7.3 Arranging Components in Control Cabinet from Mainly Electrical Point of View

The section below contains information and recommendations on the arrangement of the components in the control cabinet from mainly electrical points of view. These points of view include aspects of performance-dependent arrangement and installation in compliance with EMC.

Performance-Dependent Arrangement

Performance-Dependent Arrangement

The HMV01 supply units can supply HMS and HMD drive controllers on both sides.

Arrange drive controllers according to their performance.

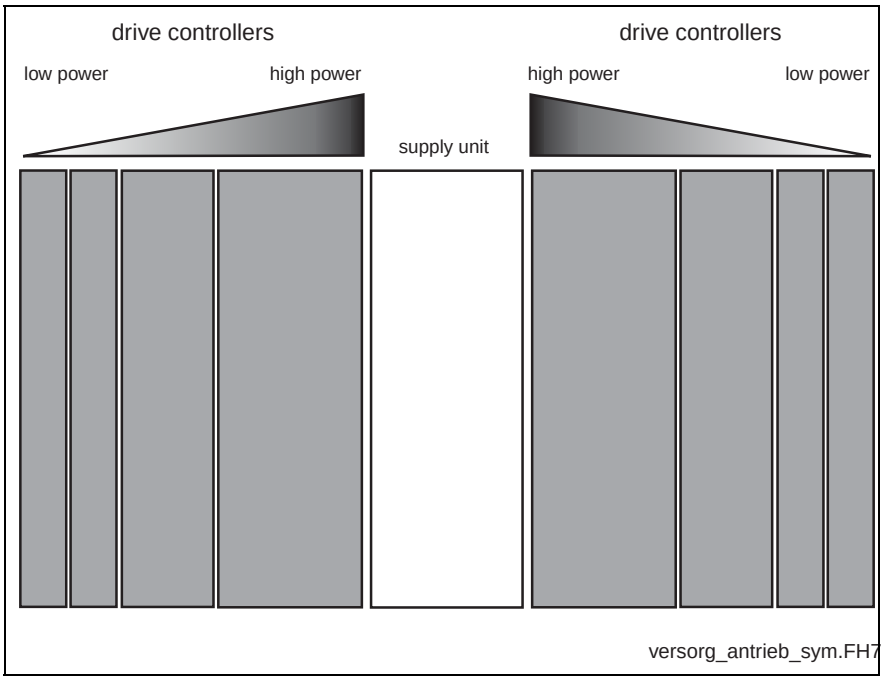

Fig. 7-21: Example of an arrangement

Note: When you use HNS02 and HNL02, the supply units HMV02 only allow mounting them on one side to the right.

Arrangement of Additional Components

- Arrange drive controllers with high performance as close to the supply unit as possible. Ideally the drive controllers should be distributed equally to the left and right side of the supply unit.

Note: If you operate HCS drive controllers with the type of mains connection "central supply", arrange the supplied drive controllers at the right side of the HCS drive controllers.

- Position DC bus capacitor unit next to drive controller with the greatest DC bus continuous power.
- Position DC bus resistor unit next to drive controller with the greatest regenerative power.
- Arrange HLR braking resistors in "standard" design above the HCS03 drive controller.
- When using DC bus resistor unit and DC bus capacitor unit in a drive system, arrange the DC bus capacitor unit between supply unit and DC bus resistor unit.

EMC Measures for Design and Installation

Rules for Design of Installations with Drive Controllers in Compliance with EMC

The following rules are the basics for designing and installing drives in compliance with EMC.

Mains Filter

Correctly use a mains filter recommended by Rexroth for radio interference suppression in the supply feeder of the AC drive system.

Control Cabinet Grounding

All metal parts of the cabinet have to be connected with one another over the largest possible surface area to establish a good electrical connection. This, too, applies to the mounting of the EMC filter. If required, use serrated washers which cut through the paint surface. The cabinet door should be connected to the cabinet using the shortest possible grounding straps.

Line Routing

Avoid coupling routes between lines with high potential of noise and noise-free lines, therefore signal, mains and motor lines and power cables have to be routed separately from another (this eliminates mutual interference!). Minimum clearance: 10 cm. Provide separating sheets between power and signal lines. Separating sheets have to be grounded at several points.

Lines with high potential of noise at the drive controller are lines for the mains supply (incl. mains synchronization), lines at the motor connection and DC bus connections.

Generally, interference injection are reduced by routing cables close to grounded sheet steel panels. For this reason, cables and wires should not be routed freely in the cabinet, but close to the cabinet housing or mounting panels. The incoming and outgoing cables of the radio interference suppression filter have to be separated.

Interference Suppression Elements

Contactors, relays, solenoid valves, electromechanical operating hour counters etc. in the control cabinet must be provided with interference suppression combinations. These combinations must be connected directly at each coil.

Twisted Wires

Non-shielded cables belonging to the same circuit (feeder and return cable) have to be twisted or the surface between feeder and return cable has to be kept as small as possible. Ground cables that are not used at both ends.

