Electronic motor starters and drives

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Electronic motor starters and drives
Drives engineering basic information

Drives egineering selection criteria

Each drive task requires a drive motor. The speed, torque and controllability of each motor must fulfill the requirements of the task. As a general rule, the application determines the drive.

The drive motor most frequently used worldwide in industrial plants and large buildings is the three-phase asynchronous motor. Its robust and simple construction as well as its high degrees of protection and standard types are the main features of this inexpensive electric motor.

Three-phase asynchronous motor

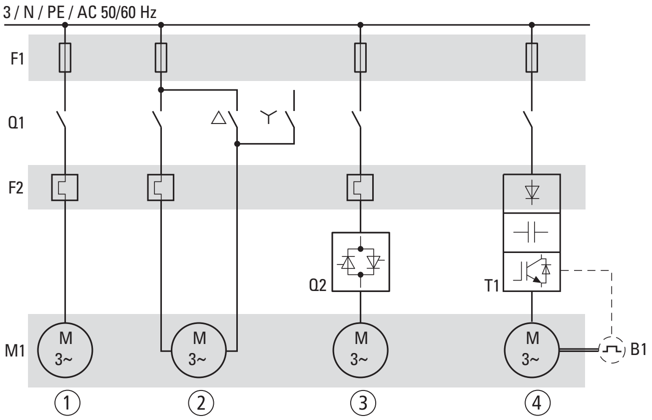
Motor starting variants

- **Direct-on-line start** (1)
  In the simplest case the motor is connected directly with a contactor. The combination of motor protection and cable protection (fuse) is called a motor starter (MSC = Motor Starter Combination).
  By applying the full mains voltage to the motor windings, DOL starting may produce large starting currents which may result in troublesome voltage changes. Direct-on-line starting three-phase motors must not cause interference voltage changes in the public utility grid. This requirement is generally fulfilled if the apparent power of a three-phase asynchronous motor does not exceed 5.2 kVA or its startup current does not exceed 60 A.
  With a mains voltage of 400 V and 8 times the starting current, this corresponds to a rated motor current of around 7.5 A and thus a motor rating of 4 kW.
  The motor rating denotes the mechanical output of the motor at the shaft.
- **Star-delta starter** (2)
  This is the most popular and commonly used starting method for motor ratings > 4 kW (400 V).
- **Electronic motor starter (EMS) and soft starter** (3)
  These enable the soft and low-noise starting of the motor. This eliminates interference producing current peaks and jerks during switching. The startup and deceleration phase of the motor can also be time-controlled depending on the load.
- **Frequency inverter** (4)
  This enables time-controlled motor starting, motor braking and operation with infinitely variable motor speeds. Depending on the application, different types of frequency inverters are used:
  – with the voltage/frequency control (U/f) or vector control for frequency-controlled motor operation,
  – with vector control or servo control for high speed accuracy and additional torque adjustment.

Associated circuit diagrams → page 2-3

Electronic motor starters and drives

Drives engineering basic information

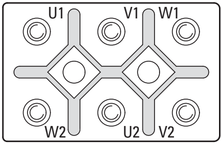


B1: Speed measuring (pulse generator)
F1: Fuse protection
(short-circuit and cable protection)
F2: Motor protection
(protection from thermal overload, overload relay)
M1: Three-phase asynchronous motor
Q1: Switching
(contactor, motor contactor)
Q2: Soft starter, electronic motorstarter
T1: Frequency inverter

Motor connection

When connecting a three-phase motor to the mains supply, the data on the rating plate of the motor must correspond to the mains voltage and frequency.

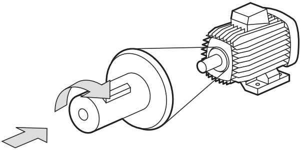
The standard connection is implemented via six screw terminals in the terminal box of the motor and with two types of circuit, the star connection and the delta connection, depending on the mains voltage.



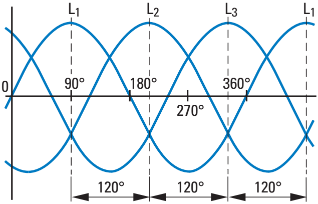
Electronic motor starters and drives

Drives engineering basic information

The rotation direction of a motor is always determined by directly looking at the drive shaft of the motor (from the drive end). On motors with two shaft ends, the driving end is denoted with D (= Drive), the non-driving end with N (= No drive).

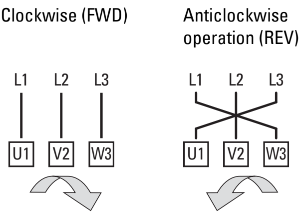


Regardless of the circuit type and the type of three-phase asynchronous motor, the connections must be labeled, so that their alphabetical sequence (e.g. U1, V1, W1) corresponds with the order of the mains voltage sequence (L1, L2, L3) and causes the motor to rotate clockwise.



On the three-phase asynchronous motor, three windings are arranged offset from each other by 120°/p (p = number of pole pairs). When a three-phase AC voltage with a 120° phase sequence is applied, this produces a rotation field in the motor.

The effect of inductance causes the rotation field and torque to be formed in the rotor winding. The speed of the motor thus depends on the number of pole pairs and the frequency of the supply voltage. The rotation direction can be reversed by swapping over two of the supply phases.



FWD = forward run (clockwise rotation field)

REV = reverse run (anticlockwise rotation field active)

Information on the rating plate

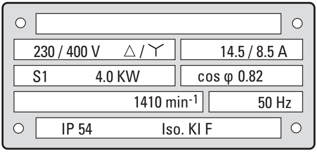
The electrical and mechanical rating data of the motor must be stated on its rating plate (IEC 34-1, VDE 0530). The data on the rating plate describes the stationary operation of the motor in the area of its operating point (M_N, e.g. at 400 V and 50 Hz). The operating data is unstable in the motor start phase.

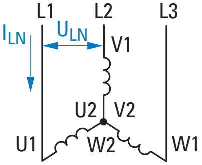
The following examples show the rating plates for two motors with a motor shaft output of 4 kW and the respective connection circuits on a three-phase AC network with 400 V and 50 Hz.

Electronic motor starters and drives

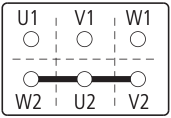
Drives engineering basic information

Star circuit



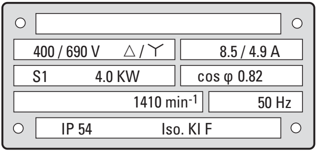


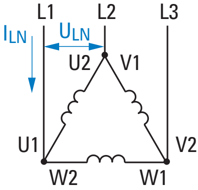
$U_{LN} = \sqrt{3} \times U_W$, $I_{LN} = I_W$



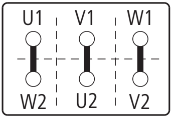
- With the specified 230/400 V voltage, this motor must be connected to the three-phase supply (U_{LN} = 400 V) in a star configuration.
- The voltage of each motor winding is designed for 230 V. The windings must therefore be connected in sequence to the phase voltage (400 V).
- The three winding phases (W2-U2-V2) are configured in the terminal box to the so-called star point. The voltage of the individual phases to the star point is 230 V (= U_W).

Delta circuit





$U_{LN} = U_W$, $I_{LN} = \sqrt{3} \times I_W$

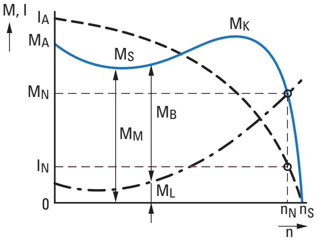


- With the specified 400/690 V voltage, this motor must be connected to the three-phase supply (U_{LN} = 400 V) in a delta configuration.
- Each motor winding is designed here for the maximum phase voltage of 400 V and can be connected directly.
- The three winding phases (U1 – W2, V1 – U2, W1 – V2) are combined in the terminal box and connected directly to the individual phases.

Electronic motor starters and drives
Drives engineering basic information

Startup characteristics

The following figure shows the characteristic startup curves of a three-phase asynchronous motor.



I_A: Starting current
I_N: Rated operational current at the operating point
M_A: Starting torque
M_B: Accelerating torque ($M_M > M_L$)
M_K: Breakdown torque
M_L: Load torque
M_M: Motor torque
M_N: Rated load torque, (stable operating point, intersection point of the three-phase speed torque characteristic with the load characteristic)
M_S: Pull-up torque
n: Speed (actual value)
n_N: Rated speed at the operating point
n_S: Synchronous speed (n_S - n_N = slip speed s)

Synchronous speed:

$$n_s = \frac{f}{p}$$

Slip speed in %:

$$s = \frac{n_s - n}{n_s} \cdot 100\,\%$$

Three-phase asynchronous motor speed:

$$n = \frac{f}{p} \cdot (1 - s)$$

f Frequency of voltage in Hz (= s^{-1})
n Speed in r.p.m.
p Number of pole pairs
s: Slip speed in r.p.m.

Electric power:

$$P_1 = U \times I \times \sqrt{3} \times \cos\varphi$$

P_1: Electrical power in W
U: Rated operating voltage in V
I: Rated operational current in A
cos φ: Power factor

Motor output (power equation):

$$P_2 = \frac{M_N \times n}{9550}$$

P_2: Mechanical shaft output power in kW
M_N: Rated torque in Nm
n: Speed in r.p.m.

Efficiency:

$$\eta = \frac{P_2}{P_1}$$

Comparison of startup variants

The features of the startup variants 1 to 4 described on page 2-2 are shown on the following pages 2-6 and 2-7.

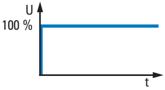
The graphs show the typical characteristics.

Electronic motor starters and drives

Drives engineering basic information

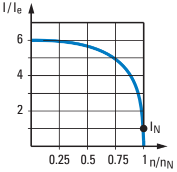
Direct Motor start ①

Voltage curve



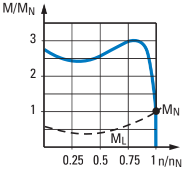
- Mains load high

Current curve



- Relative startup current
  4 to 8 x I_e (depending on motor)

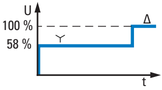
Torque behaviour



- Relative startup torque
  1.5 to 3 x M_N (depending on the motor)
- Features:
  – Strong acceleration with large starting current
  – High mechanical load
- Scope of application:
  Drives on powerful supply networks that allow high starting currents (torques)

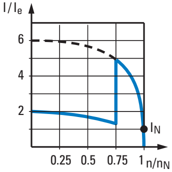
Star-delta starter ②

Voltage curve



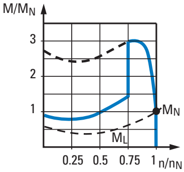
- Medium mains load

Current curve



- Relative starting current
  1.3 to 3 x I_e (~ ⅓ compared to DOL start)

Torque behaviour



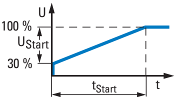
- Relative starting torque
  0.5 to 1 x M_N (~ ⅓ compared to DOL start)
- Features:
  – Startup with reduced current and torque
  – Current, torque peak on switching
- Application range:
  Drives that are only subject to loads after the startup

Electronic motor starters and drives

Drives engineering basic information

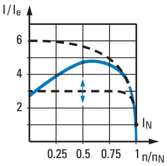
Soft starters ③

Voltage curve



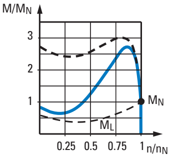
- Low to medium mains load

Current curve



- Relative starting current
  2 to 6 x I_e (reduced by voltage control)

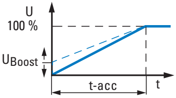
Torque behaviour



- Relative starting torque
  0.1 to 1 x M_N (M ~ U^2, quadratically adjustable by voltage control)
- Features:
  - adjustable starting characteristics
  - controlled deceleration possible
- Application range
  Drives with starting behavior adjusted to working machine.

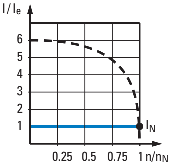
Frequency inverter ④

Voltage curve



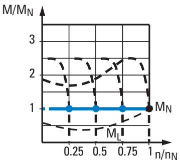
- Low mains load

Current curve



- Relative starting current
  ≦ 1 to 2 x I_e (adjustable)

Torque behaviour



- Relative starting torque
  ~ 0.1 to 2 x M_N (M ~ U/f, adjustable torque)
- Features:
  - high torque at low current
  - adjustable starting characteristics
- Application range:
  Drives requiring a controlled and infinitely variable speed adjustment.

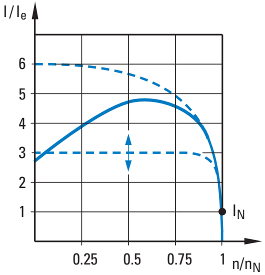
Electronic motor starters and drives

Soft starter basic information

Soft starters

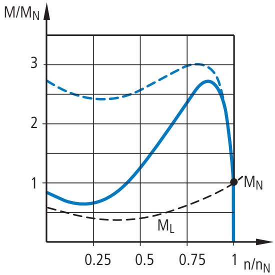
Soft starters are electronic devices for the soft starting of three-phase motors. Soft starters must comply with the product standard IEC/EN 60947-4-2.

During the startup phase of a motor, a soft starter controls the power supply smoothly and continuously up to the rated value (U_{LN}) by controlling the phase angle. This voltage control limits the starting current since the motor current behaves proportionally to the motor voltage. The resulting smooth torque increase enables the motor to be adapted to the load behavior of the motor.



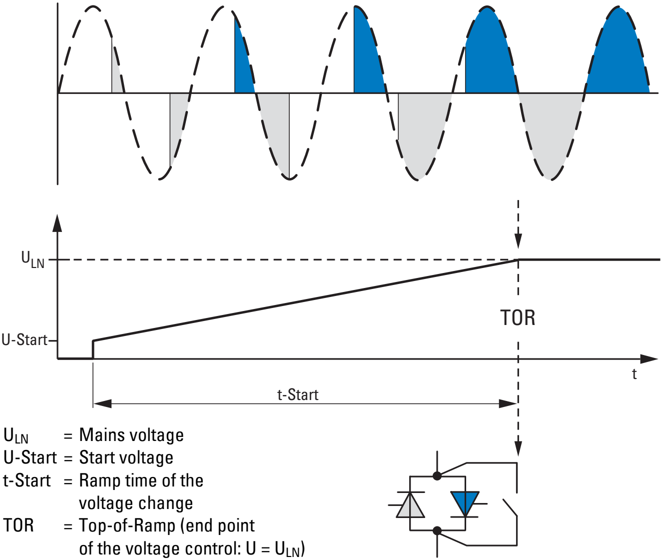
The mechanical components of this type of drive unit are therefore accelerated very smoothly. This has a positive effect on the lifespan, operating behavior and operating processes, and prevents any adverse effects such as:

- Impacting of cog edges in the gearbox
- Reduction of the water hammers in pipe systems
- Slipping of V belts
- Jitter with conveyor systems



After a time controlled voltage change has elapsed (TOR = Top-of-Ramp), so-called bypass contacts can be used to bridge the phase angle control for the static continuous operation. The considerably lower transition resistance of the mechanical switch contacts compared to power semiconductors enables heat dissipation in the soft starter to be reduced and the lifespan of the power semiconductors to be extended.

Electronic motor starters and drives
Soft starter basic information



U_{LN} = Mains voltage
U-Start = Start voltage
t-Start = Ramp time of the voltage change
TOR = Top-of-Ramp (end point of the voltage control: $U = U_{LN}$)

Note

The acceleration time of a drive with a soft starter always depends on the load and the breakaway torques. When commissioning this type of drive system, the required breakaway torque should be set first of all by means of the start voltage (U-Start) and then the shortest possible ramp time (t-Start) should be determined for the linear voltage change.

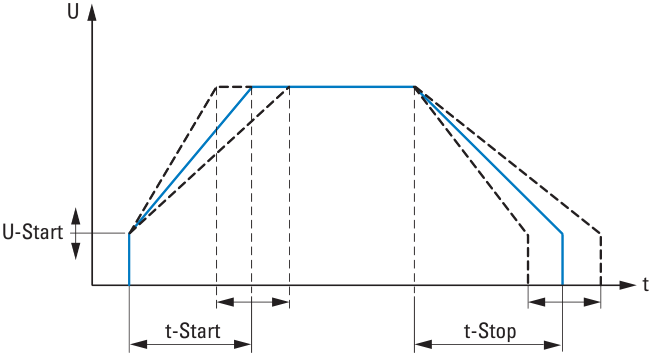
As well as the time-controlled startup of a motor, the soft starter also enables a time-controlled reduction of the motor voltage and thus a controlled stopping of the motor. This type of stop function is primarily used for pumps in order to prevent pressure waves (water hammer). Jerky movements and therefore the wear on drive chains and drive belts as well as bearings and gears can be reduced.

Note

The set ramp time for the deceleration (t-Stop) must be greater than the load-dependent uncontrolled deceleration time of the machine.

Electronic motor starters and drives
Soft starter basic information

Control of the motor voltage



The ratio of the overload current to the rated operational current, the total of the times for the controlled overload current, as well as the duty factor and start cycle form the overload current profile of a soft starter; this data is stated on the rating plate in accordance with IEC/EN 60947-4-2.

Example
55A: AC-53a: 3-5 : 75-10

55A = Rated operational current of the soft starter

AC-53a = Load cycle in accordance with IEC/EN 60947-4-2

3 = 3-fold overcurrent at start
(3 × 55 A = 165 A)

5 = Overcurrent duration in seconds

75 = Duty factor within the load cycle in %

10 = Number of permissible starts per hour

Other overload cycles and operating frequencies can be calculated.

Further information on this is provided in the relevant soft starter manual.

Note

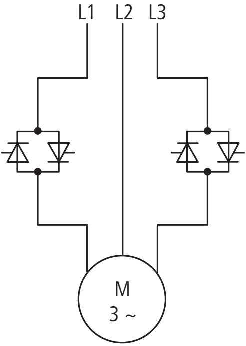
The controlled deceleration presents a similar load on the power semiconductors in the soft starter as the start phase. If therefore the deceleration ramp is activated on a soft starter with a maximum of 10 permissible starts per hour, the number of permissible starts is reduced to 5 per hour (plus 5 stops within the same hour).

