

Electromagnetic Compatibility (EMC) in Drive and Control Systems

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Project Planning Manual



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1 Applications

This documentation is meant to assist in the assembly and installation of Rexroth Indramat drive components in an installation or machine while ensuring optimum electromagnetic compatibility (EMC) of the installation or machine.

In this documentation the user of Rexroth Indramat drive or control components is given directives with which to ensure and secure all EMC requirements by taking the simplest measures which have proven their effectiveness over years of actual application.

Notes

2 Safety Instructions for Electric Servo Drives and Controls

2.1 Introduction

Read these instructions before the equipment is used and eliminate the risk of personal injury or property damage. Follow these safety instructions at all times.

Do not attempt to install, use or service this equipment without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation of the equipment prior to working with the equipment at any time. If you do not have the user documentation for your equipment contact your local Rexroth Indramat representative to send this documentation immediately to the person or persons responsible for the safe operation of this equipment.

If the product is resold, rented or transferred or passed on to others, then these safety instructions must be delivered with the product.



WARNING

Inappropriate use of this equipment, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, may result in product damage, personal injury, severe electrical shock or death!

2.2 Explanations

The safety warnings in this documentation describe individual degrees of hazard seriousness in compliance with ANSI:

| Warning symbol with signal word | Degree of hazard seriousness |
|---------------------------------|--|
| DANGER | The degree of hazard seriousness describes the consequences resulting from non-compliance with the safety guidelines. Bodily harm or product damage will occur. |
| WARNING | Death or severe bodily harm may occur. |
| CAUTION | Death or severe bodily harm may occur. |

Fig. 2-1: Classes of danger with ANSI

2.3 Hazards by inappropriate use



DANGER

**High voltage and high discharge current!
Danger to life, risk of severe electrical shock
and risk of injury!**



DANGER

**Dangerous movements! Danger to life and risk
of injury or equipment damage by unintentional
motor movements!**



WARNING

**High electrical voltage due to wrong
connections! Danger to life, severe electrical
shock and severe bodily injury!**



WARNING

**Health hazard for persons with heart
pacemakers, metal implants and hearing aids in
proximity to electrical equipment!**



CAUTION

**Surface of machine housing could be extremely
hot! Danger of injury! Danger of burns!**



CAUTION

**Risk of injury due to inappropriate handling!
Bodily injury caused by crushing, shearing,
cutting and mechanical shock or improper
handling of pressurized systems!**



CAUTION

**Risk of injury due to inappropriate handling of
batteries!**

2.4 General Information

Rexroth Indramat GmbH is not liable for damages resulting from failure to observe the warnings given in these documentation.

Order operating, maintenance and safety instructions in your language before starting up the machine. If you find that due to a translation error you can not completely understand the documentation for your product, please ask your supplier to clarify.

Proper and correct transport, storage, assembly and installation as well as care in operation and maintenance are prerequisites for optimal and safe operation of this equipment.

Trained and qualified personnel in electrical equipment:

Only trained and qualified personnel may work on this equipment or within its proximity. Personnel are qualified if they have sufficient knowledge of the assembly, installation and operation of the product as well as an understanding of all warnings and precautionary measures noted in these instructions.

Furthermore, they should be trained, instructed and qualified to switch electrical circuits and equipment on and off, to ground them and to mark them according to the requirements of safe work practices and common sense. They must have adequate safety equipment and be trained in first aid.

Only use spare parts and accessories approved by the manufacturer.

Follow all safety regulations and requirements for the specific application as practiced in the country of use.

The equipment is designed for installation on commercial machinery.

European countries: see directive 89/392/EEC (machine guideline).

The ambient conditions given in the product documentation must be observed.

Use only safety features that are clearly and explicitly approved in the Project Planning manual.

For example, the following areas of use are not allowed: Construction cranes, Elevators used for people or freight, Devices and vehicles to transport people, Medical applications, Refinery plants, the transport of hazardous goods, Radioactive or nuclear applications, Applications sensitive to high frequency, mining, food processing, Control of protection equipment (also in a machine).

Start-up is only permitted once it is sure that the machine, in which the product is installed, complies with the requirements of national safety regulations and safety specifications of the application.

Operation is only permitted if the national EMC regulations for the application are met.

The instructions for installation in accordance with EMC requirements can be found in the INDRAMAT document "EMC in Drive and Control Systems".

The machine builder is responsible for compliance with the limiting values as prescribed in the national regulations and specific EMC regulations for the application.

European countries: see Directive 89/336/EEC (EMC Guideline).

U.S.A.: See National Electrical Codes (NEC), National Electrical Manufacturers Association (NEMA), and local building codes. The user of this equipment must consult the above noted items at all times.

Technical data, connections and operational conditions are specified in the product documentation and must be followed at all times.

2.5 Protection against contact with electrical parts

Note: This section refers to equipment with voltages above 50 Volts.

Making contact with parts conducting voltages above 50 Volts could be dangerous to personnel and cause an electrical shock. When operating electrical equipment, it is unavoidable that some parts of the unit conduct dangerous voltages.



DANGER

High electrical voltage! Danger to life, severe electrical shock and severe bodily injury!

- ⇒ Only those trained and qualified to work with or on electrical equipment are permitted to operate, maintain or repair this equipment.
- ⇒ Follow general construction and safety regulations when working on electrical installations.
- ⇒ Before switching on power the ground wire must be permanently connected to all electrical units according to the connection diagram.
- ⇒ Do not operate electrical equipment at any time if the ground wire is not permanently connected, even for brief measurements or tests.
- ⇒ Before working with electrical parts with voltage potentials higher than 50 V, the equipment must be disconnected from the mains voltage or power supply.
- ⇒ The following should be observed with electrical drives, power supplies, and filter components:
Wait five (5) minutes after switching off power to allow capacitors to discharge before beginning work. Measure the voltage on the capacitors before beginning work to make sure that the equipment is safe to touch.
- ⇒ Never touch the electrical connection points of a component while power is turned on.
- ⇒ Install the covers and guards provided with the equipment properly before switching the equipment on. Prevent contact with live parts at any time.
- ⇒ A residual-current-operated protective device (r.c.d.) must not be used on an electric drive! Indirect contact must be prevented by other means, for example, by an overcurrent protective device.
- ⇒ Equipment that is built into machines must be secured against direct contact. Use appropriate housings, for example a control cabinet.

European countries: according to EN 50178/1998, section 5.3.2.3.

U.S.A: See National Electrical Codes (NEC), National Electrical Manufacturers Association (NEMA) and local building codes. The user of this equipment must observe the above noted instructions at all times.

To be observed with electrical drives, power supplies, and filter components:



DANGER

**High electrical voltage! High leakage current!
Danger to life, danger of injury and bodily harm
from electrical shock!**

- ⇒ Before switching on power for electrical units, all housings and motors must be permanently grounded according to the connection diagram. This applies even for brief tests.
- ⇒ Leakage current exceeds 3.5 mA. Therefore the electrical equipment and units must always be firmly connected to the supply network.
- ⇒ Use a copper conductor with at least 10 mm² cross section over its entire course for this protective connection!
- ⇒ Prior to startups, even for brief tests, always connect the protective conductor or connect with ground wire. High voltage levels can occur on the housing that could lead to severe electrical shock and personal injury.

European countries: EN 50178/1998, section 5.3.2.1.

USA: See National Electrical Codes (NEC), National Electrical Manufacturers Association (NEMA), and local building codes. The user of this equipment must maintain the above noted instructions at all times.

2.6 Protection by protective low voltage (PELV) against electrical shock

All connections and terminals with voltages between 5 and 50 Volts on INDRAMAT products are protective low voltages designed in accordance with the following standards on contact safety:

International: IEC 364-4-411.1.5

EU countries: see EN 50178/1998, section 5.2.8.1.



WARNING

High electrical voltage due to wrong connections! Danger to life, severe electrical shock and severe bodily injury!

- ⇒ Only equipment, electrical components and cables of the protective low voltage type (PELV = Protective Extra Low Voltage) may be connected to all terminals and clamps with 0 to 50 Volts.
 - ⇒ Only safely isolated voltages and electrical circuits may be connected. Safe isolation is achieved, for example, with an isolating transformer, an opto-electronic coupler or when battery-operated.
-

2.7 Protection against dangerous movements

Dangerous movements can be caused by faulty control or the connected motors. These causes are be various such as:

unclean or wrong wiring of cable connections

inappropriate or wrong operation of equipment

malfunction of sensors, encoders and monitoring circuits

defective components

software errors

Dangerous movements can occur immediately after equipment is switched on or even after an unspecified time of trouble-free operation.

The monitors in the drive components make faulty operation almost impossible. Regarding personnel safety, especially the danger of bodily harm and property damage, this alone should not be relied upon to ensure complete safety. Until the built-in monitors become active and effective, it must be assumed in any case that some faulty drive movements will occur. The extent of these faulty drive movements depends upon the type of control and the state of operation.



DANGER

Dangerous movements! Danger to life and risk of injury or equipment damage!

⇒ Personnel protection must be secured for the above listed reason by means of superordinate monitors or measures.

These are instituted in accordance with the specific situation of the facility and a danger and fault analysis conducted by the manufacturer of the facility. All the safety regulations that apply to this facility are included therein. By switching off, circumventing or if safety devices have simply not been activated, then random machine movements or other types of faults can occur.

Avoiding accidents, injury or property damage:

⇒ Keep free and clear of the machine's range of motion and moving parts. Prevent people from accidentally entering the machine's range of movement:

- use protective fences
- use protective railings
- install protective coverings
- install light curtains or light barriers

⇒ Fences must be strong enough to withstand maximum possible momentum.

⇒ Mount the emergency stop switch (E-stop) in the immediate reach of the operator. Verify that the emergency stop works before startup. Don't operate the machine if the emergency stop is not working.

⇒ Isolate the drive power connection by means of an emergency stop circuit or use a start-inhibit system to prevent unintentional start-up.

⇒ Make sure that the drives are brought to standstill before accessing or entering the danger zone.

⇒ Secure vertical axes against falling or slipping after switching off the motor power by, for example:

- Mechanically securing the vertical axes
- Adding an external brake / clamping mechanism
- Balancing and thus compensating for the vertical axes mass and the gravitational force

The standard equipment motor brake or an external brake controlled directly by the servo drive are not sufficient to guarantee the safety of personnel!

- ⇒ Disconnect electrical power to the equipment using a master switch and secure the switch against reconnection for:
 - maintenance and repair work
 - cleaning of equipment
 - long periods of discontinued equipment use
 - ⇒ Avoid operating high-frequency, remote control and radio equipment near electronics circuits and supply leads. If use of such equipment cannot be avoided, verify the system and the plant for possible malfunctions at all possible positions of normal use before the first start-up. If necessary, perform a special electromagnetic compatibility (EMC) test on the plant.
-

2.8 Protection against magnetic and electromagnetic fields during operations and mounting

Magnetic and electromagnetic fields generated by current-carrying conductors and permanent magnets in motors represent a serious health hazard to persons with heart pacemakers, metal implants and hearing aids.



WARNING

- Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electrical equipment!**
- ⇒ Persons with pacemakers, metal implants and hearing aids are not permitted to enter following areas:
 - Areas in which electrical equipment and parts are mounted, being operated or started up.
 - Areas in which parts of motors with permanent magnets are being stored, operated, repaired or mounted.
 - ⇒ If it is necessary for a person with a pacemaker to enter such an area, then a physician must be consulted prior to doing so. Pacemaker, that are already implanted or will be implanted in the future, have a considerable deviation in their resistance to interference. Due to the unpredictable behavior there are no rules with general validity.
 - ⇒ Persons with hearing aids, metal implants or metal pieces must consult a doctor before they enter the areas described above. Otherwise health hazards will occur.
-

2.9 Protection against contact with hot parts



CAUTION

Housing surfaces could be extremely hot! Danger of injury! Danger of burns!

- ⇒ Do not touch surfaces near the source of heat! Danger of burns!
- ⇒ Wait ten (10) minutes before you access any hot unit. Allow the unit to cool down.
- ⇒ Do not touch hot parts of the equipment, such as housings, heatsinks or resistors. Danger of burns!

2.10 Protection during handling and installation

Under certain conditions inappropriate handling and installation of parts and components may cause injuries.



CAUTION

Risk of injury through incorrect handling! Bodily harm caused by crushing, shearing, cutting and mechanical shock!

- ⇒ Observe general instructions and safety regulations during handling installation.
- ⇒ Use only appropriate lifting or moving equipment.
- ⇒ Take precautions to avoid pinching and crushing.
- ⇒ Use only appropriate tools. If specified by the product documentation, special tools must be used.
- ⇒ Use lifting devices and tools correctly and safely.
- ⇒ Wear appropriate protective clothing, e.g. safety glasses, safety shoes and safety gloves.
- ⇒ Never stay under suspended loads.
- ⇒ Clean up liquids from the floor immediately to prevent personnel from slipping.

2.11 Battery safety

Batteries contain reactive chemicals in a solid housing. Inappropriate handling may result in injuries or equipment damage.