Lines of Measuring Systems

Lines of measuring systems have to be shielded. The shield has to be connected to ground at both ends and over the largest possible surface area. The shield may not be interrupted, e.g. using intermediate terminals.

Digital Signal Lines

The shields of digital signal lines have to be grounded at both ends (transmitter **and** receiver) over the largest possible surface area and with low impedance. Bad ground connection between transmitter and receiver requires additional routing of a bonding conductor (min. 10 mm²). Braided shields are to be preferred to foil shields.

Analog Signal Lines

The shields of analog signal lines generally have to be grounded at one end (transmitter **or** receiver) over the largest possible surface area and

with low impedance, in order to avoid low-frequency interference current (in the mains frequency range) on the shield.

Connection of Mains Choke to Drive Controller

Keep connection lines of mains chokes as short as possible and twist them.

Installation of Motor Power Cable

Preferably use the motor power cables with shield provided by Rexroth. If you use other motor power cables, they have to be run in shielded form.

Keep length of motor power cable as short as possible.

Ground shield of motor cable at both ends over the largest possible surface area to establish a good electrical connection.

Run motor lines in shielded form inside the control cabinet.

Do not use any steel-shielded lines.

The shield of the motor cable mustn't be interrupted by mounted components, such as output chokes, sine filters, motor filters.

EMC-Optimal Installation in Facility and Control Cabinet

With regard to EMC-optimal installation, a spatial separation of the interference-free area (mains connection) and the interference-susceptible area (drive components) is recommended, as shown in the figures below.

Note: For EMC-optimal installation in the control cabinet use a separate control cabinet panel for the drive components.

Division into Areas (Zones)

The arrangement in the control cabinet can be seen from Fig. 7-22: Separation of interference-free area and interference-susceptible area in control cabinet.

There are three areas to be distinguished:

1. Interference-free area of control section (area A):

This includes:

- supply feeder, input terminals, fuse, main switch, mains side of mains filter for drives and corresponding connecting lines
- control voltage or auxiliary voltage connection with power supply unit, fuse and other parts unless connection is run via the mains filter of the AC drives
- all components that aren't electrically connected with the drive system

2. Interference-susceptible area (area B):

- mains connections between drive system and mains filter for drives, mains contactor
- interface lines of drive controller

3. Strongly interference-susceptible area (area C):

- motor cable including single strands

Never run lines of one of these areas in parallel with lines of another area so that there isn't any unwanted interference injection from one area to the other and that the filter is jumpered with regard to high frequency. Keep connection lines as short as possible.

For complex systems it is recommended to put the drive components into a cabinet and the controls into a separate second cabinet.

Badly grounded control cabinet doors act as antennas. It is recommended to connect the doors to the control section on top, in the middle and on the bottom via short equipment grounding conductors with a cross section of at least 6 mm^2 or, even better, via grounding straps with the same cross section. Make sure connection points have good contact.

