



# Design Guide

## VLT<sup>®</sup> HVAC Basic Drive FC 101





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# 1 Introduction

## 1.1 Purpose of the Design Guide

This design guide is intended for project and systems engineers, design consultants, and application and product specialists. Technical information is provided to understand the capabilities of the frequency converter for integration into motor control and monitoring systems. Details concerning operation, requirements, and recommendations for system integration are described. Information is provided for input power characteristics, output for motor control, and ambient operating conditions for the frequency converter.

Also included are:

- Safety features.
- Fault condition monitoring.
- Operational status reporting.
- Serial communication capabilities.
- Programmable options and features.

Also provided are design details such as:

- Site requirements.
- Cables.
- Fuses.
- Control wiring.
- Unit sizes and weights.
- Other critical information necessary to plan for system integration.

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

VLT® is a registered trademark.

## 1.2 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome.

Edition	Remarks	Software version
MG18C8xx	Update to new SW & HW version.	4.2x

Table 1.1 Document and Software Version

From software version 4.0x and later (production week 33 2017 and after), the variable speed heat sink cooling fan function is implemented in the frequency converter for power sizes 22 kW (30 hp) 400 V IP20 and below, and 18.5 kW (25 hp) 400 V IP54 and below. This function requires software and hardware updates and introduces restrictions

with regards to backwards compatibility for H1–H5 and I2–I4 enclosure sizes. Refer to *Table 1.2* for the limitations.

Software compatibility	Old control card (production week 33 2017 or before)	New control card (production week 34 2017 or after)
Old software (OSS-file version 3.xx and below)	Yes	No
New software (OSS-file version 4.xx or higher)	No	Yes
Hardware compatibility	Old control card (production week 33 2017 or before)	New control card (production week 34 2017 or after)
Old power card (production week 33 2017 or before)	Yes (only software version 3.xx or below)	Yes (MUST update software to version 4.xx or higher)
New power card (production week 34 2017 or after)	Yes (MUST update software to version 3.xx or below, the fan continuously runs at full speed)	Yes (only software version 4.xx or higher)

Table 1.2 Software and Hardware Compatibility

## 1.3 Safety Symbols

The following symbols are used in this guide:



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



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



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



### 1.4 Abbreviations

°C	Degrees Celsius
°F	Degrees Fahrenheit
A	Ampere/AMP
AC	Alternating current
AMA	Automatic motor adaptation
AWG	American wire gauge
DC	Direct current
EMC	Electro magnetic compatibility
ETR	Electronic thermal relay
FC	Frequency converter
$f_{M,N}$	Nominal motor frequency
kg	Kilogram
Hz	Hertz
$I_{INV}$	Rated inverter output current
$I_{LIM}$	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	The maximum output current
$I_{VLT,N}$	The rated output current supplied by the frequency converter
kHz	Kilohertz
LCP	Local control panel
m	Meter
mA	Milliampere
MCT	Motion control tool
mH	Millihenry inductance
min	Minute
ms	Millisecond
nF	Nanofarad
Nm	Newton meters
$n_s$	Synchronous motor speed
$P_{M,N}$	Nominal motor power
PCB	Printed circuit board
PELV	Protective extra low voltage
Regen	Regenerative terminals
RPM	Revolutions per minute
s	Second
$T_{LIM}$	Torque limit
$U_{M,N}$	Nominal motor voltage
V	Volts

Table 1.3 Abbreviations

### 1.5 Additional Resources

- *VLT® HVAC Basic Drive FC 101 Quick Guide* provides basic information on mechanical dimensions, installation, and programming.
- *VLT® HVAC Basic Drive FC 101 Programming Guide* provides information on how to program, and includes complete parameter descriptions.
- Danfoss VLT® Energy Box software. Select *PC Software Download* at [www.danfoss.com/en/service-and-support/downloads/dds/vlt-energy-box/](http://www.danfoss.com/en/service-and-support/downloads/dds/vlt-energy-box/).

VLT® Energy Box software allows energy consumption comparisons of HVAC fans and pumps driven by Danfoss frequency converters and alternative methods of flow control. Use this tool to accurately project the costs, savings, and payback of using Danfoss frequency converters on HVAC fans, pumps, and cooling towers.

Danfoss technical literature is available in electronic form on the documentation CD that is shipped with the product, or in print from your local Danfoss sales office.

#### MCT 10 Set-up Software support

Download the software from [www.danfoss.com/en/service-and-support/downloads/dds/vlt-motion-control-tool-mct-10/](http://www.danfoss.com/en/service-and-support/downloads/dds/vlt-motion-control-tool-mct-10/).

During the installation process of the software, enter access code 81463800 to activate the FC 101 functionality. A license key is not required for using the FC 101 functionality.

The latest software does not always contain the latest updates for frequency converters. Contact the local sales office for the latest frequency converter updates (in the form of \*.upd files), or download the frequency converter updates from [www.danfoss.com/en/service-and-support/downloads/dds/vlt-motion-control-tool-mct-10/#Overview](http://www.danfoss.com/en/service-and-support/downloads/dds/vlt-motion-control-tool-mct-10/#Overview).

### 1.6 Definitions

#### Frequency converter

$I_{VLT, MAX}$

The maximum output current.

$I_{VLT,N}$

The rated output current supplied by the frequency converter.

$U_{VLT, MAX}$

The maximum output voltage.

#### Input

The connected motor can start and stop via LCP and digital inputs. Functions are divided into 2 groups, as described in *Table 1.4*. Functions in group 1 have higher priority than functions in group 2.

Group 1	Reset, coast stop, reset and coast stop, quick stop, DC brake, stop, and [Off].
Group 2	Start, pulse start, reversing, start reversing, jog, and freeze output.

Table 1.4 Control Commands

#### Motor

$f_{JOG}$

The motor frequency when the jog function is activated (via digital terminals).

$f_M$

The motor frequency.

$f_{MAX}$

The maximum motor frequency.

**f<sub>MIN</sub>**

The minimum motor frequency.

**f<sub>M,N</sub>**

The rated motor frequency (nameplate data).

**I<sub>M</sub>**

The motor current.

**I<sub>M,N</sub>**

The rated motor current (nameplate data).

**n<sub>M,N</sub>**

The nominal motor speed (nameplate data).

**P<sub>M,N</sub>**

The rated motor power (nameplate data).

**U<sub>M</sub>**

The instantaneous motor voltage.

**U<sub>M,N</sub>**

The rated motor voltage (nameplate data).

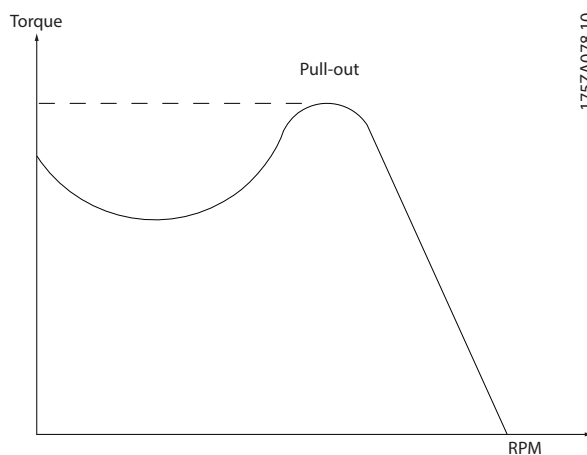
**Break-away torque**

Illustration 1.1 Break-away Torque

**η<sub>VLT</sub>**

The efficiency of the frequency converter is defined as the ratio between the power output and the power input.

**Start-disable command**

A stop command belonging to the group 1 control commands, see *Table 1.4*.

**Stop command**

See *Table 1.4*.

**Analog reference**

A signal transmitted to the analog inputs 53 or 54. It can be voltage or current.

- Current input: 0–20 mA and 4–20 mA
- Voltage input: 0–10 V DC

**Bus reference**

A signal transmitted to the serial communication port (FC port).

**Preset reference**

A defined preset reference to be set from -100% to +100% of the reference range. Selection of 8 preset references via the digital terminals.

**Ref<sub>MAX</sub>**

Determines the relationship between the reference input at 100% full scale value (typically 10 V, 20 mA) and the resulting reference. The maximum reference value is set in *parameter 3-03 Maximum Reference*.

**Ref<sub>MIN</sub>**

Determines the relationship between the reference input at 0% value (typically 0 V, 0 mA, 4 mA) and the resulting reference. The minimum reference value is set in *parameter 3-02 Minimum Reference*.

**Analog inputs**

The analog inputs are used for controlling various functions of the frequency converter.

There are 2 types of analog inputs:

- Current input: 0–20 mA and 4–20 mA
- Voltage input: 0–10 V DC

**Analog outputs**

The analog outputs can supply a signal of 0–20 mA, 4–20 mA, or a digital signal.

**Automatic motor adaptation, AMA**

The AMA algorithm determines the electrical parameters for the connected motor at standstill and compensates for the resistance based on the length of the motor cable.

**Digital inputs**

The digital inputs can be used for controlling various functions of the frequency converter.

**Digital outputs**

The frequency converter provides 2 solid-state outputs that can supply a 24 V DC (maximum 40 mA) signal.

**Relay outputs**

The frequency converter provides 2 programmable relay outputs.

**ETR**

Electronic thermal relay is a thermal load calculation based on present load and time. Its purpose is to estimate the motor temperature and prevent overheating of the motor.

**Initializing**

If initializing is carried out (*parameter 14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.

*Parameter 14-22 Operation Mode* does not initialize communication parameters, fault log, or fire mode log.

**Intermittent duty cycle**

An intermittent duty rating refers to a sequence of duty cycles. Each cycle consists of an on-load and an off-load period. The operation can be either periodic duty or non-periodic duty.

**LCP**

The local control panel (LCP) makes up a complete interface for control and programming of the frequency converter. The control panel is detachable on IP20 units and fixed on IP54 units. It can be installed up to 3 m (9.8 ft) from the frequency converter, that is, in a front panel with the installation kit option.

**Lsb**

Least significant bit.

**MCM**

Short for mille circular mil, an American measuring unit for cable cross-section. 1 MCM = 0.5067 mm<sup>2</sup>.

**Msb**

Most significant bit.

**On-line/Off-line parameters**

Changes to on-line parameters are activated immediately after the data value is changed. Press [OK] to activate off-line parameters.

**PI controller**

The PI controller maintains the desired speed, pressure, temperature, and so on, by adjusting the output frequency to match the varying load.

**RCD**

Residual current device.

**Set-up**

Parameter settings in 2 set-ups can be saved. Change between the 2 parameter set-ups and edit 1 set-up, while another set-up is active.

**Slip compensation**

The frequency converter compensates for the motor slip by giving the frequency a supplement that follows the measured motor load keeping the motor speed almost constant.

**Smart logic control (SLC)**

The SLC is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC.

**Thermistor**

A temperature-dependent resistor placed where the temperature is to be monitored (frequency converter or motor).

**Trip**

A state entered in fault situations, for example, if the frequency converter is subject to an overtemperature or when the frequency converter is protecting the motor, process, or mechanism. Restart is prevented until the cause of the fault does not exist and the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

**Trip lock**

A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, for example, if the frequency converter is subject to a short circuit on the output. A locked trip can only be canceled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip lock for personal safety.

**VT characteristics**

Variable torque characteristics used for pumps and fans.

**VVC+**

If compared with standard voltage/frequency ratio control, voltage vector control (VVC+) improves the dynamics and the stability, both when the speed reference is changed and in relation to the load torque.

## 1.7 Power Factor

The power factor indicates to which extent the frequency converter imposes a load on the mains supply. The power factor is the ratio between  $I_1$  and  $I_{RMS}$ , where  $I_1$  is the fundamental current, and  $I_{RMS}$  is the total RMS current including harmonic currents. The lower the power factor, the higher the  $I_{RMS}$  for the same kW performance.

$$\text{Power factor} = \frac{\sqrt{3} \times U \times I_1 \times \cos\phi}{\sqrt{3} \times U \times I_{RMS}}$$

The power factor for 3-phase control:

$$\text{Power factor} = \frac{I_1 \times \cos\phi_1}{I_{RMS}} = \frac{I_1}{I_{RMS}} \text{ since } \cos\phi_1 = 1$$

$$I_{RMS} = \sqrt{I_1^2 + I_5^2 + I_7^2 + \dots + I_n^2}$$

A high-power factor indicates that the different harmonic currents are low.

The frequency converters built-in DC coils produce a high-power factor, which minimizes the imposed load on the mains supply.

## 1.8 Regulatory Compliance

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

### 1.8.1 CE Mark

The CE mark (Communauté Européenne) indicates that the product manufacturer conforms to all applicable EU directives. The EU directives applicable to the design and manufacture of frequency converters are listed in *Table 1.5*.