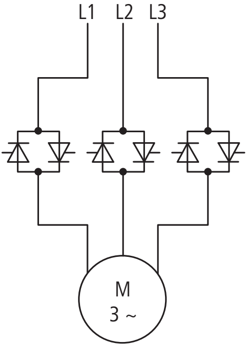
Electronic motor starters and drives
Soft starter basic information

Types

Soft starters are usually divided into two types:

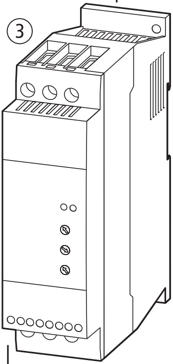
- Two-phase controlled, electronic soft starters for simple tasks:
  - Use is limited to small and medium rated motor (< 250 kW).
  - Simple handling with limited setting options and time controlled voltage ramps.
  - For simple applications where importance is placed on jerk-free operation in the starting phase.
  - They are an inexpensive alternative to the star-delta starter.
  - They can only be used in so-called In-Line configurations.
- Three-phase controlled, electronic soft starters for complex tasks:
  - For medium to high motor ratings up to 800 kW as compact devices
  - The devices are provided with an adjustable current limitation and integrated motor protection functions.
  - They have preset application characteristics and can be parameterized for optimizing the machine start functions.
  - Control inputs, signal contacts and optional fieldbus interfaces enable a wide range of communication options to be implemented.
  - They can be used in both In-Line and In-Delta configurations.
    Example: see DM4 → page 2-57





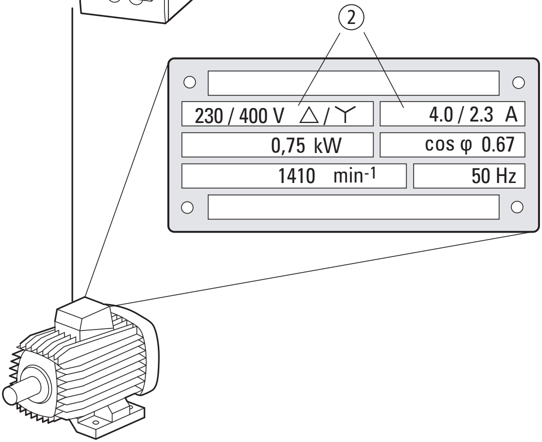
Electronic motor starters and drives

Soft starter basic information



Selection criteria

The soft starter ③ is selected on the basis of the supply voltage U_{LN} of the supply network ① and the rated operational current of the assigned motor ②. The circuit type (△/Y) of the motor must be selected according to the supply voltage ①. The rated output current I_e of the soft starter must be greater than/equal to the rated motor current.

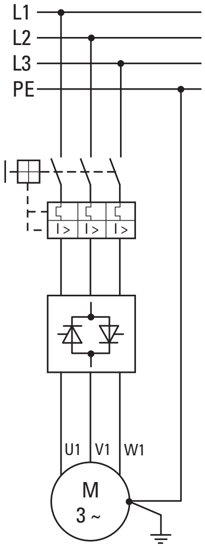


Electronic motor starters and drives
Soft starter basic information

Selection criteria

When selecting the drive, the following criteria must be known:

- Type of motor (three-phase asynchronous motor)
- Mains voltage = rated operating voltage of the motor (e.g. 3 AC ~ 400 V)
- Rated motor current (recommended value, dependent on the circuit type and the power supply)
- Load torque (quadratic, linear)
- Starting torque
- Ambient temperature (rated value +40 °C).



Motor feeder with DS7 soft starter combined with PKZM0 in In-Line circuit

The switching and protective devices (electromechanical components) in the main circuit of the motor feeder are designed on the basis of the rated operational current (I_e) of the motor and the utilization category AC-3 (standard IEC 60947-4-1).

The utilization category here is AC-53a (IEC/EN 60947-4-2 standard).

- AC-3 = squirrel-cage motors: startup, switch off during operation.
- AC-53a = control of a squirrel-cage motor: eight-hour duty with starting currents for start processes, settings, operation

Electronic motor starters and drives

Soft starter basic information

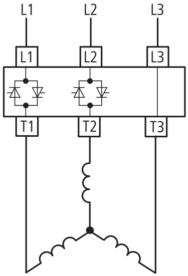
Permissible connection circuits of the motor

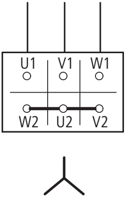
Three-phase asynchronous motors can be connected to a soft starter, depending on the mains voltage in a star or delta connection.

Example

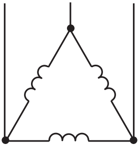
2 phase controlled soft starter (DS7)

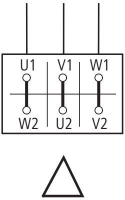
Star circuit





Delta circuit



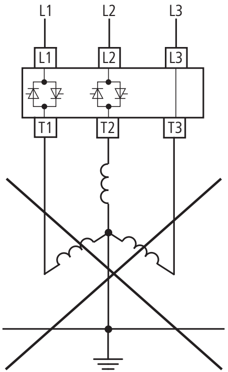


Electronic motor starters and drives

Soft starter basic information

Note

Three-phase motors with a neutral point (star circuit) must not be connected to a two-phase controlled soft starter as one phase is connected here directly to the mains voltage and causes impermissible overheating in the motor.



Caution!

Not permissible

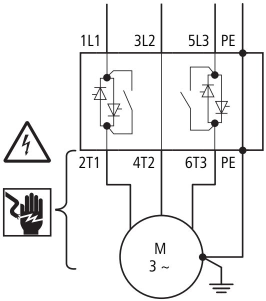
Danger!
Dangerous voltage.
Risk of death or serious injury.

The power section of soft starters is formed with semi-conductors (thyristors). When a supply voltage (U_{LN}) is present, there is also a dangerous voltage present at the output to the motor in the OFF/STOP state.

This warning applies to all soft starter types.

Example

2 phase controlled soft starter



Electronic motor starters and drives

Soft starter basic information

Soft starters and coordination types to IEC/EN 60947-4-3

The following coordination types are defined in IEC/EN 60947-4-3, 8.2.5.1:

Type 1 coordination

In type 1 coordination, the device must not endanger persons or the installation in the event of a short-circuit and does not have to be capable of continued operation without repairs or parts replacements.

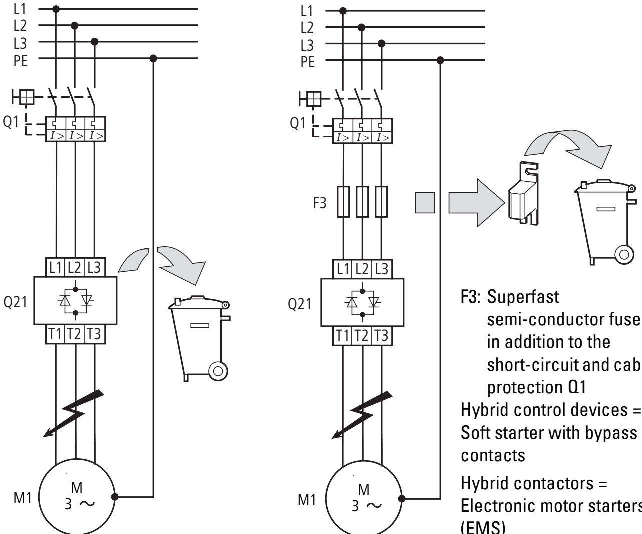
Type 2 coordination

In type 2 coordination, the device must not endanger persons or the installation in the event of a short-circuit and must be capable of continued use without repairs or parts replacements. For hybrid control devices and contactors, there is a risk of contact welding, for which the manufacturer must give maintenance instructions.

The assigned short-circuit protective device (SCPD) must trip in the event of a short-circuit. If a fuse is used, this has to be replaced. This is part of the normal operation of the fuse, also for type 2 coordination.

Note

Superfast semiconductor fuses must always be arranged directly in front of the power semiconductors (short cable lengths).



Type 1 coordination

Type 2 coordination

F3: Superfast semi-conductor fuses, in addition to the short-circuit and cable protection Q1

Hybrid control devices = Soft starter with bypass contacts

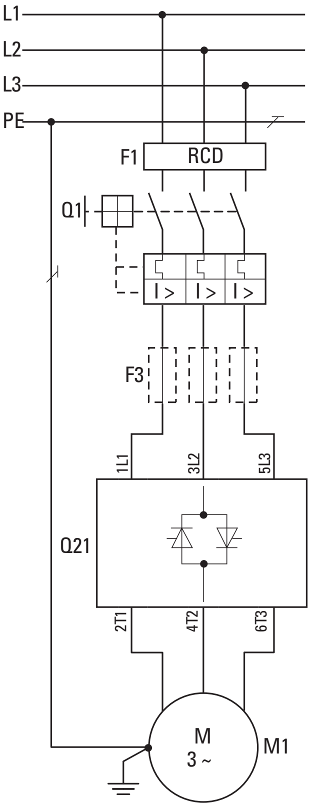
Hybrid contactors = Electronic motor starters (EMS)

Electronic motor starters and drives
Soft starter basic information

Residual current devices

Residual current devices (RCDs) protect persons and animals from the presence (not the creation!) of impermissibly high contact voltages. They prevent dangerous and fatal injuries caused by electrical accidents and also serve as fire prevention.

Standard residual current devices (RCD type A) with up to 30 mA and higher can be used with a soft starter.

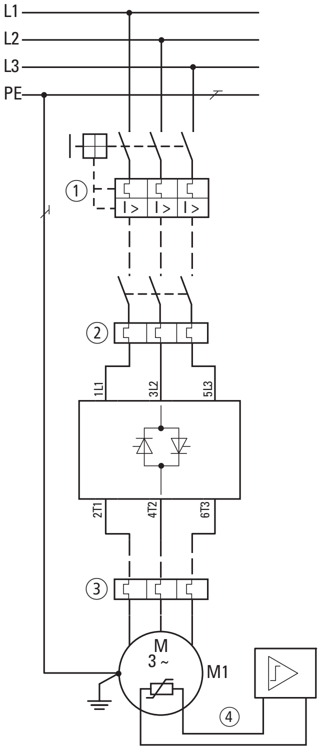


F1: Residual current device (RCD)
F3: Optional semiconductor fuses for type 2 coordination
M1: Motor
Q1: Cable protection + motor protection
Q21: Soft starter

Electronic motor starters and drives

Soft starter basic information

Motor protection



The motor protection protects the three-phase asynchronous motor from thermal overload caused by a mechanical overload or the failure of one or two connection cables.

There are two basic ways of protecting the three-phase motor from overload during operation:

- Monitoring of current consumption (motor protection, overload relay or bimetal relay)
- Direct temperature monitoring in the motor winding (PTC, thermistor)

1. Motor-protective circuit-breaker (PKZ, PKE, NZM), disconnection with manual release
2. Overload relay (ZB, ZEB) – here in combination with a contactor
3. Overload relay (ZB, ZEB) for indication of the thermal overload
4. Thermistor, PTC or positive temperature coefficient protection in the motor winding with external indication relay (EMT)

Note

The combination of the current monitoring motor protection variants 1, 2 or 3 with the temperature monitoring variants 4 is also called full motor protection.

Note

After a motor protective device has tripped, the soft starter and the protective device cannot be switched on again until it has cooled down. The reset depends on the temperature.

Electronic motor starters and drives

Soft starter basic information

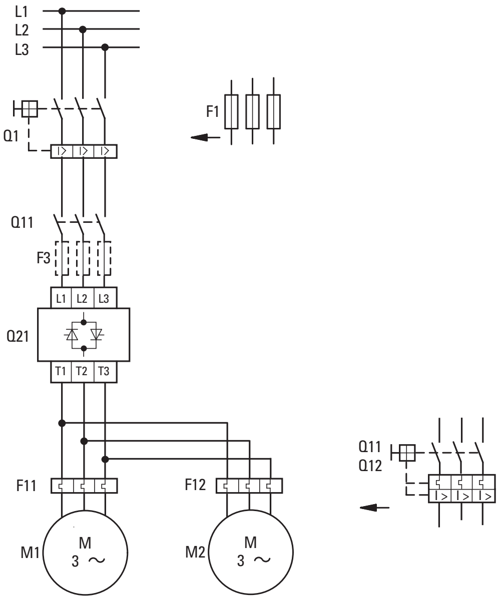
Parallel connection of several motors to a single soft starter

You can also use soft starters to start several motors connected in parallel. This does not, however, allow the startup behavior of the individual motors to be controlled.

Notes

- The current consumption of all connected motors must not exceed the rated operational current I_e of the soft starter.
- Each motor must be protected from thermal overload individually, e.g. with thermistors and/or overload relays (F11, F12) . Alternatively, motor-protective circuit-breakers (Q11, Q12) can also be used.
- It is advisable to use this circuit type only with motors of a similar rating (maximum deviation: one rating size). Problems may arise during starting if motors with significant rating differences (for example 1.5 kW and 11 kW) are connected to the output of a soft starter. The lower-rated motors may not be able to reach the required torque due to the relatively high ohmic resistance of their stators. During the startup these require a higher voltage.
- The last motor must not be switched off in operation since the resulting voltage peaks may cause damage to the electronic components in the soft starter and thus to its failure.

Electronic motor starters and drives
Soft starter basic information



F11, F12: Motor protection (overload relay) or motor-protective circuit-breaker (Q11, Q12)

F3: Superfast semi-conductor fuses (optional, additionally to Q1 and F1)

Q1 or F1: Short-circuit and cable protection

Electronic motor starters and drives

Soft starter basic information

Using soft starters with three-phase slipring motors

When upgrading or modernizing older installations, contactors and rotor resistors of multistage three-phase stator automatic starters can be replaced with soft starters. This is done by removing the rotor resistors and assigned contactors and short-circuiting the slip rings of the motor’s rotor. The soft starter is then connected into the feeder. The smooth starting of the motor can then be implemented.

→ Figure, page 2-23

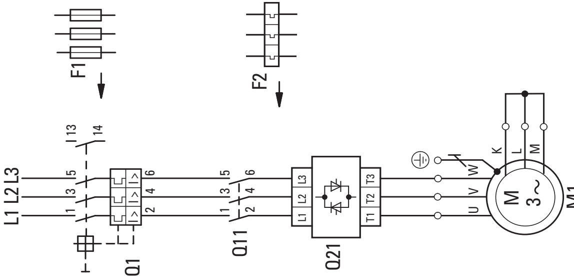
Notes

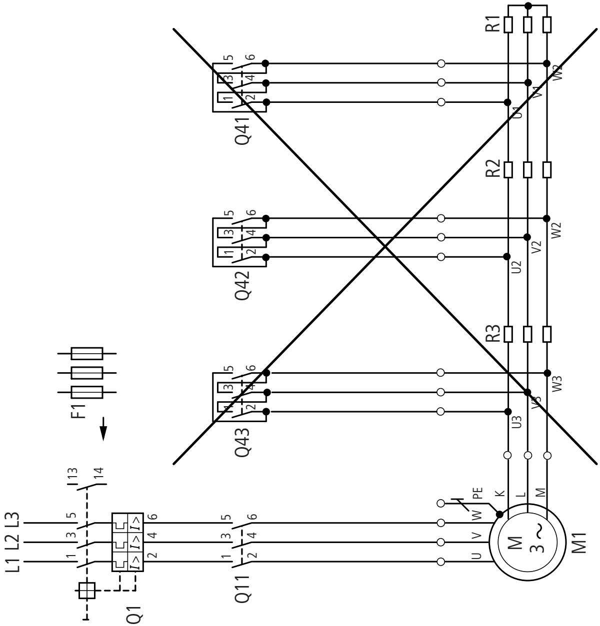
- Slip ring motors develop a high starting torque with low starting current. They can thus be started at the rated load and this must be taken into account when selecting a soft starter. The soft starter cannot replace the rotor resistors in every application.
- Depending on the type of motor, it may be necessary to keep the last resistor group permanently connected to the slipring rotor terminal (K-L-M).

Q1: Cable and motor overload protection
or
F1: Cable protection and
F2: Overload protection required (thermistor, bimetal relay) if the soft starter (Q21) does not include this function. Example: overload relay F2 in combination with contactor Q11.
M1: Slip-ring motor

Electronic motor starters and drives

Soft starter basic information





Electronic motor starters and drives
Soft starter basic information

Motors with compensation capacitors

As resistive-inductive loads, three-phase motors draw reactive power from the network. This reactive power can be compensated by means of capacitors (C_x) ① (improved power factor cos φ).

WARNING

The output of a soft starter must not be connected to any capacitive loads (capacitors) ②. This would damage the soft starter.

If capacitors are to be used for reactive power compensation and thus to improve the power factor, they must be connected to the mains side of the soft starter ③. If the soft starter is used together with an isolating or main contactor (Q11), the capacitors must be disconnected from the soft starter (Q12) when the contactor contacts are open.

The following figure ③ shows a safe arrangement. The compensation capacitors are switched via a capacitor contactor (Q12). The capacitor contactor is controlled via the TOR (Top-of-Ramp) signal of the soft starter. The capacitors are disconnected from the mains during the critical start and stop times.

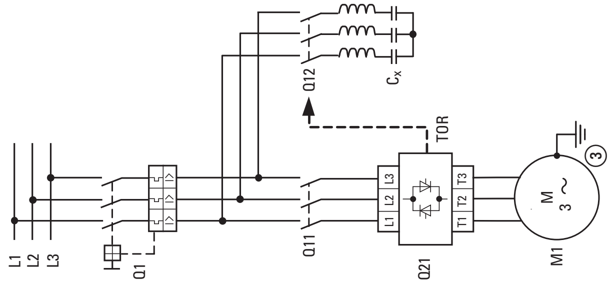
Note

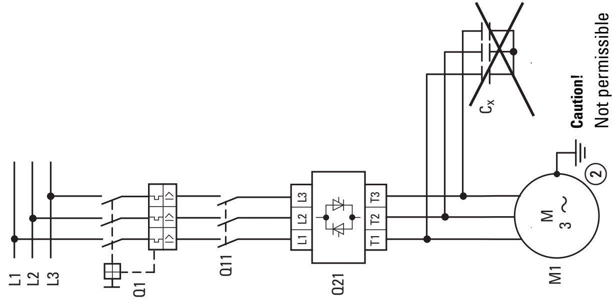
In networks with electronically controlled loads (e.g. soft starters), the compensation devices must always be connected with a series inductance.