Risk of injury through incorrect handling!

- ⇒ Do not attempt to reactivate discharged batteries by heating or other methods (danger of explosion and corrosion).
- ⇒ Never charge batteries (danger from leakage and explosion).
- ⇒ Never throw batteries into a fire.
- ⇒ Do not dismantle batteries.
- ⇒ Handle with care. Incorrect extraction or installation of a battery can damage equipment.

Note: Environmental protection and disposal! The batteries contained in the product should be considered as hazardous material for land, air and sea transport in the sense of the legal requirements (danger of explosion). Dispose batteries separately from other refuse. Observe the legal requirements given in the country of installation.

2.12 Protection against pressurized Systems

Certain Motors (ADS, ADM, 1MB etc.) and drives, corresponding to the information in the Project Planning manual, must be provided with and remain under a forced load such as compressed air, hydraulic oil, cooling fluid or coolant. In these cases, improper handling of the supply of the pressurized systems or connections of the fluid or air under pressure can lead to injuries or accidents.



Danger of injury when pressurized systems are handled by untrained personnel!

- ⇒ Do not attempt to disassemble, to open or to cut a pressurized system.
- ⇒ Observe the operation restrictions of the respective manufacturer.
- ⇒ Before the disassembly of pressurized systems, lower pressure and drain off the fluid or gas.
- ⇒ Use suitable protective clothing (for example protective eyewear, safety shoes and gloves)
- ⇒ Remove any fluid that has leaked out onto the floor immediately.

Note: Environmental protection and disposal! The fluids used in the operation of the pressurized system equipment is not environmentally compatible. Fluid that is damaging to the environment must be disposed of separate from normal waste. Observe the national specifications of the country of installation.

3 Definitions and terms

3.1 Electromagnetic compatibility (EMC)

Electromagnetic compatibility (EMC) or EMI (electromagnetic interference) entails the following:

- sufficient **immunity to interference** of an electrical installation or electrical equipment against electrical, magnetic or electromagnetic interference originating outside and transmitted via cables and in free space
- and a sufficiently low level of **emission of electrical, magnetic or electromagnetic interference** from an electrical installation or electrical equipment to other equipment in their vicinity via cables and free space.

3.2 Securing EMC demands

The EMC features of components

Rexroth Indramat AC drives and control components are designed and built according to legal requirements as specified in the EU directives EMC 89/336/EEC and German EMC laws, in compliance with the current state of standardization.

The compliance with EMC standards was checked using a typical system installation at a standard test bench. The limit values as stated in EN 61800-3/ 1996 were maintained.

| EMC type | Area | Limit value as per standard | |
|--------------------------|---|---|--|
| Emission of interference | Industrial area | group 2 class A | EN 61800-3 sections 6.2 and 6.3, 2 nd environment |
| | Residential and light industrial areas | group 1 class B (former radio-interference level N) | EN 61800-3 sections 6.2 and 6.3, 1 st environment |
| Immunity to interference | Industrial area Residential and light industrial areas | | EN 61800-3 section 5.2, 2 nd environment |

Fig. 3-1: Limit values as per standards

In addition to the in-house test, individual drive systems were subject to conformity checks in an accredited laboratory of a competent body authorized by CE.

Transferability to the final product

The readings of a typical system installation are not transferable in every case to the state as installed of the product in the machine or installation.

Immunity to interference and emission of interference are largely dependent on the:

- configuration of the connected drives
- number of connected drives
- installation conditions, location
- interference conditions, cabling and
- installation of the individual drive components within the machine or installation.

In addition, the measures which must be taken are dependent on the demands of electrical safety as well as cost-effectiveness of the application.

To prevent the effects of interference as far as possible, mounting and installation instructions are specified in the application manual of the components and in this documentation.

Drive system interference emission

To maintain the limit values for interference emission (mainly conducted radio interference of more than 9 kHz) at the points of connection of machine or installation, the application notes as specified in this description must be followed.

This particularly includes the following measures:

- Motor power cables must be routed shielded or shielded motor power cables of Rexroth Indramat must be used.
- Motor power cables must be kept as short as possible.
- An NFD mains filter as recommended by Rexroth Indramat and/or an NFE mains filter for single-phase connection must be adequately mounted in the mains conductor line of the AC drive system to cut down on interference. Information can be found in chapter 5 "Types of shielded motor power cables for Rexroth Indramat drives".

The filter also largely reduces interference, via the power connection, with units within close proximity.

Industrial area

If the limit values within an industrial area, which is isolated from the public network with a transformer substation, only have to be maintained at the borders of a piece of land or in adjacent low-voltage networks, then it may be possible to do without the filter. An interference filter is advisable, however, within proximity to radios or other high-frequency sensitive equipment such as measuring sensors, measuring leads or measuring devices.

Frequently, however, the increased resistance to interference of a sensitive unit can often be the more cost-effective solution in comparison to interference suppression measures in the drive system of the installation.

Residential, business and commercial areas

Medium-sized manufacturing plants and commercial enterprises can be connected to the public low-voltage network together with residential buildings. In this case, operating without interference suppression capabilities can represent a considerable interference risk for radio and TV reception. For this reason, taking the above measures is basically recommended.

The standard external mains filters NFD and NFE have been designed in such a way as to allow obtaining the lower limit value of interference emission in these areas (class B according to EN 55011 and EN 55014), if:

- the final product / the machine has been installed in compact form
- the number of connected drives is limited
- the motor cables length of the drives is less than 10 m
- the indicated application notes have been followed.

Since it is impossible to obtain the lower limit values for residential areas with all applications by means of the usual measures (like for example in the case of large and electrically not closed installations, longer motor cables or a large number of drives), the following note included in EN 61800-3/ A11, section 6.3 has to be observed:

Note: This is a product of restricted distribution according to IEC 61800-3! In a residential area this product can cause high-frequency interference. If this happens, the user can be requested to take appropriate measures.

Ungrounded networks If equipment is operated on an ungrounded network, then the drive system should be galvanically decoupled with a mains filter via an isolating transformer if ground fault monitoring of the facility is to be maintained.

Please note that residual-current devices trip unintentionally as a result of larger leakage current when connecting mains filters.

If the drive system is nevertheless operated directly on the ungrounded mains, make sure that

- the ground-fault detection of the mains does not operate unintentionally and
- the interference suppression, that is only activated via the parasitic mains capacities of the ungrounded mains, is still sufficient, in order to comply with the limit values required by the application.

3.3 Standards and laws

EU directives There are EU directives at the European level. These directives are interpreted at a national level in the individual countries. For EMC, EU directive 89/336/EEG sets the standard, interpreted in Germany into the EMC law (law governing electromagnetic compatibility of apparatus) dated 1992-11-9.

3.4 Technical explanations on the emission of interference

Causes of interference emission Frequency converters with rapidly alternating semi-conductors are built into regulated, speed-variable drives. The advantages of being able to change speeds with a high level of precision is achieved by modulating the pulse-width of the frequency converter voltage. This can generate sinusoidal currents with variable amplitudes and frequencies in the motor. The fast changing voltage, high pulse frequency and the resulting harmonics cause an undesirable, but physically unavoidable, emission of interference voltages and fields (broad band interference). This interference is mostly asymmetrical interference to ground.

The spreading of this interference largely depends upon the:

- configuration
- conditions of installation
- location
- radio interference conditions
- cabling and installation

of the individual drive components within the machine or installation.

If interference is emitted unfiltered out of the equipment to the attached lines, then these can, in turn, themselves emit this interference into free space (aerial effects). This includes mains supply lines.

Reducing the spread of interference

There are three possibilities:

1. Filtering:

It prevents the propagation of interference over lines, in particular over the mains supply line (mains filter). Specially developed radio interference filters are available for this purpose.

2. Shielding:

A sufficient metal shield prevents emission into free space. This is achieved by mounting the equipment into a grounded control cabinet or housing (metal encapsulation or casing). The shielding of line connections is implemented with shielded cables and leads, whereby the shields must be grounded over the greatest possible surface.

3. Grounding:

This conducts interference to earth, permitting it to flow back to source over the shortest distance possible. Grounding must be sufficiently **short and over the greatest possible surface area** to achieve low inductive resistance with low line inductance. The higher the frequency of interference, the lower ground line inductance must be.

In the following, these measures are described in detail with practical applications.

4 Selecting a mains filter

The mains filter serves to reduce the noise level in the range of 50 kHz to 30 MHz to the allowed limit values. The selection of the mains filter depends on the following data:

- applied mains voltage
- continuous current on mains side
- ambient temperature

The mains filters as illustrated in Fig. 4-3: Mains filter NFD/NFE" are used in Rexroth Indramat drive systems for interference suppression. These have been designed and dimensioned especially for Rexroth Indramat drive systems.

If filters of other manufacturers are used, then the allowed limit values prescribed by Rexroth Indramat cannot be guaranteed.

4.1 Mains side continuous current I_{Netz}

The filter is selected in terms of the mains side continuous current I_{Netz} of the drive package.

It is calculated from the apparent power S using the following formula:

| | |
|--------------------------|--|
| single-phase connection: | $I_{\text{Netz}} = \frac{S}{U_{\text{Netz}}}$ |
| three-phase connection: | $I_{\text{Netz}} = \frac{S}{\sqrt{3} \cdot U_{\text{Netz}}}$ |

U_{Netz} : voltage between the phases of the mains

S : apparent power

Fig. 4-1: Determination of mains current

See chapter 9 Determining apparent power for calculating apparent power (S).

The current of the Rexroth Indramat filter corresponds to the continuous current (r.m.s. value). In the case of short-term operations for one minute, a filter with low current levels may be selected.

The current can be calculated as per the following formula:

| | |
|---|--|
| $I_{\text{eff}} = I_1 + \hat{I}_2 \cdot \sqrt{\frac{t_1}{t_2}}$ | |
|---|--|

Fig. 4-2: Calculating short-term operations

The filters are generally designed to take four times the nominal current for approximately ten seconds without damage.

4.2 Technical data of mains filters

| Maximum connecting voltage of mains 50..60 Hz U_N | Nominal mains current I_{Netz} (1) | No. of phases | Type of mains filter | Terminals (3) | | | Power dissipation approx W | Weight kg | Type |
|---|--|---------------|-------------------------|--------------------------------|--------------------------|---------|-------------------------------|--------------|------------|
| | | | | flexible mm ² | rigid mm ² | AWG | | | |
| in V | in A | | | | | | | | |
| AC 480 V + 10 % | 7 | 3 | NFD 03.1-480-008 | 4 (3) | 6 (3) | AWG 12 | 3.9 | 0.7 | vertical |
| AC 480 V + 10 % | 16 | 3 | NFD 03.1-480-016 | 4 (3) | 6 (3) | AWG 12 | 6.4 | 1.0 | vertical |
| AC 480 V + 10 % | 30 | 3 | NFD 03.1-480-030 | 10 | 16 | AWG 6 | 11.9 | 1.4 | vertical |
| AC 480 V + 10 % | 55 | 3 | NFD 03.1-480-055 | 16 | 25 | AWG 4 | 25.9 | 2.0 | vertical |
| AC 480 V + 10 % | 75 | 3 | NFD 03.1-480-075 | 25 | 35 | AWG 3 | 30.4 | 3.5 | vertical |
| AC 480 V + 10 % | 130 | 3 | NFD 03.1-480-130 | 50 | 50 | AWG 1/0 | 38 | 4.7 | vertical |
| AC 480 V + 10 % | 180 | 3 | NFD 03.1-480-180 | 95 | 95 | AWG 4/0 | 61 | 10 | vertical |
| AC 230 V + 10 % | 7.5 | 1 | NFE 02.1-230-008 | 4 (3) | 6 (3) | AWG 10 | 7.2 | 1.1 | vertical |
| AC 230 V + 10 % | 4.7 | 1 | NFE 01.1-250-006 (2) | tab connectors 6.3 x 0.8 mm | | | 4 | 0.245 | horizontal |

NFD = three-phase filter, NFE = single-phase filter
 (1) = maximum continuous current on mains side at 45°C ambient temperature
 (2) = to be used only for interference suppression of the NTM power supply unit
 (3) = a conductor cross section of 10 mm² is to be connected for the ground wire by means of a plug connector or ring cable lug

Fig. 4-3: Mains filter NFD/NFE

| | |
|---|--|
| Operating frequency | From 0 to 60 Hz at 45 °C |
| Power dissipation | measured at 2 or 3 x $R I_{Nenn DC}^2$ |
| Temperature range | -25 ...+ 85 °C |
| Overload | 1.5 I_{Nenn} 1 minute per hour or 4 I_{Nenn} für 10 s |
| Effective attenuation | frequency range 150 kHz – 30 MHz |
| Saturation | reduction of filter attenuation by 6 dB with 2.5-to 3-fold nominal current |
| Test voltage | L/N -> PE or L -> PE: 2700 V _{DC} 2 s at 25 °C N -> L 2100 V _{DC} 2 s at 25 °C |
| Current reduced with overtemperature | see: Fig. 4-11: Calculation with higher ambient temperatures |
| Leakage current at 50 Hz | symmetrical three-phase operation: typ. 30 mA, single-phase operation or in the case of fuse failure of a phase: typ. 175 ... 190mA |
| Protection category | IP20, except for NFE01.1-250-006: IP 10 |

