ENGINEERING TOMORROW

Design Guide
VLT® DriveMotor FCP 106

vlt-drives.danfoss.com

Contents

1 Introduction

1.1 Purpose of the Design Guide

This design guide for VLT® DriveMotor FCP 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 drive 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 drive into a system. The design guide caters for selection of drives 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 Operating Guide,* for information required to install and commission the drive.
- *VLT® DriveMotor FCP 106 Design Guide* provides information required for integration of the drive into a diversity of applications.
- *VLT® DriveMotor FCP 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).
- *VLT® Modbus RTU Operating Instructions* and *VLT® DriveMotor FCP 106 BACnet Operating Instructions* for information required for controlling, monitoring, and programming of the drive.
- The *VLT® PROFIBUS DP MCA 101 Installation Guide* provides information about installing and trouble-shooting the PROFIBUS option.
- The *VLT® PROFIBUS DP MCA 101 Programming Guide* provides information about configuring the system, controlling the drive, accessing the drive, programming, and troubleshooting. It also contains some typical application examples.
- *VLT® Motion Control Tool MCT 10* enables configuration of the drive 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 *www.danfoss.com*. Search for documentation.

Danfoss VLT® Energy Box software is available at *www.danfoss.com*. Search for Energy Box.

1.3 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome. *Table 1.1* shows the document version and the corresponding software version.
In the drive, read the software version in *parameter 15-43 Software Version*.

Edition	Remarks	Software version
MG03M3xx	Software update. Removed FCM 106 from manual.	5.23

Table 1.1 Document and Software Version

1.4 Symbols, Abbreviations, Conventions, and Glossary

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.

DIx	DI1: Digital input 1. DI2: Digital input 2.
EMC	Electromagnetic compatibility.
MM	Memory module.
MMP	Memory module programmer.
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.

Table 1.2 Abbreviations

Conventions

- Numbered lists indicate procedures.
- Bullet lists indicate other information and description of illustrations.
- Italicized text indicates:
    - Cross-reference.
    - Link.
    - Footnote.
    - Parameter name.
    - Parameter group name.
    - Parameter option.
- All dimensions are in mm (inch).

Degree of protection	The degree of protection is a standardized specification for electrical equipment that describes the protection against the ingress of foreign objects and water (for example: IP20).
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 drive to an operational state after a detected error is cleared by removing the cause of the error. The error is then no longer active.
Parameter	Device data and values that can be read and set (to a certain extent).
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 1.3 Glossary

1.5 Approvals

Drives are designed in compliance with the directives described in this section.

More information on approvals and certificates, are available at *www.danfoss.com*. Search for approval or certificate.

Certification	
EC Declaration of Conformity	
UL recognized	
C-tick	

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

- Low Voltage Directive 2014/35/EU, based on EN 61800-5-1 (2007).
- EMC Directive 2014/30/EU, based on EN 61800-3 (2005) + A1 (2012), EN 61000-3-2 (2014), EN 61000-6-1 (2007), and EN 61000-6-2 (2005).

UL recognized
More evaluation is required before the combined drive and motor can be operated. The system in which the product is installed must also be UL listed by the appropriate party.

1.5.1 What is Covered

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

- The drive is sold directly to the end user. For such applications, the drive must be CE-labeled in accordance with the EMC Directive.
- The drive is sold as part of a system. It is being marked as complete system, such as an air-conditioning system. The complete system must be CE-labeled 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 drive 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 drive must be CE-labeled 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-labeled under the EMC Directive.

1.5.2 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 drives are listed in *Table 1.4*.

NOTICE

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

NOTICE

Drives 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 Directive1)	2014/32/EU
ErP Directive	2009/125/EC
ATEX Directive	2014/34/EU
RoHS Directive	2002/95/EC

Table 1.4 EU Directives Applicable to AC Drives

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

Declarations of conformity are available on request.

1.5.2.1 Low Voltage Directive

Drives must be CE-labeled in accordance with the Low Voltage Directive of January 1, 2014. The Low Voltage Directive applies to all electrical equipment in the 50–1000 V AC and the 75–1500 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.

1.5.2.2 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.

1.5.2.3 Machinery Directive

The aim of the Machinery Directive is to ensure personal safety and avoid property damage to 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.

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

When drives 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.

1.5.2.4 ErP Directive

The ErP Directive is the European Ecodesign Directive for energy-related products. The directive sets ecodesign requirements for energy-related products, including drives. 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.

1.5.3 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 drives, apply the emission limits specified in EN/IEC 61800-3.

A declaration of conformity can be provided on request.

1.5.4 UL Compliance

Illustration 1.3 UL Recognized

The drive complies with UL 508C thermal memory retention requirements. For more information, refer to *chapter 3.5.6 Motor Thermal Protection*.

1.5.5 Export Control Regulations

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

An ECCN number is used to classify all drives that are subject to export control regulations.

The ECCN number is provided in the documents accompanying the Drive.

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

1.6 Software Version

Read the software version of the drive in *parameter 15-43 Software Version*.

1.7 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.

1.8 Safety

1.8.1 General Safety Principles

If handled improperly, drives have the potential for fatal injury as they contain high voltage components. Only qualified personnel are allowed to install and operate the equipment. Do not attempt repair work without first removing power from the drive 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 drive.

Correct and reliable transport, storage, installation, operation, and maintenance are required for the trouble-free and safe operation of the drive. 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. Also, the qualified personnel must be familiar with the instructions and safety measures described in this manual.

⚠WARNING

HIGH VOLTAGE

Drives 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.**
- **Before performing any service or repair work, use an appropriate voltage measuring device to make sure that there is no remaining voltage on the drive.**

⚠WARNING

UNINTENDED START

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

WARNING

DISCHARGE TIME

The drive contains DC-link capacitors, which can remain charged even when the drive 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 supplies, including battery back-ups, UPS, and DC-link connections to other drives.**
- **Disconnect or lock PM motor.**
- **Wait for the capacitors to discharge fully. The minimum duration of waiting time is specified in *Table 1.5*.**
- **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 1.5 Discharge Time

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

WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the drive 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 drive can result in serious injury when the drive is not properly closed.

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

2 Product Overview

2.1 Introduction

The delivery comprises the drive only. A wall-mounted adapter plate, or motor adapter plate and power crimp terminals are also required for installation. Order the wall-mounted kit, or adapter plate and power crimp terminals separately.

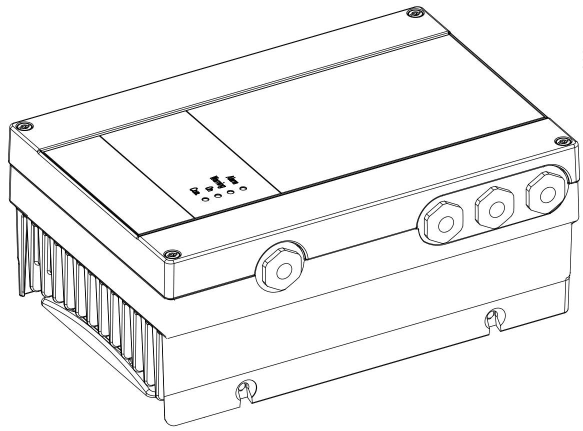


Illustration 2.1 VLT® DriveMotor FCP 106

The drive is designed for both motor- and wall-mounting. The motor is not included in delivery.

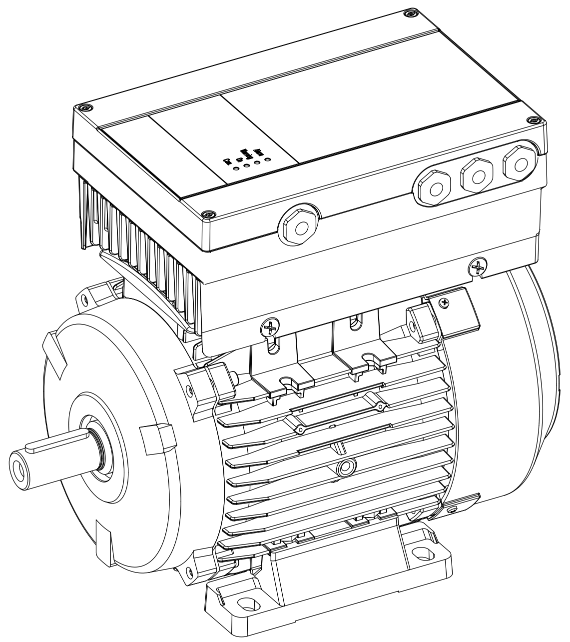


Illustration 2.2 FCP 106 Motor-mounted

2.1.1 Gasket

Mounting of the VLT® DriveMotor FCP 106 onto a motor requires fitting a customized gasket. The gasket fits between the motor adapter plate and the motor.

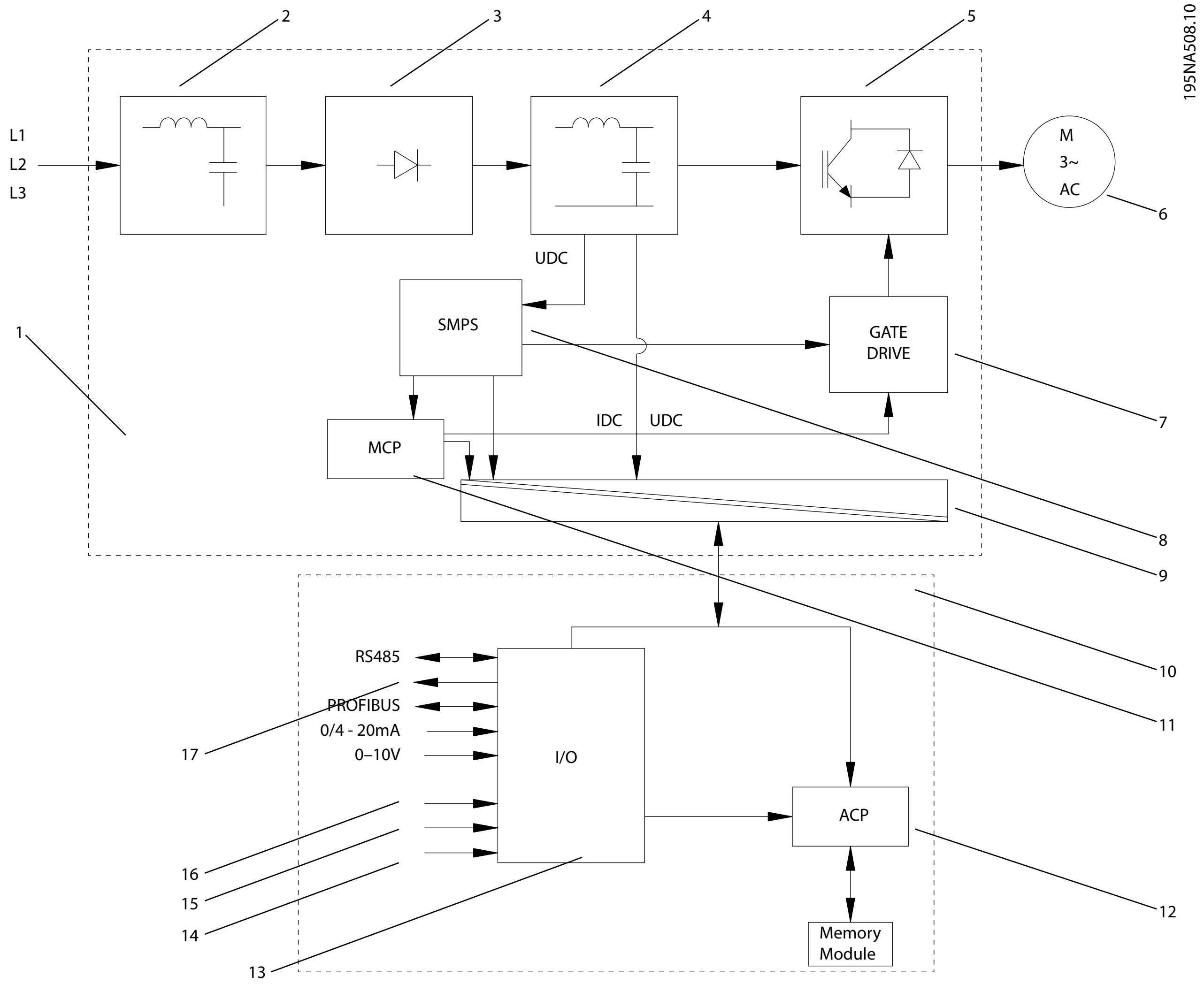
No gasket is supplied with the FCP 106 drive.

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

Requirements for gasket:

- Maintain the ground connection between the drive and the motor. The drive is grounded to the motor adapter plate. Use a wire connection between the motor and the drive.
- Use a UL-approved material for the gasket, when UL listing or recognition is required for the assembled product.
- The ingress of water or humidity by the motor connector must be avoided by suitable measures.