#### **NOTICE**

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

#### **NOTICE**

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

EU directive	Version
Low Voltage Directive	2014/35/EU
EMC Directive	2014/30/EU
ErP Directive	

Table 1.5 EU Directives Applicable to Frequency Converters

Declarations of conformity are available on request.

#### 1.8.1.1 Low Voltage Directive

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

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

#### 1.8.1.2 EMC Directive

The purpose of the EMC (electromagnetic compatibility) directive is to reduce electromagnetic interference and enhance immunity of electrical equipment and installations. The basic protection requirement of the EMC Directive 2014/30/EU states that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference and shall have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended.

Electrical equipment devices used alone or as part of a system must bear the CE mark. Systems do not require the

CE mark, but must comply with the basic protection requirements of the EMC directive.

#### 1.8.1.3 ErP Directive

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

### 1.8.2 UL Compliance

UL-listed



Illustration 1.2 UL

#### **NOTICE**

IP54 units are not certified for UL.

The frequency converter complies with UL 508C thermal memory retention requirements. For more information, refer to the section *Motor Thermal Protection* in the product-specific *design guide*.

### 1.8.3 RCM Mark Compliance



Illustration 1.3 RCM Mark

The RCM Mark label indicates compliance with the applicable technical standards for Electromagnetic Compatibility (EMC). An RCM Mark label is required for placing electrical and electronic devices on the market in Australia and New Zealand. The RCM Mark regulatory arrangements only deal with conducted and radiated emission. For frequency converters, the emission limits specified in EN/IEC 61800-3 apply. A declaration of conformity can be provided on request.

## 1.8.4 EAC



Illustration 1.4 EAC Mark

The EurAsian Conformity (EAC) mark indicates that the product conforms to all requirements and technical regulations applicable to the product per the EurAsian Customs Union, which is composed of the member states of the EurAsian Economic Union.

The EAC logo must be both on the product label and on the packaging label. All products used within the EAC area, must be bought at Danfoss inside the EAC area.

## 1.8.5 UkrSEPRO



Illustration 1.5 UkrSEPRO

UKrSEPRO certificate ensures quality and safety of both products and services, in addition to manufacturing stability according to Ukrainian regulatory standards. The UkrSepero certificate is a required document to clear customs for any products coming into and out of the territory of Ukraine.

## 2 Safety

### 2

### 2.1 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 or operate this equipment.

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

### 2.2 Safety Precautions

#### **⚠ WARNING**

##### HIGH VOLTAGE

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

- Only qualified personnel must perform installation, start-up, and maintenance.
- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that there is no remaining voltage on the frequency converter.

#### **⚠ WARNING**

##### UNINTENDED START

When the drive is connected to AC mains, DC supply, or load sharing, the motor can 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 drive from the mains.
- Completely wire and assemble the drive, motor, and any driven equipment before connecting the drive to AC mains, DC supply, or load sharing.

#### **⚠ WARNING**

##### DISCHARGE TIME

The 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 [kW (hp)]	Minimum waiting time (minutes)
3x200	0.25–3.7 (0.33–5)	4
3x200	5.5–11 (7–15)	15
3x400	0.37–7.5 (0.5–10)	4
3x400	11–90 (15–125)	15
3x600	2.2–7.5 (3–10)	4
3x600	11–90 (15–125)	15

Table 2.1 Discharge Time

#### **⚠ 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 manual.

**⚠ 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.

### 3 Product Overview

#### 3.1 Advantages

3

##### 3.1.1 Why use a Frequency Converter for Controlling Fans and Pumps?

A frequency converter takes advantage of the fact that centrifugal fans and pumps follow the laws of proportionality for such fans and pumps. For further information, see *chapter 3.1.3 Example of Energy Savings*.

##### 3.1.2 The Clear Advantage - Energy Savings

The clear advantage of using a frequency converter for controlling the speed of fans or pumps lies in the electricity savings.

When comparing with alternative control systems and technologies, a frequency converter is the optimum energy control system for controlling fan and pump systems.

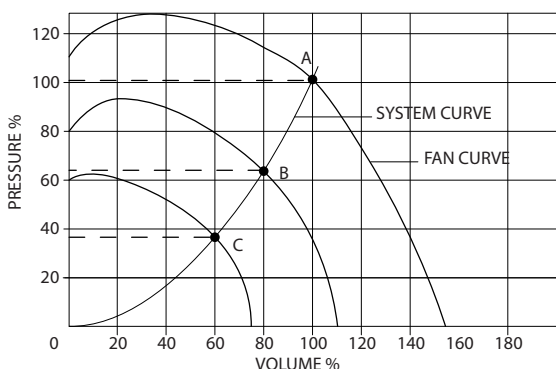


Illustration 3.1 Fan Curves (A, B, and C) for Reduced Fan Volumes

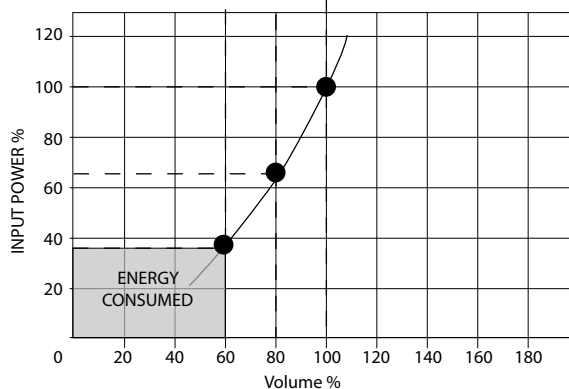
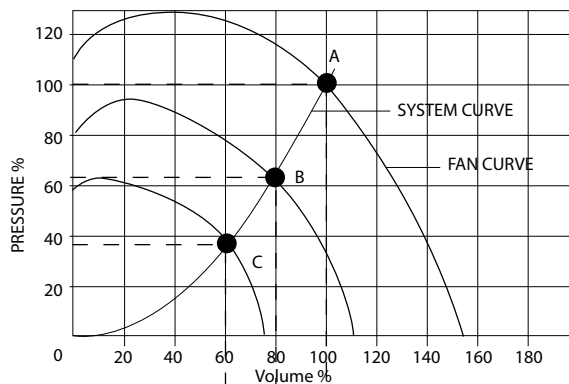


Illustration 3.2 Energy Savings with Frequency Converter Solution

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

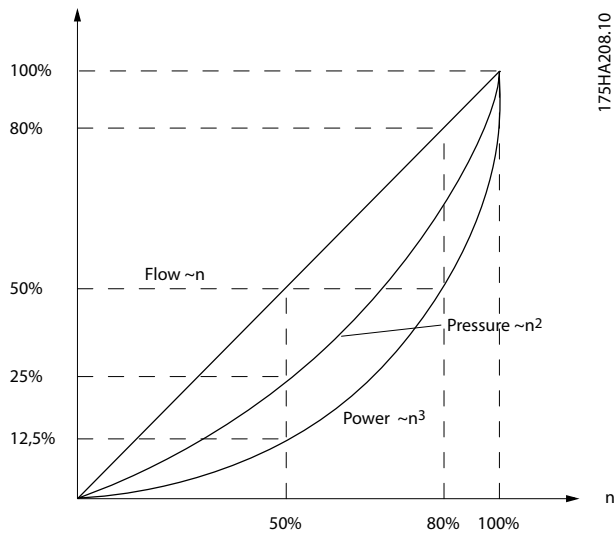
##### 3.1.3 Example of Energy Savings

As shown in *Illustration 3.3*, the flow is controlled by changing the RPM. By reducing the speed by only 20% from the rated speed, the flow is also reduced by 20%. This is because the flow is directly proportional to the RPM. The consumption of electricity, however, is reduced by 50%.

If the system in question only needs to be able to supply a flow that corresponds to 100% a few days in a year, while the average is below 80% of the rated flow for the remainder of the year, the amount of energy saved is even more than 50%.



Illustration 3.3 describes the dependence of flow, pressure, and power consumption on RPM.



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Illustration 3.3 Laws of Proportionality

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

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

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

Q = Flow	P = Power
Q <sub>1</sub> = Rated flow	P <sub>1</sub> = Rated power
Q <sub>2</sub> = Reduced flow	P <sub>2</sub> = Reduced power
H = Pressure	n = Speed control
H <sub>1</sub> = Rated pressure	n <sub>1</sub> = Rated speed
H <sub>2</sub> = Reduced pressure	n <sub>2</sub> = Reduced speed

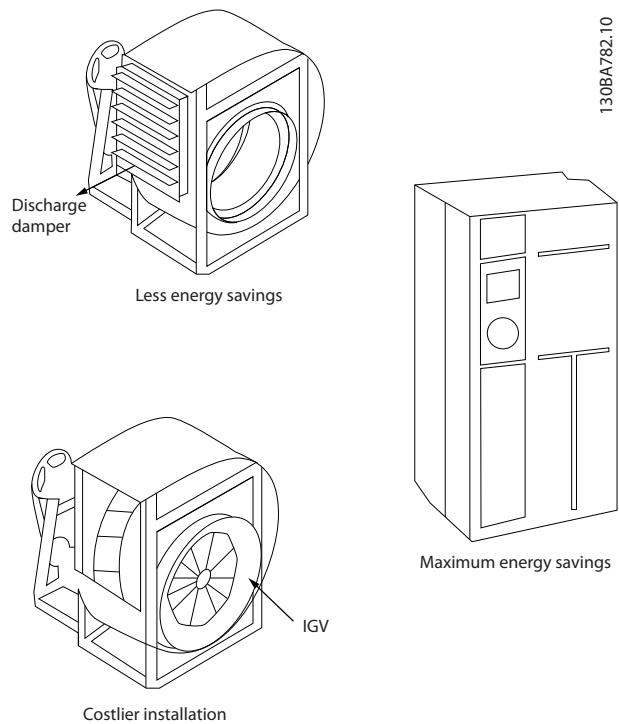
Table 3.1 The Laws of Proportionality

### 3.1.4 Comparison of Energy Savings

The Danfoss frequency converter solution offers major savings compared with traditional energy saving solutions such as discharge damper solution and inlet guide vanes (IGV) solution. This is because the frequency converter is able to control fan speed according to thermal load on the system, and the frequency converter has a built-in facility that enables the frequency converter to function as a building management system, BMS.

Illustration 3.3 shows typical energy savings obtainable with 3 well-known solutions when fan volume is reduced to 60%.

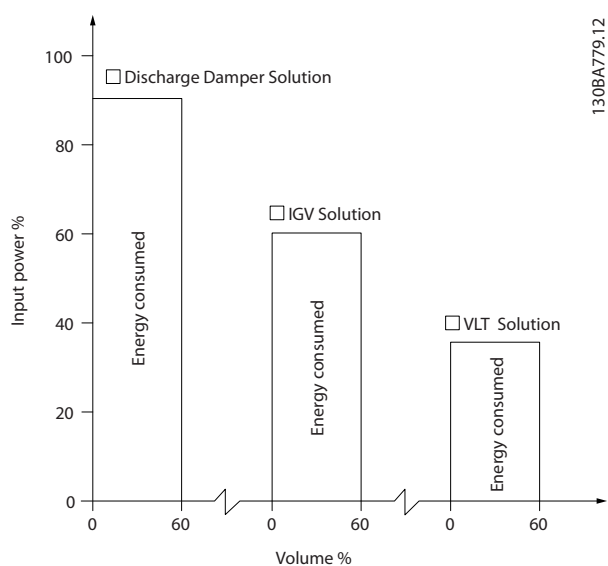
As the graph shows, more than 50% energy savings can be achieved in typical applications.



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Illustration 3.4 The 3 Common Energy Saving Systems



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Illustration 3.5 Energy Savings

Discharge dampers reduce power consumption. Inlet guide vanes offer a 40% reduction, but are expensive to install. The Danfoss frequency converter solution reduces energy consumption with more than 50% and is easy to install. It also reduces noise, mechanical stress, and wear-and-tear, and extends the life span of the entire application.

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### 3.1.5 Example with Varying Flow over 1 Year

This example is calculated based on pump characteristics obtained from a pump datasheet.

The result obtained shows energy savings of more than 50% at the given flow distribution over a year. The payback period depends on the price per kWh and the price of frequency converter. In this example, it is less than a year when compared with valves and constant speed.

