MAKING MODERN LIVING POSSIBLE

Design Guide
VLT® DriveMotor FCP 106 and FCM 106

www.danfoss.com/drives

THE REAL DRIVE

Contents

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1 Introduction

1.1 Purpose of the Design Guide

The Design Guide provides information required for integration of the frequency converter in a diversity of applications.

Literature available:

- *VLT® DriveMotor FCP 106 and FCM 106 Operating Instructions,* for information required to install and commission the frequency converter.
- *VLT® DriveMotor FCP 106 and FCM 106 Design Guide,*provides information required for integration of the frequency converter into a diversity of applications.
- *VLT® DriveMotor FCP 106 and FCM 106 Programming Guide*, for how to program the unit, including complete parameter descriptions.
- *VLT® LCP Instruction*, for operation of the local control panel (LCP).
- *VLT® LOP Instruction*, for operation of the local operation pad (LOP).
- *Operating Instructions VLT® DriveMotor FCP 106 and FCM 106 BACnet,* and
Operating Instructions VLT® DriveMotor FCP 106 and FCM 106 Metasys, for information required for controlling, monitoring and programming the frequency converter.
- *PC-based Configuration Tool MCT 10,* enables the user to configure the frequency converter from a Windows™ based PC environment.
- *Danfoss VLT® Energy Box* software, for energy calculation in HVAC applications.
- Approvals.

Technical literature and approvals are available online at *www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation.*

Danfoss VLT® Energy Box software is available at *www.danfoss.com/BusinessAreas/DrivesSolutions*, PC software download area.

1.2 Additional Resources

Literature available:

- *VLT® DriveMotor FCP 106 and FCM 106 Operating Instructions,* for information required to install and commission the frequency converter.
- *VLT® DriveMotor FCP 106 and FCM 106 Design Guide,*provides information required for integration of the frequency converter into a diversity of applications.
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1.3 Symbols, Abbreviations and Conventions

The following symbols are used in this manual.

NOTICE

Indicates highlighted information that should be regarded with attention to avoid mistakes or operate equipment at less than optimal performance.

* Indicates default setting

AC	Alternating Current
AEO	Automatic Energy Optimization
AWG	American Wire Gauge
AMA	Automatic Motor Adaptation
°C	Degrees Celsius
DC	Direct Current
EMC	Electromagnetic Compatibility
ETR	Electronic Thermal Relay
$f_{M,N}$	Nominal Motor Frequency
FC	Frequency Converter
HO	High overload
IP	Ingress Protection
I_{LIM}	Current Limit
I_{INV}	Rated Inverter Output Current
$I_{M,N}$	Nominal Motor Current
$I_{VLT,MAX}$	The Maximum Output Current
$I_{VLT,N}$	The Rated Output Current Supplied by the Frequency Converter
LCP	Local Control Panel
N.A.	Not applicable
NO	Normal overload
$P_{M,N}$	Nominal Motor Power
PCB	Printed Circuit Board
PE	Protective earth
PELV	Protective Extra Low Voltage
Regen	Regenerative Terminals
RPM	Revolutions Per Minute
T_{LIM}	Torque Limit
$U_{M,N}$	Nominal Motor Voltage

Table 1.1 Abbreviations

Conventions
Numbered lists indicate procedures.
Bullet lists indicate other information and description of illustrations.
Italicised text indicates

- cross reference
- link
- footnote
- parameter name, parameter group name, parameter option

1.4 Approvals

NOTICE

In a domestic environment, this product may cause radio interference, in which case supplementary mitigation measures may be required.

Certification		FCP 106	FCM 106
EC Declaration of Conformity		✓	✓
UL Listed		-	✓
UL Recognised		✓	-
C-tick		✓	✓

Table 1.2 Approvals

The EC declaration of conformity is based on the following directives:

- Low Voltage Directive 2006/95/EC, based on EN61800-5-1 (2007)
- EMC Directive 2004/108/EC based on EN61800-3 (2004)

UL Listed
Product evaluation is complete and the product can be installed in a system. The system must also be UL listed by the appropriate party.

UL Recognised
Additional evaluation is required before the combined frequency converter and motor can be operated. The system in which the product is installed must also be UL listed by the appropriate party.

The frequency converter complies with UL508C thermal memory retention requirements. For more information refer to the section *chapter 3.3.9 Motor Thermal Protection* .

1.4.1 CE Conformity and Labeling

The purpose of CE labeling is to avoid technical trade obstacles within EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Frequency converters are regulated by three EU directives:

The machinery directive (2006/42/EC)
All machines with critical moving parts are covered by the machinery directive of January 1, 1995. Since a frequency converter is largely electrical, it does not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, Danfoss provides information on safety aspects relating to the frequency converter. Danfoss do this by means of a manufacturer's declaration.

The low-voltage directive (2006/95/EC)
Frequency converters must be CE labeled in accordance with the low-voltage directive of October 5, 2nd edition 2007. The directive applies to all electrical equipment and appliances used in the 50-1000 V AC and the 75-1500 V DC voltage ranges. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request.

The EMC directive (2004/108/EC)
EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/ appliances does not affect the way the appliances work. The EMC directive came into effect January 1, 1996. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-correct installation, see the instructions in this Design Guide. In addition, Danfoss specifies which standards our products comply with. Danfoss offers the filters presented in the specifications and provide other types of assistance to ensure the optimum EMC result.

The frequency converter is used by professionals of the trade, most often as a component forming part of a large appliance, complex system or installation. It must be noted that to maintain the EMC properties of the frequency converter, it is the obligation of the installer to follow the installation instructions given by the manufacture. System installation responsibility rests with the installer.

1.4.2 What is Covered

The EU document "*Guidelines on the Application of Council Directive 2004/108/EC*" outlines 3 typical cases.

1. The frequency converter is sold directly to the end-user. For such applications, the frequency converter must be CE labelled in accordance with the EMC directive.
2. The frequency converter is sold as a part of a system. It is being marked as complete system, such as an air-conditioning system. The complete system must be CE labelled in accordance with the EMC directive. The manufacturer can ensure CE compliance under the EMC directive by testing the EMC of the system. The components of the system not need be CE marked.

3. The frequency converter is sold for installation in a plant. It could be a production or a heating/ ventilation plant designed and installed by professionals of the trade. The frequency converter must be CE labelled under the EMC directive. The finished plant does not require CE marking. However, the installation must comply with the essential requirements of the directive. This is assumed by the use of appliances and systems that are CE labelled under the EMC directive.

1.4.3 Danfoss Frequency Converter and CE Labelling

CE labelling is a positive feature when used for its original purpose, that is, to facilitate trade within the EU and EFTA.

However, CE labelling may cover many different specifications. Check what a given CE label specifically covers.

The specifications covered can be very different and a CE label may therefore give the installer a false feeling of security when using a frequency converter as a component in a system or an appliance.

Danfoss CE labels the frequency converters in accordance with the Low Voltage Directive. This means that if the frequency converter is installed correctly, Danfoss guarantees compliance with the Low Voltage Directive. Danfoss issues a declaration of conformity that confirms our CE labelling in accordance with the Low Voltage Directive.

The CE label also applies to the EMC directive when the instructions for EMC-correct installation and filtering are followed. On this basis, a declaration of conformity in accordance with the EMC directive is issued.

The Design Guide offers detailed instructions for installation to ensure EMC-correct installation. Furthermore, Danfoss specifies which our different products comply with.

Danfoss provides other types of assistance that can help to obtain the best EMC result.

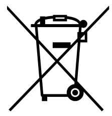
1.4.4 Compliance with EMC Directive and CE Labelling

The frequency converter is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation. It must be noted that the responsibility for the final EMC properties of the appliance, system, or installation rests with the installer. As an aid to the installer, EMC installation guidelines for the Power Drive system are supplied. See *chapter 2.5.2 EMC-Compliant Electrical Installation* and *chapter 2.5.3 Immunity Requirements* for standards and test levels. Compliance with the standards and test levels stated for Power Drive systems is achieved, provided that the EMC compliance installation instructions are followed.

1.5 Software Version

Read the software version of the frequency converter in parameter *15-43 Software Version*

1.6 Disposal Instructions



Equipment containing electrical components must not be disposed of together with domestic waste.
It must be separately collected with electrical and electronic waste according to local and currently valid legislation.

1.7 Safety

Frequency converters contain high voltage components and have the potential for fatal injury if handled improperly. Only trained technicians should install and operate the equipment. No repair work should be attempted without first removing power from the frequency converter and waiting the designated amount of time for stored electrical energy to dissipate.

Refer to the *VLT® DriveMotor FCP 106 and FCM 106 Operating Instructions*, shipped with the unit and available online for:

- discharge time, and
- detailed safety instructions and warnings.

Strict adherence to safety precautions and notices is mandatory for safe operation of the frequency converter.

2 Product Overview

2.1 Introduction

The product overview applies to both FCP 106 and FCM 106.

VLT® DriveMotor FCP 106
The delivery comprises frequency converter only. A wall adapter plate or motor adapter plate is also required for installation. Order the adapter plate separately.

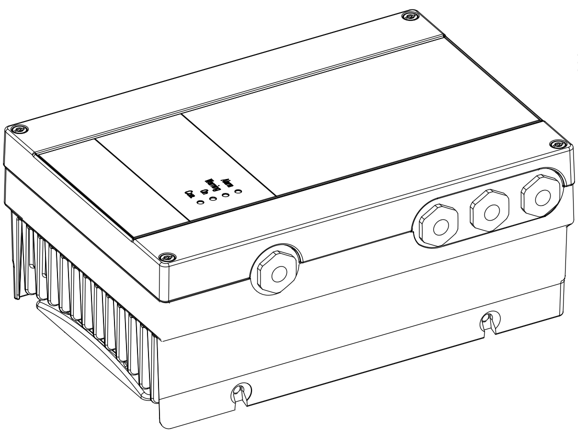


Illustration 2.1 FCP 106

VLT® DriveMotor FCM 106
The frequency converter is mounted onto the motor upon delivery. The combined FCM 106 and motor from Danfoss is known as the DriveMotor.

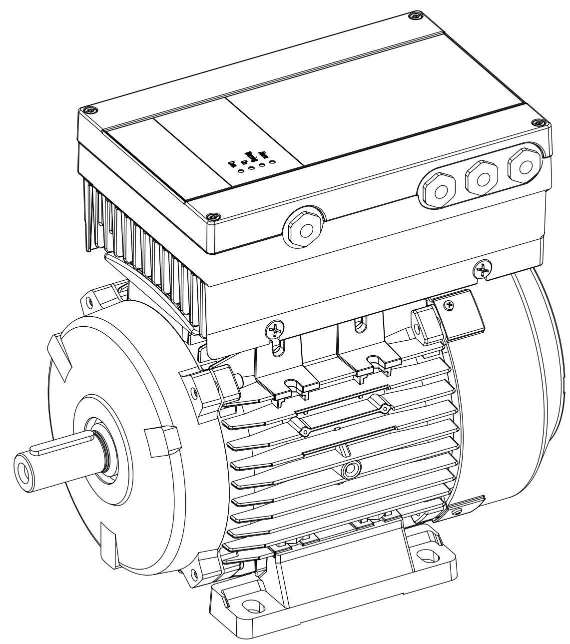


Illustration 2.2 FCM 106

2.1.1 Gasket

Mounting of FCP 106 onto a motor requires fitting a customised gasket. The gasket fits between the motor adapter plate and the motor.

No gasket is supplied with the FCP 106 frequency converter.

Therefore, before installation, design and test a gasket to fulfil the ingress protection requirement (for example IP55, IP66 or Type 4X).

Requirements for gasket:

- Maintain the ground connection between frequency converter and motor. The frequency converter is grounded to the motor adapter plate. Use a wire connection between motor and frequency converter, or ensure metallic contact between the motor adapter plate, and motor.
- Use a UL approved material for the gasket, when UL listing or recognition is required for the assembled product.

2.1.2 Key Diagram

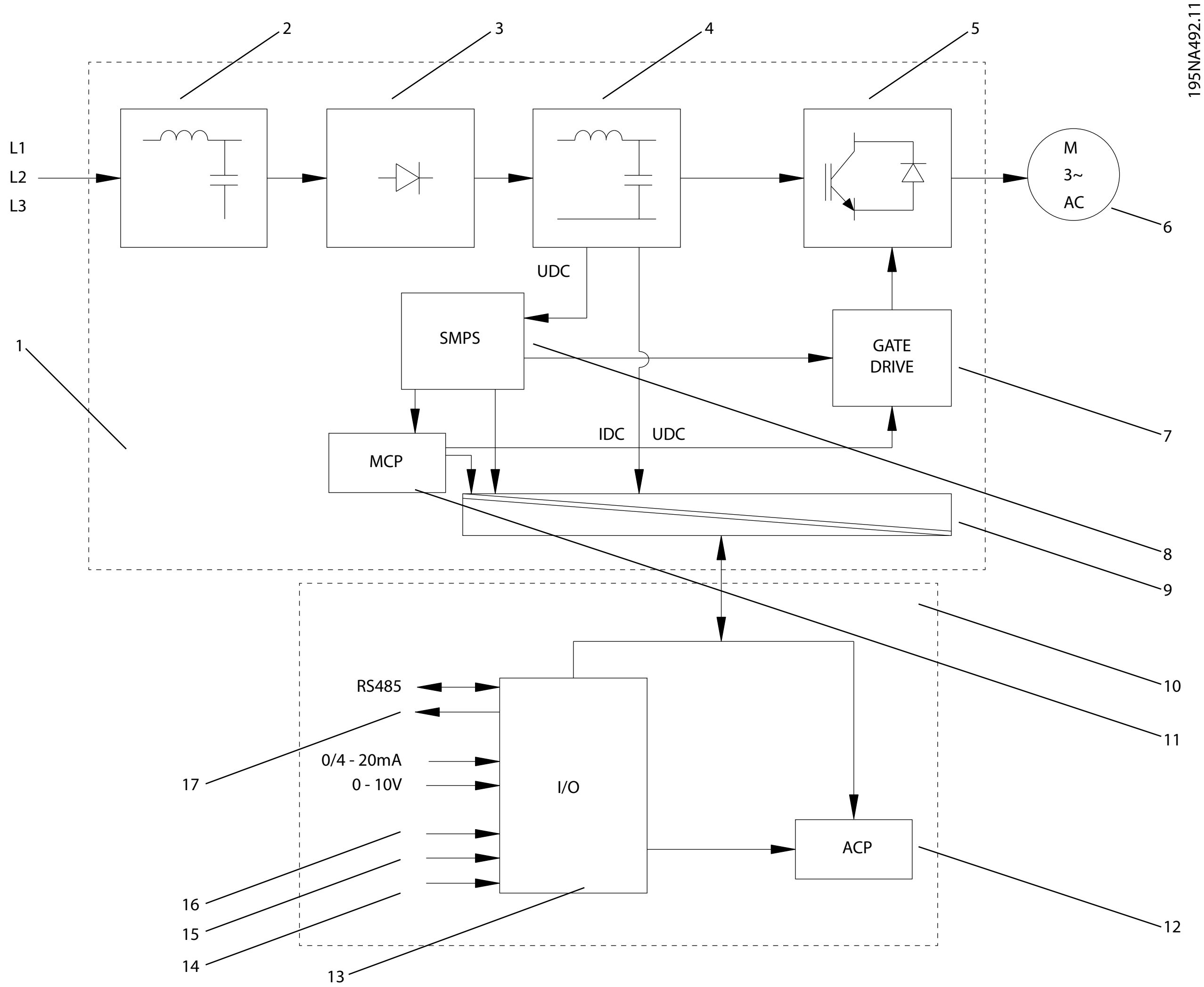


Illustration 2.3 Key Diagram

1	Power card	10	Control card
2	RFI filter	11	MCP (Motor control processor)
3	Rectifier	12	ACP (Application control processor)
4	Intermediate circuit / DC filter	13	Control terminals
5	Inverter	14	Reset
6	Motor	15	Jog
7	Gate drive	16	Start
8	SMPS	17	Analog/digital output
9	Galvanic isolation		

Table 2.1 Legend for *Illustration 2.3*

2

2.1.3 Electrical Overview

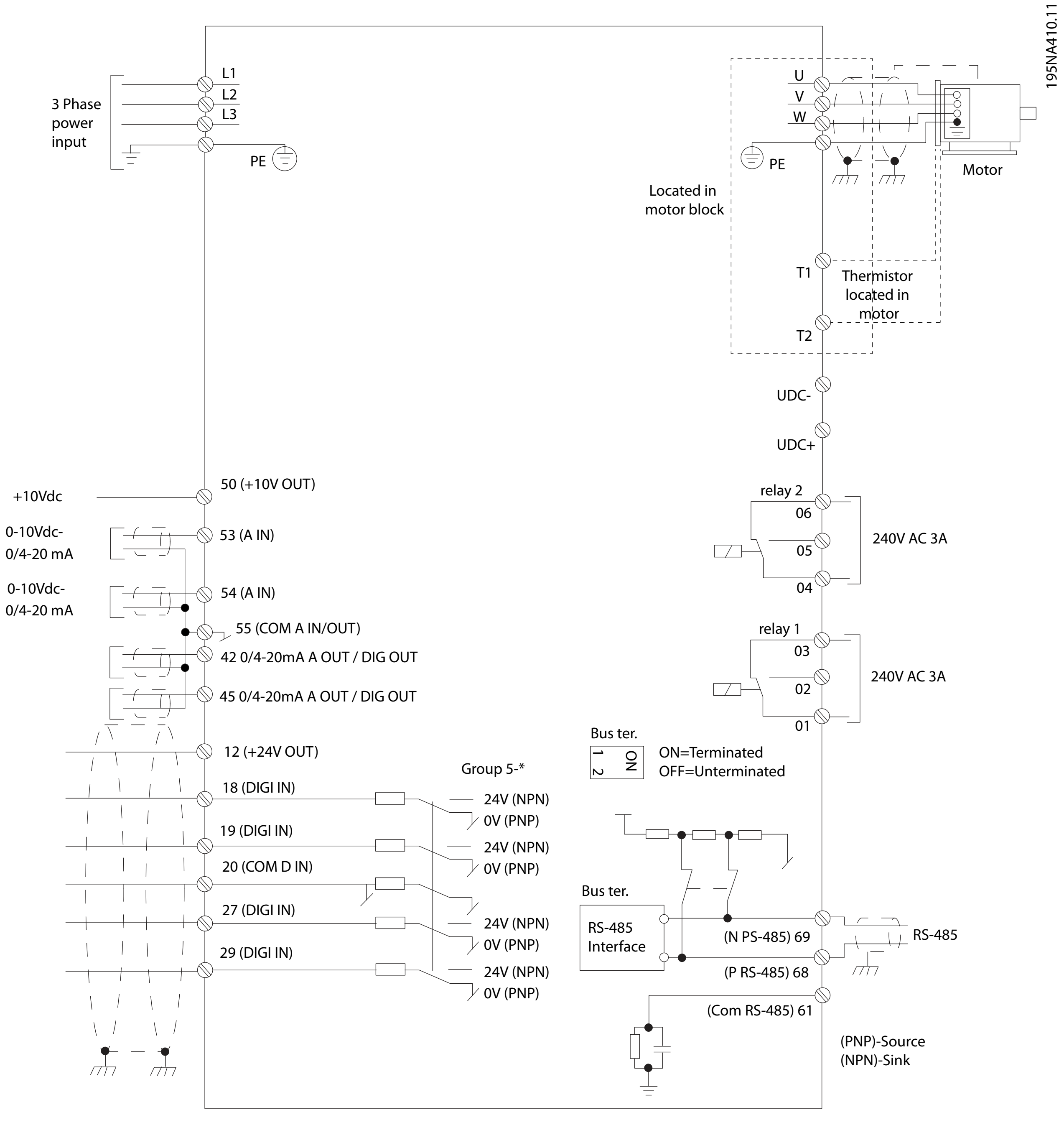


Illustration 2.4 Electrical Overview

2.1.4 Control Terminals

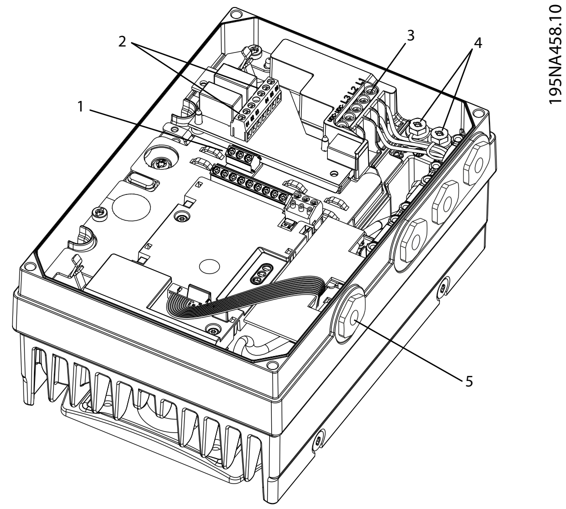


Illustration 2.5 Location of Terminals and Relays, MH1

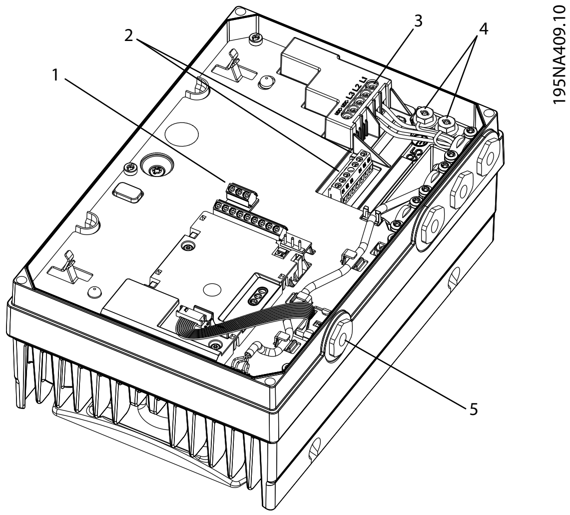


Illustration 2.6 Location of Terminals and Relays, MH2-MH3

1	Control terminals
2	Relays
3	UDC+, UDC-, Line (L3, L2, L1)
4	PE
5	LCP connector

Table 2.2 Legend to *Illustration 2.6*, *Illustration 2.5*

Control terminals

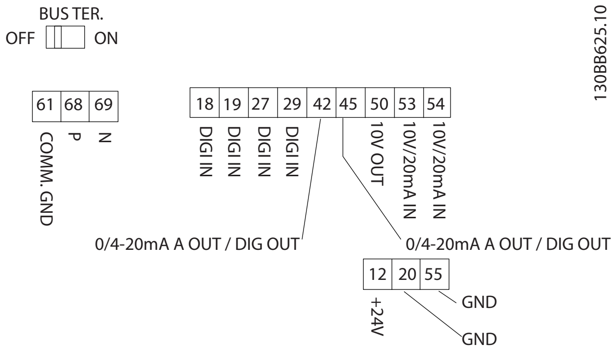


Illustration 2.7 Control Terminals

Terminal number	Function	Configuration	Factory setting
12	+24 V output		
18	Digital input	*PNP/NPN	Start
19	Digital input	*PNP/NPN	No operation
20	Com		
27	Digital input	*PNP/NPN	Coast inverse
29	Digital input	*PNP/NPN	Jog
50	+10 V output		
53	Analog input	*0-10 V/0-20 mA/ 4-20 mA	Ref1
54	Analog input	*0-10 V/0-20 mA/ 4-20 mA	Ref2
55	Com		
42	12 bit	*0-20 mA/4-20 mA/DO	Analog
45	12 bit	*0-20 mA/4-20 mA/DO	Analog
1, 2, 3	Relay 1	1,2 NO 1,3 NC	[9] Alarm
4, 5, 6	Relay 2	4,5 NO 4,6 NC	[5] Drive running

Table 2.3 Control Terminal Functions

** indicates default setting*

Note: PNP/NPN is common for terminals 18, 19 and 27

2.1.5 Serial Communication (Fieldbus) Networks

These protocols are embedded in the frequency converter:

- BACnet MSTP
- Modbus RTU
- N2 Metasys
- FC Protocol

2.2 Control Structures

In parameter *1-00 Configuration Mode* select whether open or closed loop control applies.