Fig. 4-4: Technical data mains filter NFD 3.1

4.3 Dimensions

| Mains filter type | A | B | C | D | E | F | G | H | J | K | L | M | M_{AE} | M_{AKI} |
|-------------------|------------|-----|-----|-----|-----|-----|-----|-----|------|-----|-----|-----|----------|-----------|
| NFD 03.1-480-007 | 190 | 90 | 50 | 160 | 180 | 20 | 5.4 | --- | --- | 190 | --- | M5 | 2.2 | 0.8 |
| NFD 03.1-480-016 | 250 | 90 | 55 | 220 | 235 | 25 | 5.4 | --- | --- | 250 | --- | M5 | 2.2 | 0.8 |
| NFD 03.1-480-030 | 270 | 100 | 60 | 240 | 255 | 30 | 5.4 | --- | --- | 270 | --- | M5 | 2.2 | 2 |
| NFD 03.1-480-055 | 250 | 105 | 90 | 220 | 235 | 60 | 5.4 | --- | --- | 260 | --- | M6 | 4 | 2.2 |
| NFD 03.1-480-075 | 270 | 145 | 90 | 240 | 255 | 60 | 6.5 | --- | --- | 280 | --- | M6 | 4 | 4.5 |
| NFD 03.1-480-130 | 270 | 160 | 100 | 240 | 255 | 65 | 6.5 | --- | --- | 330 | --- | M10 | 18 | 8 |
| NFD 03.1-480-180 | 380 | 180 | 130 | 350 | 365 | 102 | 6.5 | --- | --- | 455 | --- | M10 | 18 | 20 |
| NFE 02.1-230-008 | 90 | 210 | 60 | 60 | 80 | 40 | 5.3 | 40 | 0.75 | --- | 15 | 10 | 0.8 | 0.8 |
| NFE 01.1-250-006 | see figure | | | | | | | | | | | | | |

M_{AE} = maximum tightening torque of the ground stud in Nm
 M_{AKI} = maximum tightening torque of the terminal connector in Nm
 Fig. 4-5: Dimensions of the mains filters NFD/NFE

NFD03.1

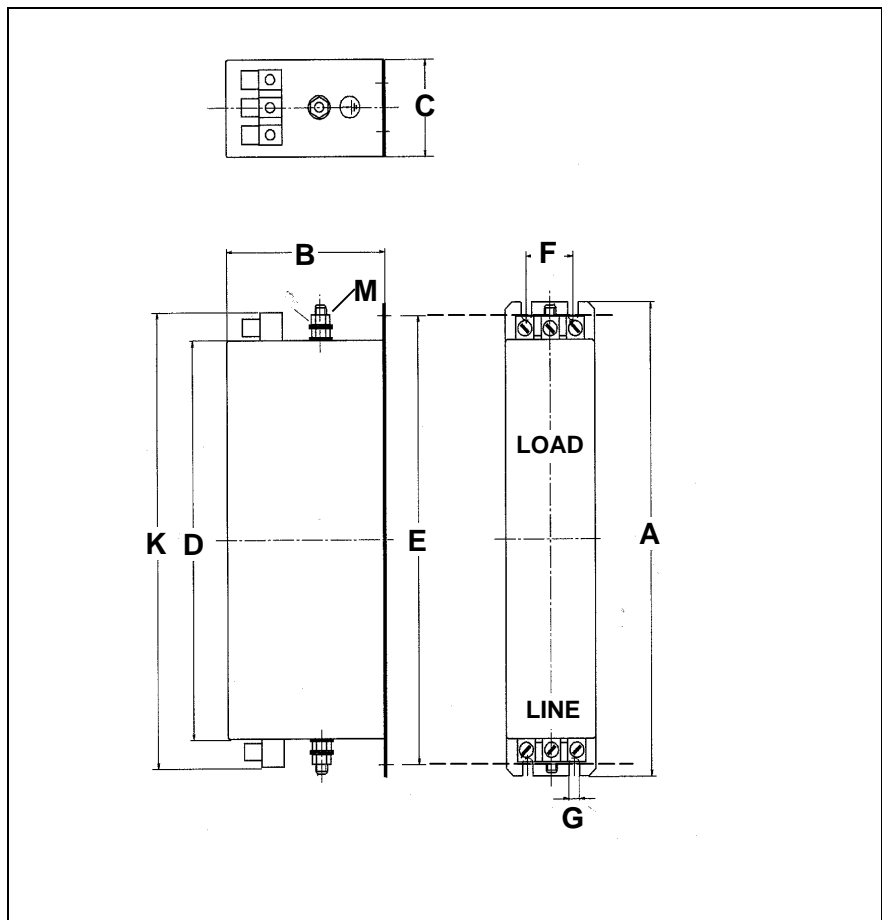
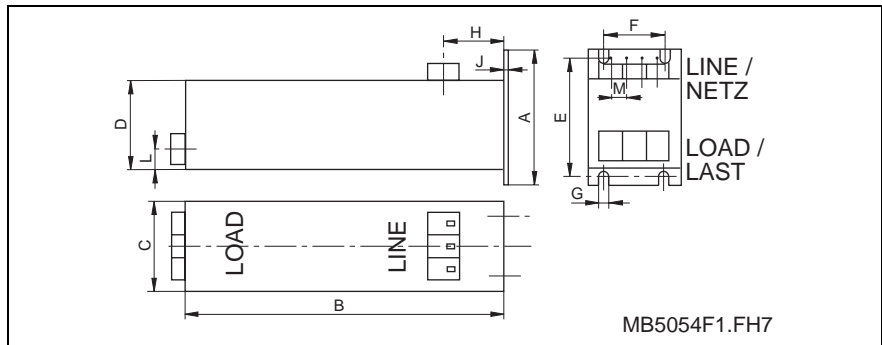


Fig. 4-6: AC filter NFD03.1 for drives

Tolerance limits for NFD03.1:

- Dimensions B, C, D, K are maximum values. They can be reduced up to 15 mm.
- The ground studs M can also stand vertically, seen from the front side, instead of horizontally.

NFE02.1



NFE02.1-230-008 (with 3 terminal connectors)

Fig. 4-7: Single-phase filter NFE02.1 for drives

NFE01.1

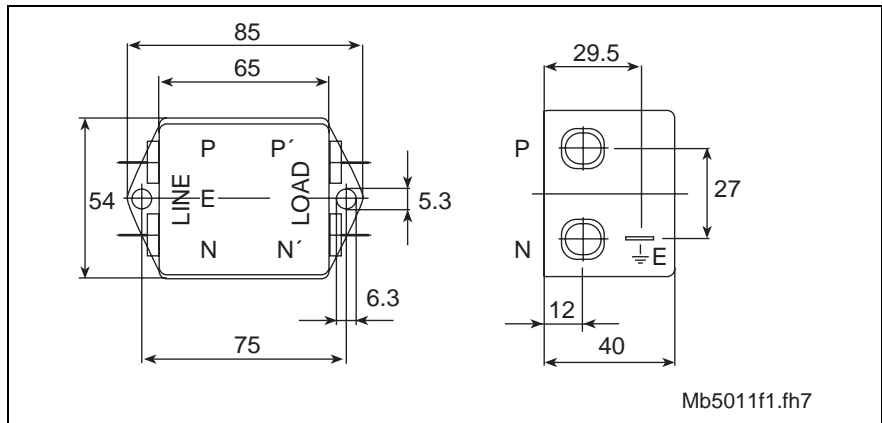


Fig. 4-8: Single-phase filter NFE01.1-250-006 for interference suppression of the power supply unit NTM

Note: The mains filter is connected by means of tab receptacles (b = 6.3 mm, d = 1 mm).