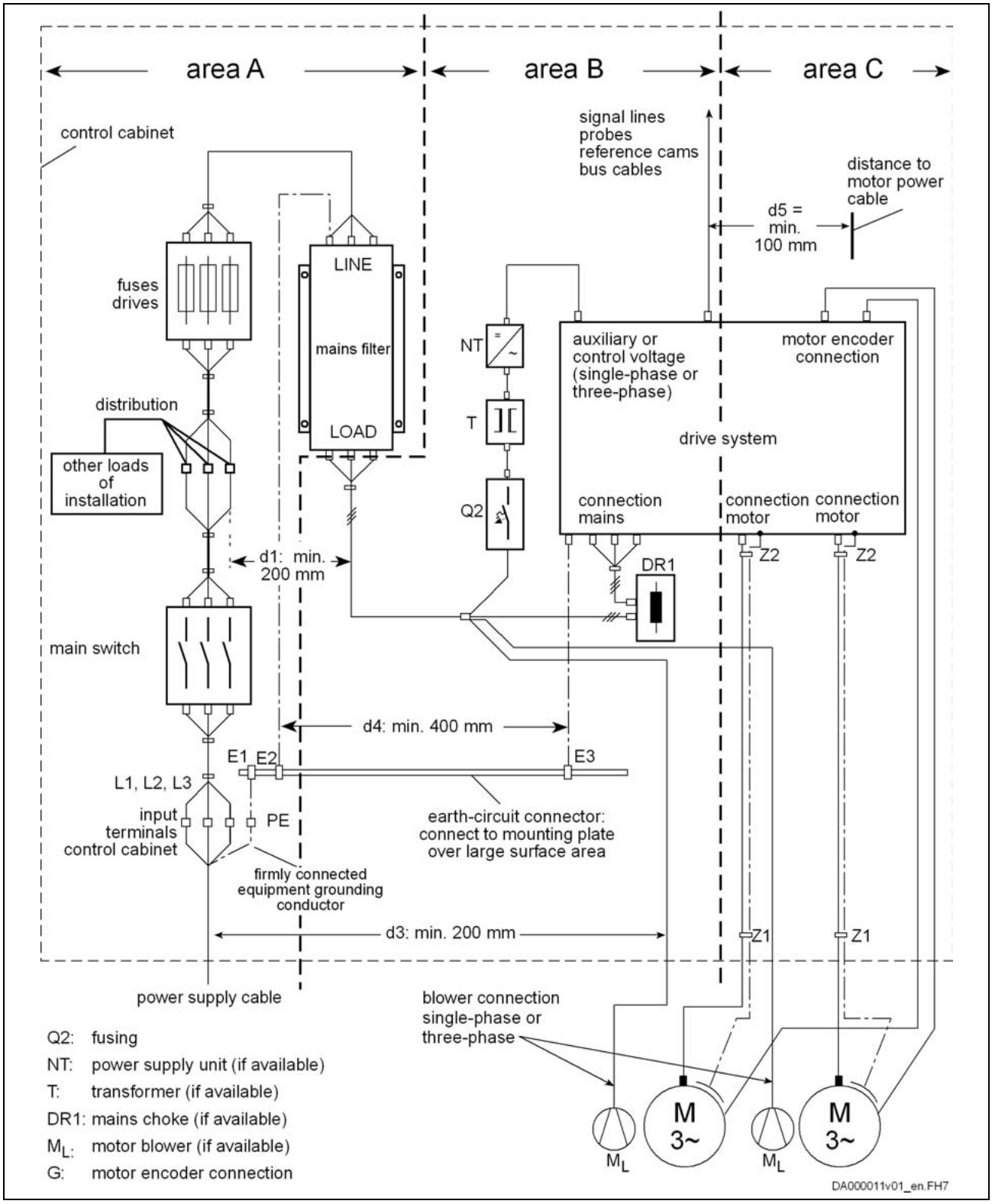

Fig. 7-22: Separation of interference-free area and interference-susceptible area in control cabinet

Design and Installation in Interference-Free Area of Control Cabinet (Area A)

Arranging the Components in the Control Cabinet

When arranging the components in the control cabinet, it is recommended that you place the components and electrical elements (switches, pushbuttons, fuses, terminal connectors) in the interference-free zone A with a distance of at least d1 = 200 mm to the components in both other zones B and C.

In particular, a distance of at least d2 = 500mm 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 supply system 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 Mains Connection

The distance between the power input line and the lines between filter and exit point from the control cabinet in area A and the lines in areas B and C must be at least 200 mm (distances d1 and d3 in the figure) 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.

Routing and Connecting a Neutral Conductor (N

If a neutral 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.

Connecting Motor Blowers

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 single-phase filter (NFE type) or three-phase filter (HNF, NFD type) near the supply connection of the control cabinet, or to be connected at the load side of the existing three-phase filter for the power connector of the drive system. When switching power off, make sure the ventilator is not switched off.

Shielding Mains Supply Lines in 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 area 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. 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 Filters for AC Drives

The mains filter ideally should be mounted on the parting line between area 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 lines to the grounding points E1, E2 in area A and the other grounding points of the drive system should be at least d4 = 400 mm, in order to minimize interference injection from ground and ground cables to the power input lines.

See also Fig. 7-22: Separation of interference-free area and interference-susceptible area in control cabinet

Point of Connection for Equipment Grounding Conductor of Machine, Installation, Control Cabinet

The equipment grounding conductor 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 equipment grounding conductor via separate terminal connectors (according to EN50178/ 1997, section 5.3.2.1). If the cross section of the outer conductor is bigger, the cross section of the equipment grounding conductor has to be adjusted accordingly.

Design and Installation in Interference-Susceptible Area of Control Cabinet (Area B)

Arranging Components and Lines

Modules, components and lines in area B should be placed at a distance of at least d1 = 200 mm from modules and lines in area A or shielded by distance plates mounted vertically on the mounting plate. As an alternative, the lines can be shielded.

Power supply units for auxiliary or control voltage connections in the drive system mustn't be directly connected to the mains, but have to be connected to the mains via a mains filter, as indicated in Fig. 7-22: Separation of interference-free area and interference-susceptible area in control cabinet.

Keep line length between drive controller and filter as short as possible. Avoid unnecessary lengths.

Control Voltage or Auxiliary Voltage Connection

Only in exceptional cases should a connection of power supply unit and fusing for the control voltage connection be made at phase and neutral conductor. In this case these components have to be mounted and installed in area A, far away from the areas B and C of the drive system. For details see chapter "Design and Installation in Interference-Free Area of Control Cabinet (Area A)".

The connection between control voltage connection of the drive system and power supply unit used has to be run through area B over the shortest distance.

Line Routing

Run the lines along grounded metal surfaces, in order to minimize radiation of interference fields to area A (transmitting antenna effect).

Design and Installation in Strongly Interference-Susceptible Area of Control Cabinet (Area C)

Area C mainly concerns the motor cables, especially at the connection point at the device.

Influence of the Motor Power Cable

The discharge capacitance is limited to ensure compliance with the limit values. The calculation of the discharge capacitance can be found in the "Calculations" chapter.

If the applications allows this, the cable length should always be kept short. Avoid unnecessary line lengths.