2.2.1 Control Structure Open Loop

In the configuration shown in *Illustration 2.8*, *1-00 Configuration Mode* is set to *[0] Open loop*. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

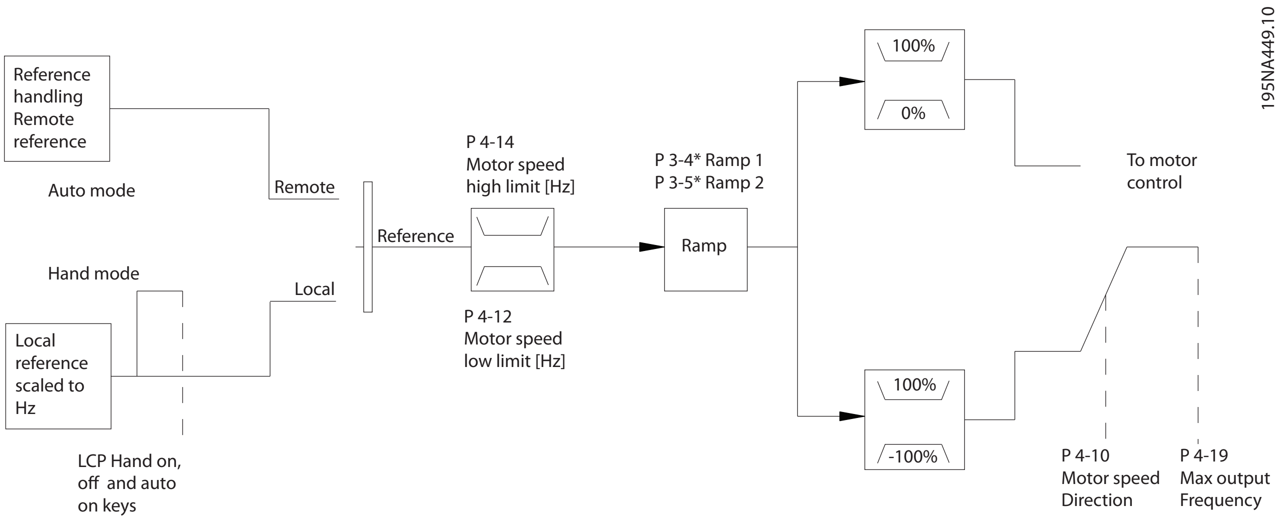


Illustration 2.8 Open Loop Structure

2.2.2 Control Structure Closed Loop (PI)

The internal controller allows the frequency converter to become an integral part of the controlled system. The frequency converter receives a feedback signal from a sensor in the system. It then compares this feedback to a set-point reference value and determines the difference, if any, between these 2 signals. It then adjusts the speed of the motor to correct this difference.

For example, consider a pump application where the speed of a pump is to be controlled so that the static pressure in a pipe is constant. The desired static pressure value is supplied to the frequency converter as the set-point reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the frequency converter as a feedback signal. If the feedback signal is greater than the set-point reference, the frequency converter slows down to reduce the pressure. In a similar way, if the pipe pressure is lower than the set-point reference, the frequency converter automatically speed up to increase the pressure provided by the pump.

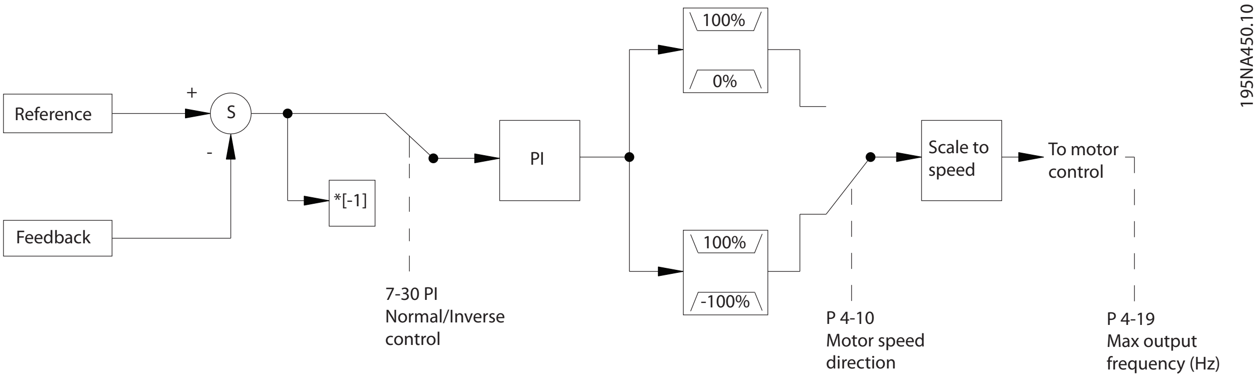


Illustration 2.9 Closed Loop Controller

While the default values for the frequency converter's Closed Loop controller often provides satisfactory performance, the control of the system can often be optimized by adjusting the Closed Loop controller parameters.

2.3 Local (Hand On) and Remote (Auto) Control

Operate the frequency converter manually via the local control panel (LCP) or remotely via analog/digital inputs or serial bus.
Start and stop the frequency converter pressing the [Hand On] and [Off/Reset] keys on the LCP. Setup required:

0-40 [Hand on] Key on LCP,

0-44 [Off/Reset] Key on LCP, and

0-42 [Auto on] Key on LCP.

Reset alarms via the [Off/Reset] key or via a digital input, when the terminal is programmed to "Reset".

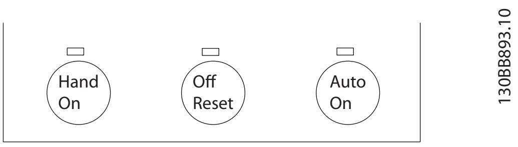


Illustration 2.10 LCP Control Keys

Local Reference forces the configuration mode to open loop, independent of the setting of *1-00 Configuration Mode*.

Local Reference is restored at power-down.

2

2.4 Feedback and Reference Handling

2.4.1 Reference Handling

Details for Open Loop and Closed Loop operation.

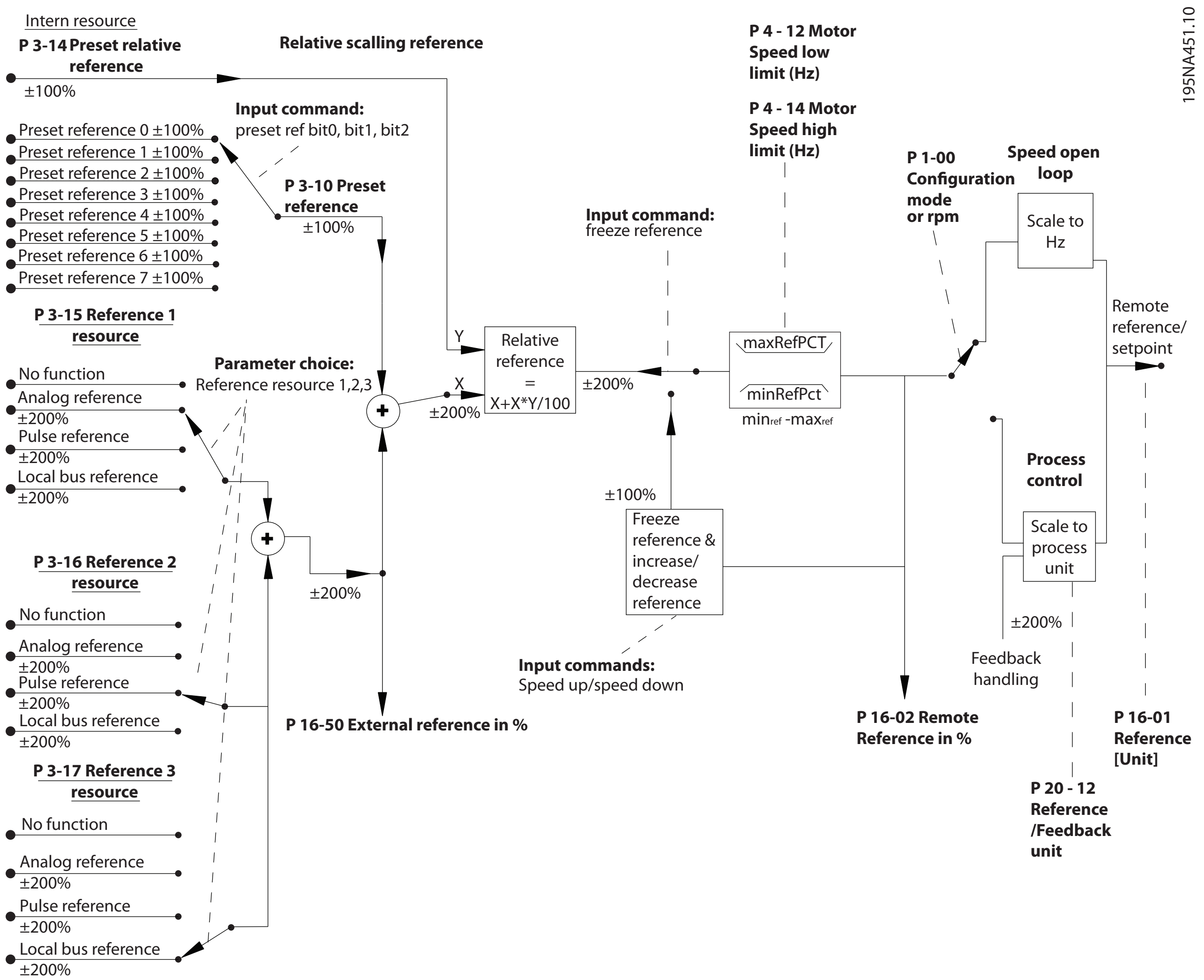


Illustration 2.11 Block Diagram Showing Remote Reference

The remote reference comprises:

- Preset references
- External references (analog inputs and serial communication bus references)
- The preset relative reference
- Feedback controlled setpoint.

Up to 8 preset references can be programmed in the frequency converter. Select the active preset reference using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. Select this external source via the 3 Reference Source parameters:

- *3-15 Reference 1 Source*,
- *3-16 Reference 2 Source*, and
- *3-17 Reference 3 Source*

Sum all reference resources and the bus reference to produce the total external reference. The external reference, the preset reference or the sum of the 2 can be selected to be the active reference. Finally, this reference can by be scaled using *3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

$$Reference = X + X \times \left(\frac{Y}{100}\right)$$

Where X is the external reference, the preset reference or the sum of these and Y is *3-14 Preset Relative Reference* in [%].

If Y, *3-14 Preset Relative Reference* is set to 0%, the reference is not affected by the scaling.

2.4.2 Feedback Handling

Feedback handling can be configured to work with applications requiring control. Configure the feedback source via parameter*20-00 Feedback 1 source.*

2.4.3 Feedback Conversion

In some applications it may be useful to convert the feedback signal. One example of this is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. See *Illustration 2.12*.

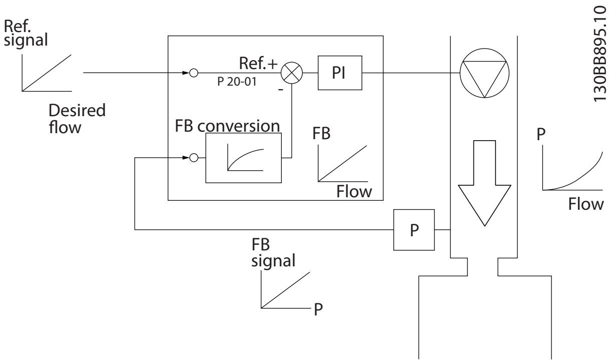


Illustration 2.12 Feedback Conversion

2.5 General Aspects of EMC

Electrical interference is conducted at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.
Capacitance in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.
The use of a screened motor cable increases the leakage current (see *Illustration 2.13*) because screened cables have higher capacitance to ground than unscreened cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there is only a small electro-magnetic field (I_4) from the screened motor cable.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. The motor cable screen must be connected to the frequency converter enclosure as well as the motor enclosure. This connection is best done by using integrated screen clamps to avoid twisted screen ends (pigtails). Pigtails increase the screen impedance at higher frequencies, which reduces the screen effect and increases the leakage current (I_4).
If a screened cable is used for relay, control cable, signal interface, and brake, the screen must be mounted on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.

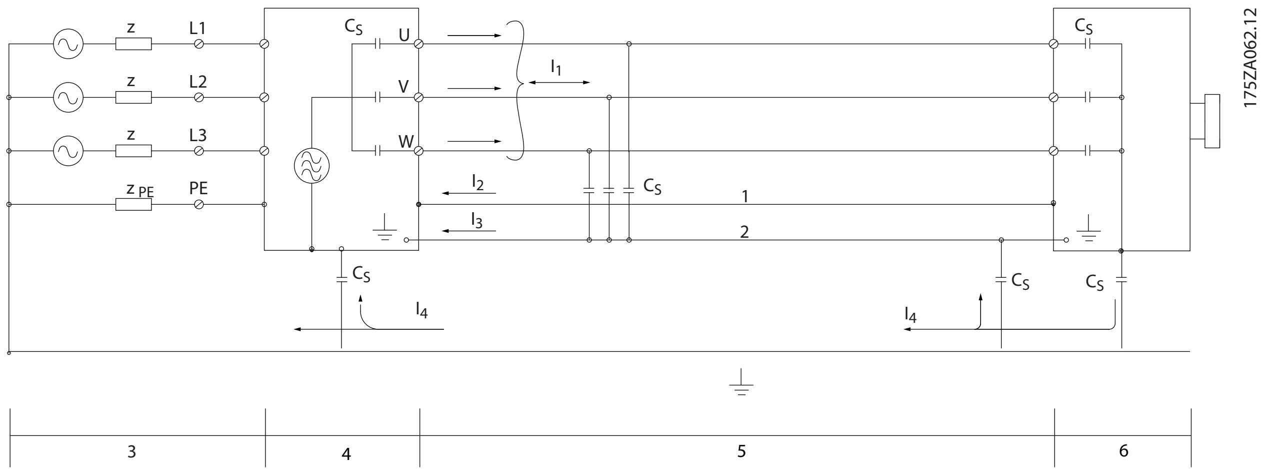


Illustration 2.13 Equivalent Diagram: Coupling of Capacitors, which Generates Leakage Currents

1	Ground wire	4	Frequency converter
2	Screen	5	Screened motor cable
3	AC mains supply	6	Motor

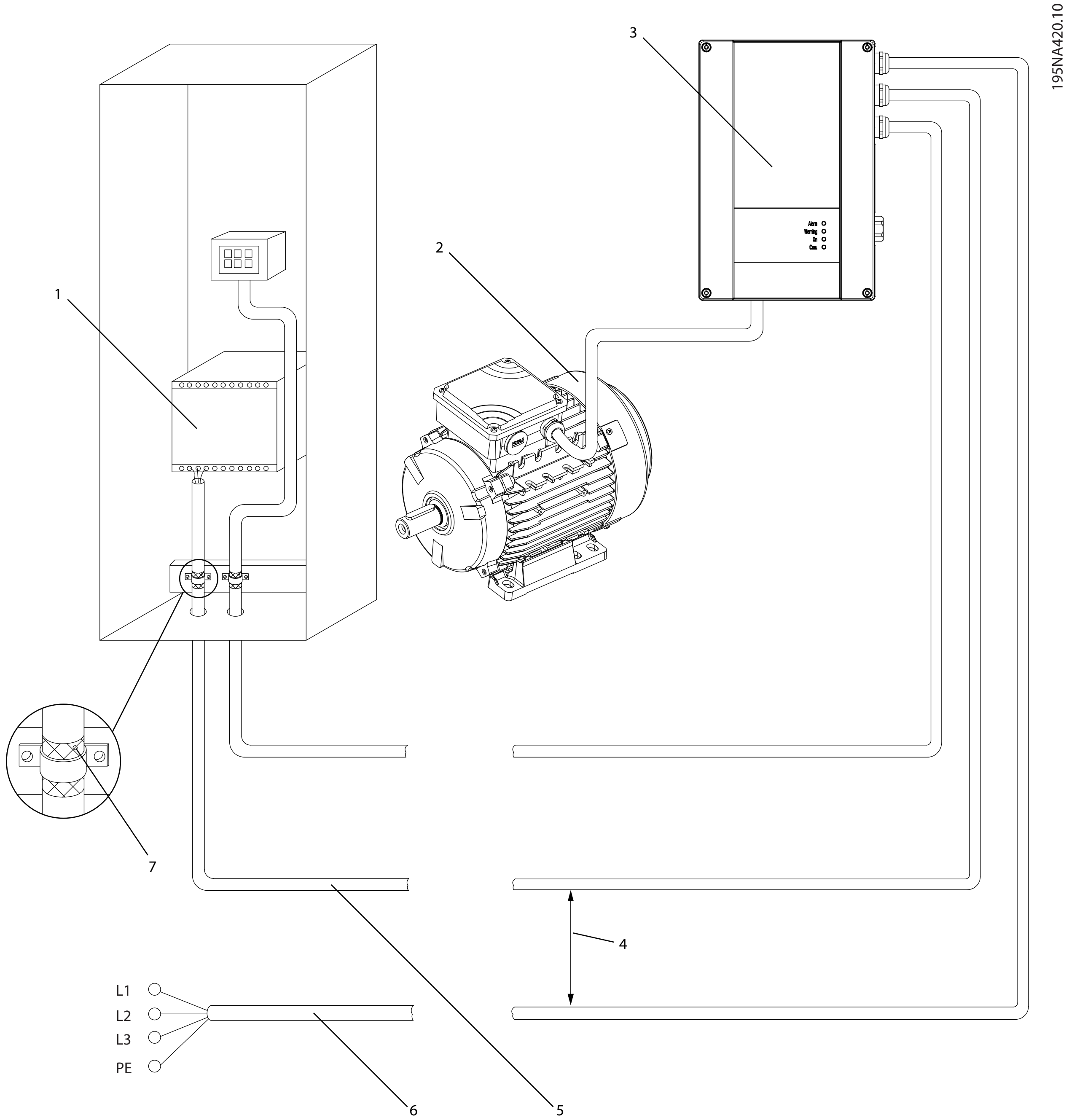
Table 2.4 Legend to *Illustration 2.13*

When positioning a screen on a frequency converter mounting plate, the mounting plate must be made of metal, to ensure that the screen currents are conveyed back to the unit. Moreover, ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter enclosure.

When unscreened cables are used, some emission requirements are not complied with, although most immunity requirements are observed.

