ENGINEERING TOMORROW

Design Guide
VLT® DriveMotor FCP 106/FCM 106

vlt-drives.danfoss.com

Contents

1 Introduction

1.1 Purpose of the Design Guide

This design guide for Danfoss VLT® DriveMotor FCP 106 and FCM 106 is intended for:

- Project and systems engineers.
- Design consultants.
- Application and product specialists.

The design guide provides technical information to understand the capabilities of the frequency converter for integration into motor control and monitoring systems.

The purpose of the design guide is to provide design considerations and planning data for integration of the frequency converter into a system. The design guide caters for selection of frequency converters and options for a diversity of applications and installations.

Reviewing the detailed product information in the design stage enables developing a well-conceived system with optimal functionality and efficiency.

VLT® is a registered trademark.

1.2 Additional Resources

Available literature:

- *VLT® DriveMotor FCP 106/FCM 106 Operating Instructions,* for information required to install and commission the frequency converter.
- *VLT® DriveMotor FCP 106/FCM 106 Design Guide* provides information required for integration of the frequency converter into a diversity of applications.
- *VLT® DriveMotor FCP 106/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).
- *Modbus RTU Operating Instructions* and *VLT® DriveMotor FCP 106/FCM 106 BACnet Operating Instructions* for information required for controlling, monitoring, and programming of the frequency converter.
- The *VLT® PROFIBUS DP MCA 101 Installation Guide* provides information about installing the PROFIBUS and troubleshooting.
- The *VLT® PROFIBUS DP MCA 101 Programming Guide* provides information about configuring the system, controlling the frequency converter, accessing the frequency converter, programming, and troubleshooting. It also contains some typical application examples.
- *VLT® Motion Control Tool MCT 10* enables configuration of the frequency converter from a Windows™-based PC environment.
- *Danfoss VLT® Energy Box* software, for energy calculation in HVAC applications.

Technical literature and approvals are available online at *vlt-drives.danfoss.com/Support/Service/*.

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

1.3 Symbols, Abbreviations, and Conventions

The following symbols are used in this manual.

NOTICE

Indicates important information to be regarded with attention to avoid mistakes or to avoid operating equipment at less than optimal performance.

* Indicates default setting.

Degree of protection	The degree of protection is a standardised specification for electrical equipment that describes the protection against the ingress of foreign objects and water (for example: IP20).
DIx	DI1: Digital input 1. DI2: Digital input 2.
EMC	Electromagnetic compatibility.
Error	Discrepancy between a computed, observed, or measured value or condition, and the specified or theoretically correct value or condition.
Factory setting	Factory settings when the product is shipped.
Fault	An error can cause a fault state.
Fault reset	A function used to restore the frequency converter to an operational state after a detected error is cleared by removing the cause of the error. The error is then no longer active.
MM	Memory module.

MMP	Memory module programmer.
Parameter	Device data and values that can be read and set (to a certain extent).
PELV	Protective extra low voltage, low voltage with isolation. For more information, see IEC 60364-4-41 or IEC 60204-1.
PLC	Programmable logic controller.
RS485	Fieldbus interface as per EIA-422/485 bus description, which enables serial data transmission with multiple devices.
Warning	If the term is used outside the context of safety instructions, a warning alerts to a potential problem that a monitoring function detected. A warning is not an error and does not cause a transition of the operating state.

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.
- All dimensions are in mm (inch).

1.4 Approvals

Frequency converters are designed in compliance with the directives described in this section.

For more information on approvals and certificates, go to the download area at *vlt-marine.danfoss.com/support/type-approval-certificates/*.

Certification		FCP 106	FCM 106
EC Declaration of Conformity		✓	✓
UL listed		–	✓
UL recognized		✓	–
C-tick		✓	✓

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

- Low Voltage Directive 2006/95/EC, based on EN 61800-5-1 (2007).
- EMC Directive 2004/108/EC, based on EN 61800-3 (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 recognized
More 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.

1.4.1 What is Covered

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

- 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.
- 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 do not need to be CE marked.
- 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.

1.4.2 CE Mark

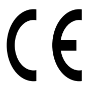


Illustration 1.1 CE

The CE mark (Communauté Européenne) indicates that the product manufacturer conforms to all applicable EU directives. The EU directives applicable to the design and manufacture of frequency converters are listed in *Table 1.2*.

NOTICE

The CE mark does not regulate the quality of the product. Technical specifications cannot be deduced from the CE mark.

NOTICE

Frequency converters with an integrated safety function must comply with the machinery directive.

EU Directive	Version
Low Voltage Directive	2014/35/EU
EMC Directive	2014/30/EU
Machinery Directive[1)]	2014/32/EU
ErP Directive	2009/125/EC
ATEX Directive	2014/34/EU
RoHS Directive	2002/95/EC

Table 1.2 EU Directives Applicable to Frequency Converters

1) Machinery Directive conformance is only required for frequency converters with an integrated safety function.

Declarations of conformity are available on request.

1.4.2.1 Low Voltage Directive

The Low Voltage Directive applies to all electrical equipment in the 50–1000 V AC and the 75–1600 V DC voltage ranges.

The aim of the directive is to ensure personal safety and avoid property damage, when operating electrical equipment that is installed, maintained, and used as intended.

1.4.2.2 EMC Directive

The purpose of the EMC (electromagnetic compatibility) Directive is to reduce electromagnetic interference and enhance immunity of electrical equipment and installations. The basic protection requirement of the EMC Directive is that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference. The devices must have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended.

Electrical equipment devices used alone or as part of a system must bear the CE mark. Systems do not require the CE mark, but must comply with the basic protection requirements of the EMC Directive.

1.4.2.3 Machinery Directive

The aim of the Machinery Directive is to ensure personal safety and avoid property damage for mechanical equipment used in its intended application. The Machinery Directive applies to a machine consisting of an aggregate of interconnected components or devices of which at least 1 is capable of mechanical movement.

Frequency converters with an integrated safety function must comply with the Machinery Directive. Frequency converters without a safety function do not fall under the Machinery Directive. If a frequency converter is integrated into a machinery system, Danfoss can provide information on safety aspects relating to the frequency converter.

When frequency converters are used in machines with at least 1 moving part, the machine manufacturer must provide a declaration stating compliance with all relevant statutes and safety measures.

1.4.2.4 ErP Directive

The ErP Directive is the European Ecodesign Directive for energy-related products. The directive sets ecodesign requirements for energy-related products, including frequency converters. The aim of the directive is to increase energy efficiency and the level of protection of the environment, while increasing the security of the energy supply. Environmental impact of energy-related products includes energy consumption throughout the entire product life cycle.

1.4.3 C-tick Compliance

Illustration 1.2 C-tick

The C-tick label indicates compliance with the applicable technical standards for Electromagnetic Compatibility (EMC). C-tick compliance is required for placing electrical and electronic devices on the market in Australia and New Zealand.

The C-tick regulatory is about conducted and radiated emission. For frequency converters, apply the emission limits specified in EN/IEC 61800-3.

A declaration of conformity can be provided on request.

1.4.4 UL Compliance

Illustration 1.3 UL Listed

Illustration 1.4 UL Recognized

The frequency converter complies with UL 508C thermal memory retention requirements. For more information, refer to *chapter 3.3.9 Motor Thermal Protection*.

1.4.5 Export Control Regulations

Frequency converters can be subject to regional and/or national export control regulations.

The frequency converters that are subject to export control regulations are classified by an ECCN number.

The ECCN number is provided in the documents accompanying the frequency converter.

In case of re-export, it is the responsibility of the exporter to ensure compliance with the relevant export control regulations.

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

1.7.1 General Safety Principles

If handled improperly, frequency converters have the potential for fatal injury as they contain high-voltage components. Only qualified personnel should install and operate the equipment. Do not attempt repair work without first removing power from the frequency converter and waiting the designated amount of time for stored electrical energy to dissipate.

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

Correct and reliable transport, storage, installation, operation, and maintenance are required for the trouble-free and safe operation of the frequency converter. Only qualified personnel are allowed to install and operate this equipment.

Qualified personnel are defined as trained staff, who are authorized to install, commission, and maintain equipment, systems, and circuits in accordance with pertinent laws and regulations. Additionally, the qualified personnel must be familiar with the instructions and safety measures described in these operating instructions.

⚠WARNING

HIGH VOLTAGE

Frequency converters contain high voltage when connected to AC mains input, DC supply, or load sharing. Failure to perform installation, start-up, and maintenance by qualified personnel can result in death or serious injury.

- **Only qualified personnel must perform installation, start-up, and maintenance.**

WARNING

UNINTENDED START

When the frequency converter is connected to AC mains, DC supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. The motor can start via an external switch, a fieldbus command, an input reference signal from the LCP, or after a cleared fault condition.
To prevent unintended motor start:

- **Disconnect the frequency converter from the mains.**
- **Press [Off/Reset] on the LCP before programming parameters.**
- **Completely wire and assemble the frequency converter, motor, and any driven equipment before connecting the frequency converter to AC mains, DC supply, or load sharing.**

WARNING

DISCHARGE TIME

The frequency converter contains DC-link capacitors, which can remain charged even when the frequency converter is not powered. High voltage can be present even when the warning LED indicator lights are off. Failure to wait the specified time after power has been removed before performing service or repair work can result in death or serious injury.

- **Stop the motor.**
- **Disconnect AC mains and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.**
- **Disconnect or lock PM motor.**
- **Wait for the capacitors to discharge fully. The minimum duration of waiting time is specified in *Table 1.3*.**
- **Before performing any service or repair work, use an appropriate voltage measuring device to make sure that the capacitors are fully discharged.**

Voltage [V]	Power range[1)] [kW (hp)]	Minimum waiting time (minutes)
3x400	0.55–7.5 (0.75–10)	4

Table 1.3 Discharge Time

1) Power ratings relate to normal overload (NO).

WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the frequency converter properly can result in death or serious injury.

- **Ensure the correct grounding of the equipment by a certified electrical installer.**

WARNING

EQUIPMENT HAZARD

Contact with rotating shafts and electrical equipment can result in death or serious injury.

- **Ensure that only trained and qualified personnel perform installation, start-up, and maintenance.**
- **Ensure that electrical work conforms to national and local electrical codes.**
- **Follow the procedures in this guide.**

WARNING

UNINTENDED MOTOR ROTATION WINDMILLING

Unintended rotation of permanent magnet motors creates voltage and can charge the unit, resulting in death, serious injury, or equipment damage.

- **Ensure that permanent magnet motors are blocked to prevent unintended rotation.**

CAUTION

INTERNAL FAILURE HAZARD

An internal failure in the frequency converter can result in serious injury when the frequency converter is not properly closed.

- **Ensure that all safety covers are in place and securely fastened before applying power.**

2 Product Overview

2

2.1 Introduction

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

VLT® DriveMotor FCP 106
The delivery comprises the frequency converter only. A wall mount adapter plate, or motor adapter plate and power crimp terminals are also required for installation. Order the wall mount kit or adapter plate and power crimp terminals separately.

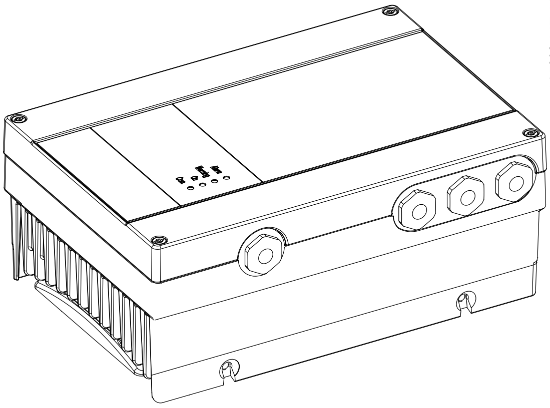


Illustration 2.1 FCP 106

VLT® DriveMotor FCM 106
The frequency converter is mounted onto the motor at delivery. The combined FCP 106 and motor is known as the VLT® DriveMotor FCM 106.

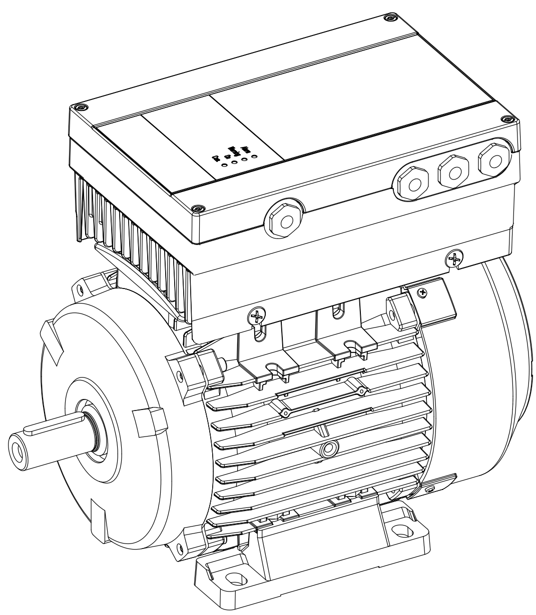


Illustration 2.2 FCM 106

2.1.1 Gasket

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

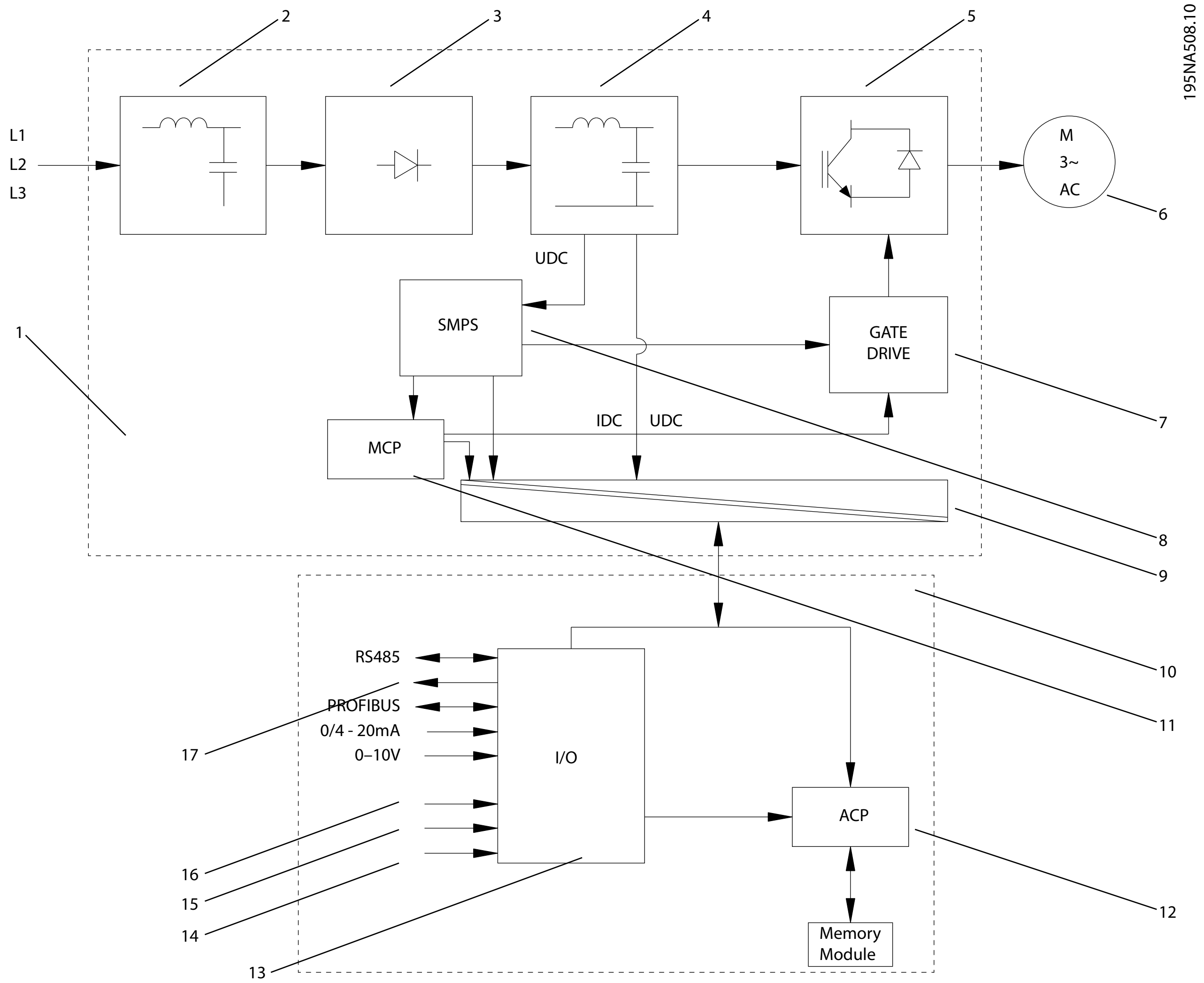
No gasket is supplied with the FCP 106 frequency converter.

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 the motor and the frequency converter.
- Use a UL-approved material for the gasket, when UL listing or recognition is required for the assembled product.

2.1.2 Key Diagram



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

Illustration 2.3 Key Diagram

2.1.3 Electrical Overview

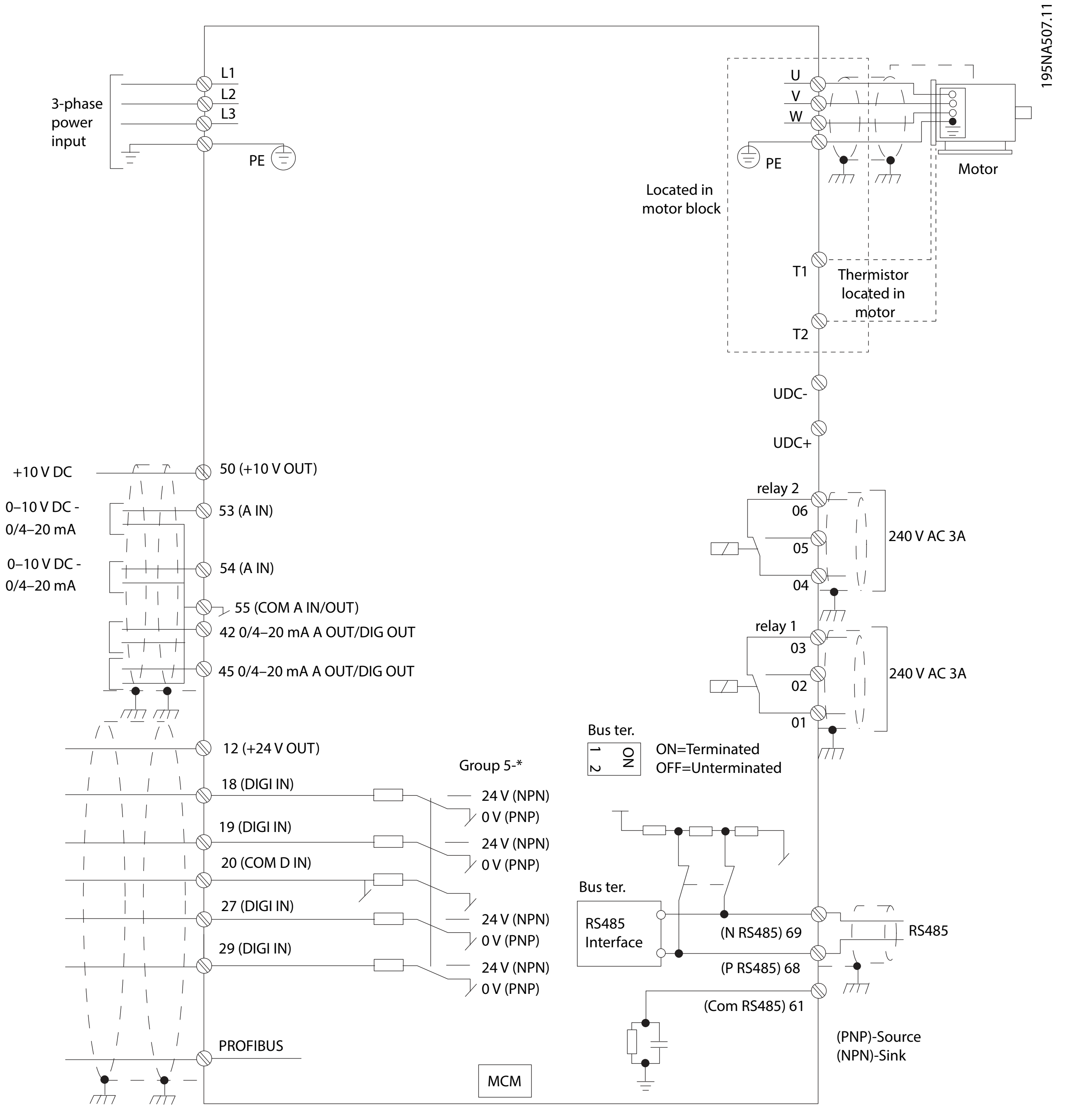
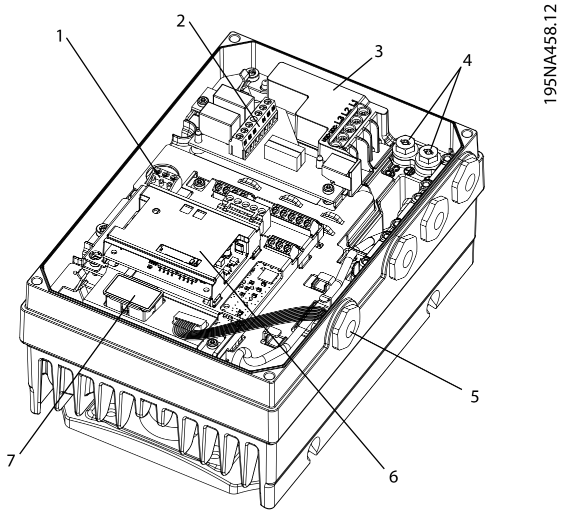


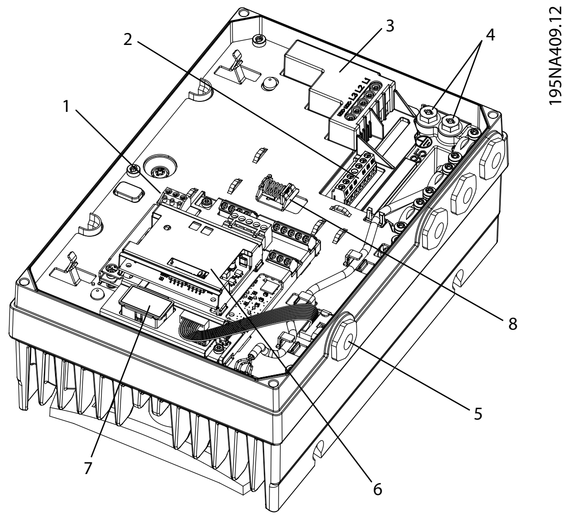
Illustration 2.4 Electrical Overview

2.1.4 Control Terminals and Relays 3



1	Control terminals
2	Relay terminals
3	UDC+, UDC-, Line (L3, L2, L1)
4	PE
5	LCP connector
6	VLT® PROFIBUS DP MCA 101
7	VLT® Memory Module MCM 101

Illustration 2.5 Location of Terminals and Relays, MH1



1	Control terminals
2	Relay terminals
3	UDC+, UDC-, Line (L3, L2, L1)
4	PE
5	LCP connector
6	VLT® PROFIBUS DP MCA 101
7	VLT® Memory Module MCM 101
8	Spring clamp for PROFIBUS cable

Illustration 2.6 Location of Terminals and Relays, MH2–MH3

Control terminals

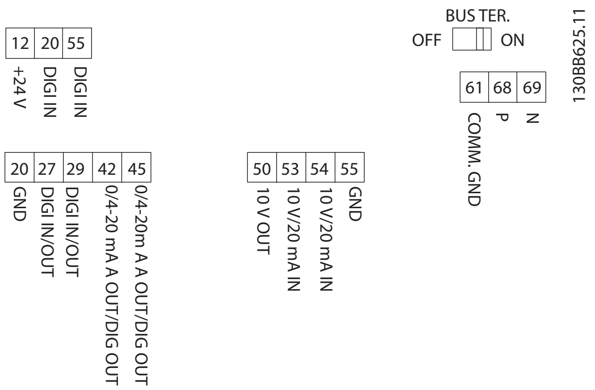


Illustration 2.7 Control Terminals

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/ output	*PNP/NPN	Coast inverse
29	Digital input/ output/pulse 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	10 bit	*0–20 mA/4–20 mA/DO	Analog
45	10 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 2.1 Control Terminal Functions

** Indicates default setting.*

NOTICE

PNP/NPN is common for terminals 18, 19, 27, and 29.