Routing the Motor Cables

The motor cables have to be run in shielded form. Besides they are always to be routed with a distance of d5 = 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 of Rexroth 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 in the following figures (Fig. 7-23: Option 1: separate routing of motor cable and mains connection lines via 2 cable ducts; Fig. 7-24: Option 2: separate routing of motor cable and mains connection lines) by the example of a drive system with separate mains connection per drive axis IndraDrive HCS.

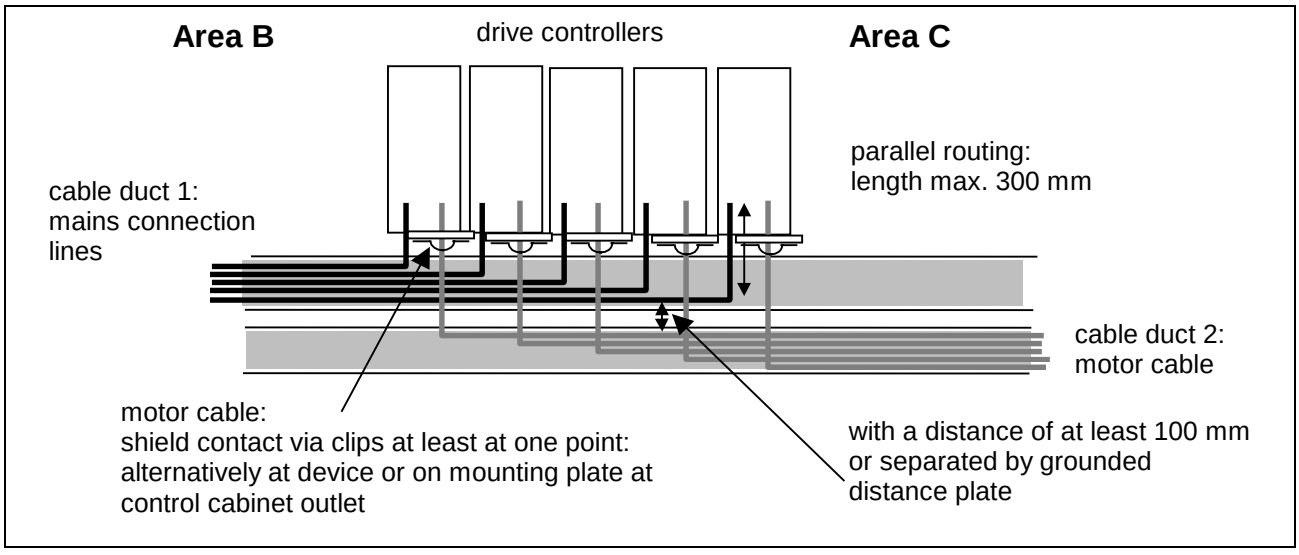

Fig. 7-23: Option 1: separate routing of motor cable and mains connection lines via 2 cable ducts

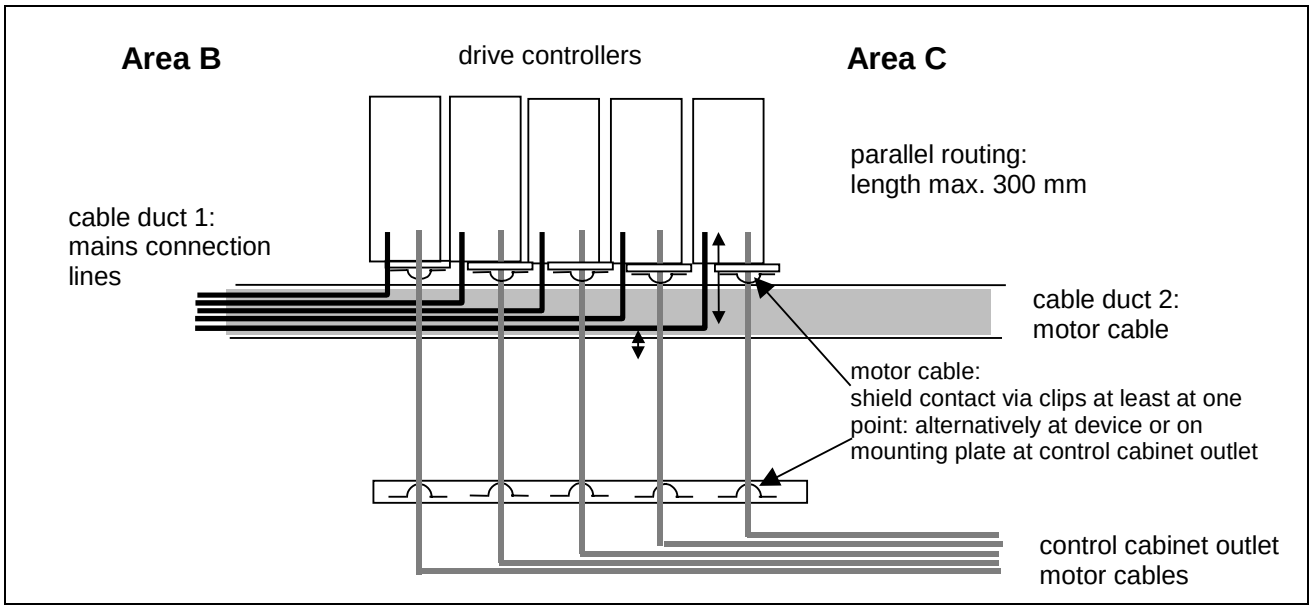

Fig. 7-24: Option 2: separate routing of motor cable and mains connection lines

Additional Recommendations on Cable Routing

The motor cables should be routed along grounded metal surfaces, both inside the control cabinet and outside of it, in order to minimize radiation of interference fields. If possible the motor cables should be routed in metal-grounded cable ducts.