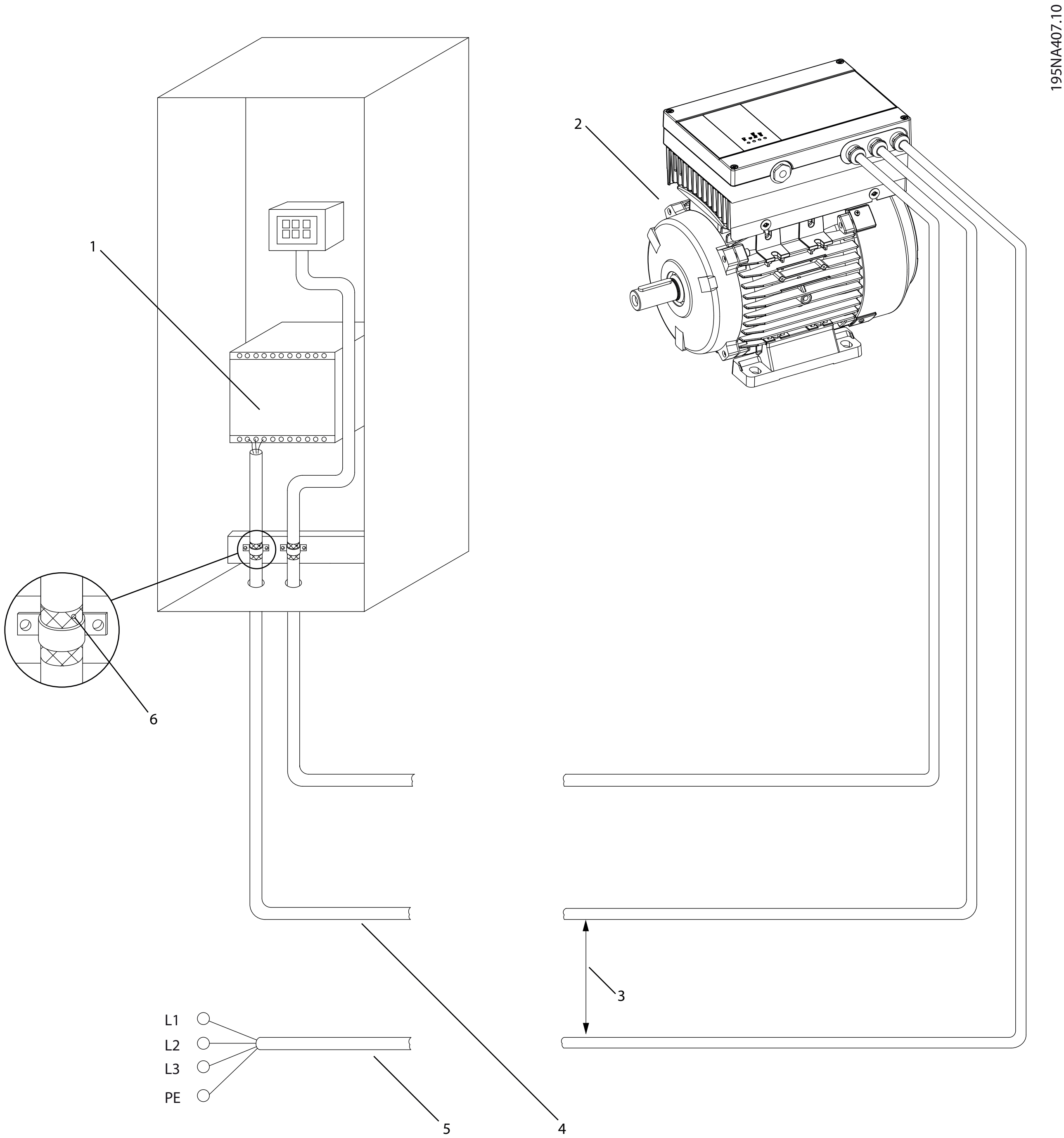
To reduce the interference level from the entire system (unit+installation), make motor cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor cables. Radio interference higher than 50 MHz (airborne) is especially generated by the control electronics. See *chapter 2.5.1 EMC-compliant Electrical Installation* for more information on EMC.

2.5.1 EMC-compliant Electrical Installation



1	PLC	5	Control cables
2	Motor	6	Mains, 3-phase, and reinforced PE
3	Frequency converter	7	Cable insulation (stripped)
4	Min. 200 mm clearance between control cable, mains cable, and mains motor cable.		

Illustration 2.14 EMC-compliant Electrical Installation, FCP 106



1	PLC	4	Control cables
2	DriveMotor	5	Mains, 3-phase, and reinforced PE
3	Min. 200 mm clearance between control cable, mains cable, and mains motor cable.	6	Cable insulation (stripped)

Illustration 2.15 EMC-compliant Electrical Installation, FCM 106

To ensure EMC-compliant electrical installation, observe these general points:

- Use only screened motor cables and screened control cables.
- Connect the screen to earth at both ends.
- Avoid installation with twisted screen ends (pigtails), since this ruins the screen effect at high frequencies. Use the cable clamps provided instead.
- Ensure the same potential between frequency converter and ground potential of PLC.
- Use star washers and galvanically conductive installation plates.

2.5.2 Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the frequency converter. The EMC product standard defines 4 categories, defined - together with the requirements for mains supply voltage conducted emissions - in *Table 2.5*.

Category	**Definition according to EN/IEC 61800-3:2004**	**Conducted emission requirement according to the limits given in EN 55011**
C1	Frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	Frequency converters installed in the second environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Frequency converters installed in the second environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. An EMC plan should be made.

Table 2.5 Emission Requirements - EN/IEC 61800-3:2004

When the generic emission standards are used, the frequency converter must comply with the following limits

Environment	**Generic standard**	**Conducted emission requirement according to the limits given in EN 55011**
First environment (home and office)	EN/IEC 61000-6-3 Emission standard for residential, commercial and light industrial environments.	Class B
Second environment (industrial environment)	EN/IEC 61000-6-4 Emission standard for industrial environments.	Class A Group 1

Table 2.6 Emission Requirements - EN/IEC 61000-6-3 and EN/IEC 61000-6-4

A system comprises

- FCP 106, motor and screened motor cable; or
- FCM 106

For either of these systems, the conducted emission complies with EN 55011 Class B, and the radiated emission complies with EN 55011 Class A, Group 1. Compliance is achieved based on the following conditions:

- built-in RFI filter
- frequency converter set to nominal switching frequency
- maximum screened motor cable length of 0.5 m

2.5.3 Immunity Requirements

The immunity requirements for frequency converters depend on the environment where they are installed. The requirements for the industrial environment are higher than the requirements for the home and office environment. All Danfoss frequency converters comply with the requirements for the industrial environment and consequently comply also with the lower requirements for home and office environment with a large safety margin.

In order to document immunity against electrical interference from electrical phenomena, the following immunity tests have been made in accordance with following basic standards:

- EN 61000-4-2 (IEC 61000-4-2): Electrostatic discharges (ESD): Simulation of electrostatic discharges from human beings.
- EN 61000-4-3 (IEC 61000-4-3): Incoming electro-magnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment as well as mobile communications equipment.
- EN 61000-4-4 (IEC 61000-4-4): Burst transients: Simulation of interference brought about by switching a contactor, relay or similar devices.
- EN 61000-4-5 (IEC 61000-4-5): Surge transients: Simulation of transients brought about e.g. by lightning that strikes near installations.
- EN 61000-4-6 (IEC 61000-4-6): RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

Basic standard	**Burst IEC 61000-4-4**	**Surge IEC 61000-4-5**	**ESD IEC 61000-4-2**	**Radiated electro-magnetic field IEC 61000-4-3**	**RF common mode voltage IEC 61000-4-6**
Accept-ance criterion	B	B	B	A	A
Line (no shield)	4kV	2kV/2Ω DM 4kV/12Ω CM	N.A.	N.A.	$10V_{rms}$
LCP cable	2kV	2kV/2 Ω 1)	N.A.	N.A.	$10V_{rms}$
Control wires	2kV	2kV/2 Ω 1)	N.A.	N.A.	$10V_{rms}$
External 24 V DC	2kV	2kV/2 Ω 1)	N.A.	N.A.	$10V_{rms}$
Relay wires	2kV	42kV/42 Ω	N.A.	N.A.	$10V_{rms}$
Enclosure	N.A.	N.A.	8 kV AD 6 kV CD	10V/m	N.A.

Table 2.7 Immunity Requirements

1) Injection on cable shield

Abbreviations:

AD - air discharge

CD - contact discharge

CM - common mode

DM - difference mode

2.6 Leakage Current

EN/IEC61800-5-1 (Power Drive System Product Standard) requires special care when the leakage current exceeds 3.5 mA. Follow national and local codes regarding protective earthing of equipment with a leakage current greater than 3.5 mA. Frequency converter technology implies high frequency switching at high power. The high frequency switching generates a leakage current in the ground connection. A fault current in the frequency converter at the output power terminals can contain a DC component which can charge the filter capacitors and cause a transient earth current. The leakage current depends on various system configurations including RFI filtering, screened motor cables, and frequency converter power. Grounding must be reinforced in one of the following ways:

- PE ground wire of at least 10 mm^2 cross-sectional area, or
- 2 separate PE ground wires both complying with the dimensioning rules.

See EN60364-5-54 paragraph 543.7 for further information.

2.6.1 Residual Current Device (RCD) Protection

This product can cause a DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B (time delayed) is allowed on the supply side of this product. Otherwise, apply another protective measure, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer.
Protective earthing of the frequency converter and the use of RCDs must always follow national and local regulations. Failure to follow recommendations for Leakage Current and Residual Current Device could result in death or serious injury.

2.7 Galvanic Isolation (PELV)

PELV offers protection by way of extra low voltage. Protection against electric shock is ensured when the electrical supply is of the PELV type and the installation is made as described in local/national regulations on PELV supplies.

All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage) (Does not apply to grounded Delta leg above 400 V).

Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the relevant creapage/clearance distances. These requirements are described in the EN/IEC 61800-5-1 standard.

The components that make up the electrical isolation, as described, also comply with the requirements for higher isolation and the relevant test as described in EN/IEC 61800-5-1.
The PELV galvanic isolation is shown in *Illustration 2.16*.

To maintain PELV, all connections made to the control terminals must be PELV.

1. High voltage circuit
2. I/O control card
3. Custom relays

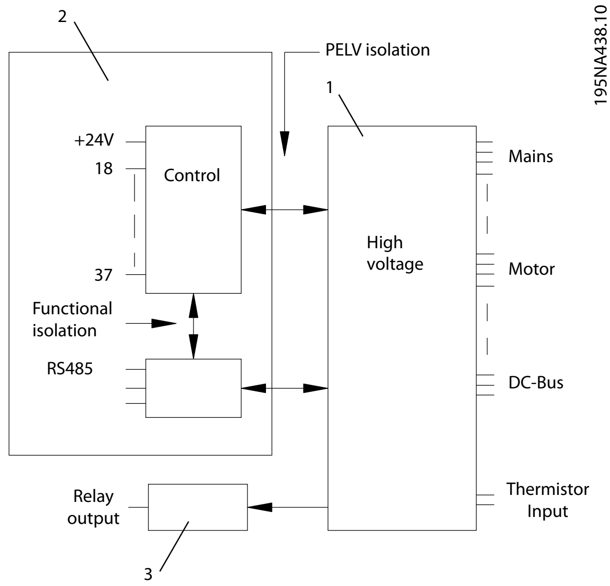


Illustration 2.16 Galvanic Isolation

NOTICE

HIGH ALTITUDE
For installation at altitudes above 2000 m, contact Danfoss hotline regarding PELV.

3 System Integration

3.1 Introduction

This chapter describes the considerations necessary to integrate the frequency converter into a system design. The chapter is divided into 4 sections:

- Ambient operating conditions for the converter including environment, enclosures, temperature, derating, and other considerations (*chapter 3.6 Ambient Conditions*)
- Input into the converter from the mains side including power, harmonics, monitoring, cabling, fusing, and other considerations (*chapter 3.2 Mains Input*)
- Output from the converter to the motor including motor types, load, monitoring, cabling, and other considerations (*chapter 3.3 Motors*)
- Integration of the converter input and output for optimal system design including converter/motor matching, system characteristics, and other considerations (*chapter 3.4 Frequency Converter/ Options Selections*).

3.1.1 FCM 106 - Integrated Frequency Converter and Motor

The Danfoss VLT frequency converter integrated onto the asynchronous or permanent magnet motor enables speed control in a single unit.

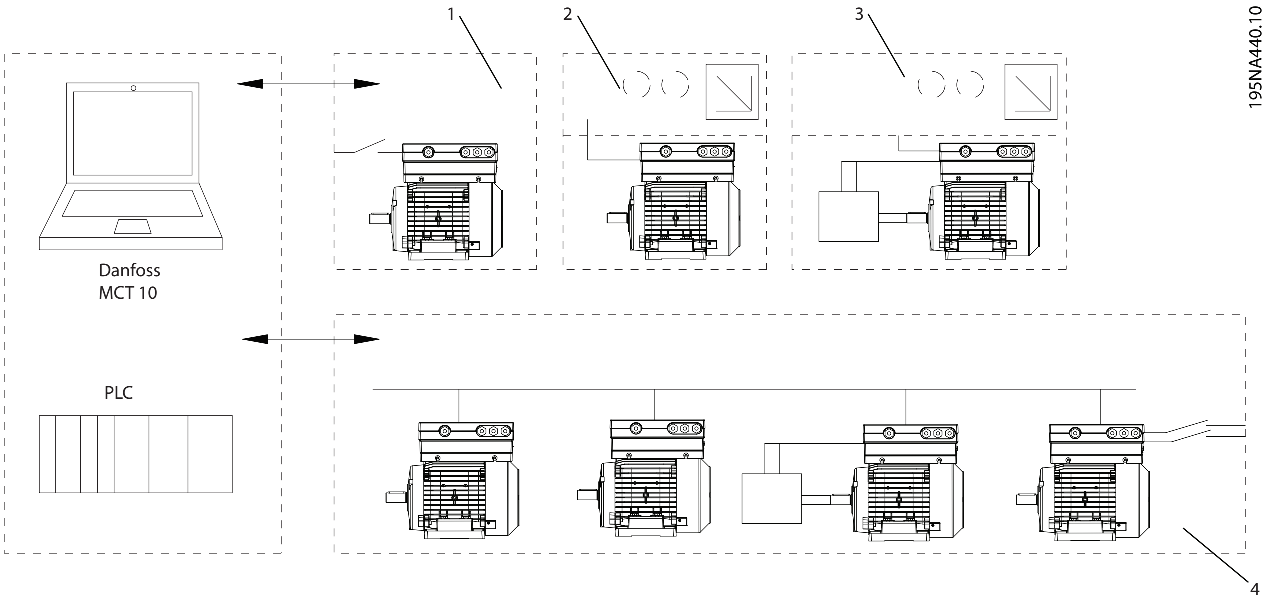
The FCM 106 is a very compact alternative to a central solution where the frequency converter and motor are installed as separate units.

- No cabinet is required
- The frequency converter is mounted directly onto the motor, instead of connecting via the motor terminal box
- Electrical installation involves mains and control connections only. There is no need for special details on wiring to meet the EMC directive, since motor cables are not necessary.

Factory-set adaption between FCM 106 and the motor gives precise and energy efficient control in addition to eliminating pre-setting on site.

The FCM 106 can be used in stand-alone systems with traditional control signals, such as start/stop signals, speed references and closed loop process control or in multiple drive systems with control signals distributed by a field bus.

Combined fieldbus and traditional control signals with closed loop PI control is possible.



1	Start/stop	3	Closed loop process control
2	2 Speed reference	4	Combined fieldbus and traditional control signals

Illustration 3.1 Example of Control Structures

3.2 Mains Input

3.2.1 Mains Supply Interference/Harmonics

3.2.1.1 General Aspects of Harmonics Emission

A frequency converter takes up a non-sinusoidal current from mains, which increases the input current I_{RMS}. A non-sinusoidal current is transformed via a Fourier analysis and split up into sine-wave currents with different frequencies, that is, different harmonic currents I_n with 50 Hz as the basic frequency:

Harmonic currents	I_1	I_5	I_7
Hz	50	250	350

Table 3.1 Harmonic Currents

The harmonic currents increase the heat losses in the installation (transformer, cables) even though they do not affect the power consumption directly. Increased heat losses can lead to overload of the transformer and high temperature in the cables. Therefore keep the harmonics at a low level by:

- using frequency converters with internal harmonic filters
- using advanced external filters (active or passive).

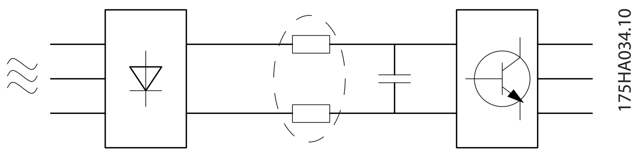


Illustration 3.2 Filters

NOTICE

Some of the harmonic currents can disturb communication equipment connected to the same transformer or cause resonance with power-factor correction batteries.

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. These coils normally reduce the input current I_{RMS} by 40%.

The voltage distortion on the mains supply voltage depends on the size of the harmonic currents multiplied by the mains impedance for the frequency in question. The total voltage distortion THD is calculated based on the individual voltage harmonics using this formula:

$$THD\% = \sqrt{U_5^2 + U_7^2 + ... + U_N^2}$$

(U_N% of U)

3

3.2.1.2 Harmonics Emission Requirements

For equipment connected to the public supply network compliance with the following standards is required:

Standard	Equipment type	Power size[1)] FCP 106 and FCM 106
IEC/EN 61000-3-2, class A	Professional 3-phase balanced equipment, only up to 1 kW total power	0.55-0.75 kW
IEC/EN 61000-3-12, Table 4	Equipment 16–75 A, and professional equipment from 1 kW up to 16 A phase current	1.1-7.5 kW

Table 3.2 Harmonics Emission Compliance

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

IEC 61000-3-2, Limits for harmonic current emissions (equipment input current ≤ 16A per phase)
The scope of IEC 61000-3-2 is equipment connected to the public low-voltage distribution system having an input current up to and including 16 A per phase. Four emission classes are defined: Class A through D. The Danfoss frequency converters are in Class A. However, there are no limits for professional equipment with a total rated power greater than 1 kW.

IEC 61000-3-12, Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16A and ≤75A
The scope of IEC 61000-3-12 is equipment connected to the public low-voltage distribution system having an input current of 16–75 A. The emission limits are currently only for 230/400 V 50 Hz systems and limits for other systems will be added in the future. The emission limits that apply for drives are given in Table 4 in the standard. There are requirements for individual harmonics (5th, 7th, 11th, and 13th) and for THD and PWHD.

3.2.1.3 Harmonics Test Results (Emission)

MH1[1)]	Individual Harmonic Current I_n/I_{ref} (%)			
	I_5	I_7	I_{11}	I_{13}
0.55-1.5 kW, 380-480 V	32.33	17.15	6.8	3.79
Limit for R_{sce}	98	86	59	48
	Harmonic current distortion factor (%)			
	THC		**PWHC**	
0.55-1.5 kW, 380-480 V (typical)	38		30.1	
Limit for R_{sce}	95		63	

Table 3.3 MH1

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

MH2[1)]	Individual Harmonic Current I_n/I_{ref} (%)			
	I_5	I_7	I_{11}	I_{13}
2.2-4 kW, 380-480 V	35.29	35.29	7.11	5.14
Limit for R_{sce}	107	99	61	61
	Harmonic current distortion factor (%)			
	THC		**PWHC**	
2.2-4 kW, 380-480 V (typical)	42.1		36.3	
Limit for R_{sce}	105		86	

Table 3.4 MH2

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

MH3[1)]	Individual Harmonic Current I_n/I_{ref} (%)			
	I_5	I_7	I_{11}	I_{13}
5.5-7.5 kW, 380-480 V	30.08	15.00	07.70	5.23
Limit for R_{sce}	91	75	66	62
	Harmonic current distortion factor (%)			
	THC		**PWHC**	
5.5-7.5 kW, 380-480 V (typical)	35.9		39.2	
Limit for R_{sce}	90		97	

Table 3.5 MH3

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

Ensure that the short circuit power of the supply S_{sc} is greater than or equal to:

$$SSC = \sqrt{3} \times RSCE \times Umains \times Iequ = \sqrt{3} \times 120 \times 400 \times Iequ$$

at the interface point between the user's supply and the public system (R_{sce}).

It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to that specified above.
Other power sizes can be connected to the public supply network by consultation with the distribution network operator.