2.1.5 Serial Communication (Fieldbus) Networks

These protocols are embedded in the frequency converter:

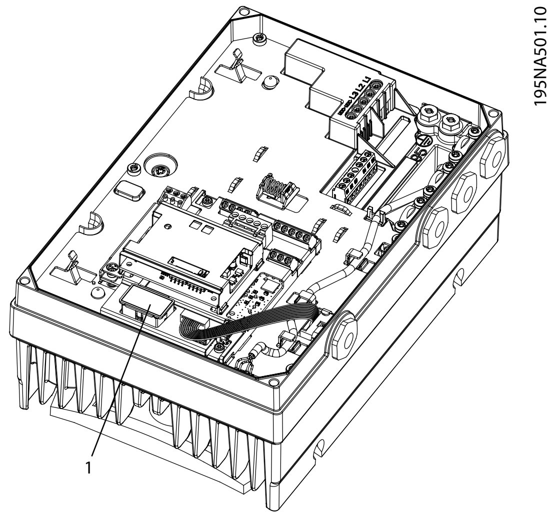
- BACnet MSTP
- Modbus RTU
- FC Protocol

2.2 VLT® Memory Module MCM 101

The VLT® Memory Module MCM 101 is a small memory plug containing data such as:

- Firmware.
- SIVP file.
- Pump table.
- Motor database.
- Parameter lists.

The frequency converter comes with the module installed from the factory.



1	VLT® Memory Module MCM 101

Illustration 2.8 Location of Memory Module

If the memory module becomes defect, it does not prevent the frequency converter from working. The warning LED on the lid flashes, and a warning shows in the LCP (if installed).

Warning 206, Memory module indicates that either a frequency converter runs without a memory module, or that the memory module is defect. To see the exact reason for the warning, refer to *parameter 18-51 Memory Module Warning Reason*.

A new memory module can be ordered as a spare part. Ordering number: 134B0791.

2.2.1 Configuring with the VLT® Memory Module MCM 101

When replacing or adding a frequency converter to a system, it is easy to transfer existing data to the new frequency converter. However, the frequency converters must be of the same power size and with compatible hardware.

⚠WARNING

DISCONNECT POWER BEFORE SERVICING!

Before performing repair work, disconnect the frequency converter from AC mains. After mains has been disconnected, wait 4 minutes for the capacitors to discharge. Failure to follow these steps can result in death or serious injury.

1. Remove the lid from a frequency converter containing a memory module.
2. Unplug the memory module.
3. Place and tighten the lid.
4. Remove the lid from the new frequency converter.
5. Insert the memory module in the new/other frequency converter and leave it in.
6. Place and tighten the lid on the new frequency converter.
7. Power up the frequency converter.

NOTICE

The first power-up takes approximately 3 minutes. During this time, all data is transferred to the new frequency converter.

2.2.2 Copying Data via PC and Memory Module Programmer (MMP)

By using a PC and the MMP, it is possible to create several memory modules with the same data. These memory modules can then be inserted in a number of VLT® DriveMotor FCP 106 or VLT® DriveMotor FCM 106.

Examples of data that can be copied are:

- Firmware.
- Parameter set-up.
- Pump curves.

While running, the download status is visible on the screen.

1. Connect an FCP 106 or FCM 106 to a PC.
2. Transfer the configuration data from the PC to the frequency converter. This data is NOT encoded.

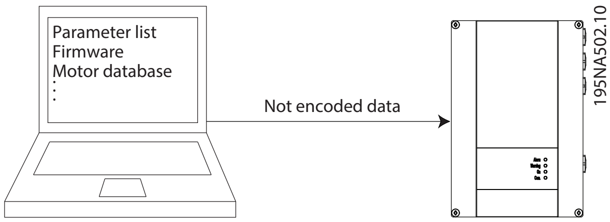


Illustration 2.9 Data Transfer from PC to Frequency Converter

3. The data is automatically transferred from the frequency converter to the memory module as encoded data.

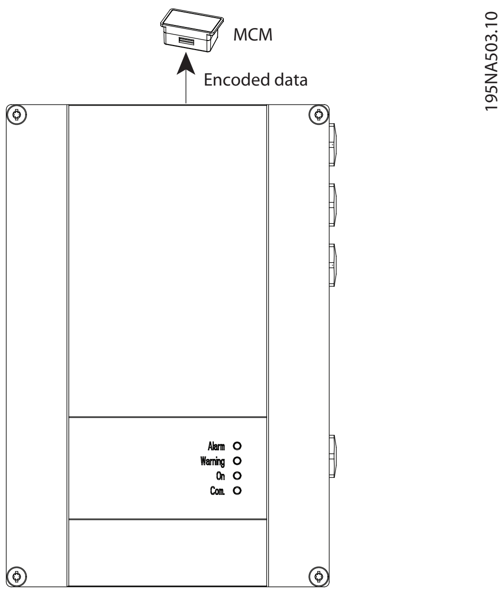


Illustration 2.10 Data Transfer from Frequency Converter to Memory Module

4. Plug the memory module into the MMP.
5. Connect the MMP to a PC to transfer the data from the memory module.

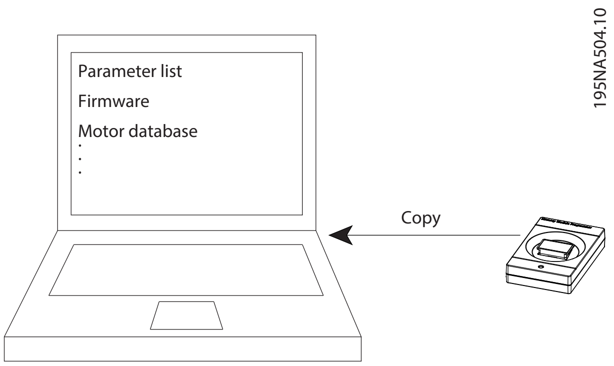


Illustration 2.11 Data Transfer from MMP to PC

6. Insert an empty memory module into the MMP.
7. Select which data to copy from the PC to the memory module.

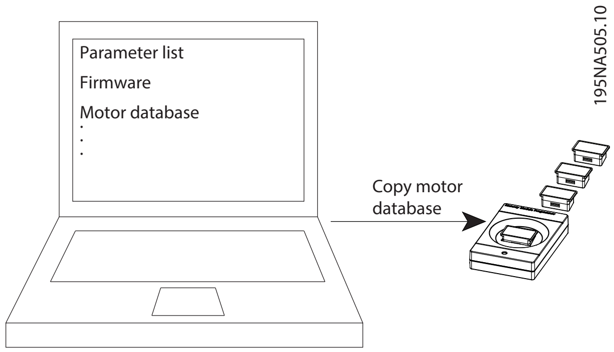


Illustration 2.12 Data Transfer from PC to Memory Module

8. Repeat steps 6 and 7 for each memory module needed with that particular configuration.
9. Place the memory modules in the frequency converters.

2.2.3 Copying a Configuration to Several Frequency Converters

It is possible to transfer the configuration of 1 VLT® DriveMotor FCP 106 or VLT® DriveMotor FCM 106 to several others. It only requires a frequency converter that already has the wanted configuration.

1. Remove the lid from the frequency converter with the configuration to be copied.
2. Unplug the memory module.
3. Remove the lid from the frequency converter to which the configuration must be copied.
4. Plug in the memory module.
5. When copying is complete, plug in an empty memory module in the frequency converter.
6. Place and tighten the lid.
7. Power cycle the frequency converter.
8. Repeat steps 3–7 for each frequency converter that is to receive the configuration.
9. Place the memory module in the original frequency converter.
10. Place and tighten the lid.

2.3 Control Structures

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

2.3.1 Control Structure Open Loop

In the configuration shown in *Illustration 2.13*, *parameter 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. After that, it is sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

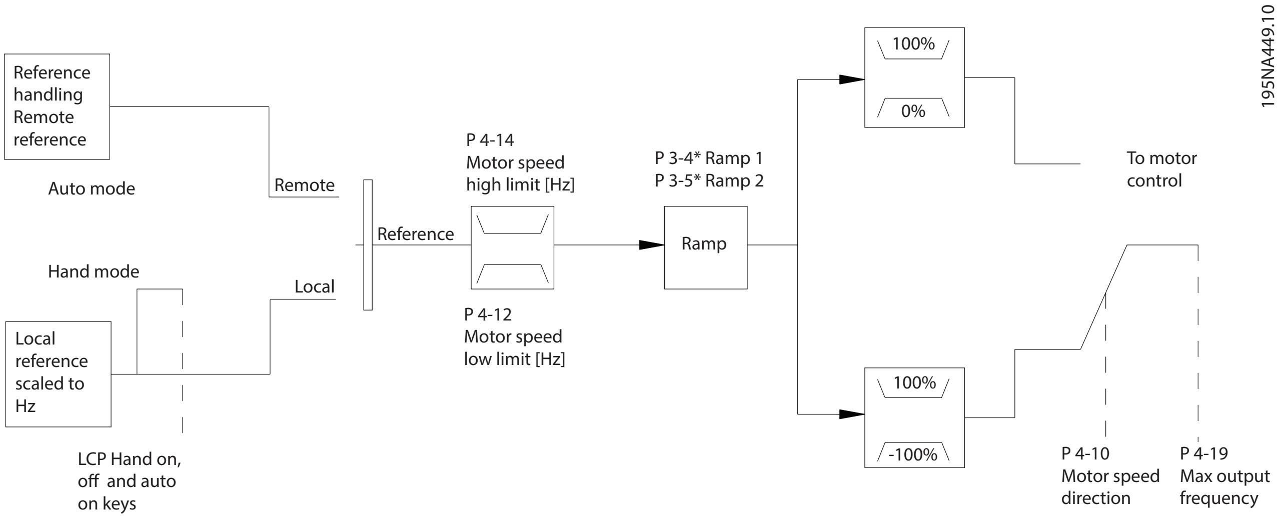


Illustration 2.13 Open-loop Structure

2.3.2 Control Structure Closed Loop (PI)

The internal controller allows the frequency converter to become a 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 setpoint 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 controlling the speed of a pump to ensure a constant static pressure in a pipe. The desired static pressure value is supplied to the frequency converter as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this data to the frequency converter as a feedback signal. If the feedback signal is greater than the setpoint reference, the frequency converter reduces speed to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the frequency converter automatically speeds up to increase the pump pressure.

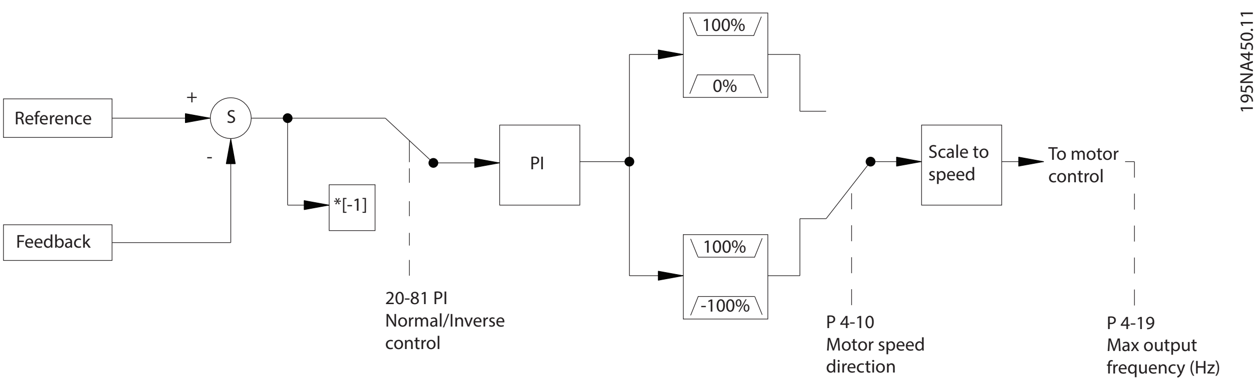


Illustration 2.14 Closed-loop Controller

While the default values for the closed-loop controller often provide satisfactory performance, the control of the system can often be optimized by adjusting the closed-loop controller parameters.

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

Operate the frequency converter manually via the local control panel (LCP) or remotely via analog/digital inputs or fieldbus.

Start and stop the frequency converter pressing the [Hand On] and [Off/Reset] keys on the LCP. Set-up is required:

- *Parameter 0-40 [Hand on] Key on LCP*.
- *Parameter 0-44 [Off/Reset] Key on LCP*.
- *Parameter 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*.

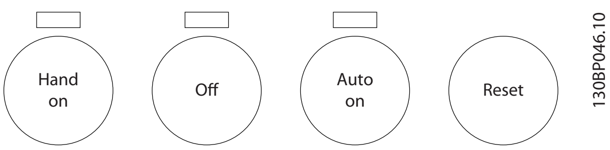


Illustration 2.15 LCP Control Keys

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

Local reference is restored at power-down.

2.5 Feedback and Reference Handling

2.5.1 Reference Handling

Details for open-loop and closed-loop operation.

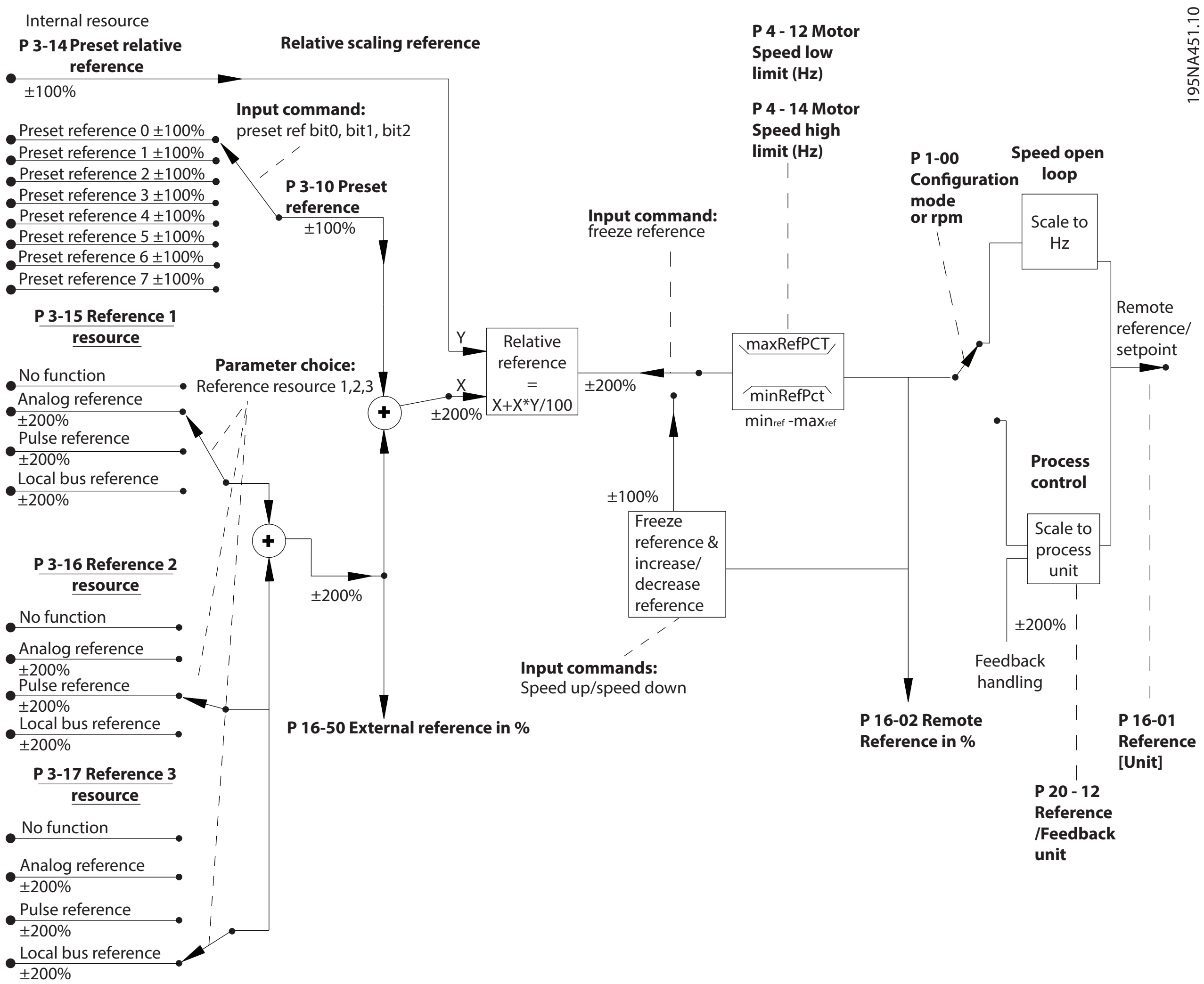


Illustration 2.16 Block Diagram Showing Remote Reference

The remote reference comprises:

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

2

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:

- *Parameter 3-15 Reference 1 Source*.
- *Parameter 3-16 Reference 2 Source*.
- *Parameter 3-17 Reference 3 Source*.

Sum all reference resources and the bus reference to produce the total external reference. Select the external reference, the preset reference, or the sum of the 2 as the active reference. Finally, this reference can by be scaled using *parameter 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 references, and Y is *parameter 3-14 Preset Relative Reference* in [%].

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

2.5.2 Feedback Handling

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

2.5.3 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 2.17*.

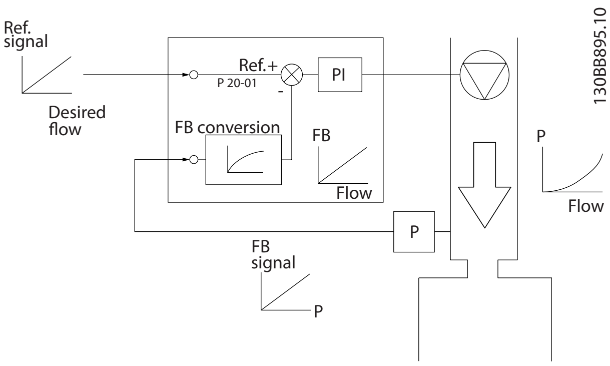


Illustration 2.17 Feedback Conversion

2.6 General Aspects of EMC

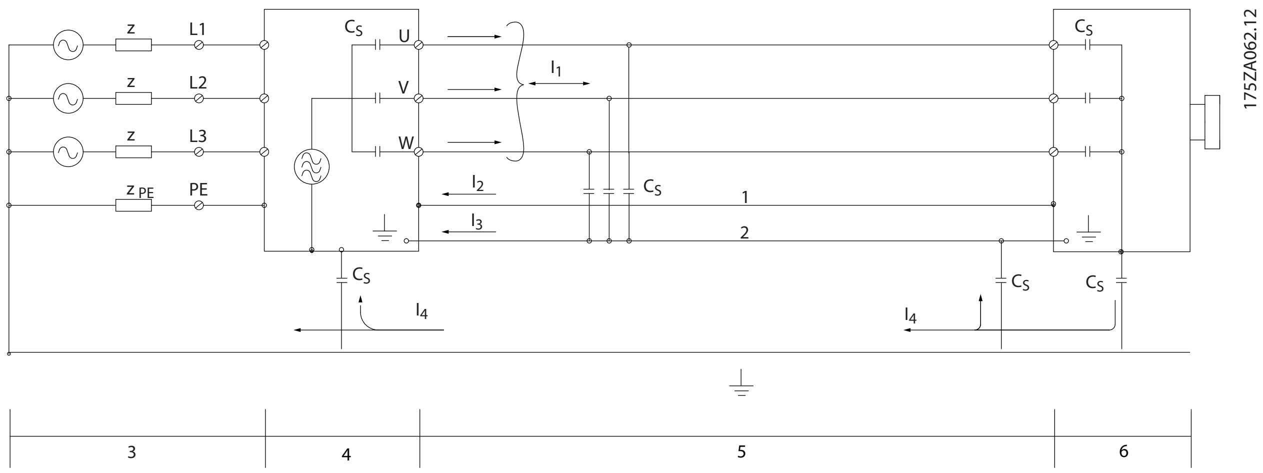
Burst transient is conducted at frequencies in the range 150 kHz to 30 MHz. The inverter, the motor cable, and the motor generate airborne interference from the frequency converter system in the range 30 MHz to 1 GHz.
Capacitance in the motor cable coupled with a high dU/dt from the motor voltage generates leakage currents.
The use of a screened motor cable increases the leakage current (see *Illustration 2.18*) 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 electromagnetic field (I_4) from the screened motor cable.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. Connect the motor cable screen to the frequency converter enclosure and to 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).

Mount the screen at both ends of the enclosure, if a screened cable is used for:

- Relay.
- Control cable.
- Signal interface.
- Brake.

In some situations, however, it is necessary to break the screen to avoid current loops.