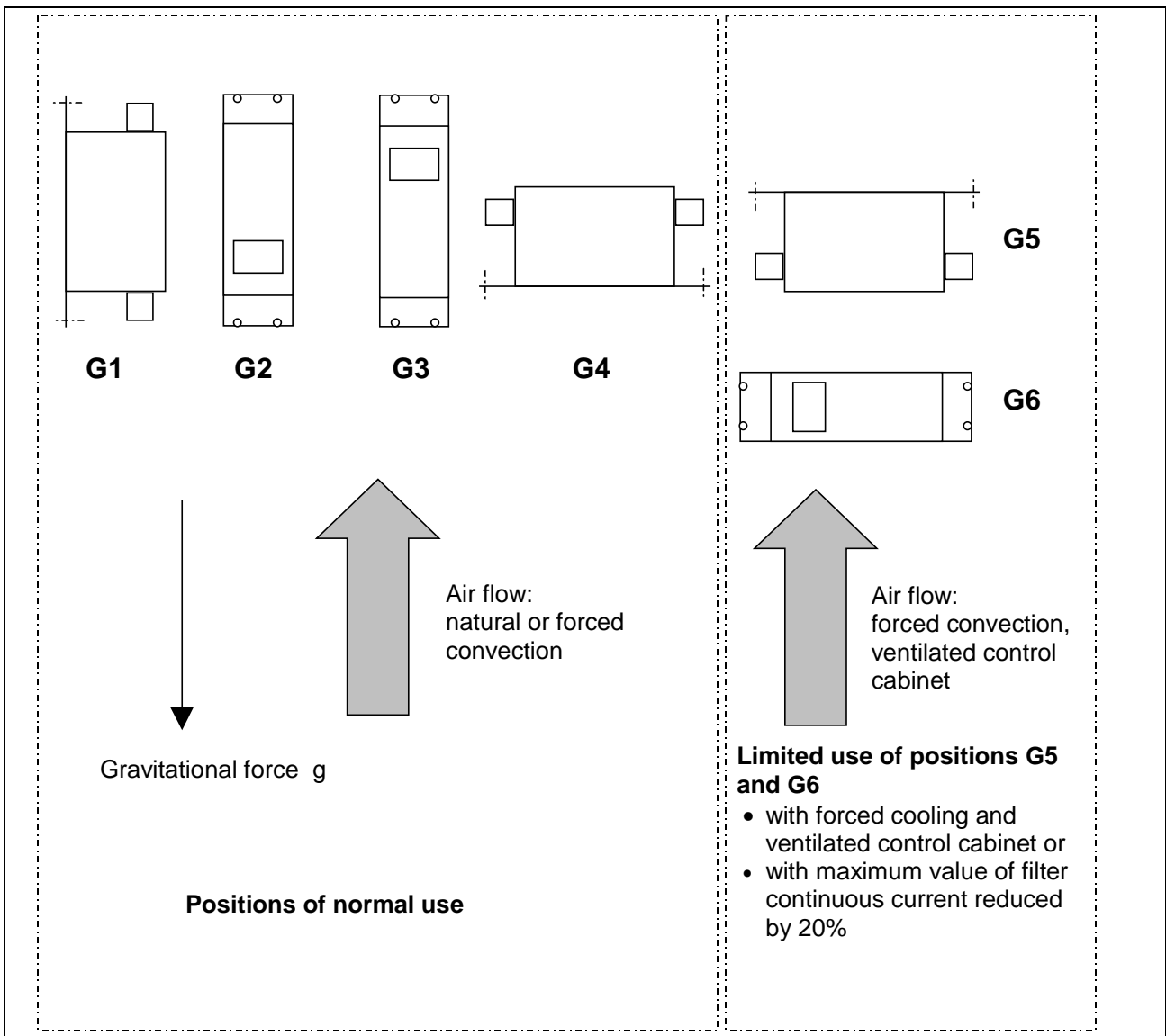


Fig. 4-9: Positions of normal use and installation of the filter NFD03.1

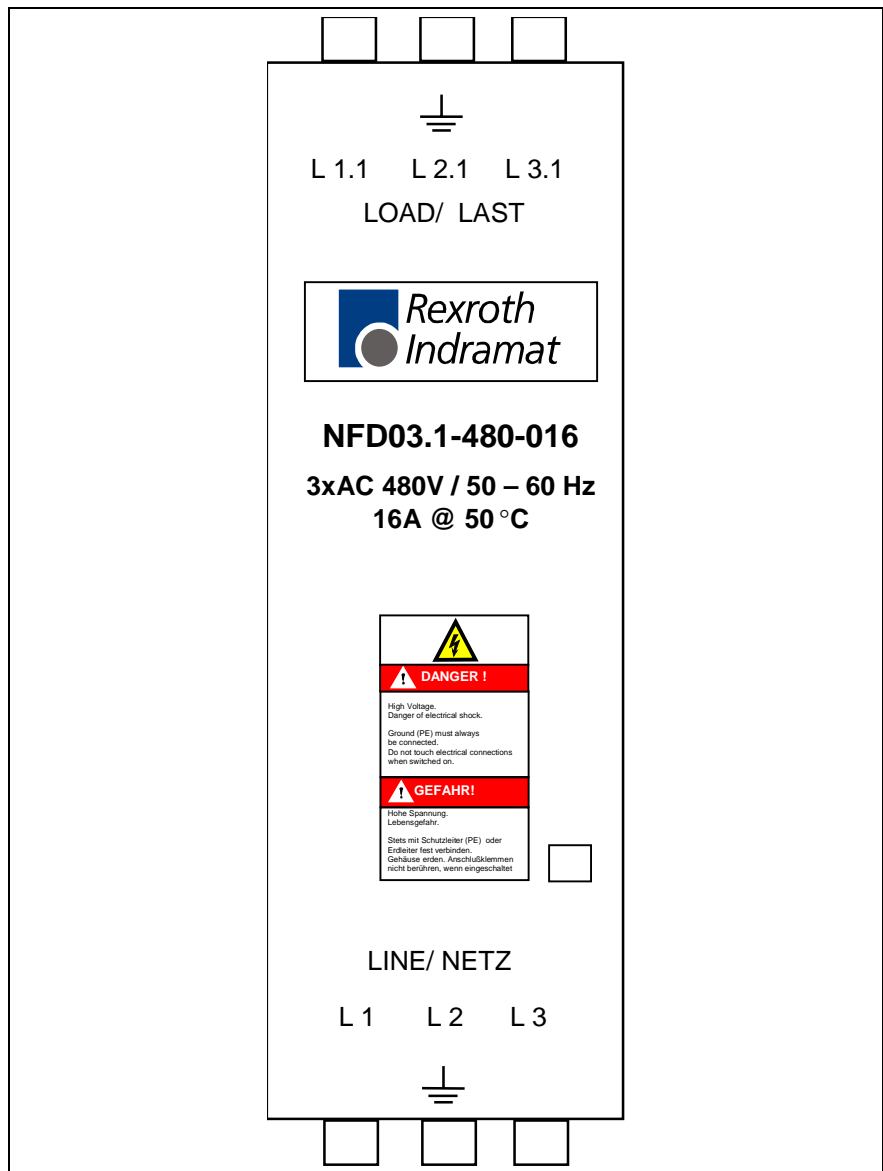


Fig. 4-10: Front view NFD03.1-480-16

4.4 Ambient temperature

The mains filters recommended by Rexroth Indramat have been designed for an ambient temperature of 45 °C.

For higher temperatures, reduce mains current as per the following formula:

$$I = I_{\text{Netz}} \cdot \sqrt{\frac{85 - T_{\text{amb}}}{40}}$$

I_{Netz} : rated current of filter at 45 °C

T_{amb} : ambient temperature

Fig. 4-11: Calculation with higher ambient temperatures

5 Types of shielded motor power cables for Rexroth Indramat drives

Shielded motor power cables from Rexroth Indramat are highly flexible cables, available as shown in Fig. 5-1: Available cables with indicated type designations.

| | Non-shielded cables | Shielded cables |
|--------------------------------------|----------------------------|------------------------|
| Cable (per meter) Example: | INK02xx INK0204 | INK06xx INK0604 |
| Ready-made cable Example: | IKLxxx IKL0122 | IKGxxx IKG0122 |

Fig. 5-1: Available cables

The cable diameter and type required for various motors can be found in the project planning manual of each motor.

For DIAX04 and ECODRIVE03 the documentation "Connecting cables DIAX04, ECODRIVE03 and Powerdrive", selection data, is available.

Notes

6 Optimum assembly of components in the cabinet

6.1 Breakdown into zones

The assembly within the control cabinet can be seen on Fig. 6-2: Optimum assembly of components in the cabinet.

There are three different zones:

1. Interference-free zone within control cabinet (**zone A**):

- Mains supply line, input terminals, fuses, mains circuits, mains side of mains filters for drives and relevant connecting lines.
- Control or auxiliary voltage connection with power supply unit, fuse and other parts, as long as these are not conducted to the AC drive via the mains filter.
- All components not electrically connected to the drive system.

2. Interference-susceptible zone (**zone B**):

- Mains connections between drive system and mains filter for drives, mains contactor.
- Interface lines of the drive controller.

3. Zone with extensive interference (**zone C**):

- Motor cable including single cores.

In no case may a line of one zone be routed in a parallel manner with a line from another zone, in order to avoid undesired interference injection from one zone to the other and to bypass the filter with regard to high frequency. All connecting cables must be kept as short as possible.

In the case of complex systems, we recommend mounting of drive components in one cabinet, while controls are mounted in another, separate cabinet.

As poorly grounded cabinet doors can function as large-area radiators, we recommend connecting the doors at the top, in the middle and at the bottom to the cabinet via short ground wires with a diameter of 6 mm² or, perhaps even better, via grounding strips with the same diameter. Make sure that the points of contact do have good contact.

6.2 Installation and assembly in the interference-free zone within the control cabinet (zone A)

Arrangement of the components in the control cabinet

When arranging the components in the control cabinet, make sure that the components and electrical elements (switches, pushbuttons, fuses, terminal connectors) in the interference-free zone A are placed with a distance of at least $d_1 = 200$ mm to the components in both other zones B and C.

In particular, a distance of at least $d_2 = 500$ mm has to be kept in zone A between magnetic components, such as transformers, line reactors and DC-link reactors, that are directly connected to the power terminals of the drive system and the interference-free components and lines between mains and filter including the mains filter. If this distance is not kept, the magnetic leakage fields are injected to the interference-free components and lines connected to the mains so that the limit values at the supply connection are exceeded in spite of the installed filter.

Cable routing of the interference-free lines to the supply connection

The distance between the power input line and the lines between filter and exit point from the control cabinet in zone A and the lines in zones B and C must be at least 200 mm (distances d_1 and d_3 in Fig. 6-2: Optimum assembly of components in the cabinet") at all points.

If this is impossible, there are two alternatives:

- Install these lines with a shield and connect the shield, at several points, but at least at the beginning and at the end of the line, to the mounting plate or the control cabinet housing over a large surface area, or:
- Separate these lines from the other interference-susceptible lines in zones B and C by means of a grounded distance plate vertically attached to the mounting plate.

In addition, these lines have to be kept as short as possible within the control cabinet and installed directly on the grounded metal surface of the mounting plate or of the control cabinet housing.

Mains supply lines from zones B and C must not be connected to the mains without a filter.

Note: In case the information on cable routing given in this section is not observed, the effect of the mains filter is totally or partly neutralized. You must therefore expect the noise level of the interference emission to be higher within the range of 150 kHz to 40 MHz and the limit values at the connection points of the machine or installation to be exceeded.

Installation and connection of a neutral conductor (N) or PEN conductor

If a neutral conductor or PEN conductor is used together with a three-phase connection, it must not be installed unfiltered in zones B and C, in order to keep interference off the mains.

Control voltage or auxiliary supply connection

If conductor-ground voltage is required in zones B or C for an auxiliary supply or control voltage connection of the drive system (including ventilator connections), or for a power supply unit, for example 230 Volt in the case of a 400 Volt mains, you can choose from the following solutions:

1. Using a control-power transformer without neutral conductor:

Generate voltage from the three-phase mains via a single-phase or three-phase transformer 400 Volt / 230 Volt, the maximum imbalance being 10%. The transformer is connected after the three-phase filter NFD before the power connector of the drives according to Fig. 6-1, illustration on top. This solution is also shown on Fig. 6-2.

- or -

2. Filtering the neutral conductor:

If the voltage is generated from a phase of the mains and the neutral conductor, phase and neutral conductor have to be routed via a single-phase filter NFE02.1-230-008 between zone A and B according to Fig. 6-1, illustration in the middle. Pay attention to the maximum current load.

In order to avoid problems with leakage current, interference and ground fault in power supply units and their circuits, these units should be galvanically isolated from the mains (isolating transformer).

Connection of motor ventilators Single-phase or three-phase supply lines of motor ventilators, that are usually routed in parallel with motor cables or interference-susceptible lines, also have to be provided with a filter. They either have to be filtered via a separate NFE single-phase filter or NFD three-phase filter near the supply connection of the control cabinet, or to be connected at the load side of the existing NFD three-phase filter for the power connector of the drive system. When switching power off, make sure the ventilator is not also switched off.

Shielding of power input lines in the control cabinet If there is a high degree of interference injection to the power input line within the control cabinet, in spite of you having observed the above instructions (to be found out by standard EMC measurement), the lines in zone A have to be routed in shielded form. In this case the shields have to be connected to the mounting plate at the beginning and the end of the line by means of clips, as illustrated in chapter 8 "Installing the motor power cable". The same procedure may be required for long cables of more than 2 m between the point of power supply connection of the control cabinet and the filter within the control cabinet.

Mains filter for AC drives The mains filter is mounted on the parting line between zone A and B. Make sure the ground connection between filter housing and housing of the drive controllers has good electrically conductive properties. If single-phase loads are connected on the load side of the filter, their current may only be a maximum of 10% of the three-phase operating current. A highly imbalanced load of the filter would deteriorate its interference suppression capacity.

If the mains voltage is more than 480 V, the filter has to be connected on the output side of the transformer and not on its supply side.

Grounding In the case of bad ground connections in the installation, the distance between the grounding points E1, E2 in zone A and the other grounding points of the drive system should be at least $d_4 = 400$ mm, in order to minimize interference injection from ground and ground cables to the power input lines.

See also: Fig. 6-2: Optimum assembly of components in the cabinet

Ground wire connection of machine, installation, control cabinet The ground wire of the power cable of the machine, installation or control cabinet of the has to be **firmly connected** at point PE and have a **cross section of at least 10 mm^2** or to be complemented by a second ground wire via separate terminal connectors (according to EN50178/ 1997, section 5.3.2.1). If the cross section of the external conductor is bigger, the ground wire cross section has to be adjusted accordingly.

