MAKING MODERN LIVING POSSIBLE

Danfoss

Service Guide

VLT® DriveMotor FCP 106 and FCM 106

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VLT® THE REAL DRIVE

Contents

1 Introduction

This section describes how to use the service guide, including:

- Intended audience.
- Conventions used.
- Related manuals.
- Identification and overview of the frequency converter.
- Tools required to perform service and maintenance procedures.
- Reference required for support request or service report.

1.1 Purpose of the Manual

The information in this service guide enables a Danfoss authorized, qualified technician to service the VLT® DriveMotor FCP 106 or VLT® DriveMotor FCM 106. Information and instructions are provided to identify faults, perform checks, and carry out repairs:

- Data for the different enclosure sizes.
- Description of user interfaces and internal processing.
- Troubleshooting and test instructions.
- Assembly and disassembly instructions.

The guide applies to frequency converter models and voltage ranges described in *chapter 9.2 Electrical Data*.

VLT® is a registered trademark.

1.2 Additional Resources

Available literature:

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

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

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

1.3 Document and Software Version

This service guide 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 frequency converter, read the software version in *parameter 15-43 Software Version*.

Edition	Remarks	Software version
MG95A2	New functionalities: PROFIBUS and memory module. Extension of power range.	5.0

Table 1.1 Document and Software Version

1.4 Abbreviations and Conventions

AC	Alternating current
AEO	Automatic energy optimization
ACP	Application control processor
AWG	American wire gauge
AMA	Automatic motor adaptation
°C	Degrees celsius
DC	Direct current
EEPROM	Electrically erasable programmable read-only memory
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
ETR	Electronic thermal relay
$f_{M,N}$	Nominal motor frequency
FC	Frequency converter
GLCP	Graphical local control panel
IP	Ingress protection
I_{LIM}	Current limit
I_{INV}	Rated inverter output current
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	Maximum output current
$I_{VLT,N}$	Rated output current supplied by the frequency converter
L_d	d-axis inductance
LCP	Local control panel
MCP	Motor control processor
MM	Memory module
MMP	Memory module programmer
N.A.	Not applicable
$P_{M,N}$	Nominal motor power
PCB	Printed circuit board
PE	Protective earth
PELV	Protective extra low voltage
PWM	Pulse-width modulation
R_s	Stator resistance
Regen	Regenerative terminals
RPM	Revolutions per minute
RFI	Radio frequency interference
SCR	Silicon controlled rectifier
SIVP	Specific initial values and protection
SMPS	Switch mode power supply
T_{LIM}	Torque limit
$U_{M,N}$	Nominal motor voltage
X_h	Main reactance

Table 1.2 Abbreviations

Conventions

- Numbered lists indicate procedures.
- Bullet lists indicate other information.
- Italicised text indicates
  - Cross-reference.
  - Link.
  - Parameter name.
  - Parameter group name.
  - Parameter option.
- * indicates default setting of a parameter.
- All dimensions are in mm (inch).

1.5 Product Overview

1.5.1 Intended Use

The frequency converter is an electronic motor controller intended for:

- Regulation of motor speed in response to system feedback or to remote commands from external controllers. A power drive system consists of:
  - The frequency converter.
  - The motor.
  - Equipment driven by the motor.
- System and motor status surveillance.

The frequency converter can also be used for motor overload protection. The frequency converter is allowed for use in residential, industrial, and commercial environments in accordance with local laws and standards.

Depending on configuration, the frequency converter can be used in standalone applications or form part of a larger application or installation.

When using a motor with thermal protection, the frequency converter is allowed for use in residential, industrial, and commercial environments in accordance with local laws and standards.

Foreseeable misuse
Do not use the frequency converter in applications which are non-compliant with specified operating conditions and environments. Ensure compliance with the conditions specified in *chapter 9 Specifications*.

1.5.2 FCP 106 and FCM 106

This service guide refers to phase-1 and phase-2 products. Use the type code string to identify whether it is a phase-1 product or phase-2 product. For phase-1 products, position 7 in the type code string is a P. For phase-2 products, position 7 in the type code string is either N or H.
The production week and year are included in the serial number on the nameplate, see *chapter 1.5.3 Nameplates*.

VLT® DriveMotor FCP 106

The VLT® DriveMotor FCP 106 comprises the frequency converter only.

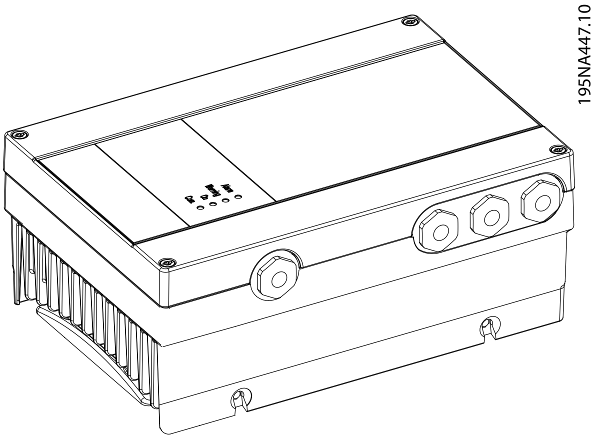


Illustration 1.1 FCP 106

VLT® DriveMotor FCM 106

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

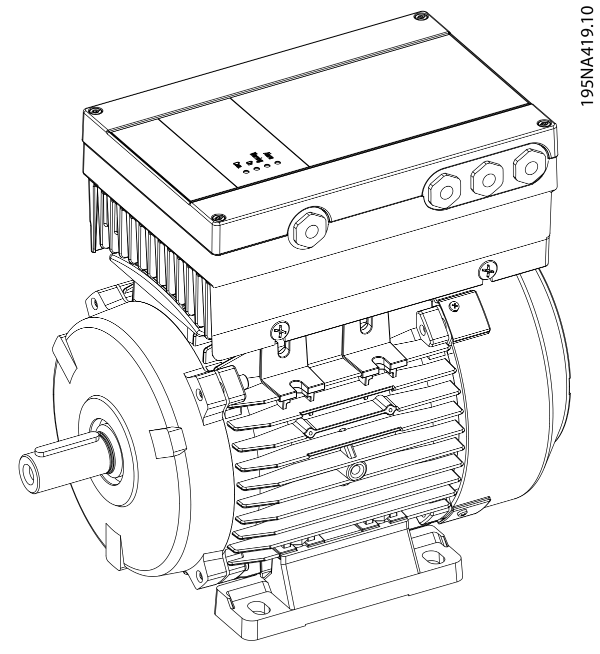
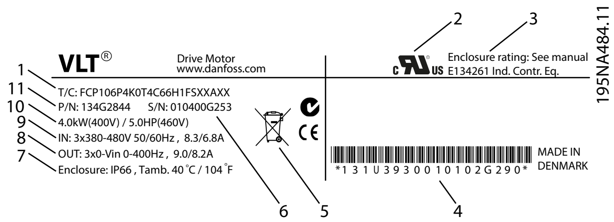


Illustration 1.2 FCM 106

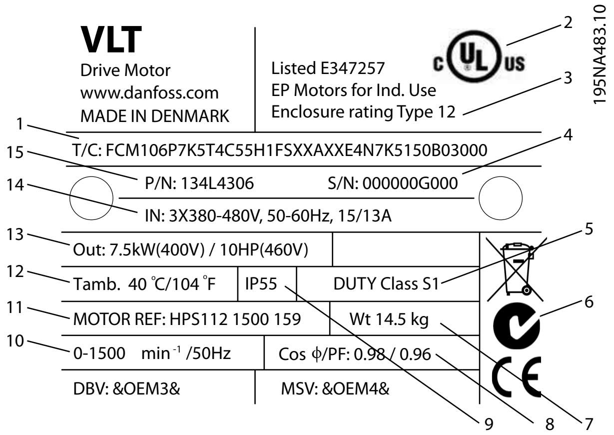
1.5.3 Nameplates



1	Type code
2	Certifications
3	Enclosure rating
4	Bar code for manufacturer use
5	Certifications
6	Serial number1)
7	Enclosure type and IP rating, maximum ambient temperature without derating
8	Output voltage, frequency, and current (at low/high voltages)
9	Input voltage, frequency, and current (at low/high voltages)
10	Power rating
11	Ordering number

Illustration 1.3 FCP 106 Nameplate (Example)

1) Example of format: Serial number 'xxxxx253' indicates manufacture in week 25, year 2013.



1	Type code
2	Certifications
3	Enclosure rating
4	Serial number1)
5	Motor duty class
6	Certifications
7	Weight
8	Motor power factor
9	Enclosure rating - ingress protection (IP) class
10	Frequency range
11	Motor reference
12	Maximum ambient temperature without derating
13	Power rating
14	Input voltage, current, and frequency (at low/high voltages)
15	Ordering number

Illustration 1.4 FCM 106 Nameplate (Example)

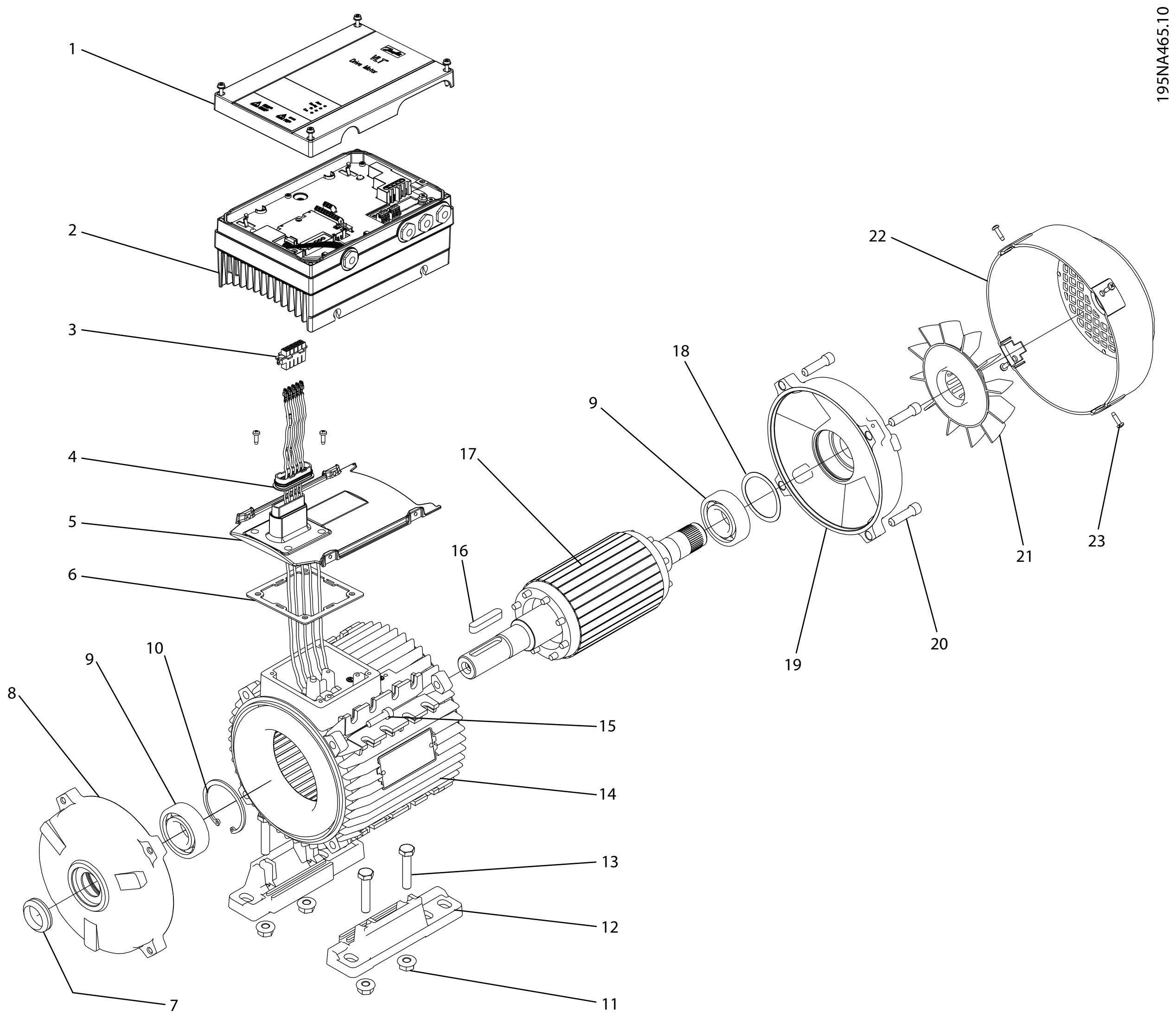
1) Example of format: Serial number 'xxxxx253' indicates manufacture in week 25, year 2013.

NOTICE

LOSS OF WARRANTY

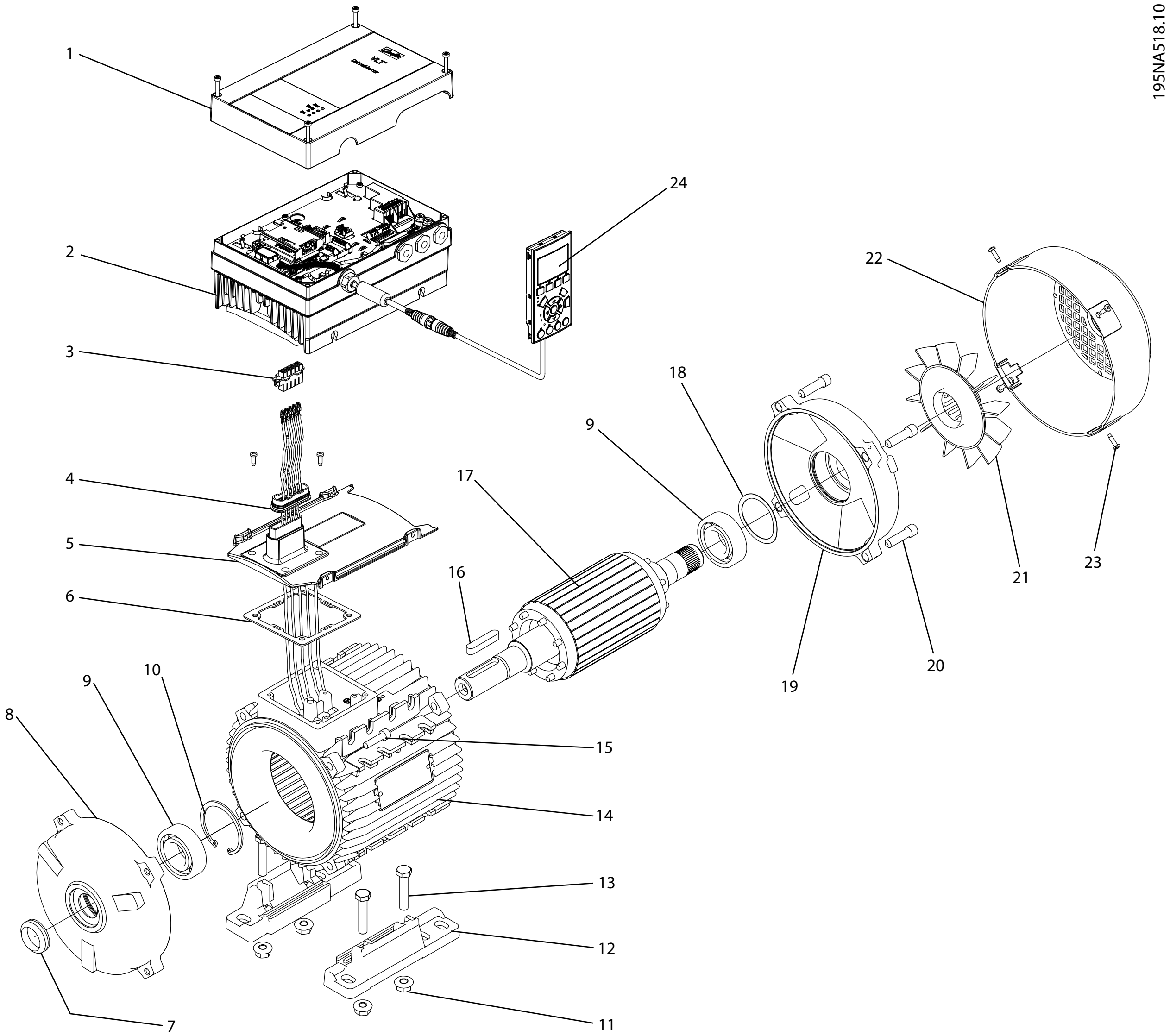
Do not remove the nameplate from the frequency converter.

1.5.4 Exploded Views



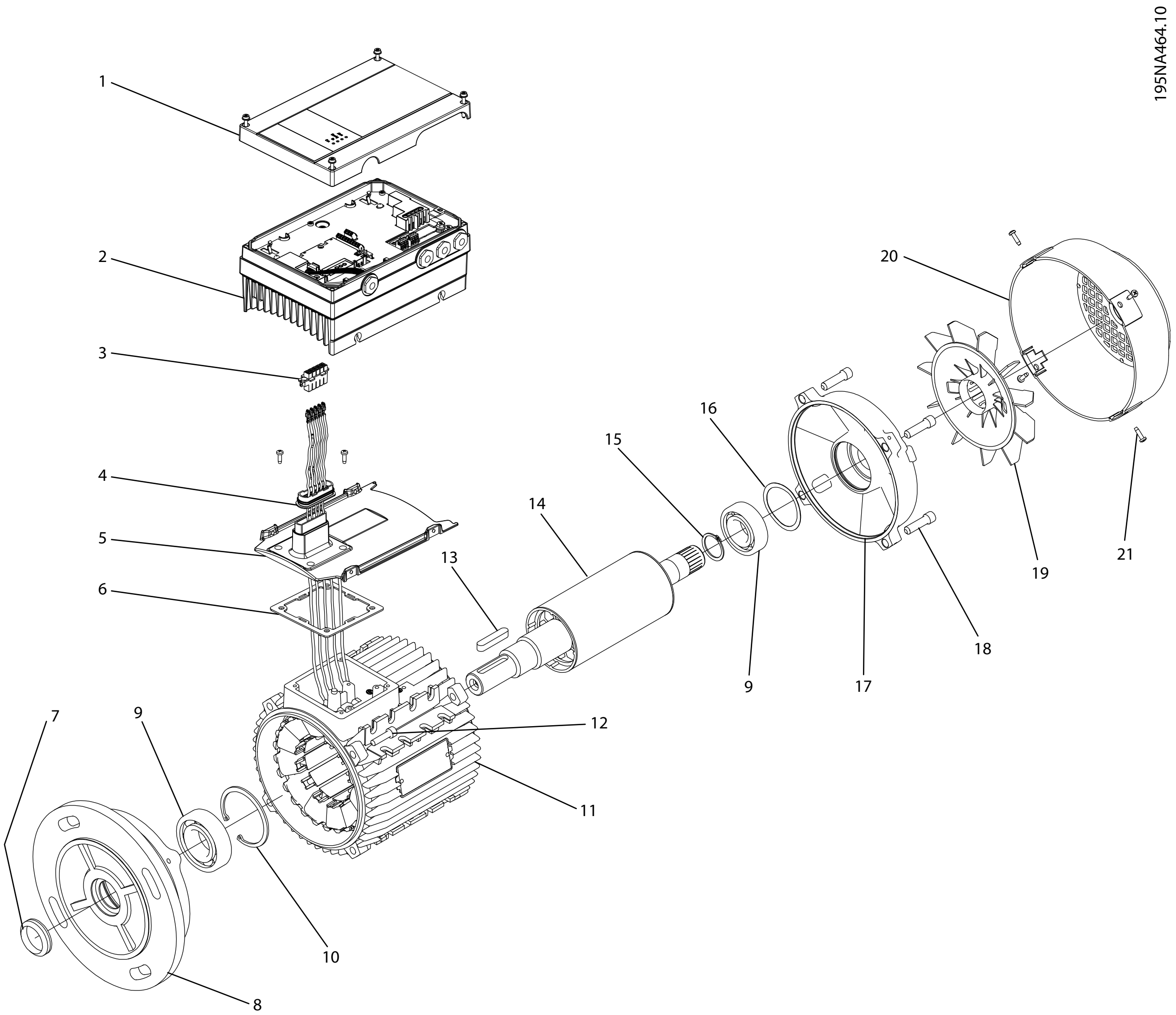
Item	Description	Item	Description
1	Frequency converter cover	13	Foot fixing bolt
2	Frequency converter enclosure	14	Stator frame
3	Motor connector	15	Fixing bolt end shield, drive end
4	Motor connector gasket	16	Shaft key
5	Motor adapter plate	17	Rotor assembly
6	Gasket between motor and motor bracket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

Illustration 1.5 FCM 106 with Asynchronous Motor, Exploded View - Phase 1



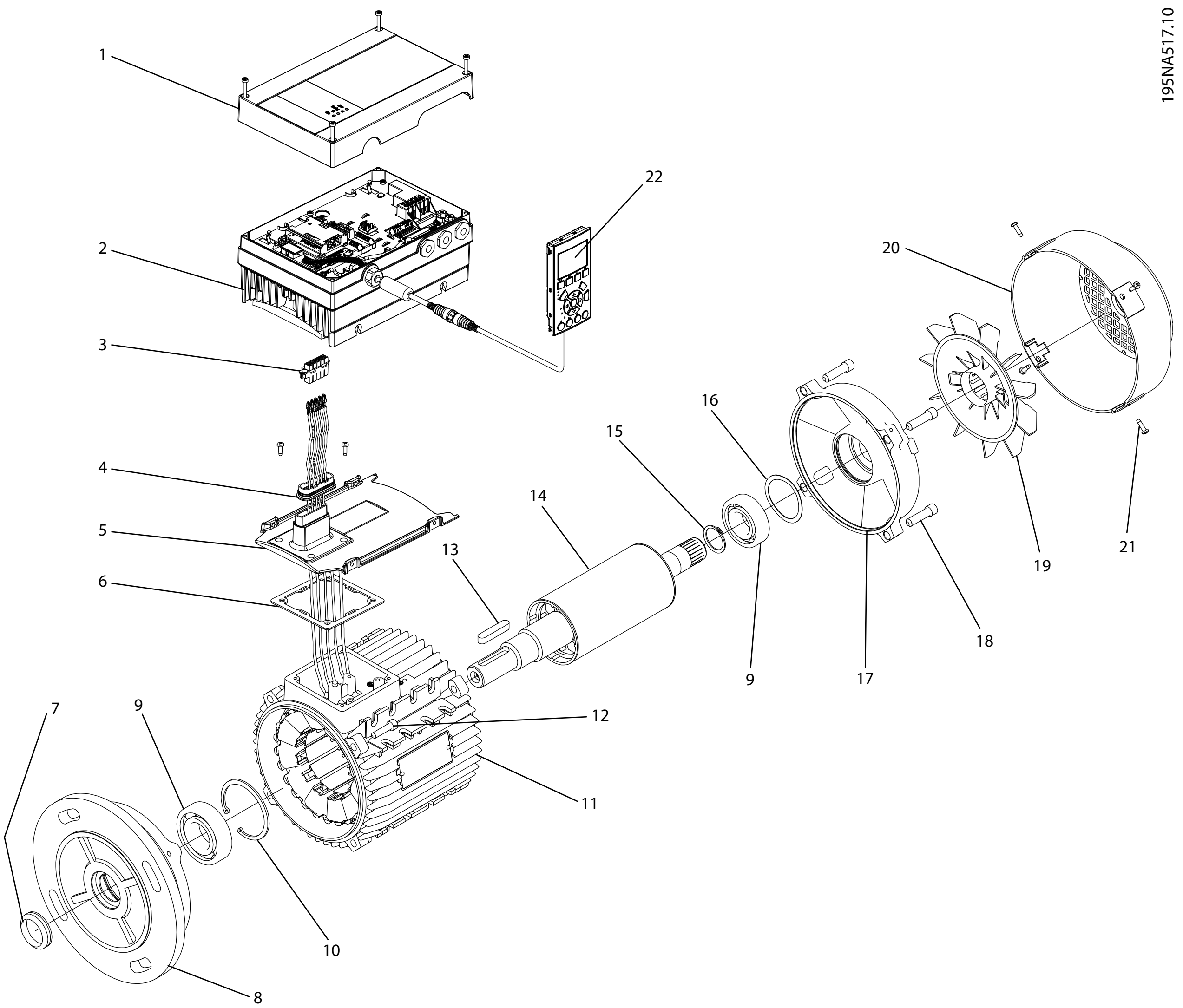
Item	Description	Item	Description
1	Frequency converter cover	13	Foot fixing bolt
2	Frequency converter enclosure	14	Stator frame
3	Motor connector	15	Fixing bolt end shield, drive end
4	Motor connector gasket	16	Shaft key
5	Motor adapter plate	17	Rotor assembly
6	Gasket between motor and motor bracket	18	Pre-load washer
7	Dust seal, drive end	19	End shield, non-drive end
8	End shield, drive end	20	Fixing bolt end shield, non-drive end
9	Bearing	21	Fan
10	Snap ring	22	Fan cover
11	Foot fixing	23	Fan cover screw
12	Detachable feet	24	GLCP

Illustration 1.6 FCM 106 with Asynchronous Motor, Exploded View - Phase 2



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

Illustration 1.7 FCM 106 with PM Motor, Exploded View - Phase 1



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

Illustration 1.8 FCM 106 with PM Motor, Exploded View - Phase 2

NOTICE

Spare parts are available from the motor supplier.
Contact Danfoss.