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

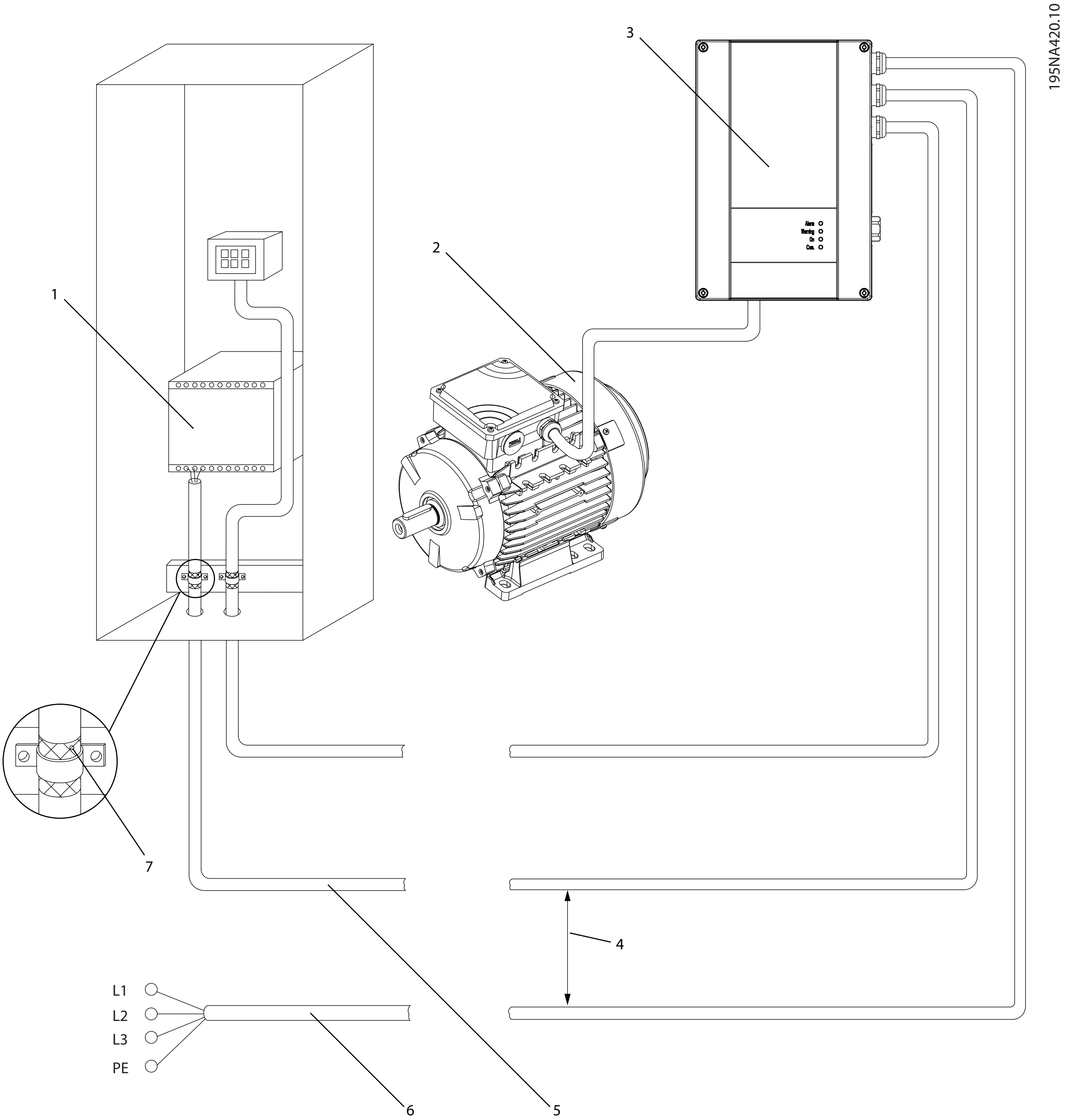
Illustration 2.18 Equivalent Diagram: Coupling of Capacitors, which Generates Leakage Currents

When positioning a screen on a frequency converter mounting plate, the mounting plate must be made of metal. Metal mounting plates 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.

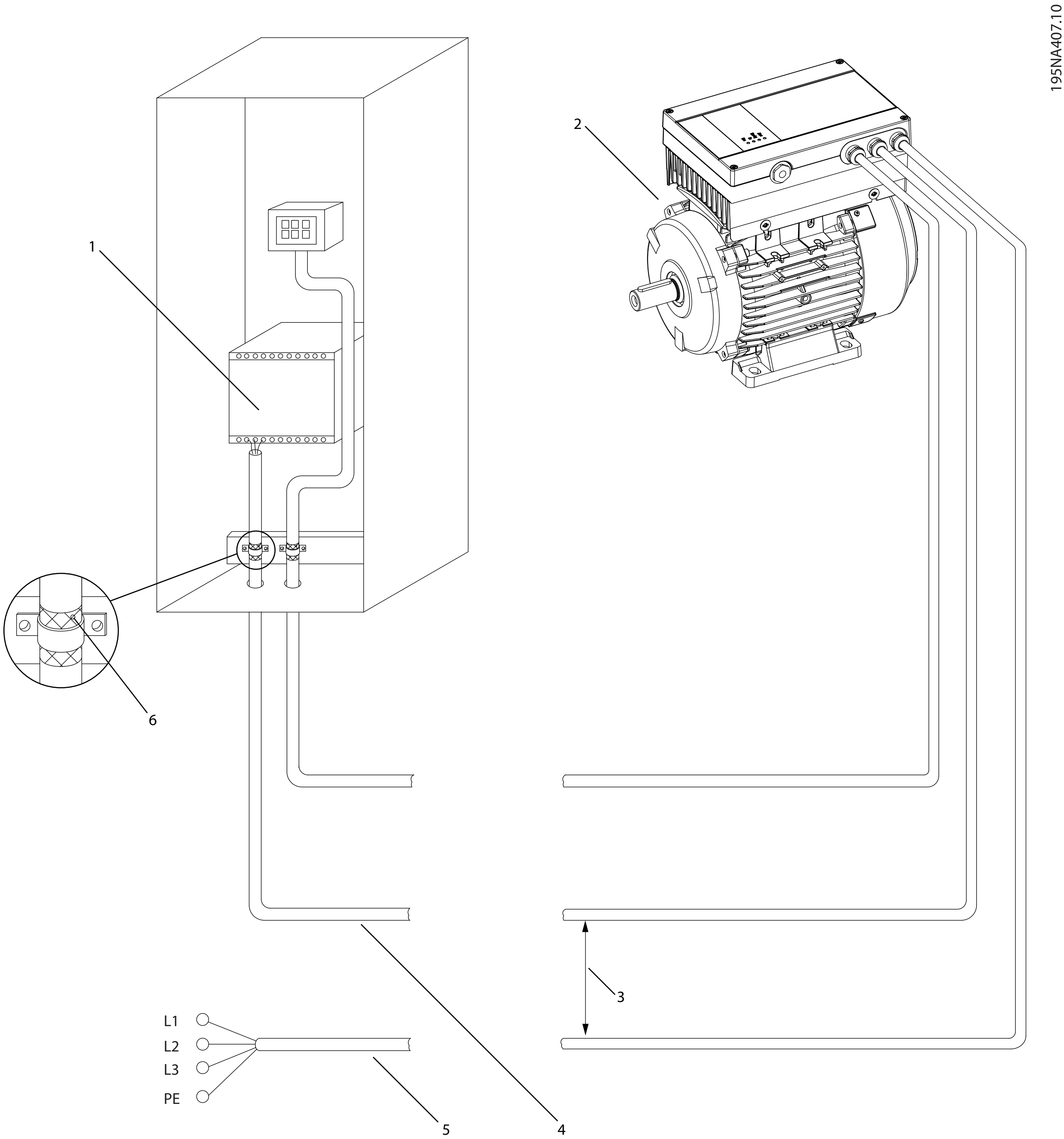
To reduce the interference level from the entire system (unit+installation), keep motor cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor cables. Particularly, control electronics generate radio interference higher than 50 MHz (airborne). See *chapter 2.6.1 EMC-compliant Electrical Installation* for more information on EMC.

2.6.1 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	Minimum 200 mm (7.87 in) clearance between control cable, mains cable, and mains motor cable.		

Illustration 2.19 EMC-compliant Electrical Installation, FCP 106



1	PLC	4	Control cables
2	DriveMotor	5	Mains, 3-phase, and reinforced PE
3	Minimum 200 mm (7.87 in) clearance between control cable and mains cable.	6	Cable insulation (stripped)

Illustration 2.20 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 ground at both ends.
- Avoid installation with twisted screen ends (pigtails), since this type of installation ruins the screen effect at high frequencies. Use the cable clamps provided instead.
- Ensure the same potential between frequency converter and ground potential of the PLC.
- Use star washers and galvanically conductive installation plates.

2.6.2 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, described in *Table 2.2*, along with the requirements for mains supply voltage conducted emissions.

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 which are intended for professional installation and commissioning.	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. Make an EMC plan.

Table 2.2 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 2.3 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 2 m (6.56 ft).

2.6.3 Immunity Requirements

The immunity requirements for frequency converters depend on the environment in which 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. Therefore, the frequency converters also comply with the lower requirements for home and office environment with a large safety margin.

To document immunity against burst transient from electrical phenomena, the following immunity tests have been carried in accordance with the 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 electromagnetic 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 for example 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
Acceptance criterion	B	B	B	A	A
Line (no screen)	4 kV	2 kV/2 Ω DM 4 kV/12 Ω CM	–	–	10 V_{rms}
LCP cable	2 kV	2 kV/2 Ω[1)]	–	–	10 V_{rms}
Control wires	2 kV	2 kV/2 Ω [1)]	–	–	10 V_{rms}
External 24 V DC	2 kV	2 kV/2 Ω[1)]	–	–	10 V_{rms}
Relay wires	2 kV	42 kV/42 Ω	–	–	10 V_{rms}
Enclosure	–	–	8 kV AD 6 kV CD	10 V/m	–

Table 2.4 Immunity Requirements

1) Injection on cable screen.

Abbreviations:

AD - air discharge.

CD - contact discharge.

CM - common mode.

DM - difference mode.

2.7 Leakage Current

2.7.1 Ground Leakage Current

Follow national and local codes regarding protective earthing of equipment where leakage current exceeds 3.5 mA.
Frequency converter technology implies high frequency switching at high power. This generates a leakage current in the ground connection.

The ground leakage current is made up of several contributions and depends on various system configurations, including:

- RFI filtering.
- Motor cable length.
- Motor cable screening.
- Frequency converter power.

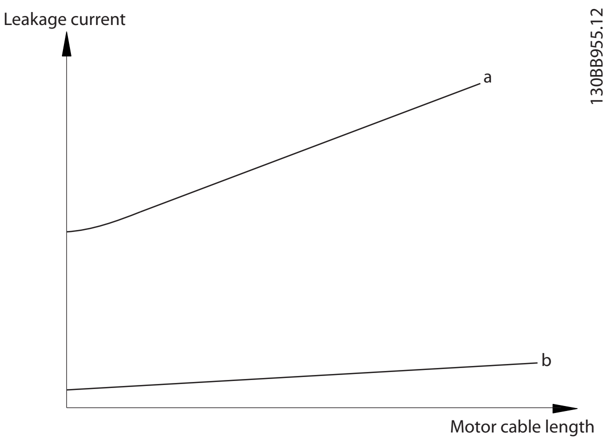


Illustration 2.21 Motor cable length and power size influence on leakage current. Power size a > power size b

The leakage current also depends on the line distortion.

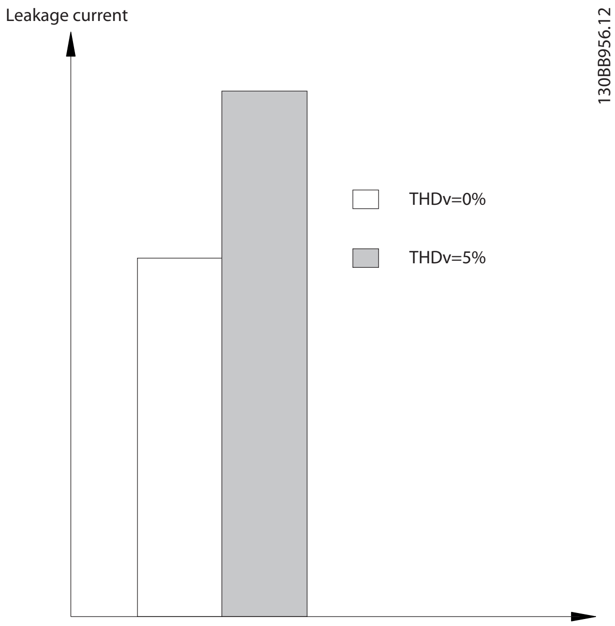


Illustration 2.22 Line Distortion Influences Leakage Current

If the leakage current exceeds 3.5 mA, compliance with EN/IEC61800-5-1 (power drive system product standard) requires special care.

Reinforce grounding with the following protective ground connection requirements:

- Ground wire (terminal 95) of at least 10 mm^2 cross-section.
- 2 separate ground wires both complying with the dimensioning rules.

See EN/IEC61800-5-1 and EN 50178 for further information.

Using RCDs

Where residual current devices (RCDs), also known as earth leakage circuit breakers (ELCBs), are used, comply with the following:

- Use RCDs of type B only as they can detect AC and DC currents.
- Use RCDs with a delay to prevent faults due to transient ground currents.
- Dimension RCDs according to the system configuration and environmental considerations.

The leakage current includes several frequencies originating from both the mains frequency and the switching frequency. Whether the switching frequency is detected depends on the type of RCD used.

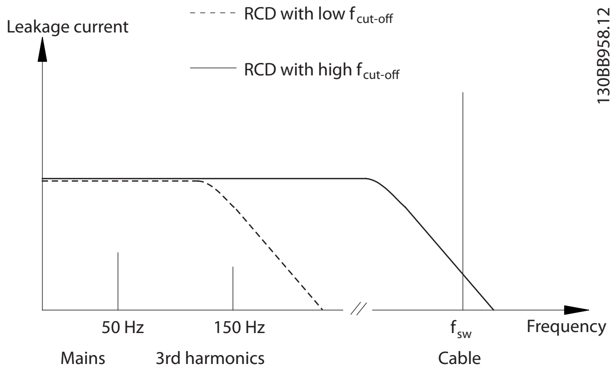


Illustration 2.23 Main Contributions to Leakage Current

The amount of leakage current detected by the RCD depends on the cut-off frequency of the RCD.

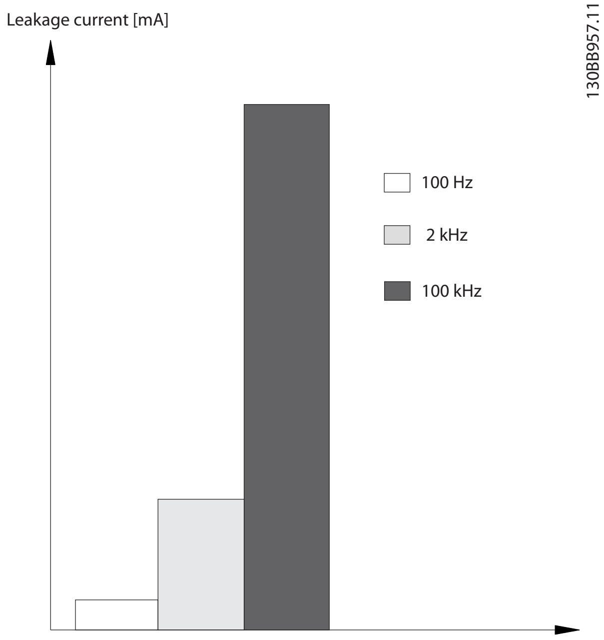


Illustration 2.24 Influence of the RCD Cut-off Frequency on Leakage Current

⚠WARNING

SHOCK HAZARD

The frequency converter can cause a DC current in the PE conductor and thus result in death or serious injury.

- **When a residual current-operated protective device (RCD) is used for protection against electrical shock, only an RCD of Type B is permitted on the supply side.**

Failure to follow the recommendation means that the RCD cannot provide the intended protection.

2.8 Galvanic Isolation (PELV)

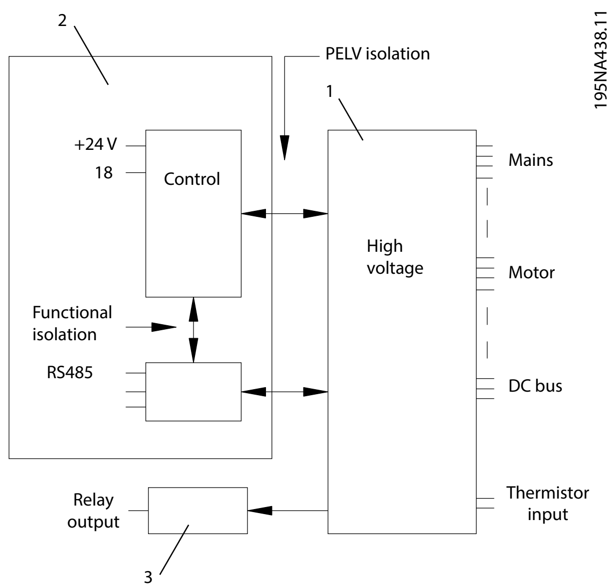
PELV offers protection by way of extra low voltage. Protection against electric shock is ensured when the electrical supply is of the PELV type and the installation is made as described in local/national regulations on PELV supplies.

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 300 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 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 2.25*.

To maintain PELV, all connections made to the control terminals must fulfil the requirements for PELV.



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

Illustration 2.25 Galvanic Isolation

NOTICE

HIGH ALTITUDE

For installation at altitudes above 2000 m (6562 ft), contact Danfoss hotline regarding clearance (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:

- Input into the frequency converter from the mains side including:
  - Power.
  - Harmonics.
  - Monitoring.
  - Cabling.
  - Fusing.
  - Other considerations (*chapter 3.2 Mains Input*).
- Output from the frequency converter to the motor including:
  - Motor types.
  - Load.
  - Monitoring.
  - Cabling.
  - Other considerations (*chapter 3.3 Motors*).
- Integration of the frequency converter input and output for optimal system design including:
  - Converter/motor matching.
  - System characteristics.
  - Other considerations (*chapter 3.4 Frequency Converter/Options Selections*).
- Ambient operating conditions for the frequency converter including:
  - Environment.
  - Enclosures.
  - Temperature.
  - Derating.
  - Other considerations (*chapter 3.6 Ambient Conditions*).

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.

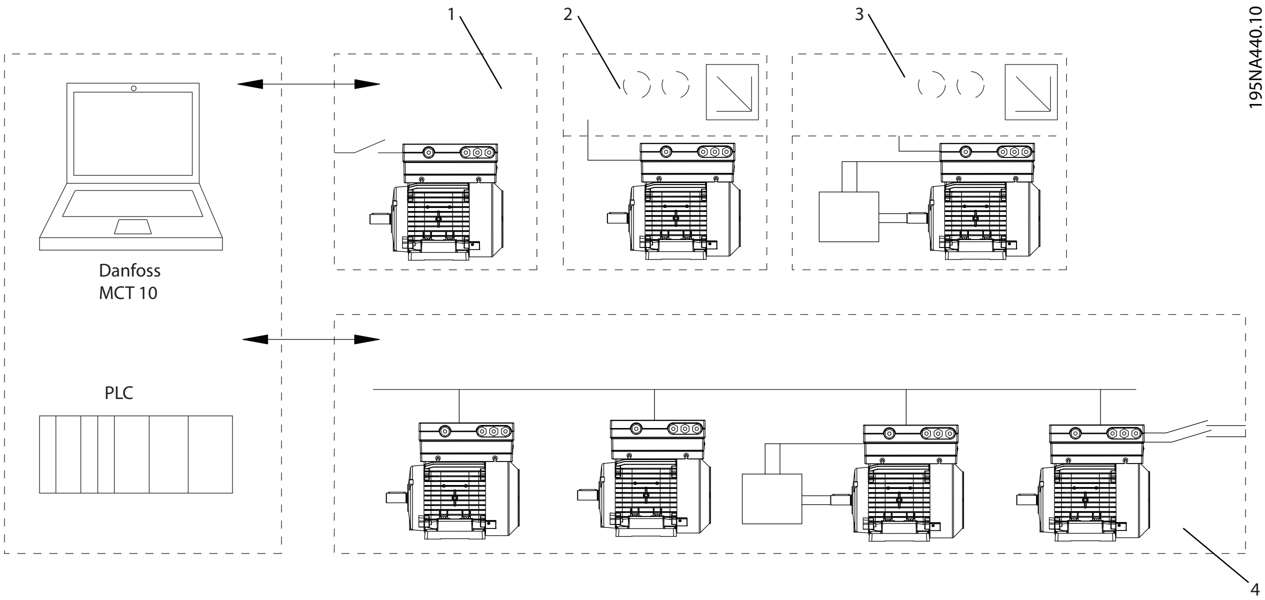
The FCM 106 is a compact alternative to a central solution where the frequency converter and motor are installed as separate units.

- 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 standalone systems with traditional control signals, such as start/stop signals, speed references, and closed-loop process control. It can also be used in multiple frequency converter systems with control signals distributed by a fieldbus.

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) but 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).

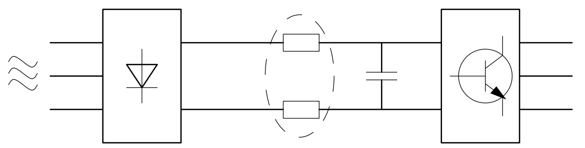


Illustration 3.2 Filters

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 DC-link 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, THDv, 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 are 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 (1.5 hp) total power.	0.55–0.75 kW (0.75–1.0 hp)
IEC/EN 61000-3-12, Table 4	Equipment 16–75 A, and professional equipment from 1 kW (1.5 hp) up to 16 A phase current.	1.1–7.5 kW (1.5–10 hp)

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 ≤16 A per phase)
The scope of IEC 61000-3-2 is equipment connected to the public low voltage distribution system having an input current ≤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 >1 kW (1.5 hp).