#### Energy savings

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

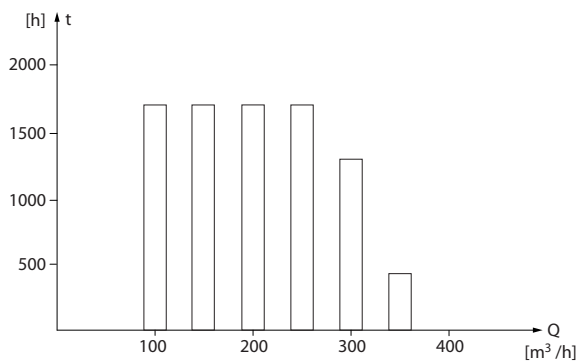


Illustration 3.6 Flow Distribution over 1 Year

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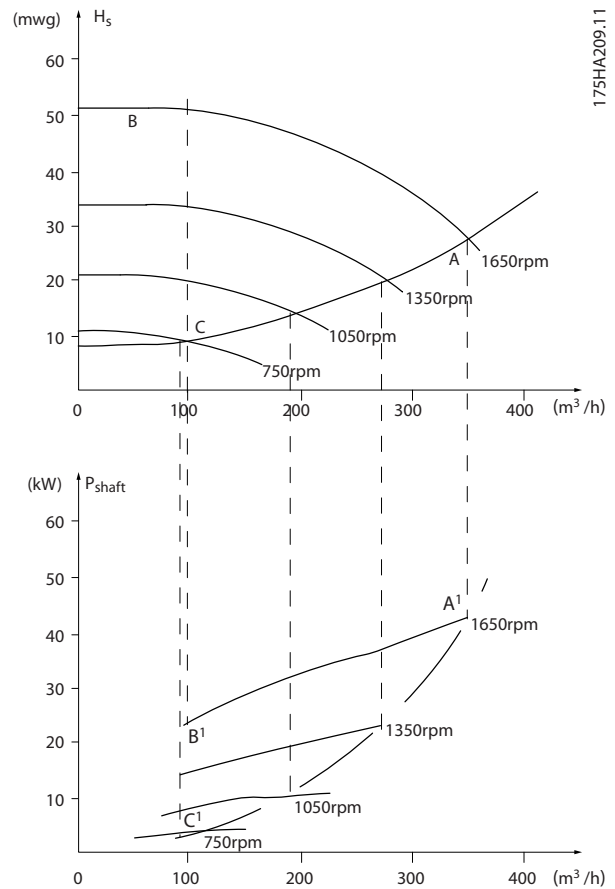


Illustration 3.7 Energy

m³/h	Distri-bution		Valve regulation		Frequency converter control	
	%	Hours	Power	Consump-tion	Power	Consump-tion
			A <sub>1</sub> - B <sub>1</sub>	kWh	A <sub>1</sub> - C <sub>1</sub>	kWh
350	5	438	42.5	18.615	42.5	18.615
300	15	1314	38.5	50.589	29.0	38.106
250	20	1752	35.0	61.320	18.5	32.412
200	20	1752	31.5	55.188	11.5	20.148
150	20	1752	28.0	49.056	6.5	11.388
100	20	1752	23.0	40.296	3.5	6.132
<b>Σ</b>	100	8760	-	275.064	-	26.801

Table 3.2 Result

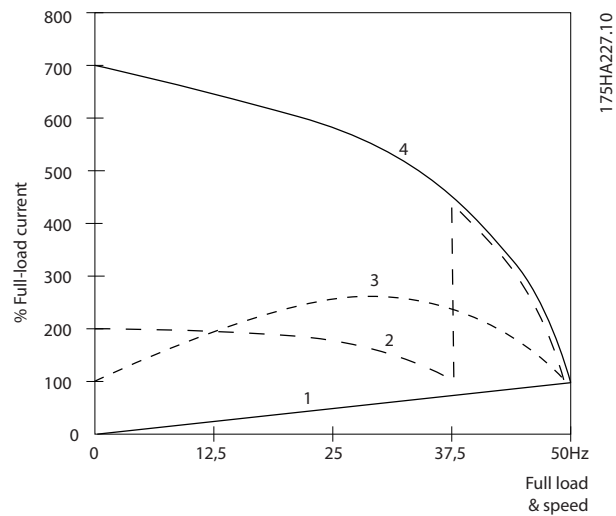
### 3.1.6 Better Control

If a frequency converter is used for controlling the flow or pressure of a system, improved control is obtained. A frequency converter can vary the speed of the fan or pump, obtaining variable control of flow and pressure. Furthermore, a frequency converter can quickly adapt the speed of the fan or pump to new flow or pressure conditions in the system. Simple control of process (flow, level, or pressure) utilizing the built-in PI control.

### 3.1.7 Star/Delta Starter or Soft Starter not Required

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

As illustrated in *Illustration 3.8*, a frequency converter does not consume more than rated current.



1	VLT® HVAC Basic Drive FC 101
2	Star/delta starter
3	Soft starter
4	Start directly on mains

Illustration 3.8 Start-up Current

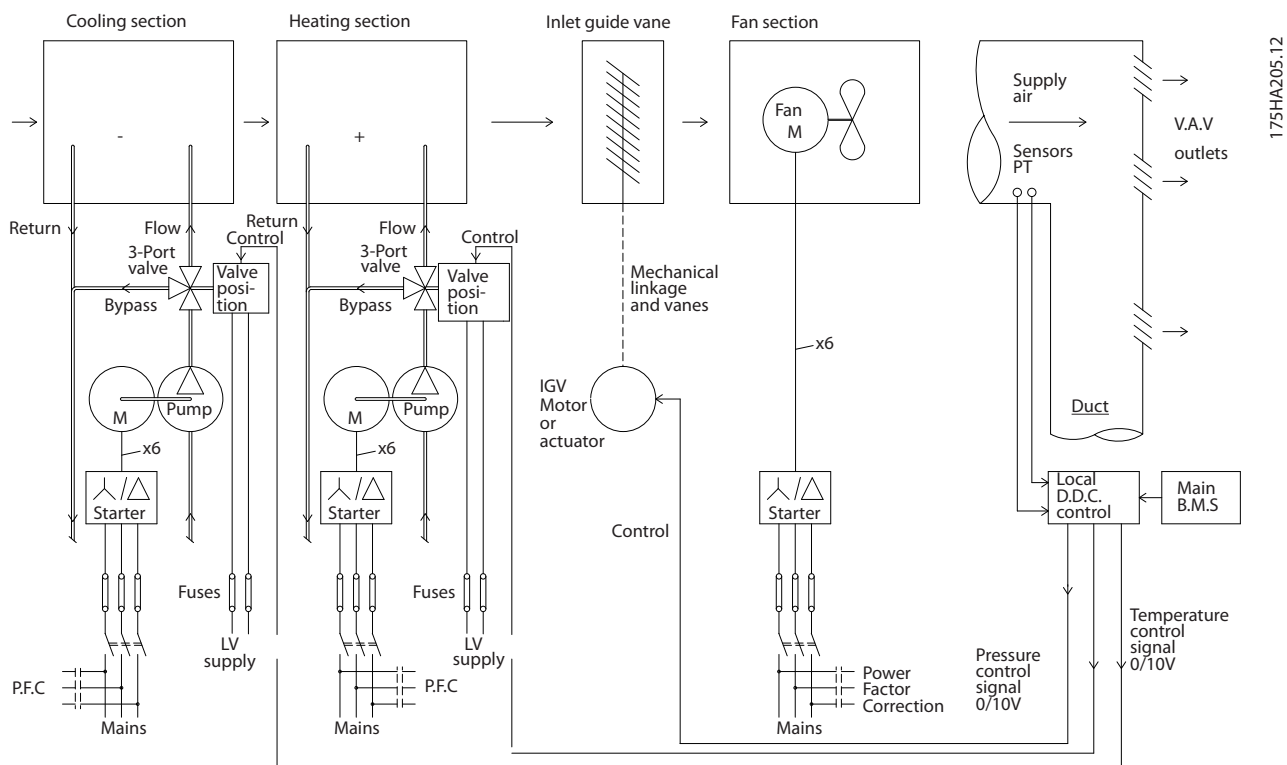
### 3.1.8 Using a Frequency Converter Saves Money

The example in *chapter 3.1.9 Without a Frequency Converter* shows that a frequency converter replaces other equipment. It is possible to calculate the cost of installing the 2 different systems. In the example, the 2 systems can be established at roughly the same price.

Use the VLT® Energy Box software that is introduced in *chapter 1.5 Additional Resources* to calculate the cost savings that can be achieved by using a frequency converter.

3.1.9 Without a Frequency Converter

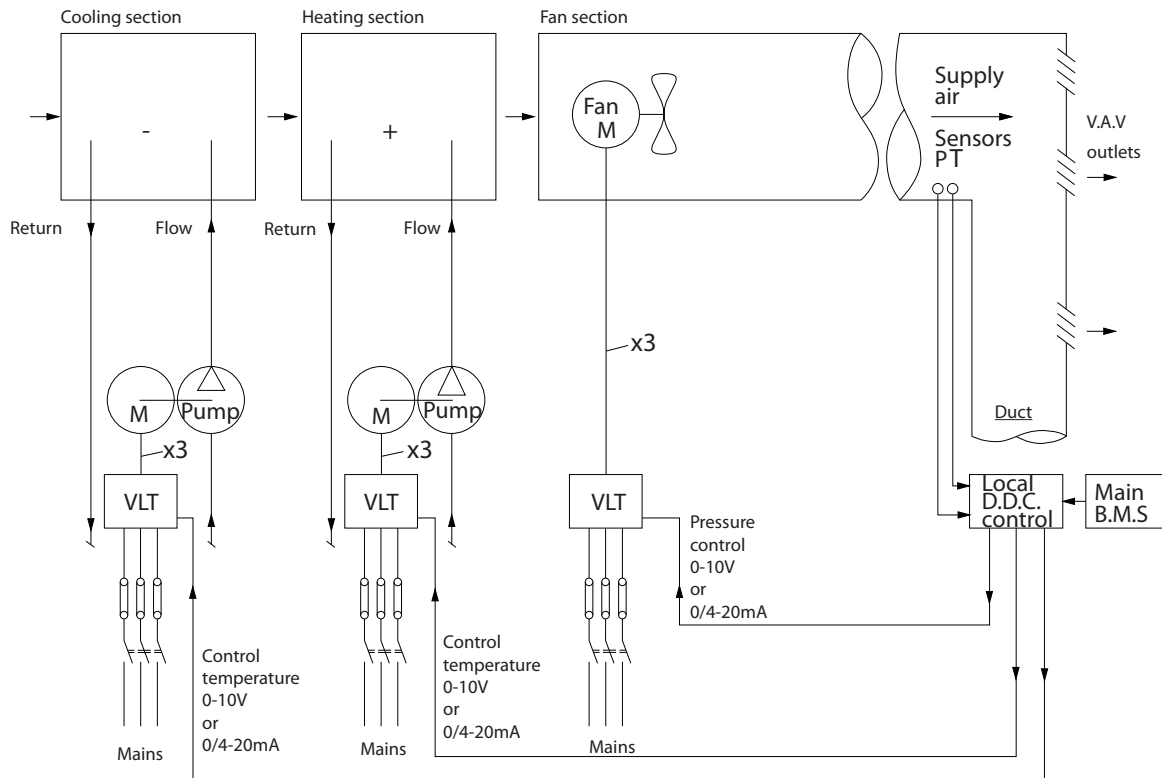
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D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

Illustration 3.9 Traditional Fan System

### 3.1.10 With a Frequency Converter



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D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

Illustration 3.10 Fan System Controlled by Frequency Converters

### 3.1.11 Application Examples

The following sections give typical examples of applications within HVAC.

### 3.1.12 Variable Air Volume

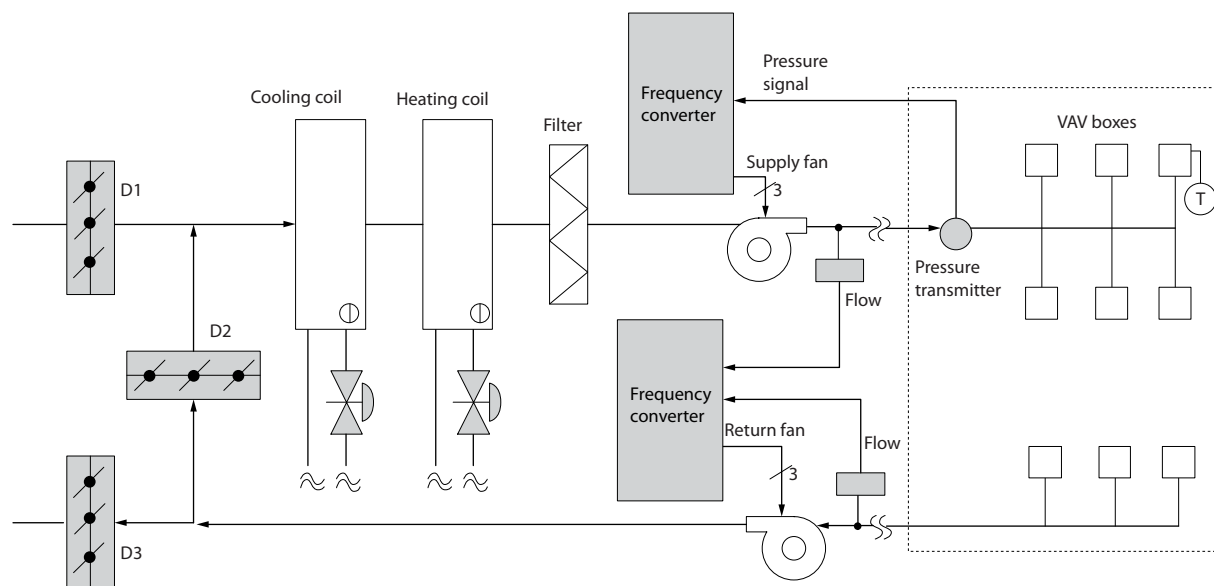
VAV or variable air volume systems, control both the ventilation and temperature to fulfill the requirements of a building. Central VAV systems are considered to be the most energy-efficient method to air condition buildings. By designing central systems instead of distributed systems, a greater efficiency can be obtained.