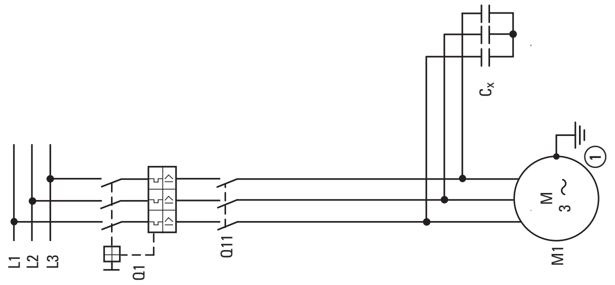
C_x: Capacitors for reactive power compensation
Q1: Motor-protective circuit-breaker
Q11: Mains contactor
Q12: Contactor for capacitors
Q21: Soft starter
M1: Three-phase asynchronous motor

Electronic motor starters and drives

Soft starter basic information







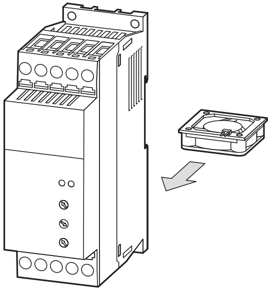
Electronic motor starters and drives

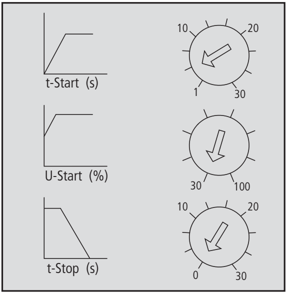
Connection example DS7

DS7 product features

- Two-phase controlled soft starter, meets the requirements of the IEC/EN 60947-4-2 product standard
- Power section and control section are galvanically isolated
- Power section:
  - Rated operational voltage: 200 – 480 V, -15 % /+10 %
  - Mains frequency: 50/60 Hz ±10 %
  - Overload cycle: AC53a: 3 – 5: 75 – 10
- Control voltage/regulator supply voltage:
  - DS7-340…: 24 V AC/DC, -15 %/+10 %
  - DS7-342…: 120 - 230 V AC, -15 %/+10 %
  - AC: 50/60 Hz ±10 %
  - Control voltage and controller power supply always have the same potential and voltage level.
- Relay contacts (potential-free)
  - TOR (Top-of-Ramp): 230 V AC, 1 A, AC-11
    In size 1 (to 12 A) with potential connection to the control section
  - RUN (operational signal): 230 V AC, 1 A, AC-11
    In size 1 (to 12 A) this relay contact is not present.
- Ambient temperature during operation: -5 to +40 °C, max. +60 °C with derating and device fan
- Load cycle: 10 starts per hour, max. 40 starts per hour, with derating and integrated device fan (optional)
- Status display (LEDs)
  - RUN = Operating signal (green)
  - Error = Error message (red)
- Parameterization/setting via three parameters accessible on the front

DS7 with device fan DS7-FAN-032





t-Start = Ramp time (1 - 30 s) for the voltage increase from the value U-Start up to mains voltage (U_{LN})

U-Start = The start voltage (30 - 100 %), determines the torque of the motor

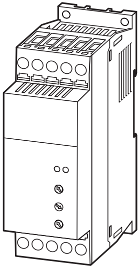
t-Stop= Ramp time (0/1 - 30 s) for the voltage reduction from the mains voltage (U_{LN}) to the value U-Start

Electronic motor starters and drives

Connection example DS7

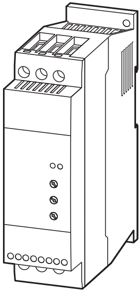
Sizes DS7

Size 1 (4 to 12 A)



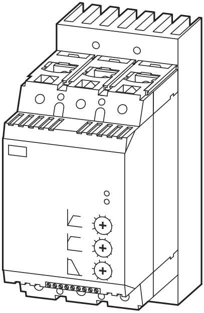
DS7-34…SX004…
DS7-34…SX007…
DS7-34…SX009…
DS7-34…SX012…

Size 2 (16 to 32 A)



DS7-34…SX016…
DS7-34…SX024…
DS7-34…SX032…

Size 3 + 4 (41 to 200 A)



DS7-34…SX041…
DS7-34…SX055…
DS7-34…SX070…
DS7-34…SX081…
DS7-34…SX100…
DS7-34…SX135…
DS7-34…SX160…
DS7-34…SX200…

Documentation

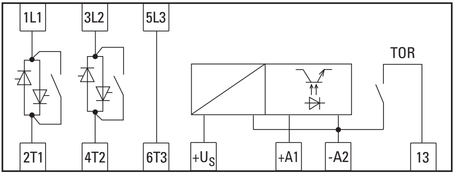
Manual: MN03901001Z-EN

Instructional leaflet:
IL03902003Z (for size 1)
IL03902004Z (for size 2)
IL03902005Z (for size 3 und 4)

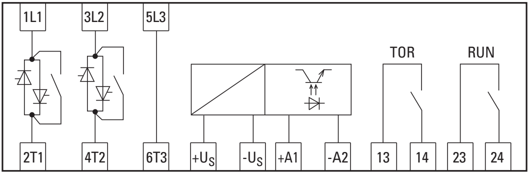
Electronic motor starters and drives
Connection example DS7

The number and arrangement of the control terminals, as well as the structure in the power section of the individual sizes vary according to the power section.

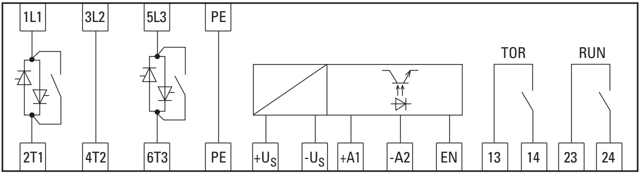
Size 1 (4 to 12 A)



Size 2 (16 to 32 A)



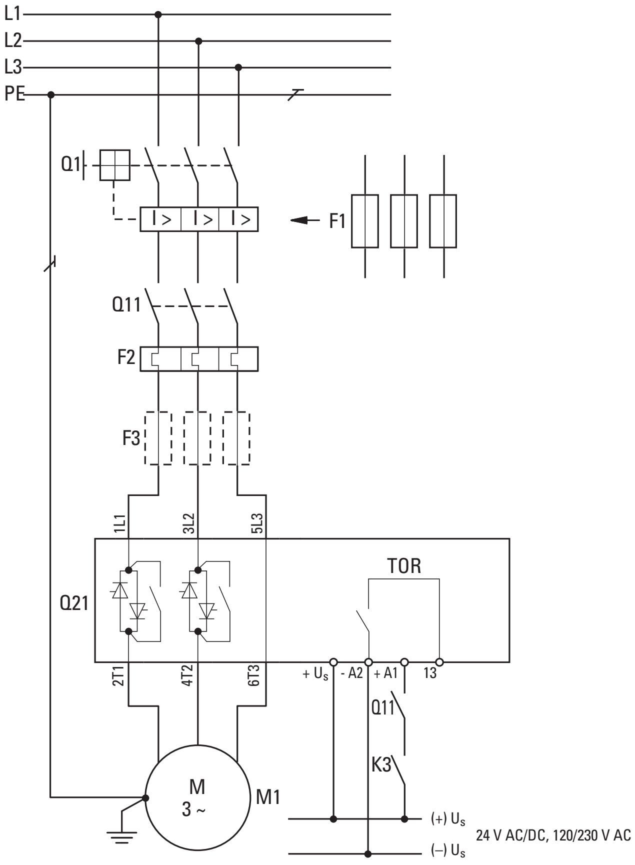
Size 3 and 4 (41 to 200 A)



Electronic motor starters and drives
Connection example DS7

Standard connection with upstream mains contactor and soft stop ramp

Standard connection with mains contactor, size 1 (4 to 12 A)

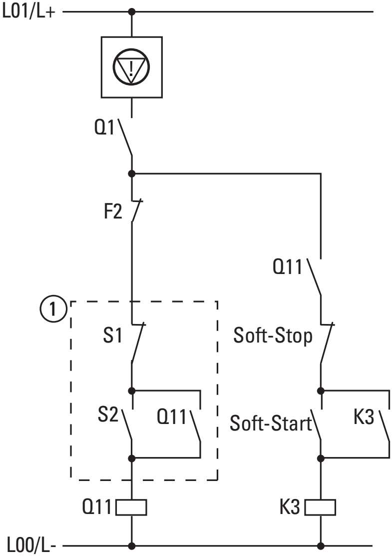


Electronic motor starters and drives
Connection example DS7

Control section with mains contactor

Q1, F1: Short-circuit- and cable protection
Q11: Mains contactor
F2: Motor protection
F3: Optional semiconductor fuse for type 2 coordination, in addition to Q1 and F1
K3: Start/Stop

① Optional – if a stop is required without a SoftStop
Setting: t-Stop > 0

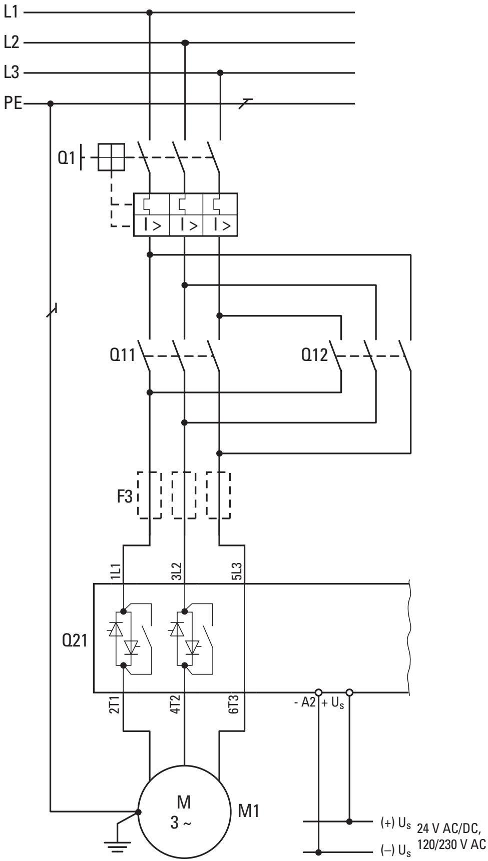


Electronic motor starters and drives

Connection example DS7

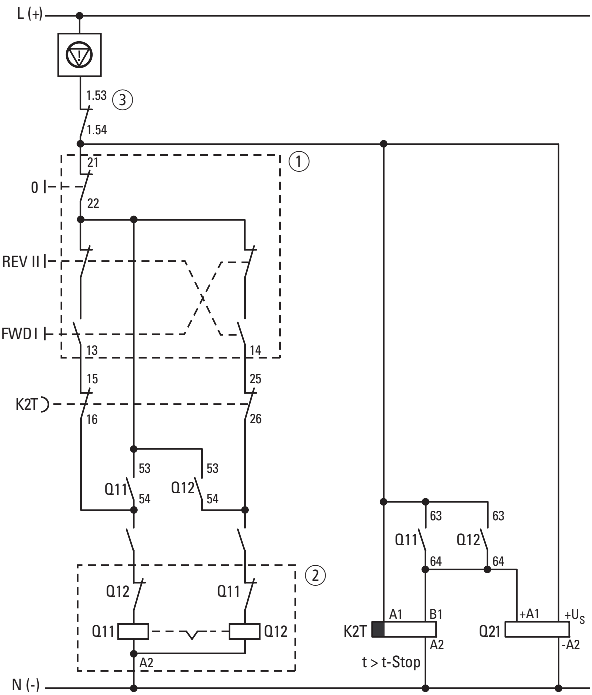
Rotation direction reversal with soft stop ramp

Size 1 (4 to 12 A)



Electronic motor starters and drives
Connection example DS7

Control section for bidirectional operation



FWD = Clockwise rotation field (Forward Run)

REV = Counterclockwise rotation field (Reverse Run)

Q11 = Mains contactor FWD

Q12 = Mains contactor REV

1. Assembled control station
2. Reversing starter
3. Standard auxiliary contact

2

Electronic motor starters and drives

Connection example DS7

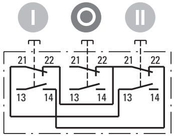
Control section for bidirectional operation

Note

The control voltages (+U_S) of the DS7 soft starter and the contactor control must have the same potential:
24 V DC/AC or 120/230 V AC

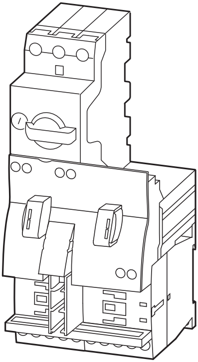
Q1, Q11, Q12 = MSC-R motor-starter combination ② is a compact device with electrical and mechanical interlocking.

The NHI-E-10-PKZ0 auxiliary contact ③ is added to Q1 for cable and motor protection.



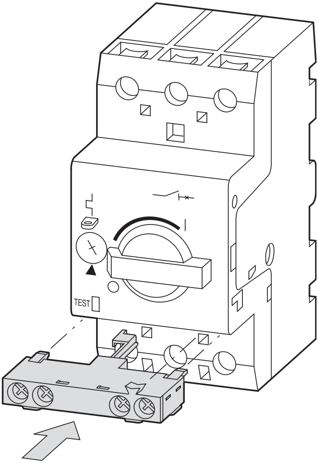
M22-I3-M1

① Contact sequence of assembled control station



MSC-R-…

② Reversing starter

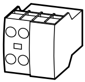


NHI-E-10-PKZ0

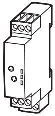
③ Standard auxiliary contact (grey)

Electronic motor starters and drives

Connection example DS7



DIL-XHI20



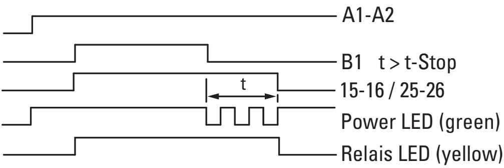
ETR2-11

Two DILA-XHI20 auxiliary contact modules are added to the two reversing contactors Q11 and Q12.

The NO contact 53/54 is used for the self-maintaining of reversing contactors Q11 and Q12; NO contact 63/64 activates the timing relay K2T and the soft starter Q21.

The pushbutton actuators 0, I, II as a complete device (M22-I3-M1) for surface mounting (1) enable the rotation direction change via the stop button.

K2T is an off-delayed timing relay (type ETR2) and simulates here the RUN signal. The drop-out time must be greater than the stop time (t-Stop) set on the DS7 soft starter. Switching to the other direction is only possible after the value set here has elapsed.

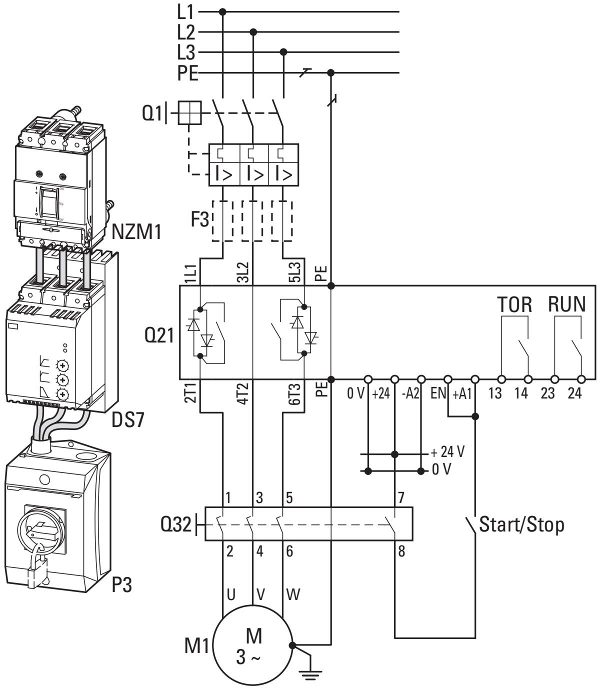


Electronic motor starters and drives

Connection example DS7

Compact motor starter with maintenance switch

Soft starter DS7, circuit-breaker NZM1 and maintenance switch P3, size 3 + 4 (41 to 200 A)



F3: Superfast semiconductor fuse (optional for type 2 coordination, additional to Q1)

Q1: Cable and motor protection

Q21: DS7 soft starters

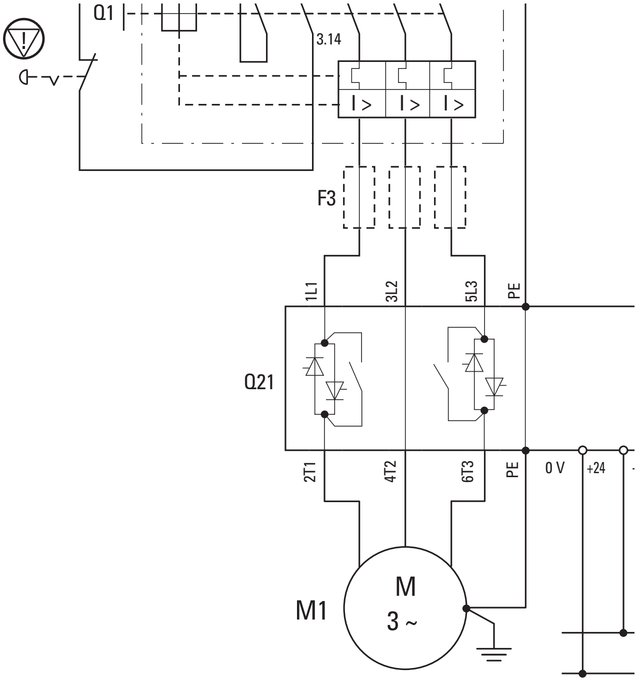
Q32: Maintenance switch (local)

M1: Three-phase motor

Electronic motor starters and drives

Connection example DS7

NZM circuit-breaker with emergency-off function to IEC/EN 60204 and VDE 0113 Part 1, size 3 + 4 (41 to 200 A)



Emergency switching off
F3: Superfast semiconductor fuse (optional for type 2 coordination, additional to Q1)
Q1: Cable and motor protection (NZM1, NZM2)
Q21: DS7 soft starters
M1: Motor

① Control circuit terminal
② Undervoltage release with early-make auxiliary contact

Electronic motor starters and drives

Connection example DS7

Bypass circuit

Note

The devices of the DS7-34… series are already provided with integrated bypass contacts. An external bypass for continuous operation with a DS7 soft starter is therefore not required.

Bypass circuit for emergency operation

In pump applications the bypass contactor is often required to provide emergency operation capability. A service switch is used to select between soft starter operation and DOL starter operation via a bypass contactor (Q22). This is used to fully isolate the soft starter. In this case, it is important that the output circuit is not opened during operation. The interlocks ensure that a switchover is only possible after a stop. An electrical and/or mechanical interlocking of contactors Q22 and Q31 ensures a safe operating state.

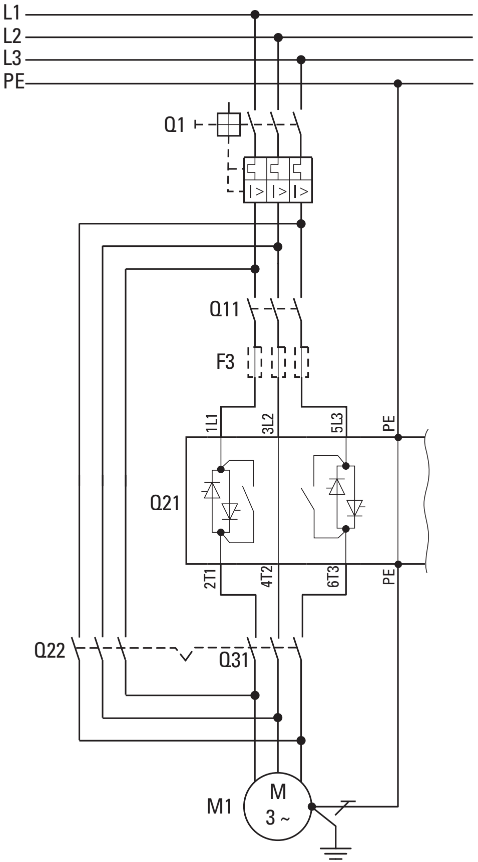
Note

Unlike simple bypass operation, the bypass contactor must be designed here in accordance with utilization category AC-3.