2.1.2 Key Diagram



1	Power card	7	Gate drive	13	Control terminals
2	RFI filter	8	SMPS (switched mode power supply)	14	Reset
3	Rectifier	9	Galvanic isolation	15	Jog
4	DC link/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

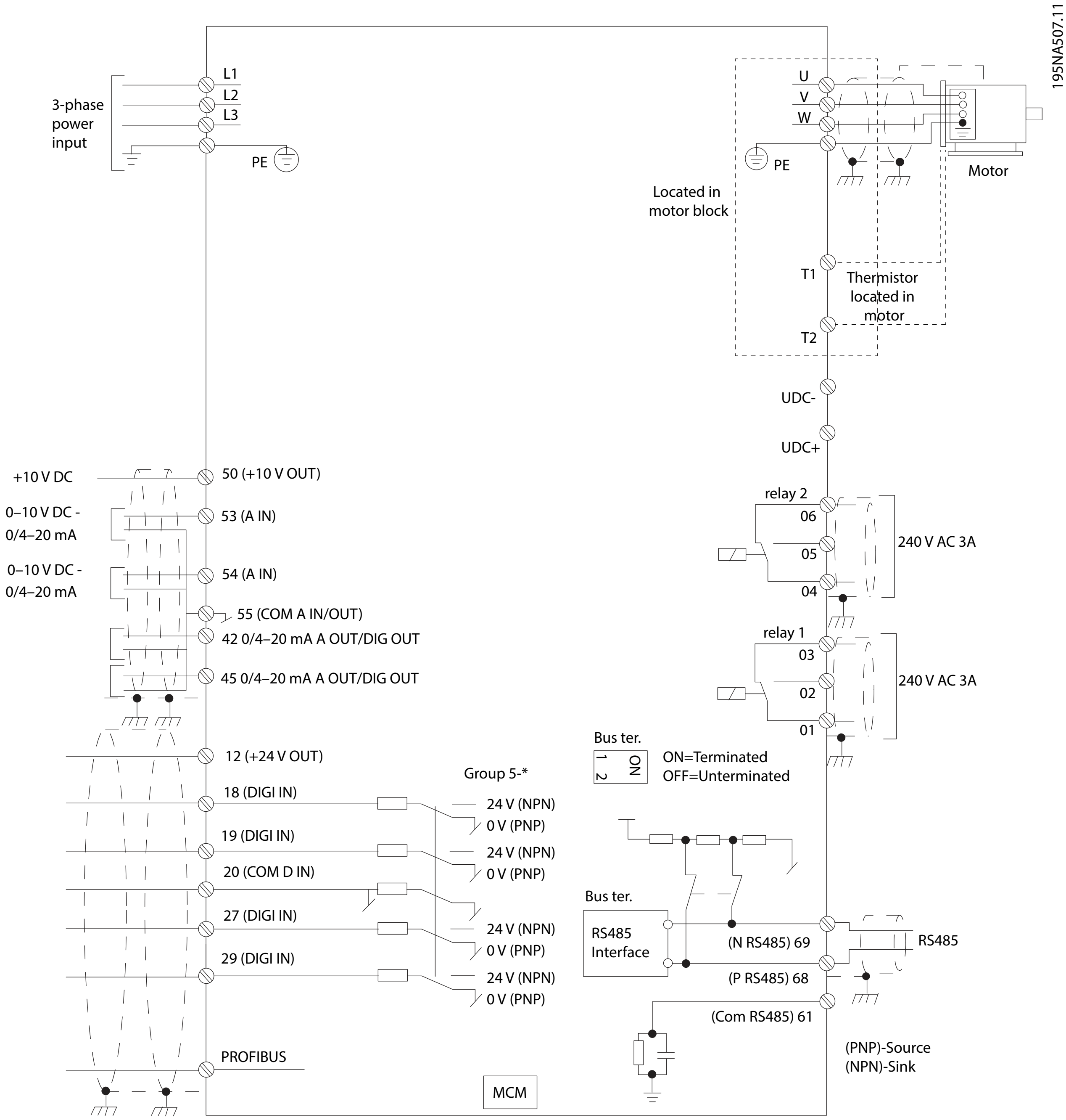
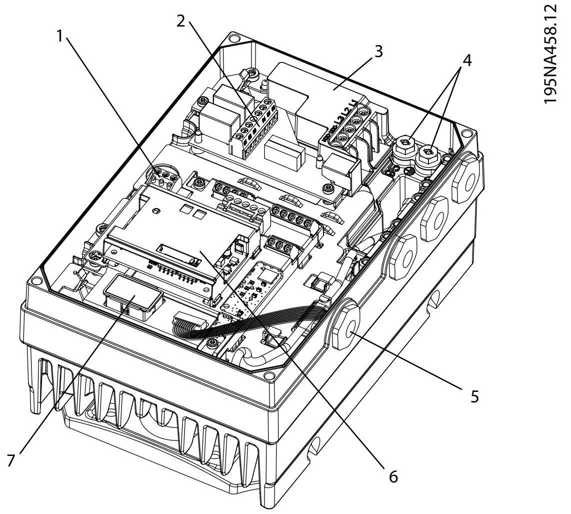


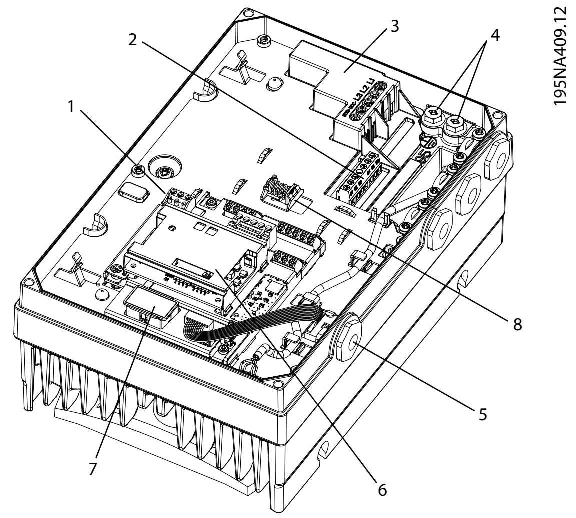
Illustration 2.4 Electrical Overview

2.1.4 Control Terminals and Relays



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

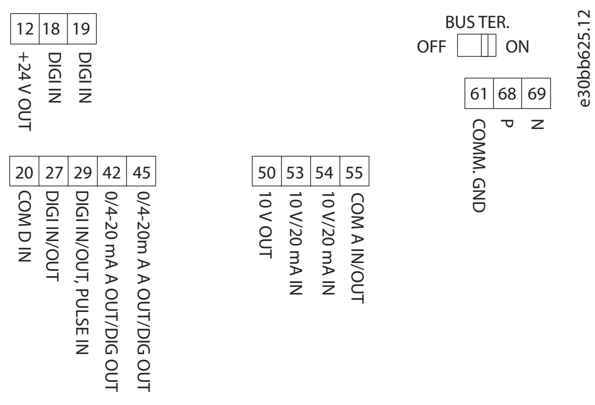


Illustration 2.7 Control Terminals

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 D in	–	–
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 A in/out	–	–
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 drive:

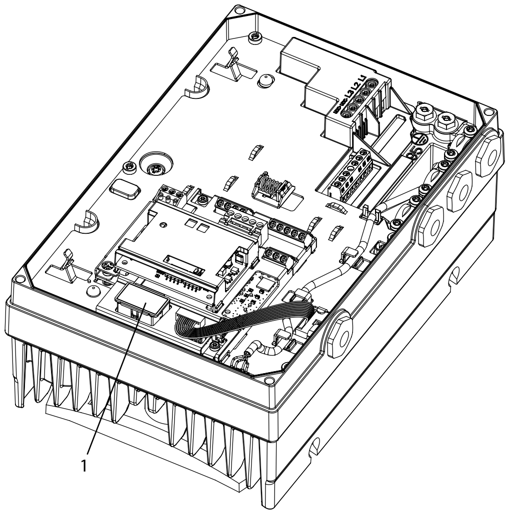
- BACnet MSTP
- Modbus RTU
- FC Protocol

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 drive 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 drive 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 drive 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. The order number is: 134B0791.

2.2.1 Configuring with the VLT® Memory Module MCM 101

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

⚠WARNING

DISCONNECT POWER BEFORE SERVICING!

Before performing repair work, disconnect the drive from AC mains. After mains have 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 drive containing a memory module.
2. Unplug the memory module.
3. Place and tighten the lid.
4. Remove the lid from the new drive.
5. Insert the memory module in the new/other drive and leave it in.
6. Place and tighten the lid on the new drive.
7. Power up the drive.

NOTICE

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

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 several VLT® DriveMotor FCP 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 to a PC.
2. Transfer the configuration data from the PC to the drive. This data is NOT encoded.

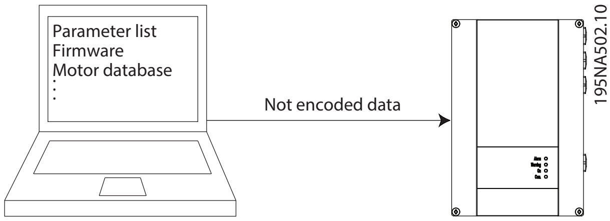


Illustration 2.9 Data Transfer from PC to Drive

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

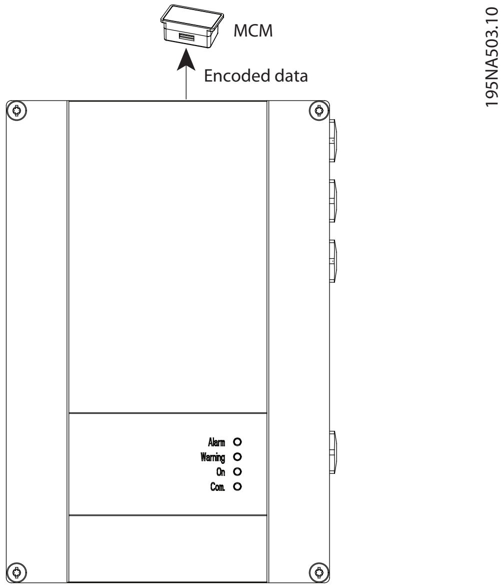


Illustration 2.10 Data Transfer from Drive to Memory Module

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

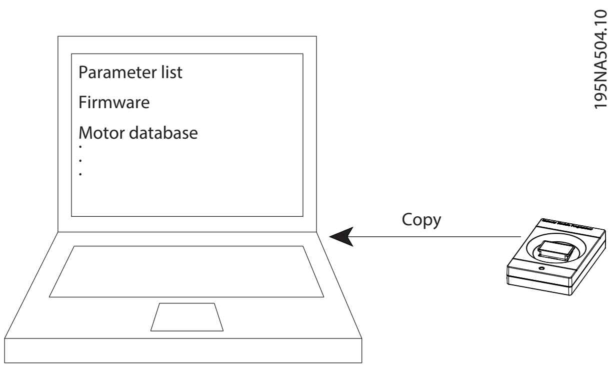


Illustration 2.11 Data Transfer from MMP to PC

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

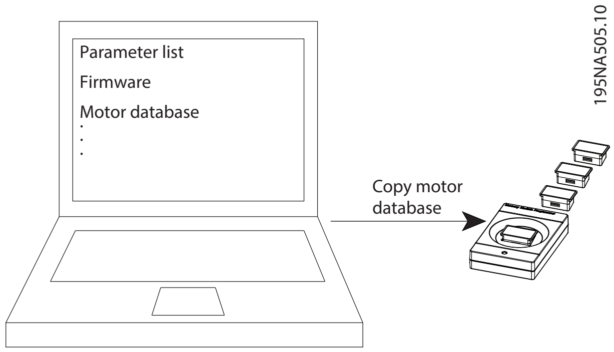


Illustration 2.12 Data Transfer from PC to Memory Module

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

2.2.3 Copying a Configuration to Several Drives

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

1. Remove the lid from the drive with the configuration to be copied.
2. Unplug the memory module.
3. Remove the lid from the drive 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 drive.
6. Place and tighten the lid.
7. Power cycle the drive.
8. Repeat steps 3–7 for each drive that is to receive the configuration.
9. Place the memory module in the original drive.
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.

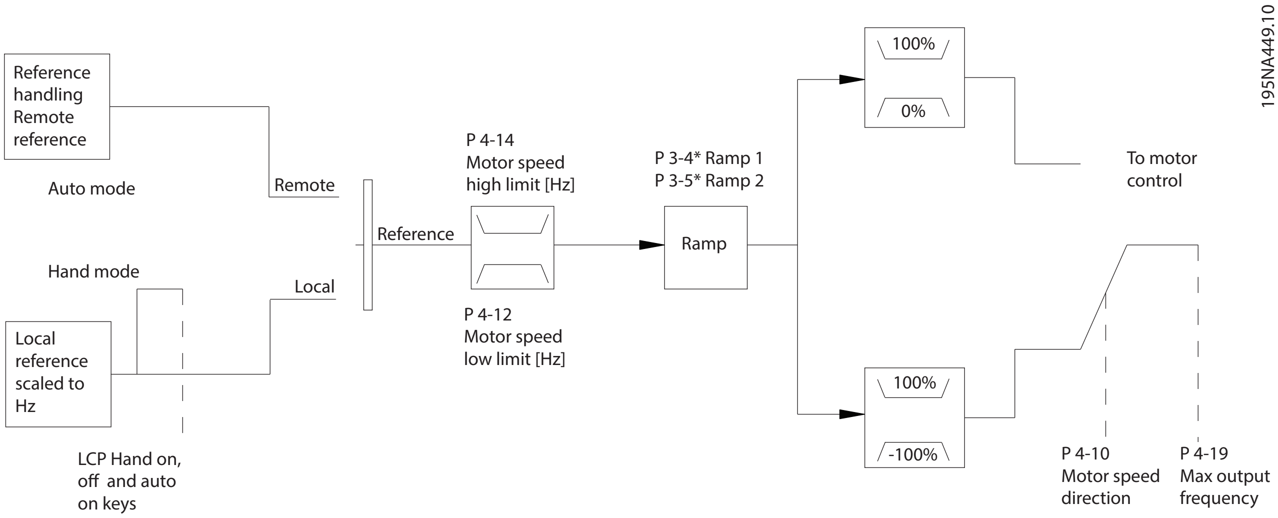


Illustration 2.13 Open-loop Structure

2.3.2 Control Structure Closed Loop (PI)

The internal controller allows the drive to become a part of the controlled system. The drive 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 drive as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this data to the drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the drive reduces speed to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the drive automatically speeds up to increase the pump pressure.