IEC 61000-3-12, Limits for harmonic currents produced by equipment connected to public low voltage systems with input current >16 A and ≤75 A
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 are added in the future. The emission limits that apply to frequency converters are given in Table 4 in the standard. There are requirements for individual harmonics (5th, 7th, 11th, and 13th), and for THDi 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}	13
0.55–1.5 kW (0.65–2.0 hp), 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 (0.75–2.0 hp), 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}	13
2.2–4 kW (3.0–5.0 hp), 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 (3.0–5.0 hp), 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}	13
5.5–7.5 kW (7.5–10 hp), 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 (7.5–10 hp), 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:

$$S_{SC} = \sqrt{3} \times R_{SCE} \times U_{mains} \times I_{equ} = \sqrt{3} \times 120 \times 400 \times I_{equ}$$

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

The installer or user of the equipment must ensure that the equipment is connected only to a supply with a short-

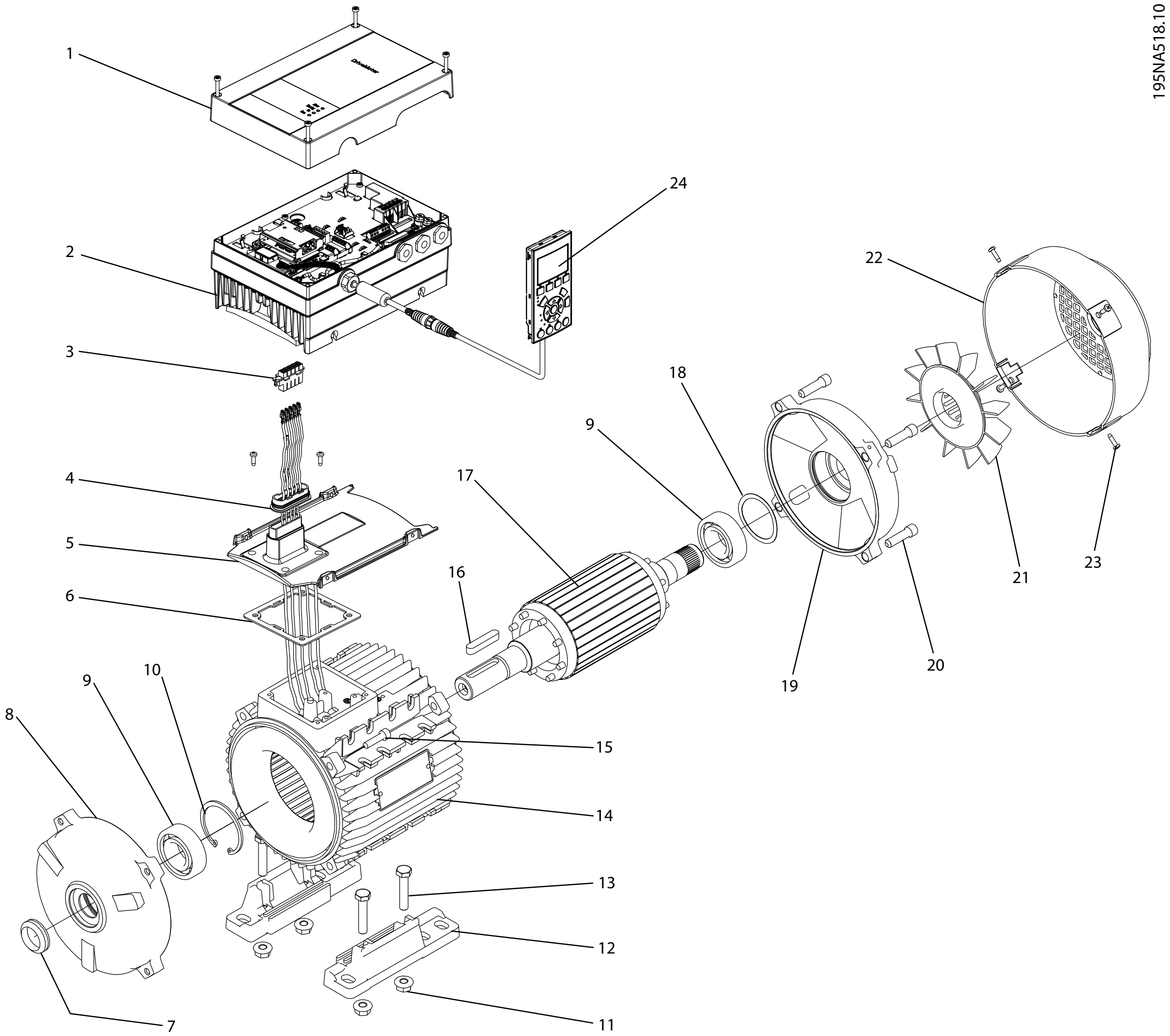
circuit power S_{sc} ≥ the value specified above. If necessary, consult the distribution network operator.
Other power sizes can be connected to the public supply network by consultation with the distribution network operator.

Compliance with various system level guidelines:
The harmonic current data in *Table 3.3* to *Table 3.5* are listed in accordance with IEC/EN 61000-3-12 regarding the power drive systems product standard. These data may be used:

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

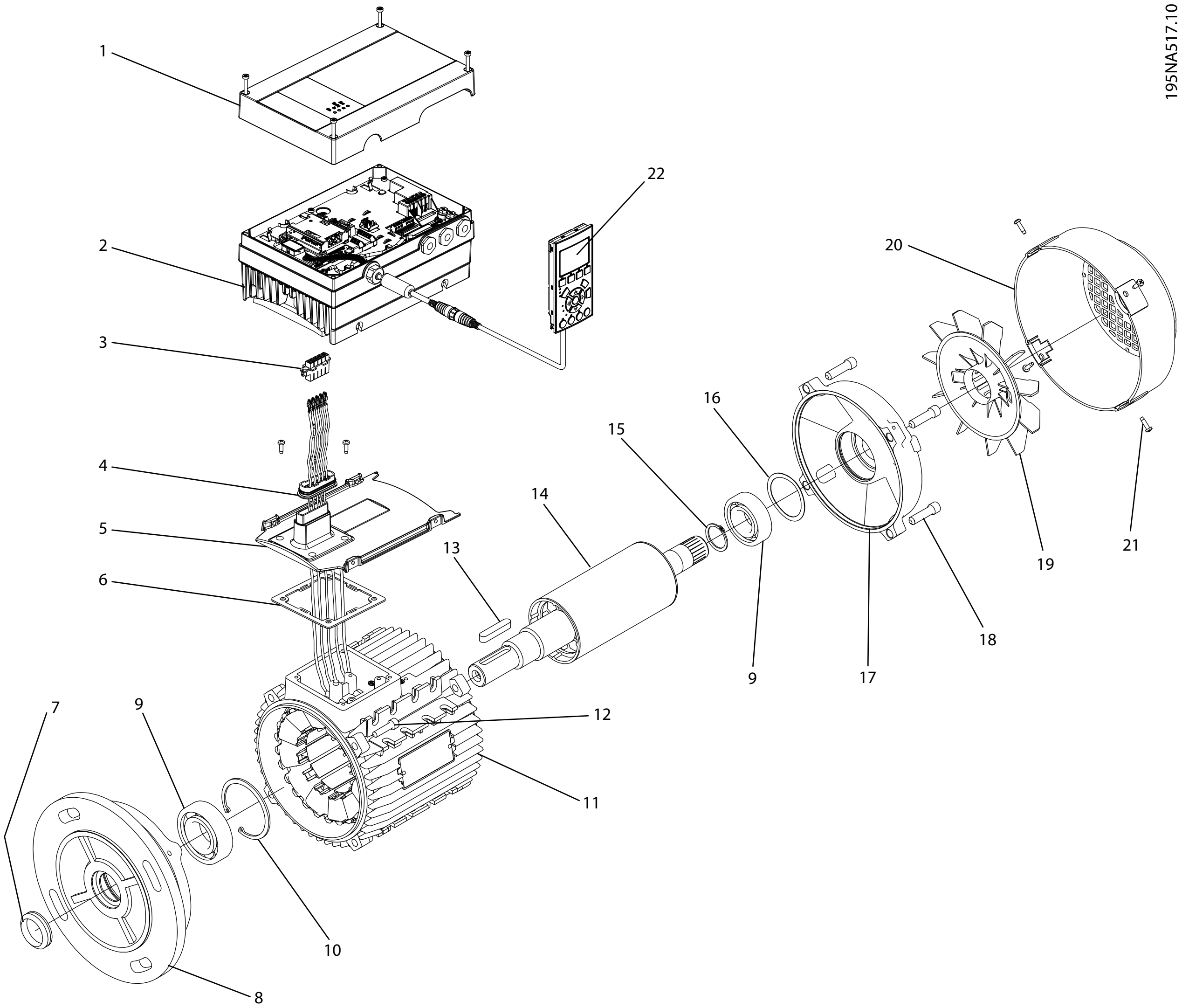
3.3 Motors

3.3.1 Exploded Views



1	Frequency converter cover	13	Foot fixing bolt
2	Frequency converter enclosure	14	Stator frame
3	Motor connector	15	Fixing bolt end shield 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	End shield non-drive end
8	End shield drive end	20	Fixing bolt end shield non-drive end
9	Bearing	21	Fan
10	Snap ring	22	Fan cover
11	Foot fixing	23	Fan cover screw
12	Detachable feet	24	LCP

Illustration 3.3 FCM 106 with Asynchronous Motor, B3 Exploded View



1	Frequency converter cover	12	Fixing bolt end shield 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	End shield non-drive end
7	Dust seal drive end	18	Fixing bolt end shield non-drive end
8	Flange end shield	19	Fan
9	Bearing	20	Fan cover
10	Snap ring	21	Fan cover screw
11	Stator frame	22	LCP

Illustration 3.4 FCM 106 with PM Motor, B5 Exploded View

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.**

Only qualified personnel must undertake handling and lifting of the unit. 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 the 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, ensure a vibration-free storage area. Where exposure to some vibration is unavoidable, lock the shaft. Bearings may be fitted with a shaft locking device, which should be kept in place during storage. Rotate shafts by hand, 1/4 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 according to *Table 3.6* and *Table 3.7*, when the following conditions are fulfilled:

- Temperature of 80 °C (176 °F).
- Radial forces in load point corresponding to half-shaft extension do not exceed the values specified in *Table 3.6* and *Table 3.7*.

IE2 50 Hz 3-phase motors		Permissible radial forces		Permissible axial forces (IMB3)		Permissible axial forces (IMV1)		Permissible axial forces (IMV1)	
				Both directions		Force upwards		Force downwards	
		20000 h	40000 h	20000 h	40000 h	20000 h	40000 h	20000 h	40000 h
Motor size	Number of poles	F rad [N]	F rad [N]	F ax [N]	F ax [N]	F ax [N]	F ax [N]	F ax [N]	F ax [N]
71	2	460	370	230	175	260	205	210	170
	4	580	465	330	250	350	275	300	240
80	2	590	475	320	255	340	280	290	220
	4	830	665	440	350	470	380	410	310
90	2	670	535	340	260	380	315	310	235
	4	940	750	480	365	470	385	440	330
100	2	920	735	480	360	540	460	430	325
	4	1290	1030	680	530	740	620	620	465
112	2	930	745	480	380	560	475	400	300
	4	1300	1040	680	540	750	630	600	450
132 S	2	1350	1080	800	625	1000	845	610	460
	4	1900	1520	1130	880	1320	1095	930	700
132 M	2	1400	1120	780	610	990	835	580	435
	4	1970	1575	1090	850	1300	1080	890	670
160 M	2	1550	1240	840	685	1180	975	500	395
	4	2170	1735	1180	950	1520	1245	830	640
160 L	2	1580	1265	820	675	1180	980	460	365
	4	2220	1775	1150	925	1510	1245	790	610

Table 3.6 Permissible Forces, IE2 50 Hz 3-phase Motors

Permissible radial forces: Load point corresponding to half-shaft extension, 0 axial force assumed.
Permissible axial forces: 0 radial force assumed.
Permissible loads of simultaneous radial and axial forces can be supplied on request.

HPS motors		Permissible radial forces		Permissible axial forces (IMB3)		Permissible axial forces (IMV1)		Permissible axial forces (IMV1)	
				Both directions		Force upwards		Force downwards	
		20000 h	40000 h	20000 h	40000 h	20000 h	40000 h	20000 h	40000 h
Motor size	Speed [RPM]	F rad [N]	F rad [N]	F ax [N]	F ax [N]	F ax [N]	F ax [N]	F ax [N]	F ax [N]
71	1500	580	465	330	250	350	275	300	240
	1800	520	420	295	225	315	250	270	215
	3000	460	370	230	175	260	205	210	170
	3600	415	335	205	155	235	185	190	150
90	1500	940	750	480	365	470	385	440	330
	1800	845	675	430	330	420	345	395	300
	3000	670	535	340	260	380	315	310	235
	3600	600	480	305	235	340	285	280	210
112	1500	1300	1040	680	540	750	630	600	450
	1800	1170	935	610	485	675	565	540	405
	3000	930	745	480	380	560	475	400	300
	3600	835	670	430	340	505	430	360	270
132 M	1500	–	–	–	–	–	–	–	–
	1800	1710	1370	1015	790	1190	985	835	630
	3000	1350	1080	800	625	1000	845	610	460
	3600	1215	970	720	565	900	760	550	415
132 XL	1500	1970	1575	1090	850	1300	1080	890	670
	1800	–	–	–	–	–	–	–	–
	3000	1400	1120	780	610	990	835	580	435
	3600	1260	1010	700	550	890	750	520	390
132 XXL	1500	1970	1575	1090	850	1300	1080	890	670
	1800	1770	1415	980	765	1170	970	800	600
	3000	1400	1120	780	610	990	835	580	435
	3600	1260	1010	700	550	890	750	520	390

Table 3.7 Permissible Forces, HPS Motors

Permissible radial forces: Load point corresponding to half-shaft extension, 0 axial force assumed.
Permissible axial forces: 0 radial force assumed.
Permissible loads of simultaneous radial and axial forces can be supplied on request.

Motor type	Motor frame size	Lubrication type	Temperature range
Asynchronous	80–180	Lithium basis	-40 to +140 °C (-40 to +280 °F)
PM	71–160		

Table 3.8 Lubrication

Motor 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	–	–	6205 2ZC3	6303 2ZC3
80	1500/3000	6204 2ZC3	6204 2ZC3	–	–
90	1500/3000	6205 2ZC3	6205 2ZC3	6206 2ZC3	6205 2ZC3
100	1500/3000	6206 2ZC3	6206 2ZC3	–	–
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	[1]	[1]	–	–
180	1500/3000	[1]	[1]	–	–

Table 3.9 Standard Bearing References and Oil Seals for Motors

1) Data available at future release.

3.3.5 Balance

The FCM 106 is balanced to class R according to ISO 8821 (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 DIN 332 Form D and a closed profile keyway as standard.

3.3.7 FCM 106 Inertia

Inertia J FCM 106[1)]	Asynchronous motor		PM motor	
[kW]	3000 RPM	1500 RPM	3000 RPM	1500 RPM
0.55	–	–	–	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 3.10 Inertia [kgm^2]

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

3.3.8 FCM 106 Motor Frame Size

Power size[1)]	Asynchronous motor		PM motor	
[kW]	1500 RPM	3000 RPM	1500 RPM	3000 RPM
0.55	–	–	71	–
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 3.11 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 overload protection can be implemented using a range of techniques:

- Electronic thermal relay (ETR).
- Thermistor sensor placed between motor windings.
- Mechanical thermal switch.

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*.

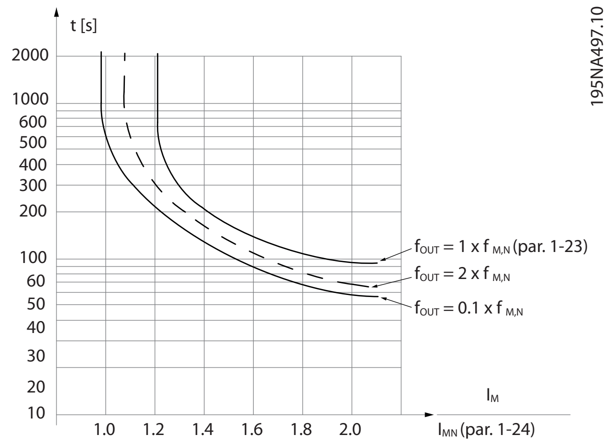


Illustration 3.5 ETR Protection Characteristic

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 0.1 x 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 overheating, even at low speed.

Summary
ETR is functional for asynchronous motors only. The ETR protects the motor against overheating, and no further motor overload 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 overheating.
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 does not activate and therefore a different method of thermal protection is required.

Activate ETR in *parameter 1-90 Motor Thermal Protection*. ETR is controlled in *parameter 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 at terminal positions T1 and T2. For terminal positions and wiring details, refer to the section *Motor Connection* in *VLT® DriveMotor FCP 106 and FCM 106 Operating Instructions.*

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

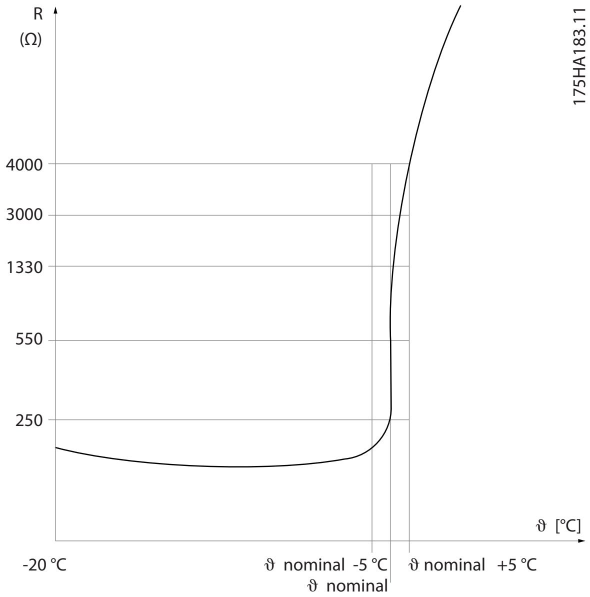


Illustration 3.6 Typical Thermistor Behaviour

When the motor temperature increases the thermistor value above 2.9 kΩ, the frequency converter trips. When the thermistor value decreases below 0.8 kΩ, the frequency converter restarts.

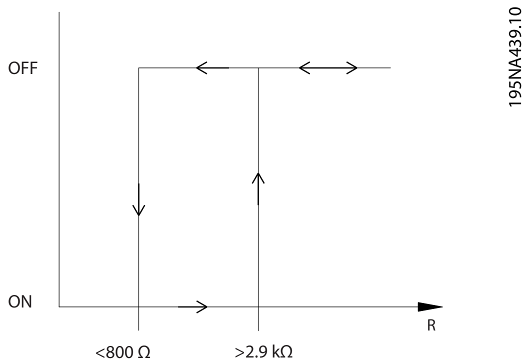


Illustration 3.7 Frequency Converter Operation with Thermistor

NOTICE

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

NOTICE

If the thermistor is not galvanically isolated, 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

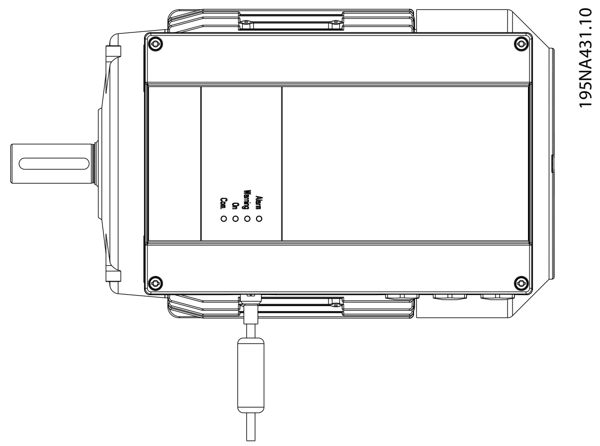
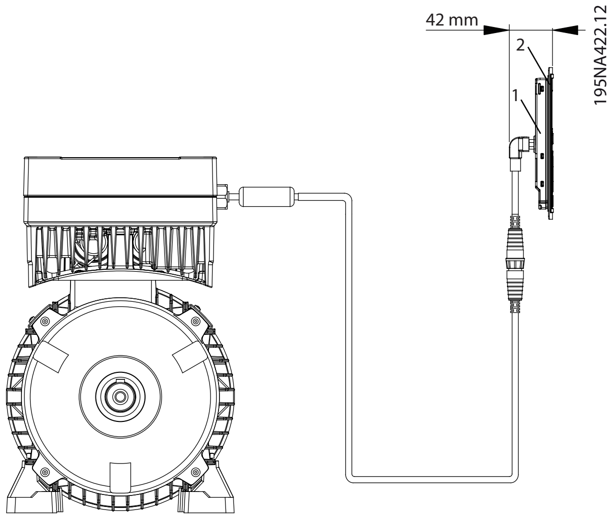
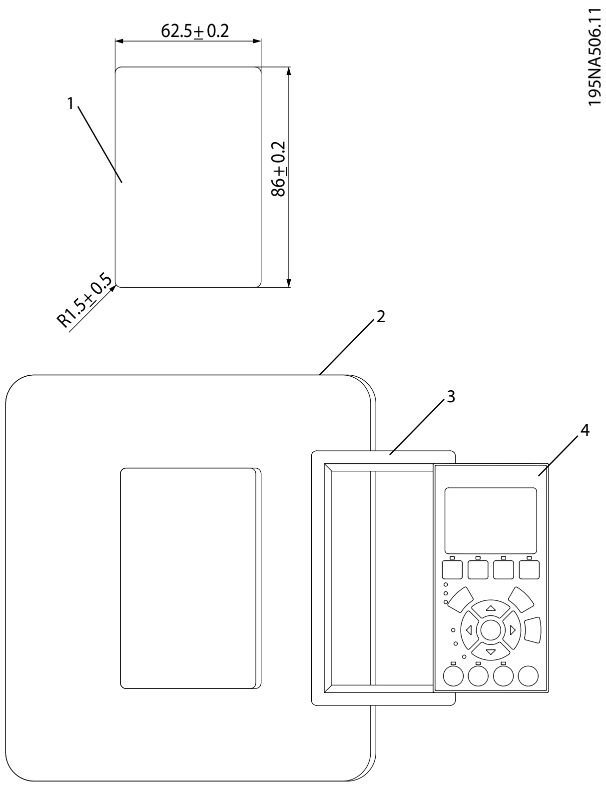


Illustration 3.8 Remote Mounting Kit Connections



1	Control panel
2	Panel door

Illustration 3.10 LCP Remote Mounting



1	Panel cutout. Panel thickness 1–3 mm (0.04–0.12 in)
2	Panel
3	Gasket
4	LCP

Illustration 3.9 Remote Mounting Kit Connector

3.4.2 Local Operation Pad

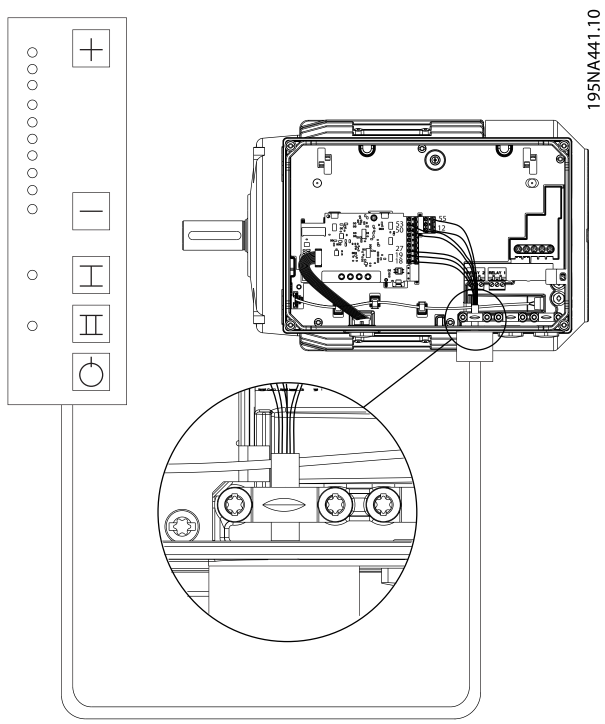


Illustration 3.11 LOP Connections

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

Table 3.12 Function

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

Table 3.13 Electrical Connections

Parameter	Dual-speed operation	Dual-mode operation	Dual-direction operation
Parameter 5-10 Terminal 18 Digital Input Terminal 18	Start*		
Parameter 5-12 Terminal 27 Digital Input Terminal 27	Reset		
Parameter 5-13 Terminal 29 Digital Input Terminal 29	Jog*	Select set-up	Start reversing
More parameters	*Parameter 3-11 Jog Speed [Hz]*	*Parameter 0-10 Active Set-up = [9] Multi set-up*	*Parameter 4-10 Motor Speed Direction = [2] Both directions*

Table 3.14 Parameter Settings

** Indicates factory setting.*

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

- Leave the brown wire unconnected, or
- Set *parameter 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

Consider derating when using the frequency converter:

- At low air pressure (high altitudes).
- At low speeds.
- With long motor cables.
- Cables with a large cross-section.
- At high ambient temperature.