F3: Superfast semiconductor fuse (optional) for type 2 coordination (additional to Q1)
Q1: Cable and motor protection
Q11: Mains contactor (optional) for disconnection in emergency operation
Q21: Soft starters
Q22: Bypass contactor
Q31: Motor contactor
M1: Motor

Electronic motor starters and drives
Connection example DS7

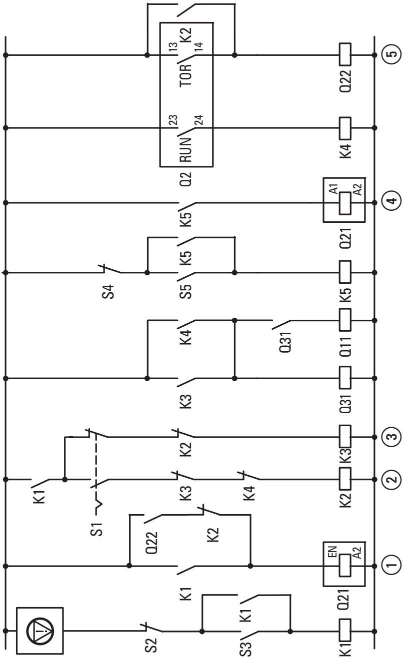
DS7 power section ≧ 41 A with bypass emergency operation (example: pump)



Electronic motor starters and drives

Connection example DS7

Actuation with bypass emergency operation – (pump operation)



① Enable
② Automatic operation (soft starter)
③ Manual/bypass operation
④ Softstart/Soft stop
⑤ Bypass contactor

S1: Operating mode switch
S2: Off
S3: On
S4: Stop (soft starter)
S5: Start (soft starter)

Note

The control system shown here can also be used for the DS7 soft starter in size 2 (16 to 32 A).

Electronic motor starters and drives
Connection example DS7

Starting several motors sequentially with a soft starter (cascaded control)

When starting several motors one after the other using a soft starter, keep to the following changeover sequence:

1. Start using soft starter
2. Switch on bypass contactor Qn2 via TOR (Top-of-Ramp)
3. Block soft starter
4. Switch soft starter output with Qn1 to the next motor
5. Restart

Notes

- When starting several motors with one soft starter the thermal load of the soft starter (starting frequency, current load) must be taken into account. If the starts are to occur in close succession, the soft starter must be dimensioned larger (i.e. the soft starter must be designed with an accordingly higher load cycle).
- Due to the thermal design of the DS7 soft starters, we recommend the use of an (optional) fan when using a DS7 series device for starting several motors.

F3: Superfast semiconductor fuse (optional for type 2 coordination, additional to Q1)
Q1: Cable protection
Q2: Soft starter DS7
Qn1: Contactor (1, 2, n)
Qn2: Mains bypass contactor for motor (1, 2, n)
Qn3: Motor protection (motor-protective circuit-breaker or bimetal relay
Mn: Motor (1, 2, n)

Notes

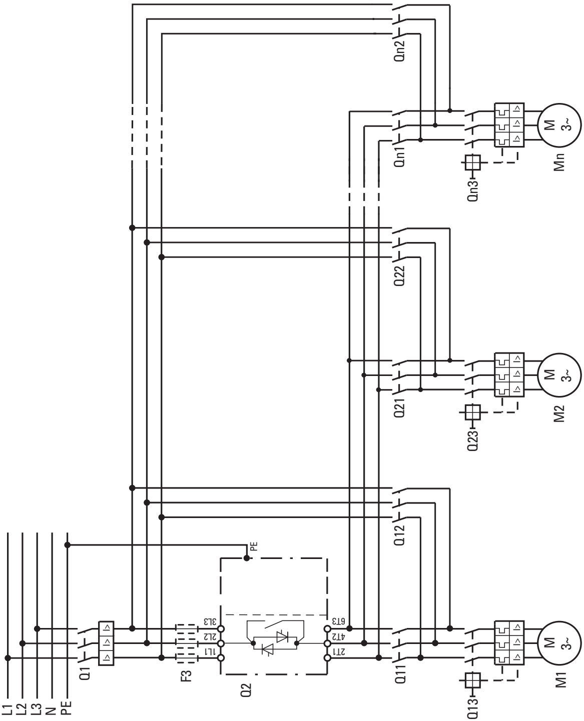
- The control system shown here can also be used for the DS7 soft starter in size 2 (16 to 32 A), however without an enable signal 1.
- Bimetal relays can also be used as an alternative to the overload relays Q13, Q23, … , Qn3 (see page 2-21).

Electronic motor starters and drives

Connection example DS7

Cascade control

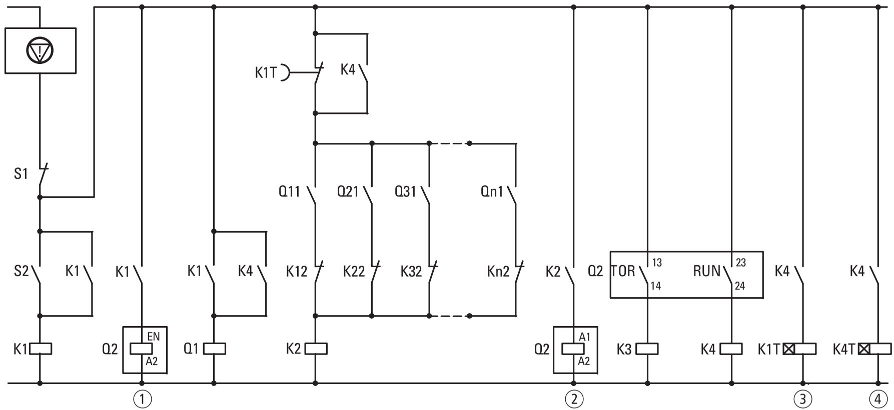
Power section for motor cascade (example for size 3 and 4)



Electronic motor starters and drives

Connection example DS7

Actuation, motor cascade, part 1



① Enable

② Softstart/Soft stop

③ Starting frequency monitoring. The timing relay must be set so that the soft starter does not have a temperature overload. The correct time is based on the permissible operating frequency of the selected soft starter.
If necessary, use soft starters with a higher rating.

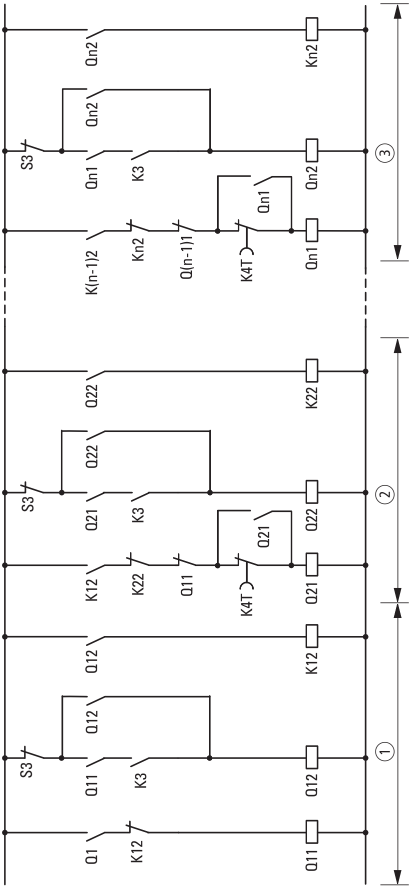
④ Set the timing relays to approx. 2 s off-delay. This ensures that the next motor branch can not be connected as long as the soft starter is running.

N/C contact S1 switches all motors off at the same time.

Electronic motor starters and drives

Connection example DS7

Actuation, motor cascade, part 2



① Motor 1
② Motor 2
③ Motor n

The N/C contact S3 is required if motors also have to be switched off individually.

Electronic motor starters and drives
DM4 connection example

DM4 product features

- Three-phase controlled soft starter; meets the requirements of the IEC/EN 60947-4-2 product standard
- Configurable and communication-enabled with pluggable control signal terminals and interface for options:
  - Operator control and programming unit
  - Serial interface
  - Fieldbus connection
- Application selector switch with user-programmable parameter sets for 10 standard applications
- I^2t controller
  - Current limitation
  - Overload protection
  - Idle/undercurrent detection (e.g. belt breakage)
- Kickstarting and heavy starting
- Automatic control voltage detection
- 3 relays, e.g. fault signal, TOR (Top-of-Ramp)
- Power section:
  Rated operational voltage 230 - 480 V, -15 % / + 10 %
  Mains frequency: 50/60 Hz ±10 %
- Control voltage/regulator supply voltage:
  - 24 V DC
  - 120 - 240 V AC, -15 % / +10 %, 50/60 Hz
- Ambient temperature during operation: 0 to +40 °C
- Load cycle: 10 starts per hour with 3.5 x I_e for max. 35 s

Pre-programmed parameter sets for ten typical applications can be simply called up with a selector switch (see page 2-48).

Additional plant-specific settings can be defined with an optional keypad. This includes, for example, the three-phase AC power controller mode. In this mode three-phase resistive and inductive loads (heaters, lighting systems, transformers) can be controlled with the DM4. Both open-loop and – with measured value feedback – closed-loop control are possible.

Instead of the keypad, intelligent interfaces can also be used:

- RS232/RS485 serial interface (configuration with PC software)
- PROFIBUS-DP fieldbus connection

The DM4 soft starter provides the most convenient method of implementing soft starting. In addition to phase failure and motor current monitoring, the motor winding temperature is evaluated through the built-in thermistor input, so that the soft starters do not require additional external components, such as motor protective relays.

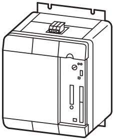
Note

The optional superfast semiconductor fuses (F3) for type 2 coordination can be used from size 2 (from 85 A) in the housing of the DM4 soft starter.

Electronic motor starters and drives

DM4 connection example

Sizes DM4

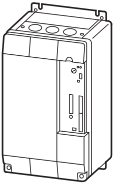


Size 1

16 - 72 A

Assigned motor power at 400 V

7.5/11 - 37 kW

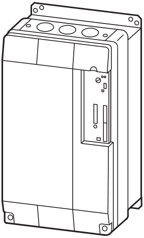


Size 2

85 - 146 A

Assigned motor power at 400 V

45/75 - 75/132 kW

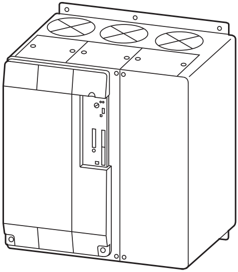


Size 3

174 - 370 A

Assigned motor power at 400 V

90/160 - 200/315 kW



Size 4

500 - 900 A

Assigned motor power at 400 V

250/400 - 500/900 kW

Electronic motor starters and drives
DM4 connection example

Documentation

Manuals:

AWB8250-1346GB
("Soft Starter Design")

AWB8250-1341GB (DM4 "Soft Starter")

AWB8240-1398 ("DE8240-NET-DP2
interface module for PROFIBUS DP")

AWB823-1279
("DE4-COM-2X interface module")

AWB8240-1344GB
("DE4-KEY-2 Keypad")

Installation instructions:

AWA8250-1704 (up to 37 kW)

AWA8250-1751 (45 to 75 kW)

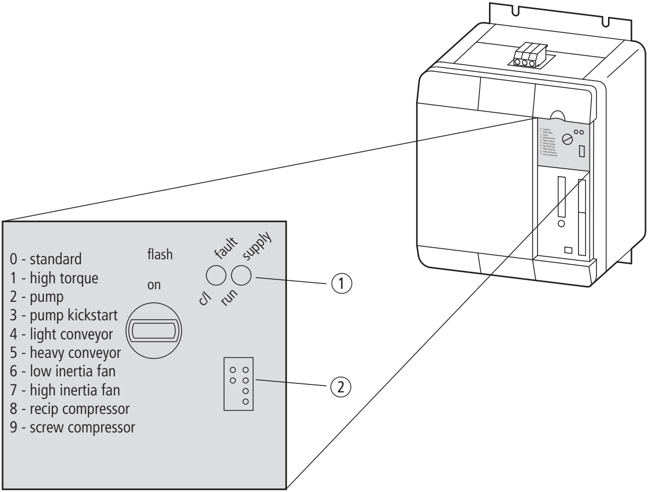
AWA8250-1752 (90 to 200 kW)

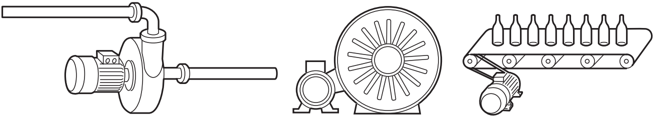
AWA8250-1783 (250 to 500 kW)

Notes

Electronic motor starters and drives
DM4 connection example

The application selector switch enables direct assignment without parameter entry.





Electronic motor starters and drives
DM4 connection example

Standard applications (selector switch)

Labelling on device	Indication on keypad	Meaning	Notes
Standard	Standard	Standard	• Default settings, suitable without adaptation for most applications
High torque[1)]	High Torque	High breakaway torque	• Drives with higher breakaway torque
Pump	Small pump	Small pump	• Pump drives up to 15 kW
Pump Kickstart	Large pump	Large pump	• Pump drives over 15 kW • Longer deceleration times
Light conveyor	Light conveyor	Light conveyor	–
Heavy conveyor	HeavyConvey	Heavy-duty conveyor	–
Low inertia fan	LowInert.fan	Low-inertia fan	• Fan drive with relatively small mass inertia moment of up to 15 times the motor’s inertia moment
High inertia fan	HighInertfan	High-inertia fan	• Fan drive with relatively large mass inertia moment of over 15 times the motor’s inertia moment. • Longer ramp-up times
Recip compressor	RecipCompres	Reciprocal compressor	• Higher start voltage • p.f. optimization matched
Screw compressor	ScrewCompres	Screw compressor	• Increased current consumption • No current limitation

1) For the “High Torque” setting, the soft starter must be able to supply 1.5 times the motor’s rated current.

Electronic motor starters and drives

DM4 connection example

Enable/immediate stop without ramp function (e.g. for Emergency-Stop)

The digital input E2 is factory set to switch the enable function. The soft starter is enabled only when a High signal is present at the terminal. The soft starter cannot be operated without the enable signal.

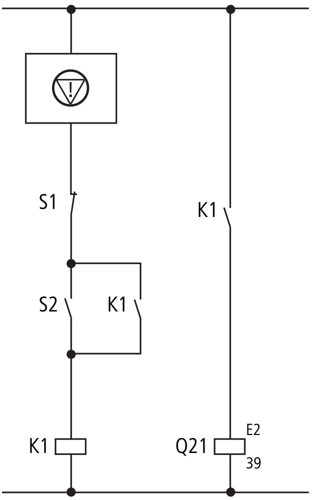
In the event of wire breakage or interruption of the signal by an Emergency-Stop circuit, the regulator in the soft starter is immediately blocked and the power circuit disconnected, and after that the ”Run“ relay drops out.

Normally the drive is always stopped via a ramp function.

When the operating conditions require an immediate de-energization, this is effected via the enabling signal.

Warning!

You must in all operating conditions always first stop the soft starter (”Run” relay scanning), before you mechanically interrupt the power conductors. Otherwise a flowing current is interrupted – thus resulting in voltage peaks, which in rare cases may destroy the thyristors of the soft starter.



Emergency switching off
E2: Digital input
Q21: Soft starter (E2 = 1 + enabled)
S1: Off
S2: On

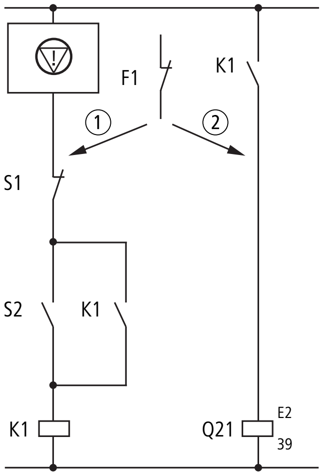
Electronic motor starters and drives

DM4 connection example

Linking the overload relay into the control system

We recommend using an external overload relay instead of a motor-protective circuit-breaker with built-in overload relay. This allows controlled ramping down of the soft starter through the control section in the event of an overload.

Warning!
The direct opening of the power lines may cause overvoltage and destruction of the soft starter's semi-conductors.



Emergency switching off
S1: Off
S2: On
Q21: Soft starter (E2 = 1 → enabled)

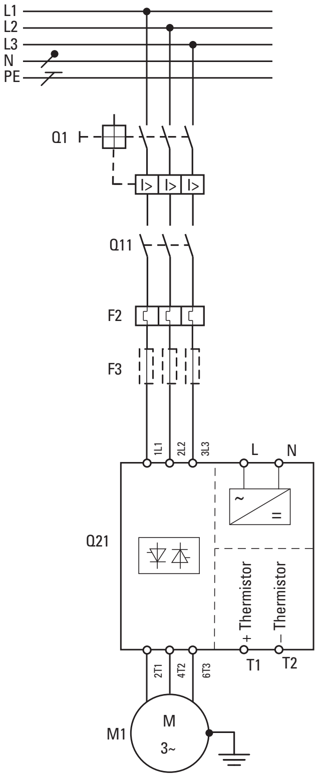
There are two ways of incorporating a motor-protective relay in the control system as shown in the diagram on the left:

1. The signalling contacts of the overload relay are incorporated in the on/off circuit. In the event of a fault, the soft starter decelerates according to the set ramp time and stops.
2. The signalling contacts of the overload relay are incorporated in the enable circuit. In the event of a fault, the soft starter's output is immediately de-energized. The soft starter switches off but the mains contactor remains on. In order to switch off the mains contactor, a second contact of the overload relay must be incorporated in the on/off circuit.

Electronic motor starters and drives

DM4 connection example

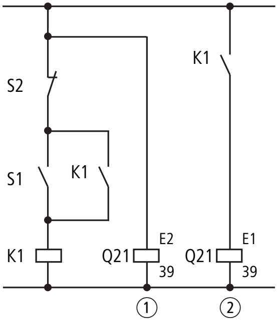
With separate contactor and overload relay



Standard connection

For isolation from the mains, either a mains contactor upstream of the soft starter or a central switching device (contactor or main switch) is necessary.