1.5.5 Electrical Overview

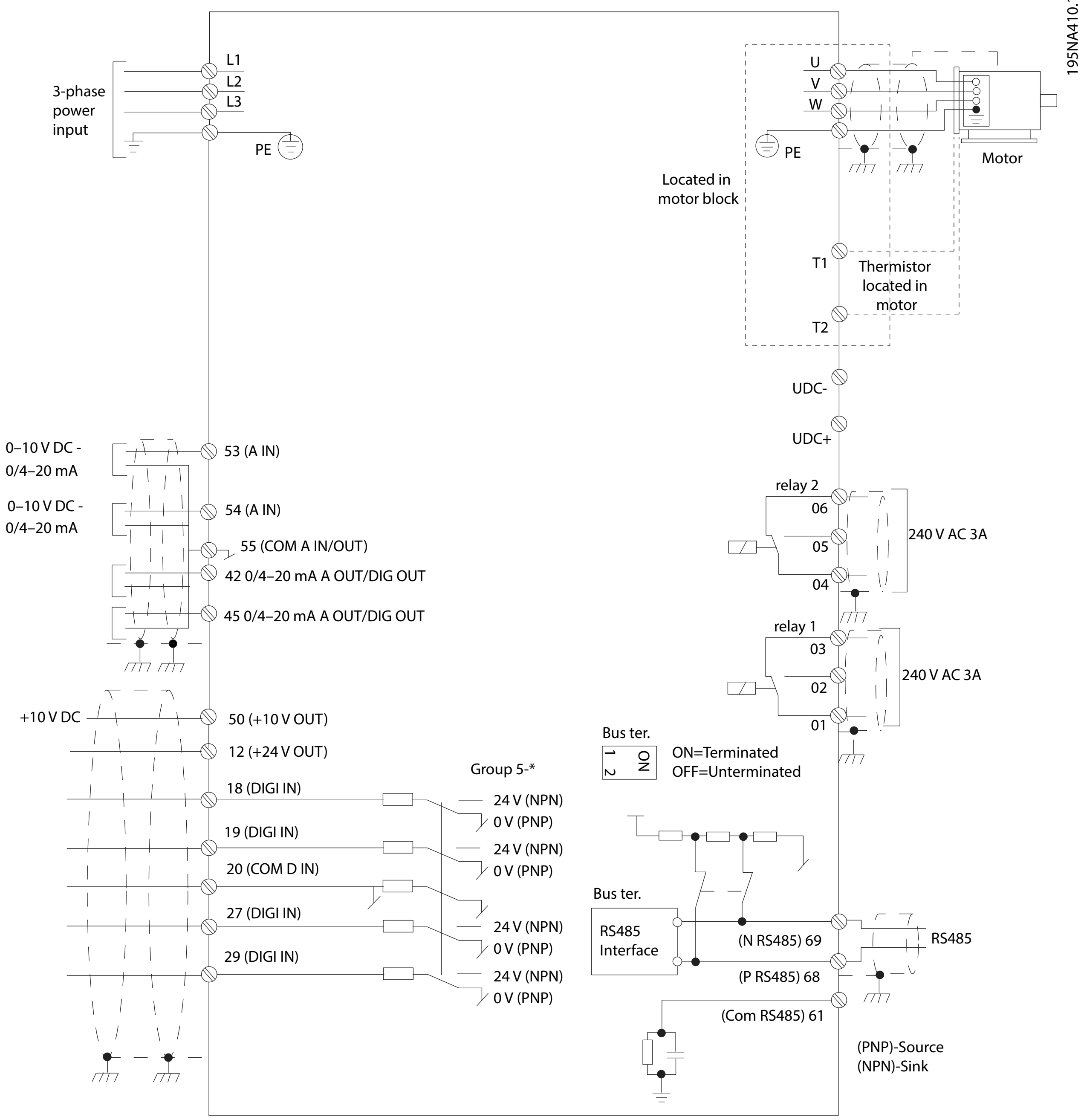


Illustration 1.9 Electrical Overview, without VLT® Memory Module MCM 101 and VLT® PROFIBUS DP MCA 101, Phase 1

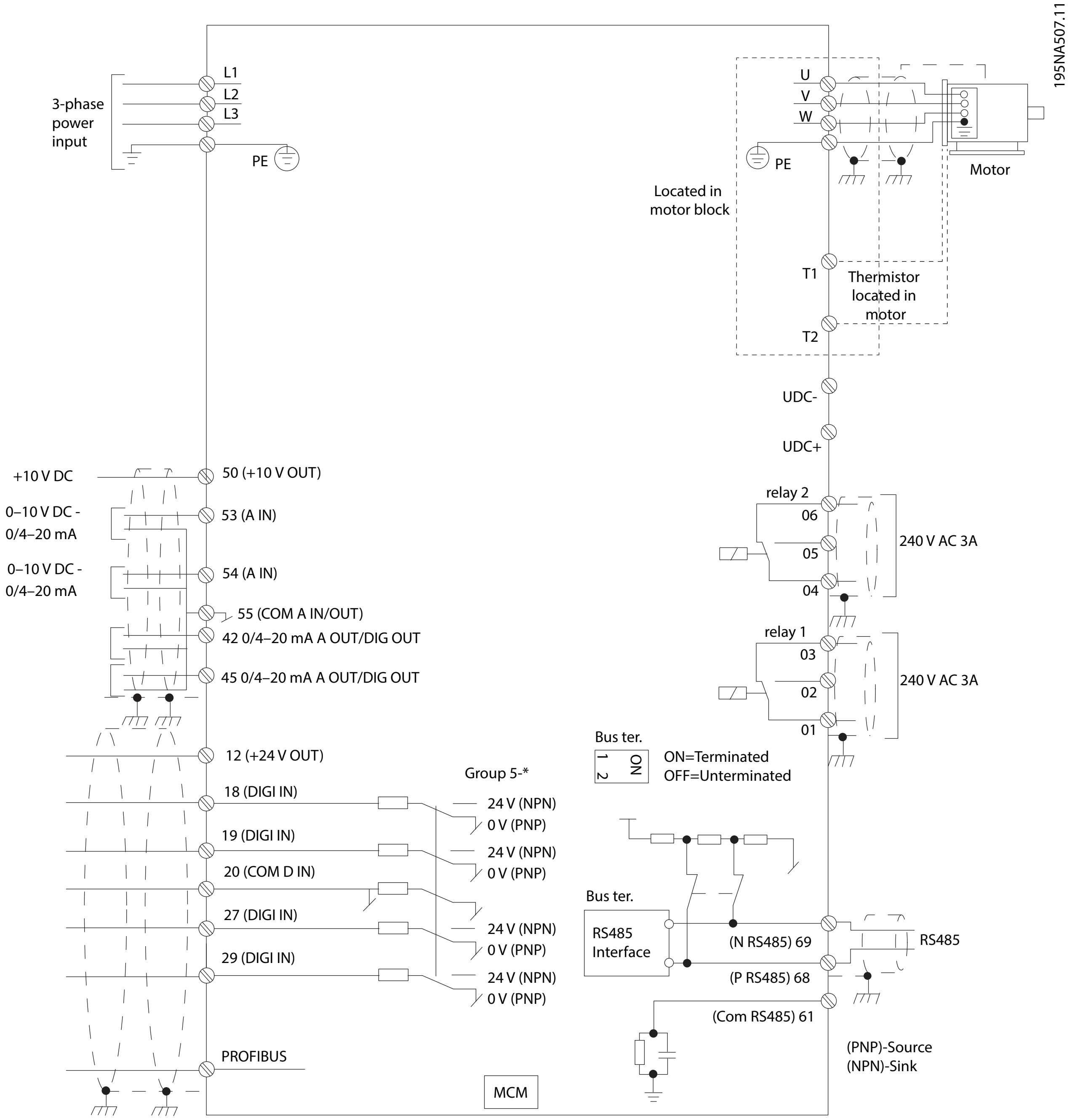


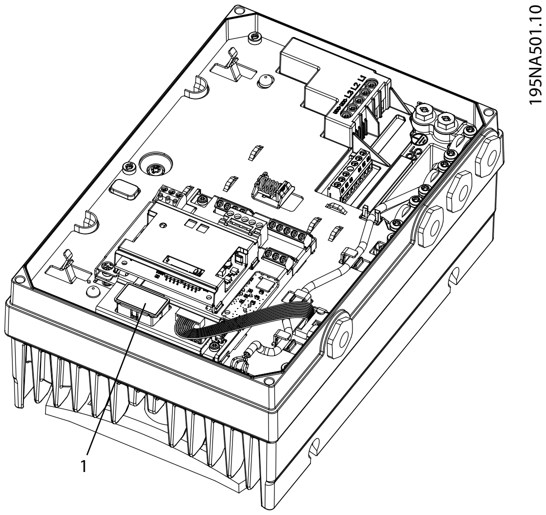
Illustration 1.10 Electrical Overview, with VLT® Memory Module MCM 101 and VLT® PROFIBUS DP MCA 101, Phase 2

1.6 VLT® Memory Module MCM 101

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

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

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



1	VLT® Memory Module MCM 101

Illustration 1.11 Location of Memory Module

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

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

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

1.6.1 Configuring with the VLT® Memory Module MCM 101

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

⚠WARNING

DISCONNECT POWER BEFORE SERVICING!

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

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

NOTICE

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

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

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

Examples of data that can be copied are:

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

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

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

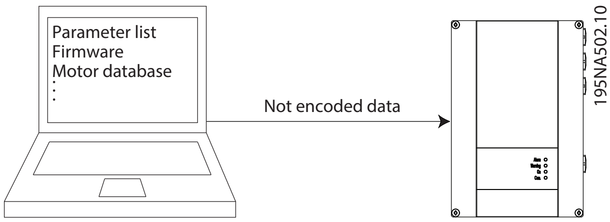


Illustration 1.12 Data Transfer from PC to Frequency Converter

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

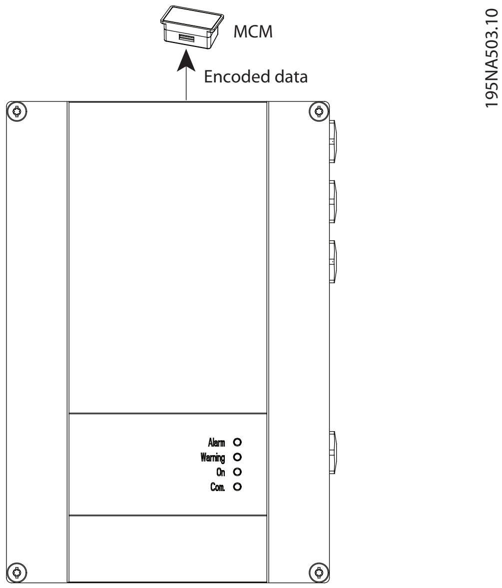


Illustration 1.13 Data Transfer from Frequency Converter to Memory Module

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

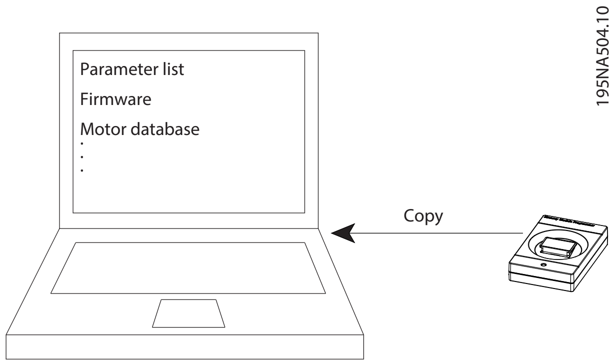


Illustration 1.14 Data Transfer from MMP to PC

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

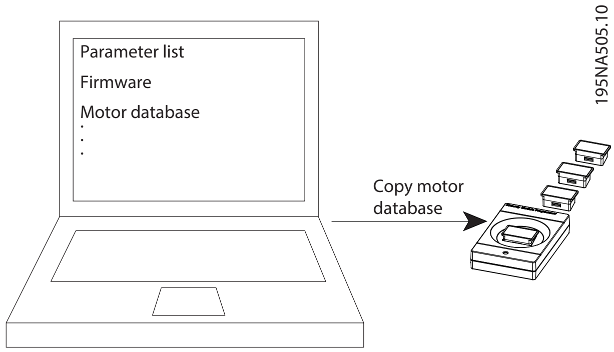


Illustration 1.15 Data Transfer from PC to Memory Module

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

1.6.3 Copying a Configuration to Several Frequency Converters

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

1. Remove the lid from the frequency converter with the configuration to be copied.
2. Unplug the memory module.
3. Remove the lid from the frequency converter to which the configuration must be copied.
4. Plug in the memory module.
5. When copying is complete, plug in an empty memory module in the frequency converter.

6. Place and tighten the lid.
7. Power cycle the frequency converter.
8. Repeat steps 3–7 for each frequency converter that is to receive the configuration.
9. Place the memory module in the original frequency converter.
10. Place and tighten the lid.

1.7 Tools Required for Service

Item	Description
ESD protection kit	Wrist strap and mat
Metric socket set	10–42 mm
Torque wrench	Torque range 1.3–7.0 Nm
Torx driver set	T10 and T20
Needle nose pliers	–
Ratchet	–
Screwdrivers	Standard and Phillips

Table 1.3 Tools Required for Service of Frequency Converter

Item	Description
Digital voltmeter or digital ohmmeter	• Rated for true RMS. • With diode mode. • Rated for 1000 V DC or 600 V units.
Analog voltmeter	–
Oscilloscope	–
Clamp-on ammeter	Clamp-on ammeter rated for true RMS.

Table 1.4 Instruments Recommended for Testing of Frequency Converter

1.8 Reference for Support or Service Report

Report the serial number of the frequency converter when requesting support, or preparing the service report. The serial number is listed on the nameplate, see *chapter 1.5.3 Nameplates*.

2 Safety

2.1 Introduction

This section describes requirements to personnel and safe practices to observe when performing service and maintenance procedures.

2.2 Safety Symbols

The following symbols are used in this manual:

WARNING

Indicates a potentially hazardous situation that could result in death or serious injury.

CAUTION

Indicates a potentially hazardous situation that could result in minor or moderate injury. It can also be used to alert against unsafe practices.

NOTICE

Indicates important information, including situations that can result in damage to equipment or property.

2.3 Qualified Personnel

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

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

2.4 Safety Precautions

WARNING

HIGH VOLTAGE

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

- **Only qualified personnel are permitted to perform installation, start-up, and maintenance.**

WARNING

UNINTENDED START

When the frequency converter is connected to AC mains, DC supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. The motor can start with an external switch, a fieldbus command, an input reference signal from the LCP or LOP, via remote operation using MCT 10 Set-up Software, or after a cleared fault condition.
To prevent unintended motor start:

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

WARNING

DISCHARGE TIME

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

- **Stop the motor.**
- **Disconnect AC mains and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other frequency converters.**
- **Disconnect or lock PM motor.**
- **Wait for the capacitors to discharge fully. The minimum duration of waiting time is specified in *Table 2.1*.**
- **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]	Minimum waiting time (minutes)
3x400	0.55–7.5	4

Table 2.1 Discharge Time

1) Power ratings relate to NO, see chapter 9.2 Electrical Data.

⚠WARNING

LEAKAGE CURRENT HAZARD

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

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

⚠WARNING

EQUIPMENT HAZARD

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

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

⚠WARNING

UNINTENDED MOTOR ROTATION WINDMILLING

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

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

⚠WARNING

SHOCK HAZARD AND RISK OF INJURY

For dynamic test procedures, mains input power is required, and all devices and supplies connected to mains are energized at rated voltage. Contact with powered components can result in death or serious injury.

- **Do not touch energized parts of the frequency converter when connected to mains.**

⚠CAUTION

INTERNAL FAILURE HAZARD

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

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

⚠WARNING

DC CURRENT RISK

This product can cause a DC current in the protective conductor. Failure to follow the precautions can lead to personal injury or property damage.
Take the following precautions:

- **When using a residual current device (RCD) for extra protection, use only an RCD of Type B (time delayed) on the supply side of this product.**
- **Protective earthing (PE) of the frequency converter and the use of RCDs must always follow national and local regulations.**

⚠CAUTION

RISK OF INJURY OR PROPERTY DAMAGE

Do not assume that a motor is wired properly after completed service of the frequency converter. Check for:

- **Loose connections.**
- **Improper programming.**
- **Added equipment.**

Failure to perform these checks can result in personal injury, property damage, or less than optimal performance.

NOTICE

LIFTING - EQUIPMENT DAMAGE RISK

Incorrect lifting can result in equipment damage.

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

NOTICE

INSTALLATION - EQUIPMENT DAMAGE RISK

Incorrect installation can result in equipment damage.

- **Before installation, check for fan cover damage, shaft damage, foot or mounting damage, and loose fasteners.**
- **Check nameplate details.**
- **Ensure level mounting surface, balanced mounting. Avoid misalignment.**
- **Ensure that gaskets, sealants, and guards are correctly fitted.**
- **Ensure correct belt tension.**

2.5 Electrostatic Discharge (ESD)

CAUTION

ELECTROSTATIC DISCHARGE

When performing service, use proper electrostatic discharge (ESD) procedures to prevent damage to sensitive components. Many electronic components within the frequency converter are sensitive to static electricity. The voltage of static electricity can reduce lifetime, affect performance, or completely destroy sensitive electronic components.

- **Do not touch components on the circuit boards.**
- **Hold circuit boards by the edges or corners only.**

3 User Interface and Control

3.1 Introduction

This section describes the optional display interfaces available for:

- The frequency converter.
- The inputs.
- The outputs.
- The control terminal functions.

The following optional interfaces are available:

- Local control panel (LCP).
- MCT 10 Set-up Software, for use with a PC.
- Local operating panel (LOP).

Use the selected interface to adapt parameter settings or to read status.
The operating status of the frequency converter is shown in real time, including:

- Supply and output voltages.
- Operational condition of the motor and load.
- Warnings and alarms.
- Status of parameter settings.

Commands given to the frequency converter are indicated on the selected interface display. Fault logs are maintained within the frequency converter for fault history. The frequency converter issues warnings and alarms for fault conditions arising within or external to the frequency converter itself. In most cases, the fault condition is found outside of the frequency converter.

NOTICE

This chapter describes the GLCP. Phase-1 frequency converters, see *chapter 1.5.2 FCP 106 and FCM 106*, use another LCP. The basic operation of the 2 LCPs is the same, but the GLCP has extended functionalities.

3.2 MCT 10 Set-up Software

The frequency converter can be programmed from the LCP or from a PC via the RS485 COM port by installing the MCT 10 Set-up Software.

3.3 Local Control Panel (LCP)

The LCP is divided into 4 functional sections.

A. Alphanumeric display.

B. Menu selection.

C. Navigation keys and indicator lights (LEDs).

D. Operation keys and indicator lights (LEDs).

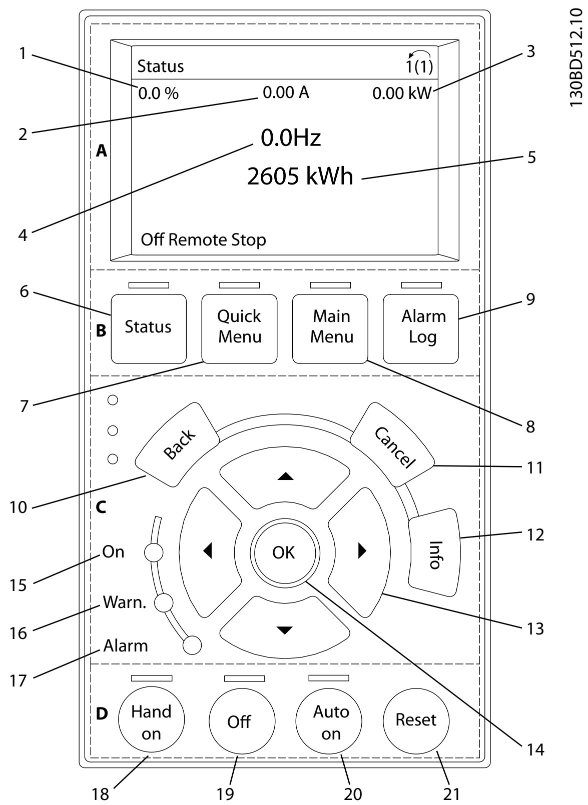


Illustration 3.1 Local Control Panel (LCP)

A. Display area

The display area is activated when the frequency converter receives power from mains voltage, a DC bus terminal, or a 24 V DC external supply.

The information shown on the LCP can be customized for user application. Select options in the Quick Menu *Q3-13 Display settings*.

Call-out	Display	Parameter number	Default setting
1	1.1	0-20	Reference %
2	1.2	0-21	Motor current
3	1.3	0-22	Power [kW]
4	2	0-23	Frequency
5	3	0-24	kWh counter

Table 3.1 Legend to *Illustration 3.1*

B. Display menu key
Menu keys are used for menu access for parameter set-up, toggling through status display modes during normal operation, and viewing fault log data.

Callout	Key	Function
6	Status	Shows operational information.
7	Quick Menu	Allows access to programming parameters for initial set-up instructions and many detailed application instructions.
8	Main Menu	Allows access to all programming parameters.
9	Alarm Log	Shows a list of current warnings, the last 10 alarms, and the maintenance log.

Table 3.2 Legend to *Illustration 3.1*

C. Navigation keys and indicator lights (LEDs)
Navigation keys are used for programming functions and moving the display cursor. The navigation keys also provide speed control in local operation. There are also 3 frequency converter status indicator lights in this area.

Callout	Key	Function
10	Back	Reverts to the previous step or list in the menu structure.
11	Cancel	Cancels the last change or command as long as the display mode has not changed.
12	Info	Press for a definition of the function shown.
13	Navigation keys	Press to move between items in the menu.
14	OK	Press to access parameter groups or to enable a selection.

Table 3.3 Legend to *Illustration 3.1*

Call-out	Indicator	Light	Function
15	ON	Green	The ON light activates when the frequency converter receives power from mains voltage, a DC bus terminal, or a 24 V external supply.
16	WARN	Yellow	When warning conditions are met, the yellow WARN light turns on, and text appears in the display area identifying the problem.
17	ALARM	Red	A fault condition causes the red alarm light to flash, and an alarm text is shown.

Table 3.4 Legend to *Illustration 3.1*

D. Operation keys and indicator lights (LEDs)
Operation keys are at the bottom of the LCP.

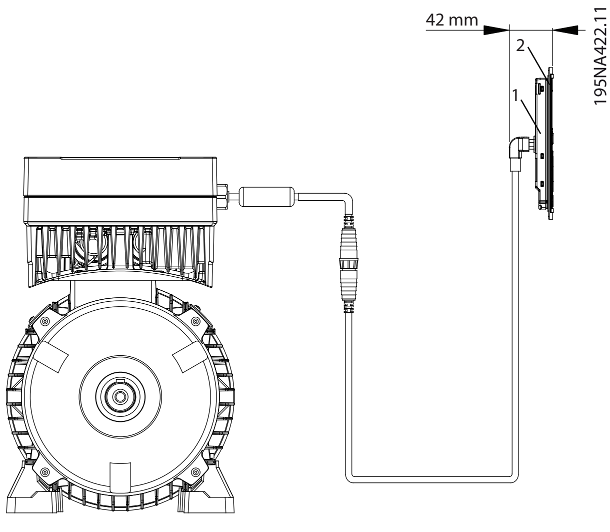
Callout	Key	Function
18	Hand On	Starts the frequency converter in local control. • An external stop signal by control input or serial communication overrides the local hand on.
19	Off	Stops the motor but does not remove power to the frequency converter.
20	Auto On	Puts the system in remote operational mode. • Responds to an external start command by control terminals or serial communication.
21	Reset	Resets the frequency converter manually after a fault has been cleared.

Table 3.5 Legend to *Illustration 3.1*

NOTICE

To adjust the display contrast, press [Status] and [▲]/[▼].

To view or change the frequency converter settings, attach the LCP using the LCP cable. See *Illustration 3.2*.
After use, remove the LCP cable from the frequency converter to maintain the ingress protection class of the enclosure.



1	Control panel
2	Panel door

Illustration 3.2 LCP Remote Mounting

3.4 LCP Menus

3.4.1 Status Menu

In the *Status* menu, the selection options are:

- Motor frequency [Hz], *parameter 16-13 Frequency*.
- Motor current [A], *parameter 16-14 Motor current*.
- Motor speed reference in percentage [%], *parameter 16-02 Reference [%]*.
- Feedback, *parameter 16-52 Feedback[Unit]*.
- Motor power *parameter 16-10 Power [kW]* for kW, *parameter 16-11 Power [hp]* for hp. If *parameter 0-03 Regional Settings* is set to *[1] North America*, motor power is shown in hp instead of kW.
- Custom readout *parameter 16-09 Custom Readout*.

3.4.2 Quick Menu

Use the *Quick Menu* to program the most common functions. The *Quick Menu* consists of:

- Wizard for open-loop applications.
- Closed-loop set-up wizard.
- Motor set-up.
- Changes made.

For details of quick menus, see *VLT® DriveMotor FCP 106/FCM 106 Operating Instructions.*

3.4.3 Main Menu

The *Main Menu* is used for access to and programming of all parameters. The *Main Menu* parameters can be accessed readily unless a password has been created via *parameter 0-60 Main Menu Password*.
For most applications, it is not necessary to access the *Main Menu* parameters. Instead the *Quick Menu* provides the simplest and quickest access to the parameters which are typically required.

3.5 Programming Parameters

Procedure:

1. Press [Menu] until the arrow in the display indicates the wanted menu: *Quick Menu* or *Main Menu*.
2. To browse through the parameter groups, press [▲] [▼].
3. To select a parameter group, press [OK].
4. To browse through the parameters in the specific group, press [▲] [▼].
5. To select the parameter, press [OK].
6. To change the parameter value, press [▲] [▼] [►].
7. To save the new setting, press [OK]. To abort, press [Back].
8. To return to the previous menu, press [Back].

3.6 Parameter Settings

3.6.1 Changing Parameter Settings

Quick access to change parameter settings:

1. To enter the *Quick Menu*, press [Menu] until the indicator in the display reaches *Quick Menu*.
2. Press [▲] [▼] to select wizard, closed-loop set-up, motor set-up, or changes made, then press [OK].
3. Press [▲] [▼] to browse through the parameters in the *Quick Menu*.
4. To select a parameter, press [OK].
5. Press [▲] [▼] to change the value of a parameter setting.
6. Press [►] to shift digit when a decimal parameter is in the editing state.
7. To accept the change, press [OK].
8. Press either [Back] twice to enter *Status*, or press [Menu] once to enter *Main Menu*.

The *Main Menu* accesses all parameters:

1. Press [Menu] until the indicator in the display reaches *Main Menu*.
2. Press [▲] [▼] to browse through the parameter groups.
3. To select a parameter group, press [OK].
4. Press [▲] [▼] to browse through the parameters in the specific group.
5. To select the parameter, press [OK].
6. Press [▲] [▼] to set/change the parameter value.

Changes made:

1. Press [Menu] until the indicator in the display reaches *Quick Menu*.
2. Press [▲] [▼] to browse through the quick menus.
3. To select *05 Changes Made*, press [OK].

- *Changes Made* lists all parameters changed from default settings.
- The list shows only parameters which have been changed in the current edit set-up.

- Parameters which have been reset to default values are not listed.
- The message *Empty* indicates that no parameters have been changed.

NOTICE

Stop the motor before backing-up or copying parameter settings.

Data storage in LCP
Once the set-up of a frequency converter is complete, store the data in the LCP. Alternatively, use a PC with the MCT 10 Set-up Software to perform the same back-up.

1. Go to *parameter 0-50 LCP Copy*.
2. Press [OK].
3. Select *[1] All to LCP*.
4. Press [OK].

Data transfer from LCP to frequency converter
Connect the LCP to another frequency converter and copy the parameter settings to this frequency converter as well.

1. Go to *parameter 0-50 LCP Copy*.
2. Press [OK].
3. Select *[2] All from LCP*.
4. Press [OK].

Select initialization mode according to the requirement for retaining parameter settings.

Recommended initialization (via *parameter 14-22 Operation Mode*).
Use this method to initialize the frequency converter without resetting communication settings.

1. Select *parameter 14-22 Operation Mode*.
2. Press [OK].
3. Select *[2] initialization* and Press [OK].
4. Cut off the mains supply and wait until the display turns off.
5. Reconnect the mains supply.