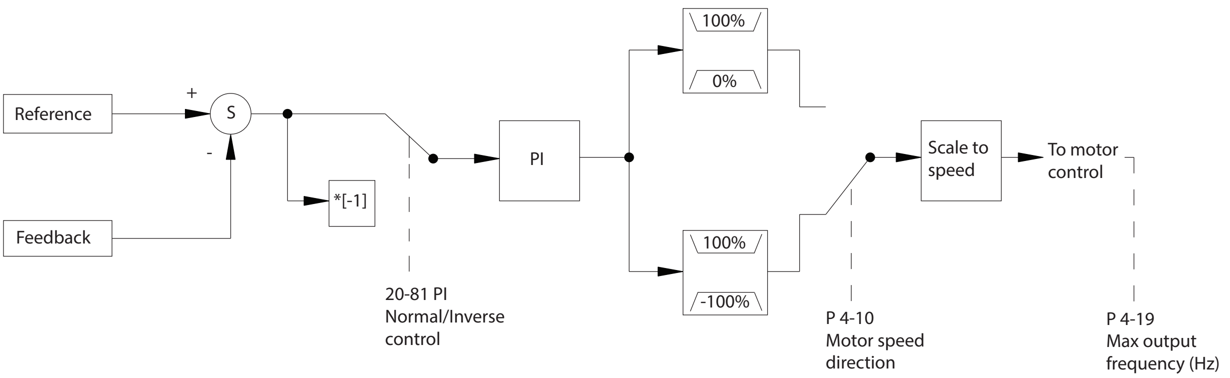


Illustration 2.14 Closed-loop Controller

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

Start and stop the drive 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*.

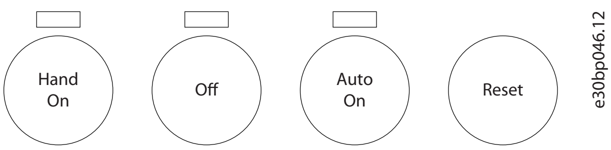


Illustration 2.15 LCP Control Keys

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

2.5 Feedback and Reference Handling

2.5.1 Reference Handling

Details for open loop and closed loop operation.

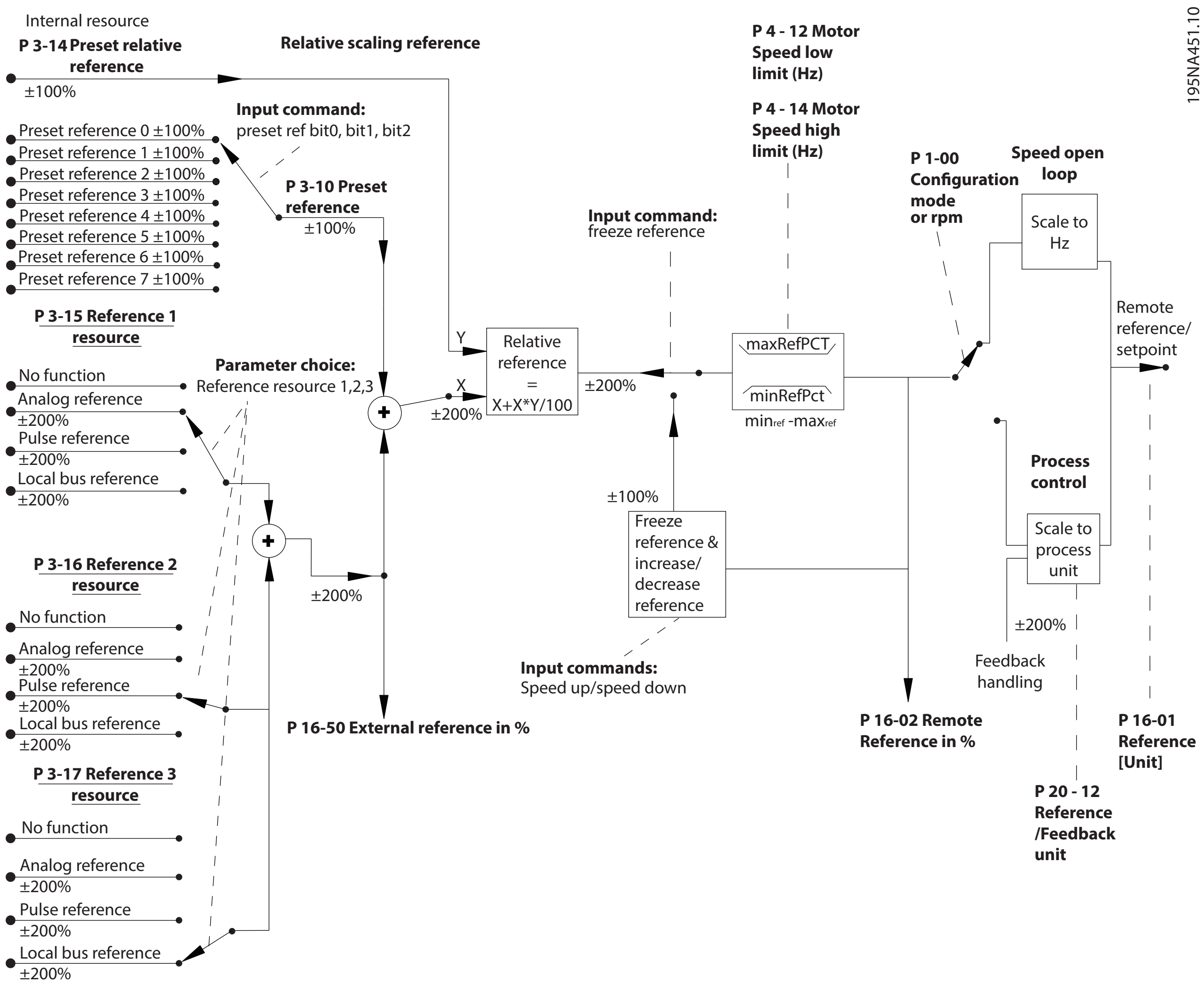


Illustration 2.16 Block Diagram Showing Remote Reference

The remote reference comprises:

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

Up to 8 preset references can be programmed in the drive. 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 be scaled by 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*.

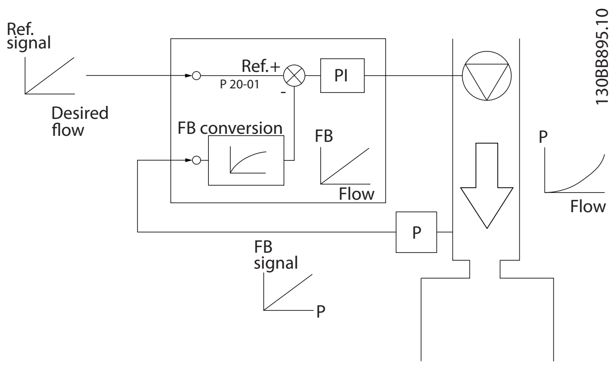


Illustration 2.17 Feedback Conversion

2.6 General Aspects of EMC

Burst transient is conducted at frequencies in the range of 150 kHz to 30 MHz. The inverter, the motor cable, and the motor generate airborne interference from the drive system in the range of 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 shielded motor cable increases the leakage current (see *Illustration 2.18*) because shielded cables have higher capacitance to ground than unshielded 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 shield (I_3), there is only a small electromagnetic field (I_4) from the shielded motor cable.

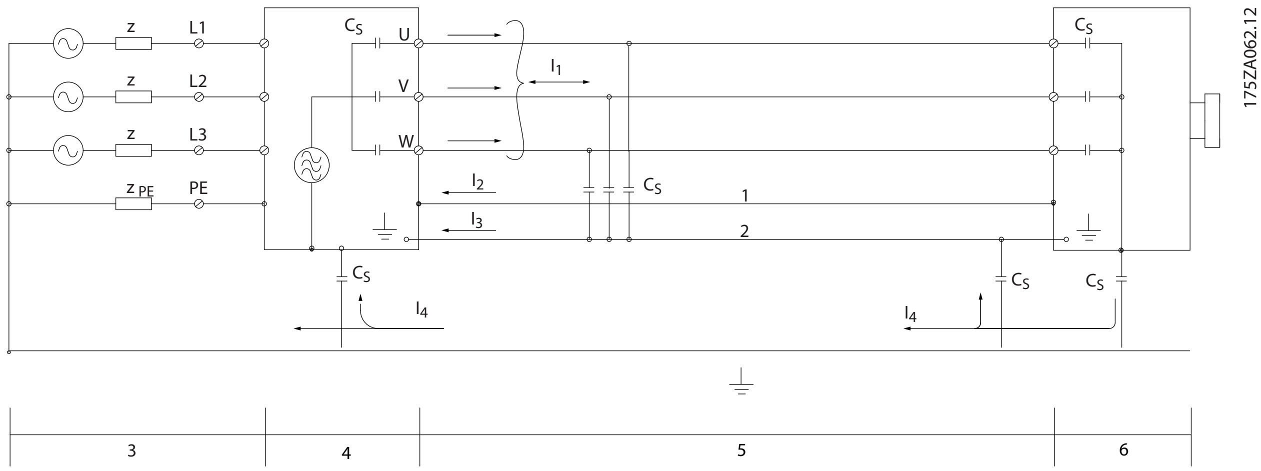
The shield reduces the radiated interference but increases the low-frequency interference on the mains. Connect the motor shield to the drive enclosure and to the motor enclosure. This connection is best done by using integrated shield clamps to avoid twisted shield ends (pigtails). Pigtails increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4).

Mount the shield at both ends of the enclosure, if a shielded cable is used for:

- Relay
- Control cable
- Signal interface
- Brake

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

2



1	Ground wire	4	Drive
2	Shield	5	Shielded motor cable
3	AC mains supply	6	Motor

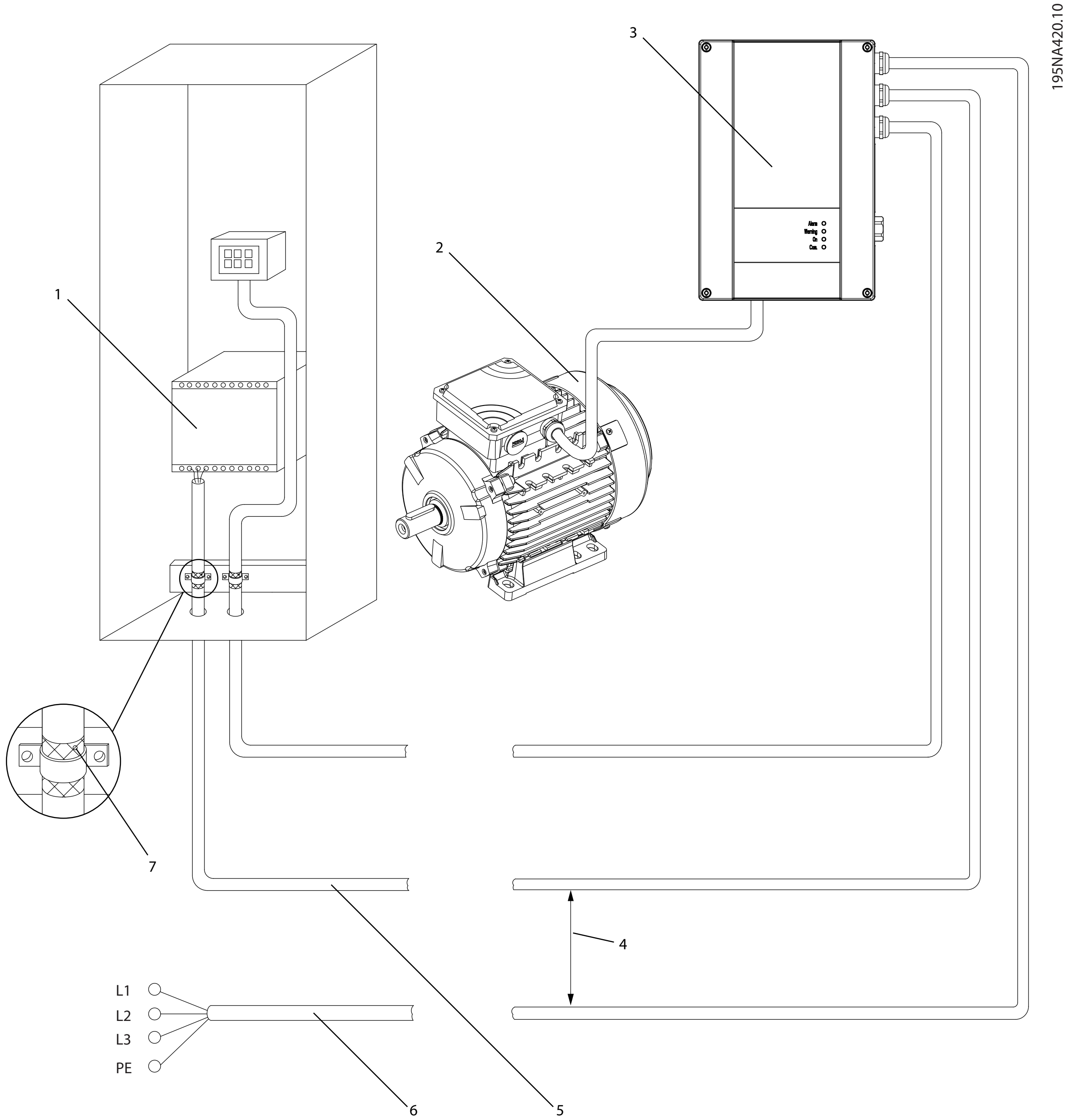
Illustration 2.18 Equivalent Diagram: Coupling of Capacitors, which Generates Leakage Currents