This section describes the actions required.

3.5.2 Derating for Ambient Temperature and Switching Frequency

Refer to *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 DC link.
- 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 100 m altitude above 1000 m, or
    - Reduce the maximum ambient temperature by 1 °C per 200 m 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 2000 m and a temperature of 45 °C ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 41.7 °C, 100% of the rated output current is available.

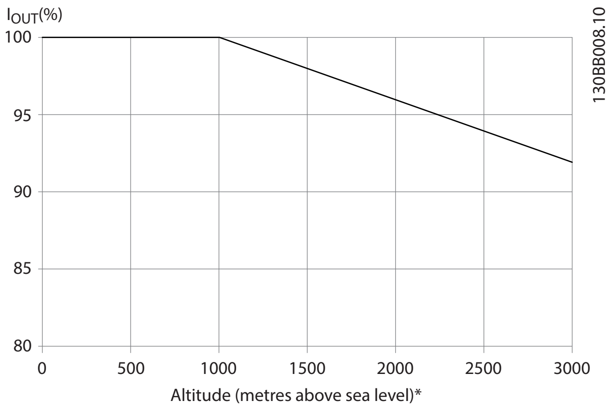


Illustration 3.12 Example

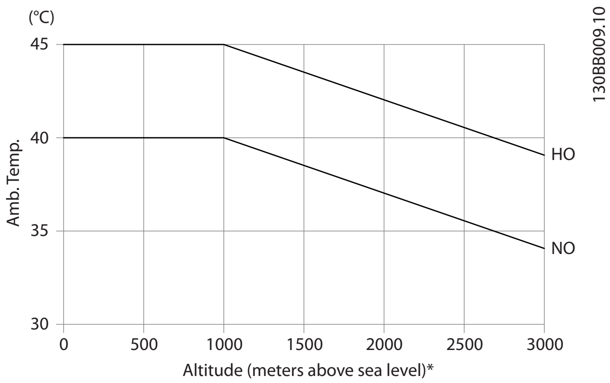


Illustration 3.13 Derating of Output Current versus Altitude at $T_{AMB, MAX}$

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 allowed value (*Alarm 16, Trip Lock*).

Switching on the output
Switching on the output between the motor and the frequency converter is allowed. Fault messages can appear. To catch a spinning motor, select *[2] Enabled always* in *parameter 1-73 Flying Start*.

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

- The load drives the motor at constant output frequency from the frequency converter. That is, the load generates energy.
- During deceleration (ramp-down) when the inertia moment 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.
- Incorrect slip compensation setting can cause higher DC-link voltage.
- 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 *parameter 4-19 Max Output Frequency* is automatically limited. The limit is based on an internal calculation, based on the values of:
    - *Parameter 1-40 Back EMF at 1000 RPM*.
    - *Parameter 1-25 Motor Nominal Speed*.
    - *Parameter 1-39 Motor Poles*.

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

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

- *Parameter 2-10 Brake Function*.
- *Parameter 2-17 Over-voltage Control*.

NOTICE

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

Mains dropout
During a mains dropout, 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 dropout and the motor load determines how long it takes for the frequency converter to coast.

Static overload in VVC+ 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 approximately 5–10 s.

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. 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 standby mode (with the unit connected to the mains) reduces the risk of condensation. However, ensure that 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.
- IEC 600721 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 maximises overall system reliability. Follow the recommendations listed for maximum performance and equipment longevity.

- Although frequency 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.
- Extra air conditioning of the cabinet or installation site may be required.

3.6.3 Cooling

Frequency converters dissipate power in the form of heat. Adhere to the following recommendations for effective cooling of the units.

- Maximum air temperature to enter the 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® 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

Do not install the frequency converter 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 protection 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 protection 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, cause chemical processes on the frequency converter components.

Such chemical reactions rapidly affect and damage 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. These checks are 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:

- External fan.
- DC intermediate circuit coils.
- RFI filter choke.

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

Table 3.15 FCP 106 Acoustic Noise Levels, Fan on, Measured 1 m from the Unit

FCM 106
Acoustic noise originates from the sources:

- Motor fan.
- External fan.
- Motor stator and rotor.
- DC intermediate circuit coils.
- 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 3.16 FCM 106 Acoustic Noise Levels, Measured 1 m from the Unit

3.6.7 Vibration and Shock

The frequency converter complies with requirements for wall- or floor-mounted units mounted at 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 3.17*.

IEC 61800-5-1 Ed.2	Vibration test, Cl. 5.2.6.4
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 3.17 Vibration and Shock Test Procedure Compliance

3

3.7 Energy Efficiency

The standard *EN 50598 Ecodesign for power drive systems, motor starters, power electronics and their driven applications* provides guidelines for assessing the energy efficiency of frequency converters.

The standard provides a neutral method for determining efficiency classes and power losses at full load and at part load. The standard allows combination of any motor with any frequency converter.

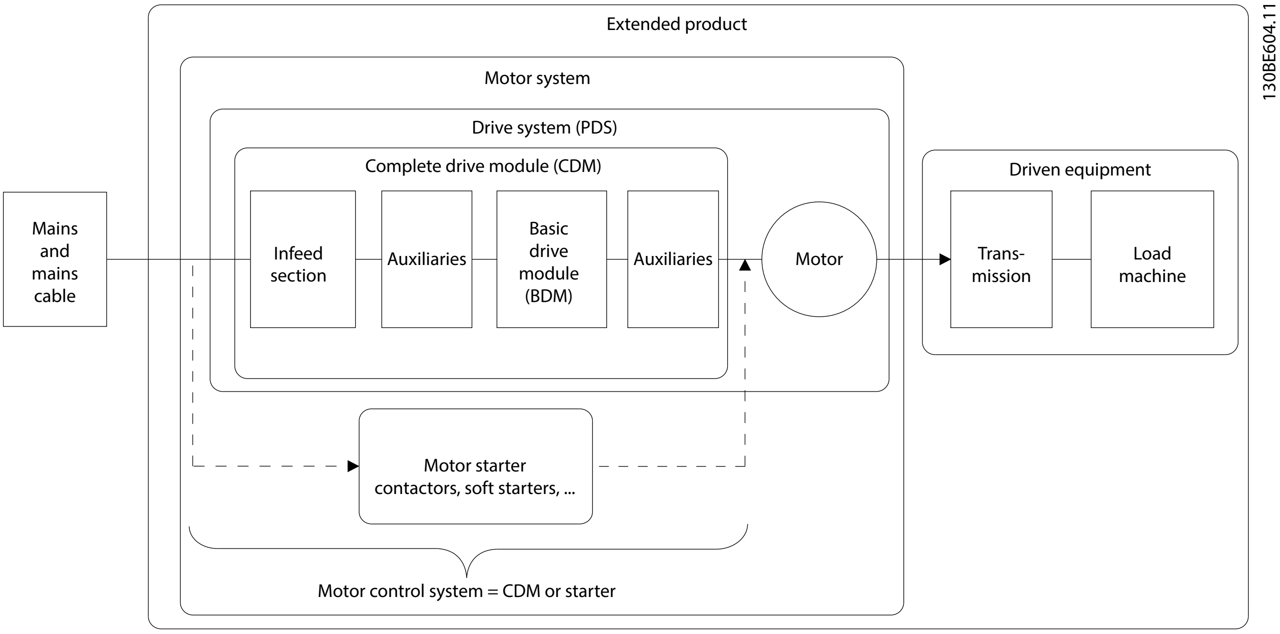


Illustration 3.14 Power Drive System (PDS) and Complete Drive Module (CDM)

3.7.1 IE and IES Classes

Complete drive modules
According to the standard EN 50598-2, the complete drive module (CDM) comprises the frequency converter, its feeding section, and its auxiliaries.

Energy efficiency classes for the CDM:

- IE0 = below state of the art.
- IE1 = state of the art.
- IE2 = above state of the art.

Danfoss frequency converters fulfill energy efficiency class IE2. The energy efficiency class is defined at the nominal point of the CDM.

Power drive systems
A power drive system (PDS) consists of a complete drive module (CDM) and a motor.

Energy efficiency classes for the PDS:

- IES0 = Below state of the art.
- IES1 = State of the art.
- IES2 = Above state of the art.

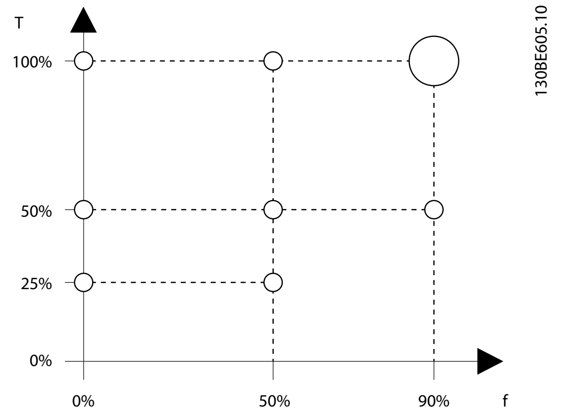
Depending on the motor efficiency, motors driven by a Danfoss VLT® frequency converter typically fulfill energy efficiency class IES2.

The energy efficiency class is defined at the nominal point of the PDS and can be calculated based on the CDM and the motor losses.

3.7.2 Power Loss Data and Efficiency Data

The power loss and the efficiency of a frequency converter depend on configuration and auxiliary equipment. To get a configuration-specific power loss and efficiency data, use the Danfoss VLT® ecoSmart application.

The power loss data are provided in % of rated apparent output power, and are determined according to EN 50598-2. When the power loss data are determined, the frequency converter uses the factory settings except for the motor data which is required to run the motor.



T	Torque [%]
f	Frequency [%]

Illustration 3.15 Frequency Converter Operating Points According to EN 50598-2

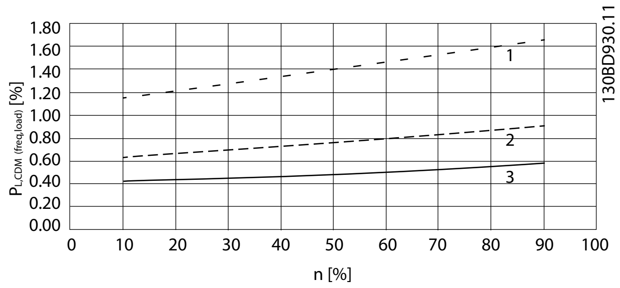
Refer to *www.danfoss.com/vltenergyefficiency* for the power loss and efficiency data of the frequency converter at the operating points specified in *Illustration 3.15*.

Use the VLT® ecoSmart application to calculate IE and IES efficiency classes. The application is available at *vlt-ecosmart.danfoss.com*.

Example of available data
The following example shows power loss and efficiency data for a frequency converter with the following characteristics:

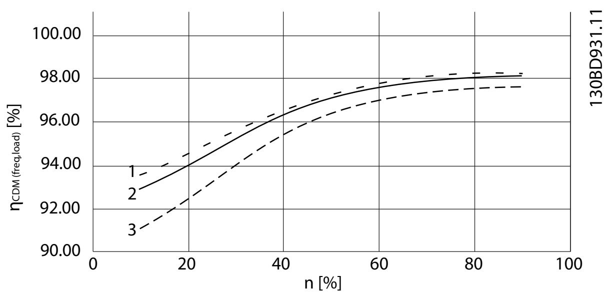
- Power rating 55 kW, rated voltage at 400 V.
- Rated apparent power, Sr, 67.8 kVA.
- Rated output power, P_{CDM}, 59.2 kW.
- Rated efficiency, η_r, 98.3%.

Illustration 3.16 and *Illustration 3.17* show the power loss and efficiency curves. The speed is proportional to the frequency.



1	100% load
2	50% load
3	25% load

Illustration 3.16 Frequency converter power loss data. CDM relative losses ($P_{L,\ CDM}$) [%] versus speed (n) [% of nominal speed].



1	100% load
2	50% load
3	25% load

Illustration 3.17 Frequency converter efficiency data. CDM efficiency ($\eta_{CDM(freq,\ load)}$) [%] versus speed (n) [% of nominal speed].

Interpolation of power loss
Determine the power loss at an arbitrary operating point using 2-dimensional interpolation.

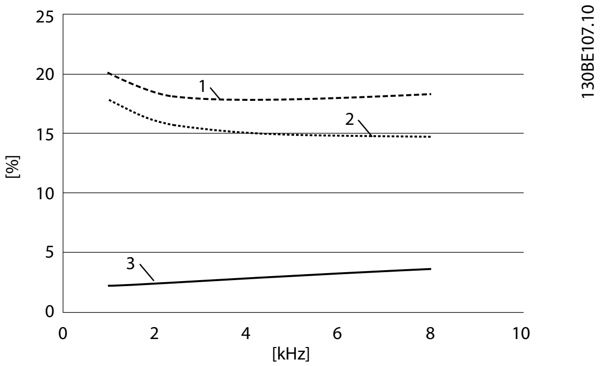
3.7.3 Losses and Efficiency of a Motor

The efficiency of a motor running at 50–100% of the nominal motor speed and at 75–100% of the nominal torque is practically constant. This is valid both when the frequency converter controls the motor, or when the motor runs directly on mains.

The efficiency depends on the type of motor and the level of magnetization.

For more information about motor types, refer to the motor technology brochure at *www.vlt-drives.danfoss.com*.

Switching frequency
The switching frequency influences magnetization losses in the motor and switching losses in the frequency converter, as shown in *Illustration 3.18*.



1	Motor and frequency converter
2	Motor only
3	Frequency converter only

Illustration 3.18 Losses [%] versus Switching Frequency [kHz]

NOTICE

A frequency converter produces extra harmonic losses in the motor. These losses decrease when switching frequency increases.

3.7.4 Losses and Efficiency of a Power Drive System

To estimate the power losses at different operating points for a power drive system, sum the power losses at the operating point for each system component:

- Frequency converter.
- Motor.
- Auxiliary equipment.

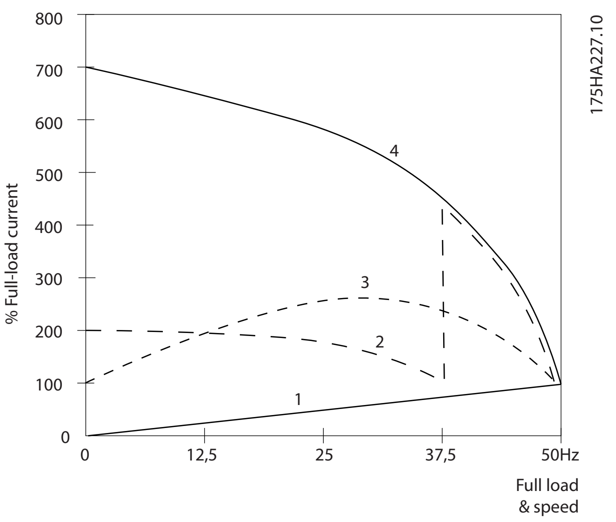
4 Application Examples

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



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

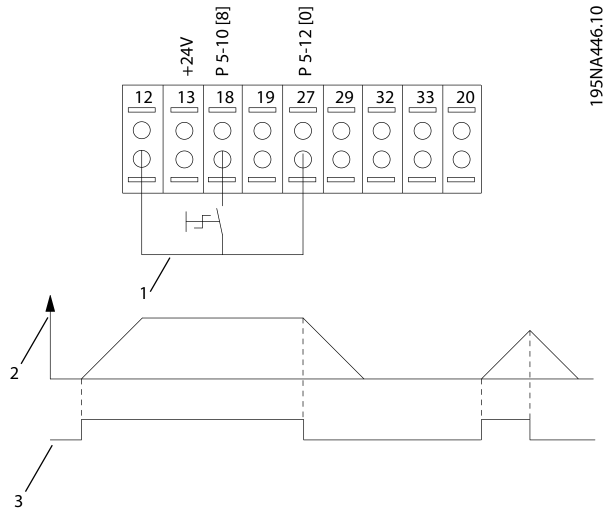
Illustration 4.1 Start-up Current

4.1.2 Start/Stop

Terminal 18 = Start/stop *parameter 5-10 Terminal 18 Digital Input [8] Start*.
Terminal 27 = No operation *parameter 5-12 Terminal 27 Digital Input [0] No operation* (Default *[2] Coast inverse*).

Parameter 5-10 Terminal 18 Digital Input = [8] Start (default).

Parameter 5-12 Terminal 27 Digital Input = [2] Coast inverse (default).



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

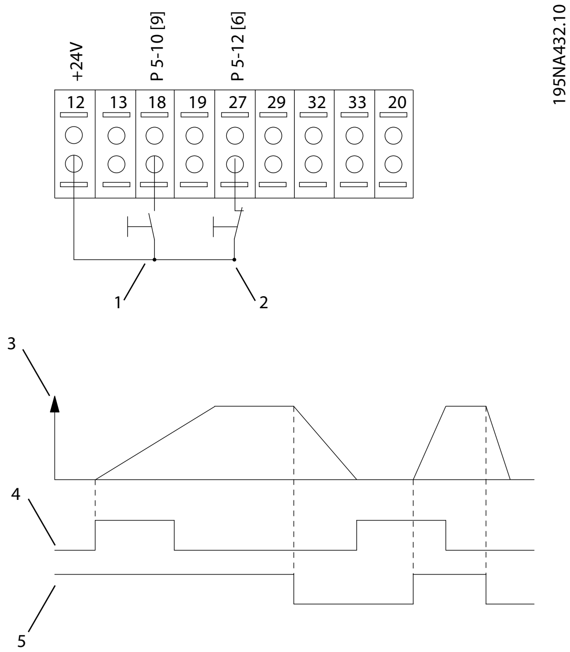
Illustration 4.2 Start/Stop and Running Speed

4.1.3 Pulse Start/Stop

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

Parameter 5-10 Terminal 18 Digital Input = *[9] Latched start*.

Parameter 5-12 Terminal 27 Digital Input = *[6] Stop inverse*.



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

Illustration 4.3 Pulse Start/Stop

4.1.4 Potentiometer Reference

Voltage reference via a potentiometer.

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

Parameter 6-10 Terminal 53 Low Voltage = 0 V.

Parameter 6-11 Terminal 53 High Voltage = 10 V.

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

Parameter 6-15 Terminal 53 High Ref./Feedb. Value = 1500 RPM.

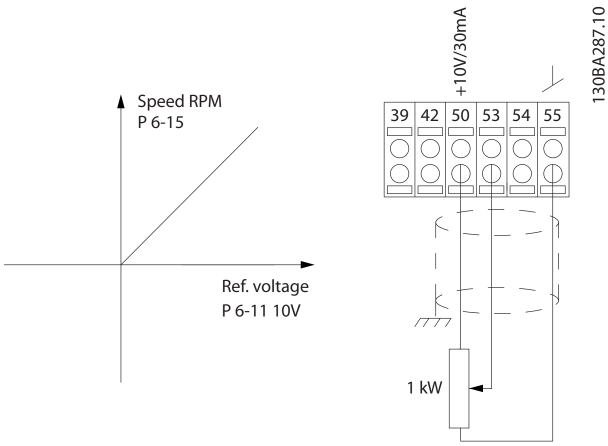


Illustration 4.4 Potentiometer Reference

4.1.5 Automatic Motor Adaptation (AMA)

AMA is an algorithm to measure the electrical motor parameters on a motor at standstill. The 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 often used where the default setting does not apply to the connected motor.
In *parameter 1-29 Automatic Motor Adaptation (AMA)*, select between *[1] Complete AMA* and *[2] Reduced AMA*. The complete AMA determines all electrical motor parameters. The reduced AMA determines 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 *parameter 1-20 Motor Power [kW]* to *parameter 1-28 Motor Rotation Check*. For asynchronous motor, enter the correct motor nameplate data in *parameter 1-24 Motor Current* and *parameter 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 increase 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 1 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. This situation is known to occur with, for example, windmilling in ventilation systems. The running motor shaft disturbs the AMA function.
- When running a PM motor (when *parameter 1-10 Motor Construction* is set to *[1] PM non-salient SPM*), only *[1] Enable complete AMA* can be activated.

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.
- 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} 45–65 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 drops below the correct motor voltage, for example at 43 Hz, 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 6th harmonic. Perform this skip by setting parameters (parameter group *4-6* Speed Bypass*) or by using the semi-auto bypass set-up *parameter 4-64 Semi-Auto Bypass Set-up*. However, there is no general design rule for making an optimal skip of frequency bands as this depends 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.

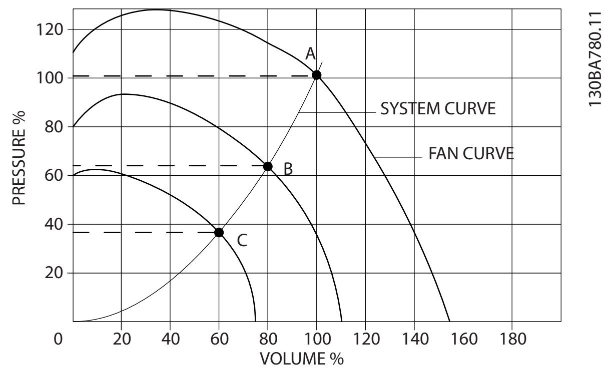


Illustration 4.5 The Graph Shows Fan Curves (A, B, and C) for Reduced Fan Volumes

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

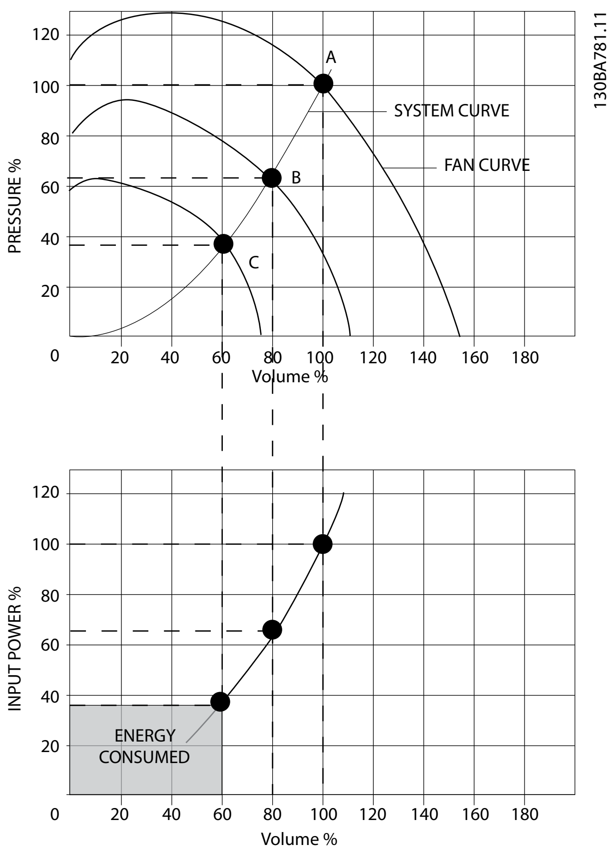


Illustration 4.6 Energy Savings at Reduced Fan Capacity

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 a system only has 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.

