

Note:

1. The reduction of the low-frequency circuit harmonic distortions on the specified THD I data implies, that the total harmonic distortion of the unaffected line voltage THD U smaller than 2% and the ratio of short circuit power and connected power $R_{SCE}$ is minimum 66. Under these requirements the THD I improve of the line current of the drive controller with the filter module RHF AS/BS to typically ≤10%. When these requirements are not or only partially complied, it still implies a significant reduction of the harmonic components, but under conditions the specified THD I-data will be not achieved.

2. Under the same conditions the THD I improves the main current of the drive control with the filter module RHF-BS to typically ≤5%.
## 6.5 General Data / Operation conditions

<table>
<thead>
<tr>
<th>Range</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid temperature range*</td>
<td>At transport of the device: -25°C...+70°C (following DIN EN 50178)</td>
</tr>
<tr>
<td></td>
<td>At storage of the device: -25°C...+55°C (following DIN EN 50178)</td>
</tr>
<tr>
<td></td>
<td>At operation of the device: -20°C...+45°C without power reduction 45°C...+60°C with power reduction</td>
</tr>
<tr>
<td>Stress of humidity*</td>
<td>Humidity class F without condensation (5% - 85% relatively humidity)</td>
</tr>
<tr>
<td>Environment: Resonance search</td>
<td>Test specification: 5 Hz, 150 Hz, 3 directions (0,5 g, 0,1 g, 0,5 g)</td>
</tr>
<tr>
<td>Environment: Sine vibration test</td>
<td>Test specification: (5 Hz-13.2 Hz)-150 Hz</td>
</tr>
<tr>
<td></td>
<td>2 mm peak to peak 0.7 g</td>
</tr>
<tr>
<td>Altitude of side h*</td>
<td>h ≤ 1000m AMSL without power reduction</td>
</tr>
<tr>
<td></td>
<td>1000m AMSL &lt; h 4000m AMSL with power reduction</td>
</tr>
<tr>
<td>Air pressure*</td>
<td>According to EN50178 (86kPa – 106kPa during operation)</td>
</tr>
<tr>
<td>Degree of pollution</td>
<td>Stress of humidity 2 following VDE 0110 part 2</td>
</tr>
<tr>
<td>Insulation stability</td>
<td>Overvoltage category III following VDE 0110</td>
</tr>
<tr>
<td>Package</td>
<td>DIN 55468 for transport package materials</td>
</tr>
<tr>
<td>Transport: Random vibration test</td>
<td>Base standard: DIN EN 60068-2-64</td>
</tr>
<tr>
<td></td>
<td>Base standard: DIN EN 30786-2</td>
</tr>
<tr>
<td>Transport: Mechanical shock test</td>
<td>Base standard: DIN EN 60068-2-27</td>
</tr>
<tr>
<td></td>
<td>Base standard: DIN EN 30786-2</td>
</tr>
<tr>
<td>Protection class</td>
<td>IP 20 (at RHF and external power choke IP 00)</td>
</tr>
<tr>
<td>Approvals</td>
<td>CE: Low- voltage directive</td>
</tr>
</tbody>
</table>

*Climatic terms following class 3K3 (EN 50178 part 6.1)
Figure 7 shows the Power reduction in dependence of the ambient temperature:

![Figure 7: Power reduction in dependence of the ambient temperature](image-url)
### 6.6 Rating values