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

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

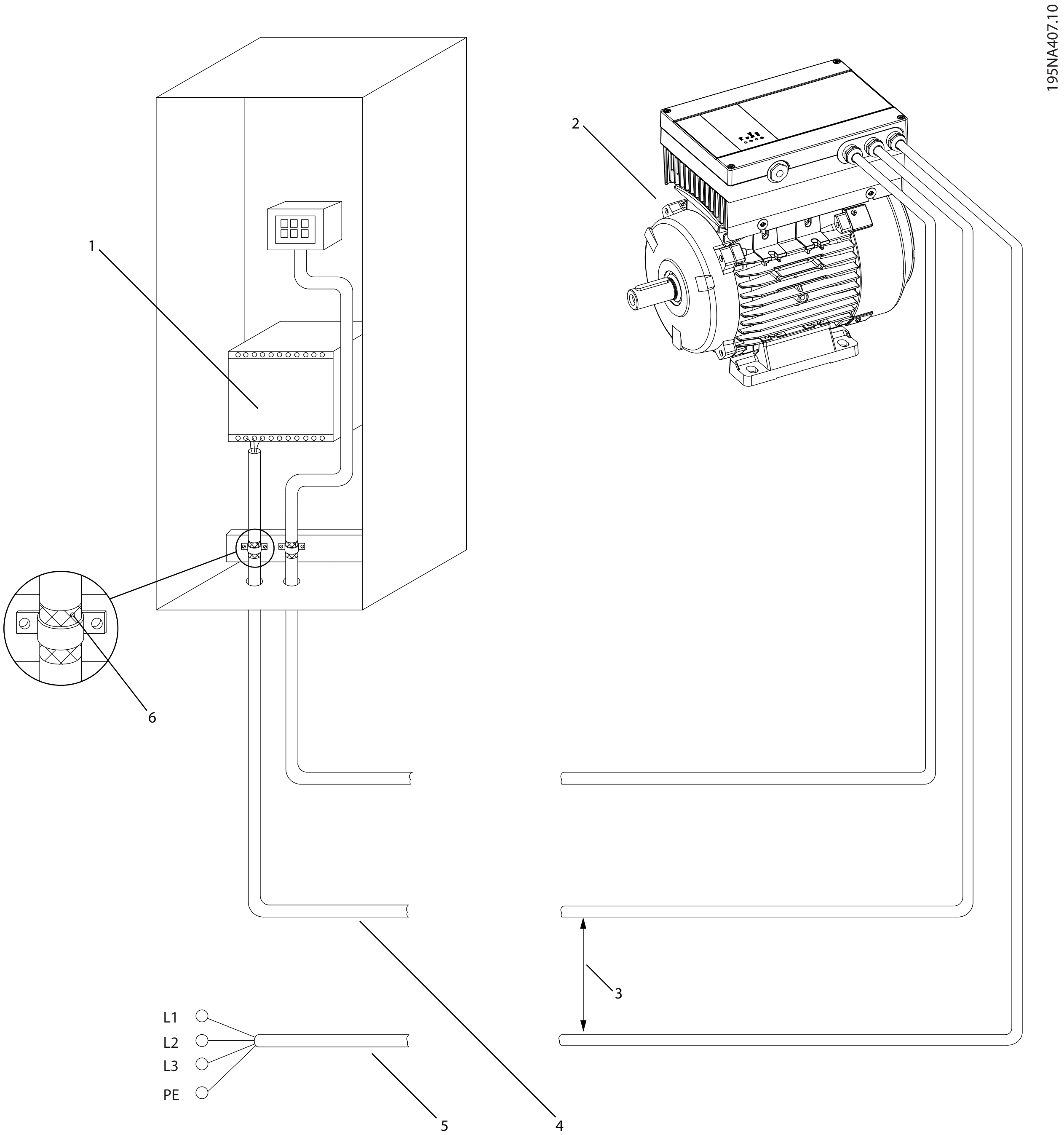
To reduce the interference level from the entire system (unit+installation), keep motor cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor cables. Particularly, control electronics generate radio interference higher than 50 MHz (airborne). See *chapter 2.6.1 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	Drive	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 Wall-mounted



1	PLC	4	Control cables
2	Drive motor-mounted	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, FCP 106 Motor-mounted

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

- Use only shielded motor cables and shielded control cables.
- Connect the shield to ground at both ends.
- Avoid installation with twisted shield ends (pigtails), since this type of installation ruins the shield effect at high frequencies. Use the cable clamps provided instead.
- Ensure the same potential between drive 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 drives EN/IEC 61800-3:2004, the EMC requirements depend on the intended use of the drive. 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	Drives installed in the 1st environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Drives installed in the 1st environment (home and office) with a supply voltage less than 1000 V, which are not plug-in or movable, and which are intended for professional installation and commissioning.	Class A Group 1
C3	Drives installed in the 2nd environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Drives installed in the 2nd 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 drive 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 VLT® DriveMotor FCP 106, motor, and shielded motor cable.

For this system, 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.
- Drive set to nominal switching frequency.
- Maximum shielded motor cable length of 2 m (6.56 ft).

2.6.3 Immunity Requirements

The immunity requirements for drives 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 drives comply with the requirements for the industrial environment. Therefore, the drives 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 electro-magnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment, as well as mobile communications equipment.
- EN 61000-4-4 (IEC 61000-4-4): Burst transients: Simulation of interference brought about by switching a contactor, relay, or similar devices.

- EN 61000-4-5 (IEC 61000-4-5): Surge transients: Simulation of transients brought about, 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 electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line (no shield)	4 kV	2 kV/2 Ω DM 4 kV/12 Ω CM	–	–	10 V_{rms}
LCP cable	2 kV	2 kV/2 Ω1)	–	–	10 V_{rms}
Control wires	2 kV	2 kV/2 Ω 1)	–	–	10 V_{rms}
External 24 V DC	2 kV	2 kV/2 Ω1)	–	–	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 shield.

Abbreviations:

- *AD - air discharge*
- *CD - contact discharge*
- *CM - common mode*
- *DM - difference mode*

2.7 Leakage Current

Follow national and local codes regarding protective earthing of equipment where leakage current exceeds 3.5 mA.
Drive 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.
- Drive power.

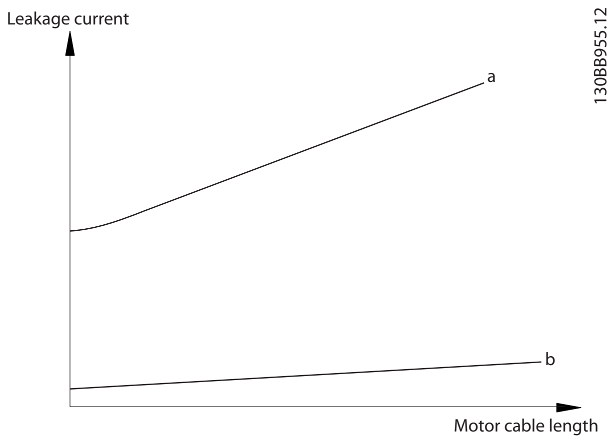


Illustration 2.21 Motor Cable Length and Power Size Influence on Leakage Current. Power Size a > Power Size b

The leakage current also depends on the line distortion.

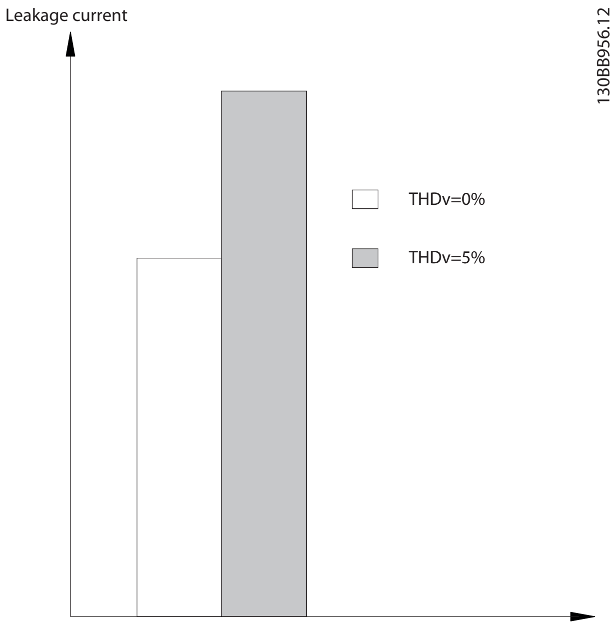


Illustration 2.22 Line Distortion Influences Leakage Current

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 configu- ration 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.

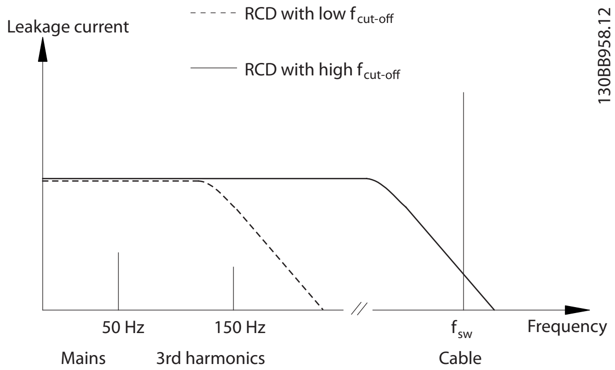


Illustration 2.23 Main Contributions to Leakage Current

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

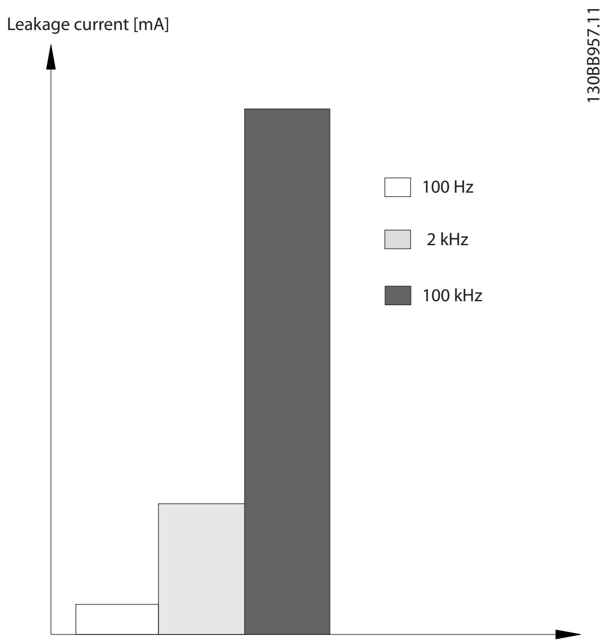


Illustration 2.24 Influence of the RCD Cut-off Frequency on Leakage Current

⚠WARNING

SHOCK HAZARD

The drive 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 allowed on the supply side.**

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

2

2.8 Galvanic Isolation (PELV)

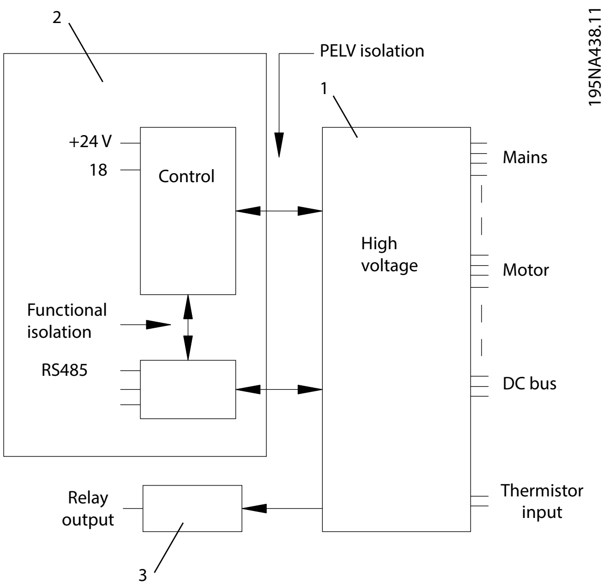
PELV offers protection by way of extra low voltage. Protection against electric shock is ensured when the electrical supply is of the PELV type and the installation is made as described in local/national regulations on PELV supplies.

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 meet 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 drive into a system design. The chapter is divided into 4 sections:

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

3.2 Motor-mounted Drive

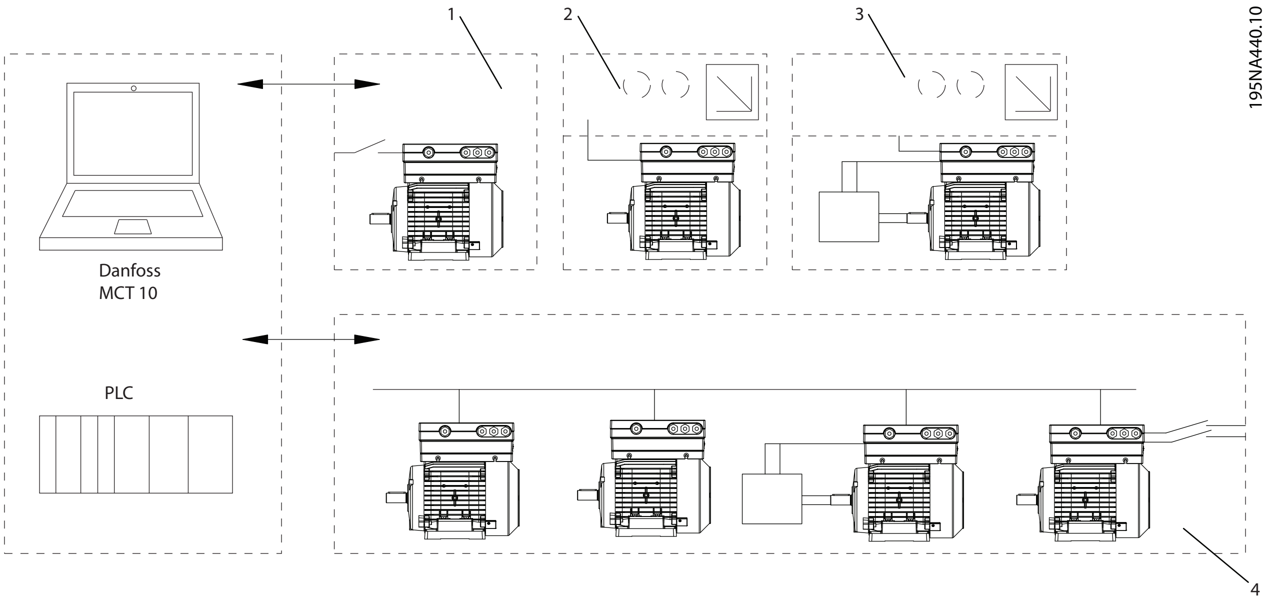
The Danfoss VLT® DriveMotor FCP 106 mounted onto the asynchronous or permanent magnet motor enables speed control in a single unit.

This is a compact alternative to a central solution where the drive and motor are installed as separate units.

- No cabinet is required.
- The drive is mounted directly onto the motor, instead of connecting via external cables to 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 internally connected between motor and drive.

The FCP 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 drive 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

3.3 Mains Supply Interference/Harmonics

3.3.1 General Aspects of Harmonics Emission

A drive 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 drives with internal harmonic filters.
- Using advanced external filters (active or passive).