The outlet of the motor cables at the control cabinet should ideally be provided in a distance of at least d3 = 200 mm from the (filtered) power supply cable.

Connection of Motor Cable to Drive Controller

There are the following minimum requirements for connecting the motor cables to the drive controller:

- Connect the shield of the motor cable **over the largest possible surface area (with low impedance)** to the drive controller. The connection of cable shields by means of round wires (so-called "pig tails") at the cable ends to ground and housing is normally insufficient.
- Make sure there is sufficient **strain relief** for the motor cable itself.

Shield Connection with Accessory HAS02

Optional accessory HAS02 to be used with connection over a large surface area directly to the device. This is the best solution. The figure below illustrates this by the example of HCS02 drive controllers:

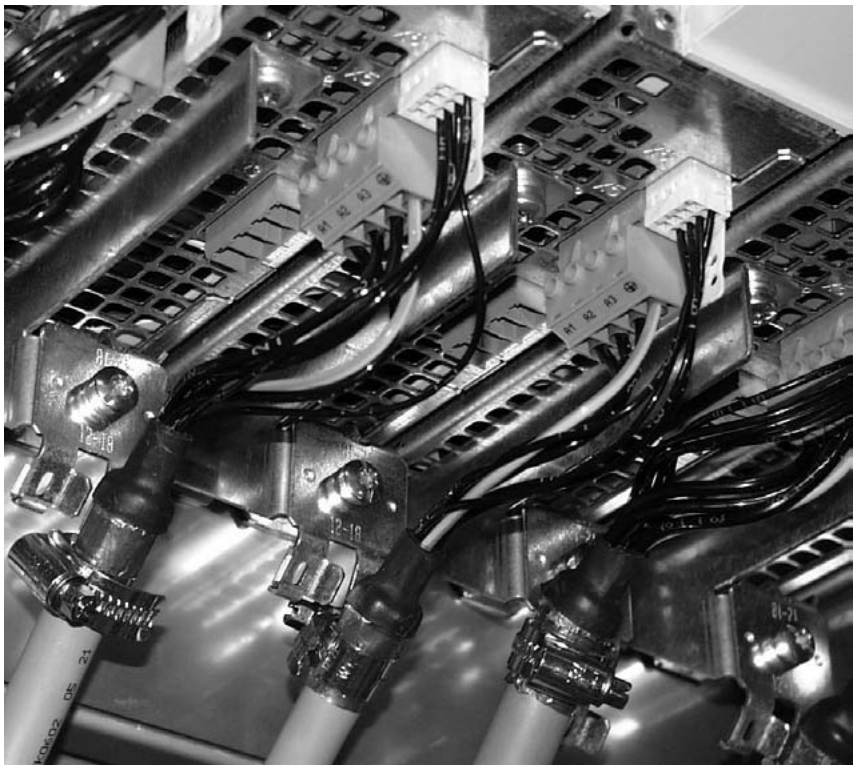

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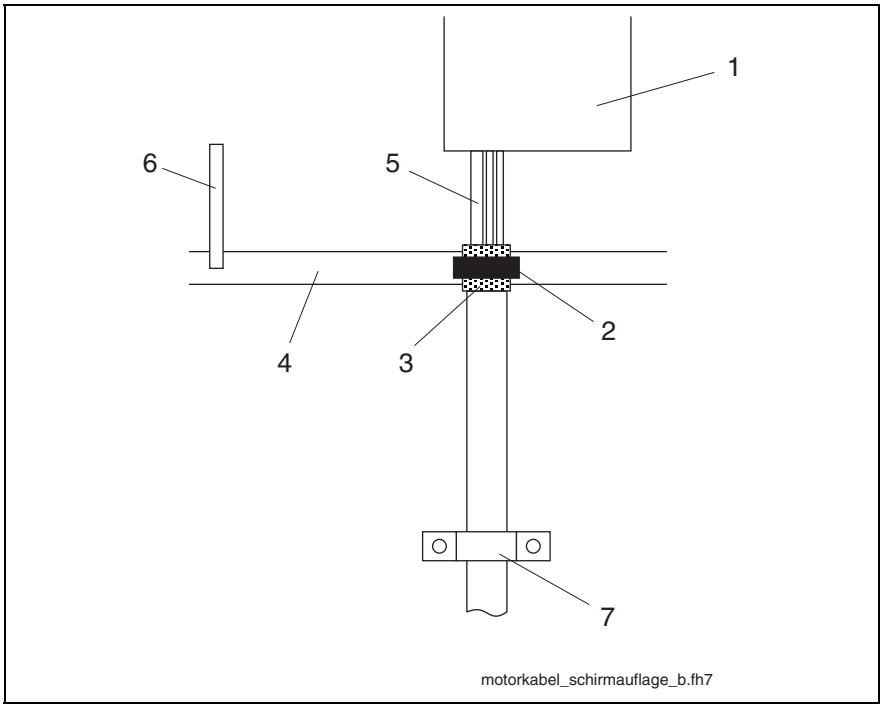
Fig. 7-25: Connecting HAS02 to HCS02