Compliance with various system level guidelines:
The harmonic current data in the table are listed in accordance with IEC/EN 61000-3-12 with reference to the Power Drive Systems product standard. These data may be used

- as the basis for calculation of the influence of harmonic currents on the power supply system, and
- for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

3.3 Motors

3.3.1 Exploded Views

The FCM 106 consists of the following parts:

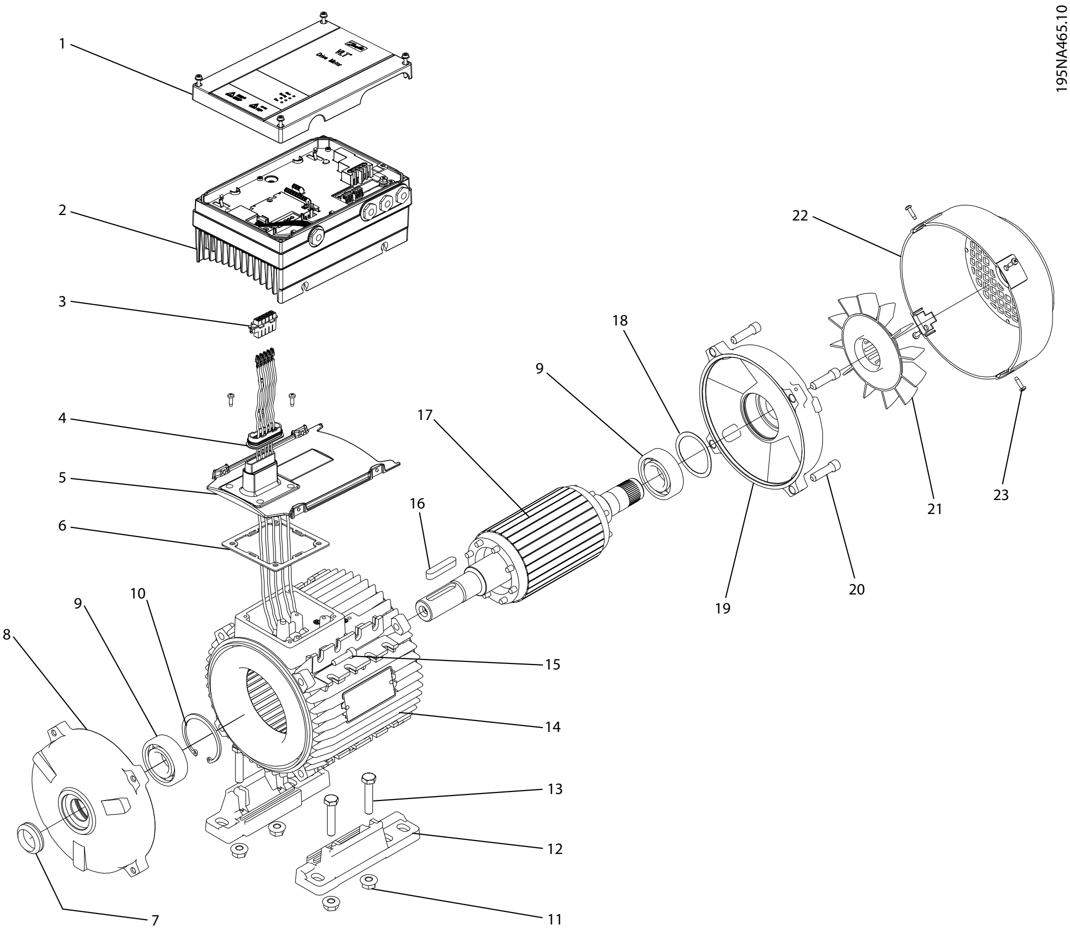


Illustration 3.3 FCM 106 with Asynchronous Motor, B3 Exploded View

Item	Description	Item	Description
1	Frequency converter cover	13	Foot fixing bolt
2	Frequency converter enclosure	14	Stator frame
3	Motor connector	15	Fixing bolt endshield drive end
4	Motor connector gasket	16	Shaft key
5	Motor adapter plate	17	Rotor
6	Gasket between motor and motor adapter plate	18	Pre-load washer
7	Dust seal drive end	19	Endshield non-drive end
8	Endshield drive end	20	Fixing bolt endshield non-drive end
9	Bearing	21	Fan
10	Snap ring	22	Fan cover
11	Foot fixing	23	Fan cover screw
12	Detachable feet		

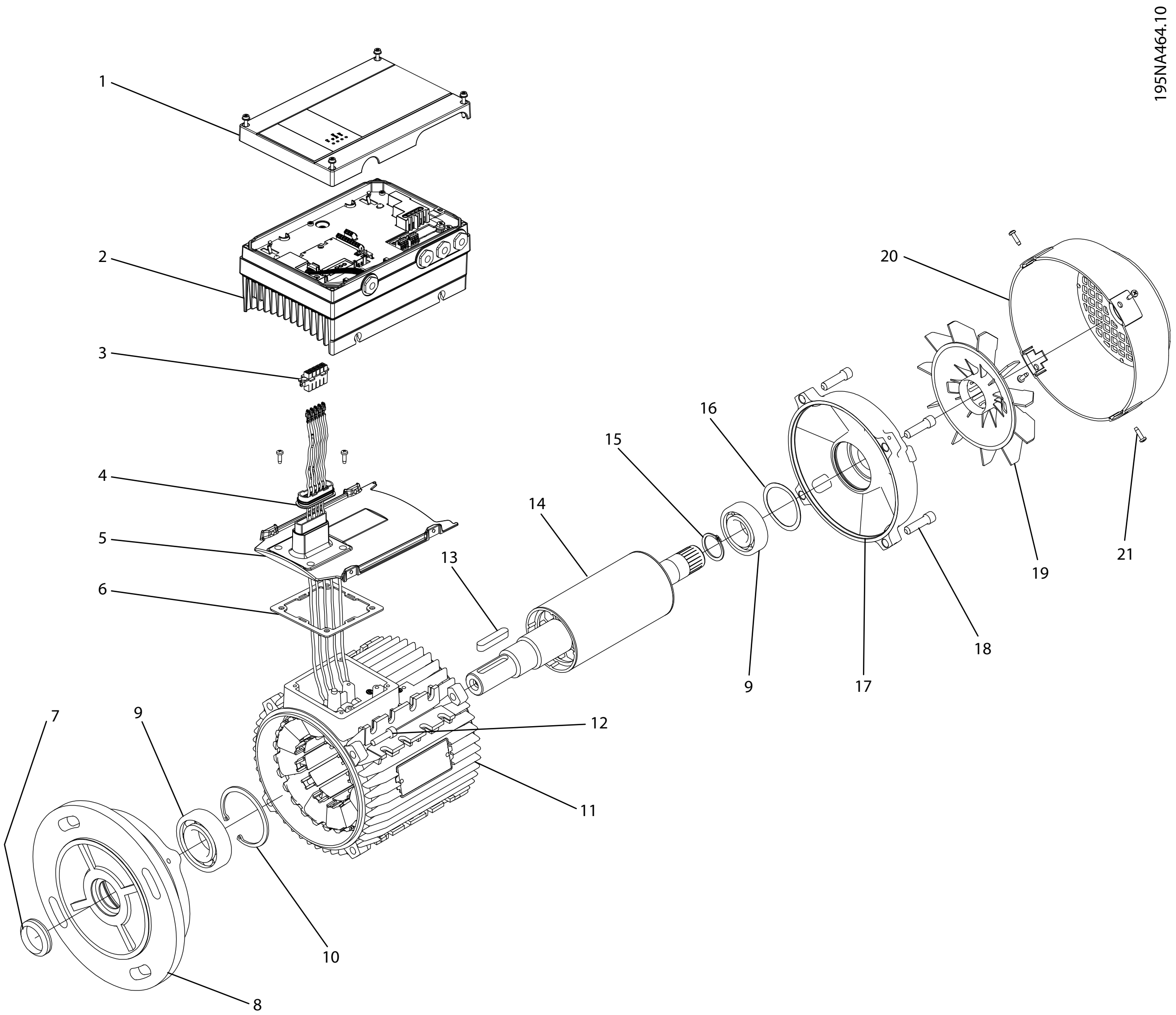


Illustration 3.4 FCM 106 with PM Motor, B5 Exploded View

Item	Description	Item	Description
1	Frequency converter cover	12	Fixing bolt endshield drive end
2	Frequency converter enclosure	13	Shaft key
3	Motor connector	14	Rotor
4	Motor connector gasket	15	Snap ring
5	Motor adapter plate	16	Pre-load washer
6	Gasket between motor and motor adapter plate	17	Endshield non-drive end
7	Dust seal drive end	18	Fixing bolt endshield non-drive end
8	Flange endshield	19	Fan
9	Bearing	20	Fan cover
10	Snap ring	21	Fan cover screw
11	Stator frame		

3.3.2 Lifting

NOTICE

LIFTING - EQUIPMENT DAMAGE RISK
Incorrect lifting can result in equipment damage.

- **Use both lifting lugs when provided.**
- **For vertical lift, prevent uncontrolled rotation.**
- **For lift machine, do not lift other equipment with motor lifting points only.**

Handling and lifting of the unit must only be undertaken by qualified personnel. Ensure

- availability of full product documentation, together with tools and equipment necessary for safe working practice.
- cranes, jacks, slings, and lifting beams are rated to bear the weight of equipment to be lifted. For weight of unit, see *chapter 6.1.5 Weight*.
- when using an eyebolt, that the shoulder of the eyebolt is tightened firmly against the face of the stator frame, before lifting.

Eyebolts or lifting trunnions supplied with the unit are rated to bear the weight of the unit only, not the additional weight of ancillary equipment attached.

3.3.3 Bearings

The standard solution is fixed bearing in the drive side of the motor (shaft output side).
To avoid static indention, the storage area should be vibration free. Where exposure to some vibration is unavoidable, the shaft should be locked. Bearings may be fitted with a shaft locking device which should be kept in place during storage. Shafts should be rotated by hand, one quarter of a revolution, at weekly intervals.
Bearings are despatched from the works fully charged with lithium-based grease.

3.3.4 Bearing Life and Lubrication

The life expectancy of the ball bearings is standard, when the following conditions are fulfilled:

- temperature of 80 °C
- radial forces in load point corresponding to half shaft extension do not exceed the values specified by motor manufacturer

Motor type	Frame size	Lubrication type	Temperature range
Asynchronous	80-180	Lithium basis	-40 to 140°C
PM	71-160		

Table 3.6 Lubrication

Frame size	Speed [RPM]	Bearing type, asynchronous motors		Bearing type, PM motors	
		Drive end	Non-drive end	Drive end	Non-drive end
71	1500/3000	N.A.	N.A.	6203 2ZC3	6203 2ZC3
80	1500/3000	6204 2ZC3	6204 2ZC3	N.A.	N.A.
90	1500/3000	6205 2ZC3	6205 2ZC3	6206 2ZC3	6205 2ZC3
100	1500/3000	6206 2ZC3	6206 2ZC3	N.A.	N.A.
112	1500/3000	6306 2ZC3	6306 2ZC3	6208 2ZC3	6306 2ZC3
132	1500/3000	6208 2ZC3	6208 2ZC3	6309 2ZC3	6208 2ZC3
160	1500/3000	*a)*	*a)*	N.A.	N.A.
180	1500/3000	*a)*	*a)*	N.A.	N.A.

Table 3.7 Standard Bearing References and Oil Seals for Motors

a) Data available upon future release.

3.3.5 Balance

The FCM 106 is balanced to class R according to ISO8821 (reduced balance). For critical applications especially at high speed (>4000 RPM) special balance (class S) may be required.

3.3.6 Output shafts

Output shafts are manufactured from 35/40 Ton (460/540 MN/m^2) tensile steel. Drive end shafts are provided with a tapped hole to DIN332 Form D and a closed profile keyway as standard.

3.3.7 FCM 106 Inertia

Inertia J	Asynchronous motor		PM motor	
FCM 106[1)]	3000 RPM	1500 RPM	3000 RPM	1500 RPM
0.55	N.A.	N.A.	N.A.	0.00047
0.75	0.0007	0.0025	0.00047	0.0007
1.1	0.00089	0.00373	0.00047	0.00091
1.5	0.00156	0.00373	0.0007	0.0011
2.2	0.0018	0.00558	0.00091	0.00082
3.0	0.00405	0.00703	0.00082	0.00104
4.0	0.00648	0.0133	0.00107	0.00131
5.5	0.014	0.03	0.00131	0.0136
7.5	0.016	0.036	0.0136	0.0206

Table 3.8 Inertia [kgm^2]

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

3.3.8 FCM 106 - Motor Frame Size

Frequency converter power size[1)]	Asynchronous motor		PM motor	
[kW]	1500 RPM	3000 RPM	1500 RPM	3000 RPM
0.55	N.A.	N.A.	71	N.A.
0.75	80	71	71	71
1.1	90	80	71	71
1.5	90	80	71	71
2.2	100	90	90	71
3	100	90	90	90
4	112	100	90	90
5.5	112	112	112	90
7.5	132	112	112	112

Table 3.9 FCM 106 - Motor Frame Size for PM and Asynchronous Motors

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

3.3.9 Motor Thermal Protection

Motor protection can be implemented using a range of techniques: Electronic Thermal Relay (ETR); thermistor sensor placed between motor windings or a mechanical thermal switch (Klixon type).

3.3.9.1 Electronic Thermal Relay

ETR is functional for asynchronous motors only. The ETR protection comprises simulation of a bimetal relay based on internal frequency converter measurements of the actual current and speed. The characteristic is shown in *Illustration 3.5*.

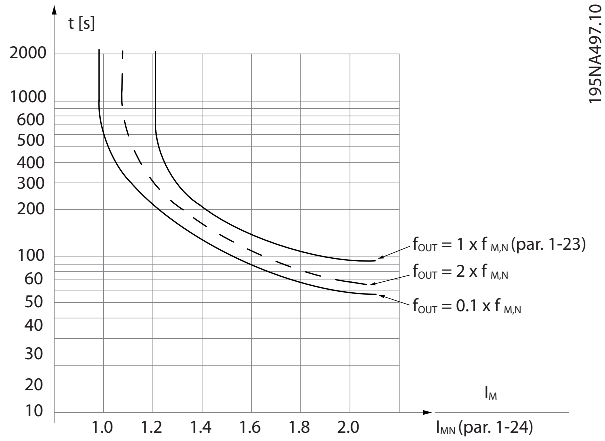


Illustration 3.5 ETR Protection Characteristic

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the frequency converter. The curves show the characteristic nominal speed at twice the nominal speed, and at 0.1x the nominal speed.

It is clear that at lower speed the ETR cuts off at lower heat, due to less cooling of the motor. In that way, the motor is protected from over-heating, even at low speed.

Summary
ETR is functional for asynchronous motors only. The ETR protects the motor against over-heating, and no further motor protection is required. When the motor is heated up, the ETR timer controls the duration of running at high temperature, before stopping the motor to prevent over-heating.
When the motor is overloaded before reaching the temperature where the ETR shuts off the motor, the current limit protects the motor and application against overload. In this case, ETR will not activate and therefore a different method of thermal protection is required.

Activate ETR in *1-90 Motor Thermal Protection*. ETR is controlled in *4-18 Current Limit Mode*.

3.3.9.2 Thermistor (FCP 106 only)

The thermistor is positioned between motor windings. The connection for the thermistor is placed in the motor plug: terminal positions T1 and T2. For terminal positions and wiring details, refer to the section *Motor Connection* in *VLT® DriveMotor FCP 106 and FCP 106 Operating Instructions*.

To monitor the thermistor, set parameter *1-90 Motor Thermal Protection* to *[1] Thermistor Warning* or *[2] Thermistor Trip*.

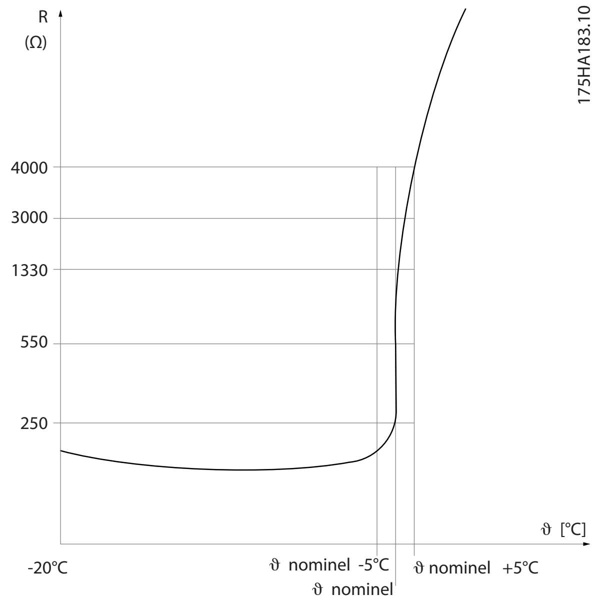


Illustration 3.6 Typical Thermistor Behaviour

The frequency converter trips when the motor temperature increases the thermistor value above 2.9 kΩ. The frequency converter is reactivated when the thermistor value decreases below 0.8 kΩ.

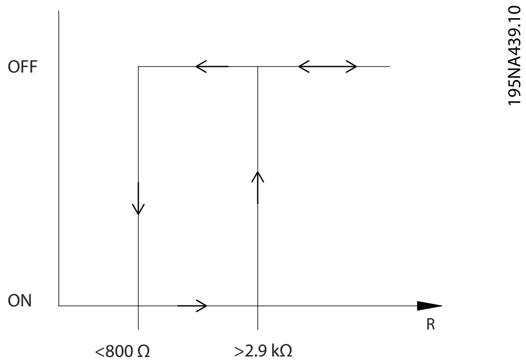


Illustration 3.7 Frequency Converter Operation with Thermistor

NOTICE

Select the thermistor according to the specification in *Illustration 3.6* and *Illustration 3.7*.

NOTICE

If the thermistor is not galvanically isolated, then interchanging the thermistor wires with the motor wires may permanently damage the frequency converter.

A mechanical thermal switch (Klixon type) can be used instead of a thermistor.

3.4 Frequency Converter/Options Selections

3.4.1 Remote Mounting Kit

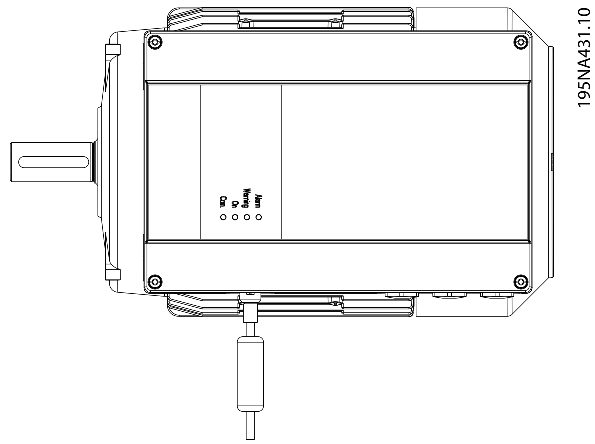


Illustration 3.8 Remote Mounting Kit Connections

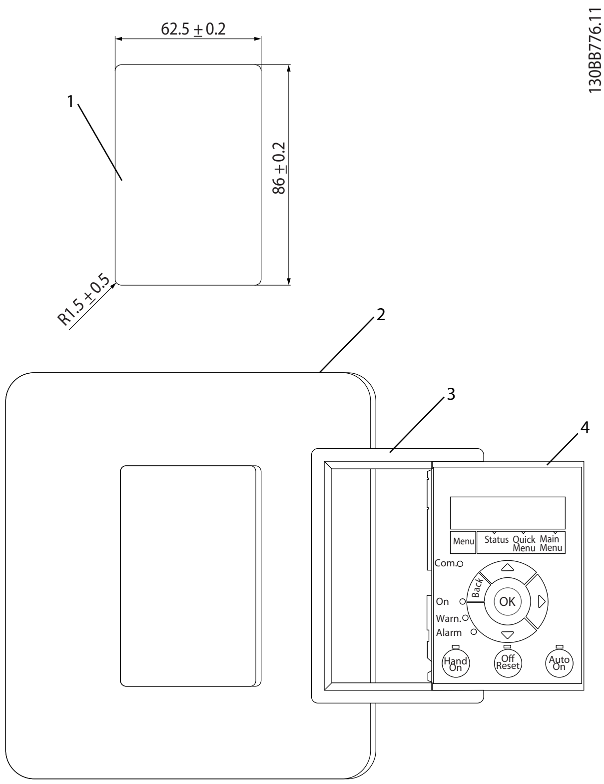
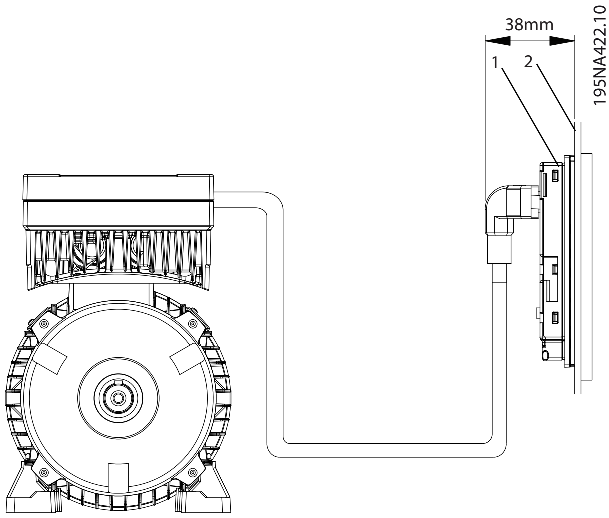


Illustration 3.9 Remote Mounting Kit Connector

1	Panel cut out. Panel thickness 1-3 mm
2	Panel
3	Gasket
4	LCP

Table 3.10 Legend to *Illustration 3.9*



1	Control panel
2	Panel door

Illustration 3.10 LCP Remote Mounting

3.4.2 Local Operation Pad

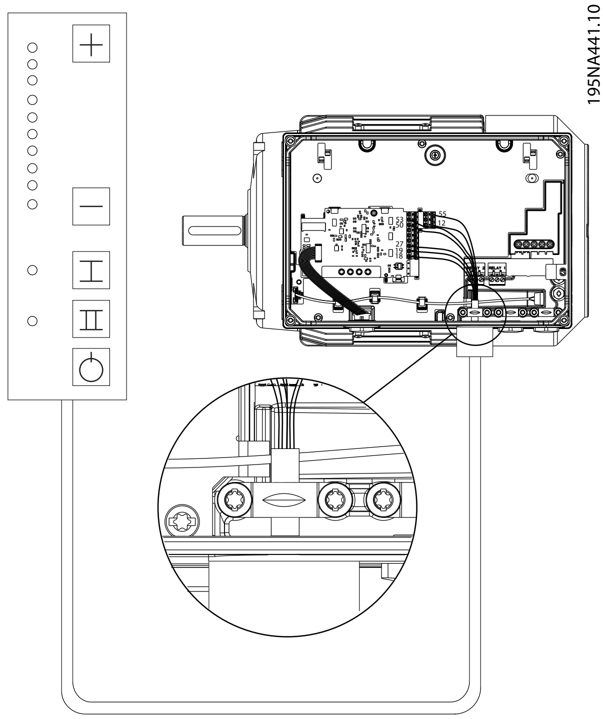


Illustration 3.11 LOP Connections

Key	Dual speed operation	Dual mode operation	Dual direction operation
Key +/-	Set reference		
Key I	Run with reference	Run with setup 1	Run forward
Key II	Run with Jog	Run with setup 2	Run reverse
Key O	Stop + Reset		

Table 3.11 Function

Terminal	Dual speed operation	Dual mode operation	Dual direction operation
18	Purple		Grey
19	-		
27	Brown		
29	Green		
12	Red		
50	Yellow		
55	Blue		

Table 3.12 Electrical Connections

Parameter	Dual speed operation	Dual mode operation	Dual direction operation
Par. 5-10 Terminal 18	Start*		
Par. 5-12 Terminal 27	Reset		
Par. 5-13 Terminal 29	Jog*	Select setup	Start reversing
Additional parameters	Par. 3-11 = Jog speed	Par. 0-10 = Multi setup	Par. 4-10 = Both directions

Table 3.13 Parameter Settings

** indicates factory setting*

Alarms are reset at every start. To avoid this reset, either

- leave the brown wire unconnected, or
- set *5-12 Terminal 27 Digital Input* to *[0] No operation*.