<table>
<thead>
<tr>
<th>Device series</th>
<th>RHF 400V</th>
<th>RHF 460V</th>
<th>RHF 500V</th>
<th>RHF 690V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal range of the line-to-line line voltage</td>
<td>$U_n[V]$</td>
<td>$380 \leq U_n \leq 415$</td>
<td>$440 \leq U_n \leq 480$</td>
<td>$480 \leq U_n \leq 525$</td>
</tr>
<tr>
<td>Tolerance of the line-to-line line voltage</td>
<td>$U_n[V]$</td>
<td>$323 \leq U_n \leq 456$</td>
<td>$374 \leq U_n \leq 528$</td>
<td>$408 \leq U_n \leq 577$</td>
</tr>
<tr>
<td>Line frequency</td>
<td>$f_n[Hz]$</td>
<td>$50 \pm 2%$</td>
<td>$60 \pm 2%$</td>
<td>$50 \pm 2%$</td>
</tr>
<tr>
<td>Overload ability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* Efficiency</td>
<td>$\eta[%]$</td>
<td></td>
<td></td>
<td>99.3-99.6</td>
</tr>
<tr>
<td>** THD I</td>
<td>[%]</td>
<td></td>
<td></td>
<td>5-10</td>
</tr>
<tr>
<td>$\cos \varphi$</td>
<td></td>
<td>At 75% $I_n$</td>
<td>0.85 cap.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>At 100% $I_n$</td>
<td>0.99 cap.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>At 150% $I_n$</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>* Cooling air requirement</td>
<td>$m^3/h$</td>
<td>a) Installation size X387-X388: 700 m³ / h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power reduction</td>
<td>[%/K]</td>
<td></td>
<td></td>
<td>See figure 7</td>
</tr>
<tr>
<td></td>
<td>[%/m]</td>
<td></td>
<td></td>
<td>1000 m AMSL $&lt; h \leq 4000$ m AMSL $\Rightarrow 5%/1000m$</td>
</tr>
</tbody>
</table>

* Depended on the device type and design
** At observation of the following connecting conditions: THD U $< 2\%$, $R_{SCE} > 66$, standard conformable electrical networks
6.7 Current rating RHF

The indicated current values refer to the nominal line current (RHF input).

**Nominal voltage 400V 50Hz**

<table>
<thead>
<tr>
<th>Type</th>
<th>Current $I_{\text{RMS}}$ 100% [A] AC</th>
<th>Current $I_{\text{RMS}}$ 150% [A] AC 1 min in 10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHF-AS/BS 252-400-50-230-A</td>
<td>252</td>
<td>378.0</td>
</tr>
<tr>
<td>RHF-AS/BS 304-400-50-230-A</td>
<td>304</td>
<td>456.0</td>
</tr>
<tr>
<td>RHF-AS/BS 325-400-50-230-A</td>
<td>325</td>
<td>487.5</td>
</tr>
<tr>
<td>RHF-AS/BS 380-400-50-230-A</td>
<td>380</td>
<td>570.0</td>
</tr>
<tr>
<td>RHF-AS/BS 433-400-50-230-A</td>
<td>433</td>
<td>649.5</td>
</tr>
<tr>
<td>RHF-AS/BS 480-400-50-230-A</td>
<td>480</td>
<td>720.0</td>
</tr>
<tr>
<td>RHF-AS/BS 550-400-50-230-A</td>
<td>550</td>
<td>825.0</td>
</tr>
<tr>
<td>RHF-AS/BS 600-400-50-230-A</td>
<td>600</td>
<td>900.0</td>
</tr>
<tr>
<td>RHF-AS/BS 650-400-50-230-A</td>
<td>650</td>
<td>975.0</td>
</tr>
<tr>
<td>RHF-AS/BS 750-400-50-230-A</td>
<td>750</td>
<td>1125.0</td>
</tr>
<tr>
<td>RHF-AS/BS 850-400-50-230-A</td>
<td>850</td>
<td>1275.0</td>
</tr>
<tr>
<td>RHF-AS/BS 980-400-50-230-A</td>
<td>980</td>
<td>1470.0</td>
</tr>
<tr>
<td>RHF-AS/BS 1090-400-50-230-A</td>
<td>1090</td>
<td>1635.0</td>
</tr>
<tr>
<td>RHF-AS/BS 1200-400-50-230-A</td>
<td>1200</td>
<td>1800.0</td>
</tr>
<tr>
<td>RHF-AS/BS 1300-400-50-230-A</td>
<td>1300</td>
<td>1950.0</td>
</tr>
</tbody>
</table>