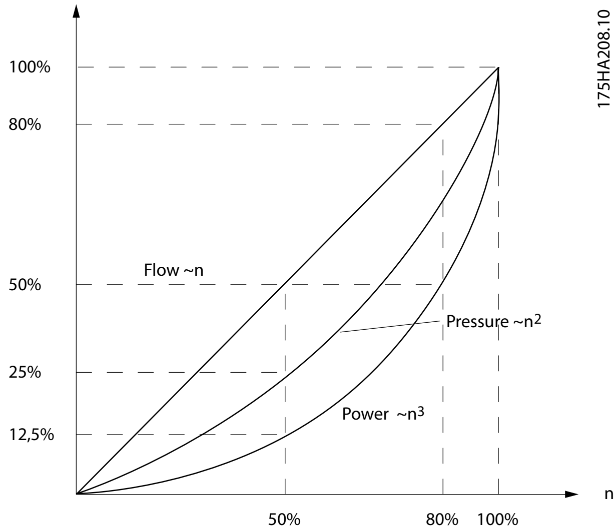


Illustration 4.7 Laws of Proportionality

$$Flow: \frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$Pressure: \frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$$

$$Power: \frac{P_1}{P_2} = \left(\frac{n_1}{n_2}\right)^3$$

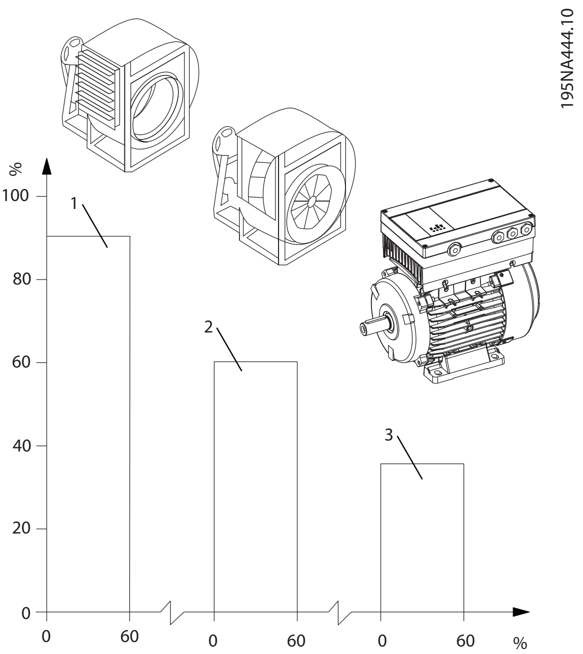
Q=Flow	P=Power
Q_1=Rated flow	P_1=Rated power
Q_2=Reduced flow	P_2=Reduced power
H=Pressure	n=Speed control
H_1=Rated pressure	n_1=Rated speed
H_2=Reduced pressure	n_2=Reduced speed

Table 4.1 Legend for Equation

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.



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

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

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 the price of the frequency converter. In this example, payback is achieved in less than 1 year, when compared with valves and constant speed. For calculation of energy savings in specific applications, use the VLT® Energy box software.

Energy savings

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

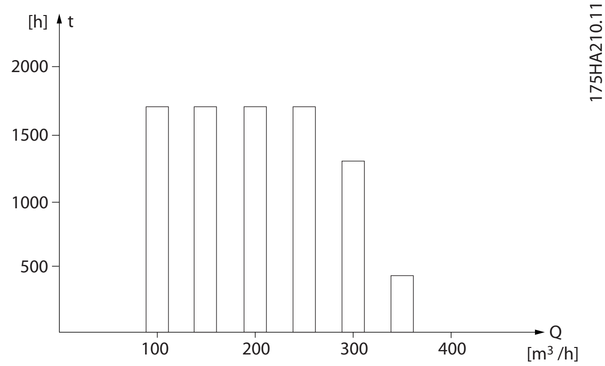


Illustration 4.9 Flow Distribution over 1 Year

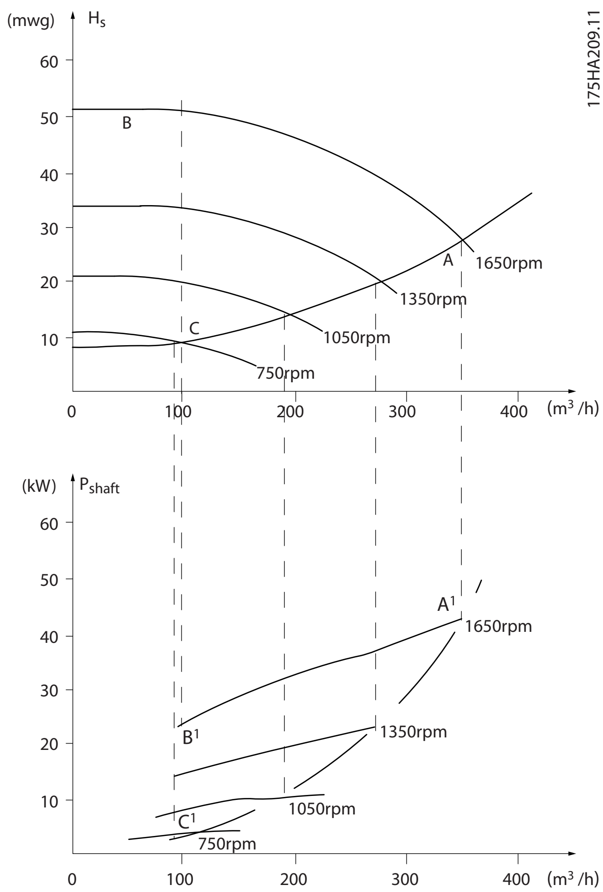


Illustration 4.10 Pump Performance

m³/h	Distribution		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 4.2 Pump Performance

4.3 Control Examples

4.3.1 Improved Control

Using a frequency converter to control flow or pressure of a system improves control.
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 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 *parameter 13-52 SL Controller Action*) executed by the SLC when the SLC evaluates the associated user-defined event (see *parameter 13-51 SL Controller Event*) as TRUE.
Events and actions are each numbered and are linked in pairs called states. When event [1] is fulfilled (attains the value TRUE), action [1] is executed. After this execution, 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 1 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 0–20 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:

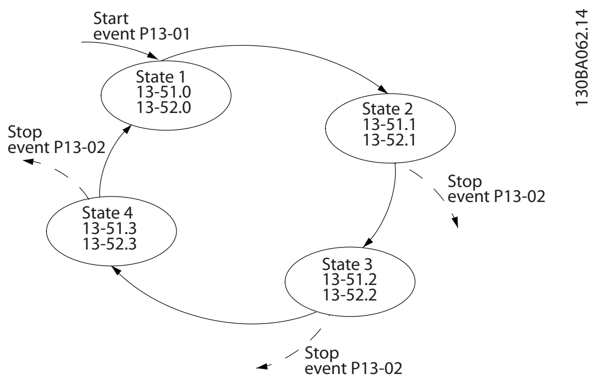
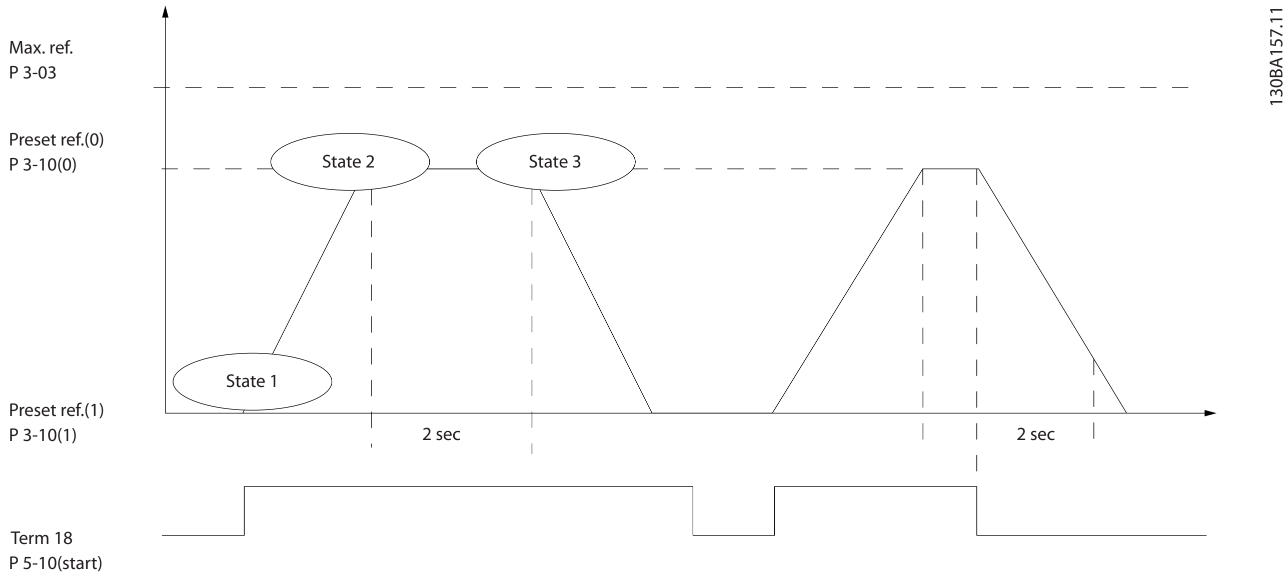


Illustration 4.11 Example with 3 Events/Actions

4.3.4 SLC Application Example



State 1	Start and ramp up.
State 2	Run at reference speed for 2 s.
State 3	Ramp down and hold shaft until stop.

Illustration 4.12 Example of a Sequence

1. Set the ramping times in *parameter 3-41 Ramp 1 Ramp Up Time* and *parameter 3-42 Ramp 1 Ramp Down Time* to the wanted times
   $t_{ramp} = \frac{t_{acc} \times n_{norm}\,(par.\ 1-25)}{ref\ [RPM]}$
2. Set terminal 27 to *[0] No Operation* (*parameter 5-12 Terminal 27 Digital Input*).
3. Set preset reference 0 to the first preset speed (*parameter 3-10 Preset Reference* [0]) in percentage of maximum reference speed (*parameter 3-03 Maximum Reference*). For example: 60%.
4. Set preset reference 1 to the second preset speed (*parameter 3-10 Preset Reference* [1] For example: 0% (zero).
5. Set the timer 0 for constant running speed in *parameter 13-20 SL Controller Timer* [0]. For example: 2 s.
6. Set event 1 in *parameter 13-51 SL Controller Event* to *[1] True*.
7. Set event 2 in *parameter 13-51 SL Controller Event* to *[4] On Reference*.
8. Set event 3 in *parameter 13-51 SL Controller Event* to *[30] Time Out 0*.
9. Set event 4 in *parameter 13-51 SL Controller Event* to *[0] False*.
10. Set action 1 in *parameter 13-52 SL Controller Action* to *[10] Select preset 0*.
11. Set action 2 in *parameter 13-52 SL Controller Action* to *[29] Start Timer 0*.
12. Set action 3 in *parameter 13-52 SL Controller Action* to *[11] Select preset 1*.
13. Set action 4 in *parameter 13-52 SL Controller Action* to *[1] No Action*.
14. Set the smart logic control in *parameter 13-00 SL Controller Mode* to *[1] ON*.

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

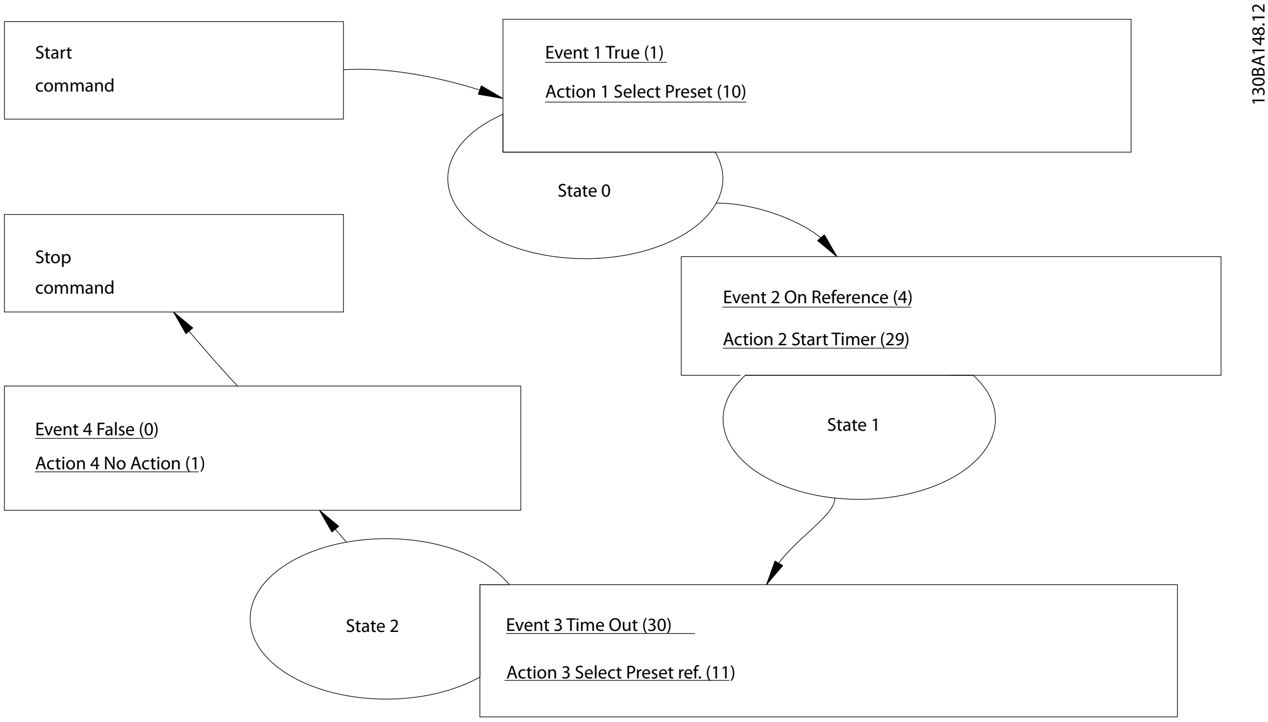


Illustration 4.13 Set Event and Action

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.

Order frequency converter motors as standard or with internal options by using a type code string, for example:

FCM106P4K0T4C55H1FSXXANXE4N4K0150B03000

Refer to *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 with a normal overload load profile is included in the frequency converter. Ordering numbers for frequency converter motor standard variants are available in *chapter 5.3 Ordering Numbers*.
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 produce 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 set-up: 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
		Load profile, frequency converter	7	N: Normal overload H: High overload
		Power size	8–10	0.55–7.5 kW (K55–7K5)
		Mains voltage	11–12	T4: 380–480 V AC
		Enclosure	13–15	C66: IP66/UL TYPE 4X (FCP 106 only) C55: IP55/Type 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 - standard software
		Options	22–23	AN: VLT® Memory Module MCM 101, without fieldbus AM: VLT® Memory Module MCM 101, VLT® PROFIBUS DP MCA 101
		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, motor	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

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

5.3 Ordering Numbers

5.3.1 Options and Accessories

Description	Enclosure size[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), IP55	130B1107		
Mounting kit including 3 m FCP 106 cable, IP55, for LCP	134B0564		
Local operating pad (LOP), IP65	175N0128		
Motor adapter plate kit: Motor adapter plate, motor connector, PE connector, motor connector gasket, 4 screws	134B0340	134B0390	134B0440
Wall mount adapter plate	134B0341	134B0391	134B0441
VLT® PROFIBUS DP MCA 101	130B1200		
VLT® Memory Module MCM 101	134B0791		
Potentiometer option	177N0011		

Table 5.3 Options and Accessories, Ordering Numbers

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

5.3.2 Spare Parts

For ordering numbers and ordering in general, refer to:

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

Item	Description	Ordering number
Fan assembly, MH1	Fan assembly, Enclosure size MH1	134B0345
Fan assembly, MH2	Fan assembly, Enclosure size MH2	134B0395
Fan assembly, MH3	Fan assembly, Enclosure size MH3	134B0445
Accessory bag, MH1	Accessory bag, Enclosure size MH1	134B0346
Accessory bag, MH2	Accessory bag, Enclosure size MH2	134B0346
Accessory bag, MH3	Accessory bag, Enclosure size MH3	134B0446

Table 5.4 Ordering Numbers, Spare Parts

5.3.3 Parts Required for Installation

More items required for motor connection:

Crimp terminals:

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

AMP standard power timer contacts, ordering numbers:

- 134B0495 (0.2–0.5 mm^2) [AWG 24–20].
- 134B0496 (0.5–1 mm^2) [AWG 20–17].
- 134B0497 (1–2.5 mm^2) [AWG 17–13.5].
- 134B0498 (2.5–4 mm^2) [AWG 13–11].
- 134B0499 (4–6 mm^2) [AWG 12–10].

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

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

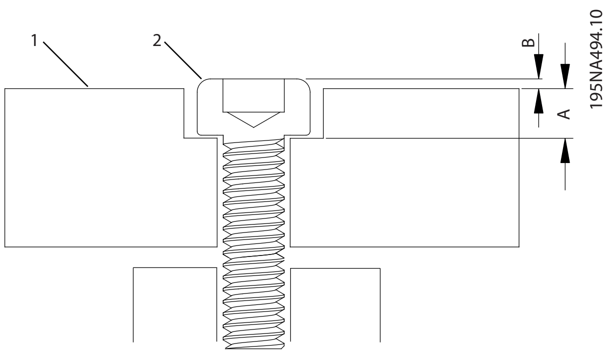
Enclosure			**Power[1)] [kW (hp)]**	**Clearance at ends [mm (in)]**	
Enclosure size	**Protection rating**		**3x380–480 V**	**Motor flange end**	**Cooling fan end**
	FCP 106	**FCM 106**			
MH1	IP66/Type 4X[2)]	IP55/Type 12	0.55–1.5 (0.75–2.0)	30 (1.2)	100 (4.0)
MH2	IP66/Type 4X[2)]	IP55/Type 12	2.2–4.0 (3.0–5.0)	40 (1.6)	100 (4.0)
MH3	IP66/Type 4X[2)]	IP55/Type 12	5.5–7.5 (7.5–10)	50 (2.0)	100 (4.0)

Table 6.1 Minimum Clearance for Cooling

1) Power ratings relate to NO, see chapter 6.2 Electrical Data.
2) The stated IP and Type rating only apply when the FCP 106 is mounted on a wall mount plate or a motor with the adapter plate. Ensure that the gasket between the adapter plate and the motor has a protection rating corresponding to the required rating for the combined motor and frequency converter. As standalone frequency converter, the enclosure rating is IP00 and Open type.