Actuation



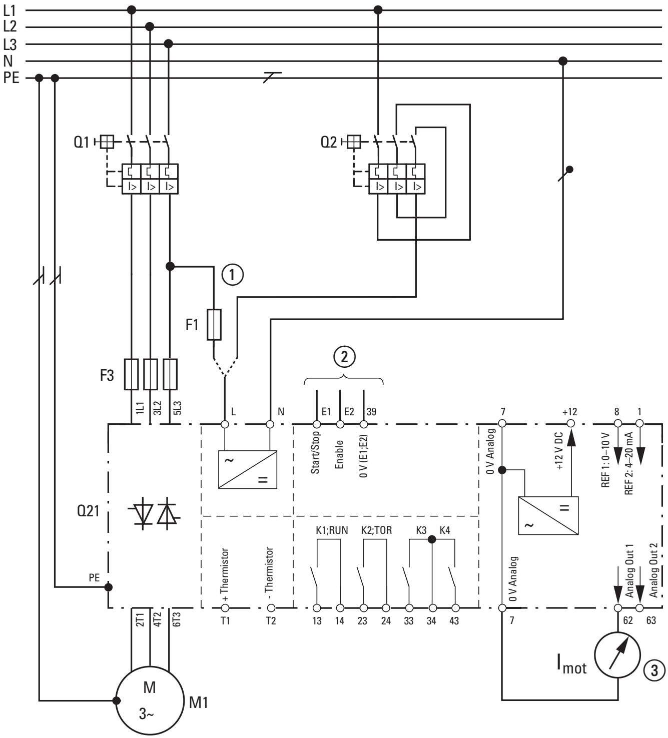
F2: Overload relays
F3: Superfast semiconductor fuses (optional)
M1: Motor
Q1: Cable protection
Q11: Mains contactor
Q21: Soft starter
S1: Soft-Start
S2: Soft-Stop

1 Enable
2 Softstart/soft stop

Electronic motor starters and drives

DM4 connection example

Without mains contactor



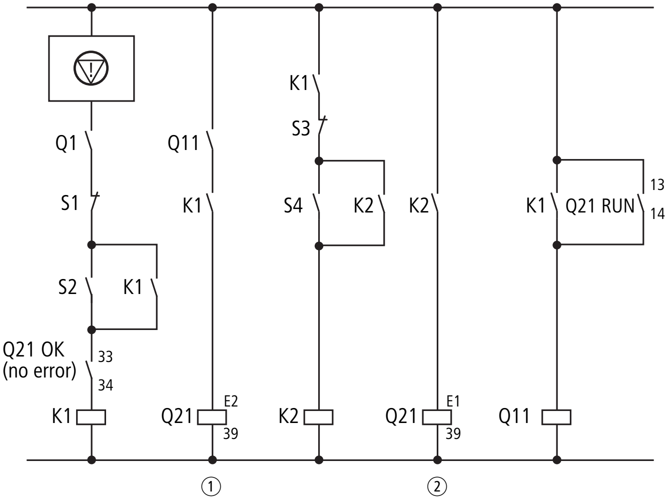
F3: Superfast semiconductor fuses (optional)
Q1: Cable and motor protection
Q21: Soft starter
M1: Motor

① Control voltage through Q1 and F11 or separately via Q2
② See Actuation
③ Motor current indication

Electronic motor starters and drives
DM4 connection example

Soft starters with separate mains contactor

Actuation



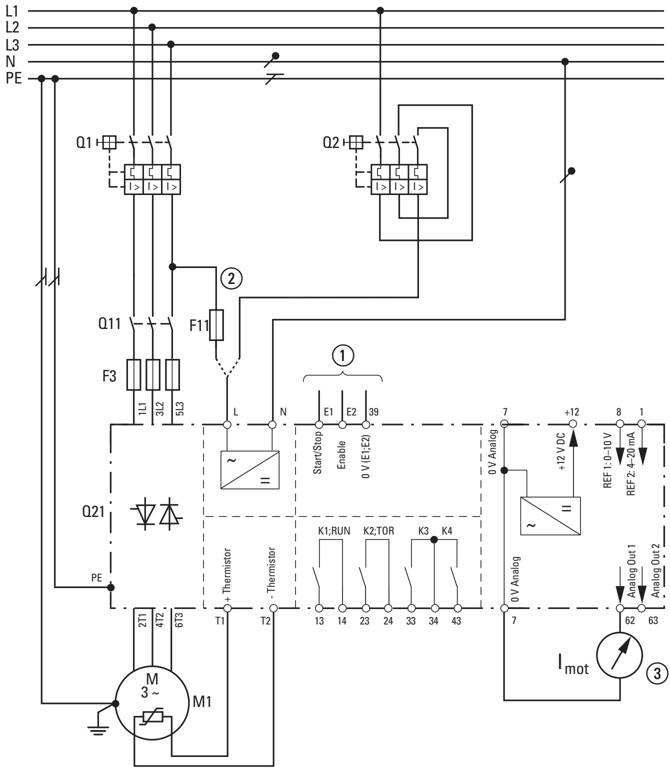
Emergency switching off
M1: Motor with temperature sensor (thermistor)
Q1: Cable and motor protection
Q21: Soft starter
S1: Off (uncontrolled deceleration)
S2: On
S3: Soft start
S4: Soft stop (deceleration ramp)

1 Enable
2 Softstart/soft stop

Electronic motor starters and drives

DM4 connection example

Soft starters with separate mains contactor



E1: Start/stop
E2: Enable
T1: + Thermistor
T2: – Thermistor

1. See Actuation
2. Control voltage through Q1 and F11 or through Q2
3. Motor current indication

Electronic motor starters and drives
DM4 connection example

In-delta connection

Soft starters are normally connected directly in series with the motor (so-called "in-line connection"). The DM4 soft starter also allows operation in an in-delta connection.

The antiparallel thyristors are connected directly in series to the individual motor windings.

Advantages (compared with in-line connection):

- Inexpensive since the soft starter only has to be designed for approx. 58 % (1/√3) of the rated current – particularly with motor ratings > 30 kW and when replacing star-delta starters.
- For the same motor rating the required soft starter rating is reduced.

Disadvantages (compared with in-line connection):

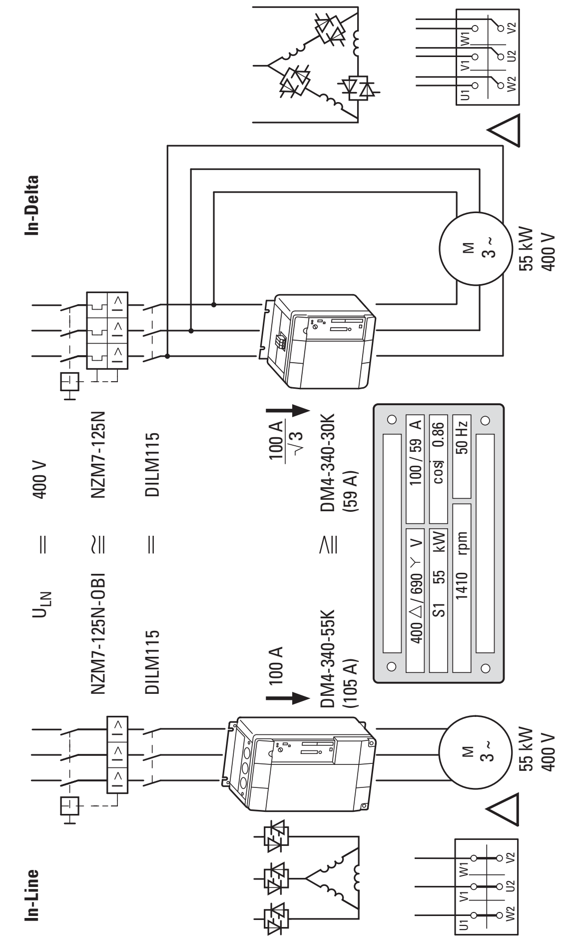
- As in a star-delta circuit, the motor must be connected with six conductors.
- The DM4 soft starter overload protection is active only in one line so that additional motor protection must be fitted in the parallel phase or in the supply cable. The motor can be protected for example via thermistors.

Notes

- The voltage of the motor winding must match the rated voltage. For a 400 V mains voltage the motor must therefore be marked with 400 V/690 V.
- The soft starter can also be bridged in the in-delta connection for continuous operation with a bypass contactor (see page 2-60). This is actuated via TOR (Top-of-Ramp).

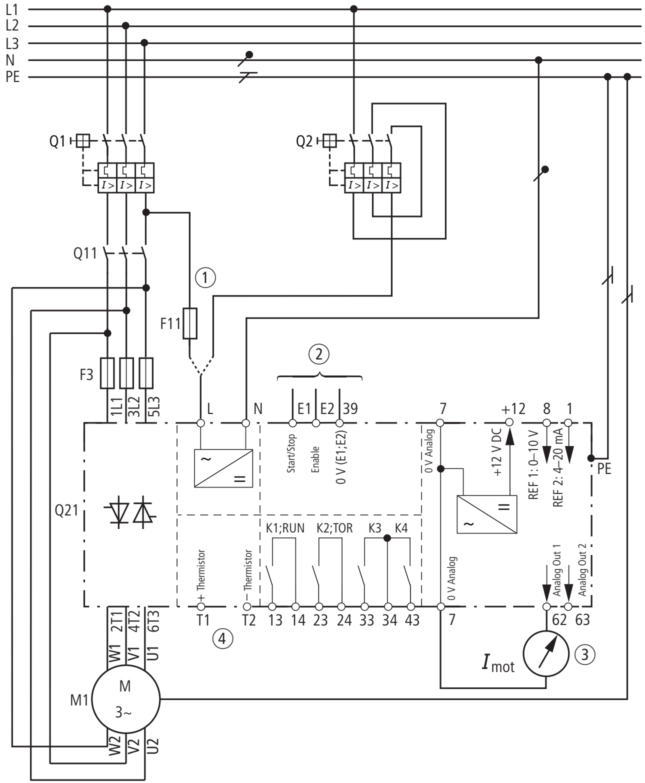
Electronic motor starters and drives
DM4 connection example

Inline/delta connection



Electronic motor starters and drives
DM4 connection example

In-delta connection



① Control voltage through Q1 and F11 or through Q2

② See Actuation (→ page 2-61)

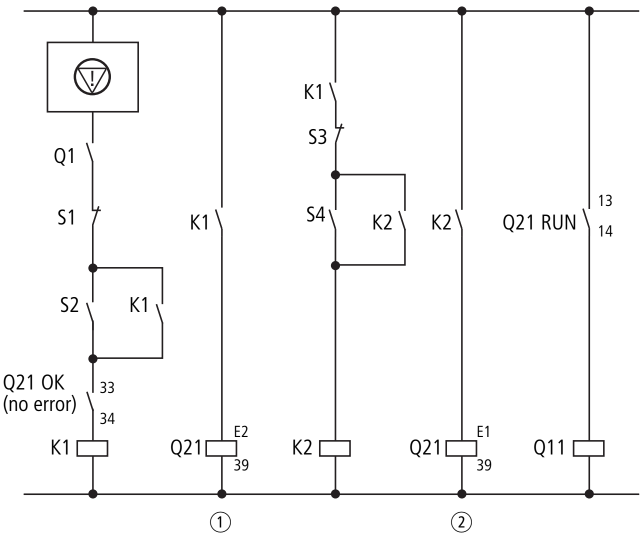
③ Motor current indication

④ Thermistor connection

Electronic motor starters and drives

DM4 connection example

Actuation



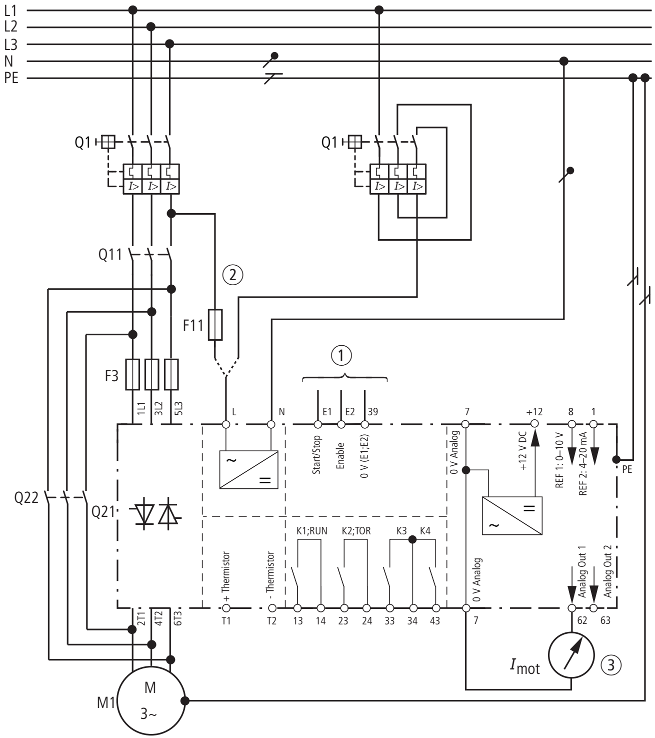
⊽ Emergency switching off
E2: Enable
Q1: Cable and motor protection
S1: OFF; uncontrolled deceleration of the motor
S2: ON/Start
S3: Soft stop

1. Enable
2. Soft start/soft stop

Electronic motor starters and drives

DM4 connection example

Bypass circuit



E1: Start/stop
E2: Enable
T1: + Thermistor
T2: – Thermistor

① See Actuation (→ page 2-61)
② Control voltage through Q1 and F11 or through Q2
③ Motor current indication

Electronic motor starters and drives
DM4 connection example

Bypass circuit

After completion of the acceleration phase (full mains voltage reached), the soft starter M4 actuates the bypass contactor. Thus, the motor is directly connected with the mains.

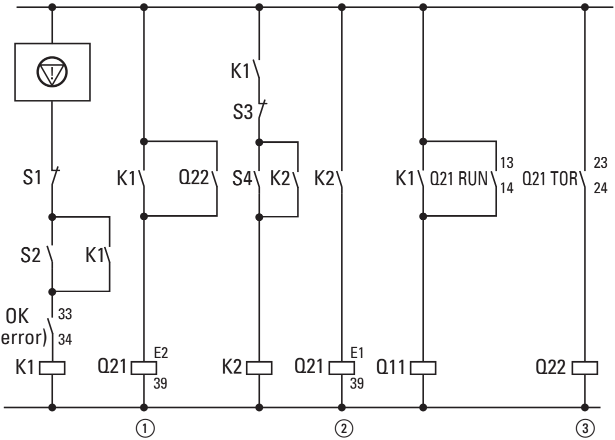
Advantage:

- The soft starter's heat dissipation is reduced to the no-load dissipation.
- The limit values of radio interference class "B" are adhered to.

The bypass contactor is now switched to a de-energized state and can therefore be designed to utilization category AC-1.

If an immediate voltage switch-off is required in the event of an emergency stop, the bypass contactor must also switch the motor load. In this case a design to utilization category AC-3 is required.

Actuation



Emergency switching off
S1: Off (uncontrolled deceleration)
S2: On

1 Enable
2 Soft start/soft stop
3 Bypass contactor

Electronic motor starters and drives
DM4 connection example

Starting several motors sequentially with a soft starter (cascaded control)

When using a soft starter to start several motors in succession, keep to the following changeover sequence:

1. Start using soft starter
2. Switch on bypass contactor
3. Block soft starter
4. Switch soft starter output to the next motor
5. Restart

→ Section "Actuation part 1", page 2-64

⊽	Emergency switching off
F3:	Superfast semiconductor fuse (optional) for type 2 coordination
Q1:	Main switch / cable protection (NZM)
Q2/F11:	Optional control voltage supply
Qn3:	Motor-protective circuit-breakers
Qn4:	Motor protection Soft starter
Qn5:	Motor contactors bypass
S1:	Q11 Off
S2:	Q11 On

① Soft start/soft stop
② RUN
③ Off-time monitoring
Set the timing relay K1T so that the soft starter is not thermally overloaded: Calculate the time from the soft starter's permissible operating frequency or select a soft starter that allows the required time to be reached.
④ Changeover monitoring
Set the timing relay to a return time of about 2 s. This ensures that the next motor branch can not be connected as long as the soft starter is running.

→ Section "Actuation, part 2", page 2-65

① Motor 1
② Motor 2
③ Motor n
⑨ Switching off individual motors

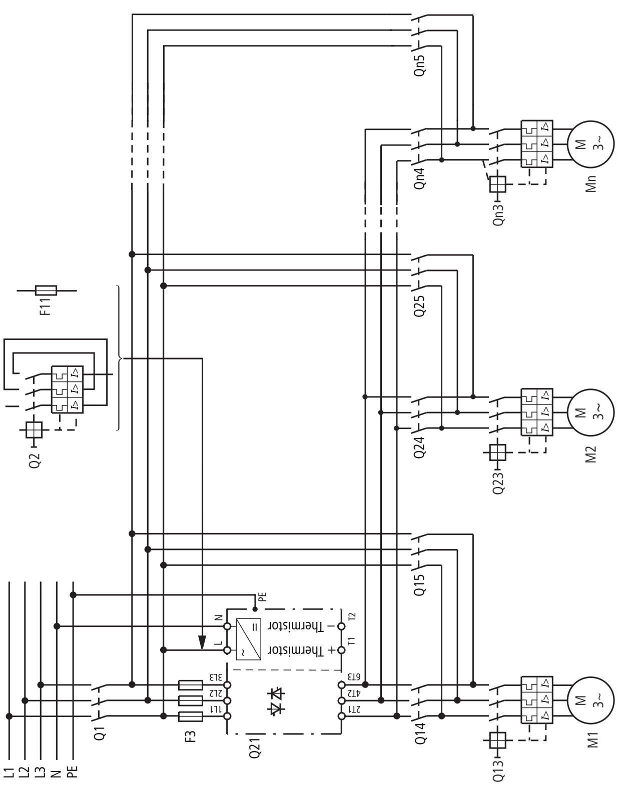
The Off switch results in all motors being switched off at the same time. To switch off individual motors, you need to make use of N/C contact ⑨.

Observe the thermal load on the soft starter (starting frequency, current load). If motors are to be started at short intervals, you may have to select a soft starter with a higher load cycle.