At power-up the unit is always in stop mode. The set reference is stored during power -down.

To set permanent start mode, disable the stop function on the LOP as follows:

- connect terminal 12 to terminal 18
- do not connect purple/grey wire to terminal 18

3.5 Special Conditions

3.5.1 Purpose of Derating

Take derating into account when using the frequency converter at low air pressure (high altitudes), at low speeds, with long motor cables, cables with a large cross section or at high ambient temperature. This section describes the actions required.

3.5.2 Derating for Ambient Temperature and Switching Frequency

Refer to section *chapter 6.10 Derating According to Ambient Temperature and Switching Frequency* in this manual.

3.5.3 Automatic Adaptations to Ensure Performance

The frequency converter constantly checks for critical levels of internal temperature, load current, high voltage on the intermediate circuit and low motor speeds. As a response to a critical level, the frequency converter can adjust the switching frequency and/or change the switching pattern to ensure the performance of the frequency converter. The capability for automatic output current reduction extends the acceptable operating conditions even further.

3.5.4 Derating for Low Air Pressure

The cooling capability of air is decreased at lower air pressure.

- Below 1000 m altitude no derating is necessary
- Above 1000 m altitude, reduce the ambient temperature or the maximum output current.
    - Reduce the output by 1% per 100m altitude above 1000m, or
    - Reduce the max. ambient temperature by 1 °C per 200m altitude.
- Above 2000 m altitude, contact Danfoss regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and thereby ensure 100% output current at high altitudes. Example: At an altitude of 2000m and a temperature of 45 ° C ($T_{AMB, MAX}$ - 3.3K), 91% of the rated output current is available. At a temperature of 41.7 ° C, 100% of the rated output current is available.

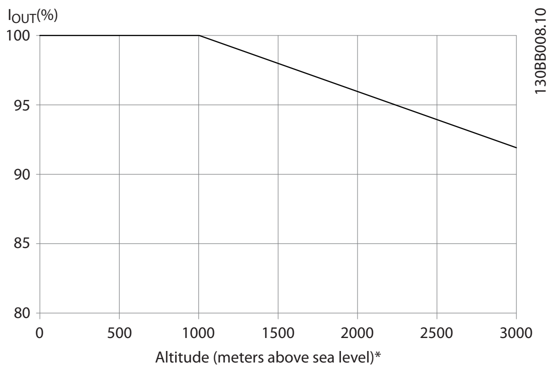


Illustration 3.12 Example

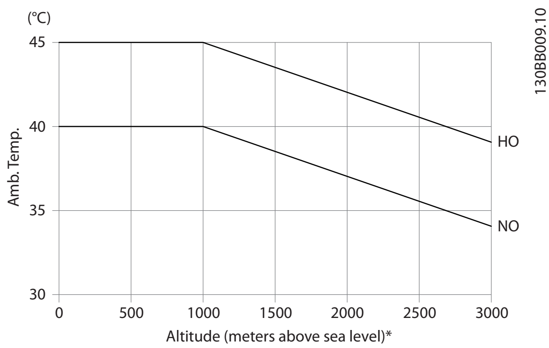


Illustration 3.13 Derating of Output Current versus Altitude at $T_{AMB, MAX}$

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3.5.5 Extreme Running Conditions

Short Circuit (Motor Phase – Phase)
The frequency converter is protected against short circuits by current measurement in each of the 3 motor phases or in the DC link. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter turns off when the short circuit current exceeds the permitted value (Alarm 16 Trip Lock).

Switching on the Output
Switching on the output between the motor and the frequency converter is permitted. Fault messages can appear. To catch a spinning motor, enable flying start.

Motor generated overvoltage
The voltage in the intermediate circuit is increased when the motor acts as a generator. This voltage increase occurs in the following cases:

1. The load drives the motor at constant output frequency from the frequency converter. That is, the load generates energy.
2. During deceleration ("ramp-down") when the moment of inertia is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor, and the installation.
3. Incorrect slip compensation setting can cause higher DC link voltage.
4. Back-EMF from PM motor operation. When coasted at high RPM, the PM motor back-EMF can potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. To help prevent this risk of damage, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation, based on the values of
    - *1-40 Back EMF at 1000 RPM*,
    - *1-25 Motor Nominal Speed*
    - *1-39 Motor Poles*.

    When the motor risks overspeed (for example, due to excessive windmilling effects) then use of a brake resistor is recommended.

The control unit can attempt to correct the ramp (*2-17 Over-voltage Control*).
The inverter turns off to protect the transistors and the intermediate circuit capacitors when a certain voltage level is reached.
Select the method used for controlling the intermediate circuit voltage level via

- *2-10 Brake Function* and
- *2-17 Over-voltage Control*

NOTICE

OVC cannot be activated when running a PM motor (that is, when*1-10 Motor Construction* is set to *[1] PM non-salient SPM*).

Mains Drop-out
During a mains drop-out, the frequency converter keeps running until the DC-link voltage drops below the minimum stop level. The minimum stop level is typically 15% below the lowest rated supply voltage of the frequency converter. The mains voltage before the drop-out and the motor load determines how long it takes for the inverter to coast.

Static Overload in VVC^{plus} mode
When the frequency converter is overloaded, the control reduces the output frequency to reduce the load.
If the overload is excessive, a current can occur that makes the frequency converter cut out after approx. 5–10s.

3.6 Ambient Conditions

3.6.1 Humidity

Although the frequency converter can operate properly at high humidity (up to 95% relative humidity), condensation must always be avoided. There is a specific risk of condensation when the frequency converter is colder than moist ambient air. Moisture in the air can also condense on the electronic components and cause short circuits. Condensation occurs to units without power. It is advisable to install a cabinet heater when condensation is possible due to ambient conditions. Avoid installation in areas subject to frost.

Alternatively, operating the frequency converter in stand-by mode (with the unit connected to the mains) reduces the risk of condensation. However, ensure the power dissipation is sufficient to keep the frequency converter circuitry free of moisture.

The frequency converter complies with the following standards:

- IEC/EN 60068-2-3, EN 50178 9.4.2.2 at 50 °C
- IEC600721 class 3K4

3.6.2 Temperature

Minimum and maximum ambient temperature limits are specified for all frequency converters. Avoiding extreme ambient temperatures prolongs the life of the equipment and maximizes overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although converters can operate at temperatures down to -10 °C, proper operation at rated load is only guaranteed at 0 °C or higher.
- Do not exceed the maximum temperature limit.
- The lifetime of electronic components decreases by 50% for every 10 °C when operated above its design temperature.
- Even devices with IP54, IP55, or IP66 protection ratings must adhere to the specified ambient temperature ranges.
- Additional air conditioning of the cabinet or installation site may be required.

3.6.3 Cooling

Frequency converters dissipate power in the form of heat. The following recommendations are necessary for effective cooling of the units.

- Maximum air temperature to enter enclosure must never exceed 40 °C [104 °F].
- Day/night average temperature must not exceed 35 °C [95 °F]
- Mount the unit to allow for unhindered cooling airflow through the cooling fins. See *chapter 6.1.1 Clearances* for correct mounting clearances.
- Provide minimum front and rear clearance requirements for cooling airflow. See the *VLT® VLT® DriveMotor FCP 106 and FCM 106 Operating Instructions* for proper installation requirements.

3.6.4 Aggressive Environments

A frequency converter contains many mechanical and electronic components. All are to some extent vulnerable to environmental effects.

NOTICE

The frequency converter should not be installed in environments with airborne liquids, particles, or gases capable of affecting and damaging the electronic components. Failure to take the necessary protective measures increases the risk of stoppages, thus reducing the life of the frequency converter.

Liquids can be carried through the air and condense in the frequency converter and may cause corrosion of components and metal parts. Steam, oil, and salt water may cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP54.

Airborne particles such as dust may cause mechanical, electrical, or thermal failure in the frequency converter. A typical indicator of excessive levels of airborne particles is dust particles around the frequency converter fan. In dusty environments, use equipment with enclosure rating IP54 or a cabinet for IP20/TYPE 1 equipment.

In environments with high temperatures and humidity, corrosive gases such as sulphur, nitrogen, and chlorine compounds causes chemical processes on the frequency converter components.

Such chemical reactions rapidly affects and damages the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the frequency converter.

Before installing the frequency converter, check the ambient air for liquids, particles, and gases. This is done by observing existing installations in this environment. Typical indicators of harmful airborne liquids are water or oil on metal parts, or corrosion of metal parts.

Excessive dust particle levels are often found on installation cabinets and existing electrical installations. One indicator of aggressive airborne gases is blackening of copper rails and cable ends on existing installations.

3.6.5 Ambient Temperature

For recommended ambient temperature during storage and operation, refer to *chapter 6.5 Ambient Conditions* and *chapter 6.10 Derating According to Ambient Temperature and Switching Frequency*.

3.6.6 Acoustic Noise

FCP 106
Acoustic noise originates from the sources:

1. External fan
2. DC intermediate circuit coils
3. RFI filter choke

Switching Frequency	MH1	MH2	MH3
[kHz]	[dB]	[dB]	[dB]
5	55	55.5	52

Table 3.14 FCP 106 Acoustic Noise Levels, Fan On, Measured 1m from the Unit

FCM 106
Acoustic noise originates from the sources:

1. Motor fan
2. External fan
3. Motor stator and rotor
4. DC intermediate circuit coils
5. RFI filter choke

Motor speed	Switching frequency	Fan	MH1	MH2	MH3
[rpm]	[kHz]	[on/off]	[dB]	[dB]	[dB]
0	5	on	55	55.5	52
150	5	off	57.5	50	57
150	5	on	61	57	59
1500	5	off	65.5	64	71.5
1500	5	on	66	65.5	71.5
1500	10	off	65	61.5	66.5
1500	16	off	64	60	65.5
1500	16	on	64.5	62	65.5

Table 3.15 FCM 106 Acoustic Noise Levels, Measured 1m from the Unit

3.6.7 Vibration and Shock

The frequency converter complies with requirements that exist for units mounted on the walls and floors of production premises, as well as in panels bolted to walls or floors.

The frequency converter has been tested according to the procedures defined in *Table 3.16*

IEC/EN 60721-3-3	Shock 3M6 (2g / 25g shock)
IEC/EN 60068-2-6	Vibration (sinusoidal) - 1970
IEC/EN 60068-2-64	Vibration, broad-band random
IEC 60068-2-34, 60068-2-35, 60068-2-36	Curve D (1-3) Long-term test 2.52 g RMS

Table 3.16 Vibration and Shock Test Procedure Compliance

4 Application Examples

4.1 HVAC Application Examples

4.1.1 Star/Delta Starter or Soft-starter not Required

When larger motors are started, it is necessary in many countries to use equipment that limits the start-up current. In more traditional systems, a star/delta starter or soft-starter is widely used. Such motor starters are not required if a frequency converter is used.

As illustrated in *Illustration 4.1*, a frequency converter does not consume more than rated current.

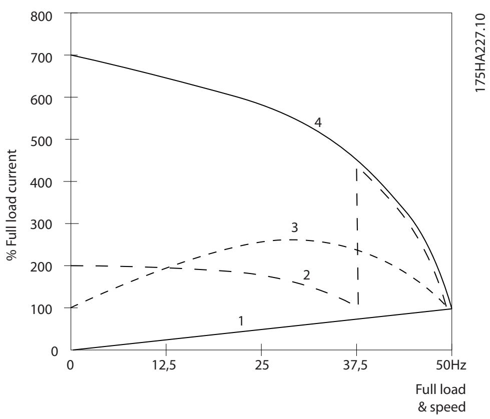


Illustration 4.1 Start-up Current

1	VLT® DriveMotor FCM 106
2	Star/delta starter
3	Soft-starter
4	Start directly on mains

Table 4.1 Legend for *Illustration 4.1*

4.1.2 Start/Stop

Terminal 18 = start/stop *5-10 Terminal 18 Digital Input* [8] *Start*
Terminal 27 = No operation *5-12 Terminal 27 Digital Input* [0] *No operation* (Default *coast inverse*)

5-10 Terminal 18 Digital Input = *Start* (default)

5-12 Terminal 27 Digital Input = *Coast inverse* (default)

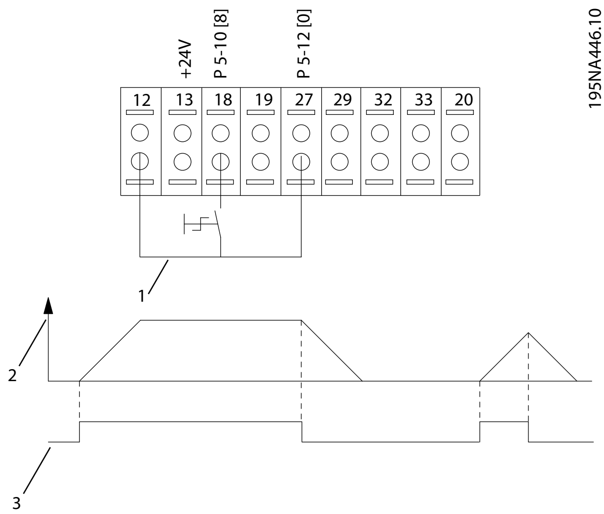


Illustration 4.2 Start/Stop and Running Speed

1	Start/Stop
2	Speed
3	Start/Stop [18]

Table 4.2 Legend for *Illustration 4.2*

4.1.3 Pulse Start/Stop

Terminal 18 = start/stop *5-10 Terminal 18 Digital Input* [9] *Latched start*
Terminal 27= Stop *5-12 Terminal 27 Digital Input* [6] *Stop inverse*

5-10 Terminal 18 Digital Input = *Latched start*

5-12 Terminal 27 Digital Input = *Stop inverse*

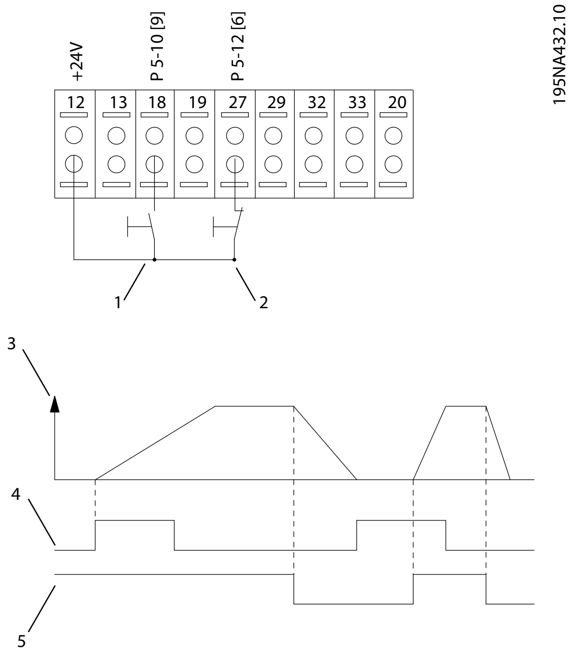


Illustration 4.3 Pulse Start/Stop

1	Start
2	Stop inverse
3	Speed
4	Start (18)
5	Stop (27)

Table 4.3 Legend for *Illustration 4.3*

4.1.4 Potentiometer Reference

Voltage reference via a potentiometer.

3-15 Reference 1 Source [1] = *Analog Input 53*

6-10 Terminal 53 Low Voltage = 0 V

6-11 Terminal 53 High Voltage = 10 V

6-14 Terminal 53 Low Ref./Feedb. Value = 0 RPM

6-15 Terminal 53 High Ref./Feedb. Value = 1.500 RPM

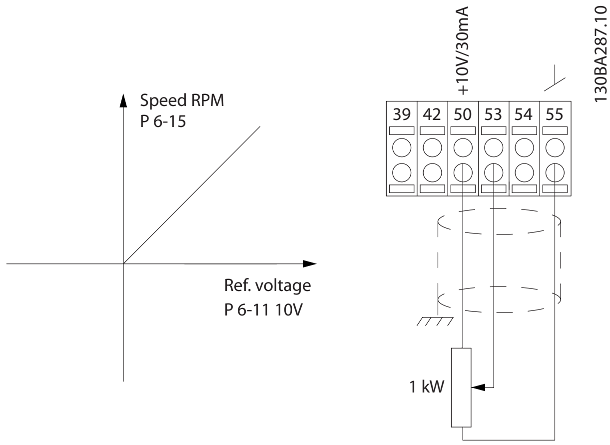


Illustration 4.4 Potentiometer Reference

4.1.5 Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill. This means that AMA itself does not supply any torque.
AMA is useful when commissioning systems and optimising the adjustment of the frequency converter to the applied motor. This feature is particularly used where the default setting does not apply to the connected motor. *1-29 Automatic Motor Adaptation (AMA)* allows a choice of complete AMA with determination of all electrical motor parameters or reduced AMA with determination of the stator resistance Rs only.
The duration of a total AMA varies from a few minutes on small motors to more than 15 minutes on large motors.

Limitations and preconditions:

- For the AMA to determine the motor parameters optimally, enter the correct motor nameplate data in *1-20 Motor Power [kW]* to *1-28 Motor Rotation Check*. For asynchronous motor, enter the correct motor nameplate data in *1-24 Motor Current* and *1-37 d-axis Inductance (Ld)*.
- For the best adjustment of the frequency converter, carry out AMA on a cold motor. Repeated AMA runs may lead to a heating of the motor, which results in an increase of the stator resistance, Rs. Normally, this is not critical.
- AMA can only be carried out if the rated motor current is minimum 35% of the rated output current of the frequency converter. AMA can be carried out on up to one oversize motor.
- It is possible to carry out a reduced AMA test with a Sine-wave filter installed. Avoid carrying out a complete AMA with a Sine-wave filter. If an overall setting is required, remove the Sine-wave filter while running a total AMA. After completion of the AMA, reinsert the Sine-wave filter.
- If motors are coupled in parallel, use only reduced AMA if any.
- The frequency converter does not produce motor torque during an AMA. During an AMA, it is imperative that the application does not force the motor shaft to run, which is known to happen with e.g. wind milling in ventilation systems. This disturbs the AMA function.
- Only Complete AMA can be activated when running a PM motor (when *1-10 Motor Construction* is set to *[1] PM non salient SPM*).

4.1.6 Fan Application with Resonance Vibrations

In the following applications resonant vibrations can arise, which can result in damage to the fan:

- motor with fan mounted directly on the motor shaft,
- running point in field weakening area, and
- running point close to or above nominal point.

Overmodulation is a way to increase the motor voltage delivered by the frequency converter for f_{mot} between 45 Hz and 65 Hz.

- Advantages of overmodulation:
    - Lower currents and higher efficiency are achievable in the field weakening area.
    - The frequency converter can give nominal grid voltage at nominal grid frequency.
    - When the mains voltage occasionally falls below the correct motor voltage, for example, at 43 Hz, then overmodulation can compensate up to the required motor voltage level.
- Disadvantage of overmodulation: The non-sinusoidal voltages increase the harmonics of the voltages. This increase results in torque ripples, which can damage the fan.

Solutions to avoid fan damage

- The best solution is to disable the overmodulation, reducing vibrations to a minimum. However, this solution can also cause derating of the applied motor in the range 5–10%, due to the missing voltage no longer applied by the overmodulation.
- An alternative solution for applications where it is not possible to disable the overmodulation, is to skip a small frequency band of the output frequencies. If the motor is designed to the limit of the fan application, the voltage losses in the frequency converter result in inadequate torque. In these situations, the problem of vibration can be reduced significantly by skipping a small frequency band around the mechanical resonance frequency, for example at the sixth harmonic. This skip can be performed by setting parameters (parameter group *4-6* Speed Bypass*) or by using the semi auto bypass set-up *4-64 Semi-Auto Bypass Set-up*. However, there is no general design rule for making an optimal skip of frequency bands as this is highly dependent on

the width of the resonance peak. In most situations, it is possible to hear the resonance.

4.2 Energy Saving Examples

4.2.1 Why use a Frequency Converter for Controlling Fans and Pumps?

A frequency converter takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information see *chapter 4.2.3 Example of Energy Savings*.

4.2.2 The Clear Advantage - Energy Savings

The clear advantage of using a frequency converter for controlling the speed of fans or pumps lies in the electricity savings.
When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

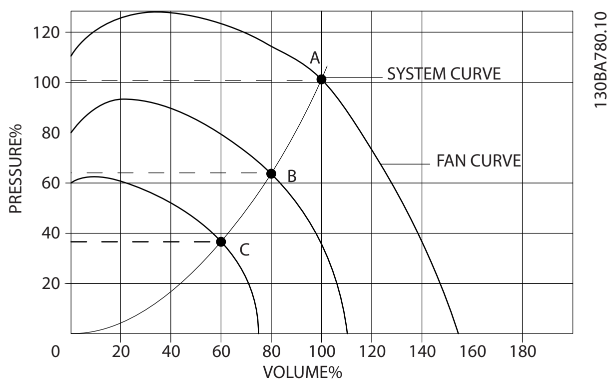


Illustration 4.5 The graph is Showing Fan Curves (A, B, and C) for Reduced Fan Volumes.