Enclosure size	**Maximum depth of hole into adapter plate (A) [mm (in)]**	**Maximum height of screw above adapter plate (B) [mm (in)]**
MH1	3 (0.12)	0.5 (0.02)
MH2	4 (0.16)	0.5 (0.02)
MH3	3.5 (0.14)	0.5 (0.02)

Table 6.2 Details for Motor Adapter Plate Screws



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	
RPM				Enclosure	Power [kW (hp)]
1500	3000	3000	1500		
71	–	–	–	MH1	0.55 (0.75)
71	71	71	80		0.75 (1.0)
71	71	80	90		1.1 (1.5)
71	71	80	90		1.5 (2.0)
90	71	90	100	MH2	2.2 (3.0)
90	90	90	100		3 (4.0)
90	90	100	112		4 (5.0)
112	90	112	112	MH3	5.5 (7.5)
112	112	112	132		7.5 (10)

Table 6.3 Motor Frame Size Corresponding to FCP 106 Enclosure

6.1.3 FCP 106 Dimensions

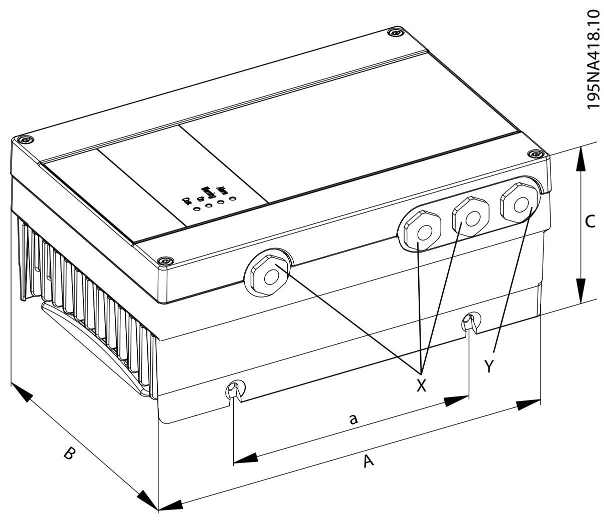


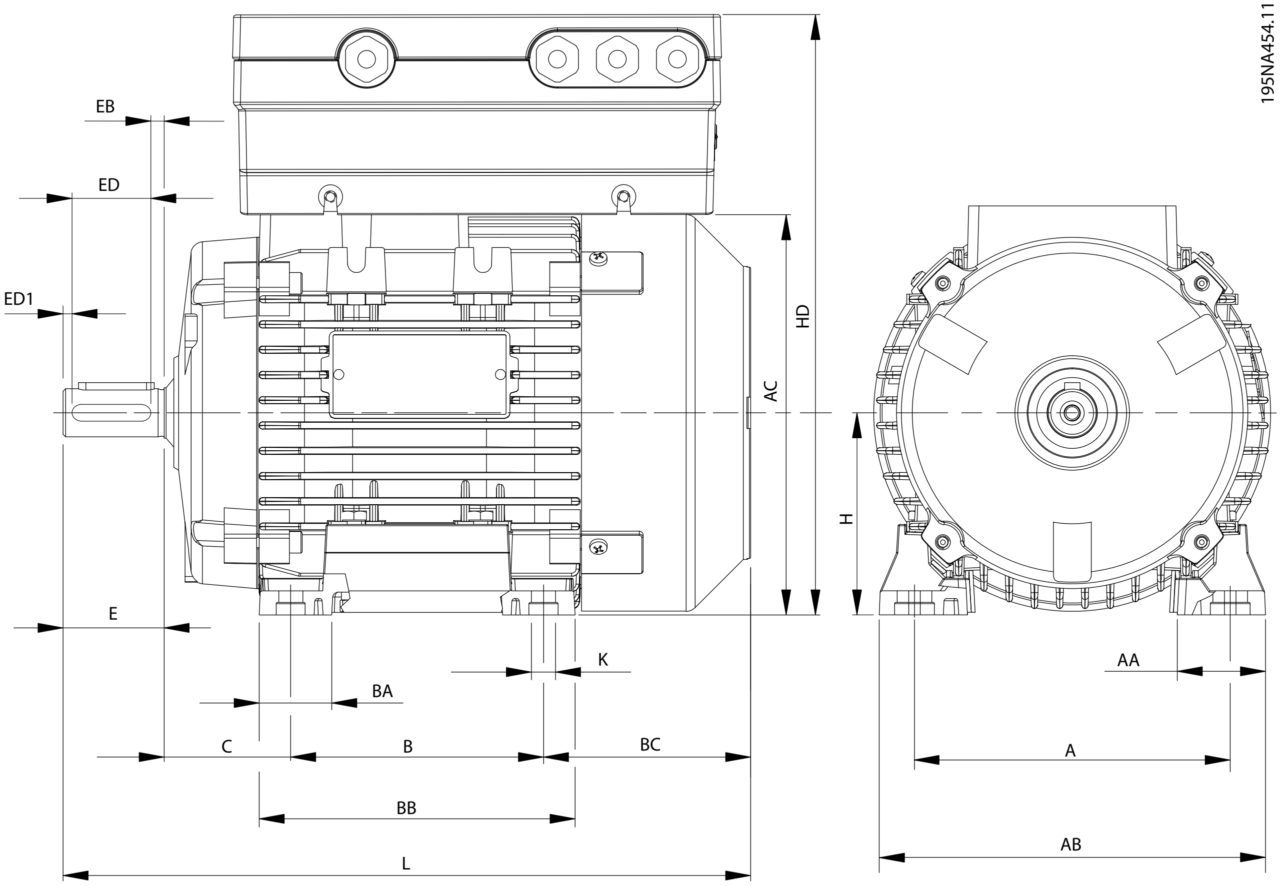
Illustration 6.2 FCP 106 Dimensions

Enclosure type	Power[1) [kW (hp)]	Length [mm (in)]		Width [mm (in)]	Height [mm (in)]		Cable gland diameter		Mounting hole
					Normal lid	High lid for VLT® PROFIBUS DP MCA 101 option			
	3x380–480 V	A	a	B	C	C	X	Y	
MH1	0.55–1.5 (0.75–2.0)	231.4 (9.1)	130 (5.1)	162.1 (6.4)	106.8 (4.2)	121.4 (4.8)	M20	M20	M6
MH2	2.2–4.0 (3.0–5.0)	276.8 (10.9)	166 (6.5)	187.1 (7.4)	113.2 (4.5)	127.8 (5.0)	M20	M20	M6
MH3	5.5–7.5 (7.5–10)	321.7 (12.7)	211 (8.3)	221.1 (8.7)	123.4 (4.9)	138.1 (5.4)	M20	M25	M6

Table 6.4 FCP 106 Dimensions

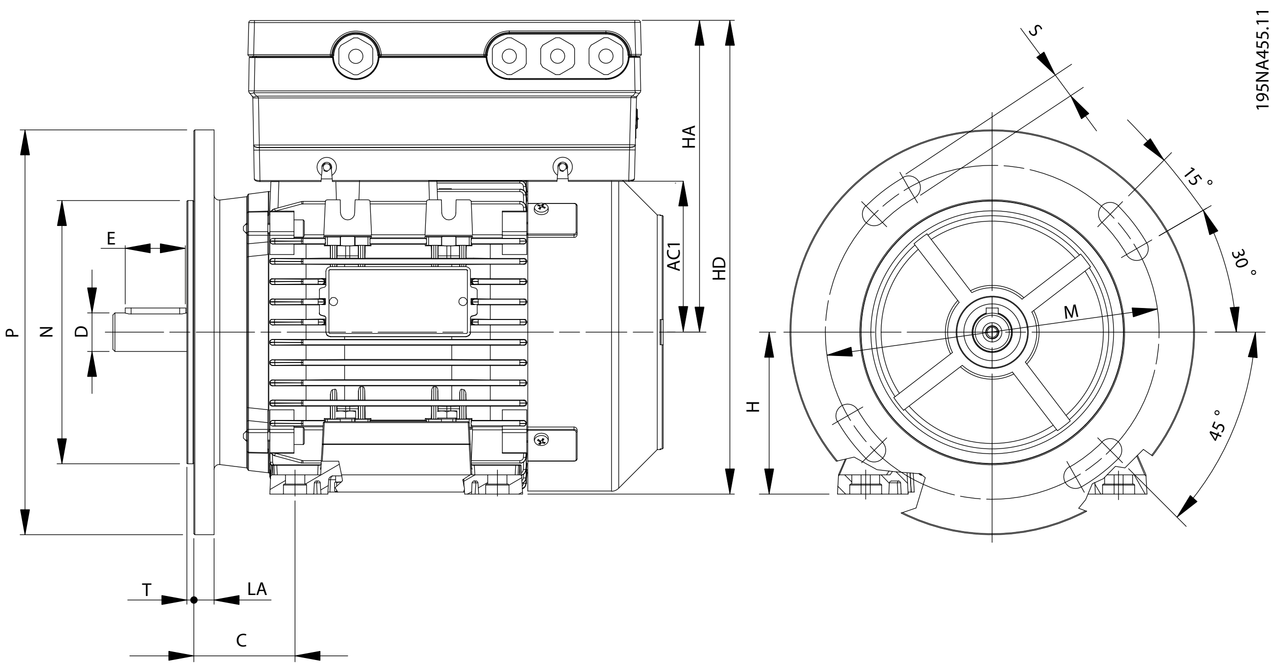
1) Power ratings relate to NO, see chapter 6.2 Electrical Data.

6.1.4 FCM 106 Dimensions



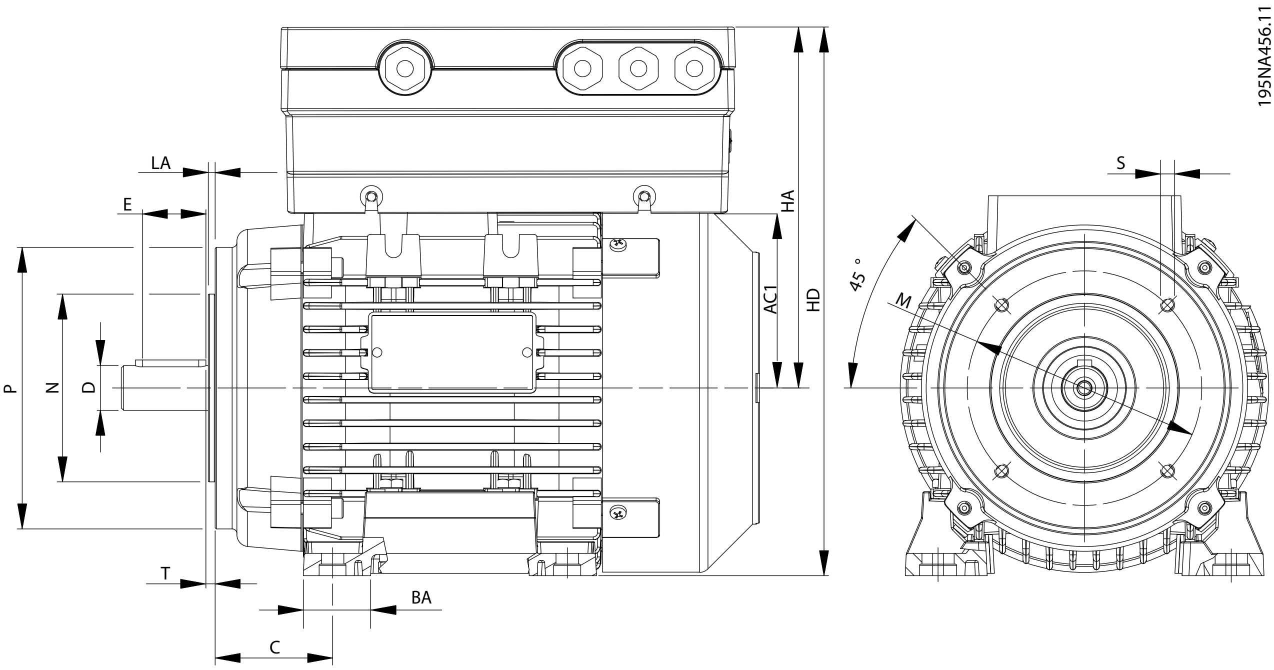
Motor frame size	71	80	90S	90L	100S	100L	112M	132S	132M
A [mm (in)]	112 (4.4)	125 (4.9)	140 (5.5)	140 (5.5)	160 (6.3)	160 (6.3)	190 (7.5)	216 (8.5)	216 (8.5)
B [mm (in)]	90 (3.5)	100 (4.0)	100 (4.0)	125 (4.9)	140 (5.5)	140 (5.5)	140 (5.5)	140 (5.5)	178 (7.0)
C [mm (in)]	45 (1.8)	50 (2.0)	56 (2.2)	56 (2.2)	63 (2.5)	63 (2.5)	70 (2.6)	89 (3.5)	89 (3.5)
H [mm (in)]	71 (2.8)	80 (3.1)	90 (3.5)	90 (3.5)	100 (4.0)	100 (4.0)	112 (4.4)	132 (5.2)	132 (5.2)
K [mm (in)]	8 (0.3)	10 (0.4)	10 (0.4)	10 (0.4)	11 (0.43)	11 (0.43)	12.5 (0.5)	12 (0.47)	12 (0.47)
AA [mm (in)]	31 (1.2)	34.5 (1.4)	37 (1.5)	37 (1.5)	44 (1.7)	44 (1.7)	48 (1.9)	59 (2.3)	59 (2.3)
AB [mm (in)]	135 (5.3)	153 (6.0)	170 (6.7)	170 (6.7)	192 (7.6)	192 (7.6)	220 (8.7)	256 (10.1)	256 (10.1)
BB [mm (in)]	108 (4.3)	125 (4.9)	150 (5.9)	150 (5.9)	166 (6.5)	166 (6.5)	176 (6.9)	180 (7.1)	218 (8.6)
BC [mm (in)]	83 (3.3)	89 (3.5)	116 (4.6)	91 (3.6)	110 (4.3)	144 (5.7)	126 (5.0)	134 (5.3)	136 (5.4)
L [mm (in)]	246 (9.7)	272 (10.7)	317 (12.5)	317 (12.5)	366 (14.4)	400 (15.7)	388 (15.3)	445 (17.5)	485 (19.1)
AC [mm (in)]	139 (5.5)	160 (6.3)	180 (7.1)	180 (7.1)	196 (7.7)	194 (7.6)	225 (8.9)	248 (9.8)	248 (9.8)
E [mm (in)]	30 (1.2)	40 (1.6)	50 (2.0)	50 (2.0)	60 (2.4)	60 (2.4)	60 (2.4)	80 (3.1)	80 (3.1)
ED [mm (in)]	20 (0.8)	30 (1.2)	30 (1.2)	40 (1.6)	40 (1.6)	50 (2.0)	50 (2.0)	70 (2.6)	70 (2.6)
EB [mm (in)]	4 (0.16)	4 (0.16)	4 (0.16)	4 (0.16)	4 (0.16)	4 (0.16)	4 (0.16)	4 (0.16)	4 (0.16)
HD [mm (in)] without VLT® PROFIBUS DP MCA 101									
MH1	247 (9.7)	267 (10.5)	286 (11.3)	286 (11.3)	–	–	–	–	–
MH2	248 (9.8)	268 (10.6)	287 (11.4)	287 (11.4)	304 (12)	304 (12)	332 (13.1)	–	–
MH3	–	–	299 (11.8)	299 (11.8)	316 (12.4)	316 (12.4)	344 (13.5)	379 (14.9)	379 (14.9)
HD [mm (in)] with VLT® PROFIBUS DP MCA 101									
MH1/	262 (10.3)	282 (11.1)	301 (11.9)	301 (11.9)	–	–	–	–	–
MH2	263 (10.4)	283 (11.1)	302 (11.9)	302 (11.9)	319 (12.6)	319 (12.6)	347 (13.7)	–	–
MH3	–	–	314 (12.4)	314 (12.4)	331 (13.0)	331 (13.0)	359 (14.1)	394 (15.5)	394 (15.5)

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



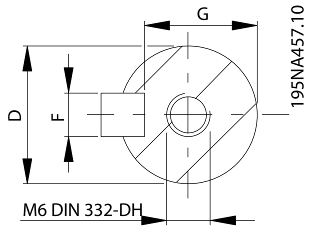
Motor frame size	71	80	90S	90L	100L	112M	132S
M [mm (in)]	130 (5.1)	165 (6.5)	165 (6.5)	165 (6.5)	215 (8.5)	215 (8.5)	265 (10.4)
N [mm (in)]	110 (4.3)	130 (5.1)	130 (5.1)	130 (5.1)	180 (7.8)	180 (7.8)	230 (9.1)
P [mm (in)]	160 (6.3)	200 (7.9)	200 (7.9)	200 (7.9)	250 (9.8)	250 (9.8)	300 (11.8)
S [mm (in)]	M8	M10	M10	M10	M12	M12	M12
T [mm (in)]	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	4 (0.16)	4 (0.16)	4 (0.16)
LA [mm (in)]	10 (0.4)	10 (0.4)	12 (0.5)	12 (0.5)	14 (0.6)	14 (0.6)	14 (0.6)
HA [mm (in)]	HA = AC1 + height of the frequency converter. For frequency converter dimensions, see *Table 6.4*.						
HD [mm (in)] without VLT® PROFIBUS DP MCA 101							
MH1	247 (9.7)	267 (10.5)	286 (11.3)	286 (11.3)	–	–	–
MH2	248 (9.8)	268 (10.6)	287 (11.4)	287 (11.4)	304 (12)	332 (13.1)	–
MH3	–	–	299 (11.8)	299 (11.8)	316 (12.4)	244 (9.6)	379 (14.9)
HD [mm (in)] with VLT® PROFIBUS DP MCA 101							
MH1	262 (10.3)	282 (11.1)	301 (11.9)	301 (11.9)	–	–	–
MH2	263 (10.4)	283 (11.2)	302 (11.9)	302 (11.9)	319 (12.6)	347 (13.7)	–
MH3	–	–	314 (12.4)	314 (12.4)	331 (13.1)	359 (14.1)	394 (15.5)

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**
M [mm (in)]	85 (3.3)	100 (4.0)	115 (4.5)	130 (5.1)	130 (5.1)	165 (6.5)
N [mm (in)]	70 (2.8)	80 (3.1)	95 (3.7)	110 (4.3)	110 (4.3)	130 (5.1)
P [mm (in)]	105 (4.1)	120 (4.7)	140 (5.5)	160 (6.3)	160 (6.3)	200 (7.9)
S [mm (in)]	M6	M6	M8	M8	M8	M10
T [mm (in)]	2.5 (0.1)	3 (0.12)	3 (0.12)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)
LA [mm (in)]	11 (0.4)	9 (0.35)	9 (0.35)	10 (0.4)	10 (0.4)	30 (0.4)
Large flange B14						
Motor frame size	**71**	**80**	**90S**	**100L**	**112M**	**132S**
M [mm (in)]	115 (4.5)	130 (5.1)	130 (5.1)	165 (6.5)	165 (6.5)	215 (8.5)
N [mm (in)]	95 (3.7)	110 (4.3)	110 (4.3)	130 (5.1)	130 (5.1)	180 (7.1)
P [mm (in)]	140 (5.5)	160 (6.3)	160 (6.3)	200 (7.9)	200 (7.9)	250 (9.8)
S [mm (in)]	M8	M8	M8	M10	M10	M12
T [mm (in)]	2.5 (0.1)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	4 (0.16)
LA [mm (in)]	8 (0.31)	8.5 (0.33)	9 (0.35)	12 (0.5)	12 (0.5)	12 (0.5)
HA [mm (in)]	HA = AC1 + height of the frequency converter. For frequency converter dimensions, see *Table 6.4*.					
HD [mm (in)] without VLT® PROFIBUS DP MCA 101						
MH1	247 (9.7)	267 (10.5)	286 (11.3)	–	–	–
MH2	248 (9.8)	268 (10.6)	287 (11.4)	304 (12)	332 (13.1)	–
MH3	–	–	299 (11.8)	316 (12.4)	244 (9.6)	379 (14.9)
HD [mm (in)] with VLT® PROFIBUS DP MCA 101						
MH1	262 (10.3)	282 (11.1)	301 (11.9)	–	–	–
MH2	263 (10.4)	283 (11.2)	302 (11.9)	319 (12.6)	347 (13.7)	–
MH3	–	–	314 (12.4)	331 (13)	359 (14.1)	394 (15.5)

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**
D [mm (in)]	14 (0.6)	19 (0.7)	24 (1.0)	28 (1.1)	28 (1.1)	38 (1.5)
F [mm (in)]	5 (0.2)	6 (0.25)	8 (0.3)	8 (0.3)	8 (0.3)	10 (0.4)
G [mm (in)]	11 (0.4)	15.5 (0.6)	20 (0.8)	24 (1.0)	24 (1.0)	33 (1.3)
DH	M5	M6	M8	M10	M10	M12

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

6

6.1.5 Weight

To calculate the total weight of the unit, add:

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

Enclosure type	Weight		
	FCP 106 [kg (lb)]	Motor adapter plate [kg (lb)]	Combined FCP 106 and motor adapter plate [kg (lb)]
MH1	3.9 (8.6)	0.7 (1.5)	4.6 (10.1)
MH2	5.8 (12.8)	1.12 (2.5)	6.92 (15.3)
MH3	8.1 (17.9)	1.48 (3.3)	9.58 (21.2)

Table 6.9 Weight of FCP 106

Shaft power [kW (hp)]	PM motor				Asynchronous motor			
	1500 RPM		3000 RPM		1500 RPM		3000 RPM	
	Motor frame size	Weight [kg (lb)]	Motor frame size	Weight [kg (lb)]	Motor frame size	Weight [kg (lb)]	Motor frame size	Weight [kg (lb)]
0.55 (0.75)	71	4.8 (10.6)	–		–		–	
0.75 (1.0)	71	5.4 (11.9)	71	4.8 (10.6)	80S	11 (24.3)	71	9.5 (20.9)
1.1 (1.5)	71	7.0 (15.4)	71	4.8 (10.6)	90S	16.4 (36.2)	80	11 (24.3)
1.5 (2.0)	71	10 (22)	71	6.0 (13.2)	90L	16.4 (36.2)	80	14 (30.9)
2.2 (3.0)	90	12 (26.5)	71	6.6 (14.6)	100L	22.4(49.4)	90L	16 (35.3)
3 (4.0)	90	14 (30.9)	90S	12 (26.5)	100L	26.5 (58.4)	100L	23 (50.7)
4 (5.0)	90	17 (37.5)	90S	14 (30.9)	112M	30.4 (67)	100L	28 (61.7)
5.5 (7.5)	112	30 (66)	90S	16 (35.3)	132S	55 (121.3)	112M	53 (116.8)
7.5 (10)	112	33 (72.8)	112M	26 (57.3)	132M	65 (143.3)	112M	53 (116.8)

Table 6.10 Approximate Weight of Motor

6.2 Electrical Data

6.2.1 Mains Supply 3x380–480 V AC Normal and High Overload

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	
Maximum cable cross-section in terminals[2] (mains, motor) [mm²/AWG]	4/12		4/12		4/12		4/12		4/12		4/12		4/12	
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
Maximum 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 (3x440–480 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
Maximum mains fuses	See *chapter 6.9 Fuse and Circuit Breaker Specifications*.													
Estimated power loss [W], best case/typical[3]	38			44		57		73		91		129		143
Efficiency [%], best case/typical[4)5)]	0.96			0.97		0.97		0.97		0.97		0.97		0.97

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

3) Applies to dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50-598-2, refer to www.danfoss.com/vltenergyefficiency.

4) Efficiency measured at nominal current. For energy efficiency class, see chapter 6.5 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

5) Measured using 4 m screened motor cables at rated load and rated frequency.

Enclosure	MH3		
	P5K5	P7K5	
Overload[1)]	NO	HO	NO
Typical shaft output [kW]	5.5		7.5
Typical shaft output [hp]	7.5		10
Maximum cable cross-section in terminals[2)] (mains, motor) [mm^2/AWG]	4/12		4/12
Output current			
40 °C ambient temperature			
Continuous (3x380–440 V) [A]	12		15.5
Intermittent (3x380–440 V) [A]	13.2	19.2	17.1
Continuous (3x440–480 V) [A]	11		14
Intermittent (3x440–480 V) [A]	12.1	13.2	15.4
Maximum 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 (3x440–480 V) [A]	10	15	14
Maximum mains fuses	See *chapter 6.9 Fuse and Circuit Breaker Specifications.*		
Estimated power loss [W], best case/typical[3)]	143	236	
Efficiency [%], best case/typical[4)5)]	0.97	0.97	

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 6.11 shows that a 1.5 kW motor for HO requires a P2K2 frequency converter.

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

3) Applies to dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50-598-2, refer to www.danfoss.com/vltenergyefficiency.

4) Efficiency measured at nominal current. For energy efficiency class, see chapter 6.5 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

5) Measured using 4 m screened motor cables at rated load and rated frequency.

6.3 Mains Supply

Mains supply (L1, L2, L3)

Supply voltage	380–480 V ±10%

Mains voltage low/mains dropout:

- *During low mains voltage or a mains dropout, the frequency converter continues until the DC-link voltage drops below the minimum stop level. This level typically corresponds 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
Maximum 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)	Maximum 2 times/min.
Environment according to EN 60664-1 and IEC 61800-5-1	Overvoltage category III/pollution degree 2

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

- 100000 RMS symmetrical Amperes, 480 V maximum, with fuses used as branch circuit protection.
- See *Table 6.14* and *Table 6.15* when using circuit breakers as branch circuit protection.