The efficiency comes from utilizing larger fans and larger chillers which have much higher efficiencies than small motors and distributed air-cooled chillers. Savings are also seen from the decreased maintenance requirements.

### 3.1.13 The VLT Solution

While dampers and IGVs work to maintain a constant pressure in the ductwork, a frequency converter solution saves much more energy and reduces the complexity of the installation. Instead of creating an artificial pressure drop or causing a decrease in fan efficiency, the frequency converter decreases the speed of the fan to provide the flow and pressure required by the system.

Centrifugal devices such as fans behave according to the centrifugal laws. This means that the fans decrease the pressure and flow they produce as their speed is reduced. Their power consumption is thereby significantly reduced. The PI controller of the VLT® HVAC Basic Drive FC 101 can be used to eliminate the need for additional controllers.



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Illustration 3.11 Variable Air Volume

### 3.1.14 Constant Air Volume

CAV, or constant air volume systems, are central ventilation systems usually used to supply large common zones with the minimum amounts of fresh tempered air. They preceded VAV systems and are therefore found in older multi-zoned commercial buildings as well. These systems preheat amounts of fresh air utilizing air handling units (AHUs) with a heating coil, and many are also used to air condition buildings and have a cooling coil. Fan coil units are frequently used to assist in the heating and cooling requirements in the individual zones.

### 3.1.15 The VLT Solution

With a frequency converter, significant energy savings can be obtained while maintaining decent control of the building. Temperature sensors or CO<sub>2</sub> sensors can be used as feedback signals to frequency converters. Whether controlling temperature, air quality, or both, a CAV system can be controlled to operate based on actual building conditions. As the number of people in the controlled area decreases, the need for fresh air decreases. The CO<sub>2</sub> sensor detects lower levels and decreases the supply fans speed. The return fan modulates to maintain a static pressure setpoint or fixed difference between the supply and return airflows.

With temperature control, especially used in air conditioning systems, as the outside temperature varies as well as the number of people in the controlled zone changes, different cooling requirements exist. As the temperature decreases below the setpoint, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure setpoint. By decreasing the air flow, energy used to heat or cool the fresh air is also reduced, adding further savings.

Several features of the Danfoss HVAC dedicated frequency converter can be utilized to improve the performance of the CAV system. One concern of controlling a ventilation system is poor air quality. The programmable minimum frequency can be set to maintain a minimum amount of supply air regardless of the feedback or reference signal. The frequency converter also includes a PI controller, which allows monitoring both temperature and air quality. Even if the temperature requirement is fulfilled, the frequency converter maintains enough supply air to satisfy the air quality sensor. The controller is capable of monitoring and comparing 2 feedback signals to control the return fan by maintaining a fixed differential airflow between the supply and return ducts as well.

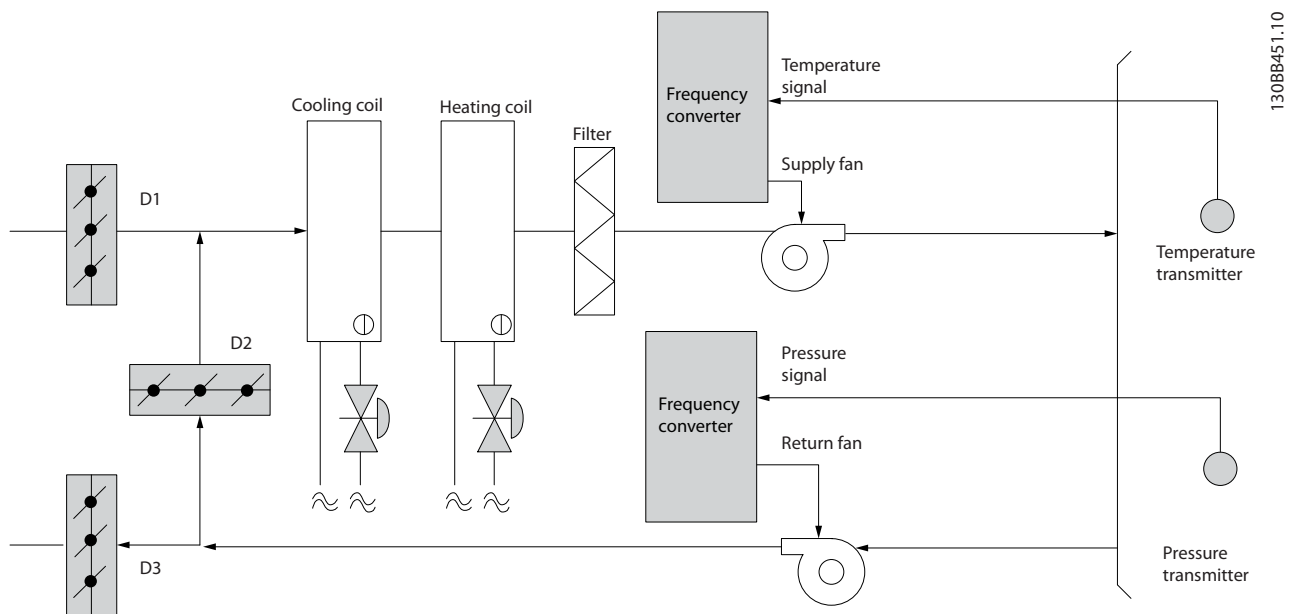


Illustration 3.12 Constant Air Volume

### 3.1.16 Cooling Tower Fan

Cooling tower fans cool condenser-water in water-cooled chiller systems. Water-cooled chillers provide the most efficient means of creating chilled water. They are as much as 20% more efficient than air cooled chillers. Depending on climate, cooling towers are often the most energy efficient method of cooling the condenser-water from chillers.

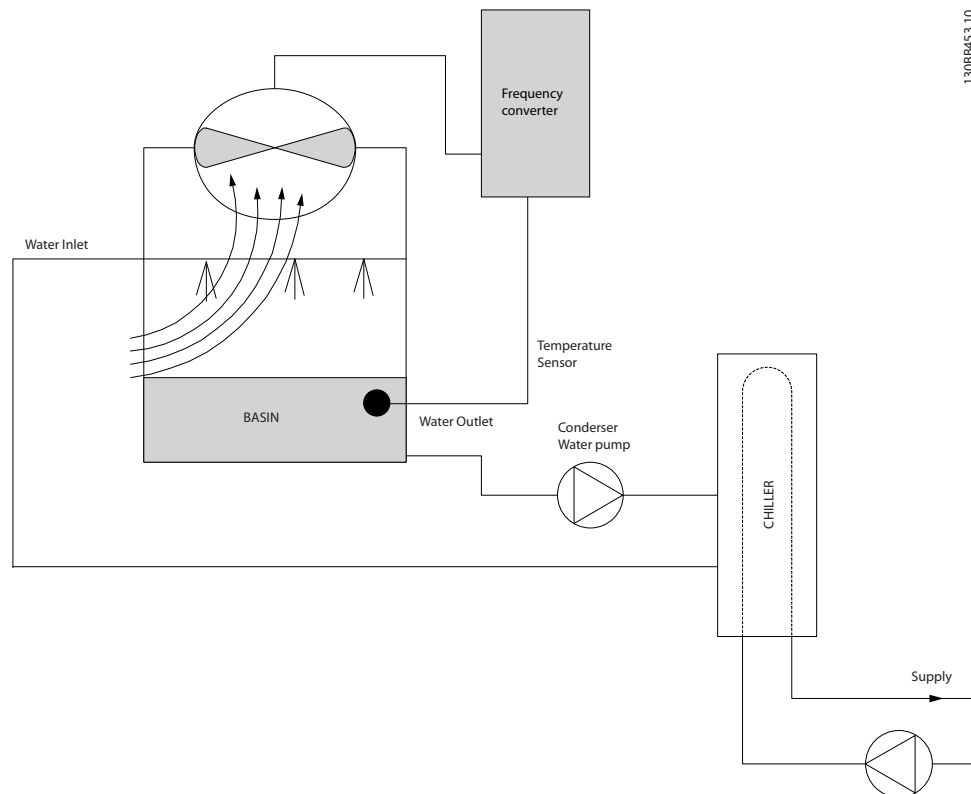
They cool the condenser water by evaporation. The condenser water is sprayed into the cooling tower until the cooling towers fill to increase its surface area. The tower fan blows air through the fill and sprayed water to aid in the evaporation. Evaporation removes energy from the water dropping its temperature. The cooled water collects in the cooling towers basin where it is pumped back into the chillers condenser and the cycle is repeated.

### 3.1.17 The VLT Solution

With a frequency converter, the cooling tower fans can be controlled to the required speed to maintain the condenser-water temperature. The frequency converters can also be used to turn the fan on and off as needed.

Several features of the Danfoss HVAC dedicated frequency converter can be utilized to improve the performance of cooling tower fans applications. As the cooling tower fans drop below a certain speed, the effect the fan has on cooling the water becomes small. Also, when utilizing a gearbox to frequency control the tower fan, a minimum speed of 40–50% is required. The customer programmable minimum frequency setting is available to maintain this minimum frequency even as the feedback or speed reference calls for lower speeds.

Also as a standard feature, the frequency converter can be programmed to enter a sleep mode and stop the fan until a higher speed is required. Additionally, some cooling tower fans have undesirable frequencies that may cause vibrations. These frequencies can easily be avoided by programming the bypass frequency ranges in the frequency converter.



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Illustration 3.13 Cooling Tower Fan



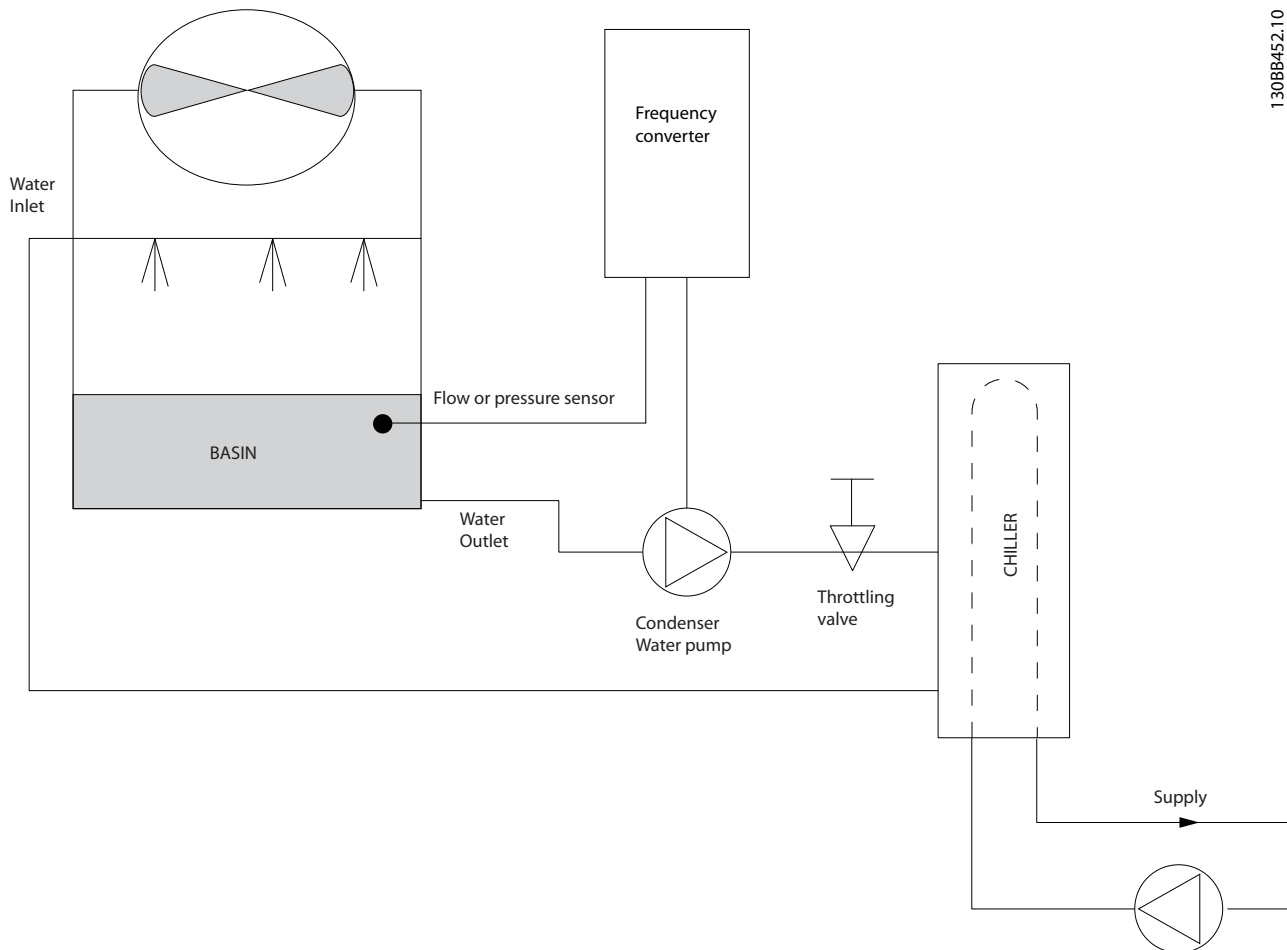
### 3.1.18 Condenser Pumps

Condenser water pumps are primarily used to circulate water through the condenser section of water cooled chillers and their associated cooling tower. The condenser water absorbs the heat from the chiller's condenser section and releases it into the atmosphere in the cooling tower. These systems are used to provide the most efficient means of creating chilled water, they are as much as 20% more efficient than air cooled chillers.