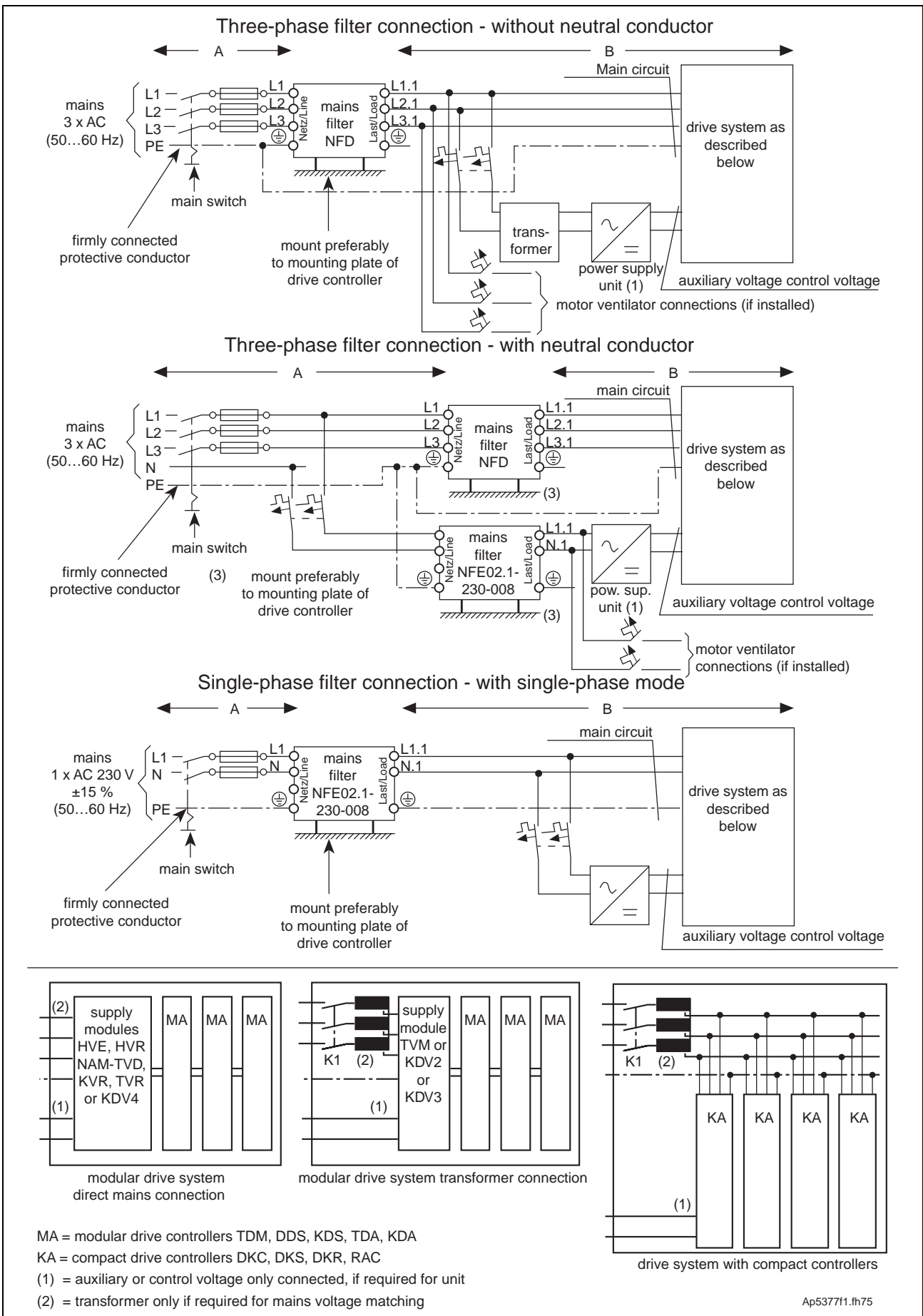


Fig. 6-1: Connection of mains filter

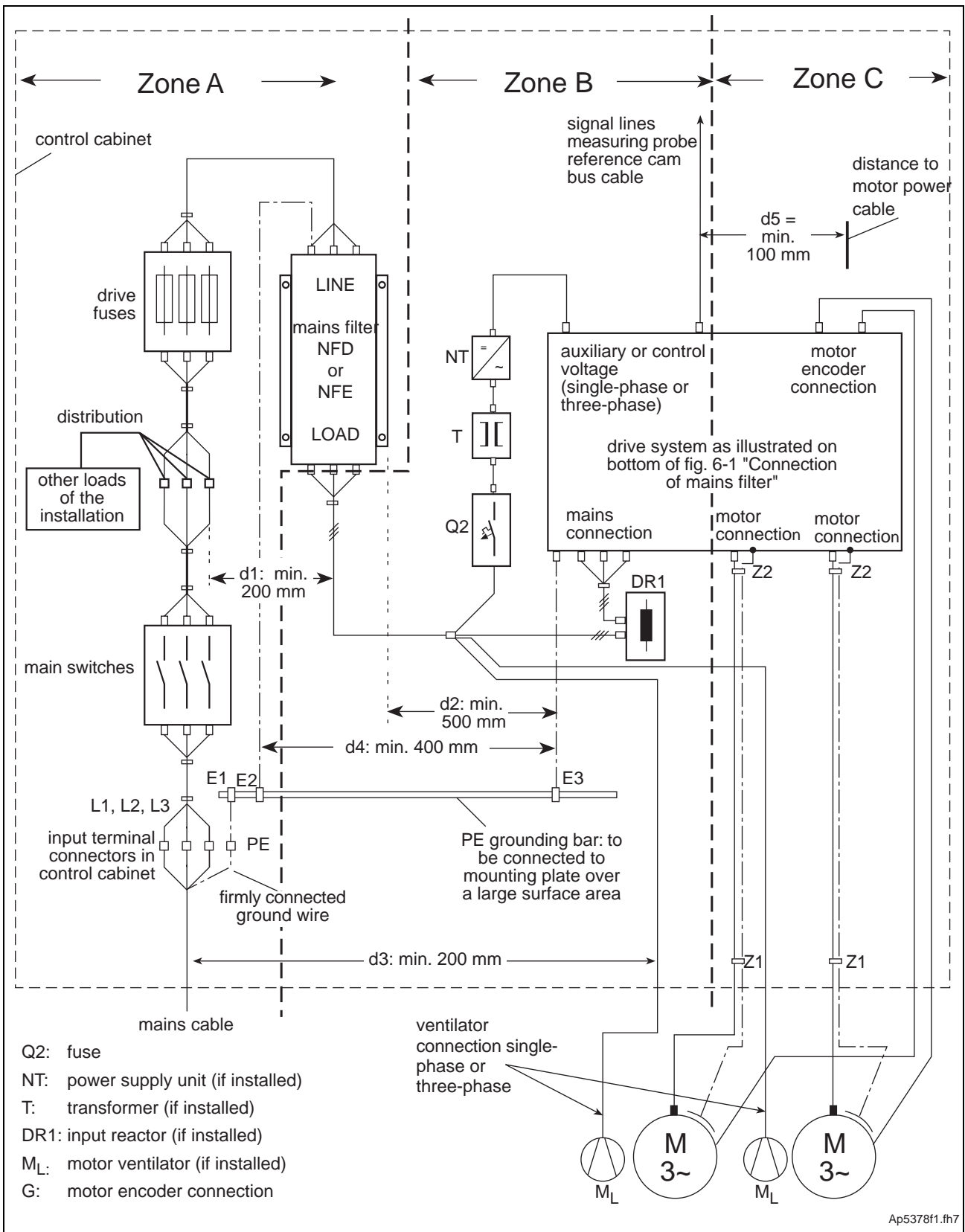


Fig. 6-2: Optimum assembly of components in the cabinet

6.3 Installation and assembly in the interference-susceptible zone within the control cabinet (zone B)

| | |
|--|---|
| Arrangement of components and lines | <p>Constructional elements, components and lines in zone B must have a clearance of at least $d_1 = 200$ mm from constructional elements and lines in zone A, or the former must be shielded by distance plates, standing on and attached to the mounting plate.</p> <p>Power supply units for auxiliary and control voltage connections in the drive system must not be connected directly to the mains, but via the mains filter, as shown in Fig. 6-1: Connection of mains filter and Fig. 6-2: Optimum assembly of components in the cabinet.</p> <p>Line length between drive controller and filter must be as short as possible. Avoid unnecessarily long lines.</p> |
| Control or auxiliary voltage connection | <p>Only in exceptional cases should power supply unit and fuse be connected to phase and neutral conductor for control voltage connection. In this case these components must be mounted and installed in zone A, far away from zones B and C of the drive system. For details see chapter 6.2 "Installation and assembly in the interference-free zone within the control cabinet (zone A)".</p> <p>The connection between control voltage connection of the drive system and power supply unit must be routed through zone B on the shortest possible way.</p> |
| Line routing | <p>The lines must be routed along grounded metal surfaces, to minimize emission of interference fields in zone A (sending aerial effects).</p> |

6.4 Installation and assembly in the zone with extensive interference within the control cabinet (zone C)

Zone C primarily concerns the motor cables.

Effects of the length of the motor power cable

To maintain limit values, the length of the motor cable must be limited. It is highly dependent on the application and ambient conditions of the installation and machine.

Provided that the installation and assembly instructions given in this manual are being observed, the following values are guide values for the max. length, if connecting several axes to a filter:

| Limit values | Setting of clock frequency in drive controller | |
|--------------------------------------|--|---|
| | Standard setting switching frequency 4 kHz | Parameter setting switching frequency 8 kHz |
| For class B, group 1, EN 55011 | 15 m | 10 m |
| For class A, group 1, EN 55011 | 25 m | 15 m |
| For class A, group 2, EN 55011 | 50 m with one axis connected: 75 m | 50 m with one axis connected: 75 m |

Fig. 6-3: Guide values for maximum motor cable length for reaching a certain interference level

The cable should always be as short as the application permits. Avoid any unnecessarily long lines.

Routing of motor cables

Shielded cables are to be used for motor cable routing (see chapter 2 Installing the mains filter). Besides they are always to be routed with a distance of $d_5 = 100$ mm to the other interference-free lines and to signal cables and lines, or to be separated from them by a grounded distance plate. The latter is not required for the feedback cables for Rexroth Indramat motors.

At the drive controller connection the motor cables and the (unfiltered) power connection lines may only be routed in parallel for a distance of 300 mm. After that distance, motor cables and power supply cables have to be routed in opposite directions in separate cables ducts, as illustrated on the following figures (Fig. 6-4; Fig. 6-5) by the example of a drive package with separate power supply connections per drive axis (ECODRIVE).

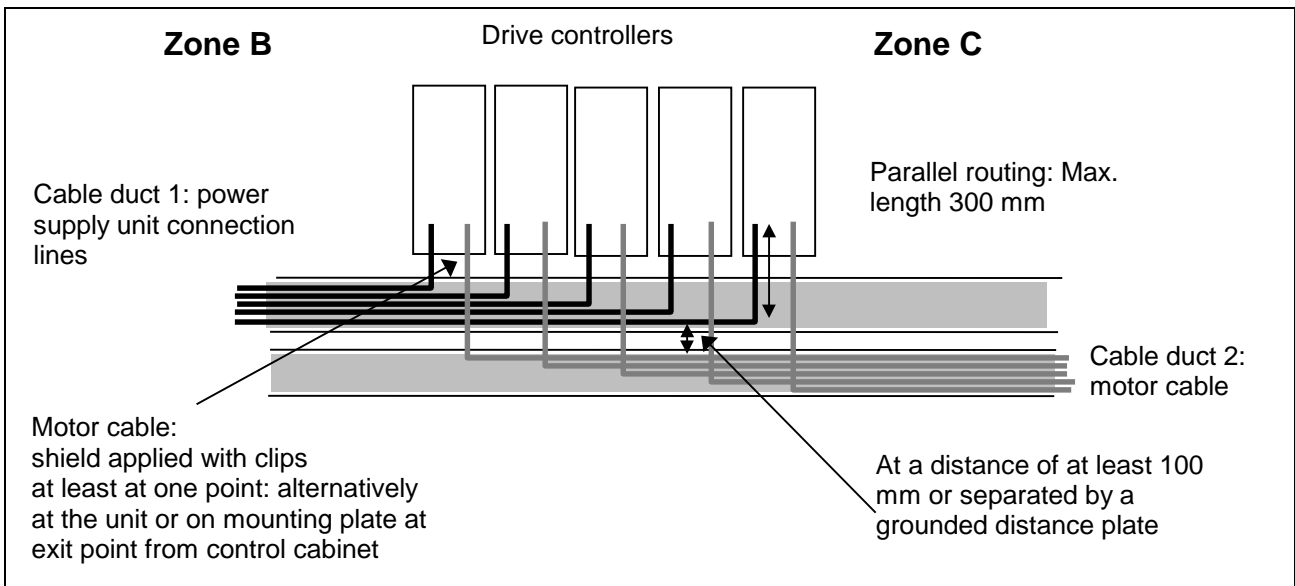


Fig. 6-4 Option 1: separate routing of motor and power supply unit connection cables via 2 cable ducts

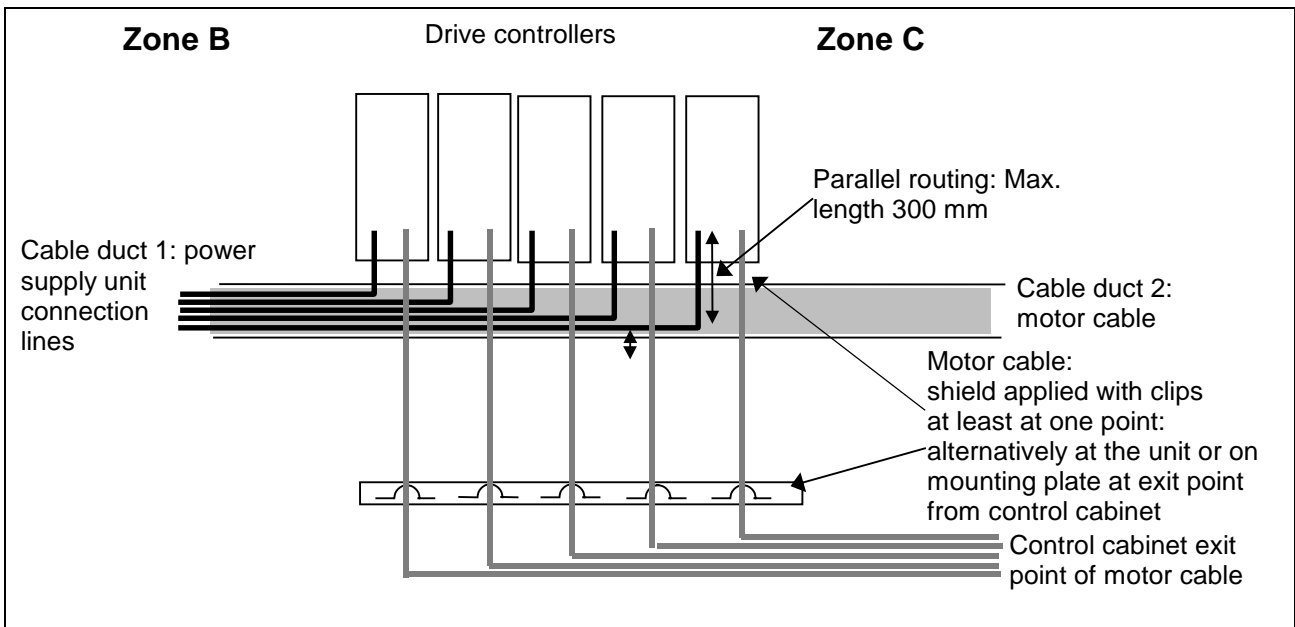


Fig. 6-5 Option 2: separate routing of motor and power supply unit connection cables

Additional recommendations for cable routing

The motor cables should be routed both in the control cabinet and outside of it along grounded metal surfaces to minimize the emission of interference. Ideally, the motor cables are routed in grounded metal cable ducts.