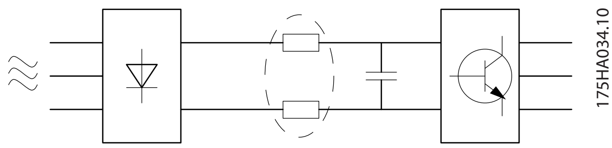


Illustration 3.2 Filters

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 drive 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:

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

(U_N% of U)

3.3.2 Harmonics Emission Requirements

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

Standard	Equipment type	Power size[1)]
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 normal overload (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 of ≤16 A per phase. Four emission classes are defined: Class A through D. The Danfoss drives 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 drives are given in Table 4 in the standard. There are requirements for individual harmonics (5th, 7th, 11th, and 13th), and for THDi and PWHD.

3.3.3 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 normal overload (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 normal overload (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 normal overload (NO), see chapter 6.2 Electrical Data.

3

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.

3.4 Drive/Options Selections

3.4.1 Remote Mounting Kit

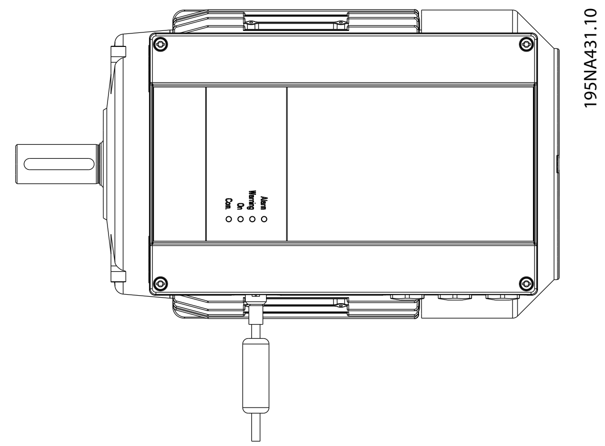
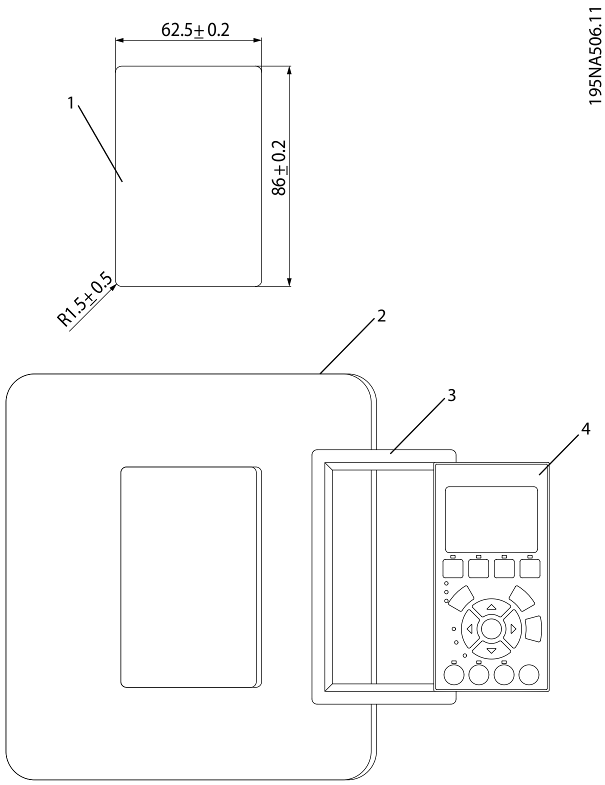
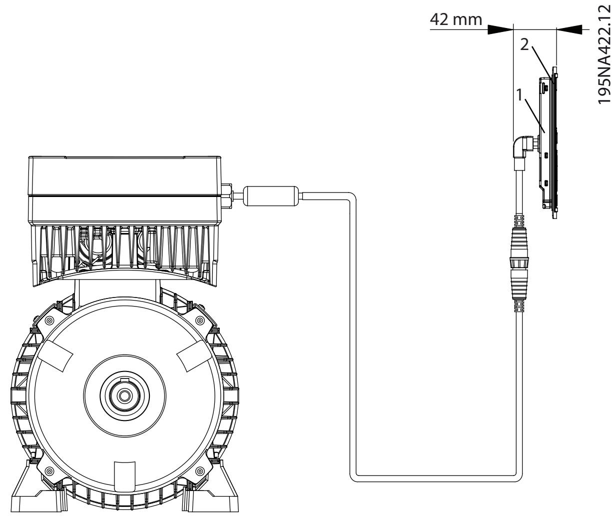


Illustration 3.3 Remote Mounting Kit Connections



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

Illustration 3.4 Remote Mounting Kit Connector



1	Control panel
2	Panel door

Illustration 3.5 LCP Remote Mounting

3.4.2 Local Operation Pad

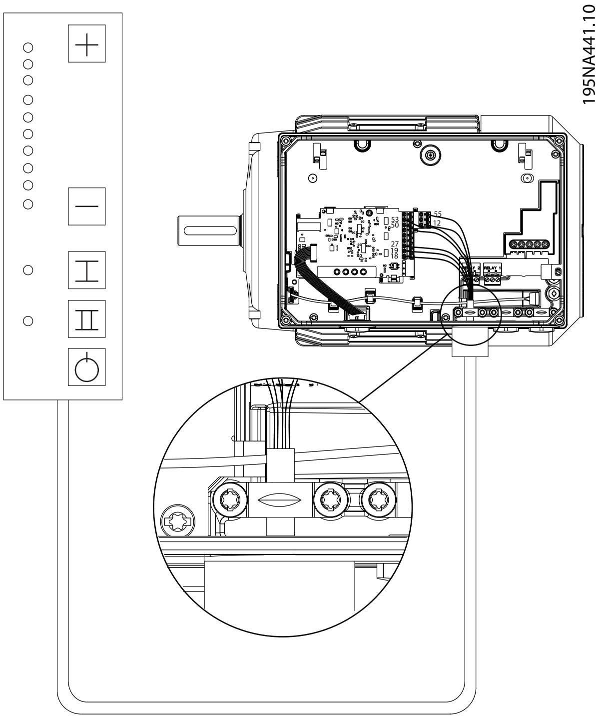


Illustration 3.6 LOP Connections

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 3.6 Function

Terminal	Dual-speed operation	Dual-mode operation	Dual-direction operation
18	Purple or orange		Gray
19	Black		
27	Brown		
29	Green		
12	Red		
50	Yellow		
53	White		
55	Blue		

Table 3.7 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 3.8 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/orange/grey wire to terminal 18.

3.5 Special Conditions

3.5.1 Purpose of Derating

Consider derating when using the drive:

- 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

3.5.2 Derating for Ambient Temperature and Switching Frequency

Refer to *chapter 6.9 Derating According to Ambient Temperature and Switching Frequency* in this manual.

3.5.3 Automatic Adaptations to Ensure Performance

The drive 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 drive can adjust the switching frequency and/or change the switching pattern to ensure the performance of the drive. 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 (3280 ft) altitude no derating is necessary.
- Above 1000 m (3280 ft) altitude, reduce the ambient temperature or the maximum output current.
    - Reduce the output by 1% per 100 m (328 ft) altitude above 1000 m (3280 ft), or
    - Reduce the maximum ambient temperature by 1 °C (33.8 °F) per 200 m (656 ft) altitude.
- Above 2000 m (6561 ft) altitude, contact Danfoss regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and by that ensure 100% output current at high altitudes. Example: At an altitude of 2000 m (6561 ft) and a temperature of 45 °C (113 °F) ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 41.7 °C (107.06 °F), 100% of the rated output current is available.

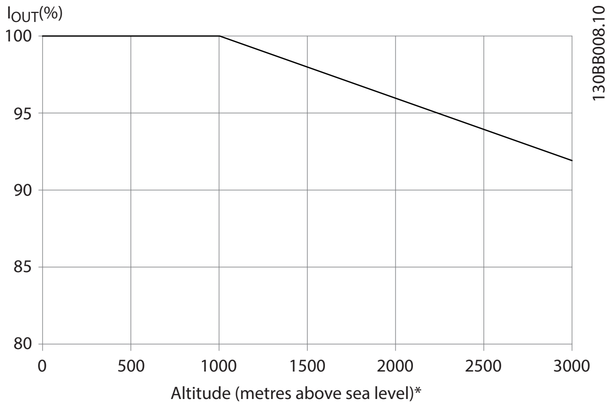
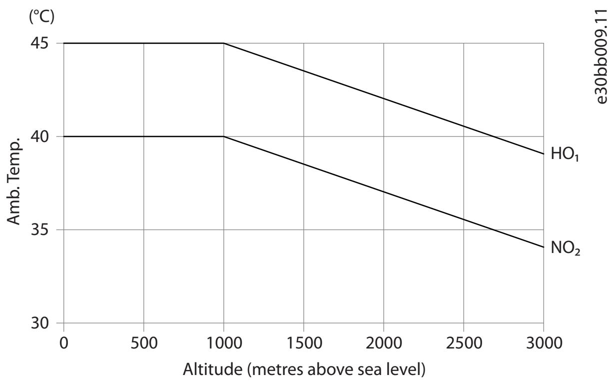


Illustration 3.7 Example



1)	HO: high overload, 160% for 1 minute
2)	NO: normal overload, 110% for 1 minute

Illustration 3.8 Derating of Output Current versus Altitude at $T_{AMB, MAX}$

3.5.5 Extreme Running Conditions

Short circuit (motor phase-phase)
The drive 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 drive 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 drive. 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 drive, 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 drive 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*.

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 drop-out
During a mains dropout, the drive 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 drive. The mains voltage before the dropout and the motor load determines how long it takes for the drive to coast.

Static overload in VVC+ mode
When the drive is overloaded, the control reduces the output frequency to reduce the load.
If the overload is excessive, a current can occur that makes the drive cut out after approximately 5–10 s.

3.5.6 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.

3.5.6.1 Electronic Thermal Relay

ETR is functional for induction motors only. The ETR protection comprises simulation of a bimetal relay based on internal drive measurements of the actual current and speed. The characteristic is shown in *Illustration 3.9*.

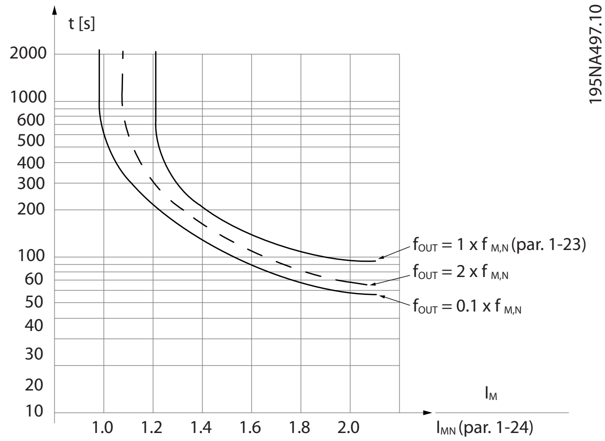


Illustration 3.9 ETR Protection Characteristic

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 drive. 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 induction 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*.

3

3.5.6.2 Thermistor

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 Operating Guide*.

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

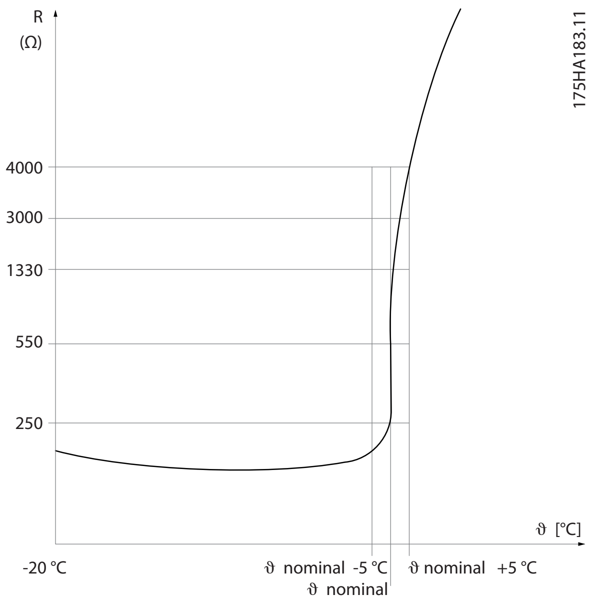


Illustration 3.10 Typical Thermistor Behavior

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

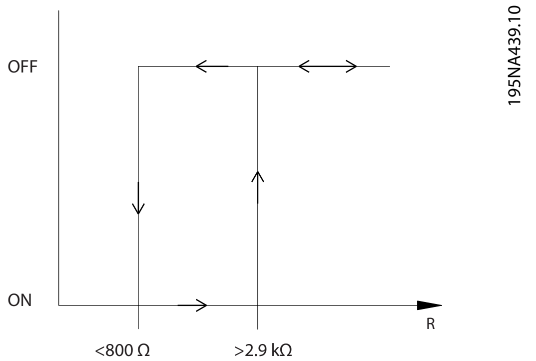


Illustration 3.11 Drive Operation with Thermistor

NOTICE

Select the thermistor according to the specification in *Illustration 3.10* and *Illustration 3.11*.

NOTICE

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

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

3.6 Ambient Conditions

3.6.1 Humidity

Although the drive 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 drive 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.

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

The drive complies with the following standards:

- IEC/EN 60068-2-3, EN 50178 9.4.2.2 at 50 °C (122 °F).
- IEC 600721 class 3K4.

3.6.2 Temperature

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

- Although drives can operate at temperatures down to -10 °C (14 °F), proper operation at rated load is only guaranteed at 0 °C (32 °F) or higher.
- Do not exceed the maximum temperature limit.
- The lifetime of electronic components decreases by 50% for every 10 °C (50 °F) 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

Drives 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 Operating Guide* for proper installation requirements.

3.6.4 Aggressive Environments

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

NOTICE

Do not install the drive 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 drive.

Liquids can be carried through the air and condense in the drive 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 drive. A typical indicator of excessive levels of airborne particles is dust particles around the drive 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 drive 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 drive.