*Table 14: Ampacity at nominal voltage 400V 50Hz*

**Nominal voltage 690V 50Hz**

<table>
<thead>
<tr>
<th>Type</th>
<th>Current $I_{\text{RMS}}$ 100% [A] AC</th>
<th>Current $I_{\text{RMS}}$ 150% [A] AC 1 min in 10 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHF-AS/BS 197-690-50-230-A</td>
<td>197</td>
<td>295.5</td>
</tr>
<tr>
<td>RHF-AS/BS 240-690-50-230-A</td>
<td>240</td>
<td>360.0</td>
</tr>
<tr>
<td>RHF-AS/BS 296-690-50-230-A</td>
<td>296</td>
<td>444.0</td>
</tr>
<tr>
<td>RHF-AS/BS 366-690-50-230-A</td>
<td>366</td>
<td>549.0</td>
</tr>
<tr>
<td>RHF-AS/BS 395-690-50-230-A</td>
<td>395</td>
<td>592.5</td>
</tr>
<tr>
<td>RHF-AS/BS 430-690-50-230-A</td>
<td>430</td>
<td>645.0</td>
</tr>
<tr>
<td>RHF-AS/BS 480-690-50-230-A</td>
<td>480</td>
<td>720.0</td>
</tr>
<tr>
<td>RHF-AS/BS 550-690-50-230-A</td>
<td>550</td>
<td>825.0</td>
</tr>
<tr>
<td>RHF-AS/BS 600-690-50-230-A</td>
<td>600</td>
<td>900.0</td>
</tr>
<tr>
<td>RHF-AS/BS 680-690-50-230-A</td>
<td>680</td>
<td>1020.0</td>
</tr>
<tr>
<td>RHF-AS/BS 760-690-50-230-A</td>
<td>760</td>
<td>1140.0</td>
</tr>
</tbody>
</table>

*Table 15: Ampacity at nominal voltage 690V 50Hz*
6.8 Cable cross section

When wiring a RHF-filter module the drive system should be wired with the same cross section as without filter module.

The current to the RHF-R filter circuit is half the site of the nominal RHF current. The cross section must be selected accordingly.

6.9 General information

With this information the installers and users of a plant should be given information on special characteristics and rules in terms on a filter module. With this information no demand of completeness will be raised.

**Compensation plants without chokes and resonance danger**

Compensation plants are used in center of the power supplies of companies. Disturbances or damages at these plants can affect to the power supplies of the company and cause expensive losses of production. In fact today there are still many compensation plants without chokes used although the actual guidelines are in conflict with this fact. The problems, which can occur in connection with a compensation plant without chokes, are manifold:

- Direct Resonance
- Resonance lifting
- Switching transients
- Impairment of ripple control transmission

Rising of resonances is not determined whether an operation itself causes harmonic distortions. Decisive for the risk to encounter a resonance is the compensation power at the transformer. The risk of a resonance will rise together with the compensation power and is influenced by the harmonic load of the medium voltage level, which is transmitted by the transformer and affects the low-voltage level. Limit exceeding, caused by resonance lifting, and may particularly be detected especially for the 5th harmonic.
### Technical data and dimension diagrams

#### 6.10 Electrical operating conditions RHF-AS/BS

**Nominal voltage 400V 50Hz**

<table>
<thead>
<tr>
<th>Type RHF-AS-</th>
<th>filter module</th>
<th>Weight [kg]</th>
<th>Torque* [Nm] Clamp X4</th>
<th>Grounding</th>
<th>Cable cross section [mm²]</th>
<th>Cable Lug**</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-400-50-230-A</td>
<td>X38</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>304-400-50-230-A</td>
<td>X38</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>325-400-50-230-A</td>
<td>X38</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>380-400-50-230-A</td>
<td>X38</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>433-400-50-230-A</td>
<td>X38B</td>
<td>108</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>480-400-50-230-A</td>
<td>X38B</td>
<td>108</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>550-400-50-230-A</td>
<td>X38B</td>
<td>108</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>600-400-50-230-A</td>
<td>2 x X38</td>
<td>2 x 80</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>650-400-50-230-A</td>
<td>2 x X38</td>
<td>2 x 80</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>750-400-50-230-A</td>
<td>2 x X38</td>
<td>2 x 104</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>850-400-50-230-A</td>
<td>2 x X38</td>
<td>2 x 104</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
<td>980-400-50-230-A</td>
<td>2 x X38</td>
<td>2 x 108</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
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<tr>
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<td>2 x 108</td>
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<td>M8</td>
<td>35-95</td>
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<td>1200-400-50-230-A</td>
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<td>M8</td>
<td>35-95</td>
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<tr>
<td>1300-400-50-230-A</td>
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<td>3 x 104</td>
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<td>35-95</td>
<td>CS</td>
</tr>
</tbody>
</table>