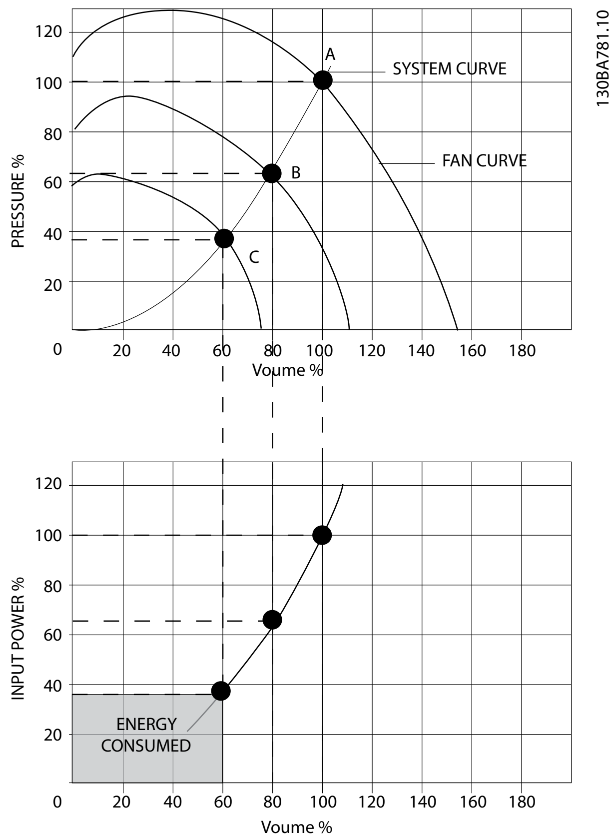


Illustration 4.6 When using a frequency converter to reduce fan capacity to 60% - more than 50% energy savings may be obtained in typical applications.

4.2.3 Example of Energy Savings

As shown in *Illustration 4.7*, the flow is controlled by changing the RPM. By reducing the speed only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.
If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.

Illustration 4.7 describes the dependence of flow, pressure and power consumption on RPM.

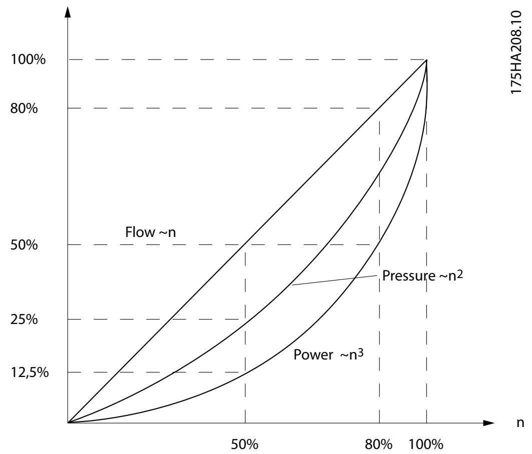


Illustration 4.7 Laws of Proportionalilty

$$Flow: \frac{Q1}{Q2} = \frac{n1}{n2}$$

$$Pressure: \frac{H1}{H2} = \left(\frac{n1}{n2}\right)^2$$

$$Power: \frac{P1}{P2} = \left(\frac{n1}{n2}\right)^3$$

Q=Flow	P=Power
Q_1=Rated flow	P_1=Rated power
Q_2=Reduced flow	P_2=Reduced power
H=Pressure	n=Speed regulation
H_1=Rated pressure	n_1=Rated speed
H_2=Reduced pressure	n_2=Reduced speed

Table 4.4 Legend for *Illustration 4.7*

4.2.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions. This is because the frequency converter is able to control fan speed according to thermal load on the system and the fact that the frequency converter has a built-in facility that enables the frequency converter to function as a Building Management System, BMS.

Illustration 4.8 shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced, for example to 60%. Energy savings of more than 50% can be achieved by applying a VLT solution in typical applications.

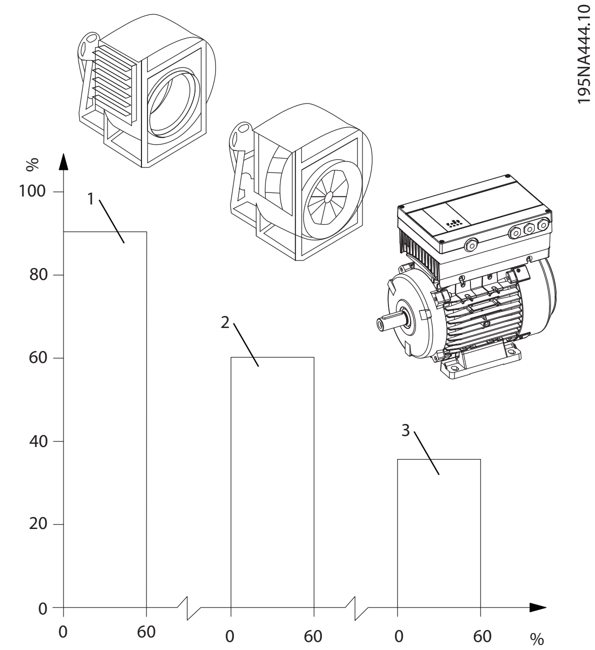


Illustration 4.8 Comparative Energy Consumption for Energy Saving Systems, Input Power (%) vs Volume (%)

1	Discharge damper solution - lower energy savings
2	IGV solution - high installation cost
3	VLT solution - maximum energy savings

Discharge dampers reduce power consumption somewhat. Inlet Guide Vans offer a 40% reduction but are expensive to install. The Danfoss frequency converter solution reduces energy consumption with more than 50% and is easy to install.

4.2.5 Example with Varying Flow over 1 Year

This example is calculated based on pump characteristics obtained from a pump datasheet.
The result obtained shows energy savings in excess of 50% at the given flow distribution over a year. The payback period depends on the price per kWh and price of frequency converter. In this example payback is achieved is less than one year, when compared with valves and constant speed. For calculation of energy savings in specific applications, use VLT Energy box software

Energy savings

$P_{shaft} = P_{shaft\ output}$

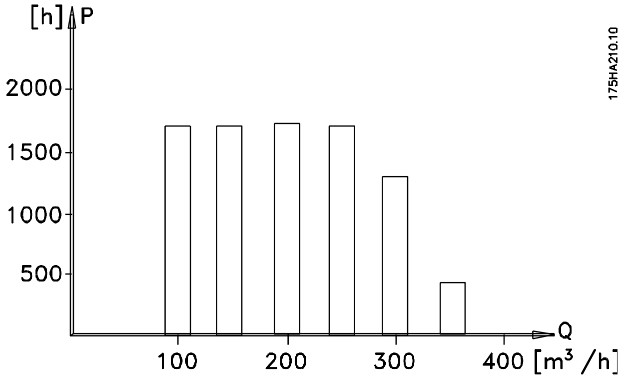


Illustration 4.9 Flow Distribution over 1 Year

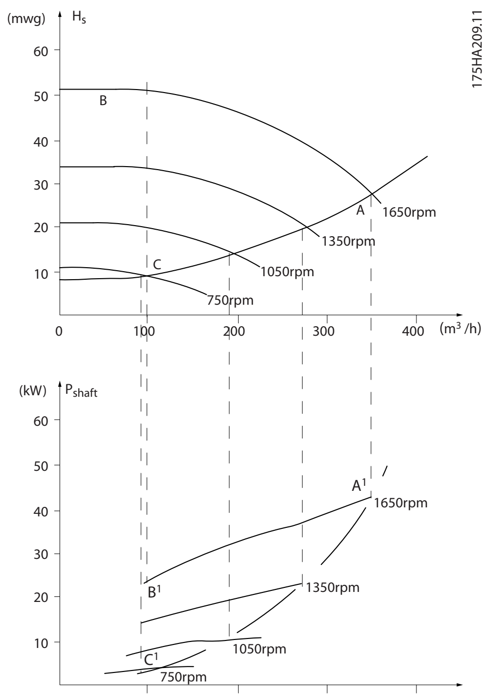


Illustration 4.10 Pump Performance

m³/ h	Distri- bution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consump- tion	Power	Consump- tion
			A_1 - B_1	kWh	A_1 - C_1	kWh
350	5	438	42.5	18.615	42.5	18.615
300	15	1314	38.5	50.589	29.0	38.106
250	20	1752	35.0	61.320	18.5	32.412
200	20	1752	31.5	55.188	11.5	20.148
150	20	1752	28.0	49.056	6.5	11.388
100	20	1752	23.0	40.296	3.5	6.132
Σ	100	8760		275.064		26.801

Table 4.5 Pump Performance

4.3 Control Examples

4.3.1 Better Control

When a frequency converter is used for controlling the flow or pressure of a system, improved control is obtained. A frequency converter can vary the speed of the fan or pump, obtaining variable control of flow and pressure. Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system.
Achieve simple control of process (Flow, Level or Pressure) using the built-in PI control.

4.3.2 Smart Logic Control

A useful facility in the frequency converter is the smart logic control (SLC).
In applications where a PLC is generates a simple sequence, the SLC can take over elementary tasks from the main control.
SLC is designed to act from events sent to or generated in the frequency converter. The frequency converter then performs the pre-programmed action.

4.3.3 Smart Logic Control Programming

The smart logic control (SLC) comprises a sequence of user-defined actions (see *13-52 SL Controller Action*) executed by the SLC when the associated user-defined *event* (see *13-51 SL Controller Event*) is evaluated as TRUE by the SLC.
Events and *actions* are each numbered and are linked in pairs called states. This means that when *event [1]* is fulfilled (attains the value TRUE), *action [1]* is executed. After this, the conditions of *event [2]* is evaluated, and if evaluated TRUE, *action [2]* is executed and so on. Events and actions are placed in array parameters.

Only one *event* is evaluated at any time. If an *event* is evaluated as FALSE, nothing happens (in the SLC) during the present scan interval and no other *events* are evaluated. This means that when the SLC starts, it evaluates *event [1]* (and only *event [1]*) each scan interval. Only when *event [1]* is evaluated TRUE, the SLC executes *action [1]* and starts evaluating *event [2]*.

It is possible to program from 0 to 20 *events* and *actions*. When the last *event/action* has been executed, the sequence starts over again from *event [1]/action [1]*. *Illustration 4.11* shows an example with 3 *events/actions*:

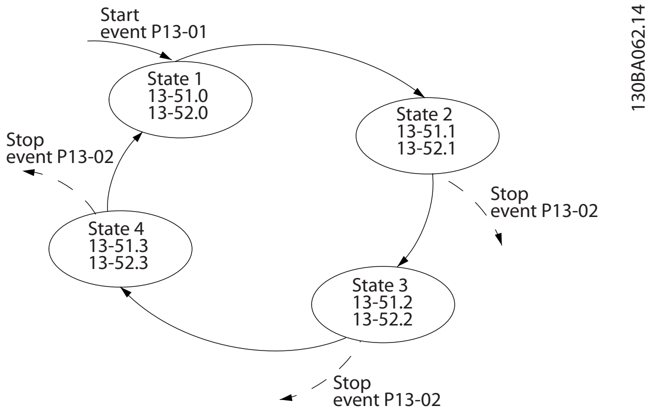


Illustration 4.11 Example with 3 Events/Actions

4.3.4 SLC Application Example

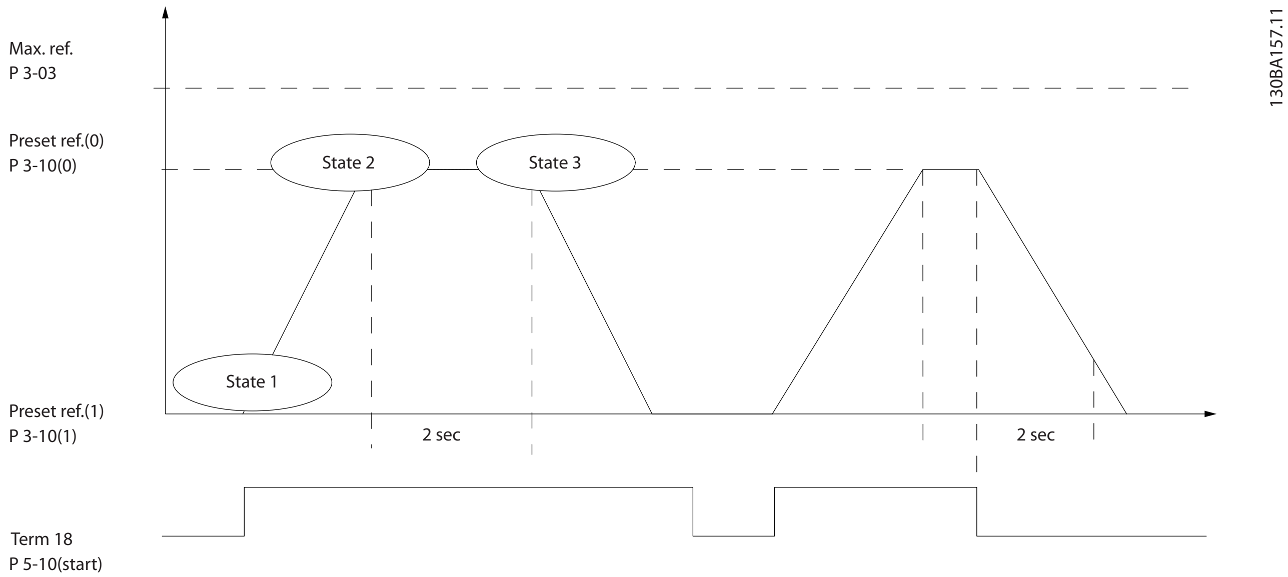


Illustration 4.12 One sequence 1: Start – ramp up – run at reference speed 2 sec – ramp down and hold shaft until stop

Set the ramping times in *3-41 Ramp 1 Ramp Up Time* and *3-42 Ramp 1 Ramp Down Time* to the wanted times

$$tramp = \frac{tacc \times nnorm\,(par.\ 1\ -\ 25)}{ref\,[RPM]}$$

Set term 27 to *No Operation* (*5-12 Terminal 27 Digital Input*)
Set Preset reference 0 to first preset speed (*3-10 Preset Reference* [0]) in percentage of Max reference speed (*3-03 Maximum Reference*). For example: 60%
Set preset reference 1 to second preset speed (*3-10 Preset Reference* [1] For example: 0 % (zero).
Set the timer 0 for constant running speed in *13-20 SL Controller Timer* [0]. For example: 2s.

Set Event 1 in *13-51 SL Controller Event* [1] to *True* [1]
Set Event 2 in *13-51 SL Controller Event* [2] to *On Reference* [4]
Set Event 3 in *13-51 SL Controller Event* [3] to *Time Out 0* [30]
Set Event 4 in *13-51 SL Controller Event* [4] to *False* [0]

Set Action 1 in *13-52 SL Controller Action* [1] to *Select preset 0* [10]
Set Action 2 in *13-52 SL Controller Action* [2] to *Start Timer 0* [29]
Set Action 3 in *13-52 SL Controller Action* [3] to *Select preset 1* [11]
Set Action 4 in *13-52 SL Controller Action* [4] to *No Action* [1]

Set the Smart Logic Control in *13-00 SL Controller Mode* to *[1] ON*.

Start/stop command is applied on terminal 18. If stop signal is applied the frequency converter ramps down and enters free mode.

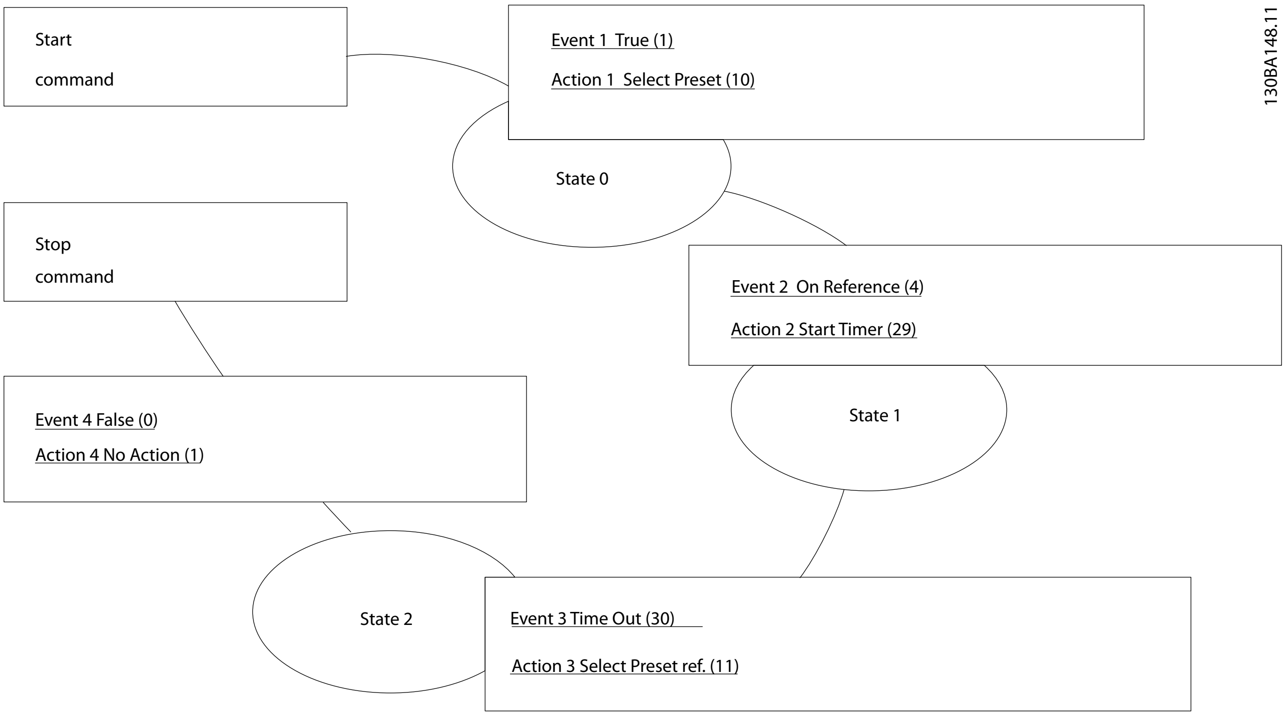


Illustration 4.13 Set Event and Action

4.4 EC+ Concept for Asynchronous and PM Motors

To ensure effective energy savings, system designers take the entire system into account. The decisive factor is not the efficiency of individual components, but rather the efficiency of the overall system. There is no benefit in high-efficiency motor design, if other components in the system work to reduce the overall system efficiency. The EC+ concept enables automatic performance optimisation for components regardless of source. Therefore the system designer is free to select an optimal combination of standard components for frequency converter, motor, and fan/pump and still achieve optimal system efficiency.

Example
A practical HVAC example is the EC version of plug fans with external-rotor motors. To achieve the compact construction, the motor extends into the intake area of the impeller. This intrusion impacts the efficiency of the fan negatively, and therefore reduces the efficiency of the entire ventilation unit. In this case, high motor efficiency does not lead to high system efficiency.

Advantages
The flexibility of EC+ ensures that such reduction of system efficiency is avoided, and provides the system designer and the end user with the following benefits:

- Superior system efficiency thanks to a combination of individual components with optimum efficiency.
- Free choice of motor technology: asynchronous or PM.
- Manufacturer independency in component sourcing.
- Easy and cost efficient retrofitting of existing systems.

FCP 106 and FCM 106 with EC+ enable the system designer to optimise system efficiency, without losing flexibility and reliability.

- The FCP 106 can be mounted on either an asynchronous or a permanent magnet motor.
- The FCM 106 is delivered with an asynchronous motor or a permanent magnet motor. The use of standard motors and standard frequency converters ensures long-term availability of components.

Programming of both FCP 106 and FCM 106 is identical to programming of all other Danfoss frequency converters.

5 Type Code and Selection Guide

5.1 Drive Configurator

Configure a frequency converter according to the application requirements, using the ordering number system.

Frequency converter motors can be ordered as standard or with internal options by using a type code string, for example

FCM106P4K0T4C55H1FSXXAXXE4N4K0150B03000

Refer to the section *chapter 5.2 Type Code String* for a detailed specification of each character in the string. In the example above, a motor with efficiency class IE4 and load profile is normal overload is included in the frequency converter motor. Ordering numbers for frequency converter motor standard variants are available later in this chapter.
To configure the correct frequency converter or frequency converter motor for an application, and generate the type code string, use the Internet based Drive Configurator. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office.
Furthermore, it can establish a project list with several products and send it to a Danfoss sales representative.
To access the Drive Configurator, go to: www.danfoss.com/drives.

5.2 Type Code String

Example of Drive Configurator interface setup: The numbers shown in the boxes refer to the letter/figure number of the Type Code String - read from left to right.