The frequency converter is now reset, except for the following parameters:

- *Parameter 0-03 Regional Settings*.
- *Parameter 8-30 Protocol*.
- *Parameter 8-31 Address*.
- *Parameter 8-32 Baud Rate*.
- *Parameter 8-33 Parity / Stop Bits*.
- *Parameter 8-35 Minimum Response Delay*.
- *Parameter 8-36 Maximum Response Delay*.
- *Parameter 8-70 BACnet Device Instance*.
- *Parameter 8-72 MS/TP Max Masters*.
- *Parameter 8-73 MS/TP Max Info Frames*.
- *Parameter 8-74 "I am" Service*.
- *Parameter 8-75 Intialisation Password*.
- *Parameter 15-00 Operating hours*.
- *Parameter 15-03 Power Up's*.
- *Parameter 15-04 Over Temp's*.
- *Parameter 15-05 Over Volt's*.
- *Parameter 15-30 Alarm Log: Error Code*.
- *Parameter group 15-4* Drive identification parameters*.
- *Parameter 1-06 Clockwise Direction*.

Two-finger initialization
Use this method to initialize the frequency converter, including reset of communication settings.

1. Power off the frequency converter.
2. Press [OK] and [Menu] simultaneously.
3. Power up the frequency converter while still pressing the above-mentioned keys for 10 s.

The frequency converter is now reset, except for the following parameters:

- *Parameter 0-03 Regional Settings*.
- *Parameter 15-00 Operating hours*.
- *Parameter 15-03 Power Up's*.
- *Parameter 15-04 Over Temp's*.
- *Parameter 15-05 Over Volt's*.
- *Parameter group 15-4* Drive identification parameters*

Alarm 80, Drive initialised appears as confirmation that parameters are initialized. Press [Reset].

3.7 Status Messages

Status messages appear in the bottom of the display. The left part of the status line indicates the active operation model of the frequency converter.

The center part of the status line indicates the references site. The last part of the status line gives the operation status, for example:

- Running.
- Stop.
- Standby.

Other status messages may appear and are related to the software version and frequency converter type.

3.8 Service Functions

Service information for the frequency converter can be shown in display lines 1 and 2. Access to 24 different items is possible. The data includes:

- Counters to tabulate hour runs.
- Fault logs to store frequency converter status values present at the 10 most recent events that stopped the frequency converter.
- Frequency converter nameplate data.

Parameter 14-28 Production Settings and *parameter 14-29 Service Code* are the relevant service parameters.

To show parameter settings, press [Main Menu].

Press [▲], [▼], [►], and [◄] to scroll through parameters.

See the *VLT® DriveMotor FCP 106/FCM 106 Programming Guide* for descriptions and procedures for service information available in parameter group *6-** Analog In/Out*.

3.9 Frequency Converter Inputs and Outputs

The frequency converter operates by receiving control input signals. The frequency converter can also output status data or control auxiliary devices.

Control input is sent to the frequency converter in 3 ways:

- Via the optional LCP connected by cable to the frequency converter, operating in hand-on mode. These inputs include:
  - Start.
  - Stop.
  - Reset.
  - Speed reference.
- Via serial communication from a fieldbus that is connected to the frequency converter through the RS485 serial port. The serial communication protocol is used to:
  - Supply commands and references to the frequency converter.
  - Program the frequency converter.
  - Read status data from the frequency converter.
- Via signal wiring connected to the frequency converter control terminals.

NOTICE

Improperly connected control wiring can result in the frequency converter failing to start or to respond to a remote input.

3.9.1 Input Signals

The frequency converter can receive 2 types of remote input signals:

- Digital inputs wired to terminals 18, 19, 20 (common), 27, and 29.
- Analog or digital inputs wired to terminals 53 or 54, and 55 (common).

Analog signals:

- Comprise 1 of the following:
  - Voltage (0 to +10 V DC).
  - Current (0–20 mA or 4–20 mA).
- Can be varied like dialing a rheostat up and down. Program the frequency converter to increase or decrease output in relation to the amount of current or voltage.

Example
A sensor or external controller supplies a variable current or voltage. The frequency converter output regulates the speed of the motor connected to the frequency converter in response to the analog signal.

Digital signals
Digital signals are a simple binary 0 or 1 acting as a switch. A 0–24 V DC signal controls the digital signals. A voltage signal lower than 5 V DC is a logic 0. A voltage higher than 10 V DC is a logic 1. 0 is open, 1 is closed. Digital inputs to the frequency converter are switched commands such as:

- Start.
- Stop.
- Reverse.
- Coast.
- Reset.

(Do not confuse these digital inputs with serial communication formats where digital bytes are grouped into communication words and protocols).

RS485
The RS485 serial communication connector is wired to terminals (+)68 and (-)69. Terminal 61 is a common terminal. It is used for terminating screens only when the control cable is run between frequency converters, and not between frequency converters and other devices.

Use parameter settings to configure the input and output using NPN and PNP.

Stop the motor before changing these parameter settings. The settings cannot be changed while the motor runs.

3.9.2 Output Signals

The frequency converter produces output signals that are carried either through the RS485 fieldbus, terminal 42, or terminal 45. Motor terminals 42 and 45 operate in the same manner as the inputs. The terminal can be programmed for either a variable analog signal in mA or a digital signal (0 or 1) in 24 V DC. Output analog signals indicate the frequency, current, and torque to an external controller or system. Digital outputs can be control signals used to open or close a damper, or send a start or stop command to auxiliary equipment.

More terminals: 01, 02, 03, 04, 05, and 06.

Terminal 12 provides 24 V DC low-voltage power to the digital input terminals. Supply those terminals with power from terminal 12, or from a customer-supplied external 24 V DC power source. Improperly connected control wiring is a common service issue for a motor not operating or the frequency converter not responding to a remote input.

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 at digital output (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

Table 3.6 Digital Output

1) Terminals 27 and 29 can also be programmed as input.
Terminals 42 and 45 can also be programmed as analog output.

3.10 Control Terminals

For correct operation of the frequency converter functions, the input control terminals must be:

- Wired properly.
- Powered.
- Programmed correctly for the intended function.

To ensure that the input terminal is wired correctly:

1. Confirm that the control and power sources are wired to the terminal.
2. Check the signal in either of 2 ways:
    - Select Display mode, then select *Digital Input*. The LCP shows the correctly wired digital inputs.
    - Use a voltmeter to check for voltage at the control terminal.

Confirm that each control terminal is programmed for the correct function. Each terminal has specific functions and a numbered parameter associated with it. The setting selected in the parameter enables the function of the terminal.

See the *VLT® DriveMotor FCP 106/FCM 106 Programming Guide* for details on changing parameters and the functions available for each control terminal.

3.11 Control Terminal Functions

For functions of the control terminals, refer to *Table 3.7*. Many of these terminals have multiple functions determined by parameter settings. See also *chapter 1.5.5 Electrical Overview*.

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

Table 3.7 Control Terminal Functions, Phase 1

** Indicates default setting.*

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

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

Table 3.8 Control Terminal Functions, Phase 2

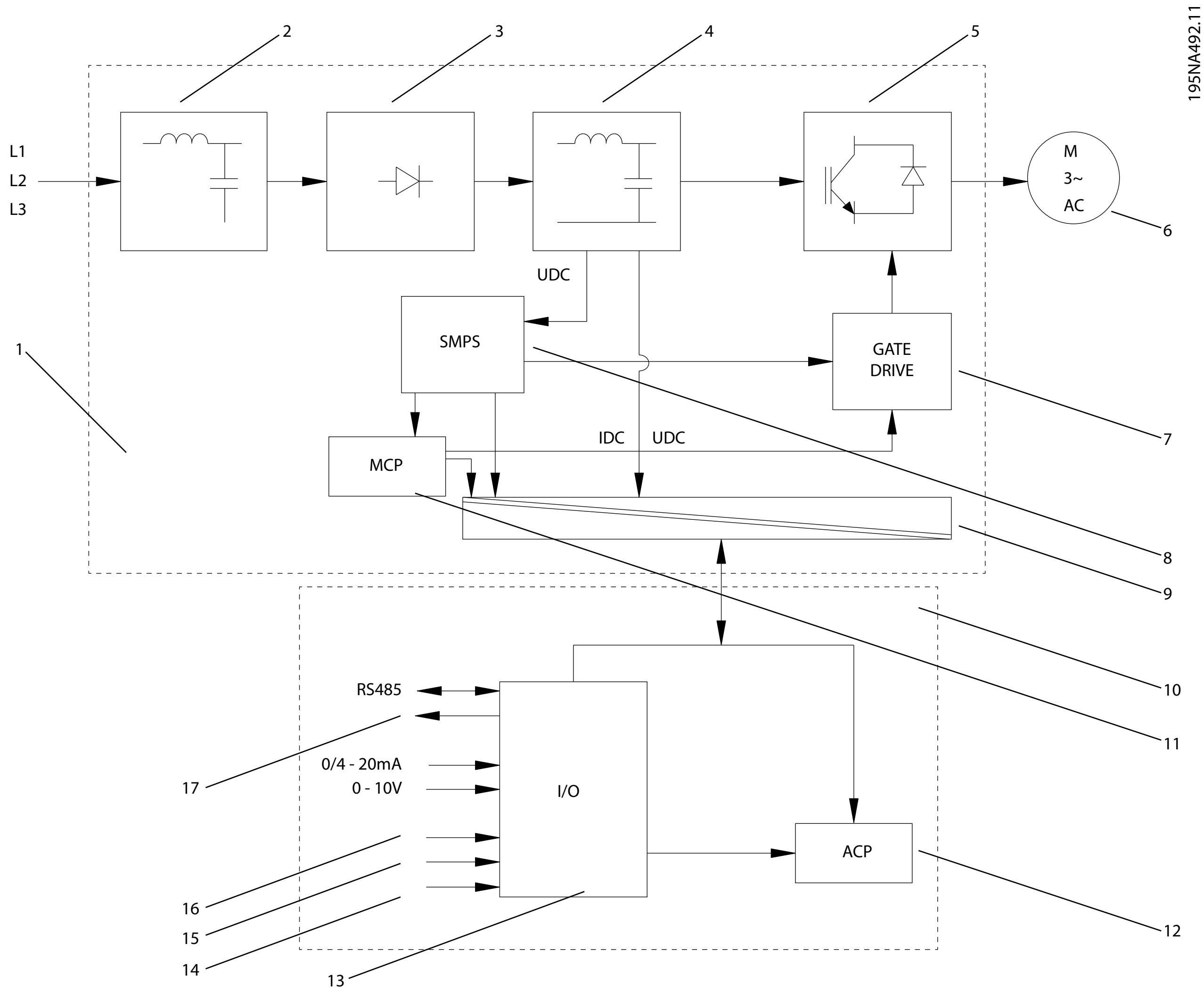
** Indicates default setting.*

4 Internal Operation

This chapter provides an operational overview of the main assemblies and circuitry in the frequency converter.

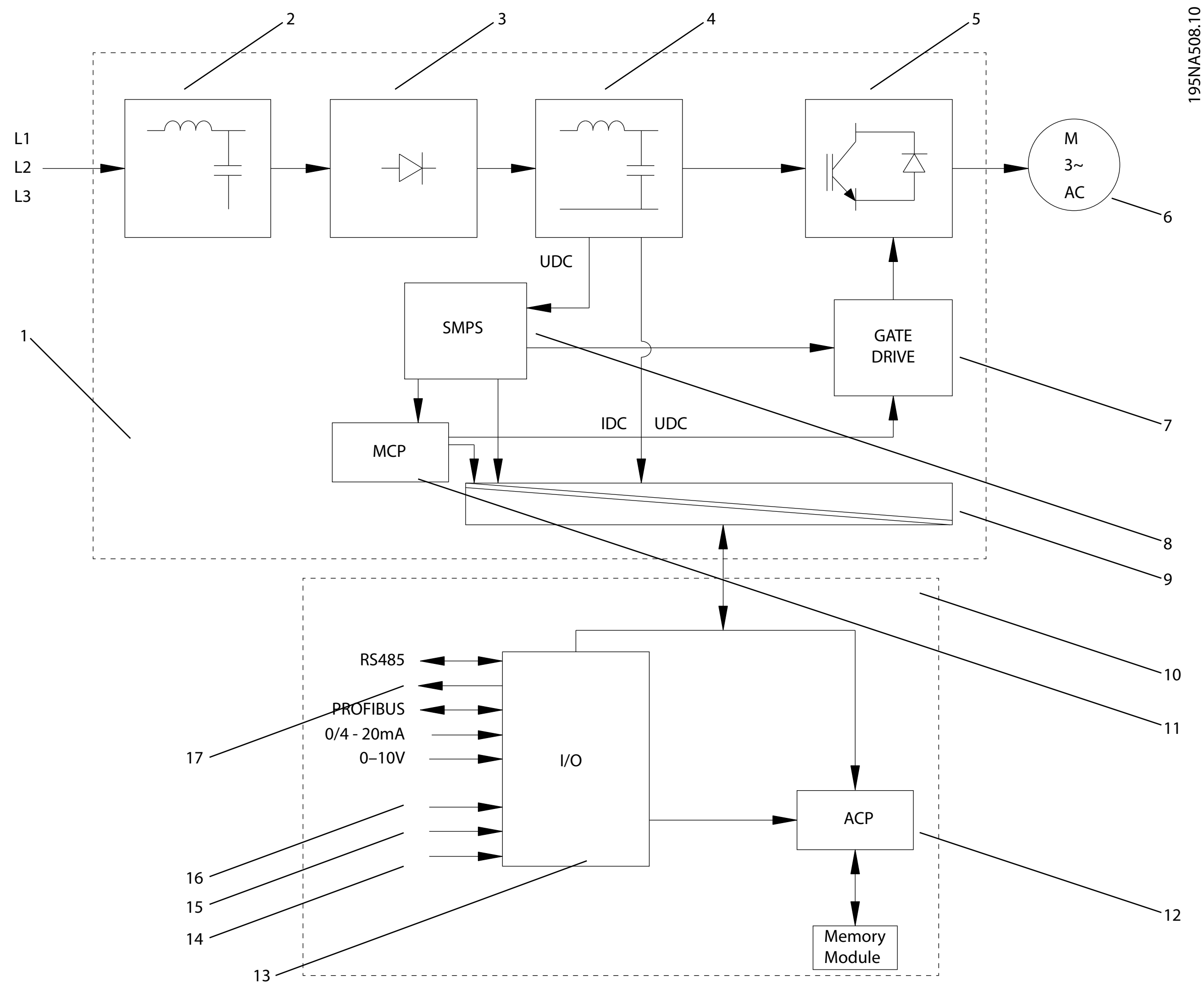
4.1 Internal Structure

4.1.1 Key Diagram



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

Illustration 4.1 Key Diagram, without VLT® Memory Module MCM 101 and VLT® PROFIBUS DP MCA 101, Phase 1



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

Illustration 4.2 Key Diagram, with VLT® Memory Module MCM 101 and VLT® PROFIBUS DP MCA 101, Phase 2

A frequency converter supplies a regulated amount of AC power to a 3-phase motor to control the motor speed. For its intended use, refer to *chapter 1.5.1 Intended Use*.

The frequency converter is divided into the following sections, shown in *Illustration 4.1* and *Illustration 4.2*:

- RFI filter.
- Rectifier.
- Intermediate circuit/DC filter.
- Inverter.
- Control and regulation.
  - MCP.
  - ACP.
- Logic to power interface.
  - SMPS.
  - Gate drive.
  - Control terminals.

In the remainder of this chapter, these sections are covered in greater detail with descriptions of how power and control signals move through the frequency converter.

4.2 Power Card

4.2.1 RFI Filter

The radio frequency interference (RFI) filter contains RFI coil and capacitor bank. The RFI filter reduces naturally occurring currents in the radio frequency range to prevent interference with other sensitive equipment in the area.

The circuit can be sensitive to unbalanced phase-to-ground voltages in the 3-phase AC input line. This sensitivity can occasionally result in nuisance overvoltage alarms.

4.2.2 Rectifier Section

The rectifier provides a path for current flowing from the line to the DC-link circuitry. As a result, the DC-link capacitors charge.

The rectifier section consists of 6 diodes.

Inrush current, which appears when connected to grid, is limited with a PTC. A relay short-circuits the PTC when the DC-link capacitors are fully charged.

As long as power is applied to the frequency converter, voltage is present in the DC link and the inverter circuit. Voltage is also fed to the switch mode power supply (SMPS) on the power card and is used for generating all other low-voltage supplies.

4.2.3 Intermediate Section

From the rectifier section, voltage passes to the intermediate section. The DC link is an LC filter circuit consisting of the DC-link inductor and the DC-link capacitor bank that smooths the rectified voltage.

The intermediate section consists of the following components:

- The DC-link inductor located in the positive side of the DC link provides series impedance to changing current. This impedance aids the filtering process while reducing harmonic distortion to the input AC current waveform normally inherent in rectifier circuits.
- The DC-link capacitors are arranged into a capacitor bank along with bleeder and balancing circuitry.
- High-frequency (HF) filter film capacitors. These capacitors reduce the common mode noise caused by switching into stray capacitors to ground in cable and motor.

The voltage on a fully charged DC link is equal to the peak voltage of the input AC line. Theoretically, this voltage can be calculated by multiplying the AC line value by 1.414 (V AC x 1.414). However, since AC ripple voltage is present on the DC link, the actual DC value is closer to (V AC x 1.38) under unloaded conditions. The DC value can drop to (V AC x 1.32) while running under load.

Example

For a frequency converter sitting idle while connected to a nominal 460 V line, the DC-link voltage is approximately 635 V DC (460 x 1.38). As long as power is applied to the frequency converter, this voltage is present in the DC link and the inverter circuit. Voltage is also fed to the switch mode power supply (SMPS) on the power card which is used for generating all other low-voltage supplies. The SMPS is activated when the DC-link voltage reaches approximately 250 V DC.

4.2.4 Inverter Section

The inverter section is made up of 6 IGBTs, commonly referred to as switches. A switch is required for each half phase of the 3-phase power, giving the total of 6. For low-power units, the 6 IGBTs are contained in 1 power module shared with the rectifier. For higher power units, there can be 2 separate power modules. The inverter section receives gate signals from the MCP.

Once a run command and speed reference are present, the IGBTs begin switching to create the output waveform, as shown in *Illustration 4.3*. Looking at the phase-to-phase voltage waveform with an oscilloscope, a train of pulses of different widths is shown. The amplitude of the pulses measures the DC-link voltage. To view the fundamental sinusoidal curve, set the oscilloscope to filter out high harmonic content.

When measuring current, the normal view is a sinusoidal curve. The amplitude of the measured current depends on the loading level (for example, higher load results in a higher current reading).

This waveform, as generated by the frequency converter, provides optimal performance and minimal losses in the motor.

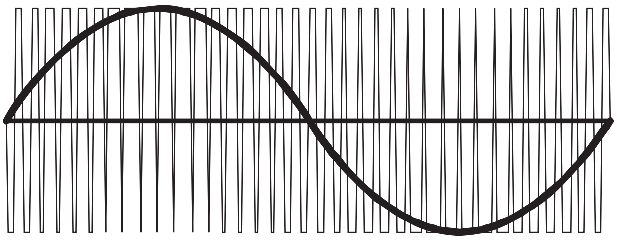


Illustration 4.3 Output Voltage and Current Waveforms

A thermal sensor mounted inside the IGBT module provides heat sink temperature feedback for the inverter.

4.2.5 Current Sensors

Current sensors monitor the output current and feed it back to the control card. The current signal is used for 2 purposes:

- To compensate for dynamic motor operation.
- To monitor overcurrent conditions, including ground faults and phase-to-phase short circuits.

During normal operation, the power card together with the control card monitor various functions within the frequency converter. The current sensors provide current feedback information. The DC-link voltage and mains voltage are monitored as well as the voltage delivered to the motor.

4.2.6 SMPS

The power card contains a switch mode power supply (SMPS). The SMPS provides the unit with 24 V DC, 16.7 V DC, 6 V DC, and 3.3 V DC operating voltage. SMPS powers the logic and interface circuitry. The DC-link voltage supplies the SMPS.

4.2.7 Relays

The frequency converter contains 2 relays for monitoring status of the frequency converter.For details of location and configuration, refer to the control wiring section in *VLT® DriveMotor FCP 106/FCM 106 Operating Instructions*.

4.2.8 MCP

The motor control processor (MCP) is a microprocessor, which supervises and controls all functions of operation of the frequency converter. In addition, a memory contains the parameters to provide the user with programmable options. These parameters are programmed to enable the frequency converter to meet specific application requirements.

These data are stored in an EEPROM, providing security during power-down and also allowing the flexibility to change the operational characteristics of the frequency converter.

The MCP provides the control signals for the IGBT conduction times. Those signals are buffered into the gate drive circuitry. The VVC+ control scheme compensates the control signals to match the application dynamics. The continuously pulsing SFAVM PWM is also available.

4.3 Control Card

The control card communicates via serial link with outside devices such as personal computers or programmable logic controllers (PLCs). The control card provides:

- 2 voltage supplies for use from the control terminals.
- Analog and digital output signals powered via an internal frequency converter supply.
- Analog and digital inputs.
- Connection to an LCP.

4.3.1 ACP

The application control processor (ACP) is the microprocessor controlling the application process. It operates in combination with the functions on the control card. Refer to *Table 3.7*, terminals 18–45.

4.3.2 Control Terminals

The functions of the control terminals are user-defined. Refer to *chapter 3.10 Control Terminals* and *chapter 3.11 Control Terminal Functions*.

5 Maintenance

This section describes routine maintenance of the frequency converter.

Under normal operating conditions and load profiles, the frequency converter is maintenance-free throughout its designed lifetime. To prevent breakdown, danger, and damage, examine the frequency converter at regular intervals depending on the operating conditions. Replace worn or damaged parts with original spare parts or standard parts. For service and support, contact the local Danfoss supplier.

5

5.1 Before Starting Repair Work

1. Read the safety warnings in *chapter 2 Safety*.
2. Disconnect the frequency converter from mains.
3. Disconnect the frequency converter from external DC supply, if present.
4. Disconnect the frequency converter from the motor as it can generate voltage when turned, for example by windmilling.
5. Wait for discharge of the DC link. For discharge time, see *Table 2.1*.
6. Remove the frequency converter from the motor adapter plate or wall mount plate.

5.2 Routine Cleaning

Remove the fan cover and ensure that all air inlet holes are free. Clean any dirt and obstructions:

- Behind the fan and along the ribs of the frame.
- Between the motor and frequency converter.

5.3 Periodic Maintenance of Motor

Periodic maintenance of motor part

1. Remove the frequency converter, motor adapter plate, fan cover, and the fan which is keyed to the shaft extension.
2. Loosen and remove bearing cover screws and end shield bolts/studs.
3. Ease the end shields off their spigots.
4. Clean to remove all dirt. Use an air line supplying dry compressed air under comparatively low pressure. Avoid using high velocity air, which can force dirt into the spaces between the windings and insulation. Avoid grease-removing solvents, which can damage impregnating varnish or insulation.
5. Reassemble the motor in the reverse order from dismantling. Ease end shields onto bearings and spigots.

NOTICE

EQUIPMENT DAMAGE

Do not use force. Using force can damage the frequency converter or motor permanently.

6. Before starting the motor, check that the rotor revolves freely. Ensure that the electrical connections are correct.
7. Refit any pulley, coupling, sprocket, and so on, which have been removed. Be careful to ensure correct alignment with the driven part, as misalignment leads to ultimate bearing trouble and shaft breakage.
8. When replacing screws and bolts, ensure requisite quality and tensile strength recommended by the manufacturer. The replacements must also be of identical thread form and screw/bolt length.

6 Diagnostics and Troubleshooting

6.1 Introduction

This section provides details of symptoms, warnings, and alarms, which signal faults within and external to the frequency converter. Recommended actions to remedy each fault condition supplement the diagnosis and troubleshooting steps. Some conditions require more test procedures to diagnose the frequency converter further. For details, see *chapter 7 Test Procedures*.

6.2 Troubleshooting

Before troubleshooting a frequency converter

1. Read the warnings in *chapter 2 Safety*.
2. Note all warnings concerning voltages present in the frequency converter. Verify the presence of AC input voltage and DC-link voltage before working on the unit. Some points in the frequency converter are referenced to the negative DC link. They are at DC-link potential even though it sometimes appears on diagrams to be a neutral reference.
3. Wait for discharge of the DC link. For discharge time, see *Table 2.1* or the label on the frequency converter.
4. Do not apply power to a unit that is suspected of being faulty. Many faulty components within the frequency converter can damage other components when power is applied. Always perform the procedure for testing the unit after repair as described in *chapter 5.1.1 Before Starting Repair Work*.
5. Do not attempt to defeat any fault protection circuitry within the frequency converter, as this action results in unnecessary component damage and can cause personal injury.
6. Use factory-approved replacement parts. The frequency converter is designed to operate within certain specifications. Incorrect parts can affect tolerances and result in further damage to the unit.
7. Read the *VLT® DriveMotor FCP 106/FCM 106 Operating Instructions*. When in doubt, consult the factory or authorized repair center for assistance.

6.3 Exterior Fault Troubleshooting

There may be slight differences in servicing a frequency converter that has been operational for an extended time, compared to a new installation. In either case, use proper troubleshooting procedures.

Take a systematic approach, beginning with a visual inspection of the system. See *Table 6.1* for items to examine.

6.4 Fault Symptom Troubleshooting

The troubleshooting procedures are divided into sections based on the different occurring symptom.

1. See the visual inspection check list in *Table 6.1*. Often, incorrect installation or wiring of the frequency converter causes the problem. The check list provides guidance through the items to inspect during servicing of the frequency converter.
2. The most common fault symptoms are described in *chapter 6.6 Fault Symptoms*:
    - Problems with motor operation.
    - A warning or alarm shown by the frequency converter.

    The frequency converter processor monitors inputs and outputs as well as internal frequency converter functions. An alarm or warning does not necessarily indicate a problem within the frequency converter itself.

For each incident, further description explains how to troubleshoot that particular symptom. When necessary, further referrals are made to other parts of the manual for more procedures.

When troubleshooting is complete, perform the list of tests provided in *chapter 7.7.1 Initial Start-up or After-repair Frequency Converter Tests*.

6.5 Visual Inspection

Visually inspect the conditions in *Table 6.1* as part of any initial troubleshooting procedure.

Inspect for	Description
Auxiliary equipment	• Look if more auxiliary equipment, switches, disconnects, or input fuses/circuit breakers reside on the input power side of frequency converter or output side to motor. • Examine operation and condition of these items as possible causes for operational faults. • Check function and installation of pressure sensors or encoders, and other equipment used for feedback to the frequency converter.
Cable routing	• Avoid routing motor wiring, AC line wiring, and signal wiring in parallel. If parallel routing is unavoidable, maintain a separation of 150–200 mm (6–8 inches) between the cables or separate them with a grounded conductive partition. • Avoid routing cables through free air.
Control wiring	• Check for broken or damaged wires and connections. • Check the voltage source of the signals. Though not always necessary depending on the installation conditions, the use of screened cable or a twisted pair is recommended. • Ensure that the screen is terminated correctly.
Frequency converter cooling	Check operational status of all cooling fans: • When voltage is applied to the frequency converter, the fan activates for a few seconds. • Check for blockage or constrained air passages.
Frequency converter display	The display shows important items, such as: • Warnings. • Alarms. • Frequency converter status. • Fault history.
Frequency converter interior	• Check that the frequency converter interior is free of: - Dirt. - Metal chips. - Moisture. - Corrosion. • Check for burnt or damaged power components, or carbon deposits that are the result of a catastrophic component failure. • Check for cracks or breaks in the housings of power semiconductors, or pieces of broken component housings, which are loose inside the unit.
EMC considerations	• Check for proper installation regarding electromagnetic capability. • Refer to the frequency converter operating instructions and this chapter for further details.
Environmental conditions	• Under specific conditions, these units can be operated within a maximum ambient of 50 °C (122 °F). • Humidity levels must be less than 95% non-condensing. • Check for harmful airborne contaminates such as sulfur-based compounds.
GLCP	• If supplied, check that the GLCP is correctly installed, and that the display is lit when powered on.
Grounding	• The frequency converter requires a dedicated ground wire from its enclosure to the building ground. It is also suggested to ground the motor to the frequency converter enclosure. • The use of conduit or mounting of the frequency converter to a metal surface is not considered to be suitable grounding. • Check for good ground connections that are tight and free of oxidation.