Shield Connection without Accessory HAS02

For shield connection without HAS02 accessory connect the cable shield with the lowest possible impedance to the drive controller.

The following paragraphs describe two basic alternatives of this kind of connection.

Alternative 1 Connect cable shield to a ground bus. The maximum distance between ground bus and device connection is 100 mm. For this purpose take the given length of the single strands at the cable end into account for ready-made Rexroth motor power cables.

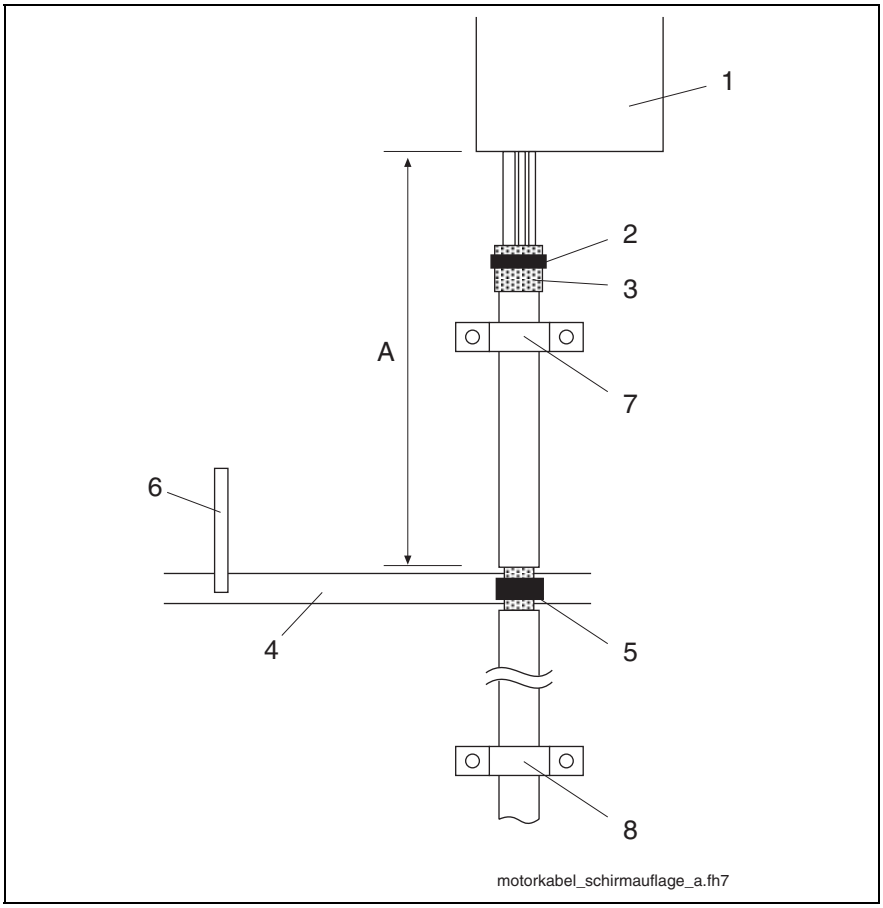


1: drive controller
2: clip for shield contact
3: overall shield of the motor power cable folded back
4: ground bus in control cabinet
5: single strands of motor power cable
6: connection of ground bus to supplying device
7: strain relief (as near as possible to control cabinet outlet)

Fig. 7-26: Shield contact, alternative 1

- With a clip (2) connect overall shield of motor power cable (3) to ground bus (4).
  (If you use your own cable make sure the shields of the two inner pairs of wires are in contact with the overall shield.)
- With a cable (6) (line cross section at least 10 mm2) connect ground bus (4) to ground connection at supplying device (Rexroth IndraDrive supply unit or Rexroth IndraDrive drive controller HCS).