*Locking torque of the electrical network and converter terminal clamp*

**Nominal voltage 400V 50Hz**

<table>
<thead>
<tr>
<th>Type RHF-BS-</th>
<th>filter module</th>
<th>Weight [kg]</th>
<th>Torque* [Nm] Clamp X4</th>
<th>Grounding</th>
<th>Cable cross section [mm²]</th>
<th>Cable Lug**</th>
</tr>
</thead>
<tbody>
<tr>
<td>252-400-50-230-A</td>
<td>X38</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>304-400-50-230-A</td>
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<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>325-400-50-230-A</td>
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<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
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<tr>
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<td>2 x 80</td>
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<td>M8</td>
<td>35-95</td>
<td>CS</td>
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<tr>
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<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
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<td>2 x X38</td>
<td>2 x 104</td>
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<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
<tr>
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<td>2 x X38</td>
<td>2 x 104</td>
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<td>35-95</td>
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<tr>
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<td>M8</td>
<td>35-95</td>
<td>CS</td>
</tr>
</tbody>
</table>

* CS △ Cable end sleeve, CL △ Cable lug*
### Nominal voltage 690V 50Hz

<table>
<thead>
<tr>
<th>Type RHF-AS-</th>
<th>filter module</th>
<th>Weight [kg]</th>
<th>Torque* [Nm]</th>
<th>Grounding</th>
<th>Cable cross section [mm²]</th>
<th>Cable Lug**</th>
</tr>
</thead>
<tbody>
<tr>
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<td>296-690-50-230-A</td>
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<td>M8</td>
<td>35-95</td>
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<td>480-690-50-230-A</td>
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<td>550-690-50-230-A</td>
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<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
</tbody>
</table>

* Locking torque of the electrical network and converter terminal clamp

** CS ≡ Cable end sleeve, CL ≡ Cable lug

### Nominal voltage 690V 50Hz

<table>
<thead>
<tr>
<th>Type RHF-BS-</th>
<th>filter module</th>
<th>Weight [kg]</th>
<th>Torque* [Nm]</th>
<th>Grounding</th>
<th>Cable cross section [mm²]</th>
<th>Cable Lug**</th>
</tr>
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<tbody>
<tr>
<td>197-690-50-230-A</td>
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<td>35-95</td>
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<td>240-690-50-230-A</td>
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</tr>
<tr>
<td>296-690-50-230-A</td>
<td>X38B</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
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<tr>
<td>366-690-50-230-A</td>
<td>X38B</td>
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<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>395-690-50-230-A</td>
<td>X38B</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
<td></td>
</tr>
<tr>
<td>430-690-50-230-A</td>
<td>X38B</td>
<td>175</td>
<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
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<tr>
<td>480-690-50-230-A</td>
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<td>M8</td>
<td>35-95</td>
<td>CS</td>
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<tr>
<td>550-690-50-230-A</td>
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<td>15</td>
<td>M8</td>
<td>35-95</td>
<td>CS</td>
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<tr>
<td>600-690-50-230-A</td>
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<td>35-95</td>
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<td>CS</td>
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</tr>
</tbody>
</table>

* Locking torque of the electrical network and converter terminal clamp

** CS ≡ Cable end sleeve, CL ≡ Cable lug
6.11 Dimensions of the RHF-R Filter module

Table 20 shows the external dimensions of the filter modules in dependence of the enclosure type:

<table>
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Table 20: The external dimensions of the filter modules

Each filter setup contains one line choke, and one or more RHF-R filter circuits. Please refer to previous chapter table 16-19.
Dimensions Enclosure X38

Figure 8: Dimension diagram configuration X38
Technical data and dimension diagrams

Dimensions Enclosure X38B

Figure 9: Dimension diagram configuration X38B
6.12 External choke dimensions

Dimensions $L_0$ RHF-AS/BS:

![Diagram of dimensions L0 RHF-AS/BS]

Table 21: Dimensions $L_0$ RHF-AS 400V 50Hz

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<thead>
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Figure 10: Dimensions L0 RHF-AS/BS

Nominal voltage 400V 50Hz
### Installation

#### Nominal voltage 400V 50Hz

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Table 22: Dimensions L0 RHF-BS 400V 50Hz

#### Nominal voltage 690V 50Hz

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Table 23: Dimensions L0 RHF-AS 690V 50Hz

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</table>

Table 24: Dimensions L0 RHF-BS 690V 50Hz
7 Installation

7.1 Mechanical installation

Important information

- Use the filter modules only as built-in type!
- Observe the free space of the installation!
  - Several filter modules in one electrical enclosure can be mounted without clearance side by side.
  - Observe 150mm free space above- and below (see figure 11).
- The natural convection must not be constrained.
- At polluted convection (dust, fibrous material, fat, aggressive gases), which could affect the function of the filter module:
  - Make adequate retaliatory actions, for example separate airflow, mounting of filter modules, regular cleaning, etc.
- Do not exceed the admissible range of the operating- ambient temperature.

![Figure 11: 150mm free space above and below](image-url)
Installation

7.2 International protection rating

Warning!
Warning before touching a hot surface! The direct touching can lead to a burning of the skin!

IP 20:

- The free space of the filter module must average minimum 150 mm
- The surface temperature of the IP 20 filter module does not exceed 70°C
- The filter module can be mounted side by side among the frequency converter

7.3 Specified mounting position

A vertical assembling is specified. The terminals must be placed at the bottom. When assembling the device within an electrical enclosure it must be ensured, that the dissipation heat in the electrical enclosure is discharged adequately. The air temperature of 45°C in direct proximity of the device must not be exceeded. The air input- and air outlet on the up- and bottom side of the device (as far as available) must not be buried by installation material as cable ducts or other devices. When mounting external of a cabinet it is recommended to use the mounting plates (accessories) and mounting rails.

Stop!
If these mounting instructions are not observed, this can lead to a thermal overcharge of the filter module.

Caution!
If these mounting instructions and the connection instructions (chapter 9.2) are not observed, this can lead to a thermal overcharge of the filter module and under circumstances to a production of smoke and/or a burning.
7.4 The air ventilation

The filter modules are cooled by ventilation. Therefore the air must be able to move free above and below the filter module. If the filter module is mounted in an electrical enclosure or in other industrial enclosures, it must be guaranteed, that an adequate airflow streams through the filter module to diminish the danger of overheating of filter module and surrounding components.

If other heat sources for example the frequency converter are installed in the same enclosure, the heat that is generated by both components must be considered when sizing the cooling for the enclosure.

The filter modules must be mounted on the wall in that way, that the air is guided through the air gap between wall and filter module (see figure 12). At an Installation on rails without rear panel, the filter module is not cooled adequate, because of the wrong air flow. This is only allowed with the optional rear panel.

Figure 12 shows the correct mounting of the filter module:

![Figure 12: The correct mounting of the filter module](image-url)
8 Electrical installation

8.1 Network configuration / Net conditions

**Danger!**
If you want to operate the filter module on electrical networks, which are not mentioned in the following chart, please confer with a technician of our company.