Inspect for	Description
Input power wiring	Check for: • Loose connections. • Proper fusing. • Blown fuses.
Memory module	• Check that the memory module is plugged in correctly.
Motor	• Check nameplate ratings of the motor. • Ensure that motor ratings coincide with frequency converters. • Ensure that the frequency converter motor parameters (*parameter 1-20 Motor Power* to *parameter 1-25 Motor Nominal Speed*) are set according to motor ratings.
Output to motor wiring	Check for: • Loose connections. • Switching components in output circuit. • Faulty contacts in switch gear.
PROFIBUS option	• Check that the option is mounted correctly on the control card.
Programming	Ensure that frequency converter parameter settings are correct according to: • Motor. • Application. • I/O configuration.
Proper clearance	The frequency converter requires top and bottom clearance adequate to ensure proper air flow for cooling in accordance with the frequency converter size. When the heat sink is exposed at the rear of the frequency converter, mount the frequency converter on a flat, solid surface.
Vibration	• Check for exposure to an unusual amount of vibration. • When the frequency converter experiences a high level of vibration, ensure solid mounting or use shock mounts.

Table 6.1 Visual Inspection Check List

6.6 Fault Symptoms

6.6.1 No Display

The LCP display provides 2 display indications. One with the backlit alphanumeric display. The other is 3 LED indicator lights near the bottom of the LCP. If the green power-on LED is illuminated, but the backlit display is dark, it indicates that the LCP is defective and must be replaced. Be certain, however, that the display is dark.

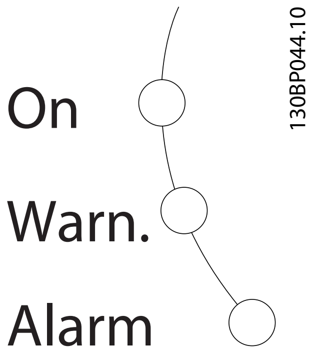


Illustration 6.1 LED Indicator Lights

A single character or just a dot in the upper corner of the LCP indicates that communications may have failed with the control card. This situation typically appears when a fieldbus communication option has been installed in the frequency converter and is either not connected properly or is malfunctioning.

If neither indication is available, then the source of the problem is elsewhere. Proceed to the next troubleshooting steps.

6.6.2 Intermittent Display

Cutting out or flashing of the entire display and power LED indicates that the supply (SMPS) is shutting down due to overload. Improper control wiring or a fault within the frequency converter itself can cause the overload.

The first step is to rule out a problem in the control wiring. To do so, disconnect all control wiring by unscrewing or unplugging the control terminal blocks from the control card.

If the display stays lit, the problem is in the control wiring (external to the frequency converter). Check all control wiring for short circuits or incorrect connections.

If the display continues to cut out, follow the procedure for *chapter 6.6.1 No Display* as though the display was not lit at all.

6.6.3 Display (Line 2) Flashing

When line 2 flashes, it indicates that an LCP stop command has been given by pressing [Off/Reset]. The frequency converter cannot accept any further run command until the LCP stop is cleared. To clear the LCP stop, press [Auto On] or [Hand On].

⚠CAUTION

IMMEDIATE START

If the frequency converter is operated in local control, or remote control with a maintained run signal, the frequency converter starts immediately. Failure to be prepared for immediate start can cause personal injury.

- **Be prepared for immediate start.**

6.6.4 WRONG or WRONG LCP Shown

The message WRONG or WRONG LCP appears due to a faulty LCP or the use of an incorrect LCP.

Replace the LCP with a correct and functioning one.

NOTICE

Error 84 appears when the LCP cannot communicate with the frequency converter.

6.6.5 Motor Does Not Run

If this symptom is detected, verify that the unit is properly powered up (display is lit) and that no warning or alarm messages are shown. The most common cause of this problem is either incorrect control logic or an incorrectly programmed frequency converter. Such occurrences result in 1 or more of the following status messages being shown:

LCP Stop
[Off] has been pressed. Line 2 of the display also flashes when this situation occurs.

Press [Auto On] or [Hand On]. Refer to *chapter 7.5.11 Input Terminal Signal Tests*.

Standby
This message indicates that there is no start signal at terminal 18.

Ensure that a start command is present at terminal 18. Refer to *chapter 7.5.11 Input Terminal Signal Tests*.

Unit ready
Terminal 27 is low (no signal).

Ensure that terminal 27 is logic 1. Refer to *chapter 7.5.11 Input Terminal Signal Tests*.

Run OK, 0 Hz
This message indicates that a run command has been given to the frequency converter but the reference (speed command) is 0 or missing.

Check control wiring to ensure that the proper reference signal is present at the input terminals. Also check that the unit is properly programmed to accept the signal provided. Refer to *chapter 7.5.11 Input Terminal Signal Tests*.

Off 1 (2 or 3)
This message indicates that bit 1 (or 2, or 3) in the control word is logic 0. This situation only occurs when the frequency converter is controlled via the fieldbus.

Ensure that a correct control word is transmitted to the frequency converter over the communication bus.

STOP
One of the digital input terminals 18, 27, or 29 is programmed for stop inverse and the corresponding terminal is low (logic 0).

Ensure that the above-mentioned parameters are programmed correctly and that any digital input programmed for stop inverse is high (logic 1).

Display indication that the unit functions, but there is no output.
If the unit is equipped with an external 24 V DC option, check that the main power is applied to the frequency converter.

NOTICE

In this case, the display flashes *Warning 8, DC Under Volt*.

6.6.6 Incorrect Motor Operation

A fault can occur in the event of incorrect motor operation. The symptoms and causes may vary considerably. The following sections list many of the possible problems by symptom along with recommended procedures for determining their causes.

Wrong speed/unit does not respond to command
Possible cause: Incorrect reference (speed command).

Actions:

1. Ensure that the unit is programmed correctly according to the reference signal being used.
2. Ensure that all reference limits are set correctly.
3. Perform the test to check for faulty reference signals.

Motor speed unstable

Possible causes:

- Incorrect parameter settings.
- Faulty current feedback circuit.
- Loss of motor (output) phase.

Actions:

1. Check settings of all motor parameters, including all motor compensation settings (slip compensation, load compensation, and so on).
2. For closed-loop operation, check PID settings.
3. Perform test as described in *chapter 7.5.11 Input Terminal Signal Tests* to check for faulty reference signals.
4. Perform test as described in *chapter 7.5.10 Output Imbalance of Motor Supply Voltage Test* to check for loss of motor phase.

Motor runs rough

Possible cause:

- Overmagnetisation (incorrect motor settings).
- IGBT misfiring.

NOTICE

The motor may stall when loaded, or the frequency converter may trip occasionally on *Alarm 13, Over Current*.

Action:

1. Check the setting of all motor parameters, see *chapter 7.5.10 Output Imbalance of Motor Supply Voltage Test*.
2. If output voltage is unbalanced, see *chapter 7.5.10 Output Imbalance of Motor Supply Voltage Test*.

Motor draws high current but cannot start

Possible causes:

- Open winding in motor.
- Open connection to motor.

Actions:

1. Perform the test in *chapter 7.5.10 Output Imbalance of Motor Supply Voltage Test* to ensure that the frequency converter provides correct output (see *Motor Runs Rough* above).
2. Check motor for open windings. Check all motor wiring connections.
3. Run an AMA to check the motor for open windings and unbalanced resistance. Inspect all motor wiring connections.

6

6.7 Warning/Alarm Messages

A warning or an alarm is signaled by the relevant LED on the front of the frequency converter and indicated by a code on the display.

Event type	LED signal
Warning	Yellow
Alarm	Flashing red

Table 6.2 Event Type LED Signals

A warning remains active until its cause is no longer present. Under certain circumstances, motor operation can continue. Warning messages can be critical, but are not necessarily so.

If an alarm occurs, the frequency converter trips. Reset of alarms is required to restart operation, once the cause has been rectified.

To reset an alarm:

- Press [Reset].
- Use the reset function via a digital input.
- Reset via serial communication.
- Use the auto reset function, which is a default setting. See *parameter 14-20 Reset Mode*. This form of reset cannot be used for a trip lock alarm.

NOTICE

To restart the motor after reset pressing [Reset], press [Auto On] or [Hand On].

When an alarm fails to reset, check:

- That the cause has been rectified.
- For trip lock. Refer to *Table 6.3*.

Trip

A trip is the action occurring when an alarm has appeared. The original event that caused an alarm cannot damage the frequency converter or cause dangerous conditions. The trip coasts the motor and can be reset by pressing [Reset] or via a digital input (parameter group *5-1* Digital Inputs [1] Reset*). For alarms with trip, but no trip lock, reset using the automatic reset function in *parameter 14-20 Reset Mode*.

Trip lock

A trip lock alarm occurs in situations which can result in equipment damage. A trip lock alarm offers more protection, because the mains supply must be switched off before the alarm can be reset. After rectification of the cause and after power cycling, the frequency converter is no longer blocked. Reset as described above.

⚠CAUTION

UNEXPECTED START

Automatic wake-up can occur when using reset via *parameter 14-20 Reset Mode*. Failure to be prepared for start can result in personal injury.

- **Be prepared for unexpected start.**

Warning and alarm

For events marked with warning and alarm in *Table 6.3*:

- A warning occurs before an alarm.
- The event can be set to signal either warning or alarm.

Example: *Parameter 1-90 Motor Thermal Protection*.
After an alarm or trip, the motor coasts, and both the alarm and warning LEDs flash. Once the cause has been rectified, only the alarm LED continues flashing.

Alarm/ warning number	Fault text	Warning	Alarm	Trip lock	Cause of problem
2	Live zero error	X	X		Signal on terminal 53 or 54 is less than 50% of value set in: • *Parameter 6-10 Terminal 53 Low Voltage*. • *Parameter 6-12 Terminal 53 Low Current*. • *Parameter 6-20 Terminal 54 Low Voltage*. • *Parameter 6-22 Terminal 54 Low Current*. See also parameter group *6-0* Analog In/Out*.
3	No motor	X			A motor has not been connected to the frequency converter.
4	Mains ph. loss	X	X	X	Missing phase on supply side or excess voltage imbalance. Check supply voltage. See *parameter 14-12 Function at Mains Imbalance*.
7	DC over volt	X	X		DC-link voltage exceeds limit.
8	DC under volt	X	X		DC-link voltage is lower than voltage warning low-limit.
9	Inverter overload	X	X		More than 100% load for too long.

Alarm/ warning number	Fault text	Warning	Alarm	Trip lock	Cause of problem
10	Motor ETR over	X	X		Motor is overheated due to more than 100% load for too long. See *parameter 1-90 Motor Thermal Protection*.
11	Motor th over	X	X		Thermistor or thermistor connection is disconnected. See *parameter 1-90 Motor Thermal Protection*.
13	Over Current	X	X	X	Inverter peak current limit is exceeded.
14	Earth Fault	X	X	X	Discharge from output phases to ground.
16	Short Circuit		X	X	Short circuit in motor or on motor terminals.
17	Control word timeout	X	X		No communication to frequency converter. See parameter group *8-0* Comm. and Options*.
24	Fan fault				External fans have failed either due to defect hardware, or due to missing fans.
25	Brake resistor short		X	X	Brake resistor short-circuited: The brake resistor is monitored during operation. If it short-circuits, the brake function is disconnected, and the warning appears. Turn off the frequency converter and replace the brake resistor.
27	Short circuited		X	X	Brake chopper fault: The brake transistor is short-circuited, or the brake function is disconnected. If short-circuited, substantial energy is dissipated in the brake resistor. Turn off the frequency converter as a fire precaution.
28	Brake check	X	X		Brake checked and failure detected.
30	U phase loss		X	X	Motor phase U is missing. Check the phase. See *parameter 4-58 Missing Motor Phase Function*.
31	V phase loss		X	X	Motor phase V is missing. Check the phase. See *parameter 4-58 Missing Motor Phase Function*.
32	W phase loss		X	X	Motor phase W is missing. Check the phase. See *parameter 4-58 Missing Motor Phase Function*.
34	Fieldbus fault	X			
35	Option fault		X		
36	Mains failure	X			
38	Internal fault		X	X	Contact the local Danfoss supplier.
40	Overload T27	X			
41	Overload T29	X			
44	Earth fault DESAT		X	X	
46	Gate drive voltage fault		X	X	
47	Control voltage fault	X	X	X	24 V DC is possibly overloaded.
51	AMA U_{nom}, I_{nom}		X		The setting of motor voltage, motor current, and motor power is presumably wrong. Check the settings.
52	AMA low I_{nom}		X		The motor current is too low. Check the settings.
53	AMA motor too big		X		The motor is too large to perform AMA.
54	AMA motor too small		X		The motor is too small to perform AMA.
55	AMA parameter out of range		X		The parameter values found from the motor are outside acceptable range.
56	AMA interrupted by user		X		The user has interrupted the AMA.

Alarm/ warning number	Fault text	Warning	Alarm	Trip lock	Cause of problem
57	AMA time-out		X		Restart the AMA a number of times, until the AMA is complete. **NOTICE** **Repeated runs can heat the motor to a level where the resistance Rs and Rr are increased. In most cases, however, this increased resistance is not critical.**
58	AMA internal	X	X		Contact the local Danfoss supplier.
59	Current limit	X	X		The current is higher than the value in *parameter 4-18 Current Limit*.
60	External Interlock		X		External interlock has been activated. To resume normal operation, apply 24 V DC to the terminal programmed for external interlock and reset the frequency converter. Reset via serial communication, digital I/O, or [Reset] on the LCP).
63	Mech. brake low		X		The minimum required current for opening the mechanical brake has not been reached.
65	Ctr. card temp	X	X	X	
66	Heat sink temperature low	X			The heat sink temperature is measured as 0 °C (32°F). This could indicate that the temperature sensor is defect. The defect causes the fan speed to increase to its maximum to cool down the power part or control card.
67	Option change		X		
69	Pwr. Card Temp	X	X	X	The temperature sensor on the power card is either too hot or too cold.
70	Illegal FC config		X	X	Power size configuration fault on the power card.
80	Drive initialised		X		All parameter settings are initialized to default settings.
87	Auto DC Braking	X			The frequency converter is auto DC braking.
88	Option detection		X	X	
93	Dry pump	X	X		
94	End of curve	X	X		
95	Broken belt	X	X		Torque is below the torque level set for no load, indicating a broken belt. See parameter group *22-6* Broken Belt Detection*.
99	Locked rotor		X		The frequency converter detected a locked rotor situation. See *parameter 30-22 Locked Rotor Protection* and *parameter 30-23 Locked Rotor Detection Time [s]*.
101	Flow/pressure info missing		X		Flow/pressure information is missing.
126	Motor Rotating		X		High back EMF voltage. Stop the rotor of the PM motor.
127	Back EMF too high	X			
200	Fire Mode	X			Fire mode has been activated.
202	Fire Mode Limits Exceeded	X			Fire mode has suppressed 1 or more warranty voiding alarms.
206	Memory module	X			
207	Memory module alarm		X	X	

Table 6.3 Warnings and Alarms

WARNING/ALARM 2, Live zero error
This warning or alarm only appears if programmed in *parameter 6-01 Live Zero Timeout Function*. The signal on 1 of the analog inputs is less than 50% of the minimum value programmed for that input. Broken wiring or a faulty device sending the signal can cause this condition.

Troubleshooting

- Check connections on all analog mains terminals.
  - Control card terminals 53 and 54 for signals, terminal 55 common.
  - VLT® General Purpose I/O MCB 101 terminals 11 and 12 for signals, terminal 10 common.
  - VLT® Analog I/O Option MCB 109 terminals 1, 3, and 5 for signals, terminals 2, 4, and 6 common.
- Check that the frequency converter programming and switch settings match the analog signal type.
- Perform an input terminal signal test.

WARNING/ALARM 3, No motor
No motor is connected to the output of the frequency converter.

WARNING/ALARM 4, Mains phase loss
A phase is missing on the supply side, or the mains voltage imbalance is too high. This message also appears for a fault in the input rectifier. Options are programmed in *parameter 14-12 Function at Mains Imbalance*.

Troubleshooting

- Check the supply voltage and supply currents to the frequency converter.

WARNING/ALARM 7, DC overvoltage
If the DC-link voltage exceeds the limit, the frequency converter trips after a certain time.

Troubleshooting

- Connect a brake resistor.
- Extend the ramp time.
- Change the ramp type.
- Activate the functions in *parameter 2-10 Brake Function*.
- Increase *parameter 14-26 Trip Delay at Inverter Fault*.
- If the alarm/warning occurs during a power sag, use kinetic back-up (*parameter 14-10 Mains Failure*).

WARNING/ALARM 8, DC under voltage
If the DC-link voltage drops below the undervoltage limit, the frequency converter checks for 24 V DC back-up supply. If no 24 V DC back-up supply is connected, the frequency converter trips after a fixed time delay. The time delay varies with unit size.

Troubleshooting

- Check that the supply voltage matches the frequency converter voltage.
- Perform an input voltage test.
- Perform a soft-charge circuit test.

WARNING/ALARM 9, Inverter overload
The frequency converter has run with more than 100% overload for too long and is about to cut out. The counter for electronic thermal inverter protection issues a warning at 98% and trips at 100% with an alarm. The frequency converter cannot be reset until the counter is below 90%.

Troubleshooting

- Compare the output current shown on the LCP with the frequency converter rated current.
- Compare the output current shown on the LCP with the measured motor current.
- Show the thermal frequency converter load on the LCP and monitor the value. When running above the frequency converter continuous current rating, the counter increases. When running below the frequency converter continuous current rating, the counter decreases.

WARNING/ALARM 10, Motor overload temperature
According to the electronic thermal protection (ETR), the motor is too hot. Select whether the frequency converter issues a warning or an alarm when the counter is >90% if *parameter 1-90 Motor Thermal Protection* is set to warning options, or whether the frequency converter trips when the counter reaches 100% if *parameter 1-90 Motor Thermal Protection* is set to trip options. The fault occurs when the motor runs with more than 100% overload for too long.

Troubleshooting

- Check for motor overheating.
- Check if the motor is mechanically overloaded.
- Check that the motor current set in *parameter 1-24 Motor Current* is correct.
- Ensure that the motor data in *parameters 1-20* to *1-25* are set correctly.
- If an external fan is in use, check that it is selected in *parameter 1-91 Motor External Fan*.
- Running AMA in *parameter 1-29 Automatic Motor Adaptation (AMA)* tunes the frequency converter to the motor more accurately and reduces thermal loading.

WARNING/ALARM 11, Motor thermistor over temp
Check whether the thermistor is disconnected. Select whether the frequency converter issues a warning or an alarm in *parameter 1-90 Motor Thermal Protection*.

Troubleshooting

- Check for motor overheating.
- Check if the motor is mechanically overloaded.
- When using terminal 53 or 54, check that the thermistor is connected correctly between either terminal 53 or 54 (analog voltage input) and terminal 50 (+10 V supply). Also check that the terminal switch for 53 or 54 is set for voltage. Check that *parameter 1-93 Thermistor Source* selects terminal 53 or 54.
- When using terminal 18, 19, 31, 32, or 33 (digital inputs), check that the thermistor is connected correctly between the digital input terminal used (digital input PNP only) and terminal 50. Select the terminal to use in *parameter 1-93 Thermistor Source*.

WARNING/ALARM 13, Over current

The inverter peak current limit (approximately 200% of the rated current) is exceeded. The warning lasts approximately 1.5 s, then the frequency converter trips and issues an alarm. Shock loading or quick acceleration with high-inertia loads can cause this fault. If the acceleration during ramp-up is quick, the fault can also appear after kinetic back-up. If extended mechanical brake control is selected, a trip can be reset externally.

Troubleshooting

- Remove the power and check if the motor shaft can be turned.
- Check that the motor size matches the frequency converter.
- Check that the motor data is correct in *parameters 1-20* to *1-25*.

ALARM 14, Earth fault

There is current from the output phases to ground, either in the cable between the frequency converter and the motor or in the motor itself.

Troubleshooting

- Remove power to the frequency converter and repair the ground fault.
- Check for ground faults in the motor by measuring the resistance to ground of the motor cables and the motor with a megohmmeter.

ALARM 16, Short circuit

There is short-circuiting in the motor or motor wiring.

Troubleshooting

- Remove the power to the frequency converter and repair the short circuit.

WARNING/ALARM 17, Control word timeout

There is no communication to the frequency converter. The warning is only active when *parameter 8-04 Control Word Timeout Function* is NOT set to *[0] Off*.

If *parameter 8-04 Control Word Timeout Function* is set to *[5] Stop and Trip*, a warning appears, and the frequency converter ramps down to a stop and shows an alarm.

Troubleshooting

- Check the connections on the serial communication cable.
- Increase *parameter 8-03 Control Word Timeout Time*.
- Check the operation of the communication equipment.
- Verify that proper EMC installation was performed.

WARNING/ALARM 24, Fan fault

The fan warning function is an extra protective function that checks if the fan is running/mounted.

Troubleshooting

- Check for proper fan operation.
- Cycle power to the frequency converter and check that the fan operates briefly at start-up.
- Check the sensors on the heat sink and control card.

ALARM 25, Brake resistor short circuit

The brake resistor is monitored during operation. If a short circuit occurs, the brake function is disabled, and the warning appears. The frequency converter is still operational but without the brake function. Remove power from the frequency converter and replace the brake resistor.

ALARM 27, Short circuited

The brake transistor is monitored during operation, and if a short circuit occurs, the brake function is disabled and a warning is issued. The frequency converter is still operational but, since the brake transistor has short-circuited, substantial power is transmitted to the brake resistor, even if it is inactive.

Troubleshooting

- Remove power to the frequency converter and remove the brake resistor.

WARNING/ALARM 28, Brake check

The brake resistor is not connected or not working.

ALARM 30, Motor phase U missing

Motor phase U between the frequency converter and the motor is missing.

Troubleshooting

- Remove the power from the frequency converter and check motor phase U.

ALARM 31, Motor phase V missing

Motor phase V between the frequency converter and the motor is missing.

Troubleshooting

- Remove the power from the frequency converter and check motor phase V.

ALARM 32, Motor phase W missing
Motor phase W between the frequency converter and the motor is missing.

Troubleshooting

- Remove the power from the frequency converter and check motor phase W.

WARNING/ALARM 34, Fieldbus fault
This warning appears when:

- There is no master communication for 60 s after power-up.
- The master is in stop mode.
- Master communication is not established, or is incorrectly configured.
- Wiring is incorrect.

Troubleshooting

- Check the master mode and master configuration.
- Check the wiring if the master mode and communication are correct.

ALARM 35, Option fault
An option alarm is received. The alarm is option-specific. The most likely cause is a power-up or a communication fault.

WARNING/ALARM 36, Mains failure
This warning is only active if the supply voltage to the frequency converter is lost and *parameter 14-10 Mains Failure* is NOT set to *[0] No Function*. Check the fuses to the frequency converter and mains supply to the unit.

ALARM 38, Internal fault
When an internal fault occurs, a code number defined in *Table 6.4* is shown.

Troubleshooting

- Cycle power.
- Check that the option is properly installed.
- Check for loose or missing wiring.

If it is necessary to contact the Danfoss supplier or service department, note the code number for further troubleshooting directions.

Number	Text
0	Serial port cannot be initialized. Contact the Danfoss supplier or Danfoss Service Department.
256–258	Power EEPROM data is defective or too old.
512–519	Internal fault. Contact the Danfoss supplier or Danfoss Service Department.
783	Parameter value outside of minimum/maximum limits.
1024–1284	Internal fault. Contact the Danfoss supplier or the Danfoss Service Department.
1379–2819	Internal fault. Contact the Danfoss supplier or Danfoss Service Department.
2561	Replace the control card.
2820	LCP stack overflow.
2821	Serial port overflow.
2822	USB port overflow.
3072–5122	Parameter value is outside its limits.
5376–6231	Internal fault. Contact the Danfoss supplier or Danfoss Service Department.

Table 6.4 Internal Fault Codes

WARNING 40, Overload of digital output terminal 27
Check the load connected to terminal 27 or remove the short-circuit connection. Check *parameter 5-00 Digital I/O Mode* and *parameter 5-01 Terminal 27 Mode*.

WARNING 41, Overload of digital output terminal 29
Check the load connected to terminal 29 or remove the short-circuit connection. Also check *parameter 5-00 Digital I/O Mode* and *parameter 5-02 Terminal 29 Mode*.

ALARM 44, Earth fault DESAT
There is a discharge from the output phases to ground, either in the cable between the frequency converter and the motor, or in the motor itself.

Troubleshooting

- Turn off the frequency converter and remove the ground fault.
- Measure the resistance to ground of the motor cables and the motor with a megohmmeter to check for ground fault in the motor.

ALARM 46, Gate drive voltage fault
The supply on the power card is out of range.

There are 3 supplies generated by the switch mode power supply (SMPS) on the power card:

- 24 V.
- 5 V.
- ±18 V.

Troubleshooting

- Check for a defective power card.

WARNING 47, 24 V supply low
The supply on the power card is out of range.

There are 3 supplies generated by the switch mode supply (SMPS) on the power card:

- 24 V.
- 5 V.
- ±18 V.

Troubleshooting

- Check for a defective power card.

ALARM 51, AMA check U_{nom} and I_{nom}
The settings for motor voltage, motor current, and motor power are wrong.

6

Troubleshooting

- Check the settings in *parameters 1-20* to *1-25*.

ALARM 52, AMA low I_{nom}
The motor current is too low.

Troubleshooting

- Check the settings in *parameter 1-24 Motor Current*.

ALARM 53, AMA motor too big
The motor is too large for the AMA to operate.

ALARM 54, AMA motor too small
The motor is too small for the AMA to operate.

ALARM 55, AMA parameter out of range
AMA cannot run because the parameter values of the motor are outside of the acceptable range.

ALARM 56, AMA interrupted by user
The AMA is manually interrupted.

WARNING/ALARM 57, AMA internal fault
Try to restart AMA. Repeated restarts can overheat the motor.

ALARM 58, AMA Internal fault
Contact the Danfoss supplier.

WARNING 59, Current limit
The current is higher than the value in *parameter 4-18 Current Limit*. Ensure that motor data in *parameters 1-20* to *1-25* is set correctly. Increase the current limit if necessary. Ensure that the system can operate safely at a higher limit.