Before installing the drive, 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 6.9 Derating According to Ambient Temperature and Switching Frequency*.

3.6.6 Acoustic Noise

Acoustic noise originates from the following sources:

- External fan
- DC intermediate circuit coils
- RFI filter inductor

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

Table 3.9 FCP 106 Acoustic Noise Levels, Fan on, Measured 1 m (3.3 ft) from the Unit

3.6.7 Vibration and Shock

The drive complies with requirements for wall- or floor-mounted units mounted at production premises, and in panels bolted to walls or floors.

The drive has been tested according to the procedures defined in *Table 3.10*.

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 3.10 Vibration and Shock Test Procedure Compliance

3

3.7 Energy Efficiency

3.7.1 Introduction to 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 drives.

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 drive.

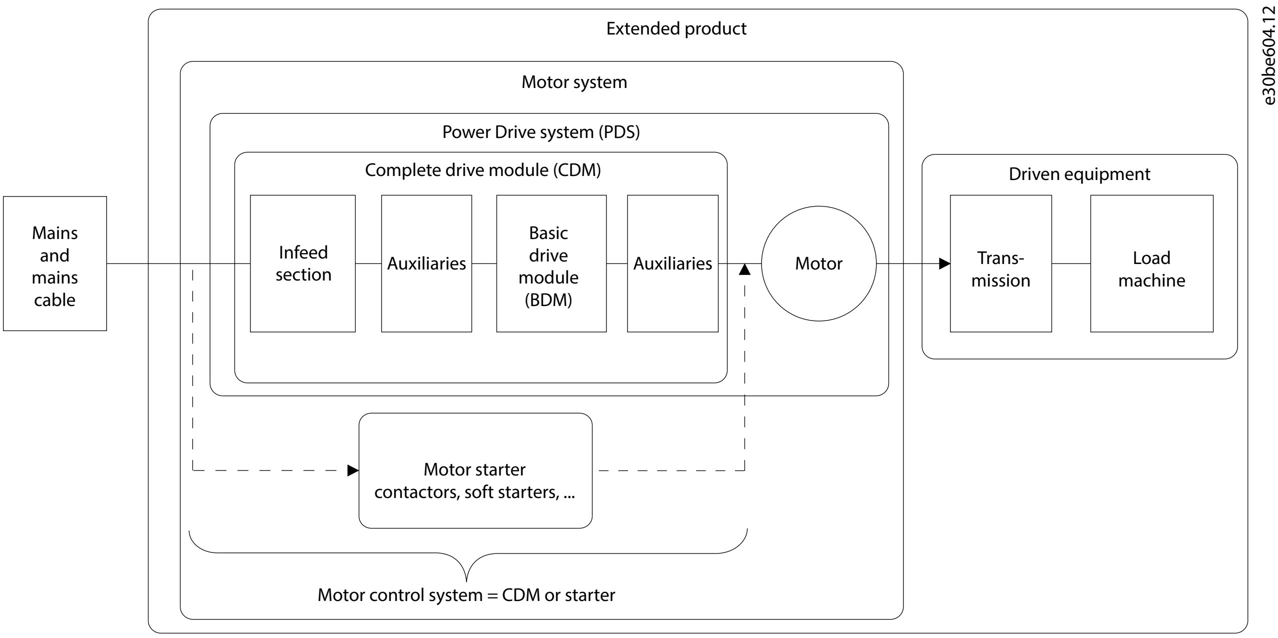


Illustration 3.12 Power Drive System (PDS) and Complete Drive Module (CDM)

Auxiliaries:

- VLT® Advanced Harmonic Filter AHF 005
- VLT® Advanced Harmonic Filter AHF 010
- VLT® Line Reactor MCC 103
- VLT® Sine-wave Filter MCC 101
- VLT® dU/dt Filter MCC 102

3.7.2 IE and IES Classes

Complete drive modules (CDM)
According to the standard EN 50598-2, the complete drive module (CDM) comprises the drive, 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 drives fulfill energy efficiency class IE2. The energy efficiency class is defined at the nominal point of the CDM.

Power drive systems (PDS)
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.

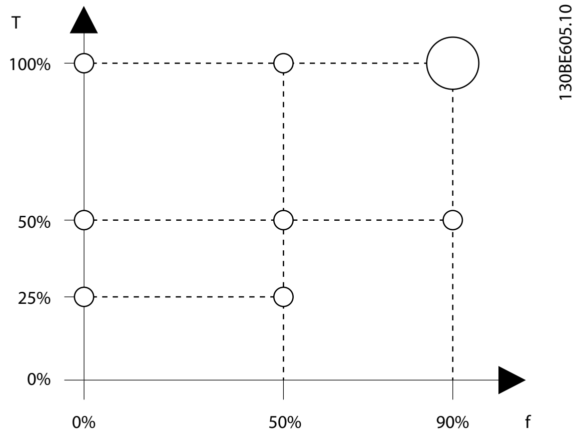
Depending on the motor efficiency, motors driven by a Danfoss VLT® drive typically fulfill energy efficiency class IES2.

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.

3.7.3 Power Loss Data and Efficiency Data

The power loss and the efficiency of a drive depend on configuration and auxiliary equipment. To get a configuration-specific power loss and efficiency data, use the Danfoss ecoSmart tool.

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



T	Torque-producing current [%]
f	Frequency [%]

Illustration 3.13 Drive Operating Points According to EN 50598-2

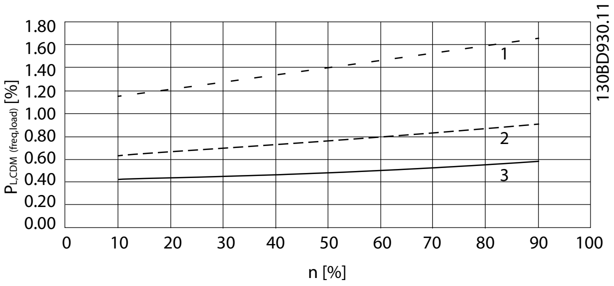
Use the Danfoss ecoSmart application to calculate the power loss data and efficiency data of the drive at the operating points, and at the IE and IES efficiency classes. The application is available at *ecosmart.danfoss.com*.

Example of available data

The following example shows power loss and efficiency data for a drive with the following characteristics:

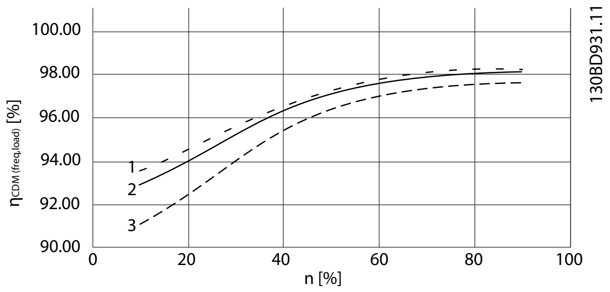
- Power rating 55 kW (75 hp), rated voltage at 400 V.
- Rated apparent power, Sr, 67.8 kVA.
- Rated output power, P_{CDM}, 59.2 kW (79.4 hp).
- Rated efficiency, η_r, 98.3%.

Illustration 3.14 and *Illustration 3.15* show the power loss and efficiency curves. The speed is proportional to the frequency.



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

Illustration 3.14 Drive 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 3.15 Drive 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.

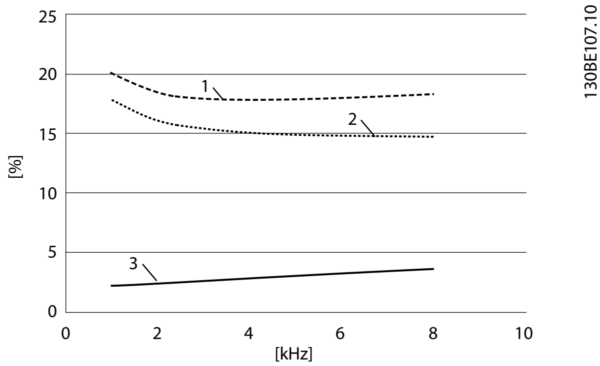
3.7.4 Losses and Efficiency of a Motor

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 drive 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.danfoss.com*. Search for motor technology.

Switching frequency
The switching frequency influences magnetization losses in the motor and switching losses in the drive, as shown in *Illustration 3.16*.



1	Motor and drive
2	Motor only
3	Drive only

Illustration 3.16 Losses [%] versus Switching Frequency [kHz]

NOTICE

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

3.7.5 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:

- Drive
- Motor
- Auxiliary equipment

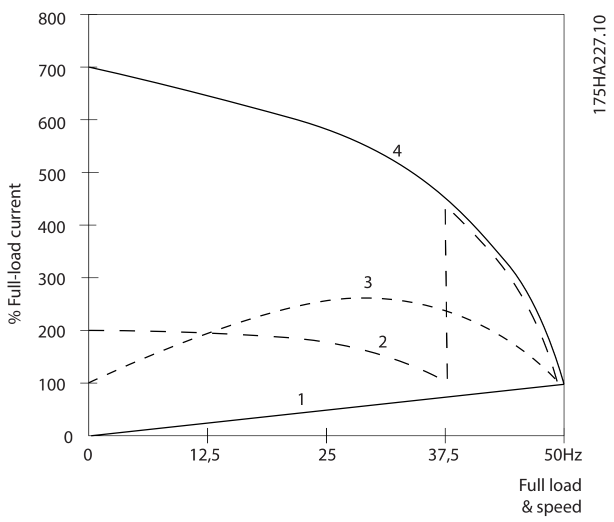
4 Application Examples

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 drive is used.

As shown in *Illustration 4.1*, a drive does not consume more than rated current.



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

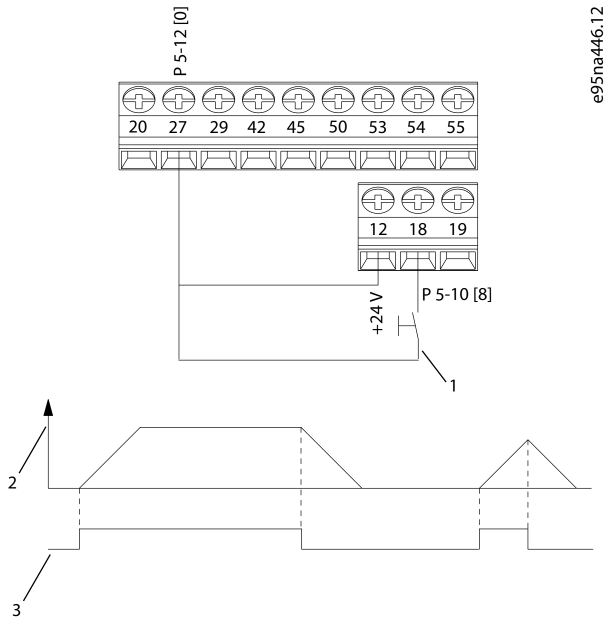
Illustration 4.1 Start-up Current

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

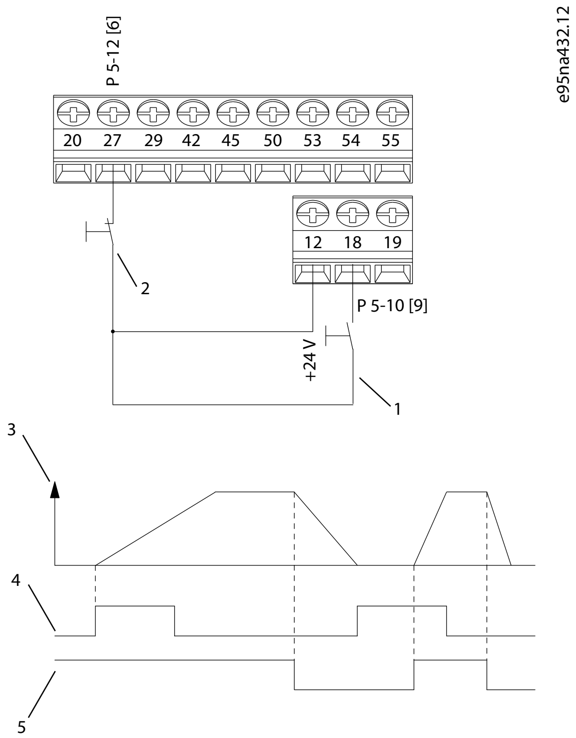
4

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.

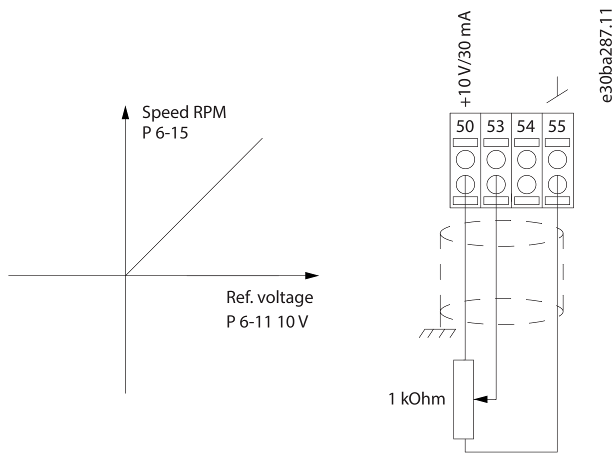


Illustration 4.4 Potentiometer Reference

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 optimizing the adjustment of the drive 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 Adaption (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* to *parameter 1-28 Motor Rotation Check*. For induction 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 drive, 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 drive. 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 drive 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 occur, 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 drive for f_{mot} 45–65 Hz.

- Advantages of overmodulation:
    - Lower currents and higher efficiency are achievable in the field weakening area.
    - The drive 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 drive 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 6^{th} 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 Drive for Controlling Fans and Pumps?

A drive 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 drive for controlling the speed of fans or pumps lies in the energy savings.
When comparing with alternative control systems and technologies, a drive is the optimum energy control system for controlling fan and pump systems.