Electronic motor starters and drives

DM4 connection example

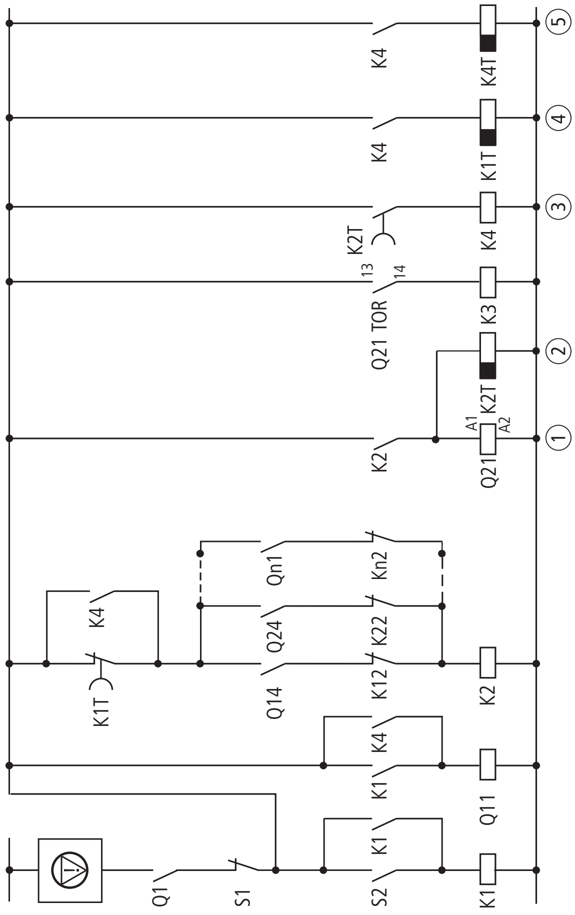
Cascade control



Electronic motor starters and drives

DM4 connection example

Actuation part 1

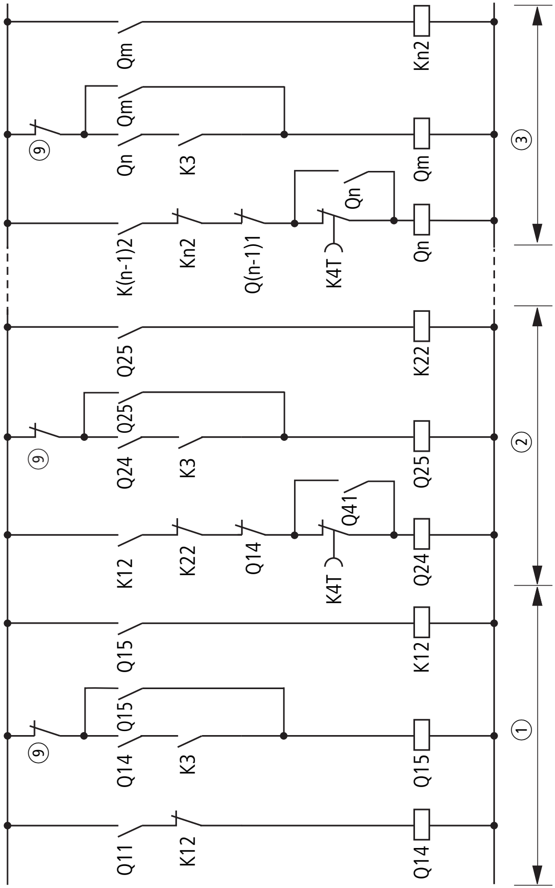


→ Section "Starting several motors sequentially with a soft starter (cascaded control)", page 2-62

Electronic motor starters and drives

DM4 connection example

Actuation, part 2



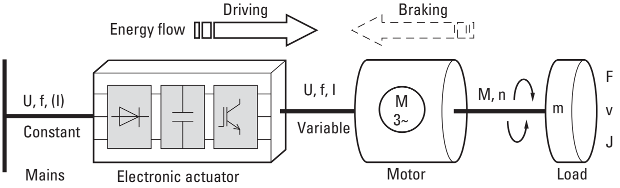
→ Section "Starting several motors sequentially with a soft starter (cascaded control)", page 2-62

Electronic motor starters and drives

Frequency inverter basic information

Design and mode of operation of frequency inverters

Frequency inverters provide variable and stepless speed control of three-phase motors.



$$P_{el} = U \times I \times \sqrt{3} \times \cos \varphi$$

$$I \sim M \qquad f \sim n$$

$$P_L = \frac{M \times n}{9550}$$

Frequency inverters convert the constant mains voltage and frequency into a DC voltage, from which they generate a new three-phase supply with variable voltage and frequency for the three-phase motor. The frequency inverter draws almost only active power (p.f. ~ 1) from the mains supply.

The reactive power needed for motor operation is supplied by the DC link. This eliminates the need for p.f. correction on the mains side.

Frequency inverters must comply with the product standard IEC/EN 60947-4-2.

U = Rated operating voltage [V]
f = Frequency [Hz]
I = Rated operational current [A]
M = Torque [Nm]
n = Speed [r.p.m.]
F = Force [N]
v = Speed [m/s]
J = Moment of inertia [kg • m²]
P_{el} = Electric power [kW]
P_L = Mechanical shaft output power [kW]

$\cos \varphi$ = power factor (P/S)
with
P = Active power = P_{el} = P_1 [kW] and
S = Apparent power [kVA]

$\eta = P_L/P_{el} = P_2/P_1$ = Efficiency

Electronic motor starters and drives

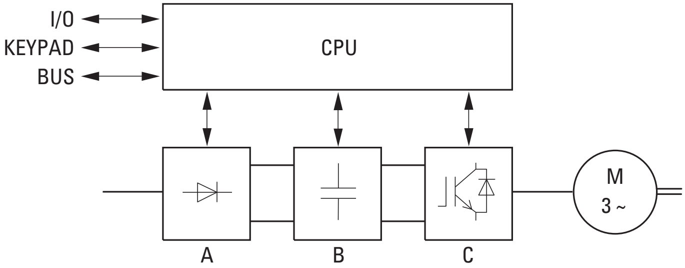
Frequency inverter basic information

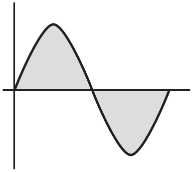
Block diagram with main components of a frequency inverter

Internal open and closed-loop control circuits (central processing unit) monitor all variable values in the frequency inverter and automatically switch the process off if a value reaches a dangerous level.

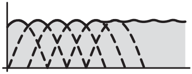
The power section of a static compact frequency inverter consists of three subgroups:

- Rectifier (A)
- Internal DC link (B)
- Inverter module (C)

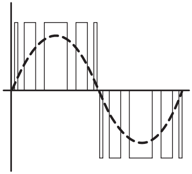




U_{LN}: Line supply from mains AC power supply

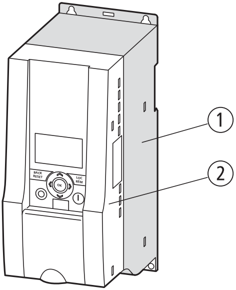


U_{DC}: DC link circuit voltage
$U_{DC} = 1.41 \times U_{LN}$ (single-phase line voltage)
$U_{DC} = 1.35 \times U_{LN}$ (three-phase line voltage)



Output voltage = switched DC link voltage with sinusoidal pulse width modulation (PWM)

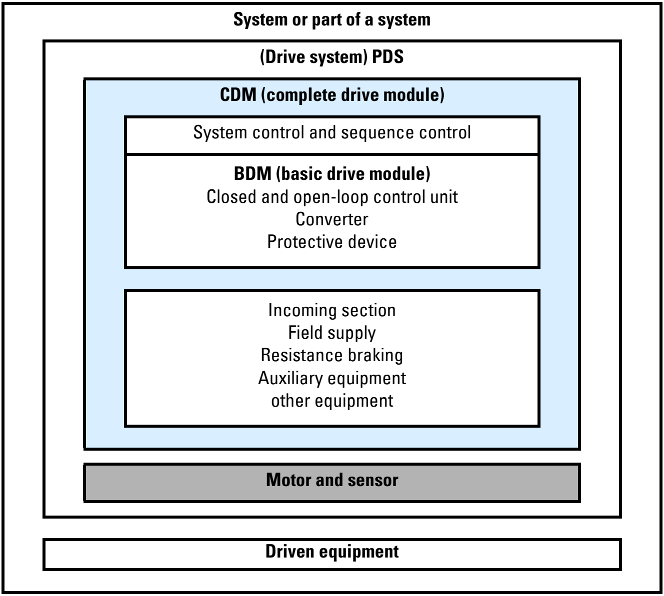
Electronic motor starters and drives
Frequency inverter basic information



1. Power section:
   A = Rectifier
   B = DC link
   C = Inverter module
2. Control section with:
   I/O = analog and binary inputs and outputs
   KEYPAD = keypad with display
   BUS = serial interfaces (RS485, fieldbus, PC interface)

Electronic motor starters and drives
Frequency inverter basic information

Drive system (PDS) to EN 61800-3



BDM (basic drive module)
Electronic power converter with associated control which is connected between the electrical power supply and a motor. The module controls speed, torque, force, position, current, frequency and voltage individually or jointly or all parameters together. The BDM can transfer the power from the electrical supply to the motor and also the power from the motor to the electrical supply.

CDM (complete drive module)
Drive module which consists of but is not restricted to the BDM and additional devices such as protective equipment, transformers, and auxiliary devices.

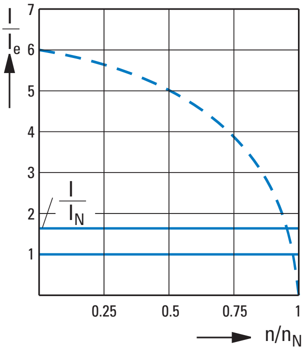
This, however, does not include the motor and the sensors that are mechanically connected to the motor shaft.

Electronic motor starters and drives

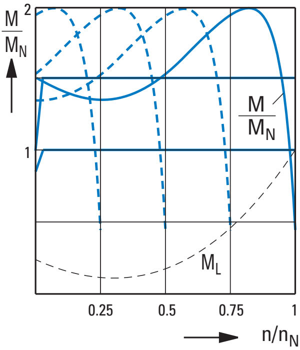
Frequency inverter basic information

The frequency-controlled three-phase motor is a standard component for infinitely variable speed and torque regulation - providing efficient, energy-saving power either as an individual drive or as part of an automated installation.

This not only refers to the frequency inverter as a component but also considers a complete drive system (PDS = Power Drives System) with motor, cables, EMC etc.(→ page 2-69).



I/I_e: 0...1.8

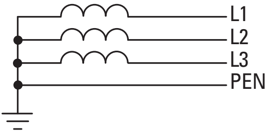


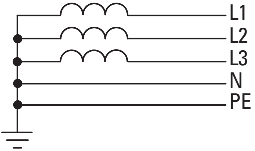
M/M_N: 0.1...1.5

Electronic motor starters and drives
Frequency inverter basic information

Electrical mains connection

Frequency inverters can be connected and operated without restriction on star-point-grounded AC mains (according to IEC 60364).





Connection and operation on asymmetrically grounded networks such as phase grounded delta networks (USA) or non-grounded or resistively grounded (> 30 Ω) IT networks are only permissible with restrictions and require additional engineering measures.

The standardized rated operating voltages of the utility companies fulfil the following conditions at the point of transfer to the consumer:

- Maximum deviation from the rated voltage (U_{LN}): ±10 %
- Maximum deviation in the voltage symmetry: ±3 %
- Maximum deviation from the rated frequency: ±4 %

A further voltage drop of 4 % in the consumer networks is permissible in relation to the lower voltage value (U_{LN} -10 %) of the supplying mains voltage. The power supply voltage at the consumer can therefore have a value of ULN -14 %.

In ring meshed networks (as used in the EU) the consumer voltages (230 V / 400 V / 690 V) are identical to the power supply voltages of the utility companies. In star networks (for example in North America/USA), the stated consumer voltages take the voltage drop from the utility company's infeed point to the last consumer into account.

Mains voltages in North America

Supply voltage U_{LN} of the utility company	Motor voltage according to UL 508 C	Consumer voltage (rated value for the motors)
120 V	110 - 120 V	115 V
240 V	220 - 240 V	230 V
480 V	440 - 480 V	460 V
600 V	550 - 600 V	575 V

Electronic motor starters and drives
Frequency inverter basic information

EMC compliance in PDS

The electrical components of a system (machine) are subject to reciprocal interference. Each device not only exerts interference on other devices but is also adversely affected by it. This occurs as a result of galvanic, capacitive and/or inductive coupling or through electromagnetic radiation. The border between line-conducted interference and radiated interference is around 30 MHz. Above 30 MHz the lines and cables act like antennas and radiate the electromagnetic waves.

The electromagnetic compatibility (EMC) for variable speed drives is implemented in accordance with product standard IEC/EN 61800-3.

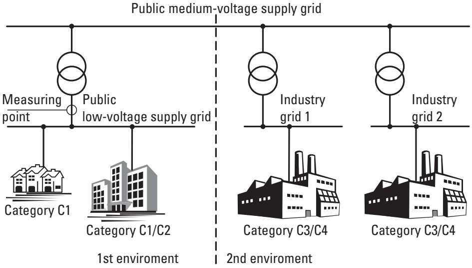
This covers the entire drive system (PDS = Power Drives System) from the mains end supply to the motor, including all components and cables. This type of drive system can also consist of several individual drives.

The generic standards of the individual components in a PDS compliant with IEC/EN 61800-3 do not apply. These component manufacturers, however, must offer solutions that ensure standards-compliant use.

In Europe, maintaining the EMC Directive is mandatory.

A declaration of conformity (CE) refers always to a "typical" power drives system (PDS). The responsibility to comply with the legally stipulated limit values and thus the provision of electromagnetic compatibility is ultimately the responsibility of the end user or system operator.

Measures must be taken to remove or minimize emission in the associated environment. It must also be ensured that the immunity of the devices or systems is increased.



EMC environment and categories

PDS categories

Drive systems (PDS) are divided into the following four categories.

PDS category C1

- PDS for use in the first environment
- Rated operating voltage < 1000 V

PDS category C2

- PDS for use in the first environment
- Rated operating voltage < 1000 V
- Not connected via plug-in devices
- No plug or movable equipment
- Connection and commissioning must be carried out by persons with suitable technical knowledge
- Hazard warning required ("This product may cause malfunctions in a domestic environment; in this case additional measures may be necessary.")

PDS category C3

- PDS for use in the second environment
- Not intended for use in the first environment
- Rated operating voltage < 1000 V
- Hazard warning required ("This PDS is not intended for connection to the public utility grid. Connection to these networks may cause electromagnetic interference.")

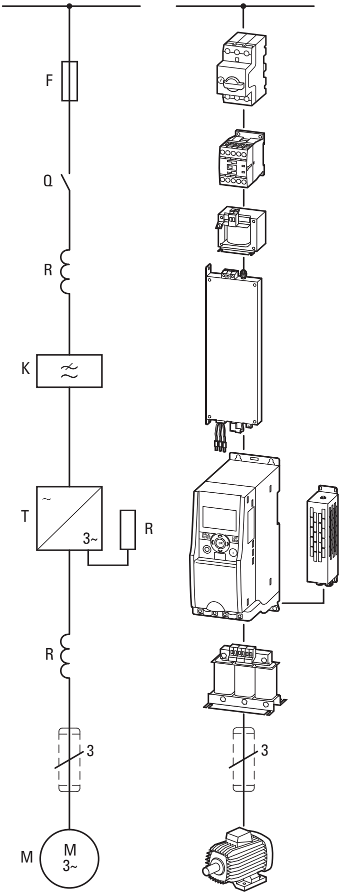
PDS category C4

- PDS for use in the second environment which fulfills at least one of the following criteria:
- Rated operating voltage > 1000 V
- Rated operational current > 400 A
- Connection to IT networks
- The required dynamic properties are not achieved due to EMC filter measures.
- EMC plan required

Electronic motor starters and drives
Frequency inverter basic information

Equipment code

- F: Fuses and circuit-breakers (cable protection)
- Q: Controlled switching in power flow (contactor, circuit-breaker)
- R: Limitation (choke, resistor)
- K: Radio interference suppression filter
- T: Frequency inverter
- M: Motor



Electronic motor starters and drives
Frequency inverter basic information

Fuses (circuit-breakers) allow the protection of lines and electrical apparatus. For the protection of persons, AC/DC-sensitive residual current devices (RCD Type B) are required in addition.

Contactors are used for the on/off switching of the mains voltage.

Mains chokes suppress any current harmonics and peaks and limit the inrush current (link circuit capacitors).

RFI suppression filters attenuate high frequency electromagnetic emissions from devices. They ensure that the EMC limit values for conducted interference specified in the applicable product standards are observed (frequency inverters).

Frequency inverters enable the infinitely variable speed control of three-phase motors.

A **braking resistor** converts the frequency inverter's regenerative braking energy into heat.
The frequency inverter must be equipped with a brake chopper, which connects the braking resistor parallel to the internal DC link.

Motor reactors

- Compensate the capacitive capacitive currents,
- Reduce current ripple and the motor's current change noise,
- Attenuate the retroaction on parallel connection of several motors.

Sinusoidal filter

- Smoothen the output voltage sinusoidally,
- Reduce motor noise through du/dt reduction, and thereby increase the motor insulation's lifespan,
- Reduce the leakage currents to allow better motor performance at improved EMC values.

Shielded motor cables attenuate emitted and conducted high-frequency emissions within the limit values specified in the applicable product standard (EMC).

Three-phase asynchronous motor (standard motor)

Electronic motor starters and drives
Frequency inverter basic information

Notes about correct installation of frequency inverters

For an EMC-compliant installation, observe the following instructions. These enable electrical and magnetic interference fields to be limited to the required levels. The necessary measures work only in combination and should be taken into consideration at the engineering stage. To subsequently modify an installation to meet EMC requirements is possible only at considerable additional cost.

Measures for EMC-compliant installation are:

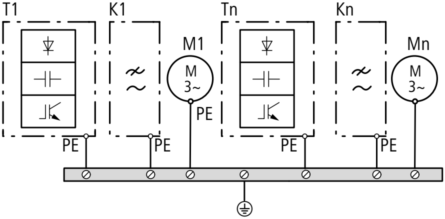
- Earthing measures,
- Shielding measures,
- Filtering measures,
- Chokes

They are described in more detail below.

Earthing measures

These must be implemented to comply with the legal standards and are a prerequisite for the effective use of further measures such as filters and shielding. All conducting metallic enclosure sections must be electrically connected to the earth potential. For EMC compliance, the important factor is not the cable's cross-section, but its surface, since this is where high frequency current flows to earth. All earth points must have a low impedance, be highly conductive and routed directly to the central earth point (potential equalization bar or star earth). The contact points must be free from paint and rust. Use galvanized mounting plates and materials.