<table>
<thead>
<tr>
<th>Standard conform grounding system</th>
<th>Operation of the filter module</th>
</tr>
</thead>
<tbody>
<tr>
<td>With direct grounded star point</td>
<td>Allowed</td>
</tr>
<tr>
<td>With indirect grounded star point</td>
<td>Allowed</td>
</tr>
<tr>
<td>With insulated star point</td>
<td>Allowed</td>
</tr>
</tbody>
</table>

**Table 25: Network configuration / Net conditions**

**Stop!**
At adverse ambient conditions (THD U >5%, Δf>2 Hz, unbalanced networks >3%) durability shortening of the components could occur.
8.2 Operation principle RHF

The RHF consists of a main inductor $L_0$ and a two-stage absorption circuit.

The absorption circuit eliminates harmonics starting at the fifth order and is specific for the designed supply frequency.

The filter performance in terms of THDI varies as a function of the load.

---

Danger!

Incorrect wiring may disturb the drive controller.

---

Figure 13: Operation principle RHF
8.3 Wiring diagram RHF-AS/BS

Figure 14: The Wiring of the filter module RHF-AS/BS to a frequency converter

*setup may contain several RHF-R modules (RHF-AS/BS = n RHF-R + L0)
If frequency converters are connected in parallel it is valid that:

- The current sum and the power sum of the frequency converter comply with the equivalent data of the filter module.

Figure 15: The connection in parallel of frequency converters

Figure 16: Galvanic isolated switch
Electrical installation

8.4 Line connection

- The cable-cross sections are references and apply to the operation
  - in electrical enclosures and machines
  - Installation in the line channel
  - max. ambient air temperature +45°C.
- At the choice of the cable-cross section the fall of voltage should be considered at load.

The observance of further standards (EN 60204-1, VDE 0289 and others) is up to the responsibility of the installer of the plant / the operator.

Connection:

- All connections have to be done as short and induction less as possible.
- To be compliant with the EMC-directives (according to consisting standards as EN 61800-3:2004 / IEC 61800-3:2004) shielded lines have to be applied.
- The connection must occur done with three phases (active wires).
- Connect the protective conductor of the input lead at the earth bolt of the device.

8.5 Fuses

To protect the installation against electrical hazard and fire hazard all filter modules must be protected against short circuit- and over current following the national / international regulations.

The fuses must be chosen corresponding to the operating instructions of the filter module.

Caution!

It is important to install the fuses before the filter module.
## 8.6 Installation in a CE-typical drive system

| **General information** | • The responsibility for the compliance of the EG directives with the Machine application is one for the user.  
  – If you observe the following measures, you can assume that at the operation of the machine no by the filter module caused EMC-problems occur and that the EG-directives respectively the EMC-directives are complied.  
  – If devices are operated in proximity to the filter modules, which do not comply with the CE-standards in terms of the interference immunity of the EN 500082-2, these devices can be affected electromagnetic by the filter module. |
| **Design** | • Connect filter modules extensive to the earthed mounting plate:  
  – Mounting plates with electrical conducting surface (zinc coated or stainless steel) allow a durable contacting.  
  – Coated plates are not adequate for a EMC-conform installation  
  • If you use several mounting plates:  
  – Connect mounting plates extensive and conducting to each other (for example with copper band)  
  • At the installing of lines observe the spatial separation of the power lines from the control lines.  
  • Conduits preferably close by reference potential. Levitating lines operate as antenna. |
| **Shielding** | • Metallic cable connections ensure an extensive connection of the shield with the enclosure  
  • At contactors and clamps in the shielded lines:  
  - Interconnect the shields of the three connected lines and also connect extensive with the mounting plate  
  • At power lines among the interference filter and the drive system longer as 300mm:  
  - Shield power lines  
  - Connect the shield of the power lines direct to the drive controller / to the feedback unit, to the interference filter and to the filter module and connect extensive to the mounting plate.  
  • Shield the control lines:  
  - Connect the shield beeline to the shield connections. |
| **Grounding** | • Ground all metallic electrically conductive Components (feedback unit, drive controller, interference filter and filter module) by corresponding lines from a central (ground point, PE-bar).  
  • Observe the in den safety regulations defined minimum cable cross section:  
  - But for the EMC is not the cable cross section decisive, but the surface of the line and the 2-dimensional contacting. |
8.7 Installation

**Functional- and proper construction of electrical enclosure or plant:**

To avoid disturbance decoupling of lines is important:

a) Power-/supply lines  
b) Motor lines of converters / servo amplifiers  
c) And control- and data lines (low voltage level < 48 V) must be installed with a clearance of minimum 15 centimeters.