4

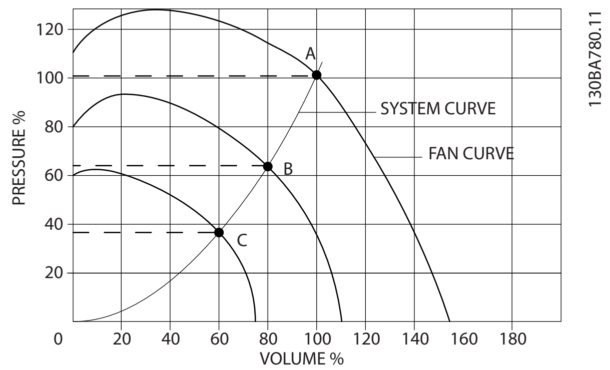


Illustration 4.5 The Graph Shows Fan Curves (A, B, and C) for Reduced Fan Volumes

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

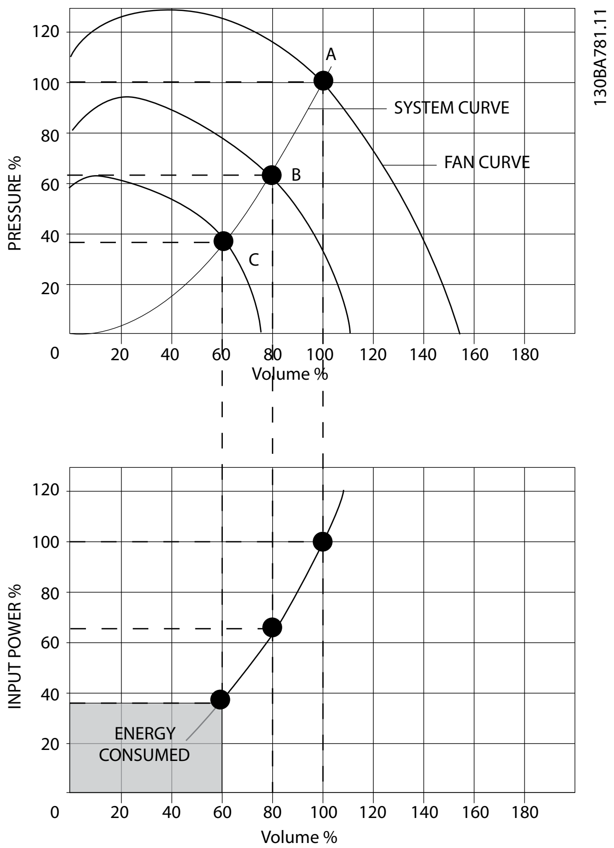


Illustration 4.6 Energy Savings at Reduced Fan Capacity

4.2.3 Example of Energy Savings

As shown in *Illustration 4.7*, the flow is controlled by changing the speed. 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 speed. The consumption of energy, 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 speed.

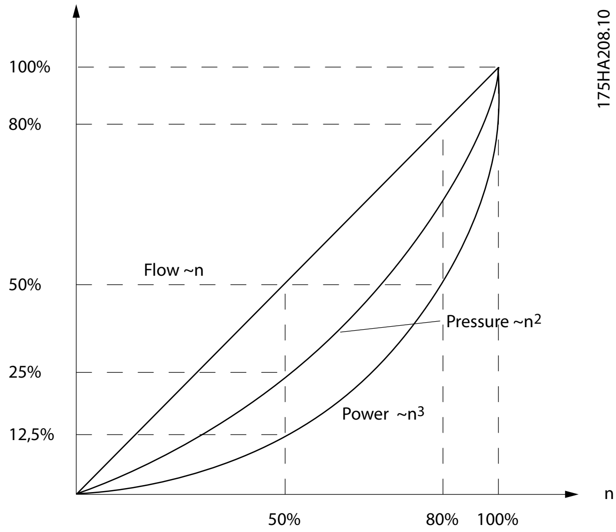


Illustration 4.7 Laws of Proportionality

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

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

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

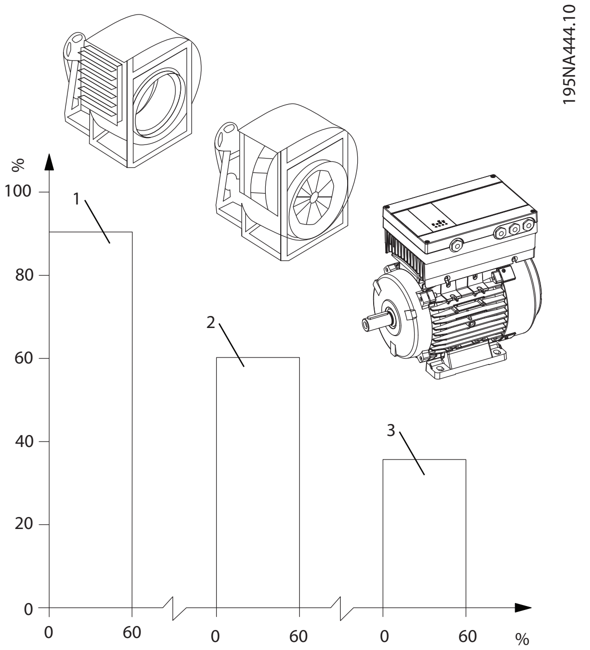
Q=Flow	P=Power
Q_1=Rated flow	P_1=Rated power
Q_2=Reduced flow	P_2=Reduced power
H=Pressure	n=Speed control
H_1=Rated pressure	n_1=Rated speed
H_2=Reduced pressure	n_2=Reduced speed

Table 4.1 Legend for Equation

4.2.4 Comparison of Energy Savings

The Danfoss drive solution offers major savings compared with traditional energy-saving solutions. This is because the drive is able to control fan speed according to thermal load on the system and the fact that the drive has a built-in facility that enables the drive 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 drive 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 of more than 50% at the given flow distribution over a year. The payback period depends on the price per kWh and the price of the drive. 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

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

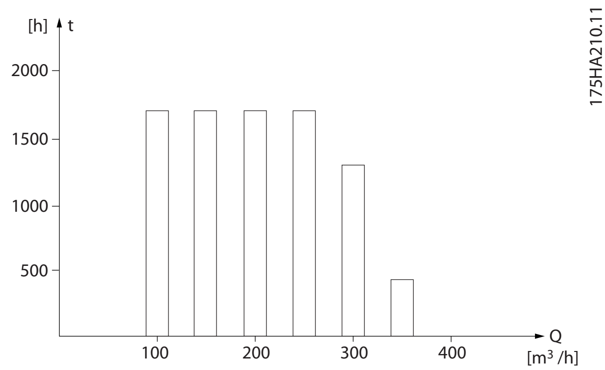


Illustration 4.9 Flow Distribution over 1 Year

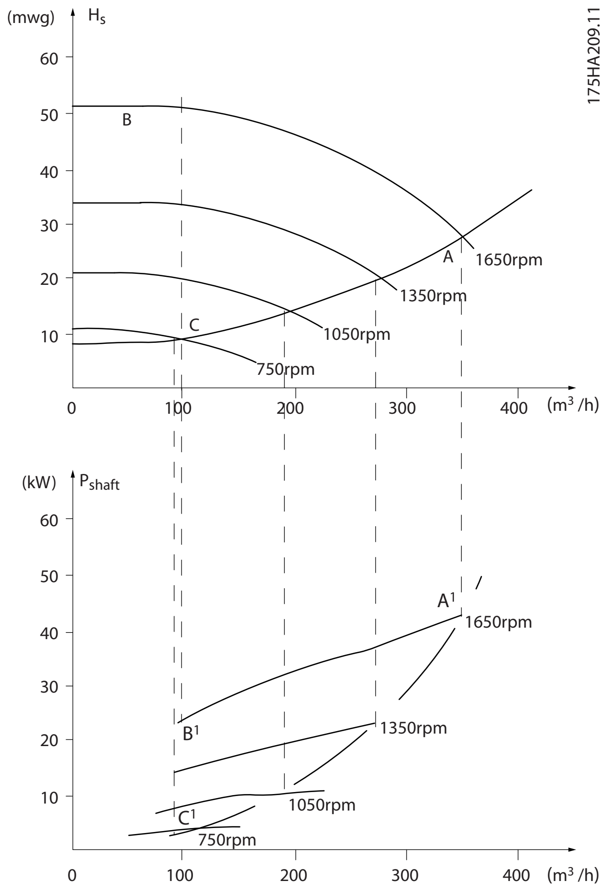


Illustration 4.10 Pump Performance

m³/h	Distribution		Valve regulation		Drive control	
	%	Hours	Power	Consumption	Power	Consumption
			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 drive to control flow or pressure of a system improves control.
A drive can vary the speed of the fan or pump, obtaining variable control of flow and pressure.
Furthermore, a drive 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 drive 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 drive. The drive 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:

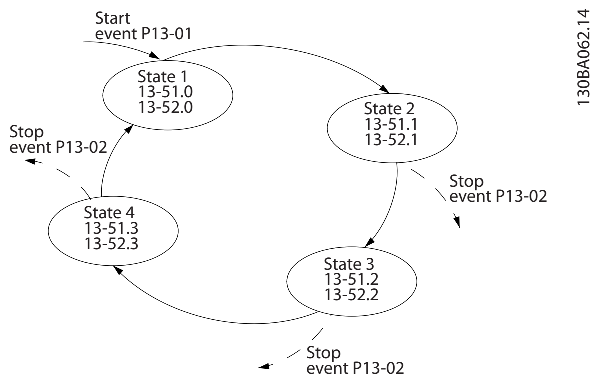
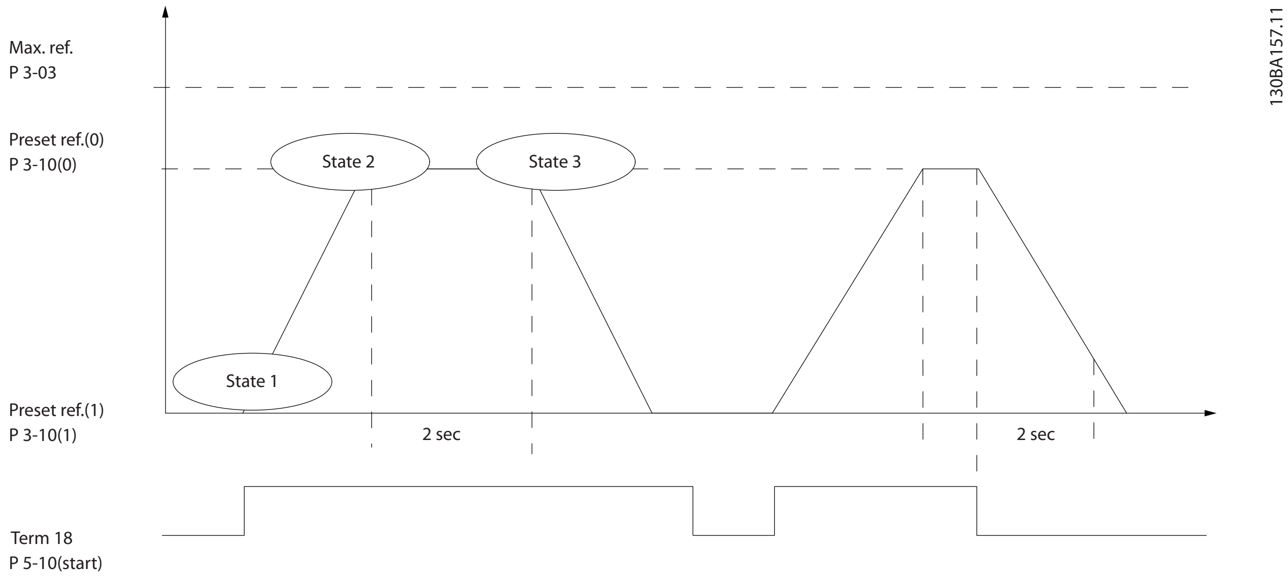


Illustration 4.11 Example with 3 Events/Actions

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 13-51 SL Controller Event* to *[10] Select preset 0*.
11. Set action 2 in *parameter 13-51 SL Controller Event* to *[29] Start Timer 0*.
12. Set action 3 in *parameter 13-51 SL Controller Event* to *[11] Select preset 1*.
13. Set action 4 in *parameter 13-51 SL Controller Event* 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 drive ramps down and enters free mode.

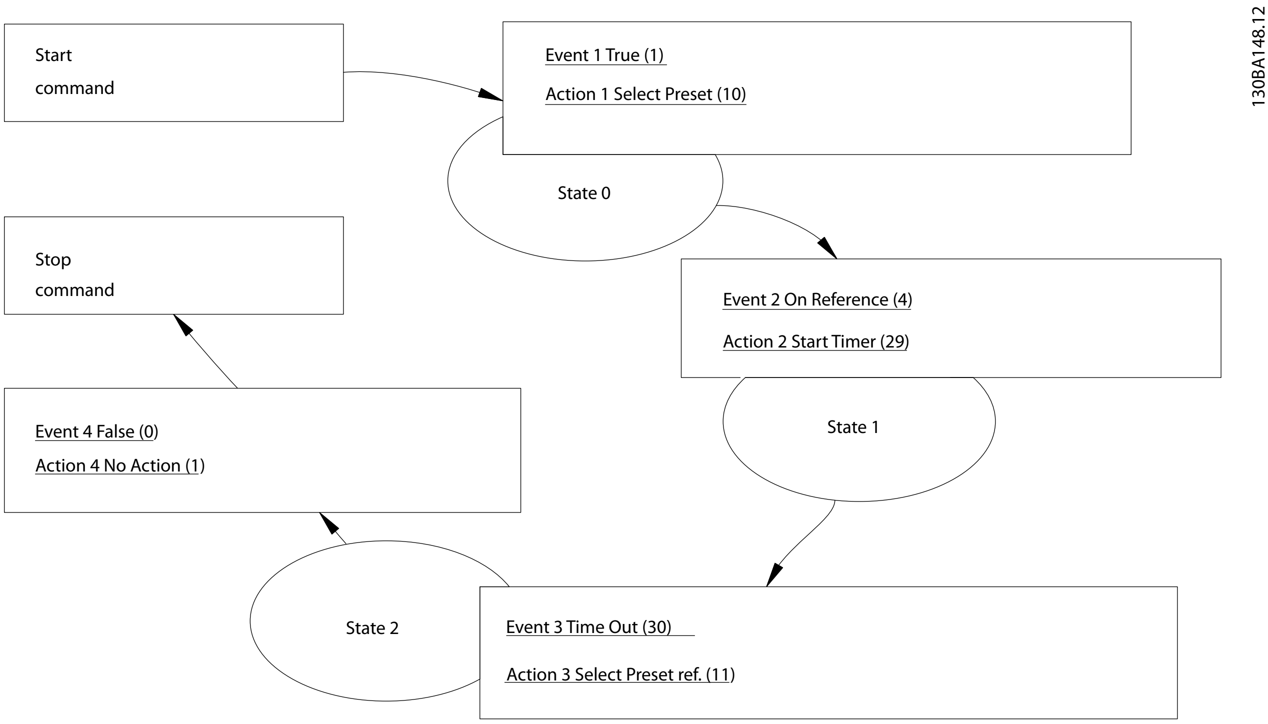


Illustration 4.13 Set Event and Action

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 optimization for components regardless of source. Therefore, the system designer is free to select an optimal combination of standard components for drive, 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 option of motor technology: Asynchronous or PM.
- Manufacturer independency in component sourcing.
- Easy and cost-efficient retrofitting of existing systems.