Using a frequency converter instead of a throttling valve simply saves the energy that would have been absorbed by the valve. This can amount to savings of 15–20% or more. Trimming the pump impeller is irreversible, thus if the conditions change and higher flow is required the impeller must be replaced.

### 3.1.19 The VLT Solution

Frequency converters can be added to condenser water pumps instead of balancing the pumps with a throttling valve or trimming the pump impeller.



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Illustration 3.14 Condenser Pumps

### 3.1.20 Primary Pumps

Primary pumps in a primary/secondary pumping system can be used to maintain a constant flow through devices that encounter operation or control difficulties when exposed to variable flow. The primary/secondary pumping technique decouples the primary production loop from the secondary distribution loop. This allows devices such as chillers to obtain constant design flow and operate properly while allowing the rest of the system to vary in flow.

As the evaporator flow rate decreases in a chiller, the chilled water begins to become overchilled. As this happens, the chiller attempts to decrease its cooling capacity. If the flow rate drops far enough, or too quickly, the chiller cannot shed its load sufficiently and the chiller's safety trips the chiller requiring a manual reset. This situation is common in large installations especially when 2 or more chillers in parallel are installed if primary/secondary pumping is not utilized.

### 3.1.21 The VLT Solution

Depending on the size of the system and the size of the primary loop, the energy consumption of the primary loop can become substantial.

A frequency converter can be added to the primary system to replace the throttling valve and/or trimming of the impellers, leading to reduced operating expenses. 2 control methods are common:

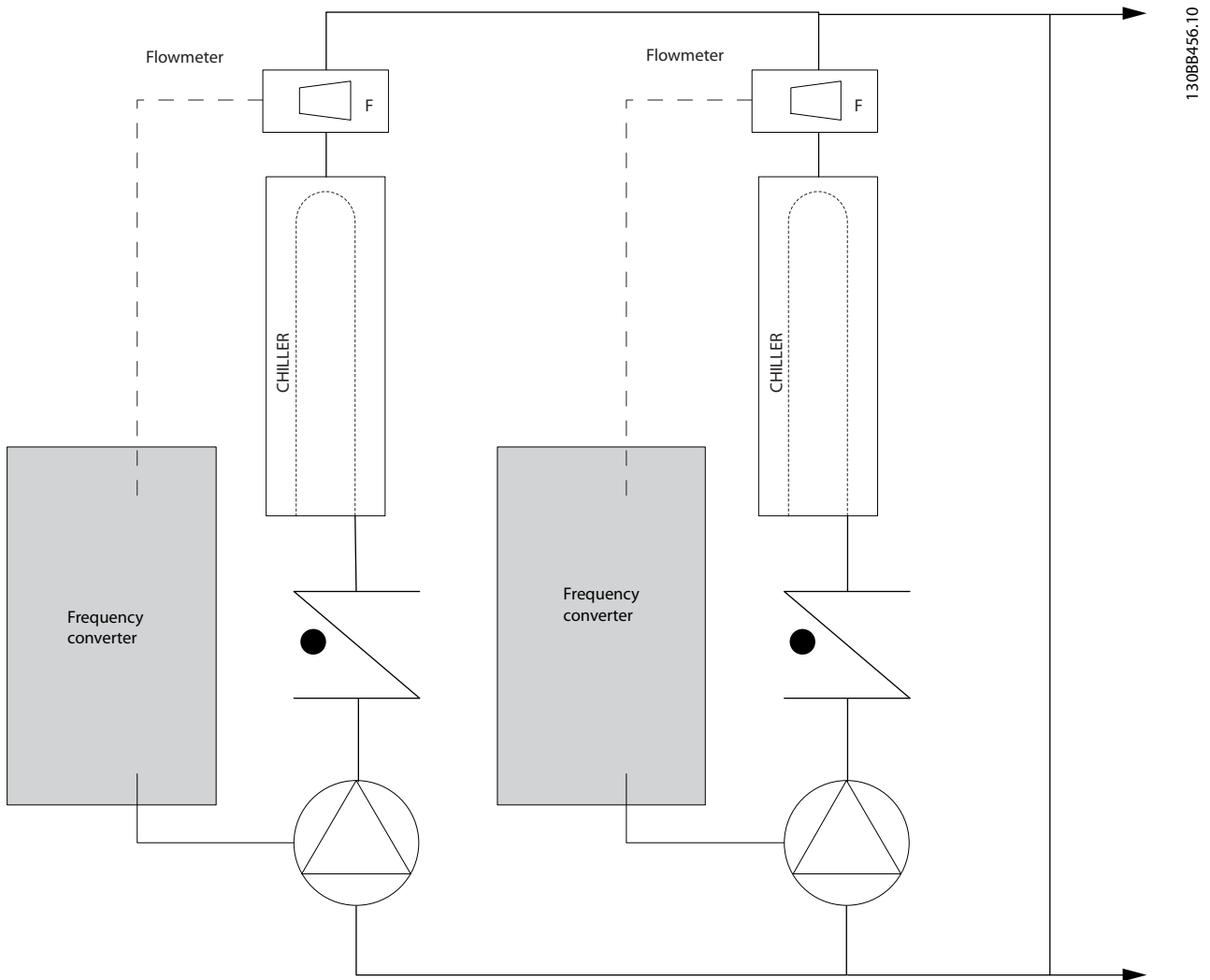
#### Flow meter

Because the desired flow rate is known and is constant, a flow meter installed at the discharge of each chiller, can be used to control the pump directly. Using the built-in PI controller, the frequency converter always maintains the appropriate flow rate, even compensating for the changing resistance in the primary piping loop as chillers and their pumps are staged on and off.

#### Local speed determination

The operator simply decreases the output frequency until the design flow rate is achieved.

Using a frequency converter to decrease the pump speed is very similar to trimming the pump impeller, except it does not require any labor, and the pump efficiency remains higher. The balancing contractor simply decreases the speed of the pump until the proper flow rate is achieved and leaves the speed fixed. The pump operates at this speed any time the chiller is staged on. Because the primary loop does not have control valves or other devices that can cause the system curve to change, and the variance due to staging pumps and chillers on and off is usually small, this fixed speed remains appropriate. If the flow rate needs to be increased later in the system's life, the frequency converter can simply increase the pump speed instead of requiring a new pump impeller.



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Illustration 3.15 Primary Pumps

### 3.1.22 Secondary Pumps

Secondary pumps in a primary/secondary chilled water pumping system distribute the chilled water to the loads from the primary production loop. The primary/secondary pumping system is used to hydraulically de-couple 1 piping loop from another. In this case, the primary pump is used to maintain a constant flow through the chillers while allowing the secondary pumps to vary in flow, increase control and save energy.

If the primary/secondary concept is not used in the design of a variable volume system when the flow rate drops far enough or too quickly, the chiller cannot shed its load properly. The chiller's low evaporator temperature safety then trips the chiller requiring a manual reset. This situation is common in large installations especially when 2 or more chillers in parallel are installed.

### 3.1.23 The VLT Solution

While the primary-secondary system with 2-way valves improves energy savings and eases system control problems, the true energy savings and control potential is realized by adding frequency converters.

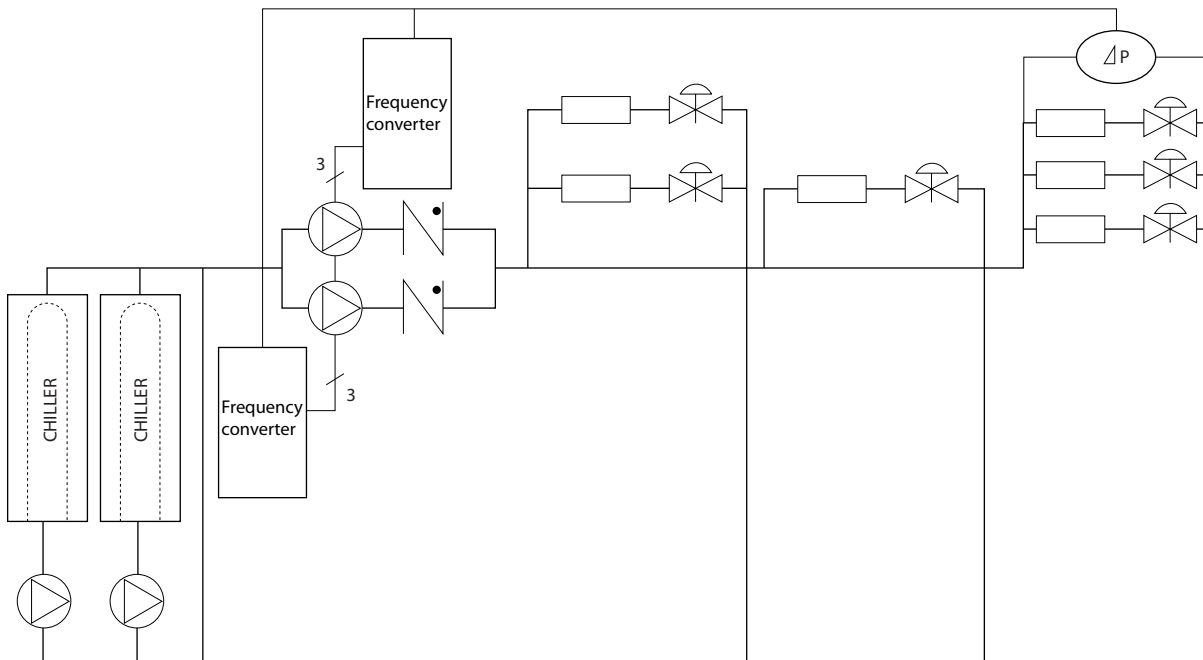
With the proper sensor location, the addition of frequency converters allows the pumps to vary their speed to follow the system curve instead of the pump curve.

This results in the elimination of wasted energy and eliminates most of the overpressurization that 2-way valves can be subjected to.

As the monitored loads are reached, the 2-way valves close down. This increases the differential pressure measured across the load and the 2-way valve. As this differential pressure starts to rise, the pump is slowed to maintain the control head also called setpoint value. This setpoint value is calculated by summing the pressure drop of the load and the 2-way valve together under design conditions.

#### NOTICE

**When running multiple pumps in parallel, they must run at the same speed to maximize energy savings, either with individual dedicated frequency converters or 1 frequency converter running multiple pumps in parallel.**



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Illustration 3.16 Secondary Pumps

### 3.2 Control Structures

Select [0] Open loop or [1] Closed loop in parameter 1-00 Configuration Mode.