WARNING 60, External interlock
A digital input signal indicates a fault condition external to the frequency converter. An external interlock has commanded the frequency converter to trip. Clear the external fault condition. To resume normal operation, apply 24 V DC to the terminal programmed for external interlock, and reset the frequency converter.

ALARM 63, Mechanical brake low
The actual motor current has not exceeded the release brake current within the start delay time window.

WARNING/ALARM 65, Control card overtemperature
The control card has reached its trip temperature of 80 °C (176 °F).

WARNING 66, Heat sink temperature low
The frequency converter is too cold to operate. This warning is based on the temperature sensor in the IGBT module. Also, a trickle amount of current can be supplied to the frequency converter whenever the motor is stopped by setting *parameter 2-00 DC Hold/Preheat Current* at 5% and *parameter 1-80 Function at Stop*.

Troubleshooting

- Check the temperature sensor.
- Check the sensor wire between the IGBT and the gate drive card.

ALARM 67, Option change
One or more options have either been added or removed since the last power-down. Check that the configuration change is intentional and reset the unit.

ALARM 69, Power card temperature
The temperature sensor on the power card is either too hot or too cold.

Troubleshooting

- Check that the ambient operating temperature is within limits.
- Check for clogged filters.
- Check fan operation.
- Check the power card.

ALARM 70, Illegal frequency converter configuration
The control card and power card are incompatible. Contact the Danfoss supplier with the type code of the unit from the nameplate and the part numbers of the cards to check compatibility.

ALARM 80, Drive initialised to default value
Parameter settings are initialized to default settings after a manual reset. To clear the alarm, reset the unit.

ALARM 87, Auto DC braking
Auto DC braking is a protective function against overvoltage at coast.

Troubleshooting

- Check that AC line input voltage does not exceed maximum limit.

ALARM 88, Option detection
A change in the option layout is detected. *Parameter 14-89 Option Detection* is set to *[0] Frozen configuration* and the option layout has been changed.

- To apply the change, enable option layout changes in *parameter 14-89 Option Detection*.
- Alternatively, restore the correct option configuration.

ALARM 93, Dry pump
A no-flow condition in the system with the frequency converter operating at high speed may indicate a dry pump. *Parameter 22-26 Dry Pump Function* is set for alarm. Troubleshoot the system and reset the frequency converter after the fault has been cleared.

ALARM 94, End of curve
Feedback is lower than the setpoint. This may indicate leakage in the system. *Parameter 22-50 End of Curve Function* is set for alarm.

Troubleshooting

- Troubleshoot the system and reset the frequency converter after the fault has been cleared.

ALARM 95, Broken belt
Torque is below the torque level set for no load, indicating a broken belt. *Parameter 22-60 Broken Belt Function* is set for alarm.

Troubleshooting

- Troubleshoot the system and reset the frequency converter after clearing the fault.

ALARM 99, Blocked rotor
The rotor is blocked.

ALARM 101, Flow/pressure info missing
Sensorless-pump table is missing or wrong.

Troubleshooting

- Download sensorless-pump table again.

ALARM 126, Motor rotating
High back EMF voltage. This alarm occurs only when running AMA on a PM motor.

Troubleshooting

- Stop the rotor of the PM motor.

WARNING 127, Back EMF too high
This warning applies to PM motors only. When the back EMF exceeds 90% x U_{invmax} (overvoltage threshold), and does not drop to normal level within 5 s, this warning is reported. The warning remains until the back EMF returns to a normal level.

WARNING 200, Fire mode
The frequency converter is operating in fire mode. The warning clears when fire mode is removed. Refer to the fire mode data in the alarm log.

WARNING 202, Fire mode limits exceeded
While operating in fire mode, 1 or more alarm conditions that would normally trip the unit have been ignored. Operating in this condition voids unit warranty. Cycle power to the unit to remove the warning. Refer to the fire mode data in the alarm log.

WARNING 206, Memory module
Several issues can trigger this warning, for example:

- The memory module is not for this particular frequency converter.
- Download has failed.
- Upload from frequency converter to memory module has failed.
- No memory module inserted in the frequency converter.
- The memory module is not paired with the frequency converter.

Troubleshooting

- Refer to *parameter 18-51 Memory Module Warning Reason* for further details.

ALARM 207, Memory module alarm
This alarm most likely relates to the hardware dongle function.

Troubleshooting

- Check that the correct memory module is used in the frequency converter.
- Contact Danfoss supplier or Danfoss Service Department for further details.

6.8 Torque Limit, Current Limit, and Unstable Motor Operation

Excessive loading of the frequency converter can result in warning or tripping on torque limit, overcurrent, or inverter time. Avoid this situation by sizing the frequency converter properly for the application. Also ensure that intermittent load conditions cause anticipated operation in torque limit or an occasional trip. However, specific parameters that are improperly set can cause nuisance or unexplained occurrences. The following parameters are important in matching the frequency converter to the motor for optimum operation.

Parameters 1-20 to *1-40* configure the frequency converter for the connected motor. These parameters set:

- Motor power.
- Voltage.
- Frequency.
- Current.
- Nominal motor speed.
- Number of poles, for PM motor.

To set these parameters accurately:

- Enter the motor data required as listed on the motor nameplate. The frequency converter relies on this information for accurate motor control in dynamic loading applications.
- Refer to parameter settings stated in the *chapter Quick Menu Motor Set-up* and *1-2* Motor Data* in the *VLT® DriveMotor FCP 106/FCM 106 Programming Guide*.

Parameter 1-29 Automatic Motor Adaption (AMA) activates the automatic motor adaptation (AMA) function. When AMA is performed, the frequency converter measures the electrical characteristics of the motor and sets various frequency converter parameters based on the findings. Key parameter values set by this function are:

- Stator resistance.
- Main reactance.
- d-axis inductance:
    - *Parameter 1-30 Stator Resistance (Rs)*.
    - *Parameter 1-35 Main Reactance (Xh)* for asynchronous motors.
    - *Parameter 1-37 d-axis Inductance (Ld)* for PM motors.

If motor operation is unstable, perform AMA if this operation has not already been performed. AMA can only be performed on single motor applications within the programming range of the frequency converter. Consult the *VLT® DriveMotor FCP 106/FCM 106 Design Guide* for more information on this function.

As stated, set the AMA function in *parameter 1-30 Stator Resistance (Rs)*, *parameter 1-35 Main Reactance (Xh)*, and *parameter 1-37 d-axis Inductance (Ld)*. The values for these parameters can either be supplied by the motor manufacturer, or contain factory default values.

NOTICE

RISK OF UNPREDICTABLE OPERATION

Do not adjust the AMA parameters to random values even though it seems to improve operation. Such adjustments can result in unpredictable operation under changing conditions.

6.8.1 Overvoltage Trips

Overvoltage trip occurs when the DC-link voltage reaches its DC-link alarm voltage high (see *chapter 6.8.2 Short Circuit and Overcurrent Trips*). Before tripping, the frequency converter shows a high-voltage warning. Mostly, fast deceleration ramps concerning load inertia cause an overvoltage condition. During deceleration of the load, inertia of the system acts to sustain the running speed. When the motor frequency drops below the running speed, the motor then starts returning energy to the frequency converter (regenerative energy). Regeneration occurs when the speed of the load is greater than the commanded speed. The diodes in the IGBT modules rectify this return and increase the DC link. If the amount of returned energy is too high, the DC voltage increases, causing the frequency converter to trip.

Methods to avoid overvoltage trips

There are 2 methods to avoid overvoltage trips:

- Reduce the deceleration rate so the frequency converter decelerates over a longer period. In general, the frequency converter can only decelerate the load slightly faster than it would take to coast it to a stop naturally.
- Use the overvoltage control function (*parameter 2-17 Over-voltage Control*) to regulate the deceleration ramp. When enabled, the overvoltage control function regulates deceleration at a rate that maintains the DC-link voltage at an acceptable level.

NOTICE

Overvoltage control does not correct for unrealistic ramp rates.

Example

The deceleration ramp has to be 100 s due to the inertia, and the ramp rate is set at 3 s. Overvoltage control initially engages, then disengages and allows the frequency converter to trip. This action is purposely done so the operation of the unit is not misinterpreted.

The frequency converter has an AC-brake function, which increases magnetization current to increase loss in motor and reduce DC-link voltage. If the DC-link voltage exceeds a certain voltage, the overvoltage control changes the frequency.

6.8.2 Short Circuit and Overcurrent Trips

The frequency converter is protected against short circuits with 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 the IGBTs individually when the short circuit current exceeds the permitted value (*Alarm 16, Trip Lock*).

6.8.3 Mains Phase Loss Trips

The frequency converter monitors phase loss by monitoring the amount of ripple voltage on the DC bus. Ripple voltage on the DC bus is a product of a phase loss and can cause overheating in the DC-bus capacitors and the DC coil. If the ripple voltage on the DC bus is unchecked, the lifetime of the capacitors is drastically reduced.

When the input voltage becomes unbalanced or a phase disappears completely, the ripple voltage increases. This increase causes the frequency converter to trip and issue *Alarm 4, Mains Phase Loss*. In addition to missing phase voltage, a line disturbance or imbalance can cause an increased bus ripple.

Possible sources of disturbance

- Line notching.
- Defective transformers.
- Other loads that can affect the form factor of the AC waveform.

Mains imbalances which exceed 3% cause sufficient DC-bus ripple to initiate a trip.
Other causes of increased ripple voltage on the DC bus are:

- Output disturbance.
- Missing or lower than normal output voltage on 1 phase.

Checks
When a mains imbalance trip occurs, check both the input and output voltage of the frequency converter.
Severe imbalance of supply voltage or phase loss is detectable with a voltmeter. View line disturbances through an oscilloscope. Conduct tests for:

- Input imbalance of supply voltage.
- Input waveform.
- Output imbalance of supply voltage.

See details in *chapter 7.5 Dynamic Test Procedures*.

6.8.4 Control Logic Problems

Problems with control logic can often be difficult to diagnose, since there is usually no associated fault indication. The typical complaint is that the frequency converter does not respond to a given command. To obtain an output, give the following 2 basic commands to the frequency converter:

- Start command: To execute.
- Reference or speed command: To identify the speed of execution.

The frequency converters are designed to accept various signals. First, determine which of these signals the frequency converter is receiving:

- Digital inputs (18, 19, 27, and 29).
- Analog outputs (42 and 45).
- 10 V output.
- Analog inputs (53 and 54).
- Serial communication bus (68 and 69).

The presence of a correct reading indicates that the microprocessor of the frequency converter has detected the wanted signal. See *chapter 3.9 Frequency Converter Inputs and Outputs*.

This data can also be read in parameter group *16-6* Inputs and Outputs*.

If there is no correct indication, check if the signal is present at the input terminals of the frequency converter. Use a voltmeter or oscilloscope in accordance with *chapter 7.5.11 Input Terminal Signal Tests*.

- If the signal is present at the terminal, the control card is defective and must be replaced.
- If the signal is not present, the problem is external to the frequency converter. Therefore, check the circuitry providing the signal along with its associated wiring.

6.8.5 Programming Problems

Difficulty with operation of the frequency converter can be a result of improper programming of the frequency converter parameters. Three areas where programming errors can affect frequency converter and motor operation are:

- Motor settings.
- References and limits.
- I/O configuration.

See *chapter 3.9 Frequency Converter Inputs and Outputs*.

Set up the frequency converter correctly for the motor or motors connected to it. Parameters must have data from the motor nameplate entered into the frequency converter. These data enable the frequency converter processor to match the frequency converter to power characteristics of the motor. Inaccurate motor data can cause the motor to draw higher than normal amounts of current when performing a task. In such cases, setting the correct values to these parameters and performing the AMA function usually solves the problem.

Any references or limits set incorrectly result in less than acceptable frequency converter performance. For instance, if maximum reference is set too low, the motor is unable to reach full speed. Set these parameters according to the requirements of the particular installation. References are set in parameter group *3-0* Reference Limits*.

Incorrectly set I/O configuration usually results in the frequency converter not responding to the function as commanded. Remember that for every control terminal input or output there are corresponding parameter settings. These settings determine how the frequency converter responds to an input signal or the type of signal present at that output. Utilizing an I/O function involves a 2-step process. Wire the wanted I/O terminal properly, and set the corresponding parameter accordingly. Control terminals are programmed in parameter groups *5-0* Digital I/O Mode* and *6-0* Analog I/O Mode*.

6.8.6 Motor/Load Problems

Problems with the motor, motor wiring, or mechanical load on the motor can develop in several ways. The motor or motor wiring can develop a phase-to-phase or phase-to-ground short circuit resulting in an alarm indication. Check whether the problem is in the motor wiring or the motor itself.

A motor with unbalanced, or asymmetrical, impedances on all 3 phases can result in uneven or rough operation, or unbalanced output currents. For measurements, use a clamp-on style ammeter to determine whether the current is balanced on the 3 output phases. See *chapter 7.5.10 Output Imbalance of Motor Supply Voltage Test*.

Usually, a current limit warning indicates an incorrect mechanical load. If possible, disconnect the motor from the load to determine if the load is incorrect.

Often, the indications of motor problems are similar to the problems of a defect in the frequency converter itself. To determine whether the problem is internal or external to the frequency converter, disconnect the motor from the frequency converter motor terminals. Perform the initial procedure with no motor connection on all 3 phases with an analog voltmeter, see *chapter 7.5.10 Output Imbalance of Motor Supply Voltage Test*. If the 3 voltage measurements are balanced, the frequency converter is functioning correctly. Hence, the problem is external to the frequency converter.

If the voltage measurements are not balanced, the frequency converter is malfunctioning. Typically, 1 or more output IGBTs are not functioning correctly. This problem can be a result of a defective IGBT or gate signal.

6.9 Internal Frequency Converter Problems

6.9.1 Overtemperature Faults

If an overtemperature indication is shown, determine whether this condition actually exists within the frequency converter, or whether the thermal sensor is defective.

6.9.2 Signal and Power Wiring Considerations for Electromagnetic Compatibility

This section provides an overview of general signal and power wiring considerations when addressing the electromagnetic compatibility (EMC) concerns for typical commercial and industrial equipment. Only certain high-frequency phenomena (such as RF emissions, RF immunity) are discussed. Low-frequency phenomena (such as harmonics, mains voltage imbalance, notching) are not covered.

NOTICE

Special installations or compliance to the European CE EMC directives require strict adherence to relevant standards and are not discussed here.

6.9.3 Effects of EMI

While electromagnetic interference-related (EMI) disturbances to the operation of the frequency converter are uncommon, the following detrimental EMI effects sometimes occur:

- Motor speed fluctuations.
- Serial communication transmission errors.
- Frequency converter CPU exception faults.
- Unexplained frequency converter trips.

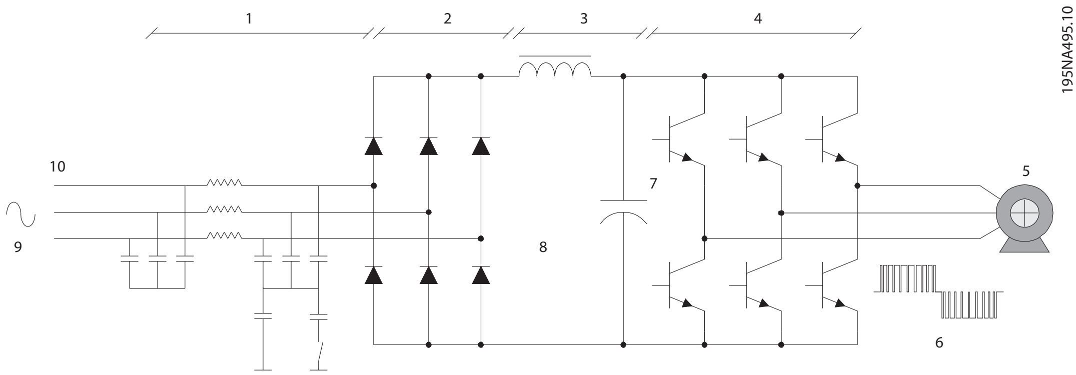
A disturbance resulting from other nearby equipment is more common. Generally, other industrial control equipment has a high level of EMI immunity. However, non-industrial, commercial, and consumer equipment is often susceptible to lower levels of EMI. Detrimental effects to these systems include the following:

- Pressure/flow/temperature signal transmitter signal distortion or aberrant behavior.
- Radio and TV interference.
- Telephone interference.
- Computer network data loss.
- Digital control system faults.

6.9.4 Sources of EMI

Modern frequency converters (see *Illustration 6.2*) utilize fast-switching electronic devices to generate the modulated output voltage waveform necessary for accurate motor control. These devices rapidly switch the fixed DC-link voltage creating a variable frequency, and variable voltage PWM waveform. This high rate of voltage change [dU/dt] is the primary source of the frequency converter generated EMI.

The high rate of voltage change caused by the IGBT switching creates high-frequency EMI.

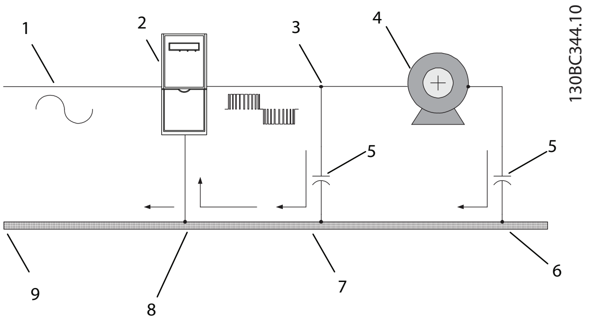


1	RFI filter	6	PWM waveform
2	Rectifier	7	IGBT
3	DC link	8	Filter reactor
4	Inverter	9	Sine-wave
5	Motor	10	AC line

Illustration 6.2 Frequency Converter Principle Diagram

6.9.5 EMI Propagation

Frequency converter generated EMI is both conducted to the mains and radiated to nearby conductors. See *Illustration 6.3*.



1	AC line
2	Frequency converter
3	Motor cable
4	Motor
5	Stray capacitance
6	Signal wiring
7	Signal wiring
8	Signal wiring
9	Ground

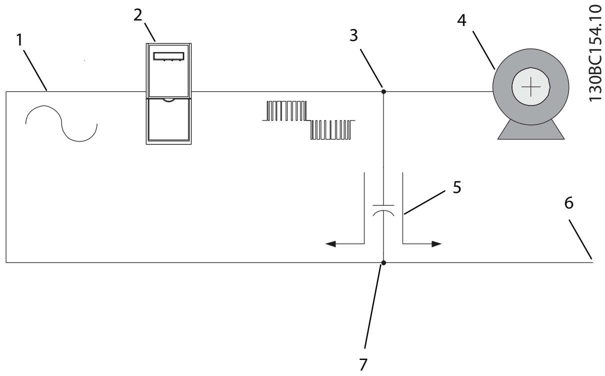
Illustration 6.3 Ground Currents

NOTICE

Stray capacitance between the motor conductors, equipment ground, and other nearby conductors results in induced high-frequency currents.

High ground circuit impedance at high frequencies results in an instant voltage at points reputed to be at ground potential. This voltage can appear throughout a system as a common mode signal that can interfere with control signals.

Theoretically, these currents return to the DC-bus via the ground circuit and a high-frequency (HF) bypass network within the frequency converter itself. However, imperfections in the frequency converter grounding or the equipment ground system can cause some of the currents to travel out to the power network.



1	AC line
2	Frequency converter
3	Motor cable
4	Motor
5	Stray capacitance
6	AC line, to BMS
7	Signal wiring

Illustration 6.4 Signal Conductor Currents

NOTICE

Unprotected or poorly routed signal conductors located close to or in parallel to motor and mains conductors are susceptible to EMI.

Signal conductors are especially vulnerable when they run in parallel to the power conductors for any distance. EMI coupled into these conductors can affect either the frequency converter or the interconnected control device. See *Illustration 6.4*.

While these currents tend to travel back to the frequency converter, imperfections in the system cause some current to flow in undesirable paths. This flow exposes other locations to the EMI.

NOTICE

High-frequency currents can be coupled into the mains supplying the frequency converter, when the mains conductors are located close to the motor cables.

6.9.6 Preventive Measures

EMI-related problems are more effectively alleviated during the design and installation phases rather than after the system is in service. Many of the listed steps can be implemented at a relatively low cost compared to the cost of identifying and fixing the problem later.

Grounding
Ground the frequency converter and motor solidly to the equipment frame. A good high-frequency connection is necessary to allow the high-frequency currents to return to the frequency converter instead of traveling through the power network. The ground connection is ineffective if it has high impedance to high-frequency currents. Therefore, it must be as short and direct as practical. Flat-braided cable has lower high-frequency impedance than round cable. Mounting the frequency converter or motor onto a painted surface creates an effective ground connection. In addition, running a separate ground conductor directly between the frequency converter and the running motor is recommended.

Cable routing
Avoid parallel routing of:

- Motor wiring.
- Mains wiring.
- Signal wiring.

If parallel routing is unavoidable, maintain a separation of 200 mm (6–8 inches) between the cables or separate them with a grounded conductive partition. Avoid routing cables through free air.

Signal cable selection
Single conductor 600 V rated wires provide the least protection from EMI. Twisted pair and screened twisted-pair cables are available and are designed to minimize the effects of EMI. While unscreened twisted-pair cables are often adequate, screened twisted-pair cables provide a higher degree of protection. The signal cable screen must be terminated in a manner that is appropriate for the connected equipment. Avoid terminating the screen through a pigtail connection as it increases the high-frequency impedance and spoils the effectiveness of the screen.

A simple alternative is to twist the existing single conductors to provide a balanced capacitive and inductive coupling. This operation cancels differential mode interference. While not as effective as true twisted-pair cable, it can be implemented in the field using the materials at hand.

Motor cable selection, FCP 106 only
Motor conductors have the greatest influence on the EMI characteristics of the system. These conductors must receive the highest attention whenever EMI is a problem. Single conductor wires provide the least protection from EMI emissions. Often, if these conductors are routed separately from the signal and mains wiring, then no further consideration is needed. If the conductors are routed close to other susceptible conductors, or if the system is suspected to cause EMI problems, consider alternate motor wiring methods.

Installing screened power cable is the most effective means to alleviate EMI problems. The cable screen forces the noise current to flow directly back to the frequency converter. Thus, the noise current cannot get back into the power network or take other undesirable high-frequency paths. Unlike most signal wiring, the screening on the motor cable must be terminated at both ends.

If a screened motor cable is not available, then 3-phase conductors along with ground in a conduit provides some degree of protection. This technique is not as effective as screened cable due to the unavoidable contact of the conduit with various points within the equipment.

Serial communications cable selection
There are various serial communication interfaces and protocols on the market. Each of these interfaces recommends 1 or more specific types of twisted pair, screened twisted pair, or proprietary cables. Refer to the manufacturer documentation when selecting these cables. Similar recommendations apply to serial communication cables as to other signal cables. Using twisted-pair cables and routing them away from power conductors is encouraged. While screened cable provides more EMI

protection, the screen capacitance can reduce the maximum allowable cable length at high data rates.

6.9.7 Grounding Screened Cables

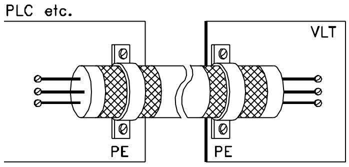
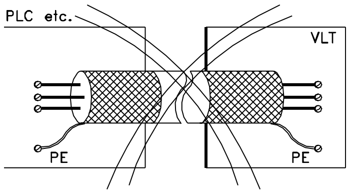
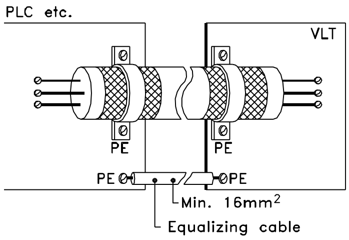
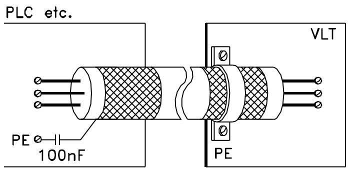
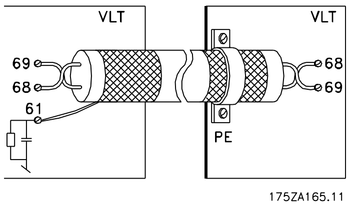
	**Correct grounding:** Fit control cables and cables for serial communication with cable clamps at both ends to ensure the best possible connection of mains.
	**Incorrect grounding:** Do not use twisted cable ends (pigtails) since they increase screen impedance at high frequencies.
	**Ground potential protection:** When the ground potential between the frequency converter and the PLC or other interface device is different, electrical noise may occur disturbing the entire system. Resolve the electrical noise by fitting an equalizing cable next to the control cable. Minimum cable cross-section is 16 mm^2 (8 AWG).
	**50/60 Hz ground loops:** When using long control cables, 50/60 Hz ground loops may occur that can disturb the entire system. Resolve the ground loops by connecting 1 end of the screen with a 100 nF capacitor and keeping the lead short.
	**Serial communication control cables:** Low-frequency noise currents between frequency converters can be eliminated by connecting 1 end of the screened cable to frequency converter terminal 61. This terminal connects to ground through an internal RC link. Use twisted-pair cables to reduce the differential mode interference between conductors.

Table 6.5 Grounding Screened Cables

7 Test Procedures

7.1 Introduction

This section contains detailed procedures for testing frequency converters. For detailed procedures for removing and replacing frequency converter components, refer to *chapter 8 Disassembly and Assembly Instructions*.

Frequency converter testing is divided into *Static Tests* and *Dynamic Tests*.

- Static tests are conducted without power applied to the frequency converter. Most frequency converter problems can be diagnosed simply with these tests. The purpose of static testing is to check for short-circuited power components. Before applying power, perform these tests on any unit suspected of containing faulty power components.
- Dynamic tests are performed with power applied to the frequency converter. Dynamic testing traces signal circuitry to isolate faulty components.

CAUTION

SHOCK HAZARD

For dynamic test procedures, mains input power is required. All devices and supplies connected to mains are energized at rated voltage. Contact with powered components could result in electrical shock and personal injury.

- **Use extreme caution when conducting tests on a powered frequency converter.**

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.**

7.1.1 Terminals for Static Tests

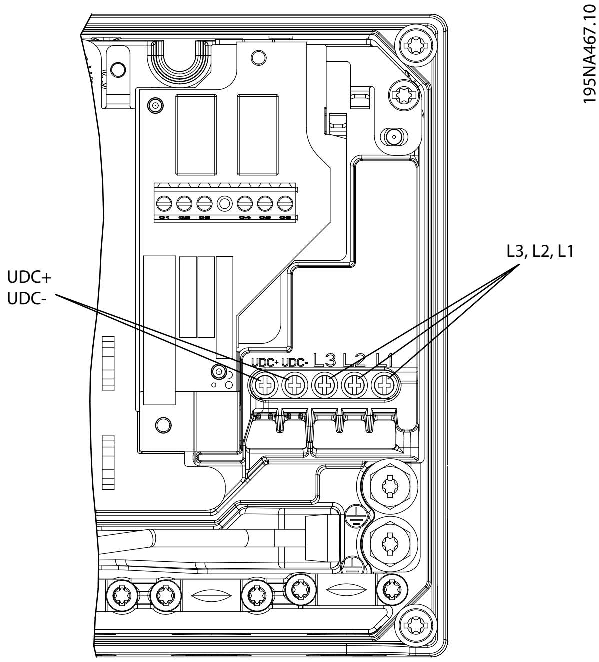


Illustration 7.1 Location of Terminals Used for Static Tests of Bridge Rectifier

7.2 Zero Voltage DC-link Test

1. After power off, wait for discharge of the DC link before taking the measurement. For duration of discharge time, see *Table 2.1*.
2. Set the multimeter to the DC voltage position.
3. Check the DC link for remaining charge by measuring the voltage on the DC terminals.
4. Measure from terminal (UDC-) to terminal (UDC+).