The motor cable exit out of the control cabinet should ideally be at least $d_3 = 400 \text{ mm}$ away from the (filtered) mains cable.

| | |
|--|---|
| Shield connection and shielding for motor cable | <p>The motor cable shield is connected to the grounded mounting plate via clips, as illustrated on Fig. 8-1: "Cable shield connection over largest possible surface area"</p> <ul style="list-style-type: none"> • at the grounding clip of the drive controller provided for this purpose, • or, if not available, at the mounting plate near the drive controller (point Z2 on fig. Fig. 6-2). In this case the shield, together with the insulation, has to remain on the cable up to the drive controller and must not be removed at all. At one point on the mounting plate it is connected to ground by means of a clip. Only at this point is the insulation of the cable stripped for a distance of approx. 10 mm, in order to obtain a conductive connection between shield and clip. • Make sure there is sufficient separate strain relief. |
| Shield connection at ANAX, DIAX01, DIAX02, DIAX03 units | <p>The connection of cable shields by means of round wires (pig tails) at the cable ends to ground and housing is normally insufficient.</p> <p>Connection of the shield by means of circular conductors is only allowed for ANAX, DIAX01, DIAX02, DIAX03 drive controllers. In this case the shield may only be removed over a maximum distance of 100 mm from the drive controller. The round wire (pig tail) between cable shield and housing must not be longer than a maximum of 70 mm and has to be connected with the housing ground over the shortest possible distance.</p> |
| Shield connection at DIAX04, ECODRIVE03 and newer | <p>For drive controllers DIAX04, ECODRIVE03 and newer it is only allowed to connect the shield at the drive controller by means of clips.</p> <p>In some particular cases it can be necessary to ground the motor shield at other points, usually at the exit point of the cable from the control cabinet (point Z2 on fig. Fig. 6-2). This reduces the emission of interference.</p> <p>If the cable is routed in a metal tube, the emission of interference is reduced even more.</p> <p>If the motor cables are routed to the control cabinet via flange boxes, the shield is directly connected to the wall of the control cabinet over a large surface area via the housing of the flange box. Make sure there is sufficient separate strain relief.</p> |
| Equipotential bonding conductor | <p>In the case of poor ground connection between motor housing and control cabinet housing, as well as long motor cables, it may be necessary to use an equipotential bonding conductor with a diameter of 10 mm² between control cabinet and motor housing. Cables longer than 50 m should have a minimum diameter of 35 mm².</p> |
| Shield connection with 1 MB motors | <p>With 1MB motors it must be noted that the connecting lines between winding and terminal box must be shielded or routed under metal, if the terminal box is not mounted directly to the spindle box.</p> |
| Shield connection with LAF and LSF linear motors | <p>With LAF and LSF motors, the shield of the connecting cable must be routed between the primary part and the terminal box via clips on the machine housing or metal enclosure.</p> |
| Shielding temperature monitor and brake | <p>The internal shields of temperature monitor and brake in the motor cable are mounted one-sided at control cabinet side, as indicated in the project planning manual of the unit.</p> |

6.5 Ground connections

- Housing and mounting plate** By means of appropriate ground connections it is possible to avoid the emission of interference, because interference is discharged to earth on the shortest possible way.
- The ground connections of the metal housing of such EMC-critical components as filters, drive system components, contact points of the cable shields, units with microprocessors and switched-mode power supply units must have good and broad surface contact. This also applies to all mounting plate screws of control cabinet walls and when connecting the PE rails (equipotential bonding rails).
- A zinc-coated or chrome-plated mounting plate is thus recommended. Compared to a varnished plate, the connections in this case have long-term stability.
- Parts used in connections** In the case of varnished mounting plates, always use screwed joints with toothed discs and zinc-coated, tin-plated screws. At the points of connection, the paint should be removed so that electrical contact over the largest possible surface is ensured. A broad-surface connection is achieved with bare connecting surfaces or several connecting screws. At screwed joints, the contact to varnished surfaces is achieved by using toothed discs.
- Metal surfaces** Always use parts in the connections that have electrically-conductive surfaces.
- Use **conductive**, bare, zinc-coated, tin-plated and chrome-plated metal surfaces. Anodized, yellow chrome-plated, burnished black or varnished metal surfaces are **poor conductors** and should thus be avoided in connecting parts (screws, nuts, washers).
- Earth conductors and shield connections** Not the diameter of earth conductors and shield connections is important, but rather the contact surface, as high-frequency interference currents primarily flow on the surface of the conductor.
- As a basic principle, ground cable shields according to Fig. 8-1: "Cable shield connection over largest possible surface area" or via the connector housing.

6.6 Installing signal lines and cables

- Line routing** Measures to prevent interference are outlined in the project planning manual of the unit. In addition, there are the following recommendations:
- Signal and control lines must be routed separately with at least $d_5 = 100$ mm, see Fig. 6-2: Optimum assembly of components in the cabinet, to the power cables or separated by a grounded distance plate. Optimum routing is a separate cable duct. Lead the signal lines into the control cabinet at only one location, if possible.
- Exception: If impossible in another way, motor feedback cables can be routed together with the motor power cables.
- If signal lines cross power cables, then these should be routed at an angle of 90° to each other to avoid interference injection.
- Reserve cables either not used or connected should at least be grounded at both ends to eliminate aerial effects.
- Avoid unnecessarily lengthy lines.
- The cables must be routed as close to a grounded metal surface (reference potential) as possible. Closed, grounded cable ducts or metal tubes are best, but only needed in the case of excessive demands (sensitive measuring leads).
- Free hanging lines or those guided in plastic ducts are to be avoided, as they not only function as good aerial receivers (immunity to interference) but also as good aerial transmitters (interference emitters). Exception: Flexible cabling systems for short distances of a maximum of 5 m.
- Shielding** The cable shield must be routed close to the unit, held as short as possible, over the greatest possible surface.
- Analog signal line shields are applied on one side, for an analog unit this is generally the control cabinet, over a broad surface. Ensure broad-surfaced and short connections to ground / housing.
- Digital signal line shields are applied on both sides, short and broad-surfaced. If there are potential differences between beginning and end of the line, then additionally route an equipotential conductor in parallel. A cross section guideline is 10 mm^2 .
- Separable connections must be equipped with connectors and coupler units with grounded metal housing.
- The send and receive lines of unshielded electric circuits must be twisted.

6.7 General interference suppression measures with relays, contactors, switches, inductors and inductive loads

If, in conjunction with electronic equipment and components, such inductive loads as inductors, contactors or relays are implemented with contacts or semi-conductors, then their interference must be suppressed. This is achieved with direct current by the arrangement of free-wheeling diodes. If AC is used, then it is achieved by allocation directly at the inductance of industry-standard RC interference suppression components that are dependent upon the type of contactor. Only that interference suppression component located directly at the inductance can achieve the intended purpose. Otherwise, a high level of interference will be emitted which cannot only negatively influence the function of the electronic system, but that of the drive also.

Mechanical switches and contacts should be snap-action contacts. Both contact pressure and materials must be suited to the switching current.

Replace creeping contacts with snap-action or contactless switches. This is recommended because creeping contacts bounce considerably and remain in an undefined state for longer periods of time during which, in the case of inductive loads, electromagnetic waves are emitted. This is particularly critical with pressure or temperature switches.

6.8 Residual-current-operated circuit-breakers

Leakage current For the purpose of drive speed variation with a high degree of positioning accuracy and dynamic response, certain modulation procedures are indispensable. For physical reasons, these modulation procedures give rise to inevitable leakage current produced during normal operation. With a symmetrical power source it is negligibly low, but with unbalanced loads of the mains phases and a large number of drives it can easily be some 100 mA of r.m.s. value.

The leakage current is not sinusoidal. The degree of leakage current depends on the following features of the installation:

- number and type of drives that are used
- length of the connected motor power cables
- grounding conditions of the mains at the place of installation
- imbalance of the three-phase system
- EMC measures

If measures are taken to improve the electromagnetic compatibility (EMC) of the installation (mains filter, shielded lines), the leakage current in the ground wire is inevitably increased, especially when the units are switched on or with the power source being imbalanced.

False tripping without error The result is that residual-current devices (FI, r.c.c.b. = residual-current-operated circuit-breakers) trip with the above operating states, without an error having occurred.

Failure to trip in case of error Besides the residual-current-operated circuit-breaker does not trip in the case of smoothed direct fault current that can be caused by power supply units, power rectifiers and drive controllers. The residual-current-operated circuit-breaker can be saturated owing to a ground fault and will only actuate at a much higher current. Personal safety is therefore not guaranteed and it is prohibited to use a residual-current-operated circuit-breaker according to EN 50178 as the only safety measure.

Dependent on the capacity of the electrical installation, it is at least possible to use a residual-current-operated circuit-breaker of 300 mA as an additional safety device to protect machinery, but not for personal protection.

Other protective measures According to IEC 364 and EN 50178, the supply-side contact guard for indirect contact, i.e. in the case of insulation failure, has to be provided in a different way, for example by means of overcurrent protective device, protective grounding, protective-conductor system, protective separation or total insulation.

Generally, an overcurrent protective device with protective grounding according to IEC 364 and EN 50178 is recommended as a contact guard in the machine or installation in which a drive system is being used. The overcurrent protective device normally consists of fuses or overcurrent release devices (circuit breakers, motor circuit breakers) installed at the supply connection.

Isolating transformer used to reduce leakage current in mains If it is nevertheless necessary to use a residual-current-operated circuit-breaker owing to particular local conditions of the mains, an isolating transformer has to be connected between mains connection and power connection of the drive system. This reduces the leakage current in the ground wire of the mains that is produced during normal operation.

The neutral point of the secondary winding of the isolating transformer is connected to the protective conductor of the drive system.

The ground-fault loop impedance must then be adjusted to the overcurrent protective device so that the unit can be switched off in the case of failure.

Before operating enable please check for correct function including activation in the case of failure.

7 Installing the mains filter

7.1 General safety directives



High electrical voltage!

Danger to life or severe bodily harm!

- ⇒ The protective grounding must be attached to the filter and grounded as per section 7.3 before commissioning!
- ⇒ Before touching bare connecting cables and terminal connectors, remove or switch off filter with its attached loads from the mains.
- ⇒ Then allow a discharge time of 1/2 minute!
- ⇒ Work on the connecting cable or filter may proceed! Do not operate without attached protective conductor due to high leakage current of filter! Operate only with an attached protective conductor which has sufficient cross section.

7.2 Mounting the filter

The mains filter must be mounted in the power supply line of the control cabinet or housing in which the drive controller is installed.

The mounting plate of the drive controller in the control cabinet or the control cabinet wall are suitable mounting locations and filter grounding, as this is the best possible way of grounding.

The filter is fixed to the base with four screws. Use zinc-coated or tin-plated screws, do not use varnished or anodized connecting elements and screws.

With varnished mounting plates please observe the following additional proceeding:

- Remove all paint at the contact points on the mounting surface. This assures a contact of the broadest possible surface.
- Realize screwed joint as per Fig. 7-1: Screwed joint of the filter on the mounting surface with toothed discs and zinc-coated or tin-plated screws.

Only proper grounding assures proper functioning of the mains filter.

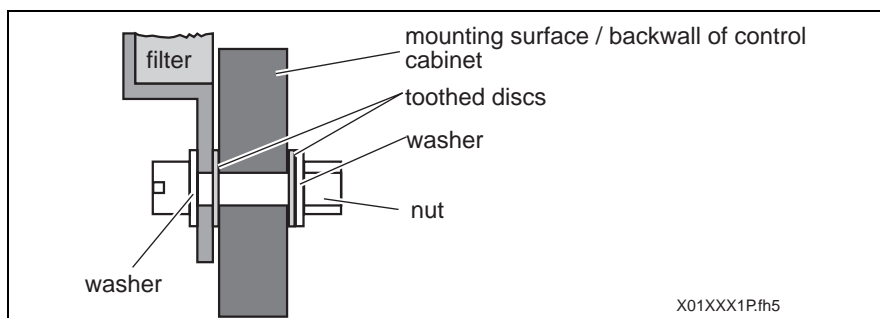


Fig. 7-1: Screwed joint of the filter on the mounting surface

7.3 Connecting the filter

Fig. 6-1: Connection of mains filter depicts the connection of the mains filter.

The cables are connected to the power source and load side at the terminal connectors as indicated by the labelling.

For safety reasons, the protective conductor between mains and filter must

- have a **cross section of at least 10 mm²** or be complemented by a second protective conductor via separate terminal connectors (according to EN50178/1997, section 5.3.2.1). If the cross section of the external conductor is bigger than that, the cross section of the protective conductor has to be adapted accordingly.
- be **firmly connected**. Tools must be needed to release it.

The reasons for this is that an unbalanced load in the three-phase current system or with phase failure can cause high leakage current of the radio interference suppression filter in the grounding conductor. The filters must be grounded prior to initial commissioning. Appropriate connecting points have to be provided in the machine, in the installation and in the control cabinet.

See chapter 6 Optimum assembly of components in the cabinet for further details.

7.4 Commissioning the filter

Check all protective conductor connections visually before connecting or applying the mains voltage. Give special attention to the bare line ends in the terminal connectors. These must be firmly attached and tightly screwed into place.

If necessary, check whether the resistance between the main protective conductor connections of the system and the filter housing is less than 0.1 Ohm.