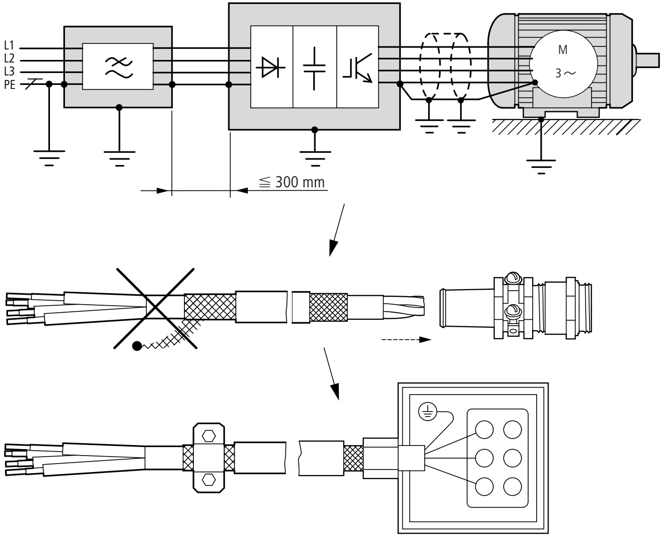
K1 = Radio interference suppression filter
T1 = Frequency inverter

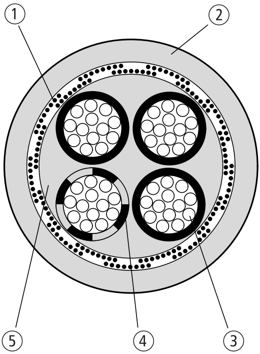


Electronic motor starters and drives

Frequency inverter basic information

Shielding measures





Four-core shielded motor supply cable:

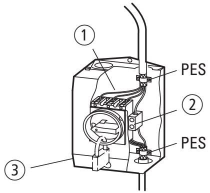
1. Copper shield braid, earth at both ends with large-area connections
2. PVC outer casing
3. Drain wire (copper, U, V, W, PE)
4. PVC core insulation,
   3 x black, 1 x green–yellow
5. Textile and PVC fillers

Electronic motor starters and drives
Frequency inverter basic information

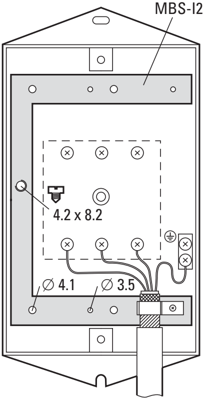
Shielding reduces emitted interference (noise immunity of neighboring systems and devices against external influences). Cables between frequency inverters and motor must be shielded. However, the shield must not be considered a replacement for the PE cable. Four-wire motor cables are recommended (three phases plus PE). The shield must be connected to earth (PES) at both ends with a large-area connection. Do not connect the shield with pigtails. Interruptions in the shield, such as terminals, contactors, chokes, etc., must have a low impedance and be bridged with a large contact area.

To do this, sever the shield near the module and establish a large-area contact with earth potential (PES, shield terminal). Free, unshielded cables should not be longer than about 100 mm.

Example: Shield attachment for maintenance switch



① Metal plate (e.g. MSB-I2)
② Earthing terminal
③ Maintenance switch



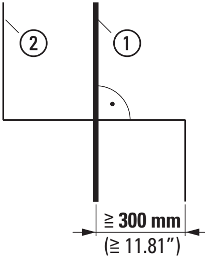
Note

Maintenance switches at of frequency inverter outputs must be operated only at zero current.

Control and signal lines must be twisted and may be double-shielded, the inner shield being connected to the voltage source at one end and the outer shield at both ends.

Electronic motor starters and drives

Frequency inverter basic information



The motor cable must be laid separately from the control and signal lines (> 30 cm) and must not run parallel to any power cables.

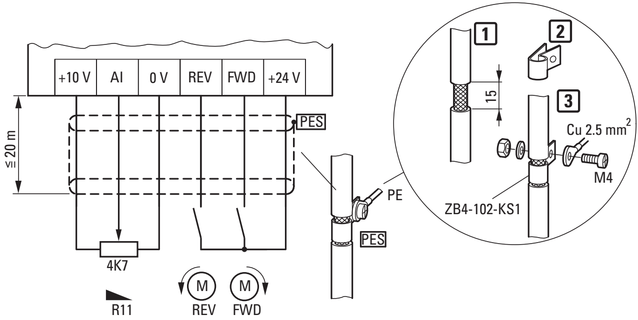
Note

Inside control panels also cables should be shielded if they are more than 30 cm long.

① Power cables: network, motor, DC link circuit, braking resistor
② Signal cables: analog and digital control signals

Example of shielding control and signal cables:

Standard connection of a frequency inverter with setpoint potentiometer R11 (M22-4K7), control signals for clockwise and anticlockwise rotation (FWD, REV) and ZB4-102-KS1 mounting accessory



Electronic motor starters and drives
Frequency inverter basic information

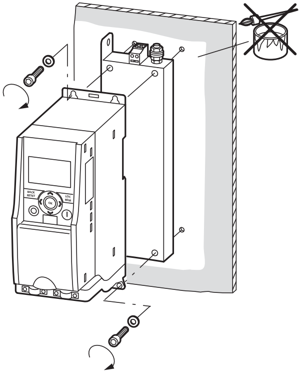
Filtering measures

Radio interference filters and line filters (combinations of radio interference filter and mains choke) protect against conducted high-frequency interference (noise immunity) and reduce the frequency inverter's high-frequency interference which is transmitted through or emitted from the mains cable, and which must be limited to a prescribed and legal level (emitted interference).

Nowadays, filters are frequently integrated in the frequency inverter or should be installed in close proximity of the frequency inverter. When using externally installed RFI filters, the connection cable between the frequency inverter and filter must be kept short (≦ 30 cm).

Note

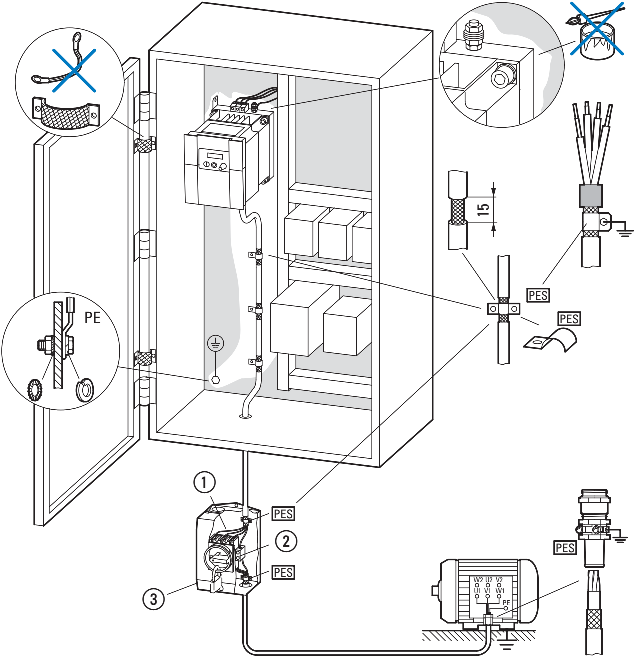
The mounting surfaces of frequency inverters and radio interference filters must be free from paint and must have good HF conductivity.



Electronic motor starters and drives

Frequency inverter basic information

EMC-compliant mounting and connection



① Metal plate with PE connection
② Earthing terminal (connection of PE conductor and earthing of the plate ①)
③ Maintenance switch

Electronic motor starters and drives
Frequency inverter basic information

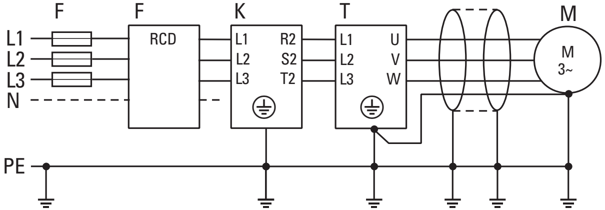
Residual-current device (RCD)

Radio interference filters produce leakage currents which, in the event of a fault (phase failure, load unbalance), can be considerably larger than the rated values. To prevent dangerous voltages, all components (frequency inverter, RFI filter, motor, shielded motor cables) in the PDS must be earthed. As the leakage currents are high-frequency interference sources, the earthing connections and cables must have a low impedance and large contact surfaces.

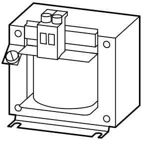
The residual current device on the frequency inverter must be of type B as sinusoidal AC and pulsed DC residual currents may occur.

With leakage currents ≧ 3.5 mA, EN 60335 states that one of the following conditions must be fulfilled:

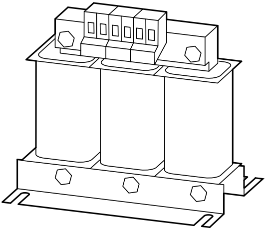
- The protective conductor must have a cross-section ≧ 10 mm²,
- The protective conductor must be open-circuit monitored, or
- An additional protective conductor must be fitted.



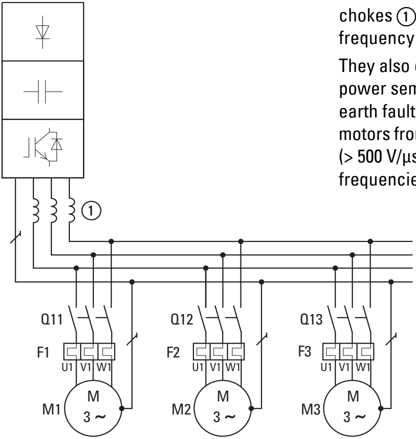
Electronic motor starters and drives
Frequency inverter basic information



Single-phase chokes



Three-phase chokes



Mains chokes

Fitted on the frequency inverter's input side, chokes reduce the current-dependent mains feedback and improve the power factor. This reduces the current harmonics and improves the mains quality. The use of mains chokes is especially recommended when several frequency inverters are connected to a single mains supply point and when other electronic devices are also connected on the network.

A reduction of the mains current interference is also achieved by installing DC chokes in the frequency inverter's DC link. This eliminates the need for mains chokes.

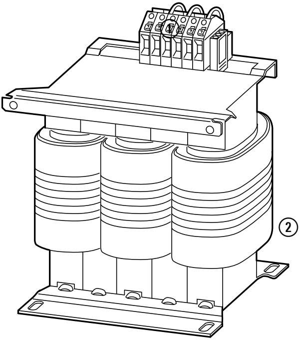
Motor chokes

With long motor cables or the parallel connection of several motors, motor chokes (1) are used at the output of the frequency inverter.

They also enhance the protection of the power semiconductors in the event of an earth fault or short-circuit, and protect the motors from excessive rates of voltage rise (> 500 V/µs) resulting from high pulse frequencies.

Electronic motor starters and drives
Frequency inverter basic information

Sinusoidal filter



SFB400/…

Sinusoidal filters are a combination of choke and capacitor (low pass filter).

They improve the sinusoidal shape of the frequency inverter output voltage, thus reducing the noise and the temperature rise of the motor.

Advantages of the sinusoidal filter:

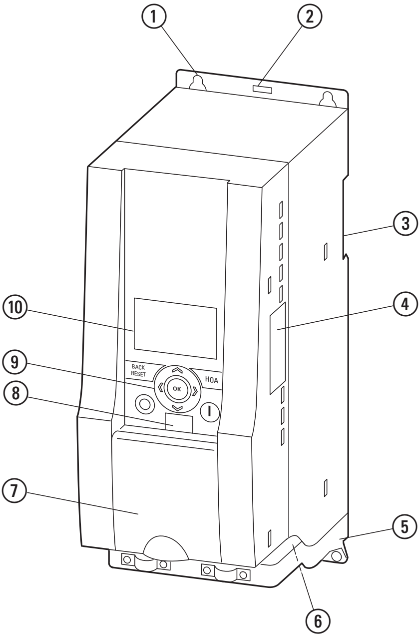
- Long shielded motor supply cables possible
  - max. 400 m on supply voltages up to 240 V +10 %
  - max. 200 m on supply voltages up to 480 V +10 %
- Extended lifespan – like that of a mains-operated motor
- Low noise generation of the motor
- Low motor temperature rise
- Reduced du/dt values (< 500 V/µs)

Disadvantages of a sinusoidal filter:

- Up to 30 V voltage drop
- Operation only with fixed pulse frequency possible

Electronic motor starters and drives
Connection example for M-Max™

M-Max™ product features



Designations on M-Max™

① Fixing holes (screw fastening)
② Release (dismantling from mounting rail)
③ Cutout for mounting on mounting rail (DIN EN 50022-35)
④ Interface for fieldbus connection modules (optional, MMX-NET-XA)
⑤ EMC installation accessories
⑥ Power section terminals
⑦ Cover flap of control signal terminals and microswitches
⑧ Interface for PC connection module MMX-COM-PC (Option)
⑨ Keypad with 9 control buttons
⑩ Display unit (LCD)

Electronic motor starters and drives
Connection example for M-Max™

Functions

A comprehensive range of protection functions allow safe operation and the protection of frequency inverter, motor and application. They offer protection against:

- Overcurrent, earth fault
- Overload (electronic motor protection)
- Overtemperature
- Overvoltage, undervoltage

Further functions:

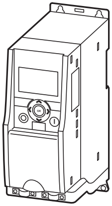
- Restart inhibit
- U/f control or sensorless vector control
- 2-fold starting current and 1.5 fold overcurrent
- PID controller
- Sequence control
- Braking control (DC braking)
- 8 fixed frequencies
- Electronic motor potentiometer
- Logic function (AND, OR, XOR)
- Upper and lower frequency and current limits
- Frequency hopping (frequency masking)
- DC braking before start and up to motor standstill
- 2 parameter sets

Documentation

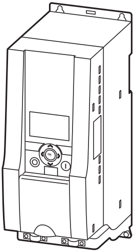
Manual: MN04020001Z-EN
Instructional leaflet: IL04020001E

Electronic motor starters and drives
Connection example for M-Max™

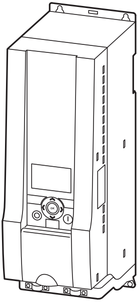
M-Max™ sizes



Size 1 (FS1)
MMX12…: 1.7 - 2.8 A
MMX32…: 1.7 - 2.8 A
MMX34…: 1.4 - 2.4 A



Size 2 (FS2)
MMX12…: 3.7 - 7 A
MMX32…: 3.7 - 7 A
MMX34…: 3.3 - 5.6 A



Size 3 (FS3)
MMX12…: 9.6 A
MMX32…: 9.6 A
MMX34…: 7.6 - 14 A

FS = Frame Size

MMX12…: Single-phase mains connection, rated operating voltage MMX230 V

MMX32…: Three-phase power supply, rated operating voltage 230 V

MMX34…: Three-phase power supply, rated operating voltage 400 V

Electronic motor starters and drives
Connection example for M-Max™

Application

M-Max™ frequency inverters allow the continuously variable speed control of three-phase asynchronous motors. They are especially suitable for applications where simple operation and profitability are important.

The characteristics-controlled voltage/frequency (U/f) control already allows a wide range of applications even with the default settings: from simple pump and fan drives, standard packaging applications right through to the operation of multiple motors in horizontal transportation and conveying. With sensorless vector control, an individual drive can also be used in demanding applications, in which a high torque and concentricity in the lower speed range are vital, for example in the plastics and metal industries, the textile, paper and printing industries or in crane and elevator systems.

Rated operating currents from 1.4 to 14 A allow the operation of standard 4 pole asynchronous motors in an assigned performance range of :

- 0.25 to 2.2 kW at 230 V (single-phase mains connection),
- 0.25 to 2.2 kW at 230 V (three-phase mains connection),
- 0.37 to 5.5 kW at 400 V (three-phase mains connection).

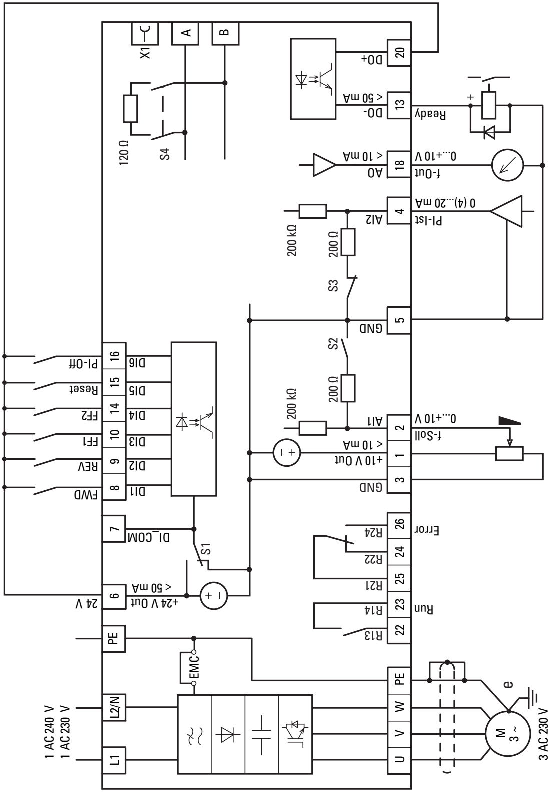
Instructions

- For UL®-compliant installation and operation, the mains side switching devices must allow for a 1.25 times higher input current.
- Mains contactors shown here take into account the rated operating current I_{LN} of the frequency inverter at the input without a mains choke. Their selection is based on the thermal current (AC-1).
- With frequency inverters, the inching range is not permitted via the mains contactor (pause time ≧ 60 s between switching off and on).

Electronic motor starters and drives

Connection example for M-Max™

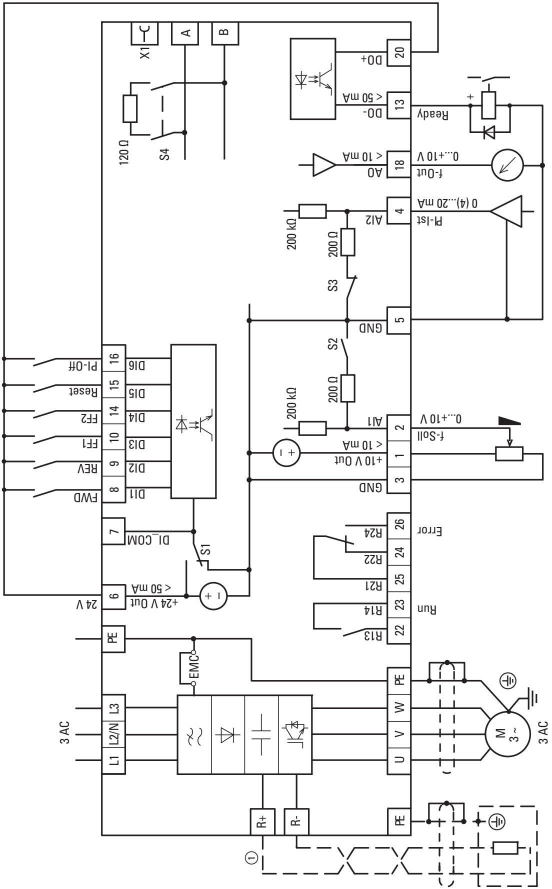
Block diagram for MMX12…



Electronic motor starters and drives

Connection example for M-Max™

Block diagram for MMX32... and MMX34...