#### 3.2.1 Control Structure Open Loop

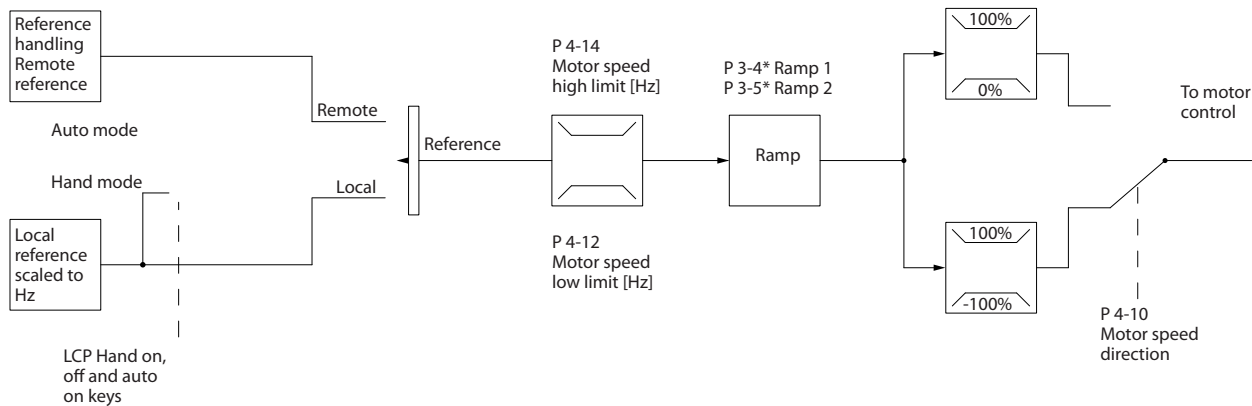


Illustration 3.17 Open-loop Structure

In the configuration shown in *Illustration 3.17*, parameter 1-00 Configuration Mode is set to [0] Open loop. The resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output from the motor control is then limited by the maximum frequency limit.

#### 3.2.2 PM/EC+ Motor Control

The Danfoss EC+ concept provides the possibility for using high-efficient PM motors (permanent magnet motors) in IEC standard enclosure sizes operated by Danfoss frequency converters.

The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by utilizing the Danfoss VVC+ PM control strategy.

Customer advantages:

- Free choice of motor technology (permanent magnet or induction motor).
- Installation and operation as know on induction motors.
- Manufacturer independent when selecting system components (for example, motors).
- Best system efficiency by selecting best components.
- Possible retrofit of existing installations.
- Power range: 45 kW (60 hp) (200 V), 0.37–90 kW (0.5–121 hp) (400 V), 90 kW (121 hp) (600 V) for

induction motors and 0.37–22 kW (0.5–30 hp) (400 V) for PM motors.

Current limitations for PM motors:

- Currently only supported up to 22 kW (30 hp).
- LC filters are not supported with PM motors.
- Kinetic back-up algorithm is not supported with PM motors.
- Support only complete AMA of the stator resistance  $R_s$  in the system.
- No stall detection (supported from software version 2.80).

#### 3.2.3 Local (Hand On) and Remote (Auto On) Control

The frequency converter can be operated manually via the local control panel (LCP) or remotely via analog/digital inputs or serial bus. If allowed in parameter 0-40 [Hand on] Key on LCP, parameter 0-44 [Off/Reset] Key on LCP, and parameter 0-42 [Auto on] Key on LCP, it is possible to start and stop the frequency converter via LCP by pressing [Hand On] and [Off/Reset]. Alarms can be reset via the [Off/Reset] key.

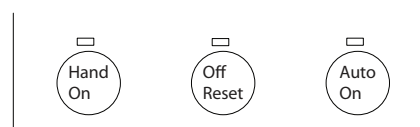


Illustration 3.18 LCP Keys

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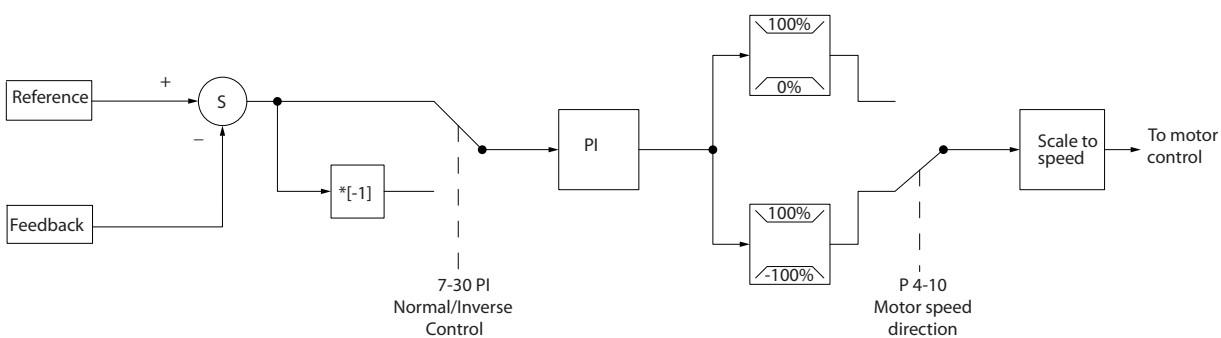
Local reference forces the configuration mode to open-loop, independent on the setting of parameter 1-00 Configuration Mode.

Local reference is restored at power-down.

### 3.2.4 Control Structure Closed Loop

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

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



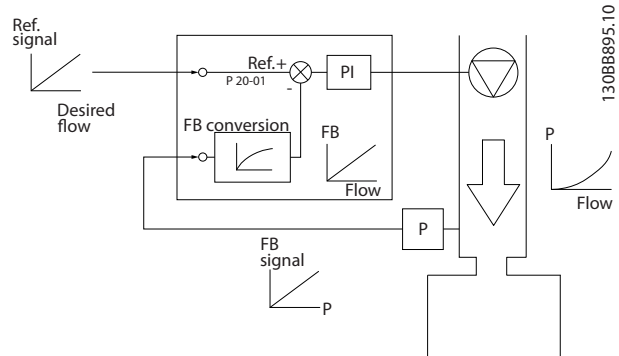
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Illustration 3.19 Control Structure Closed-loop

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

### 3.2.5 Feedback Conversion

In some applications, it may be useful to convert the feedback signal. One example of this is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow. See Illustration 3.20.

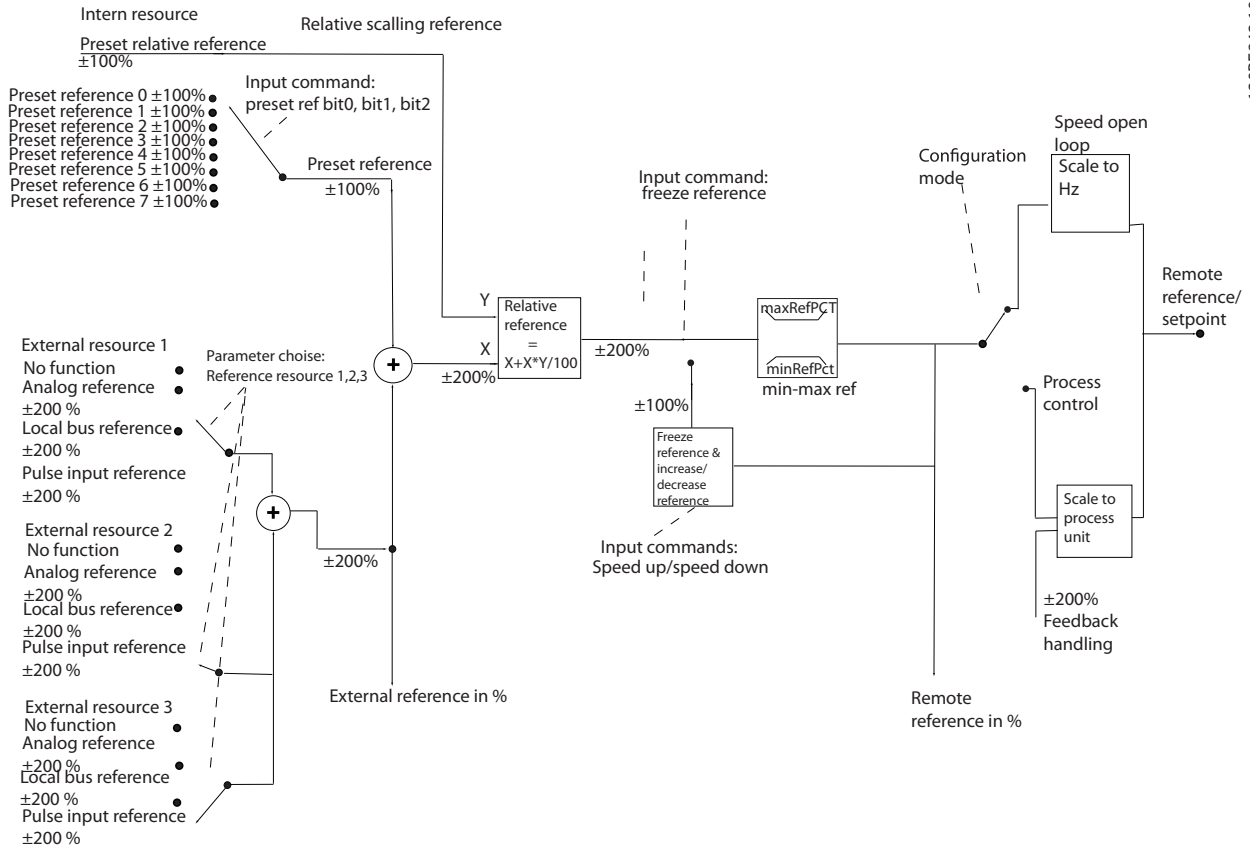


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Illustration 3.20 Feedback Signal Conversion

### 3.2.6 Reference Handling

Details for open-loop and closed-loop operation.



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Illustration 3.21 Block Diagram Showing Remote Reference

The remote reference consists of:

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

Up to 8 preset references can be programmed in the frequency converter. The active preset reference can be selected using digital inputs or the serial communications bus. The reference can also be supplied externally, most commonly from an analog input. This external source is selected by 1 of the 3 reference source parameters (*parameter 3-15 Reference 1 Source*, *parameter 3-16 Reference 2 Source*, and *parameter 3-17 Reference 3 Source*). All reference resources and the bus reference are added to produce the total external reference. The external reference, the preset reference, or the sum of the 2 can be selected to be the active reference. Finally, this reference can be scaled using *parameter 3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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

### 3.2.7 Tuning the Drive Closed-loop Controller

Once the frequency converter's closed-loop controller has been set up, test the performance of the controller. Often, its performance may be acceptable using the default values of *parameter 20-93 PI Proportional Gain* and *parameter 20-94 PI Integral Time*. However, sometimes it may be helpful to optimize these parameter values to provide faster system response while still controlling speed overshoot.

### 3.2.8 Manual PI Adjustment

1. Start the motor.
2. Set *parameter 20-93 PI Proportional Gain* to 0.3 and increase it until the feedback signal begins to oscillate. If necessary, start and stop the frequency converter or make step changes in the setpoint reference to attempt to cause oscillation.
3. Reduce the PI proportional gain until the feedback signal stabilizes.
4. Reduce the proportional gain by 40–60%.
5. Set *parameter 20-94 PI Integral Time* to 20 s and reduce it until the feedback signal begins to oscillate. If necessary, start and stop the frequency converter or make step changes in the setpoint reference to attempt to cause oscillation.
6. Increase the PI integral time until the feedback signal stabilizes.
7. Increase the integral time by 15–50%.

### 3.3 Ambient Running Conditions

The frequency converter has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 9.4.2.2 at 50 °C (122 °F).

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 is operated at high ambient temperature, decrease the continuous output current.