Alternative 2 Connect cable shield to a ground bus. The cable length between device and ground bus mustn't be more than a max. of 1 m. For this purpose prepare the motor cable in accordance with the description below:



1: drive controller
2: cable tie
3: overall shield of the motor power cable folded back
4: ground bus in control cabinet
5: connection between overall shield of motor power cable laying bare and ground bus
6: connection of ground bus to supplying device
7: strain relief (as near as possible to the drive-side cable end)
8: strain relief (as near as possible to control cabinet outlet)
A: cable length between ground bus and device: < 1m

Fig. 7-27: Shield contact, alternative 2

- With a cable tie (2) press the drive-side cable end in such a way that the shields of the two inner pairs of wires (motor temperature, holding brake) have good contact with the overall shield of the motor power cable (3).
  (If you use your own cable make sure the shields of the two inner pairs of wires are in contact with the overall shield.)
- On the level of the ground bus in the control cabinet remove a piece of the cable sheath from the motor power cable in order to lay bare the overall shield (5).
- Connect overall shield (5) to ground bus in the control cabinet with an appropriate connection (clip). The connection must have a cross section of at least 10 mm2.
- With a cable (6) (line cross section at least 10 mm2) connect ground bus (4) to ground connection at supplying device (Rexroth IndraDrive supply unit or Rexroth IndraDrive drive controller HCS).
- Make sure there is sufficient strain relief for the motor power cable as near as possible to the drive-side cable end (7).

- In addition, make sure there is sufficient strain relief for the motor power cable as near as possible to the control cabinet outlet of the motor power cable (8).

Note: Do not remove the shield of the motor cable between ground bus and device.

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.

Bonding Conductor

Bad ground connection between motor housing and control cabinet housing, as well as long motor cables, can require additional routing of a bonding conductor of a cross section of normally 10 mm² between control cabinet housing and motor housing.

Note: For cable lengths of more than 50 m the cross section should be at least 35 mm^2.

Shield Connection of Kit Motors

For kit motors make sure that the connection lines are run in shielded form or under metal between winding and terminal box, if the terminal box is not directly mounted on the spindle case.

Shield Connection for Linear Motors

For linear motors connect the shield of the connection cable between primary part and terminal box via clips to machine housing or metal shell.

Shielding of Temperature Monitor and Brake

The inner shields of temperature monitor and brake in the motor cable are connected to the drive controller at one end.

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. Ground connection of the metal housings of EMC-critical components such as filters, devices of the drive system, connection points of the cable shields, devices with microprocessor and switching power supply units have to be over a large surface area and well contacted. This also applies to all screw connections of between mounting plate and control cabinet wall and to the mounting of a ground bus to the mounting plate.

For this purpose it is recommended to use a zinc-coated or chromatized mounting plate. Compared to a lacquered plate, the connections in this case have a good long-time stability.

Connection Elements

For lacquered mounting plates always use screw connections with tooth lock washers and zinc-coated, tinned screws as connection elements. At the connection points selectively scratch off the lacquer so that there is safe electrical contact over a large surface area. Contact over a large surface area is established by means of bare connection surfaces or several connection screws. For screw connections the contact to lacquered surfaces is ensured by using tooth lock washers.

Metal Surfaces

In any case use connection elements with good electroconductive surface.

Bare zinc-coated, tinned and chromatized metal surfaces have **good electroconductive properties**. Anodized, yellow chromatized, black gunmetal finish or lacquered metal surfaces have **bad electroconductive properties** and therefore shouldn't be used for connection elements (screws, nuts, plain washers).

Ground Wires and Shield Connections

For connecting ground wires and shield connections it is not the cross section but the size of contact surface that is important, as the high-frequency interference currents mainly flow on the surface of the conductor.

Any connection of cable shields, especially of shields of the motor power cables with ground potential (see section "Connection of Motor Cable to Drive Controller") always has to be provided over a large surface area.

Installing Signal Lines and Cables

Line Routing

For measures to prevent interference see the Project Planning Manuals of the respective device. In addition, observe the following recommendations:

Signal and control lines have to be routed separately from the power cables with a minimum distance of d5 = 100 mm (see Fig. 7-22: Separation of interference-free area and interference-susceptible area in control cabinet) or with a grounded separating sheet. The optimum way is to route them in separate cable ducts. If possible, lead signal lines into control cabinet at one point only.

Exception: If there is no other way to do it, motor feedback cables can be routed together with the motor power cables.

If signal lines are crossing power cables, they should be routed in an angle of 90° in order to avoid interference injection.

Spare cables that are not used and have been connected should be grounded at least at both ends so that they don't have any antenna effect.

Avoid unnecessary line lengths.

Run cables as close as possible to grounded metal surfaces (reference potential). The ideal solution are closed, grounded cable ducts or metal pipes which, however, is only obligatory for high requirements (sensitive instrument leads).

Avoid suspended lines or lines routed along synthetic carriers, because they are functioning both like good reception antennas (noise immunity) and like good transmitting antennas (emission of interference). Exceptional cases are trailing cable installations over short distance of a max. of 5 m.

Shielding

The cable shield has to be connected immediately at the devices in the shortest and most direct possible way and over the largest possible surface area.

The shield of **analog signal lines** is connected at one end over a large surface area, normally in the control cabinet at the analog device. Make sure the connection to ground/housing is over a large surface area and short.