Electronic motor starters and drives
Connection example for M-Max™

Configuration of the control signal terminals

The control signal terminals are factory set as follows:

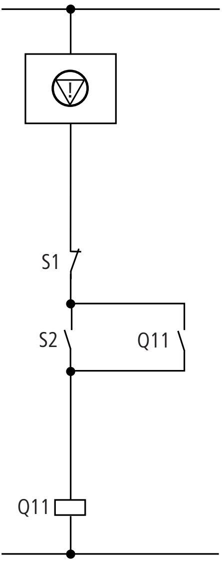
2: AI1: f-Set = Frequency setpoint (0 - +10V)
4: AI2: PI-Act = Actual value for PID controller (process variable, 4 - 20 mA)
8: DI1: FWD = Clockwise rotation field enable (Forward)
9: DI2: REV = Anticlockwise rotation field enable (Reverse)
10: DI3: FF1 = Fixed frequency 1
13: DO-: Ready = Ready to start (transistor output with the voltage of terminal 20)
14: DI4: FF2 = Fixed frequency 2
15: DI5: Reset = Acknowledge fault message
16: DI6: PI-Off = PID controller deactivated
18: AO: f-Out = Output frequency to motor (0 - +10 V)
20: DO+: Input voltage for transistor output (+24 V DC)
22/23: R13/R14 (NO contact): RUN = Operating signal (relay)
24/25/26: R21/R22/R24 (changeover contact): Error =Fault signal (relay)

① Connection terminals R+ and R- for external braking resistor (optional) – for size 2 (FS2) and size 3 (FS3)

Electronic motor starters and drives

Connection example for M-Max™

Basic control



Example 1

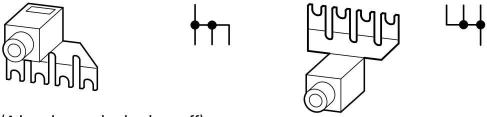
Reference input through potentiometer R11. Enable (START/STOP) and direction control through terminals 1 and 2 with internal control voltage

⊽	Emergency switching off circuit
F1:	Cable protection
PES:	Cable shield PE connection
Q11:	Mains contactor
M1:	230 V 3-phase motor
S1:	OFF
S2:	ON

Notes

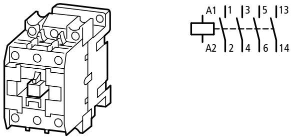
- For EMC-compliant mains connection, suitable radio interference suppression measures must be implemented according to product standard IEC/EN 61800-3.
- With frequency inverters with a single-phase mains connection, the use of parallel links is recommended for equalizing the load on the contacts.

DILM12-XP1



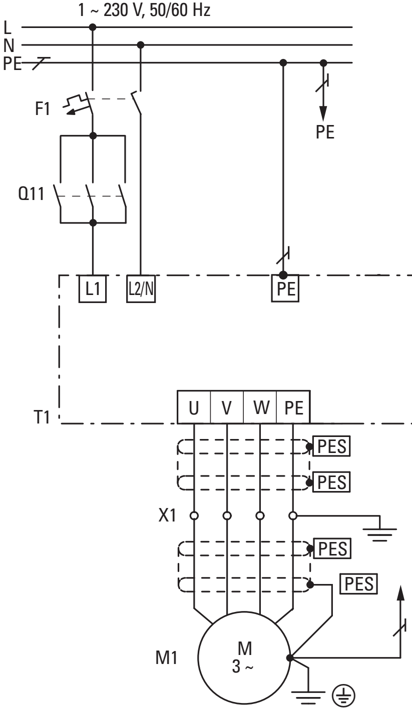
(4th pole can be broken off)

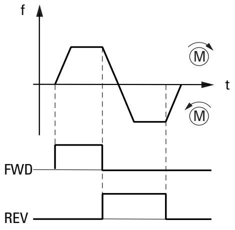
DILM



Electronic motor starters and drives
Connection example for M-Max™

Wiring (MMX12…)





- MMX12…Single-phase frequency inverter
- Directional control through terminals 8 and 9
- External reference value input via R11

FWD: Clockwise rotation field enable
REV: Anticlockwise rotation field enable

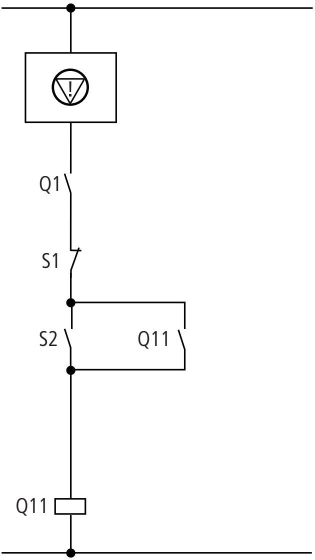
Electronic motor starters and drives
Connection example for M-Max™

Frequency inverters MMX34… with external RFI filter

Note

Only for MMX…N0-0 (without internal RFI filter)

Actuation

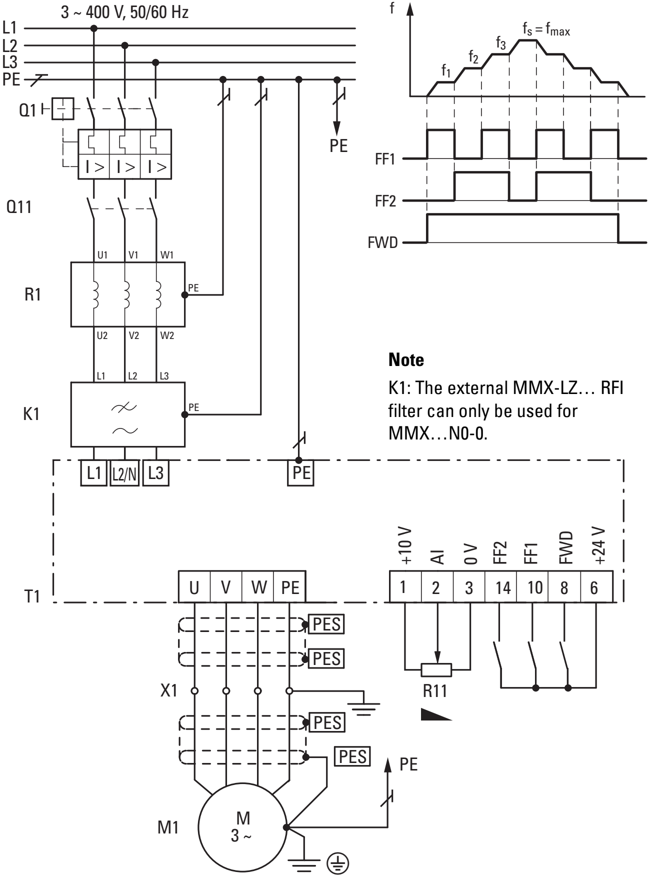


Example 2
Setpoint entry via potentiometer R11 (f_s) and fixed frequency (f_1, f_2, f_3) via terminal 10 and 14 with internal control voltage
Enable (START/STOP) and rotation direction selection via terminal 8 (FWD)

	Emergency switching off circuit
FF1:	Fixed frequency f_1
FF2:	Fixed frequency f_2
FF1+ FF2:	Fixed frequency f_3
FWD:	Enable clockwise rotation field, analog setpoint value frequency f_S
K1:	Radio interference suppression filter MMX-LZ…
M1:	400 V 3-phase motor
PES:	Cable screen PE connection
Q1:	Cable protection
Q11:	Mains contactor
R1:	Main choke
S1:	OFF
S2:	ON

Electronic motor starters and drives
Connection example for M-Max™

Wiring (MMX34…)



Note

K1: The external MMX-LZ… RFI filter can only be used for MMX…N0-0.

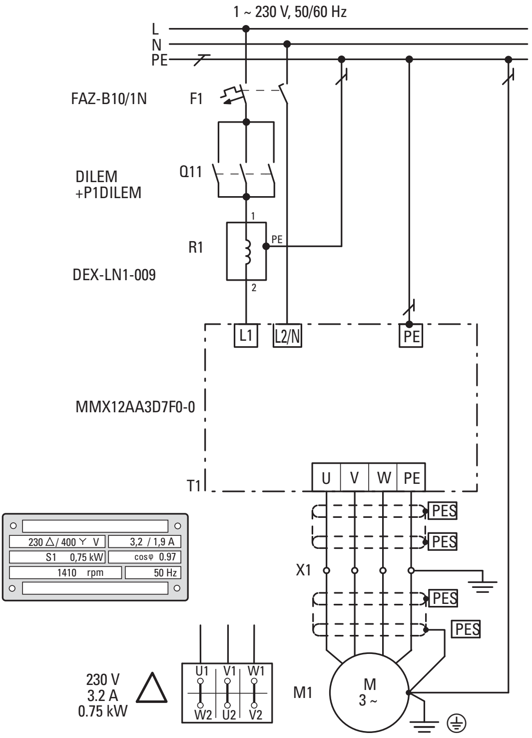
Electronic motor starters and drives
Connection example for M-Max™

Terminal Models

Version A:
Motor in delta circuit (MMX12...)
The 0.75 kW motor described below can be delta-connected to a single-phase 230 V mains (version A) or star-connected to a 3-phase 400 V mains.

Motor: P = 0.75 kW

Mains: 1/N/PE 230 V 50/60 Hz



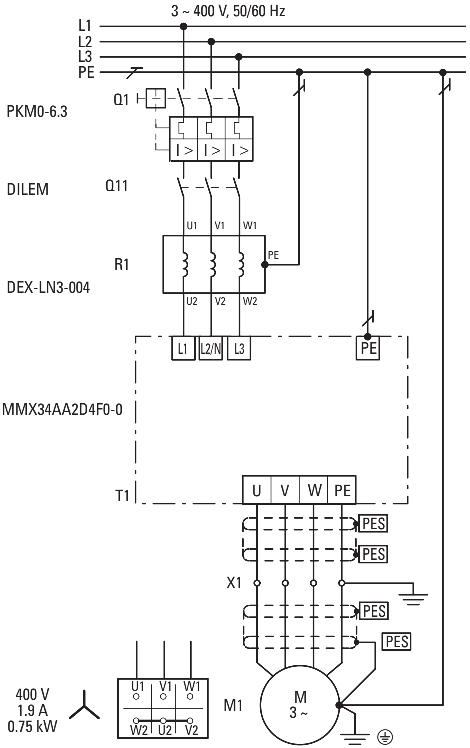
Electronic motor starters and drives

Connection example for M-Max™

Version B:
Motor in star circuit (MMX 34...)

Motor: P = 0.75 kW

Mains: 3/PE 400 V 50/60 Hz



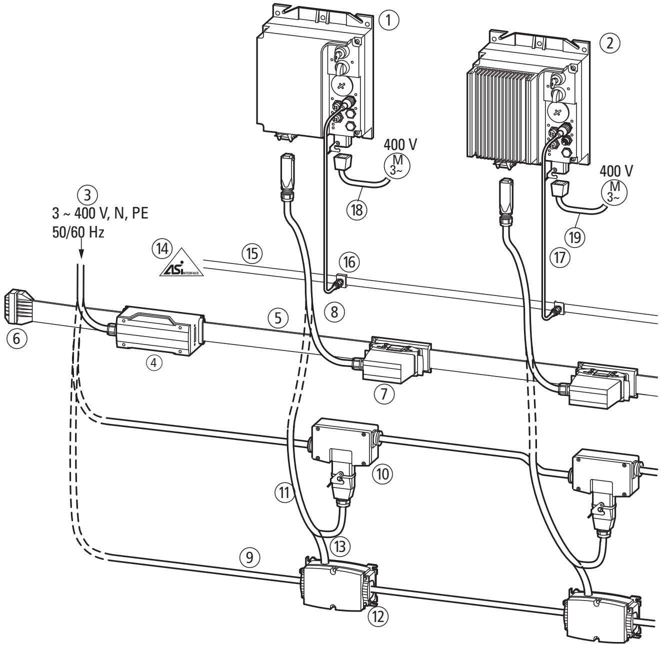
Electronic motor starters and drives
Rapid Link System 4.0

System overview of Rapid Link RA 4.0 modules

Rapid Link is a remote switching and installation system.

Thanks to its compact design and its high degree of protection to IP65 these motor starters can be installed in the direct vicinity of the motor.

Pluggable connection cables with standard terminals reduce the wiring requirement and provide the preferred installation technology for conveying system.



Electronic motor starters and drives
Rapid Link System 4.0

Function modules:

① RAMO motor starter (Motor Control Unit) → three-phase, electronic DOL starter or reversing starter, with electronic motor protection for the assigned ratings of 90 W to 3 kW (at 400 V).

② RASP speed control unit → three-phase, frequency controlled motor starter (fixed speeds, two rotation directions, soft starting), in four ratings (2.4 A/3.3 A/4.3 A/ 5.6 A) with electronic motor protection for assigned ratings from 0.18 kW to 2.2 kW (at 400 V).

Power bus:

③ Incoming supply (3 AC 400 V) via circuit-breaker for overload and short-circuit protection
④ Incoming supply for ribbon cable
⑤ Ribbon cable für 400 V AC
⑥ End-piece for flat cable
⑦ Flexible busbar junction
⑧ Power adapter cable to flexible busbar junction
⑨ Round cable for 400 V AC
⑩ Plug-in link for round cable
⑪ Power adapter cable to round cable junction
⑫ Link for round cable
⑬ Power adapter cable (round cable) to power box
⑭ AS-Interface® – Supply via main cable
Data bus:

⑮ AS-Interface® ribbon cable
⑯ Link for M12 connector cables
⑰ Extension M12

Motor connection:

⑱ Unshielded motor cable
⑲ Shielded motor cable (EMC)

Product features

The system is installed with a power bus and data bus that are plugged into all modules of the Rapid Link system.

Customer and sector-specific requirements for material handling applications are the main focus of system design.

Rapid Link version 4.0 provides modules with the following features:

- Degree of protection IP65
- Ambient temperature during operation from -10 °C to +55 °C
- Max. cable length 10 m
- AS-Interface® Profi 7.4 for communication and diagnostics
- Pluggable terminal design to ISO 23570
- Local operation/hand operation
- Maintenance and manual override switches (optional)
- RAMO-D electronic DOL starter
- RAMO-W electronic reversing starter
- RASP frequency controlled speed control

Documentation

Manual: MN03406003Z-EN

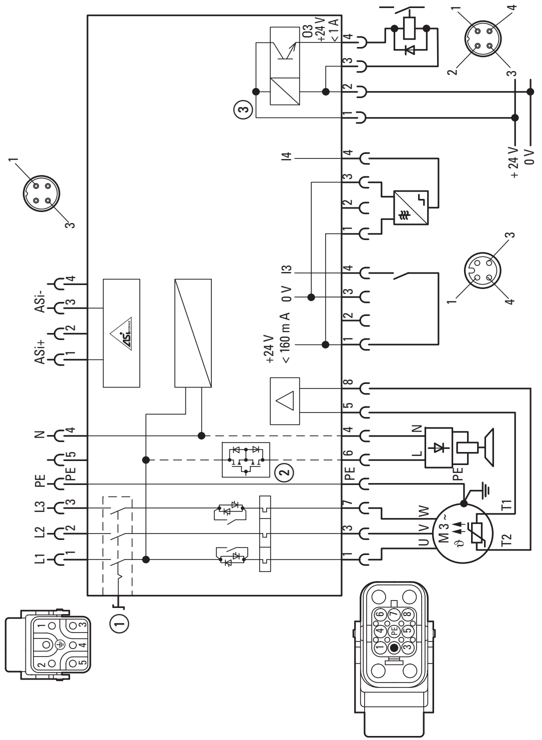
Installation instructions:
IL003406019Z
IL003406020Z

Electronic motor starters and drives

Rapid Link System 4.0

Block diagram RAMO-D…

Electronic DOL starter



Optional variant:

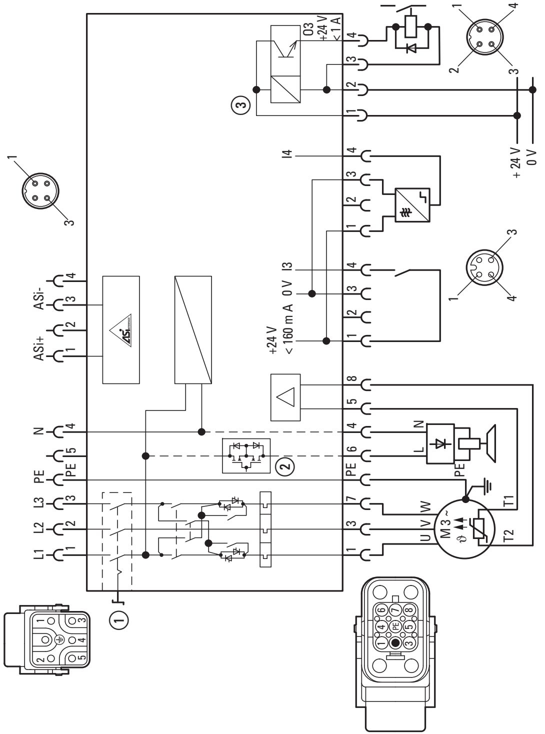
① Repair switch
② Actuation of external brake (230 V)
③ Actuator output

Electronic motor starters and drives

Rapid Link System 4.0

Block diagram RAMO-W…

Electronic reversing starter



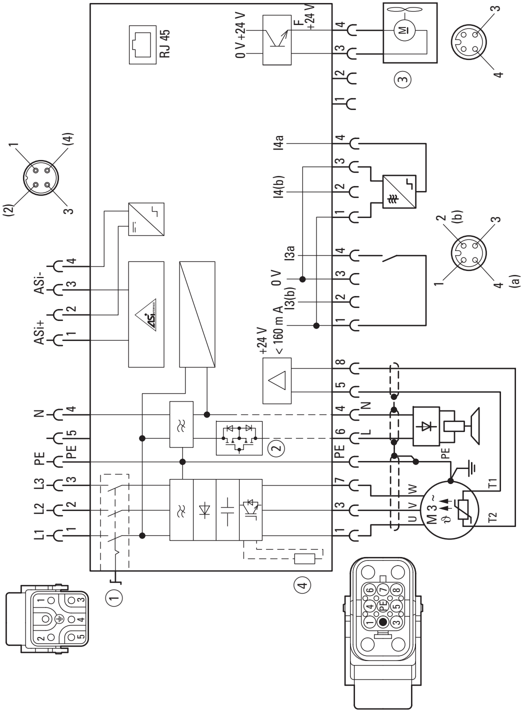
Optional variant:

① Repair switch
② Actuation of external brake (230 V)
③ Actuator output

Electronic motor starters and drives
Rapid Link System 4.0

Block diagram RASP-…

Frequency inverter



Optional variant:

① Repair switch
② Actuation of external brake (230 V)
③ Device fans
④ Internal braking resistor