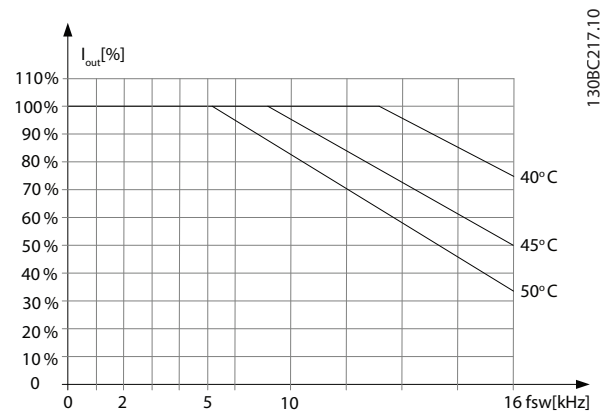


Illustration 3.22 0.25–0.75 kW (0.34–1.0 hp), 200 V, Enclosure Size H1, IP20

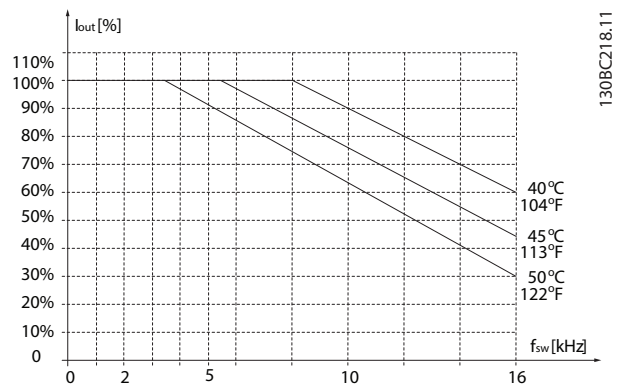


Illustration 3.23 0.37–1.5 kW (0.5–2.0 hp), 400 V, Enclosure Size H1, IP20

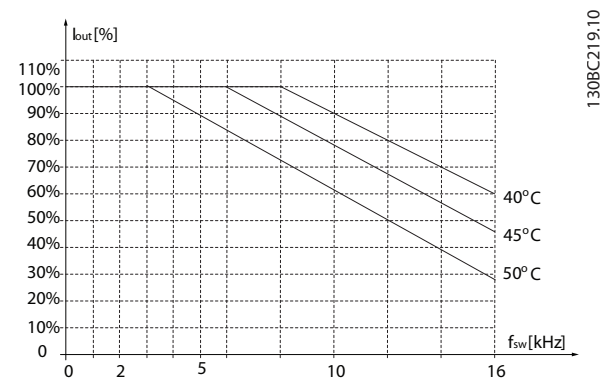


Illustration 3.24 2.2 kW (3.0 hp), 200 V, Enclosure Size H2, IP20



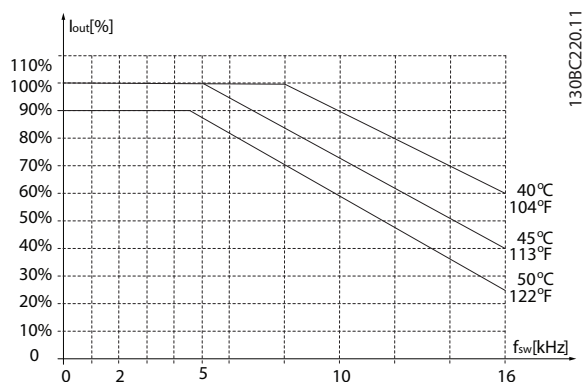


Illustration 3.25 2.2–4.0 kW (3.0–5.4 hp), 400 V, Enclosure Size H2, IP20

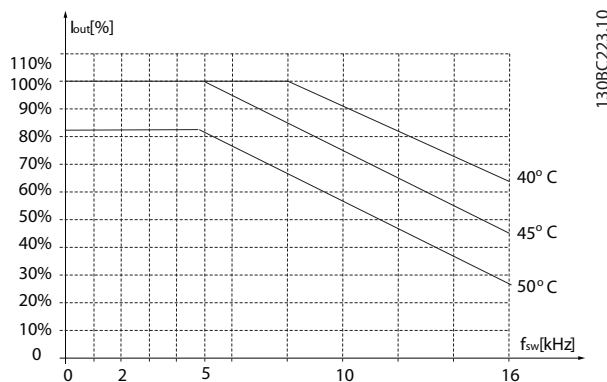


Illustration 3.28 5.5–7.5 kW (7.4–10 hp), 200 V, Enclosure Size H4, IP20

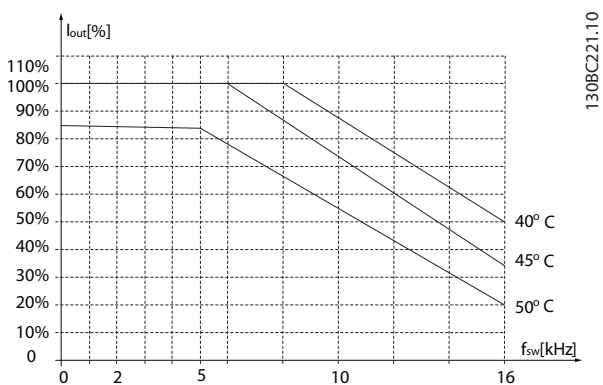


Illustration 3.26 3.7 kW (5.0 hp), 200 V, Enclosure Size H3, IP20

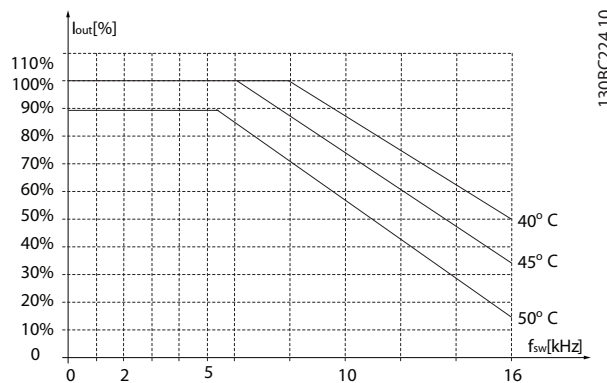


Illustration 3.29 11–15 kW (15–20 hp), 400 V, Enclosure Size H4, IP20

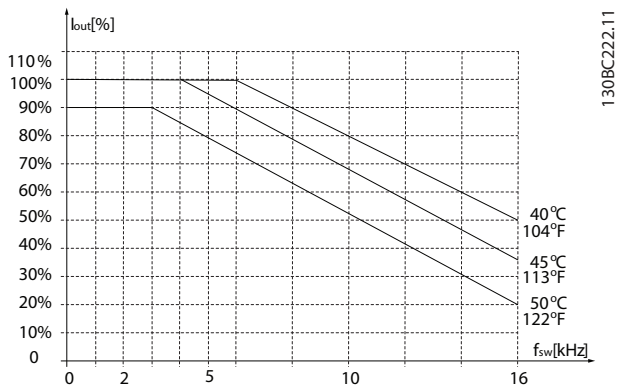


Illustration 3.27 5.5–7.5 kW (7.4–10 hp), 400 V, Enclosure Size H3, IP20

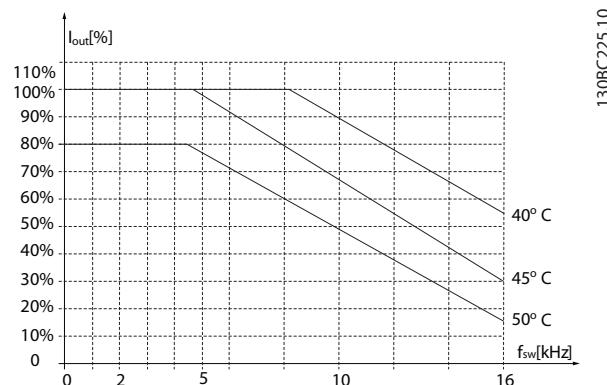


Illustration 3.30 11 kW (15 hp), 200 V, Enclosure Size H5, IP20

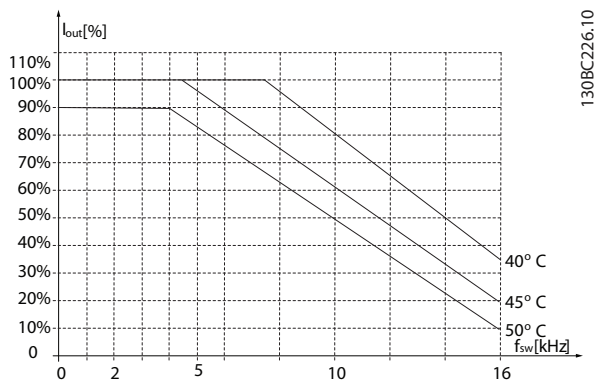


Illustration 3.31 18.5–22 kW (25–30 hp), 400 V, Enclosure Size H5, IP20

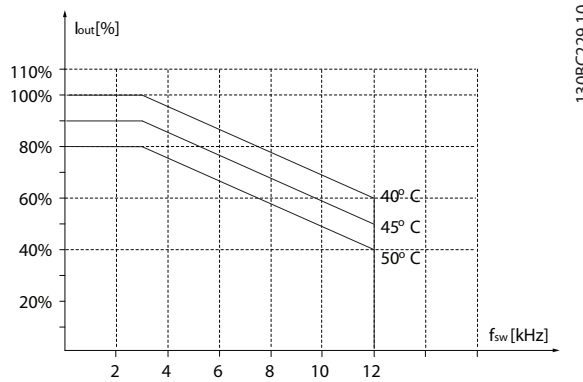


Illustration 3.34 45 kW (60 hp), 400 V, Enclosure Size H6, IP20

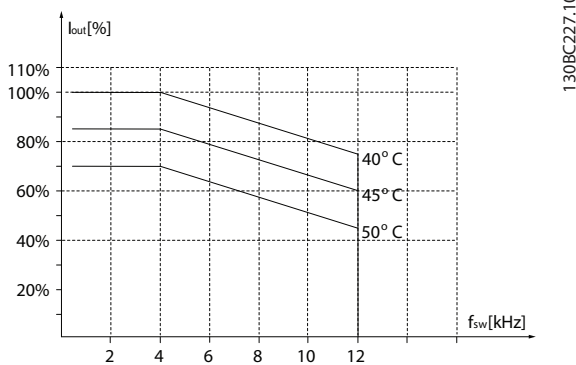


Illustration 3.32 15–18.5 kW (20–25 hp), 200 V, Enclosure Size H6, IP20

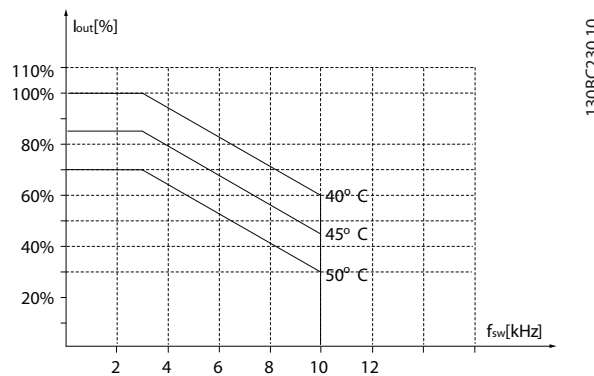


Illustration 3.35 22–30 kW (30–40 hp), 600 V, Enclosure Size H6, IP20

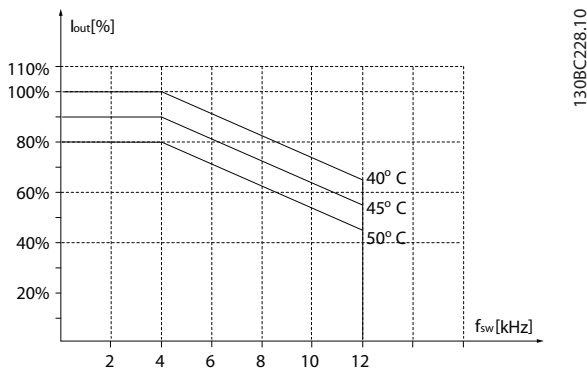


Illustration 3.33 30–37 kW (40–50 hp), 400 V, Enclosure Size H6, IP20

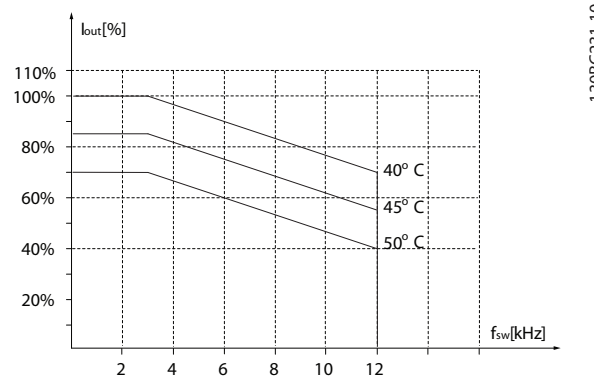


Illustration 3.36 22–30 kW (30–40 hp), 200 V, Enclosure Size H7, IP20

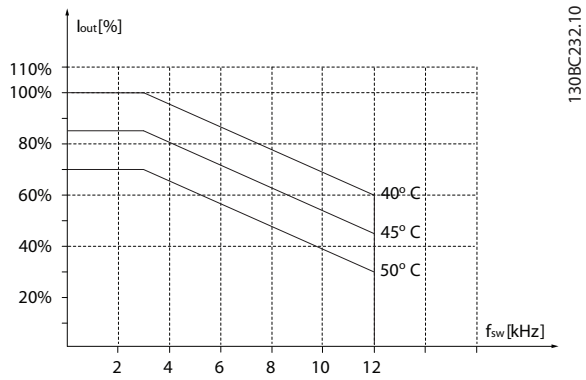


Illustration 3.37 55–75 kW (74–100 hp), 400 V, Enclosure Size H7, IP20

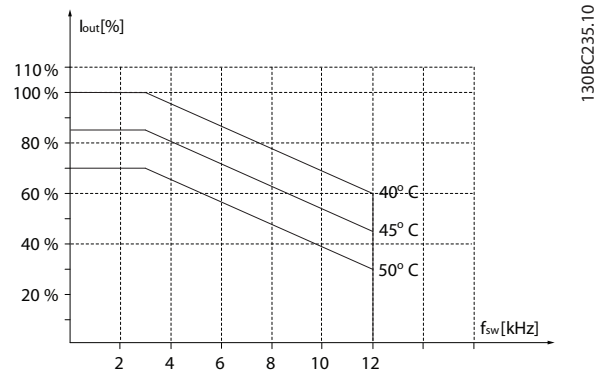


Illustration 3.40 90 kW (120 hp), 400 V, Enclosure Size H8, IP20

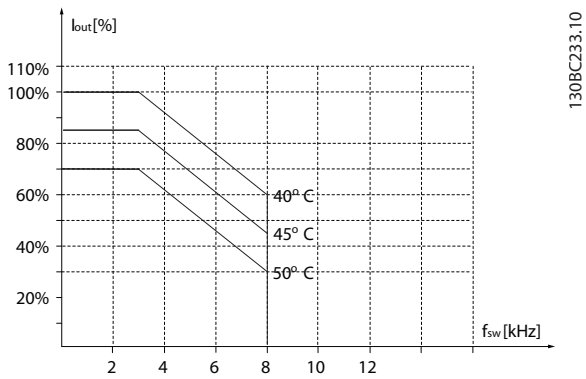


Illustration 3.38 45–55 kW (60–74 hp), 600 V, Enclosure Size H7, IP20

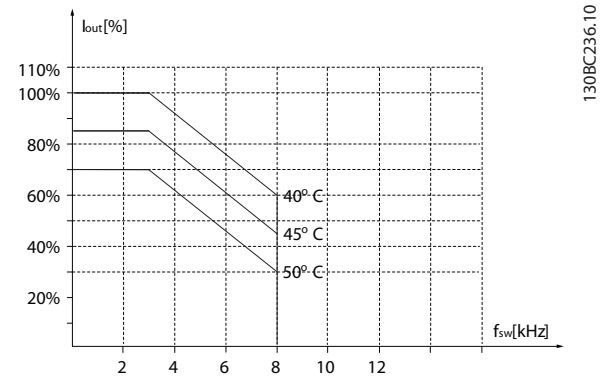


Illustration 3.41 75–90 kW (100–120 hp), 600 V, Enclosure Size H8, IP20