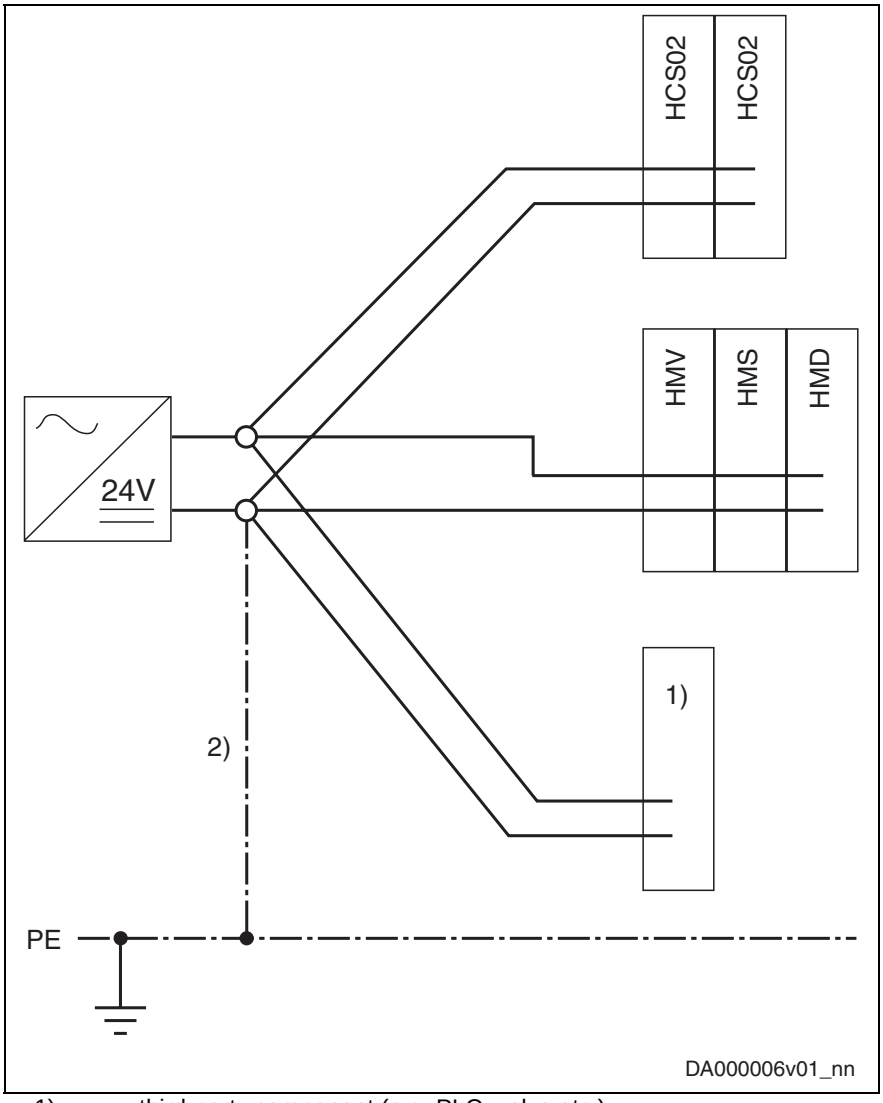
The shield of digital signal lines is connected at both ends over a large surface area and in short form. In the case of potential differences between beginning and end of the line, run an additional bonding conductor in parallel. The guide value for the cross section is 10 mm^2.

You absolutely have to equip separable connections with connectors with grounded metal housing.

In the case of non-shielded lines belonging to the same circuit, twist feeder and return cable.

Installing the 24V Supply

As a matter of principle, the 24V supply of the components of the drive system Rexroth IndraDrive has to be installed in star-shaped form, i.e. for each group of drive controllers or third-party components it is necessary to run separate supply lines. This, too, applies to multiple-line arrangement in the case of supply from a supply unit, for example.



1) third-party component (e.g. PLC, valve etc.)
2) connection to central ground point (e.g. earth-circuit connector)

Fig. 7-28: Installing the 24V supply

Note: If you use several power supply units for 24 V supply, make sure that

- the reference conductors 0V of the individual power supply units are interconnected with low impedance
- the output voltages of the power supply units are within the allowed voltage range
- the power supply units are synchronously switched on and off.

General Measures of Radio Interference Suppression for Relays, Contactors, Switches, Chokes, Inductive Loads

If, in conjunction with electronic devices and components, inductive loads, such as chokes, contactors, relays are switched by contacts or semiconductors, appropriate interference suppression has to be provided for them. In the case of d.c. operation, this is achieved by arranging free-wheeling diodes and in the case of a.c. operation, by arranging usual RC interference suppression elements depending on the contactor type, immediately at the inductance. Only the interference suppression element arranged immediately at the inductance serves this purpose. Otherwise the emitted noise level is too high which can affect the function of the electronic system and of the drive.

If possible, mechanical switches and contacts should only be realized as snap contacts. Contact pressure and contact material must be suited for the corresponding switching currents.

Slow-action contacts should be replaced by snap switches or by solid-state switches, because slow-action contacts strongly bounce and are in an undefined switching status for a long time which emits electromagnetic waves in the case of inductive loads. These waves are an especially critical aspect in the case of manometric or temperature switches.