The voltage reading must be 0 V.
Then it is safe to proceed with the static tests.

7.3 Static Test Procedures

The purpose of performing static testing is to check for any short circuit of the power components.

For all tests, use a meter capable of testing diodes. Use a digital Volt-Ohm meter (VOM) set on the diode scale or an analog ohmmeter set on Rx100 scale. Before making any checks, disconnect all connections for:

- Input.
- Motor.
- Brake resistor.

7

Ensure that the frequency converter is disconnected from power, before performing static tests.

WARNING

SHOCK HAZARD

Disconnection of the input cable while the frequency converter is powered could result in electrical shock, death, and personal injury.

- **Do not disconnect the input cable while the frequency converter is powered.**

7.3.1 Pre-test Precautions

Consider the following safety precautions before performing static tests.

- Prepare the work area according to the ESD regulations.
- Ground the ESD mat and wrist strap.
- Ensure that the ground connection between body, the ESD mat, and the frequency converter is always present while performing service.
- Handle disassembled electronic parts with care.
- Perform the static test before powering up the fault unit.
- Perform static test after completing the repair and assembly of the frequency converter.
- Connect the frequency converter to the mains only after completion of static tests.
- Complete all necessary precautions for system start-up, before applying power to frequency converter.

7.3.2 Rectifier Circuit Test

Before starting tests, set the multimeter to diode mode, as shown in *Illustration 7.2*.

Rectifier test part I

1. Connect the positive (+) terminal of the multimeter lead to the positive DC bus terminal (UDC+).
2. Connect the negative (-) terminal of the multimeter lead to each of the input terminals L1, L2, and L3 in sequence. L1, L2, and L3 are on the 3-pole mains connector.

The test is successful when:

- Each reading shows infinity directly in diode measuring mode.
- In Ω measuring mode, the multimeter reading starts at a low value and slowly climbs towards infinity. The gradual increase is due to the meter charging the capacitance within the frequency converter.

Rectifier test part II

3. Reverse the multimeter leads by connecting the negative (-) multimeter lead to the positive DC bus terminal (UDC+).
4. Connect the positive (+) multimeter lead to each of the input terminals L1, L2, and L3 in sequence. The multimeter indicates *Diode open*.

The test is successful when each reading shows a diode drop.

Rectifier test part III

5. Connect the positive (+) multimeter lead to the negative DC bus terminal (UDC-).
6. Connect the negative (-) multimeter to each of the input terminals L1, L2, and L3, in sequence.

The test is successful when each reading shows a diode drop.

Rectifier test part IV

7. Reverse the multimeter leads by connecting the negative (-) multimeter lead to the negative DC bus terminal (UDC-).
8. Connect the positive (+) multimeter lead to each of the input terminals L1, L2, and L3 in sequence.

The test is successful when each reading shows infinity.

7.3.3 Inverter Section Tests

NOTICE

DISCONNECT MOTOR CABLES

When motor cables are connected, it is difficult to isolate a defective phase.For dismounting of motor cables, see *chapter 8.4.1 Remove Frequency Converter from Motor Adapter Plate/Wall Mount Plate*. For connection of motor cables, see *chapter 8.4.2 Remount Frequency Converter onto Motor Adapter Plate/Wall Mount Plate*.

- **Disconnect motor cables when testing the inverter section.**

NOTICE

Access to motor terminals is only possible on phase-1 frequency converters, see *chapter 1.5.2 FCP 106 and FCM 106*.

Access to motor terminals

The motor terminals U, V, and W are located under the control card. Establish access to terminals U, V, and W by removing the control card. See *chapter 8.2.1 Remove Control Card*. To remount the control card after completion of the tests, see *chapter 8.2.2 Remount Control Card*.

Before starting tests, set the multimeter to diode mode, as shown in *Illustration 7.2*.

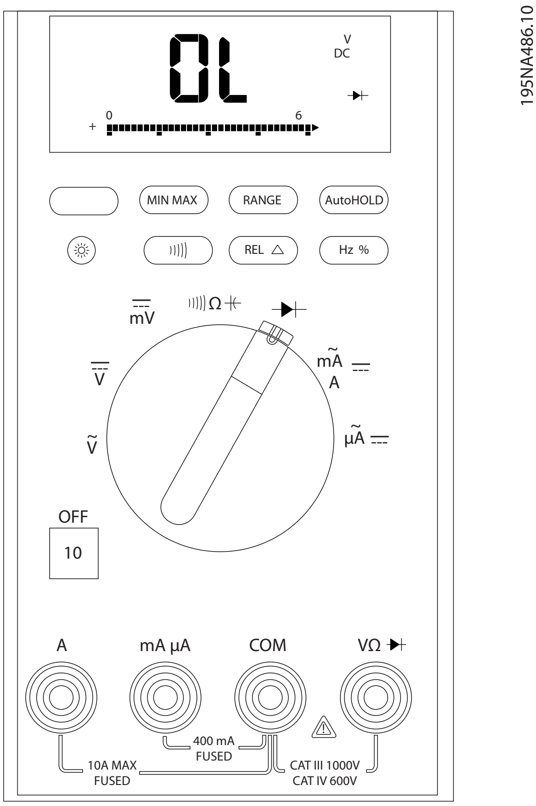


Illustration 7.2 Set Multimeter to Diode Mode

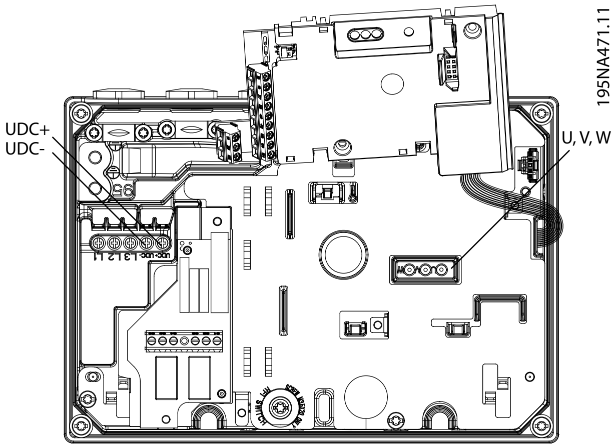


Illustration 7.3 Location of Motor Terminals U, V, W and of DC Link Terminals UDC+ and UDC- on Phase-1 Frequency Converters

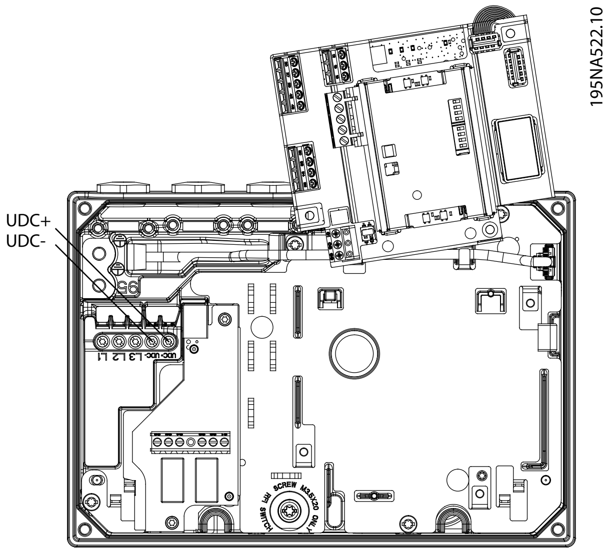


Illustration 7.4 Location of DC Link Terminals UDC+ and UDC- on Phase-2 Frequency Converters

Inverter test part I

1. Connect the positive (+) multimeter lead to the positive DC-link terminal (UDC+).
2. Connect the negative (–) multimeter lead to each of the terminals U, V, and W in sequence. U, V, and W are on the 3-pole terminals.

The test is successful when each reading shows infinity.

Inverter test part II

3. Reverse the multimeter leads by connecting the negative (–) meter lead to the positive DC-link terminal (UDC+).
4. Connect the positive (+) multimeter lead to each of the terminals U, V, and W in sequence.

The test is successful when each reading shows a diode drop.

Inverter test part III

5. Connect the positive (+) multimeter lead to the negative DC-link terminal (UDC-).
6. Connect the negative (–) multimeter lead to terminals U, V, and W in sequence.

The test is successful when each reading shows a diode drop.

Inverter test part IV

7. Reverse the multimeter leads by connecting the negative (–) multimeter lead to the negative DC link terminal (UDC-).
8. Connect the positive (+) multimeter lead to each of terminals U, V, and W in sequence.

The test is successful when each reading shows infinity.

7.3.4 Intermediate Section Tests

The intermediate section of the frequency converter is made up of:

- DC bus capacitors.
- DC coils.
- Balance circuit for the capacitors.

Test procedures

1. Test for short circuits with the ohmmeter set on Rx100 scale or, for a digital meter, select diode.
2. Measure across the positive (+) DC terminal and the negative (–) DC terminal. Observe the meter polarity.
3. The meter starts out with low ohms and then moves towards infinity as the meter charges the capacitors.
4. Reverse meter leads.
5. The meter measures 0 while the meter discharges the capacitors. The meter then begins moving slowly toward 2 diode drops as the meter charges the capacitors in the reverse direction. Although the test does not ensure that the capacitors are fully functional, it ensures that no short circuits exist in the DC link.

Incorrect reading
A short circuit in the inrush circuit, rectifier, or inverter section can cause a short circuit. Be sure that the tests for these circuits have already been performed successfully. A failure in 1 of these sections is read in the intermediate section, since they are all routed via the DC bus.

The only other likely cause is a defective capacitor within the capacitor bank.

There is no effective test of the capacitor bank when it is fully assembled. For more information contact hotline.

7.4 Heat Sink Temperature Sensor Check

The maximum allowed temperature of the heat sink without derating is 70 °C (158 °F).
To check the heat sink temperature:

1. Connect the LCP.
2. Start the frequency converter under full load, and let it run for 15 minutes. If full load is not achievable, run the test at rated current.
3. Go to *parameter 16-34 Heatsink Temp.* on the LCP.
4. Read the heat sink temperature.
5. When the temperature is within the correct range, no action is required.
6. When the temperature exceeds the temperature specified in *chapter 9.4 Protection and Features*:
   - 6a Turn off the frequency converter.
   - 6b Wait until the discharge time has elapsed, see *Table 2.1*.
   - 6c Perform the fan check, see *chapter 7.6 Fan Tests*.

7.5 Dynamic Test Procedures

7.5.1 Safety Warnings

See *chapter 2 Safety* for general safety instructions.

- Take all the necessary safety precautions for system start-up before applying power to the frequency converter.
- Test procedures in this section are numbered for reference only. Tests do not need to be performed in this order. Perform tests only as necessary.

⚠WARNING

SHOCK HAZARD AND RISK OF INJURY

For dynamic test procedures, mains input power is required, and all devices and supplies connected to mains are energized at rated voltage. Contact with powered components can result in death or serious injury.

- **Do not touch energized parts of the frequency converter when connected to mains.**

⚠WARNING

SHOCK HAZARD

Disconnection of input cabling with mains power applied can result in death and personal injury. Contact with powered components could result in electrical shock, which can cause death and personal injury.

- **When power is applied, do not disconnect input cabling.**

7.5.2 Access to Terminals U, V, and W for Dynamic Tests

For dynamic tests, access terminals U, V, and W externally at the base of the frequency converter as shown in *Illustration 7.5*.

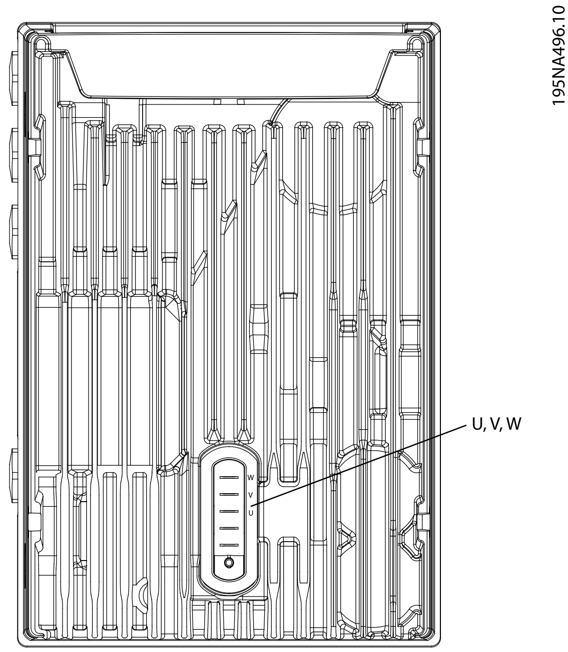


Illustration 7.5 External Access to Terminals U, V, and W for Dynamic Tests

7.5.3 Zero Voltage D-link Test

1. After power-off, wait for discharge of the DC link before measuring. For duration of discharge time, see *Table 2.1*.
2. Set the multimeter to the DC voltage position.
3. Check the DC link for remaining charge by measuring the voltage on the DC terminals.
4. Measure from terminal (UDC-) to terminal (UDC+), see *Illustration 7.3*.

The voltage reading must be 0 V.
Then it is safe to proceed with the dynamic tests.

7.5.4 Dynamic Test on IGBT

Dynamic tests are performed with power applied to the frequency converter. Dynamic testing traces signal circuitry to isolate faulty components.

Preparation

- Close the cover on the frequency converter.
- Disconnect the motor from the frequency converter.
- Ensure that the frequency converter is powered up.
- Program the frequency converter to approximately 50 Hz on start.
- Set the multimeter to AC 1000 V.

Procedure for dynamic test on the IGBT

NOTICE

Short-circuiting the UVW terminals can damage the frequency converter. Do not touch more than 1 terminal at a time with the measuring probes.

1. Connect the positive terminal of the multimeter lead to the U connector, and connect the negative terminal to the V terminal.
2. Connect the positive terminal of the multimeter lead to the U connector, and connect the negative terminal to the W terminal.
3. Connect the positive terminal of the multimeter lead to the V connector, and connect the negative terminal to the W terminal.

The meter reading is 450 V ±25 V when performing the dynamic test at 400 V mains. With PM motors, the reading may differ. Contact hotline for help.

The reading must be within ±1.5%.

7.5.5 No Display Test (Display is Optional)

There can be several reasons for no display in the LCP. First, verify that there is no display. A single character in the display or a dot in the upper corner of the display indicates a communication error. Check that all option cards are properly installed. When this condition occurs, the green power-on LED is illuminated.

If the display is dark and the green power-on LED is not lit, proceed with the following tests.

First test for proper input voltage.

7

7.5.6 Input Voltage Test

1. Apply power to frequency converter.
2. Use the DVM to measure the input mains voltage between the frequency converter input terminals in sequence:
   - 2a L1 to L2.
   - 2b L1 to L3.
   - 2c L2 to L3.

For 380 V frequency converters, all measurements must be within the range of 342–550 V AC. Readings of less than 342 V AC indicate problems with the input mains voltage.

In addition to the actual voltage reading, the balance of the voltage between the phases is also important. The frequency converter can operate within specifications as long as the imbalance of supply voltage is not more than 3%.

Danfoss calculates mains imbalance according to an IEC specification.

$$\text{Imbalance} = 0.67 \times (V_{max}–V_{min})/V_{avg}$$

For example, if 3-phase readings were taken, and the results were 500 V AC, 478.5 V AC, and 485.7 V AC; then:

- 500 V AC is V_{max}.
- 478.5 V AC is V_{min}.
- 485.7 V AC is V_{avg}.

This result gives an imbalance of 3%.

Although the frequency converter can operate at higher mains imbalances, the lifetime of components, such as DC bus capacitors, is shortened.

Incorrect reading

NOTICE

Open (blown) input fuses or tripped circuit breakers usually indicate a more serious problem. Before replacing fuses or resetting breakers, perform static tests.

An incorrect reading here requires further investigation of the mains supply. Typical items to check:

- Open (blown) input fuses or tripped circuit breakers.
- Poor connections, or open line side contactors.
- Problems with the power distribution system.

If this test was successful, check for voltage to the control card.

7.5.7 Basic Control Card Voltage Test

1. Measure the control voltage at terminal 12 regarding terminal 20.
   The meter must read 21–27 V DC.

An incorrect reading here could indicate that a fault in the customer connections loads down the supply. Disconnect control wiring and repeat the test. If this test is successful, then continue. Remember to check the customer connections. If still unsuccessful, replace the unit.

2. Measure the 10 V DC control voltage at terminal 50 regarding terminal 55. The meter must read between 9.2 and 11.2 V DC.

An incorrect reading here could indicate that a fault in the customer connections loads down the supply. Disconnect control wiring and repeat the test. If this test is successful, then continue. Remember to check the customer connections. If still unsuccessful, replace the unit.

7.5.8 Input Imbalance of Supply Voltage Test

Theoretically, the current drawn on all 3 input phases must be equal. Some imbalance may be seen, however, due to variations in the phase-to-phase input voltage, and single-phase loads within the frequency converter.

A current measurement of each phase reveals the balanced condition of the line. To obtain an accurate reading, the frequency converter must run at its rated load, or at a load of not less than 40%.

1. Perform the input voltage test before checking the current, in accordance with procedure.
   Voltage imbalances automatically result in a corresponding current imbalance.
2. Apply power to the frequency converter and place it in run.
3. Using a clamp-on ammeter (analog preferred), read the current on each of 3 input lines at L1 (R), L2 (S), and L3 (T).
   Typically, the current should not vary from phase-to-phase by more than 5%. If a greater current variation exists, it indicates a possible problem with the mains supply to the frequency converter, or a problem within the frequency converter. One way to determine if the mains supply is at fault is to swap 2 of the incoming phases. This assumes that 2 phases read 1 current while the 3rd deviates by more than 5%. If all 3 phases are different from one another, swap the phase with the highest current with the phase with the lowest current:

3a Remove power to the frequency converter.

3b Swap the phase that appears to be incorrect with 1 of the other 2 phases.

3c Reapply power to the frequency converter and place it in run.

3d Repeat the current measurements.

If the imbalance of supply voltage moves with swapping the leads, the mains supply is suspect. Otherwise, it may indicate a problem with the gating of the rectifiers.

7.5.9 Input Waveform Test

Testing the current waveform on the input of the frequency converter can help troubleshooting mains phase loss conditions or suspected problems with the diode modules. Phase loss caused by the mains supply can be easily detected. In addition, the diode modules control the rectifier section. If 1 of the diode modules becomes defective, the frequency converter provides a response which is the same as loss of 1 of the phases.

The following measurements require an oscilloscope with voltage and current probes.

Under normal operating conditions, the waveform of a single phase of input AC voltage to the frequency converter appears as in *Illustration 7.6*.

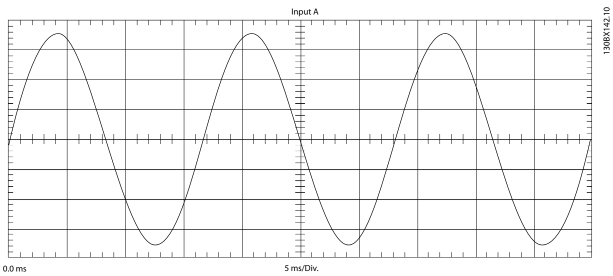


Illustration 7.6 Normal AC Input Voltage Waveform

The waveform shown in *Illustration 7.7* shows the input current waveform for the same phase as shown in *Illustration 7.6* while the frequency converter is running at 40% load. The 2 positive and 2 negative jumps are typical of any 6-diode bridge. It is the same for frequency converters with diode modules.

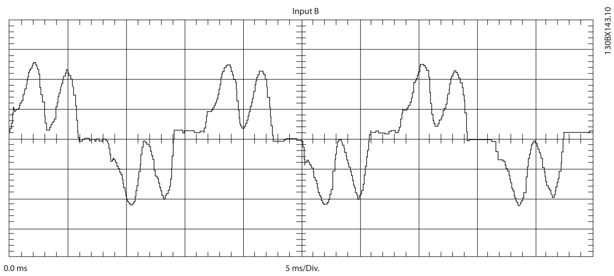


Illustration 7.7 AC Input Current Waveform with Diode Bridge

With a phase loss, the current waveform of the remaining phases would take on the appearance shown in *Illustration 7.8*.

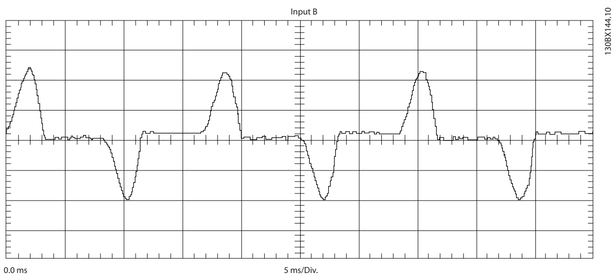


Illustration 7.8 Input Current Waveform with Phase Loss

Always verify the condition of the input voltage waveform before drawing a conclusion. The current waveform follows the voltage waveform. If the voltage waveform is incorrect, proceed to investigate the reason for the AC supply problem. If the voltage waveform on all 3 phases is correct, but the current waveform is not, the input rectifier circuit in the frequency converter is suspect. Perform the static soft-charge and rectifier tests, and also the dynamic diode module test.

7.5.10 Output Imbalance of Motor Supply Voltage Test

Before checking output imbalance, make sure to test the inverter module. When testing the phase-to-phase output, both voltage and current are monitored. Perform the initial test with the motor connected and running its load.

NOTICE

FALSE OUTPUT READINGS

Use an analog voltmeter for monitoring output voltage. Digital voltmeters are sensitive to waveform and switching frequencies and commonly return erroneous readings.

7

If the voltage is balanced, but the current is not, the motor is drawing an uneven load. This can be caused by:

- Defective motor.
- Poor connection in the wiring between the frequency converter and the motor.
- Defective motor overload.

If both the output current and voltage are unbalanced, the frequency converter does not work properly. This can be caused by the following:

- Defective power card.
- Improper connection of the output circuitry.

If suspect readings are recorded, perform the following steps:

1. Stop the motor and wait until the motor has stopped rotating.
2. Set the frequency converter to coast.
3. Disconnect the motor cables.
4. Use a voltmeter to measure AC output voltage at the frequency converter motor terminals U, V, and W. Measure phase-to-phase, checking U to V, then U to W, and then V to W.
   All 3 readings must be within 8 V AC of each other. The actual value of the voltage depends on the speed at which the frequency converter runs. The V/Hz ratio is relatively linear (except in VT mode). For example, if the rated motor frequency is 60 Hz, the voltage should be approximately equal to the applied mains voltage. At 30 Hz, it is about half of that. This also applies to any other speed selected. The exact voltage reading is less important than balance between phases.
5. Reconnect the motor to the frequency converter.
6. Use a clamp-on ammeter to monitor current on the 3 output phases at the motor terminals U, V, and W. An analog ammeter is recommended. To achieve an accurate reading, run the frequency converter above 40 Hz.
7. Check that the output current is balanced from phase-to-phase, with no phase varying more than 2–3%.
   - 7a If each phase is within 2–3%, the frequency converter is balanced.
   - 7b If any phase is above 3%, disconnect the motor cables and repeat the voltage balance test.
     If a voltage imbalance is detected with the motor cables disconnected, then either the IGBT or gate driver card is defective.

7.5.11 Input Terminal Signal Tests

The presence of signals on either the digital or analog input terminals of the frequency converter can be verified on the frequency converter display. Digital or analog input status can be selected or read in *parameters 16-60* to *16-64*.

Digital inputs
With digital inputs shown, control terminals 18, 19, 27, and 29 are shown left to right, with 1 indicating the presence of a signal.

If the expected signal is not present in the display, the problem is either in the external control wiring to the frequency converter or a faulty control card. To determine the fault location, use a voltmeter to test for voltage at the control terminals.

Verify that the control voltage supply is correct as follows:

1. Use a voltmeter for measuring voltage at control card terminal 12 with respect to terminal 20. The meter should read 21–27 V DC.

If the 24 V supply voltage is not present, test the control card in *chapter 7.5.7 Basic Control Card Voltage Test*.

If 24 V is present, proceed to check the individual inputs as follows:

2. Connect the (-) negative meter lead to reference terminal 20.
3. Connect the (+) positive meter lead to the terminals in sequence.

The presence of a signal at the wanted terminal must correspond to the digital input display readout. A reading of 24 V DC indicates the presence of a signal. A reading of 0 V DC indicates that no signal is present.

Analog inputs
The value of signals on analog input terminals 53 and 54 can also be shown. The voltage or current in mA, depending on the switch setting, is shown in line 2 of the display.

If the wanted signal is not present in the display, the problem is either in the external control wiring to the frequency converter, or a faulty control card. To determine the fault location, use a voltmeter to test for a signal at the control terminals.

Verify that the reference voltage supply is correct as follows:

1. Use a voltmeter for measuring the voltage at control card terminal 50 with respect to terminal

55. The meter must read between 9.2 and 11.2 V DC.

If the 10 V supply voltage is not present, conduct *chapter 7.5.7 Basic Control Card Voltage Test* earlier in this section.

If 10 V is present, proceed with checking the individual inputs as follows:

2. Connect the (-) negative meter lead to reference terminal 55.
3. Connect the (+) positive meter lead to terminal 53 or 54, as required.

The analog input terminals 53 and 54 require a DC voltage between 0 and +10 V DC to match the analog signal sent to the frequency converter. A reading of 0.9 to 4.8 V DC corresponds to a 4–20 mA signal.

NOTICE

A (-) minus sign preceding any reading above indicates a reversed polarity. In this case, reverse the wiring to the analog terminals.

7.6 Fan Tests

The frequency converter is equipped with 2 fans.
During normal operation of the frequency converter, the fans run only when the heat sink temperature exceeds 65 °C (149 °F). For temperatures below 65 °C (149 °F), the fans do not run.
To ensure that the fans operate correctly, run the following test.

1. Shut down the frequency converter.
2. Wait for the discharge time to elapse, see *Table 2.1*.
3. Start up the frequency converter.
4. After start-up, the fans run briefly, for 1 s only. Check that both fans rotate.
5. When both fans rotate during start-up, fan operation is correct.
6. When a fan does not rotate during start-up:
    - Check fan connections.
    - See also fan assembly replacement instructions in *chapter 8 Disassembly and Assembly Instructions*.

7.7 Initial Start-up or After-repair Frequency Converter Tests

Perform these tests under the following conditions:

- Starting a frequency converter for the first time.
- Approaching a frequency converter that is suspected of being faulty.
- After a repair of the frequency converter.

Following this procedure ensures that all circuitry in the frequency converter is functioning properly before putting it into operation.