Do not connect the mains before running this check.

8 Installing the motor power cable

To keep interference low, select one of the following options for the motor power cables of the drive:

- Route (unshielded) motor power cables in well-grounded metal tubes or cable ducts and check the shielding capacity by means of an EMC measurement, or
- use a shielded motor power cable. Apply the shield to both the motor and the control cabinet to a well-grounded spot. It must be short and the contact surface must cover the largest possible surface. It should be grounded to the same mounting panel as the drive controller, and cover the largest possible surface, as per Fig. 8-1: Cable shield connection over largest possible surface area.

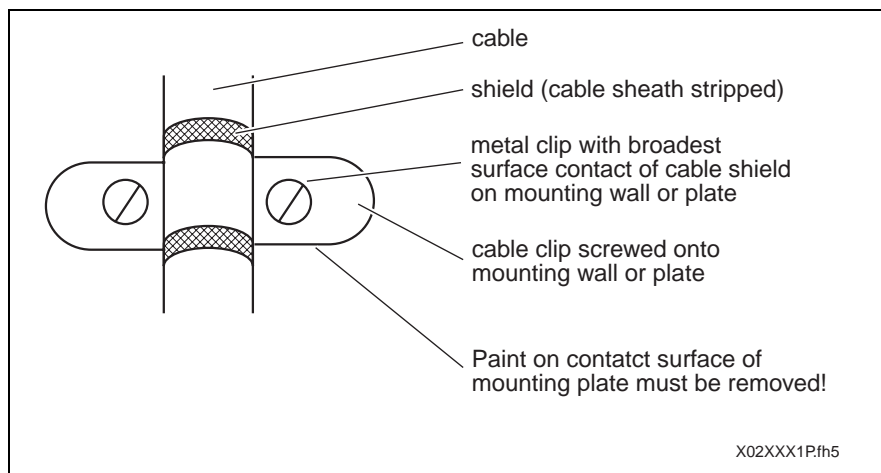


Fig. 8-1: Cable shield connection over largest possible surface area

For further details with regard to routing and shield connection of the motor cable see chapter 6.5 Ground connections.

Notes

9 Determining apparent power

9.1 From the selection data

Determine apparent power as follows:

- Compact drive controller: use selection data directly
- Modular drive components: calculate apparent power as per formula:

$$S = k1 \cdot P_{DC}$$

S: apparent power
 k1: factor from Fig. 9-4: Factors for calculating the apparent power
 P_{DC} : DC bus continuous power from selection data
 Fig. 9-1: Formula to calculate apparent power

9.2 From the motor data

If selection data are not available, then the motor data can be used to calculate apparent power, as per the following formulas.

$$S = k \cdot P_m$$

S: apparent power
 k: factor from Fig. 9-4: Factors for calculating the apparent power
 P_m : average mechanical output of all connected drives
 Fig. 9-2: Formula to calculate apparent power based on motor data

Mechanical output P_m of a drive

The mechanical output of the drive is calculated as follows:

$$P_m = \frac{M_{\text{eff}} \cdot n_{AV}}{9550}$$

P_m : mechanical output
 M_{eff} : effective torque
 n_{AV} : average speed
 Fig. 9-3: Calculating mechanical output

| Drive controller / supply unit U_N : (1) | K | | | | | | K1 | | | | | | |
|--|-------|------|-----------|------|-------|------|-------|------|-----------|------|-------|----|--|
| | 400 V | | 480 V (2) | | 230 V | | 400 V | | 480 V (2) | | 230 V | | |
| | 100 | 25 | 100 | 25 | 100 | 25 | 100 | 25 | 100 | 25 | 100 | 25 | |
| Work load in % of nominal current of power supply unit | | | | | | | | | | | | | |
| HVR | 1.26 | | | | | | 1.03 | | | | | | |
| DKR, RAC | 1.32 | | 1.58 | | | | | | | | | | |
| HVE <u>with</u> smoothing reactor GLD | 1.34 | | 1.56 | | | | 1.1 | | 1.3 | | | | |
| HVE <u>without</u> smoothing reactor GLD | 1.89 | 2.35 | 2.2 | 2.43 | | | 1.51 | 1.87 | 1.8 | 2.01 | | | |
| DKC...-7 | 2.32 | 2.88 | 2.68 | 2.97 | | | 1.85 | 2.32 | 2.13 | 2.38 | | | |
| DKC...-3 DKS, DDC 3-phase connection | | | | | 1.7 | 2.06 | | | | | | | |
| DKC...-3 DKS, DDC 1-phase connection | | | | | 1.9 | 2.3 | | | | | | | |
| KDV04 | 2.4 | 2.66 | 3.57 | 3.98 | | | 1.92 | 2.13 | 2.85 | 3.18 | | | |
| KDV 2, KDV 3 <u>with</u> smoothing reactor GLD | | | | | 1.34 | | | | | | 1.1 | | |
| TVM, KDV <u>without</u> smoothing reactor GLD | | | | | 1.89 | | | | | | 1.51 | | |
| KVR, TVD, TVR | 1.7 | | 1.86 | | | | 1.36 | | 1.48 | | | | |

(1) U_N = nominal voltage of the mains between the conductors
(2) with RAC: 460 V

Fig. 9-4: Factors for calculating the apparent power

Actual torque M_{eff} This generally corresponds to the torque at standstill M_{dN} of the motor. Use the following formula for cyclic transmission:

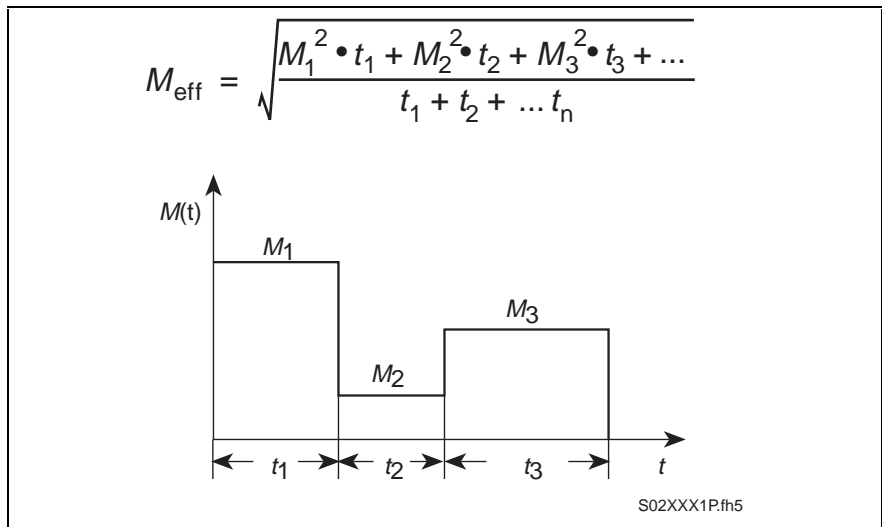


Fig. 9-5: Calculating actual torque

Average motor speed n_{av} If the drive is operated at constant speed for a duration greater than acceleration and deceleration time, then the following applies:

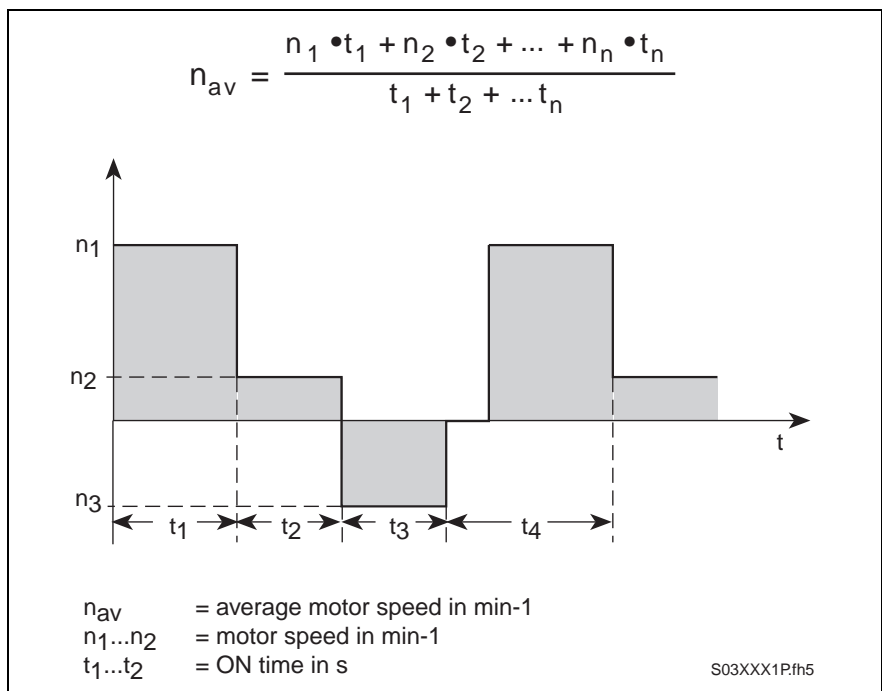


Fig. 9-6: Calculating average motor speed

In dynamic applications with short cycle times as, for example, roll feed control and nibbling machines, acceleration and deceleration time are taken into consideration.

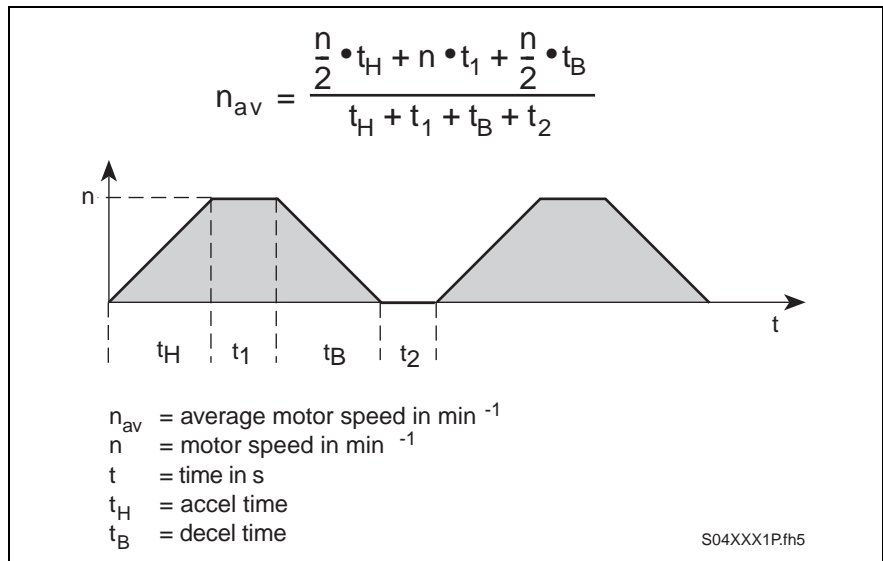


Fig. 9-7: Calculating average motor speed with short cycle times

Mechanical output P_m with several drives

If several drives are connected, then the average mechanical output P_m is based on average operating time.

$$P_m = P_{mH} + \frac{(P_{mS1} + P_{mS2} + \dots + P_{mSn})}{F_G}$$

- F_G : simultaneity factor (see Fig. 9-9: Simultaneity factor)
- P_m : average mechanical output
- P_{mS1} : continuous mechanical output of servo drive 1 in kW
- P_{mH} : nominal output for main drive (shaft output) in kW

Fig. 9-8: Calculating the mechanical output with several drives

| Number of axes | 1 | 2 | 3 | 4 | 5 | 6 |
|---------------------------|---|------|------|------|-----|------|
| Simultaneity factor F_G | 1 | 1.15 | 1.32 | 1.75 | 2.0 | 2.25 |

Fig. 9-9: Simultaneity factor

10 System perturbation of drive systems

Every load connected to the mains affects the form of system voltage and current (distortion). To keep voltage and current sine-wave within specified tolerances, it is frequently necessary to maintain limit values. The limit values specified by the suppliers of electricity only refer to the mains connection points (frequently on the high-voltage level of the mains), but not to the connections within the industrial mains themselves.

The following data are guide values for Rexroth Indramat drives.