Product		Name	Position	Selection options
FCM 106	FCP 106	Product Group	1-3	FCP FCM
		Series	4-6	106
		Power size	7-10	0.55-7.5 kW (PK55 - P7K5)
		Mains voltage	11-12	T4: 380-480 V AC
		Enclosure	13-15	C66: IP 66/UL TYPE 4X (FCP 106 only) C55: IP 55/NEMA 12 (FCM 106 only)
		RFI filter	16-17	H1: RFI filter Class C1
		Fan option	18	F: with fan
		Special version	19-21	SXX: Latest release - std. Software
		Options	22-23	AX: no option AN: Memory module, without fieldbus [a)] AM: Memory module, Profibus DP V1[a)]
		Not assigned	24	X: Reserved
		Motor range	25	E: Standard motor range
		Efficiency class	26	2: Motor Efficiency IE2 4: Motor Efficiency IE4
		Load profile	27	N: Normal overload H: High overload
		Shaft power	28-30	0.55-7.5 kW (K55-7K5)
		Nominal motor speed	31-33	150: 1500 RPM 180: 1800 RPM 300: 3000 RPM 360: 3600 RPM
		Motor mounting option	34-36	B03: Foot mounting B05: B5 flange B14: B14 Face B34: Foot and B14 face B35: Foot and B5 flange
		Motor flange	37-39	000: Foot mounting only 085: Motor flange size 85 mm 100: Motor flange size 100 mm 115: Motor flange size 115 mm 130: Motor flange size 130 mm 165: Motor flange size 165 mm 215: Motor flange size 215 mm 265: Motor flange size 265 mm 300: Motor flange size 300 mm 350: Motor flange size 350 mm

Table 5.1 Type Code Specification

a) Available for future release

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
F	C	M	1	0	6					T	4	P	5	5	H	1		S	X	X			X	E									B					

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
F	C	P	1	0	6					T	4	P	6	6	H	1		S	X	X			X

195NA445.10

Illustration 5.1 Type Code String Example

5.2.1 Motor Frame Sizes and Flanges

Flange sizes corresponding to motor frame size and FCM 106 rating are listed in *Table 5.2*.

FCM 106 rating	Motor frame size	Mounting version	Flange size, standard (S)	Flange size, alternatives (B)
	4 pole		[mm]	[mm]
0.55 kW	80	B5/B35	165	
		B14/B34	100	75/85/115/130
0.75 kW	80	B5/B35	165	
		B14/B34	100	75/85/115/130
1.1 kW	90	B5/B35	165	215
		B14/B34	115	85/100/130/165
1.5 kW	90	B5/B35	165	215
		B14/B34	115	85/100/130/165
2.2 kW	100	B5/B35	215	
		B14/B34	130	85/100/115
3.0 kW	100	B5/B35	215	
		B14/B34	130	85/100/115
4.0 kW	112	B5/B35	215	
		B14/B34	130	85/100/115
5.5 kW	132	B5/B35	265	
		B14/B34	165	
7.5 kW	132	B5/B35	265	
		B14/B34	165	

Table 5.2 Flange Sizes Corresponding to FCM 106 Rating

S: Available as standard shaft

B: Available as an alternative with standard shaft for frame, requiring no modification

5

5.3 Ordering Numbers

5.3.1 Options and Accessories

Description	Enclosure type[1)] Mains voltage T4 (380-480 V AC)		
	MH1 [kW/Hp]	MH2 [kW/Hp]	MH3 [kW/Hp]
	0.55-1.5/ 0.75-2	2.2-4/ 3-5.5	5.5-7.5/ 7.5-10
Local Control Panel (LCP), IP 55	132B0200		
Mounting kit incl. 3 m cable, IP 55, for LCP	134B0557		
Local Operating Pad (LOP), IP 65	175N0128		
Motor adapter plate kit: motor adapter plate, motor plug, PE connector, gasket for use between FCP 106 and adapter plate, 4 screws	134B0340	134B0390	134B0440
Wall adapter plate kit	*a)*	*a)*	*a)*
Potentiometer option	177N0011		

Table 5.3 Options and Accessories, Ordering Numbers

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

a) Data available upon future release.

5.3.2 Spare Parts

For ordering numbers and ordering in general, refer to

- VLT Shop at http://vltshop.danfoss.com.
- Drive Configurator at www.danfoss.com/drives.

Item	Description	Ordering No.
Fan assembly, MH1	Fan assembly, enclosure type MH1	134B0345
Fan assembly, MH2	Fan assembly, enclosure type MH2	134B0395
Fan assembly, MH3	Fan assembly, enclosure type MH3	134B0445
Accessory bag, MH1	Accessory bag, enclosure type MH1	134b0346
Accessory bag, MH2	Accessory bag, enclosure type MH2	134b0346
Accessory bag, MH3	Accessory bag, enclosure type MH3	134b0446

Table 5.4 Ordering Numbers, Spare parts

5.3.3 Parts Required for Installation

Additional items required for motor connection:

Crimp terminals

- 3 pcs for motor terminals, UVW
- 2 pcs for thermistor (optional)

AMP standard power timer contacts, TE order numbers:

- 927827 (0.5-1 mm^2) [AWG 20-17]
- 927833 (1.5-2.5 mm^2) [AWG 15.5-13.5]
- 927824 (2.5-4 mm^2) [AWG 13-11]

For full installation information including motor connection, refer to the *VLT® DriveMotor FCP 106 and FCM 106 Operating Instructions*.

6 Specifications

6.1 Clearances, Dimensions, and Weights

6.1.1 Clearances

Observe the minimum clearances listed in *Table 6.1* to ensure sufficient air flow for the frequency converter.
When air flow is obstructed close to the frequency converter, ensure adequate inlet of cool air and exhaust of hot air from the unit.

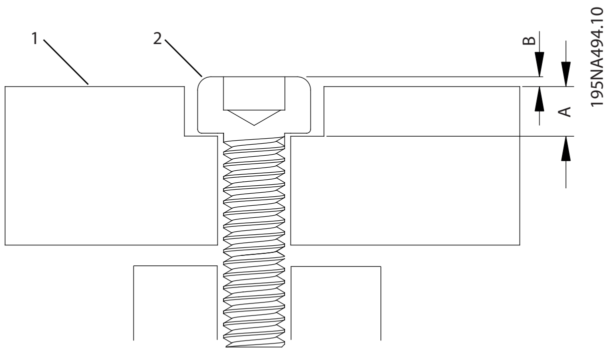
Enclosure		Power1) [kW]	Clearance at ends [mm]	
Enclosure type	IP class	3x380-480 V	Motor flange end	Cooling fan end
MH1	IP66/Type 4X	0.55-1.5	30	100
MH2	IP66/Type 4X	2.2-4.0	40	100
MH3	IP66/Type 4X	5.5-7.5	50	100

Table 6.1 Minimum Clearance for Cooling

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

Enclosure type	Maximum depth of hole into adapter plate (A) [mm]	Maximum height of screw above adapter plate (B) [mm]
MH1	3	0.5
MH2	4	0.5
MH3	3.5	0.5

Table 6.2 Information for Screws to Fasten Motor Adapter Plate



1	Adapter plate
2	Screw
A	Maximum depth of hole into adapter plate
B	Maximum height of screw above adapter plate

Illustration 6.1 Screws to Fasten Motor Adapter Plate

6.1.2 Motor Frame Size Corresponding to FCP 106 Enclosure

PM motor		Asynchronous motor		FCP 106	
1500 RPM	3000 RPM	3000 RPM	1500 RPM	Enclosure	Power [kW]
71	N.A.	N.A.	N.A.	MH1	0.55
71	71	71	80		0.75
71	71	80	90		1.1
71	71	80	90		1.5
90	71	90	100	MH2	2.2
90	90	90	100		3
90	90	100	112		4
112	90	112	112	MH3	5.5
112	112	112	132		7.5

Table 6.3 Motor Frame Size Corresponding to FCP 106 Enclosure

6.1.3 FCP 106 Dimensions

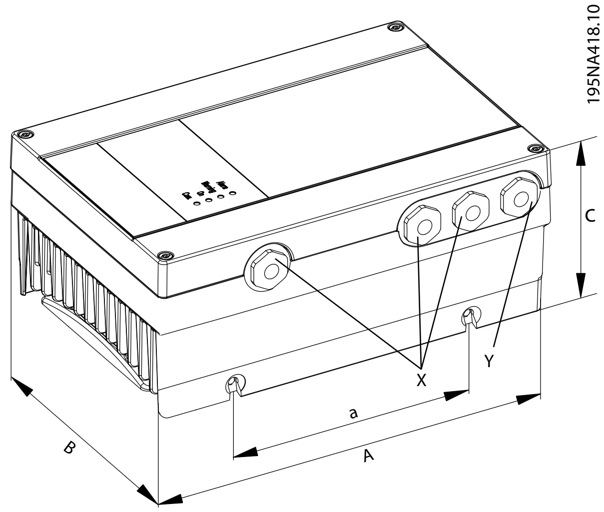


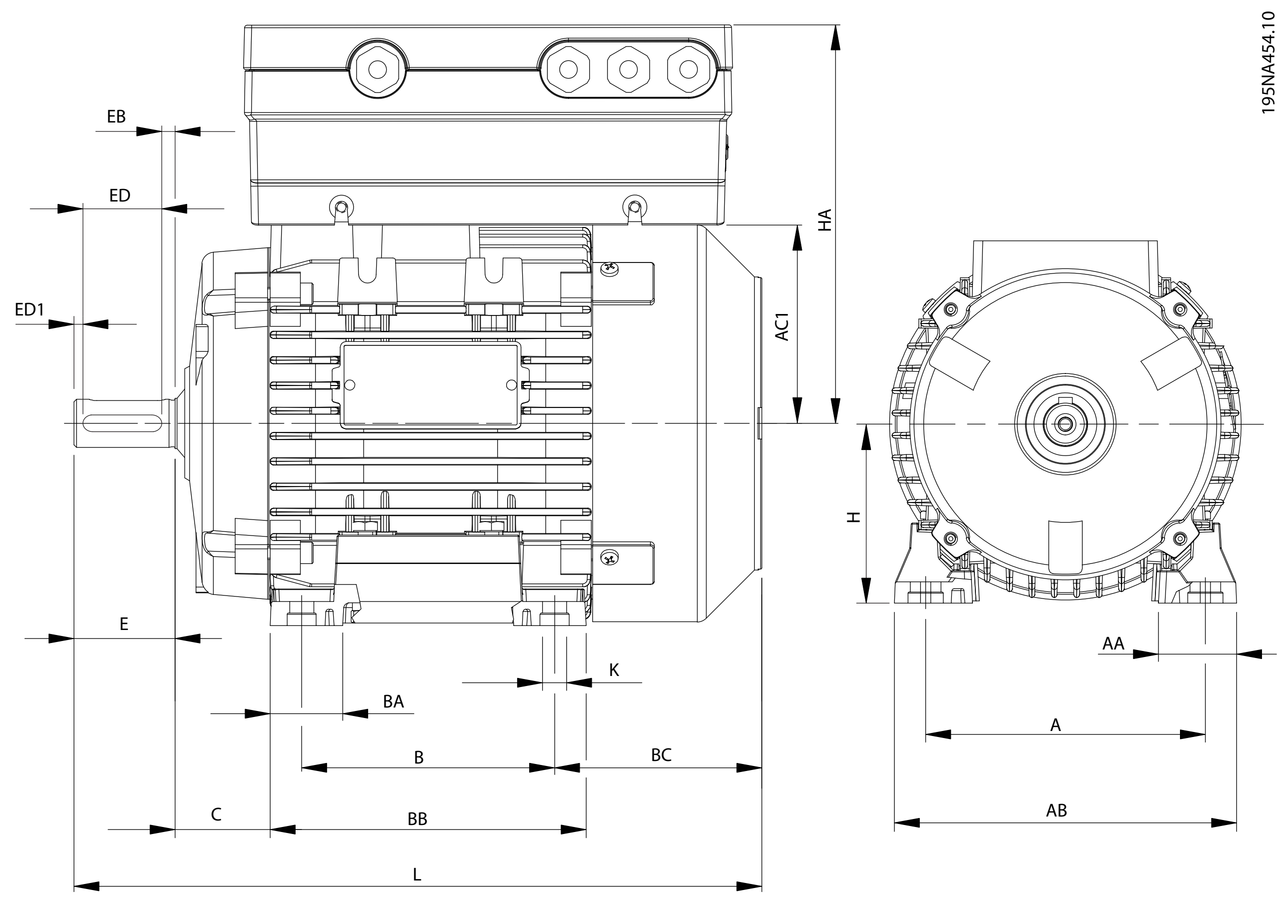
Illustration 6.2 FCP 106 Dimensions

Enclosure type	Power1) [kW]	Length [mm]		Width [mm]	Height [mm]	Cable gland diameter		Mounting hole
	3x380-480 V	A	a	B	C	X	Y	
MH1	0.55-1.5	231.4	130	162.1	106.8	M20	M20	M6
MH2	2.2-4.0	276.8	166	187.1	113.2	M20	M20	M6
MH3	5.5-7.5	321.7	211	221.1	123.4	M20	M25	M6

Table 6.4 FCP 106 Dimensions

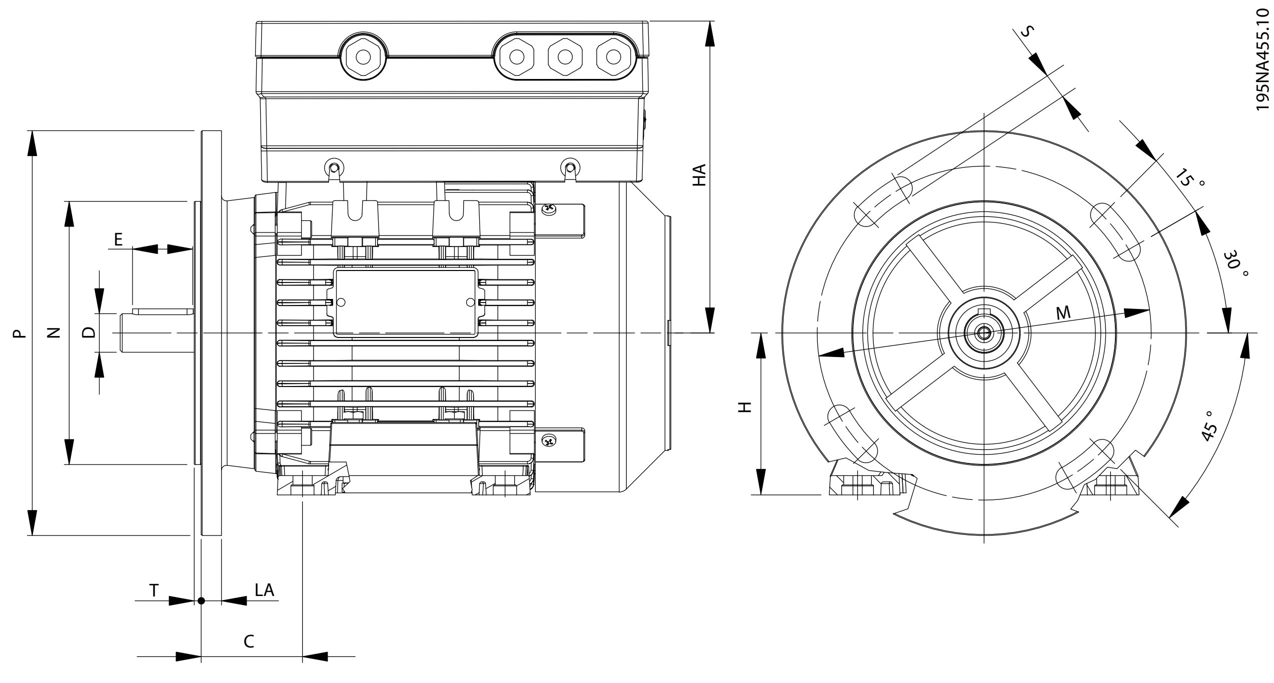
1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

6.1.4 FCM 106 Dimensions



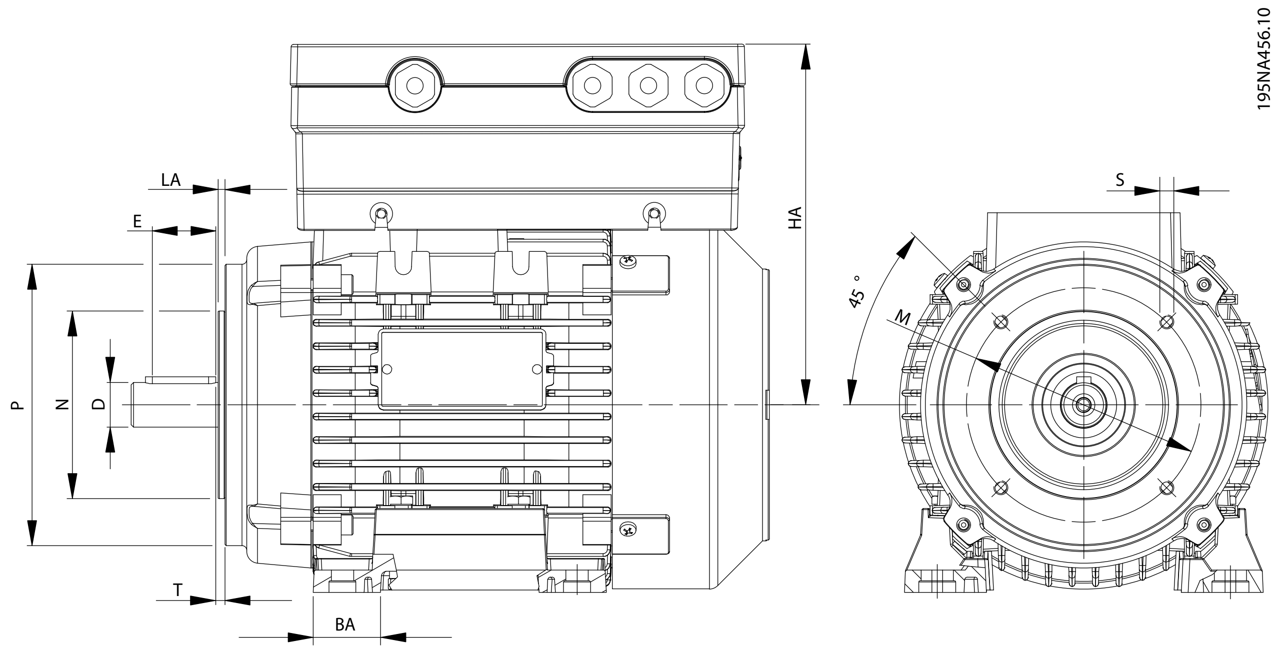
Motor frame size	71	80	90S	90L	100L	100L	112M	132S	132M	160M	160L	180M	180L
A [mm]	112	125	140	140	160	160	190	216	216	254	254	279	279
B [mm]	90	100	100	125	140	140	140	140	178	210	254	241	279
C [mm]	45	50	56	56	63	63	70	89	89	108	108	121	121
H [mm]	71	80	90	90	100	100	112	132	132	160	160	180	180
K [mm]	8	10	10	10	11	11	12.5	12	12	14	14	15	15
AA [mm]	31	34.5	37	37	44	44	48	59	59	76	76	75	75
AB [mm]	135	153	170	170	192	192	220	256	256	320	320	348	348
BB [mm]	108	125	150	150	166	166	176	180	218	270	310	310	348
BC [mm]	83	89	116	91	110	144	126	134	136	180	180	256	256
L [mm]	246	272	317	317	366	400	388	445	485	608	652	687	725
AC [mm]	139	160	180	180	196	194	225	248	248	317	317	360	360
E [mm]	30	40	50	50	60	60	60	80	80	110	110	110	110
ED [mm]	20	30	30	40	40	50	50	70	70	100	100	100	100
EB [mm]	4	4	4	4	4	4	4	4	4	4	4	5	5
FCL [mm]													
FCW [mm]													
HA [mm]	HA = H + (height of the frequency converter) For frequency converter dimensions, see *Table 6.4*.												

Table 6.5 FCM 106 Dimensions: Foot Mounting - B3 Asynchronous or PM Motor



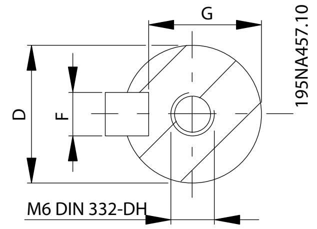
Motor frame size	71	80	90S	90L	100L	112M	132S	160M	180M
M [mm]	130	165	165	165	215	215	265	300	300
N [mm]	110	130	130	130	180	180	230	250	250
P [mm]	160	200	200	200	250	250	300	350	350
S [mm]	M8	M10	M10	M10	M12	M12	M12	M16	M16
T [mm]	3.5	3.5	3.5	3.5	4	4	4	5	5
LA [mm]	10	10	12	12	14	14	14	15	13
HA [mm]	HA = H + (height of the frequency converter) For frequency converter dimensions, see *Table 6.4*.								

Table 6.6 FCM 106 Dimensions: Flange Mounting - B5, B35 for Asynchronous or PM Motor



Small flange B14								
Motor frame size	**71**	**80**	**90S**	**100L**	**112M**	**132S**	**160M/L**	**180M**
M [mm]	85	100	115	130	130	165	215	-
N [mm]	70	80	95	110	110	130	180	-
P [mm]	105	120	140	160	160	200	250	-
S [mm]	M6	M6	M8	M8	M8	M10	M12	-
T [mm]	2.5	3	3	3.5	3.5	3.5	4	-
LA [MM]	11	9	9	10	10	30	12	-
Large flange B14								
Motor frame size	**71**	**80**	**90S**	**100L**	**112M**	**132S**	**160M/L**	**180M**
M [mm]	115	130	130	165	165	215	265	-
N [mm]	95	110	110	130	130	180	230	-
P [mm]	140	160	160	200	200	250	300	-
S [mm]	M8	M8	M8	M10	M10	M12	M16	-
T [mm]	2.5	3.5	3.5	3.5	3.5	4	5	-
LA [MM]	8	8.5	9	12	12	12	12	-
HA [mm]	HA = H + (height of the frequency converter) For frequency converter dimensions, see *Table 6.4*.							