To receive low resistive high frequency connections, groundings and shielding and other metallic connections (for example mounting plate, installed devices) must be applied extensive on metallic blank background. Use grounding- and potential equalization lines with large as possible cross-section (minimum 10mm²) or thick ground strap.  
Use shielded lines only with copper- or tinned copper braid, because steel braid is inappropriate in high frequency range. Always connect the shield with clamps or metal bolting on the equalization lines, and accordingly PE-connections. No extending with single conductors!

Inductive switching elements (contactor, relay and similar) always must be connected to suppressor elements like varistors, RC-circuits or protective diodes. Make all connections as short as possible and lead close to reference potential, because levitating lines operate as antenna.  
Avoid loops at all connection lines. Lay not accounted stranded wires on both sides at protective earth.

At unshielded lines forward- and return conductor must be twisted, to attenuate symmetric disturbances.
8.8 Installation of a EMC-conform electrical enclosure

Figure 17: EMC-conform electrical enclosure

1. Electrical enclosure
2. Power line
3. Motor line
4. Control line
5. Line between filter module and drive control
6. Power line of the filter module and the drive control
7. Mounting plate
8. Potential equalization with the construction ground
9. Filter module
10. Power connection
11. SPS
12. Drive controller
13. Electrical network fuse
14. Electrical network contactor
An electrical enclosure has to be divided fundamentally in power area and control area. It is irrelevant, if the system is installed inside an electrical enclosure or comprises several electrical enclosures. Because of the strong radiation of the power lines the installation of a screening wall is recommended to separate the control lines. It must be excellent connected with the frame or the mounting plate (remove the lacquer).

The mounting plate of the drive control is to be used as star point for the total grounding and screening connection in the machine or plant. If the drive or other plant components emit or suffer disturbances, the HF-connection of these components is bad. In that case a potential equalization must be parallel executed.
9 Commissioning

Danger!
Check before first switching-on the wiring on completeness, polarity reversal, short circuit and earth fault.

Danger!
In case of an incorrect wiring a disturbance of the drive controller may occur.

Danger!
If (e.g. during commissioning) only a provisional power supply is provided, which does not comply with the in this operating instruction specified data (for example: chapter 3) it is strongly recommended to disconnect the filter circuit.

9.1 First switching-on

• Switch on the electrical network
• Check the operation state of the drive systems
10 Capacitor disconnection

In no load conditions (standby-operation) the frequency converter current is negligible. The main current drawn at standby operation at the input of the harmonic filter is a purely capacitive reactive current which flows through the capacitor of the harmonic filter. This reactive current component corresponds typically to ca. 20-25% of the specified nominal harmonic filter current (depending on the respective harmonic filter type). The power factor of the drive is at this condition very low and changes, depending on the load, to one.

The following graphs show typical values for the true power factor of a RHF-AS and RHF-BS:

Figure 18: Typical power factor of a RHF-AS

Figure 19: Typical power factor of a RHF-BS
Capacitor disconnection

To reduce this reactive current and to prevent an overcompensation of the mains it is recommended to disconnect this reactive current at standby operation. This reactive current can be disconnected by a contactor. Depending on the short-circuit power in the most industrial mains supplies a commercial AC3 contactor can be used for the disconnection. *The power of the AC3 contactor should be minimum 50% of the nominal power of the filter.* This contactor can be connected and disconnected, depending on the drive performance, to a load of maximal 30%.

Wait 25 seconds before restarting until the capacitors are discharged completely.

To ensure dynamic cycles of operation the C-disconnection may be done with special capacitor contactors. In this case the connection of the capacitors may be done to a maximal power of 30% without holding time!

For drives operating on generators (e.g. ship applications) capacitor contactors are recommended in general.
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