VLT® DriveMotor FCP 106 with EC+ enable the system designer to optimize system efficiency, without losing flexibility and reliability.

- The FCP 106 can be mounted on either an asynchronous or a permanent magnet motor.
- The use of standard motors and standard drives ensures long-term availability of components.

Programming of FCP 106 is similar to programming of all other Danfoss drives.

5 Type Code and Selection Guide

5.1 Drive Configurator

Configure a drive according to the application requirements, using the order number system.

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

FCP106N4K0T4C66H1FSXXA00

Refer to *chapter 5.2 Type Code String* for a detailed specification of each character in the string. Ordering numbers for drive motor standard variants are available in *chapter 5.3 Ordering Numbers*.
To configure the correct drive 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*, and search for drive configurator.

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.

Name	**Position**	**Selection options**
Product group	1–3	FCP
Series	4–6	106
Load profile, drive	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
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	22–24	AX0: VLT® Memory Module MCM 101 AO0: VLT® Memory Module MCM 101, VLT® PROFIBUS DP MCA 101

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
F	C	P	1	0	6					T	4	P	6	6	H	1	F	S	X	X	A		0

e95na445.11

Illustration 5.1 Type Code String Example

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 (9.8 ft) 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 5.2 Options and Accessories, Ordering Numbers

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

5.3.2 Spare Parts

For order numbers and ordering in general, refer to:

- VLT Shop at *vltshop.danfoss.com*.
- Drive Configurator at *www.danfoss.com*. Search for Drive Configurator.

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 5.3 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 terminal switches, order 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 Operating Guide*.

6 Specifications

6.1 Clearances, Dimensions, and Weights

6.1.1 Clearances

To ensure sufficient airflow for the drive, observe the minimum clearances listed in *Table 6.1*.
When airflow is obstructed close to the drive, 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
MH1	IP66/Type 4X[2)]	0.55–1.5 (0.75–2.0)	30 (1.2)	100 (4.0)
MH2	IP66/Type 4X[2)]	2.2–4.0 (3.0–5.0)	40 (1.6)	100 (4.0)
MH3	IP66/Type 4X[2)]	5.5–7.5 (7.5–10)	50 (2.0)	100 (4.0)

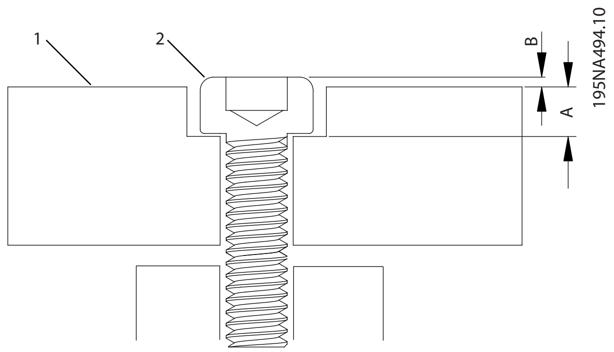
Table 6.1 Minimum Clearance for Cooling

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

2) The stated IP and Type rating only apply when the VLT® DriveMotor FCP 106 is mounted on a wall mounting 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 drive. As standalone drive, the protection 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

6.1.2 Dimensions

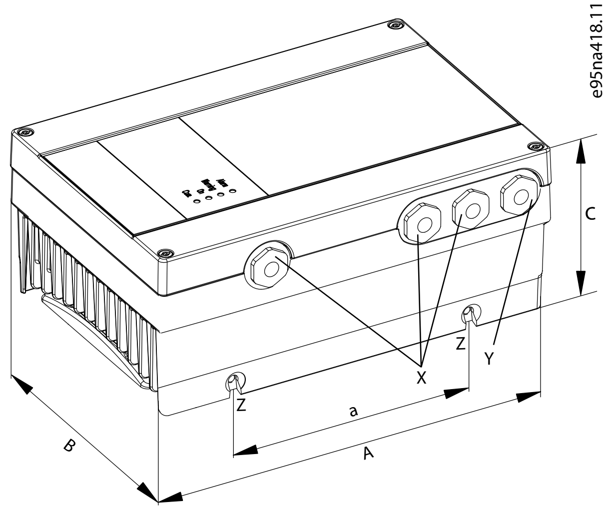


Illustration 6.2 FCP 106 Dimensions

Enclosure type	Power1) [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	Z
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 6.3 Dimensions

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

6.1.3 Weight

To calculate the total weight of the unit, add the weight of the combined drive and adapter plate, see *Table 6.4*.

Enclosure size	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 6.4 Weight of FCP 106

6.2 Electrical Data

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

Enclosure	MH1							MH2						MH3
	NK55	NK75		N1K1		N1K5		N2K2		N3K0		N4K0		N5K5
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 (104 °F) 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 6.8 Fuse and Circuit Breaker Specifications*.													
Estimated power loss [W][3)]	44	55		63		71		89		119		152		201
Efficiency [%][4)5)]	0.95	0.95		0.96		0.96		0.97		0.97		0.97		0.97

Table 6.5 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. H7K5: 150% for 1 minute.

A drive intended for HO requires a corresponding motor rating. For example, Table 6.5 shows that a 1.5 kW motor for HO requires a N2K2 drive.

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 drive 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 50598-2, refer to www.danfoss.com and search for ecoSmart.

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

5) Measured using 4 m (13.1 ft) shielded motor cables at rated load and rated frequency.

Enclosure	MH3			
	N5K5	N7K5		H7K5
Overload[1)]	NO	HO	NO	HO
Typical shaft output [kW]	5.5		7.5	
Typical shaft output [hp]	7.5		10	
Maximum cable cross-section in terminals[2)] (mains, motor) [mm²/AWG]	4/12		4/12	
Output current				
40 °C (104 °F) ambient temperature				
Continuous (3x380–440 V) [A]	12		15.5	
Intermittent (3x380–440 V) [A]	13.2	19.2	17.1	23.3
Continuous (3x440–480 V) [A]	11		14	
Intermittent (3x440–480 V) [A]	12.1	17.6	15.4	21
Maximum input current				
Continuous (3x380–440 V) [A]	11		15	
Intermittent (3x380–440 V) [A]	12	17	17	23
Continuous (3x440–480 V) [A]	9.4		13	
Intermittent (3x440–480 V) [A]	10	15	14	19
Maximum mains fuses	See *chapter 6.8 Fuse and Circuit Breaker Specifications.*			
Estimated power loss [W][3)]	201	252		
Efficiency [%][4)5)]	0.97	0.97		

Table 6.6 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. H7K5: 150% for 1 minute.
A drive intended for HO requires a corresponding motor rating. For example, Table 6.5 shows that a 1.5 kW motor for HO requires a N2K2 drive.
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 drive 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 50598-2, refer to www.danfoss.com and search for ecoSmart.
4) Efficiency measured at nominal current. For energy efficiency class, see chapter 6.5 Ambient Conditions. For part load losses, see www.danfoss.com and search for ecoSmart.
5) Measured using 4 m (13.1 ft) shielded 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 drive 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 drive. Power-up and full torque cannot be expected at mains voltage lower than 10% below the lowest rated supply voltage of the drive.*

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 6.7* and *Table 6.8* when using circuit breakers as branch circuit protection.

6

6.4 Protection and Features

Protection and features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the drive 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 drive autoderating function ensures that the heat sink temperature does not reach 90 °C (194 °F).
- The drive 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 drive trips and issues an alarm.
- When a mains phase is missing, the drive trips or issues a warning (depending on the load).
- Monitoring of the DC-link voltage ensures that the drive trips when the DC-link voltage is too low or too high.
- 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 mounting 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, FCP 106[2)]	IE2

1) The stated IP and Type rating only apply when the VLT® DriveMotor FCP 106 is mounted on a wall mounting 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 drive. As standalone drive, the protection rating is IP00 and Open type.
2) Determined according to EN 50598-2 at:

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

6

6.6 Cable Specifications

Cable lengths and cross-sections

Maximum motor cable length for wall mounting 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 size 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 outputs

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 outputs

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. Terminal 29 can also be programmed as pulse 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 outputs

Programmable relay outputs	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
Maximum terminal load (DC-1)[1)] on 01-03/04-06 (NC) (Resistive load)	30 V DC, 2 A
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 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 6.7* and *Table 6.8* for circuit breaker 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 6.7*, *Table 6.8*, and *Table 6.9*.

NOTICE

EQUIPMENT DAMAGE

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

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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 6.7 Circuit Breakers, UL

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

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[2)]	15000
MH3	5.5 (7.5)	CTI25M - 47B3150	50000	CTI25M - 047B3102[2)]	15000
	7.5 (10)	CTI25M - 47B3151	15000	CTI25M - 047B3102[1)]	15000

Table 6.8 Circuit Breakers, Non-UL

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

2) Trip level maximum set to 32 A.

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 6.9 Fuses

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

6.9 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 drive operates at high ambient temperature, decrease the constant output current.

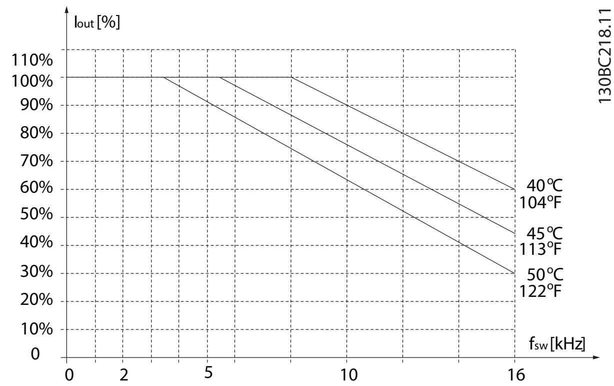

Illustration 6.3 400 V MH1 0.55–1.5 kW (0.75–2.0 hp)

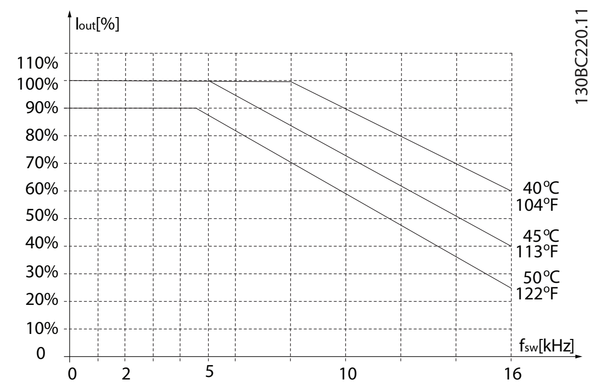

Illustration 6.4 400 V MH2 2.2–4.0 kW (3.0–5.0 hp)

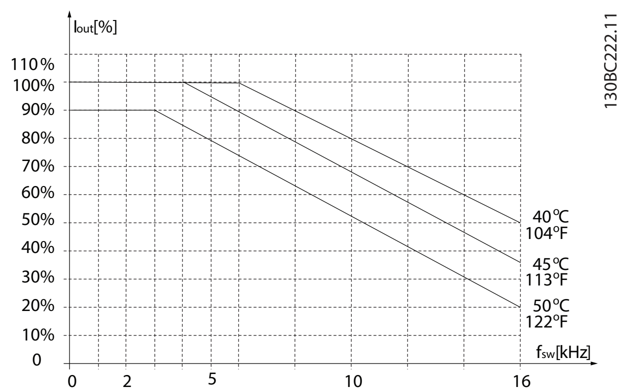

Illustration 6.5 400 V MH3 5.5–7.5 kW (7.5–10 hp)

6.10 dU/dt

Shaft output power [kW (hp)]	Motor 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 6.10 dU/dt, MH1–MH3

1) Data available at future release.

6.11 Efficiency

Efficiency of the drive (η_{VLT})
The load on the drive 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 if there is part loads.

This also means that the efficiency of the drive 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.

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

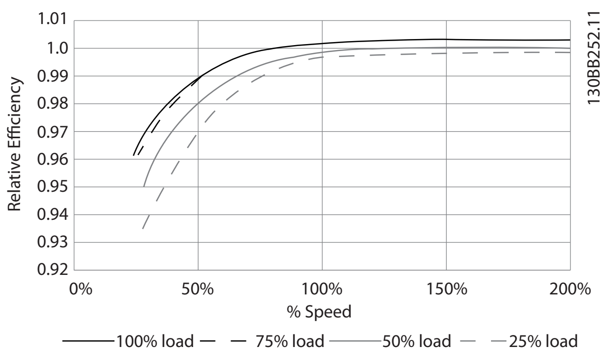

Illustration 6.6 Typical Efficiency Curves

Example: Assume a 22 kW (30 hp), 380–480 V AC drive runs at 25% load at 50% speed. The graph shows 0.97, whereas rated efficiency for a 22 kW (30 hp) drive 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 drive 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 drive 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 drive (η_{VLT}) is multiplied by the efficiency of the motor (η_{MOTOR}):

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

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