1. Perform visual inspection procedures as described in *Table 6.1*.
2. Perform static test procedures to ensure that the frequency converter is safe to start.
3. Disconnect motor cables from motor terminals (U, V, W) of the frequency converter.
4. Apply AC power to frequency converter.
5. Give the frequency converter a run command and slowly increase reference (speed command) to approximately 40 Hz.
6. Using an analog voltmeter or a DVM capable of measuring true RMS, measure phase-to-phase output voltage on all 3 phases: U to V, U to W, V to W. All voltages must be balanced within 8 V. If measuring unbalanced voltage, refer to *chapter 7.5.6 Input Voltage Test*.
7. Stop the frequency converter and remove input power. Wait for the discharge time to elapse listed in *Table 2.1* to allow DC capacitors to discharge fully.
8. Reconnect motor cables to frequency converter motor terminals (U, V, W).
9. Reapply power and restart frequency converter. Adjust motor speed to a nominal level.
10. Set load to 50%.
11. Using a clamp-on ammeter, measure output current on each output phase. All currents must be balanced.
12. The correct measurement is 50% rated current.

8 Disassembly and Assembly Instructions

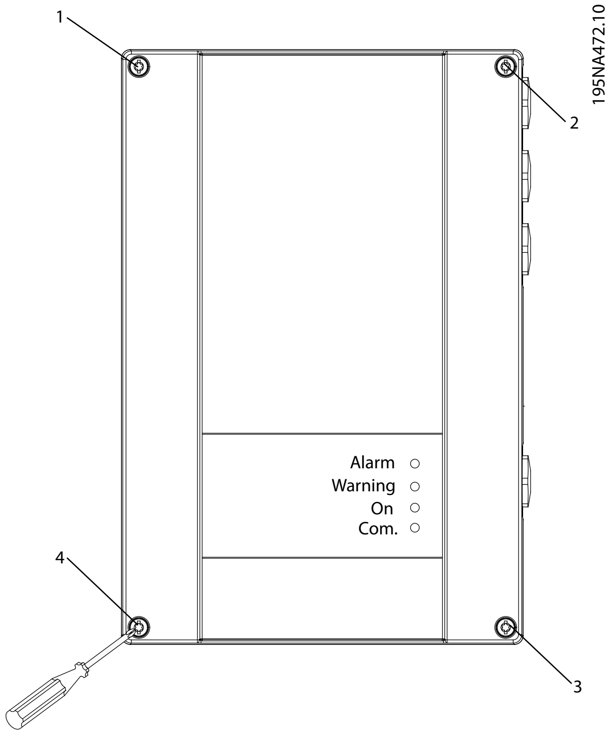
This section describes procedures for disassembly and reassembly of the frequency converter for:

- Access to terminals and other internal components.
- Replacement of spare parts.

8.1 Frequency Converter Cover

8.1.1 Remove Cover

1. Loosen the 4 screws using a Torx 20 screwdriver as shown in *Illustration 8.1*. When released, the screws remain sitting in position in the cover.
2. Lift off the cover and place it on a clean surface.

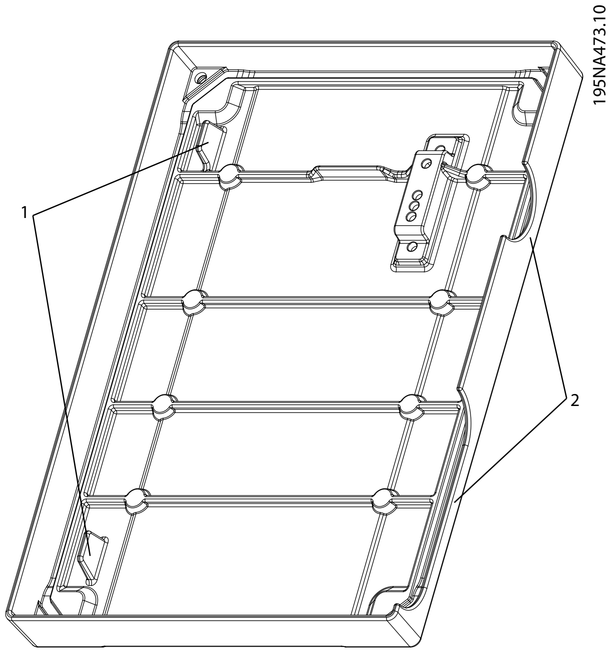


1, 2, 3, 4	Screws

Illustration 8.1 Remove Cover

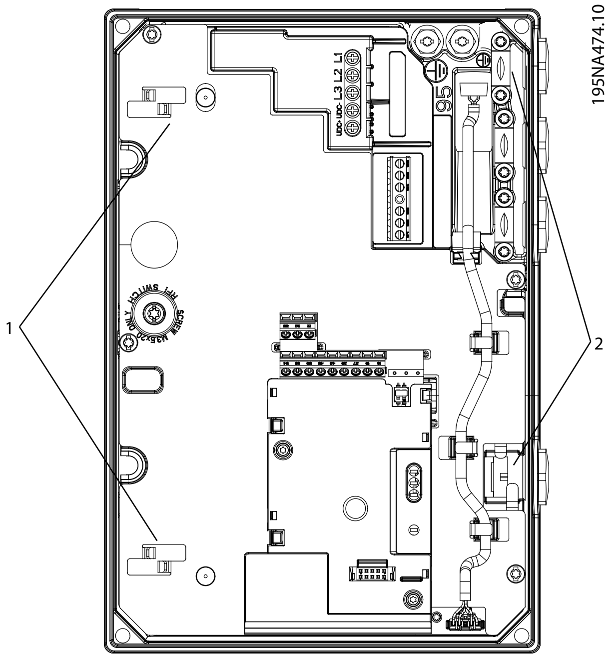
8.1.2 Remount Cover

1. Orient the cover to align grounding points and cutouts for cables and cable glands. See *Illustration 8.2*.
2. Lower the cover onto the frequency converter. Ensure connection at grounding clips. See *Illustration 8.3* and *Illustration 8.4*.
3. Fasten the 4 screws using a Torx 20 screwdriver, see *Table 9.13* for tightening torques.



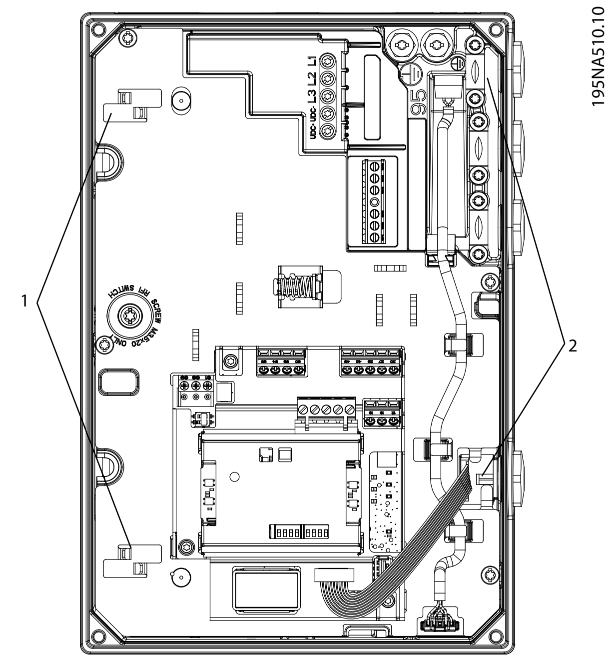
1	Grounding points
2	Cutouts for cable entries

Illustration 8.2 Orient the Cover



1	Grounding clips
2	Cable entries

Illustration 8.3 Grounding Clips and Cable Entries



1	Grounding clips
2	Cable entries

Illustration 8.4 Cable Entries, Phase 2

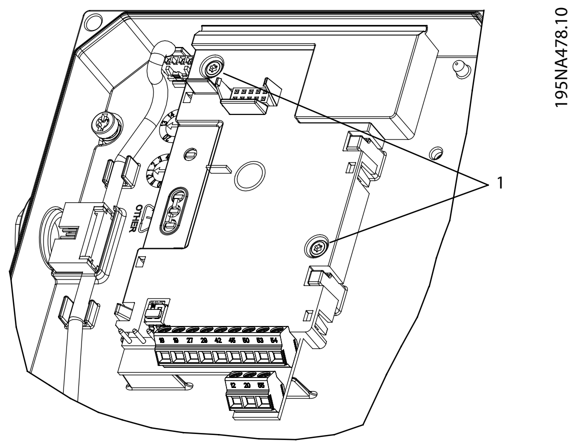
8.2 Control Card

8.2.1 Remove Control Card

NOTICE

This procedure only applies to phase-1 frequency converters, see *chapter 1.5.2 FCP 106 and FCM 106*.

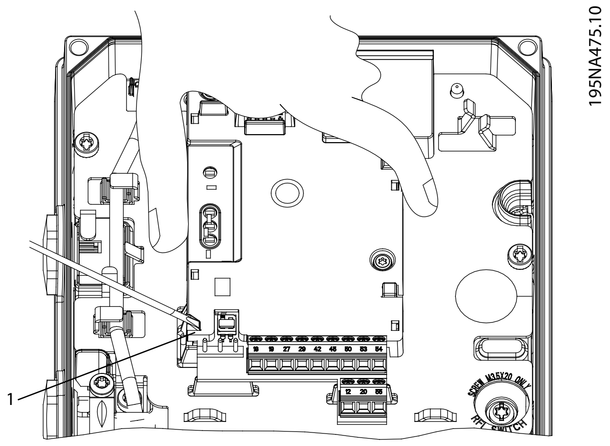
1. Remove the 2 screws holding the control card and cover in place, using a Torx 10 screwdriver. See *Illustration 8.5*.
2. Release the snap connector carefully, using the screwdriver. See *Illustration 8.6*.
3. Do not disconnect the ribbon cable. The ribbon cable must remain connected, as shown in *Illustration 8.7*.
4. Lift the control card up. Loosen the control card cover slightly, if required. Take care not to pull the ribbon cable.
5. Carefully place the control card in the enclosure, with cover on as shown in *Illustration 8.7*.
6. The motor terminals U, V, and W are now accessible.



1	Screws

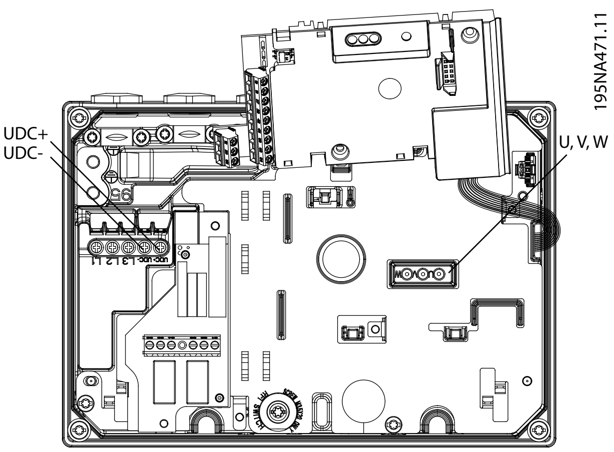
Illustration 8.5 Location of Screws, Phase 1 only

8



1	Snap connector

Illustration 8.6 Release Snap Connector, Phase 1 only



1	Ribbon cable

Illustration 8.7 Position Control Card for Access to Motor Terminals U, V, and W, Phase 1 only

8.2.2 Remount Control Card

NOTICE

This procedure only applies to phase-1 frequency converters, see *chapter 1.5.2 FCP 106 and FCM 106*.

1. Slide the control card into place as shown in *Illustration 8.8*. Loosen the control card cover slightly, if required.
2. Press the control card down. When it makes a click sound, it is fastened correctly.
3. Fasten the 2 screws using a Torx 10 screwdriver, tightening torque 1.3 Nm. See *Illustration 8.5*.

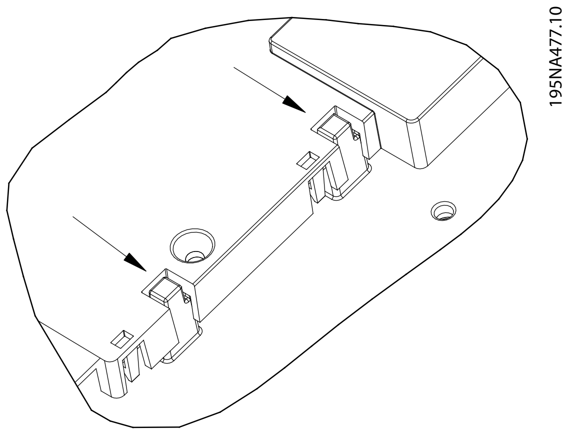
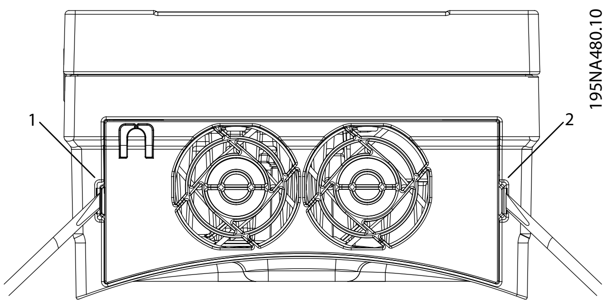


Illustration 8.8 Reposition Control Card, Phase 1 only

8.3 Fan Assembly

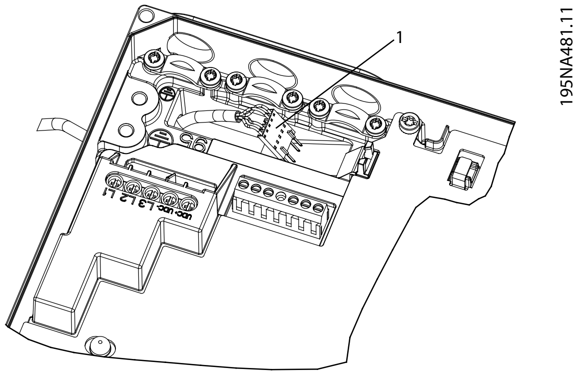
1. Release the fan cable. See *Illustration 8.11* and *Illustration 8.12* for location of the fan cable plug.
2. Release the snaps on each side of the fan assembly, using a screwdriver. See *Illustration 8.9*.
3. Lift out the fan assembly.



1, 2	Snaps

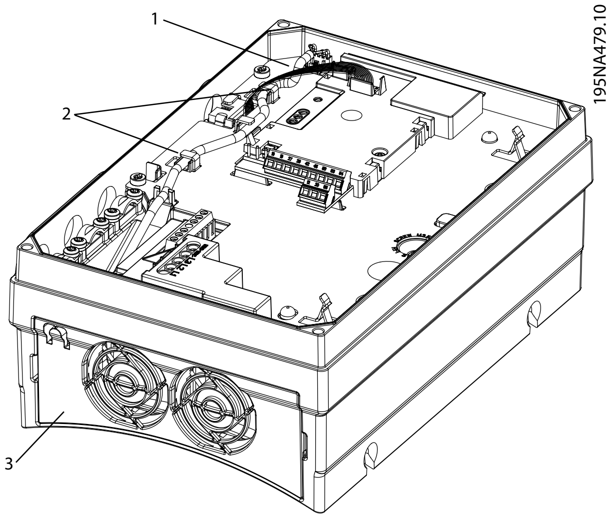
Illustration 8.9 Release the Fan Assembly

1. Insert the fan cable through the cable entry point, see *Illustration 8.10*.
2. Insert the fan assembly. Press carefully in place until the snaps make a click sound.
3. Plug in the fan cable as shown in *Illustration 8.11* and *Illustration 8.12*. Use the cable holders to hold the cable in place.



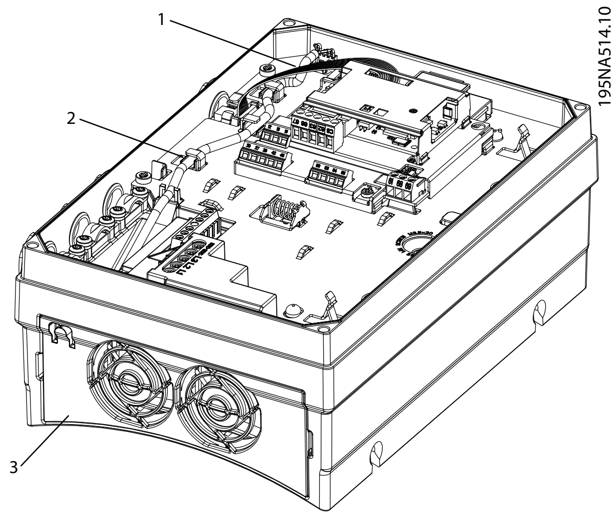
1	Fan cable with plug

Illustration 8.10 Fan Cable Entry Point



1	Fan cable plug connection point
2	Cable holder
3	Fan assembly

Illustration 8.11 Plug in the Fan Cable, Phase 1



1	Fan cable plug connection point
2	Cable holder
3	Fan assembly

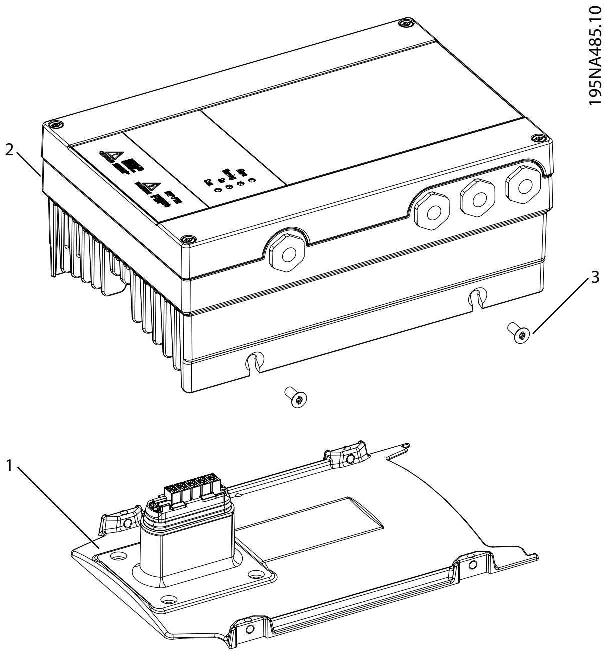
Illustration 8.12 Plug in the Fan Cable, Phase 2

8

8.4 Motor Adapter Plate and Wall Mount Plate

8.4.1 Remove Frequency Converter from Motor Adapter Plate/Wall Mount Plate

1. Release the 4 screws using a Torx 20 screwdriver, see *Illustration 8.13*.
2. Lift the frequency converter perpendicular to the motor adapter plate.
3. *Illustration 8.13* shows the motor adapter plate. The same procedure applies to the wall mount plate.



1	Motor adapter plate
2, 3	Screw positions

Illustration 8.13 Removal and Remounting of Frequency Converter to Motor Adapter Plate

8.4.2 Remount Frequency Converter onto Motor Adapter Plate/Wall Mount Plate

1. Lower the frequency converter onto the motor adapter plate, aligning the screws and slots, see *Illustration 8.13*. The motor plug connection automatically aligns.
2. Fasten the 4 screws using a Torx 20 screwdriver.
3. The same procedure applies to the wall mount plate.

9 Specifications

This section lists specifications related to the frequency converter, input, output, and surroundings.

9.1 Clearances, Dimensions, and Weights

9.1.1 Clearances

To ensure sufficient air flow for the frequency converter, observe the minimum clearances listed in *Table 9.1*.
When air flow is obstructed close to the frequency converter, ensure adequate inlet of cool air and exhaust of hot air from the unit.

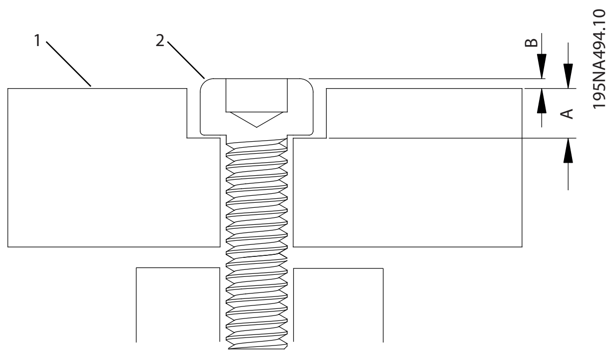
Enclosure			Power[1)] [kW (hp)]	Clearance at ends [mm (in)]	
Enclosure size	Protection rating		3x380–480 V	Motor flange end	Cooling fan end
	FCP 106	FCM 106			
MH1	IP66/Type 4X[2)]	IP55/Type 12	0.55–1.5 (0.75–2.0)	30 (1.2)	100 (4.0)
MH2	IP66/Type 4X[2)]	IP55/Type 12	2.2–4.0 (3.0–5.0)	40 (1.6)	100 (4.0)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

Table 9.1 Minimum Clearance for Cooling

1) Power ratings relate to NO, see chapter 9.2 Electrical Data.
2) The stated IP and Type rating only apply when the FCP 106 is mounted on a wall mount plate or a motor with the adapter plate. Ensure that the gasket between the adapter plate and the motor has a protection rating corresponding to the required rating for the combined motor and frequency converter. As standalone frequency converter, the enclosure rating is IP00 and Open type.

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

Table 9.2 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 9.1 Screws to Fasten Motor Adapter Plate

9

9.1.2 Motor Frame Size Corresponding to FCP 106 Enclosure

PM motor		Asynchronous motor		FCP 106	
RPM				Enclosure	Power [kW (hp)]
1500	3000	3000	1500		
71	–	–	–	MH1	0.55 (0.75)
71	71	71	80		0.75 (1.0)
71	71	80	90		1.1 (1.5)
71	71	80	90		1.5 (2.0)
90	71	90	100	MH2	2.2 (3.0)
90	90	90	100		3 (4.0)
90	90	100	112		4 (5.0)
112	90	112	112	MH3	5.5 (7.5)
112	112	112	132		7.5 (10)

Table 9.3 Motor Frame Size Corresponding to FCP 106 Enclosure

9.1.3 FCP 106 Dimensions

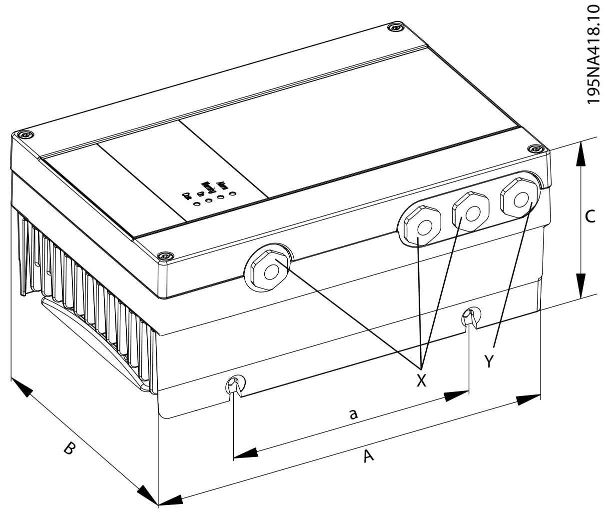


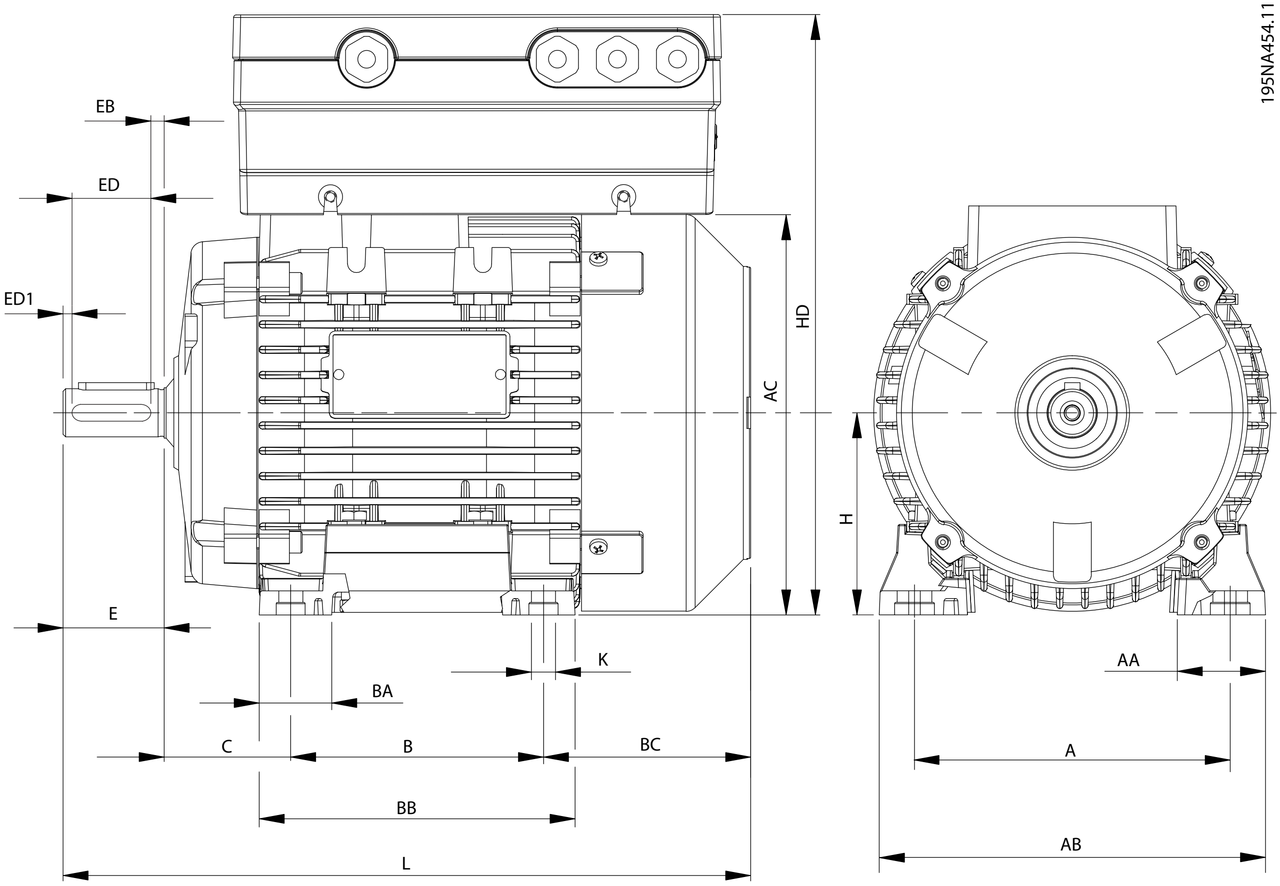
Illustration 9.2 FCP 106 Dimensions

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

Table 9.4 FCP 106 Dimensions

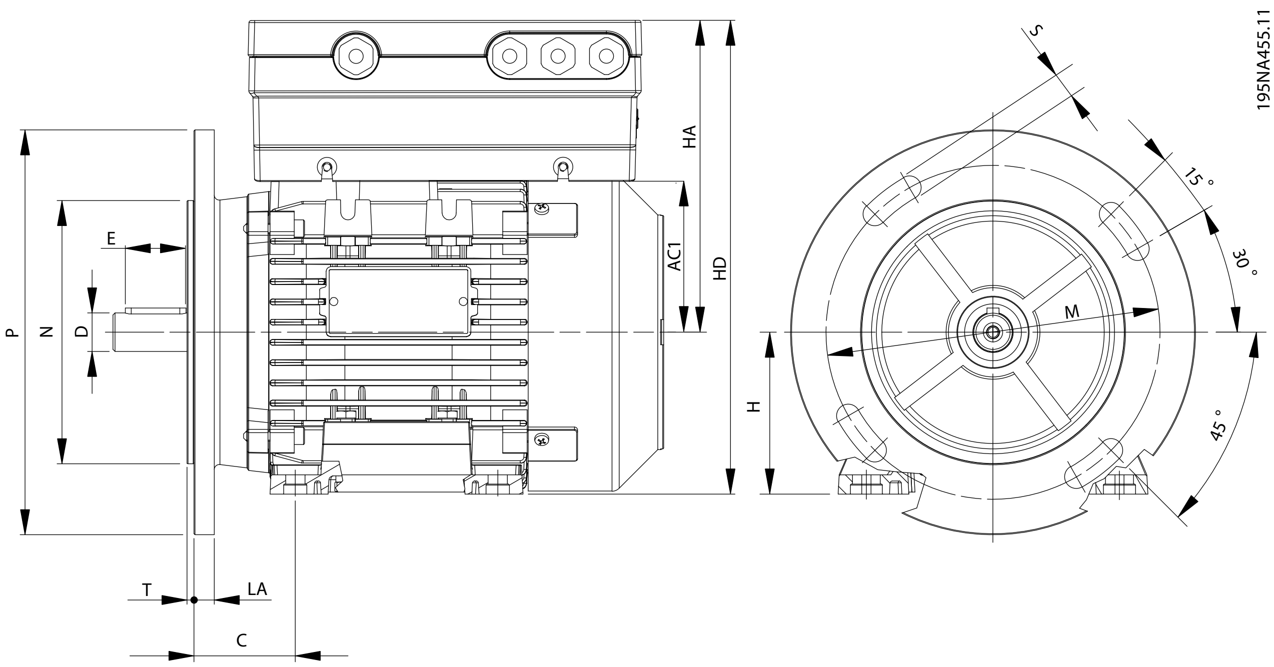
1) Power ratings relate to NO, see chapter 9.2 Electrical Data.