6.4 Protection and Features

Protection and features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the frequency converter trips when the temperature reaches 90 °C (194 °F) ±5 °C (41 °F). An overload temperature cannot be reset until the temperature of the heat sink is below 70 °C (158 °F) ±5 °C (41 °F). However, these temperatures may vary for different power sizes, enclosures, and so on. The frequency converter autoderating function ensures that the heat sink temperature does not reach 90 °C (194 °F).
- The frequency converter motor terminals U, V, and W are protected against ground faults at power-up and start of the motor.
- 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 DC-link voltage ensures that the frequency converter trips when the DC-link voltage is too low or too high.
- The frequency converter is protected against ground faults on motor terminals U, V, and W.
- All control terminals and relay terminals 01–03/04–06 comply with PELV (protective extra low voltage). However, this compliance does not apply to grounded delta leg above 300 V.

6.5 Ambient Conditions

Environment

Enclosure protection rating	IP66/Type 4X[1)]
Enclosure protection rating FCP 106 between lid and heat sink	IP66/Type 4X
Enclosure protection rating FCP 106 between heat sink and adapter plate	IP66/Type 4X
FCP 106 wall mount kit	IP66
Stationary vibration IEC61800-5-1 Ed.2	Cl. 5.2.6.4
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 (104 °F) (24-hour average)

Minimum ambient temperature during full-scale operation	-10 °C (14 °F)
Minimum ambient temperature at reduced performance	-20 °C (-4 °F)
Maximum ambient temperature at reduced performance	50 °C (122 °F)
Temperature during storage	-25 to +65 °C (-13 to +149 °F)
Temperature during transport	-25 to +70 °C (-13 to +158 °F)
Maximum altitude above sea level without derating	1000 m (3280 ft)
Maximum altitude above sea level with derating	3000 m (9842 ft)
Safety standards	EN/IEC 60204-1, EN/IEC 61800-5-1, UL 508C
EMC standards, emission	EN 61000-3-2, EN 61000-3-12, EN 55011, EN 61000-6-4
EMC standards, immunity	EN 61800-3, EN 61000-6-1/2
Energy efficiency class, VLT® DriveMotor FCP 106 2)	IE2
Energy efficiency class, VLT® DriveMotor FCM 106	IES

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1) The stated IP and Type rating only apply when the FCP 106 is mounted on a wall mount plate or a motor with the adapter plate. Ensure that the gasket between the adapter plate and the motor has a protection rating corresponding to the required rating for the combined motor and frequency converter. As standalone frequency converter, the enclosure rating is IP00 and Open type.
2) Determined according to EN50598-2 at:

- *Rated load.*
- *90% rated frequency.*
- *Switching frequency factory setting.*
- *Switching pattern factory setting.*

6.6 Cable Specifications

Cable lengths and cross-sections

Maximum motor cable length for wall mount kit, screened/armored	2 m (6.56 ft)
Maximum cross-section to motor, mains for MH1–MH3	4 mm^2/11 AWG
Maximum cross-section DC terminals on enclosure type MH1–MH3	4 mm^2/11 AWG
Maximum cross-section to control terminals, rigid wire	2.5 mm^2/13 AWG
Maximum cross-section to control terminals, flexible cable	2.5 mm^2/13 AWG
Minimum cross-section to control terminals	0.05 mm^2/30 AWG
Maximum cross-section to thermistor input (at motor connector)	4 mm^2/11 AWG

6.7 Control Input/Output and Control Data

Digital inputs

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	Approximately 4 kΩ
Digital input 29 as pulse input	Maximum frequency 32 kHz push-pull-driven and 5 kHz (O.C.)

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Terminal 53 mode	*Parameter 6-19 Terminal 53 mode*: 1=voltage, 0=current
Terminal 54 mode	*Parameter 6-29 Terminal 54 mode*: 1=voltage, 0=current
Voltage level	0–10 V
Input resistance, R_i	Approximately 10 kΩ

Maximum voltage	20 V
Current level	0/4 to 20 mA (scalable)
Input resistance, R_i	<500 Ω
Maximum current	29 mA

Analog output

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

1) Terminals 42 and 45 can also be programmed as digital outputs.

Digital output

Number of digital outputs	4
Terminals 27 and 29	
Terminal number	27, 29[1]
Voltage level at digital output	0–24 V
Maximum output current (sink and source)	40 mA
Terminals 42 and 45	
Terminal number	42, 45[2]
Voltage level at digital output	17 V
Maximum output current at digital output	20 mA
Maximum load at digital output	1 kΩ

1) Terminals 27 and 29 can also be programmed as input.
2) Terminals 42 and 45 can also be programmed as analog output.
The digital outputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control card, RS485 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

Terminal number	12
Maximum load	80 mA

Relay output

Programmable relay output	2
Relay 01 and 02	01-03 (NC), 01-02 (NO), 04-06 (NC), 04-05 (NO)
Maximum terminal load (AC-1)[1] on 01-02/04-05 (NO) (Resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15)[1] on 01-02/04-05 (NO) (Inductive load @ COSφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1)[1] on 01-02/04-05 (NO) (Resistive load)	30 V DC, 2 A
Maximum terminal load (DC-13)[1] on 01-02/04-05 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1)[1] on 01-03/04-06 (NC) (Resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15)[1] on 01-03/04-06 (NC) (Inductive load @ COSφ 0.4)	250 V AC, 0.2 A
	30 V DC, 2 A
Maximum terminal load (DC-1)[1] on 01-03/04-06 (NC) (Resistive load)	Minimum 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 sections 4 and 5.

Control card, 10 V DC output

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

6.8 FCM 106 Motor Specifications

Motor output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency, asynchronous motor	0–200 Hz (VVC+), 0–400 Hz (u/f)
Output frequency, PM motor	0–390 Hz (VVC+ 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

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6.8.1 Motor Overload Data, VLT DriveMotor FCM 106

Type	Size	Speed [RPM]	Pn [kW (hp)]	TN100 [Nm (in-lb)]	Frequency converter current [A] 100%	T110 [Nm (in-lb)]	Drive current [A] 110%	T160 [Nm (in-lb)]	Drive current [A] 160%
HPS	71	1500	0.55 (0.74)	4.54 (40.2)	1.7	4.91 (43.5)	1.9	6.74 (59.7)	2.7
HPS	71	1500	0.75 (1.0)	6.07 (53.7)	2.2	6.38 (56.5)	2.4	8.99 (79.6)	3.5
HPS	71	1500	1.10 (1.47)	8.37 (74.1)	3	8.96 (79.3)	3.3	12.55 (111.1)	4.8
HPS	71	1500	1.50 (2.0)	10.18 (90.1)	3.7	11.08 (98.1)	4.1	15.35 (135.9)	5.9
HPS	71	1800	0.55 (0.74)	4.52 (40)	1.7	4.81 (42.6)	1.9	6.63 (58.7)	2.7
HPS	71	1800	0.75 (1.0)	5.06 (44.8)	2.2	5.32 (47.1)	2.4	7.48 (66.2)	3.5
HPS	71	1800	1.10 (1.47)	6.93 (61.3)	3	7.44 (65.8)	3.3	10.40 (92)	4.8
HPS	71	1800	1.50 (2.0)	8.97 (79.4)	3.7	9.70 (85.9)	4.1	13.43 (118.9)	5.9
HPS	71	3000	0.75 (1.0)	3.03 (26.8)	2.2	3.17 (28.1)	2.4	4.50 (39.8)	3.5
HPS	71	3000	1.10 (1.47)	4.18 (37)	3	4.48 (39.7)	3.3	6.27 (55.5)	4.8
HPS	71	3000	1.50 (2.0)	5.25 (46.5)	3.7	5.71 (50.5)	4.1	7.90 (69.9)	5.9
HPS	71	3000	2.20 (2.95)	7.56 (66.9)	5.3	8.13 (72)	5.8	11.44 (101.3)	8.5
HPS	71	3600	0.75 (1.0)	2.53 (22.4)	2.2	2.66 (23.5)	2.4	3.74 (3.1)	3.5
HPS	71	3600	1.10 (1.47)	3.47 (30.7)	3	3.72 (32.9)	3.3	5.20 (46)	4.8
HPS	71	3600	1.50 (2.0)	4.53 (40.1)	3.7	4.91 (43.5)	4.1	6.79 (60.1)	5.9
HPS	71	3600	2.20 (2.95)	6.26 (55.4)	5.3	6.74 (59.7)	5.8	9.48 (83.9)	8.5
HPS	90	1500	1.50 (2.0)	10.18 (90.1)	3.7	11.08 (98.1)	4.1	15.35 (135.6)	5.9
HPS	90	1500	2.20 (2.95)	14.49 (128.2)	5.3	15.63 (138.3)	5.8	21.99 (194.6)	8.5
HPS	90	1500	3.00 (4.02)	19.70 (174.4)	7.2	21.37 (189.1)	7.9	29.83 (264)	11.5
HPS	90	1500	4.00 (5.36)	29.81 (263.8)	9	32.19 (284.9)	9.9	44.81 (396.6)	14.4
HPS	90	1800	2.20 (2.95)	12.63 (111.8)	5.3	13.59 (120.3)	5.8	19.12 (166.2)	8.5
HPS	90	1800	3.00 (4.02)	16.40 (145.2)	7.2	17.79 (157.5)	7.9	24.84 (219.9)	11.5
HPS	90	1800	4.00 (5.36)	22.42 (198.4)	9	24.27 (214.8)	9.9	33.88 (299.9)	14.4
HPS	90	3000	2.20 (2.95)	7.25 (64.2)	5.3	7.81 (69.1)	5.8	10.99 (97.3)	8.5
HPS	90	3000	3.00 (4.02)	9.90 (87.6)	7.2	10.73 (95)	7.9	14.99 (132.7)	11.5
HPS	90	3000	4.00 (5.36)	13.29 (117.6)	9	14.32 (126.7)	9.9	20.03 (177.3)	14.4
HPS	90	3000	5.50 (7.37)	18.32 (162.1)	12	19.91 (176.2)	13.2	27.78 (245.9)	19.2
HPS	90	3600	3.00 (4.02)	8.25 (73)	7.2	8.95 (79.2)	7.9	12.50 (110.6)	11.5
HPS	90	3600	4.00 (5.36)	10.67 (94.4)	9	11.61 (102.8)	9.9	16.21 (143.5)	14.4
HPS	90	3600	5.50 (7.37)	15.40 (136.3)	12	16.61 (147)	13.2	23.23 (205.6)	19.2
HPS	112	1500	5.50 (7.37)	36.62 (324.1)	12	39.66 (351)	13.2	55.41 (490.4)	19.2
HPS	112	1500	7.50 (10.05)	49.59 (438.9)	15.5	53.98 (477.8)	17.1	71.01 (628.5)	23.3
HPS	112	1800	5.50 (7.37)	30.36 (268.7)	12	32.94 (291.5)	13.2	45.99 (407)	19.2
HPS	112	1800	7.50 (10.05)	42.14 (373)	15.5	45.80 (405.4)	17.1	60.25 (533.3)	23.3
HPS	112	3000	7.50 (10.05)	24.66 (218.5)	15.5	26.83 (237.5)	17.1	35.30 (312.4)	23.3
HPS	112	3600	7.50 (10.05)	21.33 (188.8)	15.5	23.23 (205.6)	17.1	30.52 (270.1)	23.3
AMHE	71Z	2865	0.75 (1.0)	2.89 (25.6)	2.2	3.55 (31.4)	2.4	5.10 (45.1)	3.5
AMHE	80Z	1430	0.75 (1.0)	6.11 (54.1)	2.2	7.67 (67.9)	2.4	11.20 (99.1)	3.5
AMHE	80Z	2880	1.10 (1.47)	4.32 (38.2)	3	5.78 (15.2)	3.3	8.77 (77.6)	4.8
AMHE	80Z	2880	1.50 (2.0)	5.44 (48.1)	3.7	6.96 (61.6)	4.1	10.61 (93.9)	5.9
AMHE	90S	1430	1.10 (1.47)	8.76 (77.5)	3	11.30 (100)	3.3	16.91 (149.7)	4.8
AMHE	90L	1430	1.50 (2.0)	10.88 (96.3)	3.7	13.29 (117.6)	4.1	20.52 (181.6)	5.9
AMHE	90L	2860	2.20 (2.95)	8.79 (77.8)	5.3	10.48 (92.8)	5.8	15.62 (138.2)	8.5
AMHE	90L	2880	3.00 (4.02)	11.69 (103.5)	7.2	14.33 (126.8)	7.9	19.61 (173.6)	11.5
AMHE	100L	1450	2.20 (2.95)	15.07 (133.4)	5.3	18.21 (161.2)	5.8	28.62 (253.3)	8.5
AMHE	100L	1440	3.00 (4.02)	19.63 (173.7)	7.2	22.61 (200.1)	7.9	32.93 (291.5)	11.5
AMHE	100L	2920	4.00 (5.36)	15.12 (133.8)	9	18.75 (166)	9.9	27.23 (241)	14.4
AMHE	112M	1450	4.00 (5.36)	27.85 (246.5)	9	33.22 (294)	9.9	51.53 (456.1)	14.4

Type	Size	Speed [RPM]	Pn [kW (hp)]	TN100 [Nm (in-lb)]	Frequency converter current [A] 100%	T110 [Nm (in-lb)]	Drive current [A] 110%	T160 [Nm (in-lb)]	Drive current [A] 160%
AMHE	112M	1450	5.50 (7.37)	36.50 (323.1)	12	42.60 (377)	13.2	62.05 (549.2)	19.2
AMHE	112M	2920	5.50 (7.37)	20.88 (184.8)	12	26.45 (234.1)	13.2	34.27 (303.3)	19.2
AMHE	112M	2900	7.50 (10.05)	28.79 (254.8)	15.5	31.84 (281.8)	17.1	42.09 (372.5)	23.3
AMHE	132M	1450	7.50 (10.05)	49.18 (435.3)	15.5	56.62 (501.1)	17.1	78.74 (696.9)	23.3

Table 6.13 Motor Overload Data

6.9 Fuse and Circuit Breaker Specifications

Overcurrent protection

Provide overload protection to avoid overheating of the cables in the installation. Always carry out overcurrent protection according to local and national regulations. Design fuses for protection in a circuit capable of supplying a maximum of 100000 A_{rms} (symmetrical), 480 V maximum. See *Table 6.14* and *Table 6.15* for breaking capacity for Danfoss CTI25M circuit breaker at 480 V maximum.

UL/non-UL compliance

To ensure compliance with UL 508C or IEC 61800-5-1, use the circuit breakers or fuses listed in *Table 6.14*, *Table 6.15*, and *Table 6.16*.

NOTICE

EQUIPMENT DAMAGE

If there is a malfunction, failure to follow the protection recommendation can result in damage to the frequency converter.

Enclosure size	Power[1)] [kW (hp)] 3x380–480 V	Circuit breaker			
		Recommended UL	Breaking capacity	Maximum UL	Breaking capacity
MH1	0.55 (0.75)	CTI25M - 47B3146	100000	CTI25M - 047B3149	50000
	0.75 (1.0)	CTI25M - 47B3147	100000	CTI25M - 047B3149	50000
	1.1 (1.5)	CTI25M - 47B3147	100000	CTI25M - 047B3150	6000
	1.5 (2.0)	CTI25M - 47B3148	100000	CTI25M - 047B3150	6000
MH2	2.2 (3.0)	CTI25M - 47B3149	50000	CTI25M - 047B3151	6000
	3.0 (4.0)	CTI25M - 47B3149	50000	CTI25M - 047B3151	6000
	4.0 (5.0)	CTI25M - 47B3150	6000	CTI25M - 047B3151	6000
MH3	5.5 (7.5)	CTI25M - 47B3150	6000	CTI25M - 047B3151	6000
	7.5 (10)	CTI25M - 47B3151	6000	CTI25M - 047B3151	6000

Table 6.14 Circuit Breakers, UL

Enclosure size	Power[1)] [kW (hp)] 3x380–480 V	Circuit breaker			
		Recommended non-UL	Breaking capacity	Maximum non-UL	Breaking capacity
MH1	0.55 (0.75)	CTI25M - 47B3146	100000	CTI25M - 47B3149	100000
	0.75 (1.0)	CTI25M - 47B3147	100000	CTI25M - 47B3149	100000
	1.1 (1.5)	CTI25M - 47B3147	100000	CTI25M - 47B3150	50000
	1.5 (2.0)	CTI25M - 47B3148	100000	CTI25M - 47B3150	50000
MH2	2.2 (3.0)	CTI25M - 47B3149	100000	CTI25M - 047B3151	15000
	3.0 (4.0)	CTI25M - 47B3149	100000	CTI25M - 047B3151	15000
	4.0 (5.0)	CTI25M - 47B3150	50000	CTI25M - 047B3102[1)]	15000
MH3	5.5 (7.5)	CTI25M - 47B3150	50000	CTI25M - 047B3102[1)]	15000
	7.5 (10)	CTI25M - 47B3151	15000	CTI25M - 047B3102[1)]	15000

Table 6.15 Circuit Breakers, Non-UL

1) Trip level maximum set to 32 A.

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Enclosure size	Power[1)] [kW] 3x380–480 V	Fuse							
		Recommended UL	Maximum UL					Recommend-ed non-UL	Maximum non-UL
		Type							
		RK5, RK1, J, T, CC	RK5	RK1	J	T	CC	gG	gG
MH1	0.55 (0.75)	6	6	6	6	6	6	10	10
	0.75 (1.0)	6	6	6	6	6	6	10	10
	1.1 (1.5)	6	10	10	10	10	10	10	10
	1.5 (2.0)	6	10	10	10	10	10	10	10
MH2	2.2 (3.0)	6	20	20	20	20	20	16	20
	3.0 (4.0)	15	25	25	25	25	25	16	25
	4.0 (5.0)	15	30	30	30	30	30	16	32
MH3	5.5 (7.5)	20	30	30	30	30	30	25	32
	7.5 (10)	25	30	30	30	30	30	25	32

Table 6.16 Fuses

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 (41 °F) lower than the maximum ambient temperature. If the frequency converter operates at high ambient temperature, decrease the constant output current.

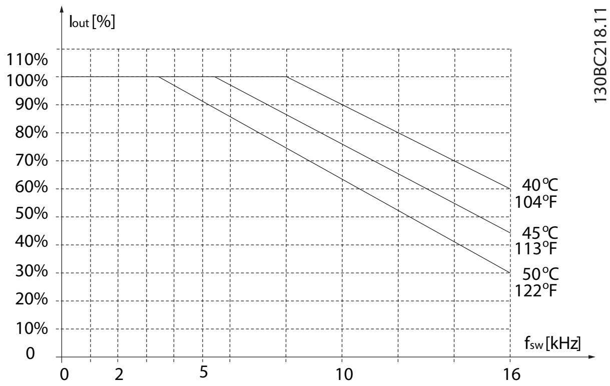

Illustration 6.3 400 V MH1 0.55–1.5 kW (0.75–2.0 hp)

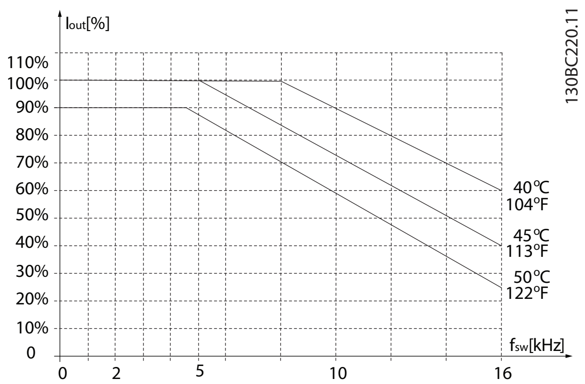

Illustration 6.4 400 V MH2 2.2–4.0 kW (3.0–5.0 hp)

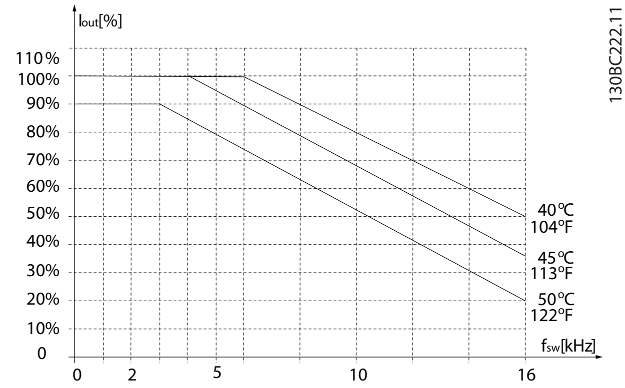

Illustration 6.5 400 V MH3 5.5–7.5 kW (7.5–10 hp)

6.11 dU/dt

Shaft output power [kW (hp)]	Cable length [m (ft)]	Mains voltage [V]	Rise time [μs]	V_{peak} [kV]	dU/dt [kV/μs]
0.55 (0.75)	0.5 (1.6)	400	0.1	0.57	4.5
0.75 (1.0)	0.5 (1.6)	400	0.1	0.57	4.5
1.1 (1.5)	0.5 (1.6)	400	0.1	0.57	4.5
1.5 (2.0)	0.5 (1.6)	400	0.1	0.57	4.5
2.2 (3.0)	<0.5 (1.6)	400	1)	1)	1)
3.0 (4.0)	<0.5 (1.6)	400	1)	1)	1)
4.0 (5.0)	<0.5 (1.6)	400	1)	1)	1)
5.5 (7.5)	<0.5 (1.6)	400	1)	1)	1)
7.5 (10)	<0.5 (1.6)	400	1)	1)	1)

Table 6.17 dU/dt, MH1–MH3

1) Data available at 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%, that is 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 selected.
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. If the mains voltage is 480 V, the efficiency is also slightly reduced.

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

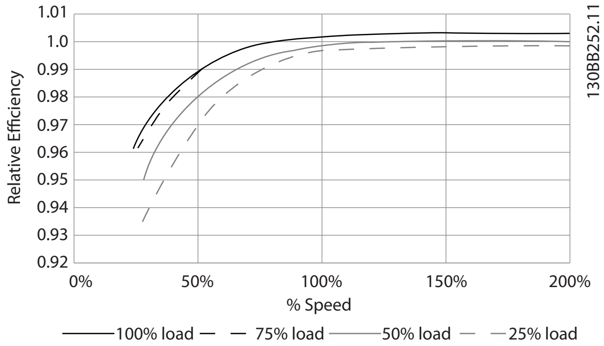

Illustration 6.6 Typical Efficiency Curves

Example: Assume a 22 kW (30 hp), 380–480 V AC frequency converter runs at 25% load at 50% speed. The graph shows 0.97, whereas rated efficiency for a 22 kW (30 hp) frequency converter is 0.98. The actual efficiency is then: 0.97 x 0.98 = 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 as good as with mains operation. The efficiency of the motor depends on the motor type.

In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant. The constant efficiency applies both when a frequency converter controls the motor, and when the motor runs directly on mains.

In small motors, the influence from the U/f characteristic on efficiency is marginal. However, in motors from 11 kW (15 hp) and up, the advantages are significant.

In general, the switching frequency does not affect the efficiency of small motors. Motors from 11 kW (15 hp) and up have their efficiency improved (1–2%). This improvement is due to an almost perfect sine shape of the motor current 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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T

U

V

W

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