10.1 Power factor DPF, $\cos\varphi_1$ to calculate the reactive-power load of the mains

Definition:

The factor DPF is used to calculate the reactive-current compensation.

$$DPF = \cos \varphi_1 = \frac{P_{netz}}{S_{1netz}} = \frac{\text{real mains power}}{\text{apparent mains power of fundamental component}}$$

Fig. 10-1: DPF

| Drive controller / supply unit | System voltage U_N , feed operation | | | | | | | |
|--|---------------------------------------|------|-------|------|-------|------|-------|------|
| | 400 V | | 480 V | | 460 V | | 230 V | |
| | fe | rec | fe | rec | fe | rec | fe | rec |
| HVR | 0.98 | 0.99 | | | | | | |
| DKR | 0.98 | 0.90 | 0.84 | 0.76 | | | | |
| HVE <u>with</u> smoothing reactor GLD | 0.98 | | 0.97 | | | | | |
| HVE <u>without</u> smoothing reactor GLD | 0.97 | | 0.97 | | | | | |
| DKC...-7 | 0.97 | | 0.97 | | | | | |
| KDV04 | 0.57 | 0.51 | 0.45 | 0.40 | | | | |
| KDV01, KDV02 <u>with</u> smoothing reactor GLD | | | | | | | 0.98 | |
| RAC | 0.98 | 0.90 | | | 0.81 | 0.74 | | |
| DKS, DDC, DKC...-3 TVM, KDV01, KDV02 without smoothing reactor GLD | | | | | | | 0.98 | |
| KDV03 | | | | | | | 0.98 | 0.89 |
| KVR | | | | | | | 0.98 | 0.90 |
| TVD, TVR | | | | | | | 0.97 | |

U_N = nominal voltage of the mains between the conductors
fe = feed operation, acceleration, rec = recovery operation, deceleration

Fig. 10-2: Power factor DPF, $\cos\varphi_1$

10.2 Power factor TPF, λ

Definition:

$$TPF = \lambda = \cos \varphi = \frac{P_{netz}}{S_{netz}} = \frac{\text{real mains power}}{\text{apparent mains power}}$$

Fig. 10-3: : TPF

| Drive controller / supply unit | System voltage U _N , feed operation | | | | | | | |
|--|--|------|-------|------|-------|------|-------|------|
| | 400 V | | 480 V | | 460 V | | 230 V | |
| | fe | rec | fe | rec | fe | rec | fe | rec |
| HVR | 0.97 | 0.99 | | | | | | |
| DKR | 0.93 | 0.84 | 0.77 | 0.70 | | | | |
| HVE <u>with</u> smoothing reactor GLD | 0.92 | | 0.76 | | | | | |
| HVE <u>without</u> smoothing reactor GLD | 0.67 | | 0.56 | | | | | |
| DKC...-7 | 0.56 | | 0.47 | | | | | |
| KDV04 | 0.52 | 0.47 | 0.35 | 0.31 | | | | |
| KDV01, KDV02 <u>with</u> smoothing reactor GLD | | | | | | | 0.92 | |
| RAC | 0.93 | 0.84 | | | 0.75 | 0.68 | | |
| DKS, DDC, DKC...-3 TVM, KDV01, KDV02 <u>without</u> smoothing reactor GLD | | | | | | | 0.71 | |
| KDV03 | | | | | | | 0.95 | 0.88 |
| KVR | | | | | | | 0.75 | 0.68 |
| TVD, TVR | | | | | | | 0.75 | |

U_N = nominal voltage of the mains between the conductors
 fe = feed operation, acceleration, rec = recovery operation, deceleration

Fig. 10-4: Power factor TPF, cosφ, based on nominal power of unit

10.3 Harmonic components of mains at point of connection

Harmonic components of mains current

The following table shows the percentage of the individual harmonic components based on the fundamental component during continuous feed operation with nominal power of the unit.

| Harmonic component | | Drive controller / supply unit | | | | | | | | | |
|--------------------|-------------|--------------------------------|-------|----------|-----------|---------------------------------------|-------|---|-------|---|---------------------------------------|
| Per-centage | Fre-quen-cy | HVR | | DKR, RAC | | HVE <u>with</u> smoothing reactor GLD | | HVE <u>without</u> smoothing reactor GLD, DKC | | TVM, TVD, DKS, DDC KDV <u>without</u> smoothing-reactor GLD | KDV <u>with</u> smoothing reactor GLD |
| | | 400 V | 480 V | 400 V | 480 V (1) | 400 V | 480 V | 400 V | 480 V | 230 V | 230 V |
| 2. | 100 Hz | 4.0 % | | 1.5 % | 1.3 % | 1.5 % | 2 % | 2 % | | 2 % | 1.5 % |
| 3. | 150 Hz | 1.0 % | | 1.0 % | 1 % | 1.0 % | 1 % | 1 % | | 1 % | 1.0 % |
| 4. | 200 Hz | 1.9 % | | 0.5 % | 1 % | 0.5 % | 2.5 % | 1 % | | 1 % | 0.5 % |
| 5. | 250 Hz | 4.0 % | | 32 % | 35 % | 35 % | 40 % | 90 % | | 90 % | 35 % |
| 6. | 300 Hz | 0.6 % | | 0.5 % | 1 % | 0.5 % | 1 % | 1 % | | 1 % | 0.5 % |
| 7. | 350 Hz | 3.8 % | | 10 % | 6 % | 12 % | 13 % | 80 % | | 80 % | 12 % |
| 8. | 400 Hz | 0.7 % | | 0.1 % | 0.5 % | 0.1 % | 0.5 % | 1 % | | 1 % | 0.1 % |
| 9. | 450 Hz | 1.7 % | | 0.3 % | 0.5 % | 0.3 % | 0.5 % | 1 % | | 1 % | 0.3 % |
| 10. | 500 Hz | 1.5 % | | 0.3 % | 0.5 % | 0.3 % | 0.5 % | 1 % | | 1 % | 0.3 % |
| 11. | 550 Hz | 0.5 % | | 7.5 % | 6 % | 8 % | 6 % | 70 % | | 70 % | 8 % |
| 12. | 600 Hz | 0.3 % | | 0.5 % | 0.5 % | 0.5 % | 0.5 % | 1 % | | 1 % | 0.5 % |
| 13. | 650 Hz | 0.5 % | | 5.0 % | 2.5 % | 5.0 % | 2.5 % | 60 % | | 60 % | 5.0 % |
| 14. | 700 Hz | 0.6 % | | 0.5 % | 0.5 % | 0.5 % | 0.5 % | 1 % | | 1 % | 0.5 % |
| 15. | 750 Hz | 0.5 % | | 0.3 % | 0.5 % | 0.3 % | 0.5 % | 1 % | | 1 % | 0.3 % |
| 16. | 800 Hz | <0.5% | | 0.5 % | 1 % | 0.5 % | 1 % | 1 % | | 1 % | 0.5 % |
| 17. | 850 Hz | <0.5% | | 5.0 % | 4 % | 4.5 % | 3 % | 25 % | | 25 % | 4.5 % |
| 18. | 900 Hz | <0.5% | | 0.5 % | 1 % | 0.5 % | 1 % | 1 % | | 1 % | 0.5 % |
| 19. | 950 Hz | <0.5% | | 3.0 % | 2 % | 3.0 % | 2 % | 18 % | | 18 % | 3.0 % |
| 20. | 1000 Hz | <0.5% | | 0.1 % | 0.4 % | 0.1 % | 0.4 % | 1 % | | 1 % | 0.1 % |
| 21. | 1050 Hz | <0.5% | | 0.1 % | 0.5 % | 0.1 % | 0.5 % | 1 % | | 1 % | 0.1 % |
| 22. | 1100 Hz | <0.5% | | 0.1 % | 0.3 % | 0.1 % | 0.3 % | 1 % | | 1 % | 0.1 % |
| 23. | 1150 Hz | <0.5% | | 2.5 % | 2.5 % | 3.0 % | 1.4 % | 15 % | | 15 % | 3.0 % |
| 24. | 1200 Hz | <0.5% | | 0.3 % | 0.5 % | 0.3 % | 0.5 % | 1 % | | 1 % | 0.3 % |
| 25. | 1250 Hz | <0.5% | | 2.0 % | 1 % | 2.5 % | 0.5 % | 13 % | | 13 % | 2.5 % |
| | 1- 2 kHz | - | | < 5 % | - | < 5 % | - | < 5 % | < 5 % | < 5 % | < 5 % |

(1) = with RAC: 460 V

Fig. 10-5: Percentage of harmonic components (intermediate values can be interpolated)

| | Drive controller / supply unit | | | | | | | | | |
|-----------------------------------|--------------------------------|-------|----------|-----------|---------------------------------------|-------|--|-------|---|---------------------------------------|
| | HVR | | DKR, RAC | | HVE <u>with</u> smoothing reactor GLD | | HVE <u>without</u> smoothing reactor GLD DKC...7 | | TVM, TVD, DKS, DDC KDV <u>without</u> smoothing reactor GLD | KDV <u>with</u> smoothing reactor GLD |
| | 400 V | 480 V | 400 V | 480 V (1) | 400 V | 480 V | 400 V | 480 V | 230 V | 230 V |
| THD - total harmonic distortion | 7.8 % | | 36 % | 37 % | 39 % | 43 % | 156 % | | 156 % | 39 % |
| Percentage of harmonic components | 7.8 % | | 34 % | 35 % | 36 % | 40 % | 84 % | | 84 % | 36 % |
| Crest factor | 1.5 | | 1.6 | 1.7 | 1.61 | 1.7 | | | | |

(1) = with RAC: 460 V

Definitions:

$$THD = Total\ Harmonic\ Distortion = \sqrt{\sum_{n=2}^{40} \left(\frac{I_n}{I_1}\right)^2}$$

- L: I1 = percentage of fundamental components of mains current
- L: In = nth harmonic component of mains current
- L: I = amplitude of harmonic current

Fig. 10-6: THD = Total Harmonic Distortion

$$Crest\ factor = \frac{\hat{I}}{I_{eff}}$$

Fig. 10-7: Crest factor of nominal current

$$Harmonic\ distortion = \frac{percentage\ of\ harmonic\ components}{alternating\ components} = \sqrt{\frac{\sum_{k=2}^{\infty} I_k^2}{\sum_{k=1}^{\infty} I_k^2}}$$

Fig. 10-8: THD, harmonic distortion

The alternating components are made up of fundamental component (I₁) and harmonic components (I_k) without direct component (I₀).

Harmonic components of mains voltage (voltage distortion)

Voltage harmonics depend on how the mains is set up, especially on mains inductance or mains fault level at the points of connection. The same load can cause different voltage harmonics on different mains and points of connection.

Guide values:

In a normal system, the harmonic distortion of the mains voltage when operating Rexroth Indramat drives generally equals less than 10%. Short-term mains power failures equal less than 20%.

Precise values can only be calculated with precise mains data (mains topology), such as line inductance and capacity as these relate to the points of connection.

These values, however, can temporally vary greatly depending on the control state. This also changes the harmonic components on the mains voltage.

Rough approximate mains data are not sufficient for a preliminary calculation of the harmonic components, as the points of resonance within the mains, which are always present, considerably affect the harmonic components.

To keep the harmonic components of the mains as small as possible, it is recommended that neither capacitors nor reactive power compensation equipment (capacitor batteries) be connected directly to the mains. If it is, however, absolutely necessary to do so, then these should only be connected to the mains via reactors (inductor reactive power compensation equipment).

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12 Service & Support

12.1 Helpdesk

Unser Kundendienst-Helpdesk im Hauptwerk Lohr am Main steht Ihnen mit Rat und Tat zur Seite. Sie erreichen uns

- Telefonisch: **+49 (0) 9352 40 50 60**
über Service-Call Entry Center Mo-Fr 07:00-18:00
- per Fax: **+49 (0) 9352 40 49 41**
- per e-Mail: **service@indramat.de**

Our service helpdesk at our headquarters in Lohr am Main, Germany can assist you in all kinds of inquiries. Contact us

- by phone: **+49 (0) 9352 40 50 60**
via Service-Call Entry Center Mo-Fr 07:00 am -6:00 pm
- by fax: **+49 (0) 9352 40 49 41**
- by e-mail: **service@indramat.de**

12.2 Service-Hotline

Außerhalb der Helpdesk-Zeiten ist der Service direkt ansprechbar unter

oder **+49 (0) 171 333 88 26**
+49 (0) 172 660 04 06

After helpdesk hours, contact our service department directly at

or **+49 (0) 171 333 88 26**
+49 (0) 172 660 04 06

12.3 Internet

Weitere Hinweise zu Service, Reparatur und Training finden Sie im Internet unter

www.indramat.de

Außerhalb Deutschlands nehmen Sie bitte zuerst Kontakt mit Ihrem lokalen Ansprechpartner auf. Die Adressen sind im Anhang aufgeführt.

Additional notes about service, repairs and training are available on the Internet at

www.indramat.de

Please contact the sales & service offices in your area first. Refer to the addresses on the following pages.

12.4 Vor der Kontaktaufnahme... - Before contacting us...

Wir können Ihnen schnell und effizient helfen wenn Sie folgende Informationen bereithalten:

detaillierte Beschreibung der Störung und der Umstände.

Angaben auf dem Typenschild der betreffenden Produkte, insbesondere Typenschlüssel und Seriennummern.

Tel./Faxnummern und e-Mail-Adresse, unter denen Sie für Rückfragen zu erreichen sind.

For quick and efficient help, please have the following information ready:

1. Detailed description of the failure and circumstances.
2. Information on the type plate of the affected products, especially type codes and serial numbers.
3. Your phone/fax numbers and e-mail address, so we can contact you in case of questions.

12.5 Kundenbetreuungsstellen - Sales & Service Facilities

Verkaufsniederlassungen
 Niederlassungen mit Kundendienst

sales agencies
 offices providing service

Deutschland – Germany

vom Ausland: (0) nach Landeskenziffer weglassen!
from abroad: don't dial (0) after country code!

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