9.1.4 FCM 106 Dimensions



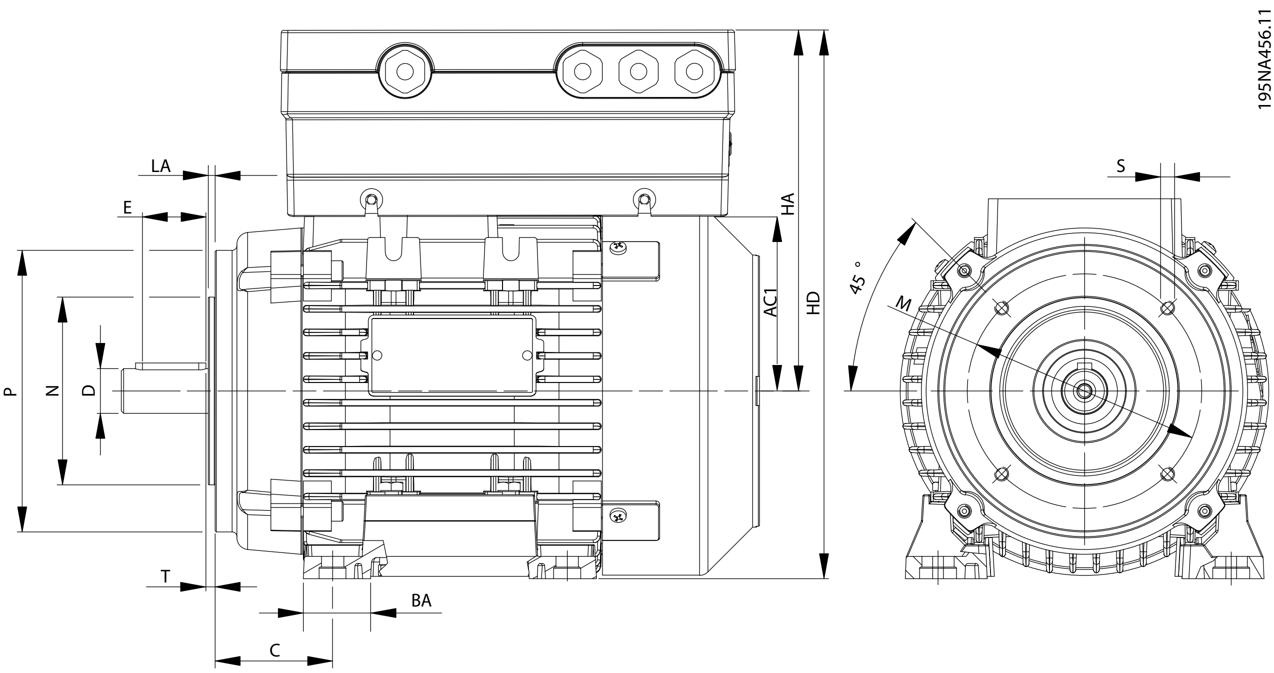
Motor frame size	71	80	90S	90L	100S	100L	112M	132S	132M
A [mm (in)]	112 (4.4)	125 (4.9)	140 (5.5)	140 (5.5)	160 (6.3)	160 (6.3)	190 (7.5)	216 (8.5)	216 (8.5)
B [mm (in)]	90 (3.5)	100 (4.0)	100 (4.0)	125 (4.9)	140 (5.5)	140 (5.5)	140 (5.5)	140 (5.5)	178 (7.0)
C [mm (in)]	45 (1.8)	50 (2.0)	56 (2.2)	56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

Table 9.5 FCM 106 Dimensions: Foot Mounting - B3 Asynchronous or PM Motor



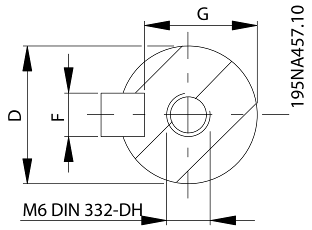
Motor frame size	71	80	90S	90L	100L	112M	132S
M [mm (in)]	130 (5.1)	165 (6.5)	165 (6.5)	165 (6.5)	215 (8.5)	215 (8.5)	265 (10.4)
N [mm (in)]	110 (4.3)	130 (5.1)	130 (5.1)	130 (5.1)	180 (7.8)	180 (7.8)	230 (9.1)
P [mm (in)]	160 (6.3)	200 (7.9)	200 (7.9)	200 (7.9)	250 (9.8)	250 (9.8)	300 (11.8)
S [mm (in)]	M8	M10	M10	M10	M12	M12	M12
T [mm (in)]	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	4 (0.16)	4 (0.16)	4 (0.16)
LA [mm (in)]	10 (0.4)	10 (0.4)	12 (0.5)	12 (0.5)	14 (0.6)	14 (0.6)	14 (0.6)
HA [mm (in)]	HA = AC1 + height of the frequency converter. For frequency converter dimensions, see *Table 9.4*.						
HD [mm (in)] without VLT® PROFIBUS DP MCA 101							
MH1	247 (9.7)	267 (10.5)	286 (11.3)	286 (11.3)	–	–	–
MH2	248 (9.8)	268 (10.6)	287 (11.4)	287 (11.4)	304 (12)	332 (13.1)	–
MH3	–	–	299 (11.8)	299 (11.8)	316 (12.4)	244 (9.6)	379 (14.9)
HD [mm (in)] with VLT® PROFIBUS DP MCA 101							
MH1	262 (10.3)	282 (11.1)	301 (11.9)	301 (11.9)	–	–	–
MH2	263 (10.4)	283 (11.2)	302 (11.9)	302 (11.9)	319 (12.6)	347 (13.7)	–
MH3	–	–	314 (12.4)	314 (12.4)	331 (13.1)	359 (14.1)	394 (15.5)

Table 9.6 FCM 106 Dimensions: Flange Mounting - B5, B35 for Asynchronous or PM Motor



Small flange B14						
Motor frame size	**71**	**80**	**90S**	**100L**	**112M**	**132S**
M [mm (in)]	85 (3.3)	100 (4.0)	115 (4.5)	130 (5.1)	130 (5.1)	165 (6.5)
N [mm (in)]	70 (2.8)	80 (3.1)	95 (3.7)	110 (4.3)	110 (4.3)	130 (5.1)
P [mm (in)]	105 (4.1)	120 (4.7)	140 (5.5)	160 (6.3)	160 (6.3)	200 (7.9)
S [mm (in)]	M6	M6	M8	M8	M8	M10
T [mm (in)]	2.5 (0.1)	3 (0.12)	3 (0.12)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)
LA [mm (in)]	11 (0.4)	9 (0.35)	9 (0.35)	10 (0.4)	10 (0.4)	30 (0.4)
Large flange B14						
Motor frame size	**71**	**80**	**90S**	**100L**	**112M**	**132S**
M [mm (in)]	115 (4.5)	130 (5.1)	130 (5.1)	165 (6.5)	165 (6.5)	215 (8.5)
N [mm (in)]	95 (3.7)	110 (4.3)	110 (4.3)	130 (5.1)	130 (5.1)	180 (7.1)
P [mm (in)]	140 (5.5)	160 (6.3)	160 (6.3)	200 (7.9)	200 (7.9)	250 (9.8)
S [mm (in)]	M8	M8	M8	M10	M10	M12
T [mm (in)]	2.5 (0.1)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	3.5 (0.14)	4 (0.16)
LA [mm (in)]	8 (0.31)	8.5 (0.33)	9 (0.35)	12 (0.5)	12 (0.5)	12 (0.5)
HA [mm (in)]	HA = AC1 + height of the frequency converter. For frequency converter dimensions, see *Table 9.4*.					
HD [mm (in)] without VLT® PROFIBUS DP MCA 101						
MH1	247 (9.7)	267 (10.5)	286 (11.3)	–	–	–
MH2	248 (9.8)	268 (10.6)	287 (11.4)	304 (12)	332 (13.1)	–
MH3	–	–	299 (11.8)	316 (12.4)	244 (9.6)	379 (14.9)
HD [mm (in)] with VLT® PROFIBUS DP MCA 101						
MH1	262 (10.3)	282 (11.1)	301 (11.9)	–	–	–
MH2	263 (10.4)	283 (11.2)	302 (11.9)	319 (12.6)	347 (13.7)	–
MH3	–	–	314 (12.4)	331 (13)	359 (14.1)	394 (15.5)

Table 9.7 FCM 106 Dimensions: Face Mounting - B14, B34 for Asynchronous or PM motor



FCM 106 with Asynchronous or PM motor						
Motor frame size	**71**	**80**	**90S**	**100L**	**112M**	**132S**
D [mm (in)]	14 (0.6)	19 (0.7)	24 (1.0)	28 (1.1)	28 (1.1)	38 (1.5)
F [mm (in)]	5 (0.2)	6 (0.25)	8 (0.3)	8 (0.3)	8 (0.3)	10 (0.4)
G [mm (in)]	11 (0.4)	15.5 (0.6)	20 (0.8)	24 (1.0)	24 (1.0)	33 (1.3)
DH	M5	M6	M8	M10	M10	M12

Table 9.8 FCM 106 Dimensions: Shaft Drive End - Asynchronous or PM Motor

9.1.5 Weight

To calculate the total weight of the unit, add:

- The weight of the combined frequency converter and adapter plate, see *Table 9.9*.
- The weight of the motor, see *Table 9.10*.

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

Table 9.9 Weight of FCP 106

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

Table 9.10 Approximate Weight of Motor

9.2 Electrical Data

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

Enclosure	MH1							MH2						MH3
	PK55	PK75		P1K1		P1K5		P2K2		P3K0		P4K0		P5K5
Overload[1)]	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO	HO
Typical shaft output [kW]	0.55		0.75		1.1		1.5		2.2		3.0		4.0	
Typical shaft output [hp]	0.75		1.0		1.5		2.0		3.0		4.0		5.0	
Maximum cable cross-section in terminals[2)] (mains, motor) [mm²/AWG]	4/12		4/12		4/12		4/12		4/12		4/12		4/12	
Output current														
40 °C ambient temperature														
Continuous (3x380–440 V) [A]	1.7		2.2		3.0		3.7		5.3		7.2		9.0	
Intermittent (3x380–440 V) [A]	1.9	2.7	2.4	3.5	3.3	4.8	4.1	5.9	5.8	8.5	7.9	11.5	9.9	14.4
Continuous (3x440–480 V) [A]	1.6		2.1		2.8		3.4		4.8		6.3		8.2	
Intermittent (3x440–480 V) [A]	1.8	2.6	2.3	3.4	3.1	4.5	3.7	5.4	5.3	7.7	6.9	10.1	9.0	13.2
Maximum input current														
Continuous (3x380–440 V) [A]	1.3		2.1		2.4		3.5		4.7		6.3		8.3	
Intermittent (3x380–440 V) [A]	1.4	2.0	2.3	2.6	2.6	3.7	3.9	4.6	5.2	7.0	6.9	9.6	9.1	12.0
Continuous (3x440–480 V) [A]	1.2		1.8		2.2		2.9		3.9		5.3		6.8	
Intermittent (3x440–480 V) [A]	1.3	1.9	2.0	2.5	2.4	3.5	3.2	4.2	4.3	6.3	5.8	8.4	7.5	11.0
Maximum mains fuses	See *chapter 9.9 Fuse and Circuit Breaker Specifications*.													
Estimated power loss [W], best case/typical[3)]	38			44		57		73		91		129		143
Efficiency [%], best case/typical[4)5)]	0.96			0.97		0.97		0.97		0.97		0.97		0.97

Table 9.11 Mains Supply 3x380–480 V AC Normal and High Overload: MH1, MH2, and MH3 Enclosure

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

A frequency converter intended for HO requires a corresponding motor rating. For example, Table 9.11 shows that a 1.5 kW motor for HO requires a P2K2 frequency converter.

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

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

4) Efficiency measured at nominal current. For energy efficiency class, see chapter 9.5 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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

Enclosure	MH3		
	P5K5	P7K5	
Overload[1)]	NO	HO	NO
Typical shaft output [kW]	5.5		7.5
Typical shaft output [hp]	7.5		10
Maximum cable cross-section in terminals[2)] (mains, motor) [mm^2/AWG]	4/12		4/12
Output current			
40 °C ambient temperature			
Continuous (3x380–440 V) [A]	12		15.5
Intermittent (3x380–440 V) [A]	13.2	19.2	17.1
Continuous (3x440–480 V) [A]	11		14
Intermittent (3x440–480 V) [A]	12.1	13.2	15.4
Maximum input current			
Continuous (3x380–440 V) [A]	11		15
Intermittent (3x380–440 V) [A]	12	17	17
Continuous (3x440–480 V) [A]	9.4		13
Intermittent (3x440–480 V) [A]	10	15	14
Maximum mains fuses	See *chapter 9.9 Fuse and Circuit Breaker Specifications.*		
Estimated power loss [W], best case/typical[3)]	143	236	
Efficiency [%], best case/typical[4)5)]	0.97	0.97	

Table 9.12 Mains Supply 3x380–480 V AC Normal and High Overload: MH3 Enclosure

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

A frequency converter intended for HO requires a corresponding motor rating. For example, Table 9.11 shows that a 1.5 kW motor for HO requires a P2K2 frequency converter.

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

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

4) Efficiency measured at nominal current. For energy efficiency class, see chapter 9.5 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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

9.3 Mains Supply

Mains supply (L1, L2, L3)

Supply voltage	380–480 V ±10%

Mains voltage low/mains dropout:

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

Supply frequency	50/60 Hz
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor (λ)	≥0.9 nominal at rated load
Displacement power factor (COSφ)	Near unity (>0.98)
Switching on the input supply L1, L2, L3 (power-ups)	Maximum 2 times/min.
Environment according to EN 60664-1 and IEC 61800-5-1	Overvoltage category III/pollution degree 2

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

- 100000 RMS symmetrical Amperes, 480 V maximum, with fuses used as branch circuit protection.
- See *Table 9.19* and *Table 9.20* when using circuit breakers as branch circuit protection.

9.4 Protection and Features

Protection and features

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

9.5 Ambient Conditions

Environment

Enclosure protection rating	IP66/Type 4X[1)]
Enclosure protection rating FCP 106 between lid and heat sink	IP66/Type 4X
Enclosure protection rating FCP 106 between heat sink and adapter plate	IP66/Type 4X
FCP 106 wall mount kit	IP66
Stationary vibration IEC61800-5-1 Ed.2	Cl. 5.2.6.4
Non-stationary vibration (IEC 60721-3-3 Class 3M6)	25.0 g
Relative humidity (IEC 60721-3-3; Class 3K4 (non-condensing))	5–95% during operation
Aggressive environment (IEC 60721-3-3)	Class 3C3
Test method according to IEC 60068-2-43	H2S (10 days)
Ambient temperature	40 °C (104 °F) (24-hour average)

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

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

2) Determined according to EN50598-2 at:

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

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9.6 Cable Specifications

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper or aluminum conductors required (75 °C (167 °F) recommended).

Cable lengths and cross-sections

Maximum motor cable length for wall mount kit, screened/armored	0.5 m (1.64 ft)
Maximum cross-section to motor, mains for MH1–MH3	4 mm^2/11 AWG
Maximum cross-section DC terminals on enclosure type MH1–MH3	4 mm^2/11 AWG
Maximum cross-section to control terminals, rigid wire	2.5 mm^2/13 AWG
Maximum cross-section to control terminals, flexible cable	2.5 mm^2/13 AWG
Minimum cross-section to control terminals	0.05 mm^2/30 AWG
Maximum cross-section to thermistor input (at motor connector)	4 mm^2/11 AWG

9.7 Connection Tightening Torques

Location	Type	Torque [Nm (in-lb)]
Front cover screws	T20 or slot	3–3.5 (26.6–31)
Plastic cable blind plugs	24 mm or 28 mm socket	2.2 (19.5)
Control card	T10	1.3 (11.5)
Relay card	T10	1.3 (11.5)
Control plate	T20 or slot	1.5 (13.3)
Connection to adapter plate	T20 or slot	7.0 (62)

Table 9.13 Tightening Torques for Frequency Converter External Screws

Enclosure size	Power[1)] [kW (hp)]	Torque [Nm (in-lb)]						
	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay	RFI switch
MH1	0.55–1.5 (0.75–2.0)	1.4 (12.4)	Crimp, no applied torque	1.4 (12.4)	0.5 (4.4)	3.0 (26.6)	0.5 (4.4)	0.9 (8.0)
MH2	2.2–4 (3.0–5.0)							
MH3	5.5–7.5 (7.5–10)							

Table 9.14 Tightening Torques for Frequency Converter Internal Screws

1) Power ratings relate to NO, see chapter 9.2 Electrical Data.

Enclosure size	Power[1)] [kW (hp)]	Type						
	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay	RFI switch
MH1	0.55–1.5 (0.75–2.0)	Slot or Phillips	Crimp	Slot or Phillips	Slot or Phillips	T20, slot, or 10 mm socket	Slot	T20 or slot
MH2	2.2–4 (3.0–5.0)							
MH3	5.5–7.5 (7.5–10)							

Table 9.15 Screw Types for Frequency Converter Internal Screws

1) Power ratings relate to NO, see chapter 9.2 Electrical Data.

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9.7.1 Tightening Torques for Connection of Adapter Plate to Motor, FCP 106

For FCP 106 only, fasten the adapter plate to the motor with screw sizes and torques detailed in *Table 9.16*.

Enclosure	Screw size	Minimum thread engagement in motor [mm (in)]	Torque [Nm (in-lb)]	Screw type
MH1	M4	8 (0.3)	2.2 (19.5)	Internal hexagon
MH2	M5	10 (0.4)	5 (44.3)	
MH3	M6	12 (0.5)	6 (53.1)	

Table 9.16 Tightening Torques for Connection of Adapter Plate to Motor, FCP 106

9.7.2 Tightening Torques for Reassembly of Motor

Secure end shields and lid with the bolt sizes and torques detailed in *Table 9.17*.

Motor frame size	Bolt diameter	Torque [Nm (in-lb)]
70		
80	M5	5 (44.3)
90	M5	5 (44.3)
100	M6 (taptite)	8–10 (70.8–88.5)
112	M6 (taptite)	8–10 (70.8–88.5)
132	M8 (taptite)	29 (256.7)

Table 9.17 Motor Bolt Torques

9.8 FCM 106 Motor Specifications

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

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

9.8.1 Motor Overload Data, VLT DriveMotor FCM 106

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

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

Table 9.18 Motor Overload Data

9.9 Fuse and Circuit Breaker Specifications

Overcurrent protection

Provide overload protection to avoid overheating of the cables in the installation. Always carry out overcurrent protection according to local and national regulations. Design fuses for protection in a circuit capable of supplying a maximum of 100000 A_{rms} (symmetrical), 480 V maximum. See *Table 9.19* and *Table 9.20* for breaking capacity for Danfoss CTI25M circuit breaker at 480 V maximum.

UL/non-UL compliance

To ensure compliance with UL 508C or IEC 61800-5-1, use the circuit breakers or fuses listed in *Table 9.19*, *Table 9.20*, and *Table 9.21*.

NOTICE

EQUIPMENT DAMAGE

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

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Enclosure size	Power1) [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 9.19 Circuit Breakers, UL

Enclosure size	Power1) [kW (hp)] 3x380–480 V	Circuit breaker			
		Recommended non-UL	Breaking capacity	Maximum non-UL	Breaking capacity
MH1	0.55 (0.75)	CTI25M - 47B3146	100000	CTI25M - 47B3149	100000
	0.75 (1.0)	CTI25M - 47B3147	100000	CTI25M - 47B3149	100000
	1.1 (1.5)	CTI25M - 47B3147	100000	CTI25M - 47B3150	50000
	1.5 (2.0)	CTI25M - 47B3148	100000	CTI25M - 47B3150	50000
MH2	2.2 (3.0)	CTI25M - 47B3149	100000	CTI25M - 047B3151	15000
	3.0 (4.0)	CTI25M - 47B3149	100000	CTI25M - 047B3151	15000
	4.0 (5.0)	CTI25M - 47B3150	50000	CTI25M - 047B3102 1)	15000
MH3	5.5 (7.5)	CTI25M - 47B3150	50000	CTI25M - 047B3102 1)	15000
	7.5 (10)	CTI25M - 47B3151	15000	CTI25M - 047B3102 1)	15000

Table 9.20 Circuit Breakers, Non-UL

1) Trip level maximum set to 32 A.

Enclosure size	Power[1)] [kW] 3x380–480 V	Fuse							
		Recommended UL	Maximum UL					Recommended 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 9.21 Fuses

1) Power ratings relate to NO, see chapter 9.2 Electrical Data.

9.10 Derating According to Ambient Temperature

The ambient temperature measured over 24 hours should be at least 5 °C (41 °F) lower than the maximum ambient temperature. If the frequency converter operates at high ambient temperature, decrease the constant output current.

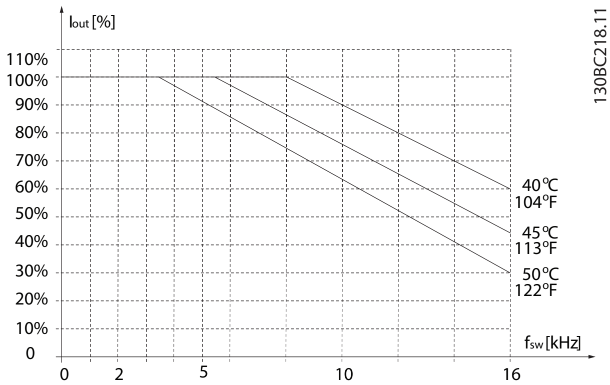

Illustration 9.3 400 V MH1 0.55–1.5 kW (0.75–2.0 hp)

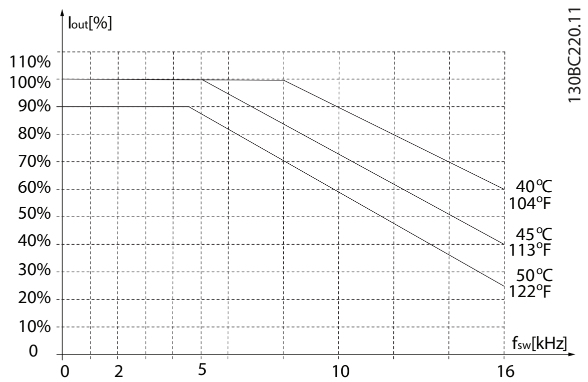

Illustration 9.4 400 V MH2 2.2–4.0 kW (3.0–5.0 hp)

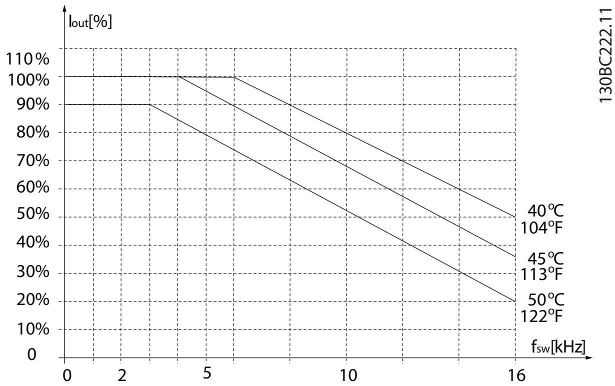

Illustration 9.5 400 V MH3 5.5–7.5 kW (7.5–10 hp)

9.11 dU/dt

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

Table 9.22 dU/dt, MH1–MH3

1) Data available at future release.

9.12 Efficiency

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

This also means that the efficiency of the frequency converter does not change even if other U/f characteristics are selected.
However, the U/f characteristics influence the efficiency of the motor. The efficiency declines a little when the switching frequency is set to a value of above 5 kHz. If the mains voltage is 480 V, the efficiency is also slightly reduced.

Frequency converter efficiency calculation
Calculate the efficiency of the frequency converter at different loads based on *Illustration 9.6*. Multiply the factor in this graph with the specific efficiency factor listed in the specification tables.

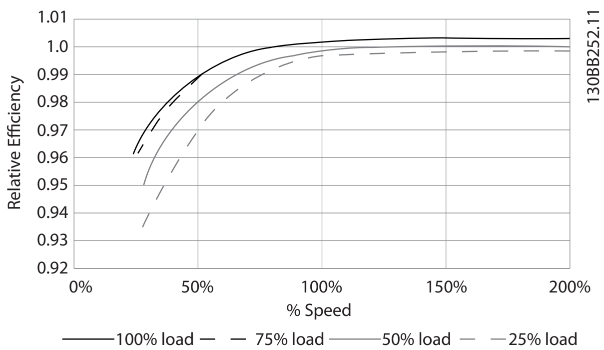

Illustration 9.6 Typical Efficiency Curves

Example: Assume a 22 kW (30 hp), 380–480 V AC frequency converter runs at 25% load at 50% speed. The graph shows 0.97, whereas rated efficiency for a 22 kW (30 hp) frequency converter is 0.98. The actual efficiency is then: 0.97 x 0.98 = 0.95.

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

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

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

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

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

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