Table 6.7 FCM 106 Dimensions: Face Mounting - B14, B34 for Asynchronous or PM motor



FCM 106 with Asynchronous or PM motor								
Motor frame size	71	80	90S	100L	112M	132S	160M/L	180M
D [mm]	14	19	24	28	28	38	42	48
F [mm]	5	6	8	8	8	10	12	14
G [mm]	11	15.5	20	24	24	33	37	42.5
DH	M5	M6	M8	M10	M10	M12	M16	M16

Table 6.8 FCM 106 Dimensions: Shaft Drive End - Asynchronous or PM Motor

6.1.5 Weight

To calculate the total weight of the unit, add

- weight of combined frequency converter and adapter plate, see *Table 6.9*, and
- weight of motor, see *Table 6.10*.

Enclosure type	Weight		
	FCP 106 [kg]	Motor adapter plate [kg]	Combined FCP 106 and motor adapter plate [kg]
MH1	3.9	0.42	4.3
MH2	5.8	0.54	6.3
MH3	8.1	0.78	8.9

Table 6.9 Weight of FCP 106

Shaft power [kW]	PM motor				Asynchronous motor			
	1500 rpm		3000 rpm		1500 rpm		3000 rpm	
	Frame size	Weight [kg]	Frame size	Weight [kg]	Frame size	Weight [kg]	Frame size	Weight [kg]
0.55	71	4.8	N.A.		N.A.		N.A.	
0.75	71	5.4	71	4.8	80S	11	71	9.5
1.1	71	7.0	71	4.8	90S	16.4	80	11
1.5	71	10	71	6.0	90L	16.4	80	14
2.2	90	12	71	6.6	100L	22.4	90L	16
3	90	14	90S	12	100L	26.5	100L	23
4	90	17	90S	14	112M	30.4	100L	28
5.5	112	30	90S	16	132S	55	112M	53
7.5	112	33	112M	26	132M	65	112M	53

Table 6.10 Approximate Weight of Motor

6.2 Electrical Data

Enclosure	MH1							MH2						MH3
	PK55	PK75		P1K1		P1K5		P2K2		P3K0		P4K0		P5K5
Overload[1)]	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO
Typical shaft output [kW]	0.55		0.75		1.1		1.5		2.2		3.0		4.0	
Typical shaft output [hp]	0.75		1.0		1.5		2.0		3.0		4.0		5.0	
Max. cable cross-section in terminals[2] (mains, motor) [mm²/AWG]	4/10		4/10		4/10		4/10		4/10		4/10		4/10	
Output current														
40 °C ambient temperature														
Continuous (3x380-440 V) [A]	1.7		2.2		3.0		3.7		5.3		7.2		9.0	
Intermittent (3x380-440 V) [A]	1.9	2.7	2.4	3.5	3.3	4.8	4.1	5.9	5.8	8.5	7.9	11.5	9.9	14.4
Continuous (3x440-480 V) [A]	1.6		2.1		2.8		3.4		4.8		6.3		8.2	
Intermittent (3x440-480 V) [A]	1.8	2.6	2.3	3.4	3.1	4.5	3.7	5.4	5.3	7.7	6.9	10.1	9.0	13.2
Max. input current														
Continuous (3x380-440 V)[A]	1.3		2.1		2.4		3.5		4.7		6.3		8.3	
Intermittent (3x380-440 V) [A]	1.4	2.0	2.3	2.6	2.6	3.7	3.9	4.6	5.2	7.0	6.9	9.6	9.1	12.0
Continuous (3x440-480 V) [A]	1.2		1.8		2.2		2.9		3.9		5.3		6.8	
Intermittent (3 x 440-480 V) [A]	1.3	1.9	2.0	2.5	2.4	3.5	3.2	4.2	4.3	6.3	5.8	8.4	7.5	11.0
Max. mains fuses	See *chapter 6.9 Fuse and Circuit Breaker Specifications*													

Table 6.11 Mains Supply 3x380-480 V AC Normal and High Overload: MH1, MH2, and MH3 Enclosure

1) NO: Normal overload, 110% for 1 minute. HO: High overload, 160% for 1 minute

A frequency converter intended for HO requires a corresponding motor rating. For example, Table 6.11 shows that a 1.5 kW motor for HO requires a P2K2 frequency converter.

2) Max. cable cross-section is the largest cable cross-section that can be attached to the terminals. Always observe national and local regulations.

Enclosure	MH3		
	P5K5	P7K5	
Overload[1)]	NO	HO	NO
Typical shaft output [kW]	5.5		7.5
Typical shaft output [hp]	7.5		10
Max. cable cross-section in terminals[2] (mains, motor) [mm^2/AWG]	4/10		4/10
Output current			
40 °C ambient temperature			
Continuous (3x380-440 V) [A]	12		15.5
Intermittent (3x380-440 V) [A]	13.2	14.4	17.1
Continuous (3x440-480 V) [A]	11		14
Intermittent (3x440-480 V) [A]	12.1	13.2	15.4
Max. input current			
Continuous (3x380-440 V)[A]	11		15
Intermittent (3x380-440 V) [A]	12	17	17
Continuous (3x440-480 V) [A]	9.4		13
Intermittent (3 x 440-480 V) [A]	10	15	14
Max. mains fuses	See *chapter 6.9 Fuse and Circuit Breaker Specifications*		

Table 6.12 Mains Supply 3x380-480 V AC Normal and High Overload: MH3 Enclosure

1) NO: Normal overload, 110% for 1 minute. HO: High overload, 160% for 1 minute
A frequency converter intended for HO requires a corresponding motor rating. For example, Table 6.12 shows that a 5.5 kW motor for HO requires a P7K5 frequency converter.

2) Max. cable cross-section is the largest cable cross-section that can be attached to the terminals. Always observe national and local regulations.

6.3 Mains Supply

Mains supply (L1, L2, L3)	
Supply voltage	380-480 V ±10%

Mains voltage low/mains drop-out:

- *During low mains voltage or a mains drop-out, the frequency converter continues until the intermediate circuit voltage drops below the minimum stop level, which corresponds typically to 15% below the lowest rated supply voltage of the frequency converter. Power-up and full torque cannot be expected at mains voltage lower than 10% below the lowest rated supply voltage of the frequency converter.*

Supply frequency	50/60 Hz
Max. imbalance temporary between mains phases	3.0% of rated supply voltage
True Power Factor (λ)	≥ 0.9 nominal at rated load
Displacement Power Factor (cosφ)	near unity (>0.98)
Switching on the input supply L1, L2, L3 (power-ups)	Max. 2 times/min.
Environment according to EN 60664-1	overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than

- 100,000 RMS symmetrical Amperes, 480 V maximum, with fuses used as branch circuit protection
- 10,000 RMS symmetrical Amperes, 480 V maximum, with circuit breakers used as branch circuit protection

6

6.4 Protection and Features

Protection and features

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heat sink ensures that the frequency converter trips when the temperature reaches 90 °C ±5°C. An overload temperature cannot be reset until the temperature of the heatsink is below 70 °C ±5 °C (Guideline - these temperatures may vary for different power sizes, enclosures etc.). The frequency converter auto derating function ensures that the heatsink temperature does not reach 90 °C.
- The frequency converter is protected against short-circuits between motor terminals U, V, W.
- When a motor phase is missing, the frequency converter trips and issues an alarm.
- When a mains phase is missing, the frequency converter trips or issues a warning (depending on the load).
- Monitoring of the intermediate circuit voltage ensures that the frequency converter trips, when the intermediate circuit voltage is too low or too high.
- The frequency converter is protected against earth faults on motor terminals U, V, W.
- All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage). However this does not apply to grounded Delta leg above 400 V.

6.5 Ambient Conditions

Environment	
Enclosure	IP66/Type 4X
Stationary vibration (IEC 60721-3-3 Class 3M6)	2.0 g
Non-stationary vibration (IEC 60721-3-3 Class 3M6)	25.0 g
Relative humidity (IEC 60721-3-3; Class 3K4 (non-condensing))	5%-95% during operation
Aggressive environment (IEC 60721-3-3)	Class 3C3
Test method according to IEC 60068-2-43	H2S (10 days)
Ambient temperature	40 °C (24-hour average)

Minimum ambient temperature during full-scale operation	-10 °C
Minimum ambient temperature at reduced performance	-20 °C
Temperature during storage	-25 to +65 °C
Temperature during transport	-25 to +70 °C

Maximum altitude above sea level without derating	1000 m
Maximum altitude above sea level with derating	3000 m
Safety standards	EN/IEC 60204-1, EN/IEC 61800-5-1, UL 508C
EMC standards, Emission	EN61000-3-2, EN61000-3-12, EN55011, EN61000-6-4
EMC standards, Immunity	EN61800-3, EN61000-6-1/2

6.6 Cable Specifications

Cable lengths and cross sections

Max. motor cable length, screened/armoured	0.5 m
Max. cross section to motor, mains for MH1-MH3.	4 mm^2/10 AWG
Max. cross section DC terminals on enclosure type MH1-MH3	4 mm^2/10 AWG
Maximum cross section to control terminals, rigid wire	2.5 mm^2/14 AWG
Maximum cross section to control terminals, flexible cable	2.5 mm^2/14 AWG
Minimum cross section to control terminals	0.05 mm^2/30 AWG
Max. cross section to thermistor input (at motor connector)	4.0 mm^2

6

6.7 Control Input/Output and Control Data

Digital inputs[A)]

Programmable digital inputs	4
Terminal number	18, 19, 27, 29
Logic	PNP or NPN
Voltage level	0-24 V DC
Voltage level, logic '0' PNP	<5 V DC
Voltage level, logic '1' PNP	>10 V DC
Voltage level, logic '0' NPN	>19 V DC
Voltage level, logic '1' NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	Approx. 4 kΩ
Digital input 29 as Pulse input	Max frequency 32 kHz Push-Pull-Driven & 5 kHz (O.C.)

Analog inputs[A)]

Number of analog inputs	2
Terminal number	53, 54
Terminal 53 mode	Parameter 6-19: 1=voltage, 0=current
Terminal 54 mode	Parameter 6-29: 1=voltage, 0=current
Voltage level	0-10 V
Input resistance, R_i	approx. 10 kΩ
Max. voltage	20 V
Current level	0/4 to 20 mA (scalable)
Input resistance, R_i	<500 Ω
Max. current	29 mA

Analog output[A)]

Number of programmable analog outputs	2
Terminal number	42, 45[1)]
Current range at analog output	0/4-20 mA
Max. load to common at analog output	500 Ω
Max. voltage at analog output	17 V
Accuracy on analog output	Max. error: 0.4% of full scale
Resolution on analog output	10 bit

[1)] Terminal 42 and 45 can also be programmed as digital outputs.

Digital output

Number of digital outputs	2
Terminal number	42, 45[1)]
Voltage level at digital output	17 V
Max. output current at digital output	20 mA
Max. load at digital output	1 kΩ

1) Terminals 42 and 45 can also be programmed as analog output.

Control card, RS-485 serial communication

Terminal number	68 (P, TX+, RX+), 69 (N, TX-, RX-)
Terminal number	61 Common for terminals 68 and 69

Control card, 24 V DC output[A)]

Terminal number	12
Maximum load	80 mA

Relay output[A)]

Programmable relay output	2
Relay 01 and 02	01-03 (NC), 01-02 (NO), 04-06 (NC), 04-05 (NO)
Max. terminal load (AC-1)[1)] on 01-02/04-05 (NO) (Resistive load)	250 V AC, 3 A
Max. terminal load (AC-15)[1)] on 01-02/04-05 (NO) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 01-02/04-05 (NO) (Resistive load)	30 V DC, 2 A
Max. terminal load (DC-13)[1)] on 01-02/04-05 (NO) (Inductive load)	24 V DC, 0.1 A
Max. terminal load (AC-1)[1)] on 01-03/04-06 (NC) (Resistive load)	250 V AC, 3 A
Max. terminal load (AC-15)[1)] on 01-03/04-06 (NC) (Inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Max. terminal load (DC-1)[1)] on 01-03/04-06 (NC) (Resistive load)	30 V DC, 2 A Min. terminal load on 01-03 (NC), 01-02 (NO) 24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

[1)] IEC 60947 parts 4 and 5.

Control card, 10 V DC output[A)]

Terminal number	50
Output voltage	10.5 V ±0.5 V
Max. load	25 mA

[A)] All inputs, outputs, circuits, DC supplies and relay contacts are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

6.8 FCM Motor Specifications

Motor output (U, V, W)	
Output voltage	0-100% of supply voltage
Output frequency, asynchronous motor	0-200 Hz (VVC^{plus}), 0-400 Hz (u/f)
Output frequency, PM motor	0-390 Hz (VVC^{plus} PM)
Switching on output	Unlimited
Ramp times	0.05-3600 s

Thermistor input (at motor connector)	
Input conditions	Fault: >2.9 kΩ, no fault: <800 Ω

6.9 Fuse and Circuit Breaker Specifications

6

Overcurrent protection

Provide overload protection to avoid overheating of the cables in the installation. Overcurrent protection must always be carried out according to local and national regulations. Fuses must be designed for protection in a circuit capable of supplying a maximum of 100,000 A_{rms} (symmetrical), 480 V maximum. Circuit breakers must be designed for protection in a circuit capable of supplying a maximum of 10,000 A_{rms} (symmetrical), 480 V maximum; or the value rated on the individual circuit breaker.

UL/Non UL Compliance

Use the circuit breakers or fuses listed in *Table 6.13*, to ensure compliance with UL or IEC 61800-5-1.
Circuit breakers must be designed for protection in a circuit capable of supplying a maximum of 10,000 A_{rms} (symmetrical), 480 V maximum.
In the event of malfunction, failure to follow the protection recommendation can result in damage to the frequency converter.

Enclosure type	Power [1] [kW] 3x 380-480 V	Circuit Breaker				Fuse							
						Rec. UL	Maximum UL					Rec. non-UL	Max. non-UL
		Rec. UL	Max. UL	Rec. non-UL	Max. non-UL	Type							
						RK5, RK1, J, T, CC	RK5	RK1	J	T	CC	gG	gG
MH1	0.55	CTI25M - 047B3146	CTI25M - 047B3149	CTI25M - 047B3146	CTI25M - 047B3149	6	6	6	6	6	6	10	10
	0.75	CTI25M - 047B3147	CTI25M - 047B3149	CTI25M - 047B3147	CTI25M - 047B3149	6	6	6	6	6	6	10	10
	1.1	CTI25M - 047B3147	CTI25M - 047B3150	CTI25M - 047B3147	CTI25M - 047B3150	6	10	10	10	10	10	10	10
	1.5	CTI25M - 047B3148	CTI25M - 047B3150	CTI25M - 047B3148	CTI25M - 047B3150	6	10	10	10	10	10	10	10
MH2	2.2	CTI25M - 047B3149	CTI25M - 047B3152	CTI25M - 047B3149	CTI25M - 047B3152	6	20	20	20	20	20	16	20
	3.0	CTI25M - 047B3149	CTI25M - 047B3152	CTI25M - 047B3149	CTI25M - 047B3152	15	25	25	25	25	25	16	25
	4.0	CTI25M - 047B3150	CTI25M - 047B3102	CTI25M - 047B3150	CTI25M - 047B3102	15	30	30	30	30	30	16	32
MH3	5.5	CTI25M - 047B3150	CTI25M - 047B3102	CTI25M - 047B3150	CTI25M - 047B3102	20	30	30	30	30	30	25	32
	7.5	CTI25M - 047B3151	CTI25M - 047B3102	CTI25M - 047B3151	CTI25M - 047B3102	25	30	30	30	30	30	25	32

Table 6.13 Fuses and Circuit Breakers

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

6.10 Derating According to Ambient Temperature and Switching Frequency

The ambient temperature measured over 24 hours should be at least 5 °C lower than the max. ambient temperature. If the frequency converter is operated at high ambient temperature, the continuous output current should be decreased.

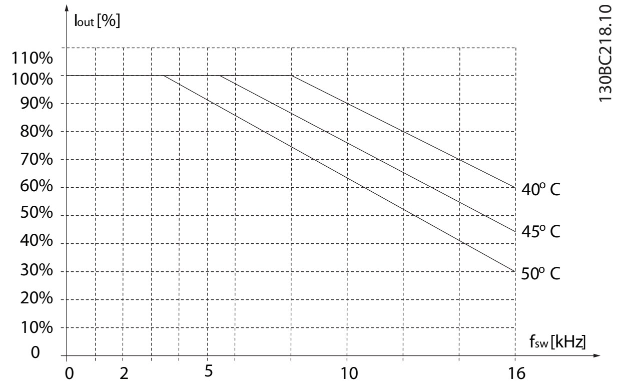


Illustration 6.3 400 V MH1 0.55-1.5 kW

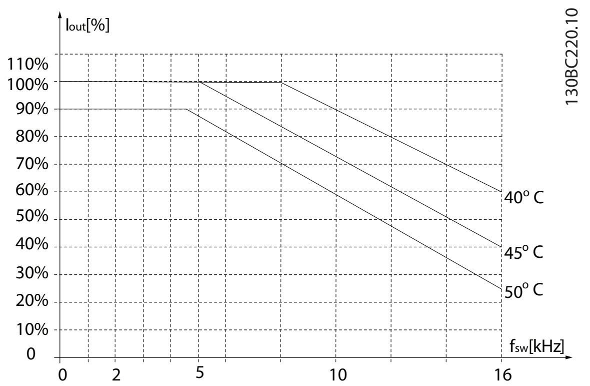


Illustration 6.4 400 V MH2 2.2-4.0 kW

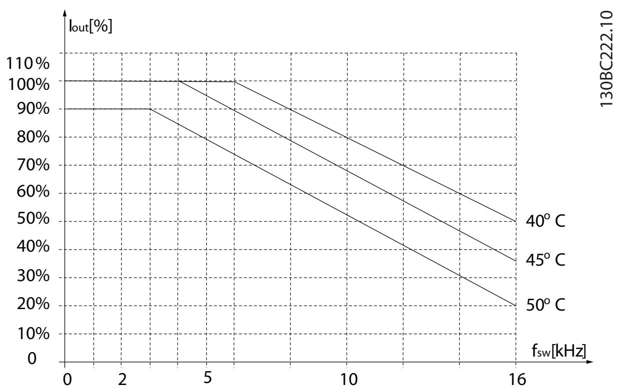


Illustration 6.5 400 V MH3 5.5-7.5 kW

6.11 dU/dt

Shaft output power [kW]	Cable length [m]	AC line voltage [V]	Rise time [µs]	V_{peak} [kV]	dU/dt [kV/µs]
0.55	0.5	400	0.1	0.57	4.5
0.75	0.5	400	0.1	0.57	4.5
1.1	0.5	400	0.1	0.57	4.5
1.5	0.5	400	0.1	0.57	4.5
2.2	<0.5	400	*a)*	*a)*	*a)*
3.0	<0.5	400	*a)*	*a)*	*a)*
4.0	<0.5	400	*a)*	*a)*	*a)*
5.5	<0.5	400	*a)*	*a)*	*a)*
7.5	<0.5	400	*a)*	*a)*	*a)*

Table 6.14 dU/dt, MH1-MH3

a) Data available upon future release

6.12 Efficiency

Efficiency of the frequency converter (η_{VLT})
The load on the frequency converter has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency $f_{M,N}$, even if the motor supplies 100% of the rated shaft torque or only 75%, i.e. in case of part loads.

This also means that the efficiency of the frequency converter does not change even if other U/f characteristics are chosen.
However, the U/f characteristics influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value of above 5 kHz. The efficiency will also be slightly reduced if the mains voltage is 480V.

Frequency converter efficiency calculation
Calculate the efficiency of the frequency converter at different loads based on *Illustration 6.6*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables:

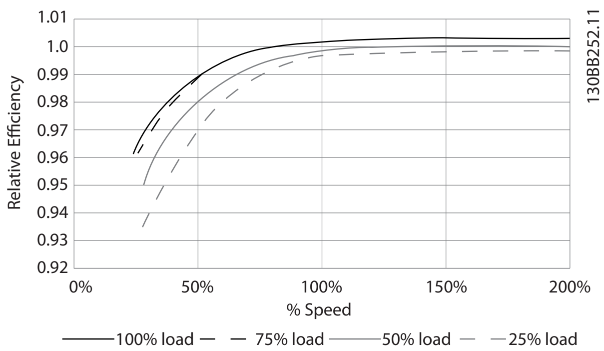


Illustration 6.6 Typical Efficiency Curves

Example: Assume a 22 kW, 380-480V AC frequency converter runs at 25% load at 50% speed. The graph shows 0.97, whereas rated efficiency for a 22 kW frequency converter is 0.98. The actual efficiency is then: 0.97x0.98=0.95.

Efficiency of the motor (η_{MOTOR})
The efficiency of a motor connected to the frequency converter depends on the magnetizing level. In general, the efficiency is just as good as with mains operation. The efficiency of the motor depends on the type of motor.

In the range of 75-100% of the rated torque, the efficiency of the motor is practically constant, both when it is controlled by the frequency converter and when it runs directly on mains.

In small motors, the influence from the U/f characteristic on efficiency is marginal. However, in motors from 11 kW and up, the advantages are significant.

In general, the switching frequency does not affect the efficiency of small motors. Motors from 11 kW and up have their efficiency improved (1-2%). This is because the sine shape of the motor current is almost perfect at high switching frequency.

Efficiency of the system (η_{SYSTEM})
To calculate the system efficiency, the efficiency of the frequency converter (η_{VLT}) is multiplied by the efficiency of the motor (η_{MOTOR}):

$\eta_{SYSTEM} = \eta_{VLT} \times \eta_{MOTOR}$

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