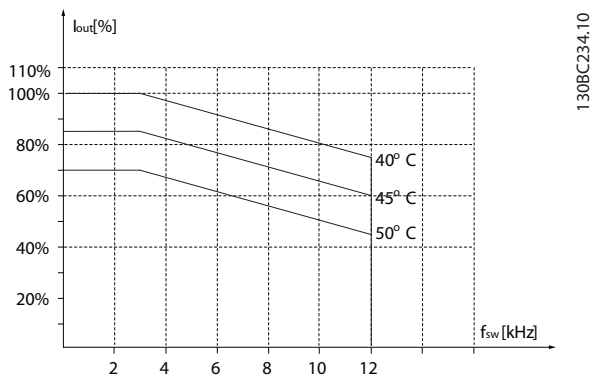


Illustration 3.39 37–45 kW (50–60 hp), 200 V, Enclosure Size H8, IP20

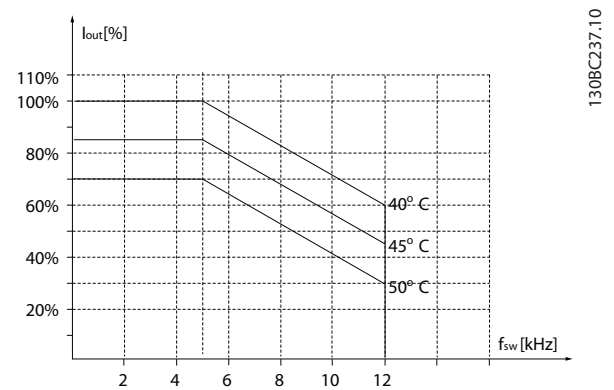


Illustration 3.42 2.2–3 kW (3.0–4.0 hp), 600 V, Enclosure Size H9, IP20

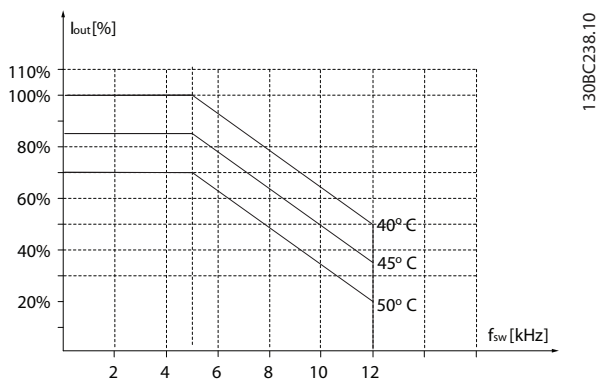


Illustration 3.43 5.5–7.5 kW (7.4–10 hp), 600 V, Enclosure Size H9, IP20

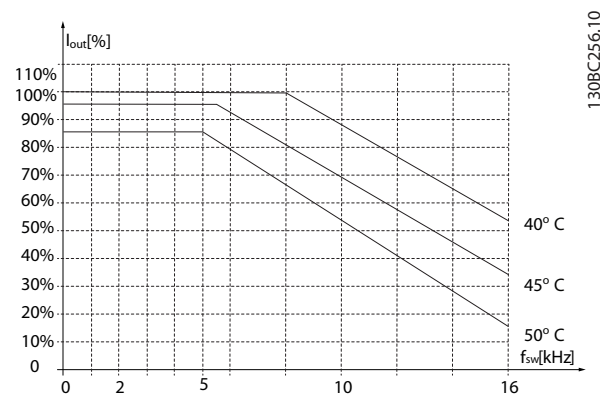


Illustration 3.46 5.5–7.5 kW (7.4–10 hp), 400 V, Enclosure Size I3, IP54

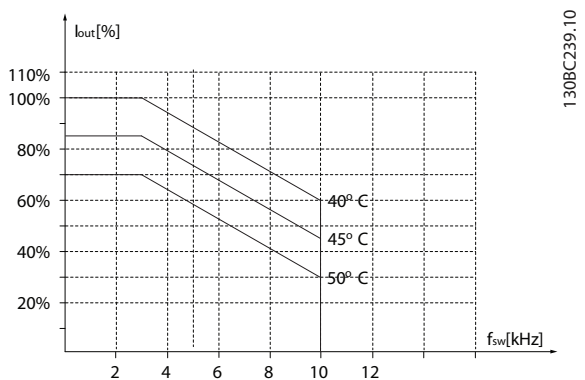


Illustration 3.44 11–15 kW (15–20 hp), 600 V, Enclosure Size H10, IP20

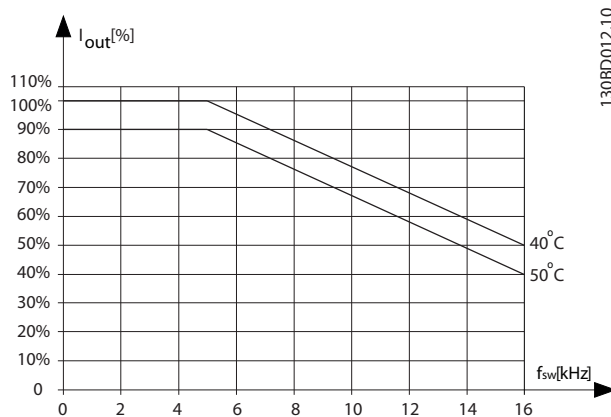


Illustration 3.47 11–18.5 kW (15–25 hp), 400 V, Enclosure Size I4, IP54

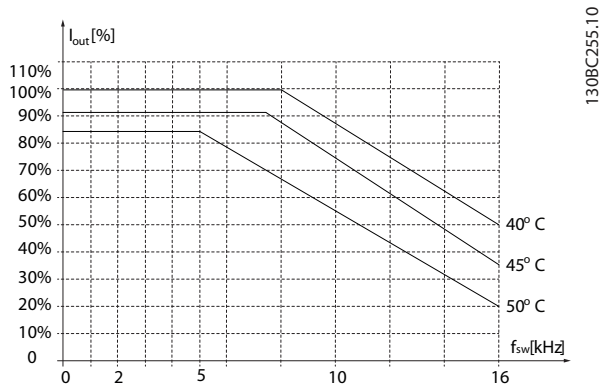


Illustration 3.45 0.75–4.0 kW (1.0–5.4 hp), 400 V, Enclosure Size I2, IP54

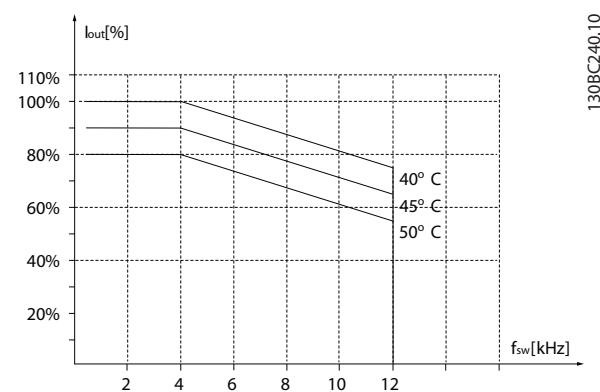


Illustration 3.48 22–30 kW (30–40 hp), 400 V, Enclosure Size I6, IP54

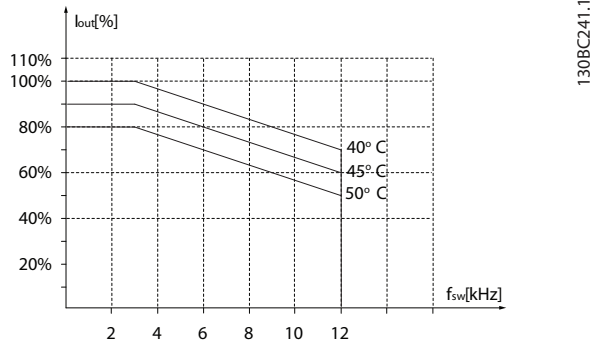


Illustration 3.49 37 kW (50 hp), 400 V, Enclosure Size I6, IP54

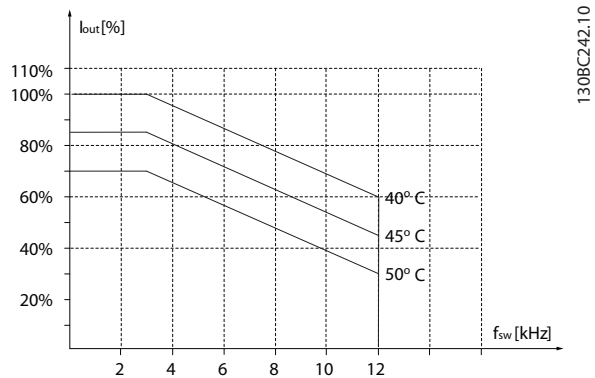


Illustration 3.50 45-55 kW (60-74 hp), 400 V, Enclosure Size I7, IP54

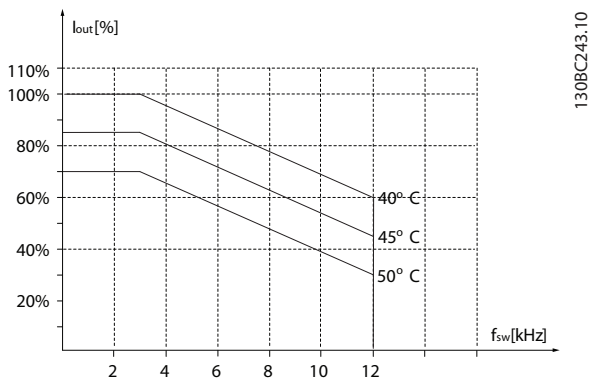


Illustration 3.51 75-90 kW (100-120 hp), 400 V, Enclosure Size I8, IP54

If the motor or the equipment driven by the motor - for example, a fan - makes noise or vibrations at certain frequencies, configure the following parameters or parameter groups to reduce or eliminate the noise or vibrations:

- Parameter group 4-6\* Speed Bypass.
- Set parameter 14-03 Overmodulation to [0] Off.
- Switching pattern and switching frequency parameter group 14-0\* Inverter Switching.
- Parameter 1-64 Resonance Dampening.

The acoustic noise from the frequency converter comes from 3 sources:

- DC-link coils.
- Integral fan.
- RFI filter choke.

Enclosure size	Level [dBA] <sup>1)</sup>
H1	43.6
H2	50.2
H3	53.8
H4	64
H5	63.7
H6	71.5
H7	67.5 (75 kW (100 hp) 71.5 dB)
H8	73.5
H9	60
H10	62.9
I2	50.2
I3	54
I4	67.4
I6	70
I7	62
I8	65.6

Table 3.3 Typical Values Measured at a Distance of 1 m (3.28 ft) from the Unit

1) The values are measured under the background of 35 dBA noise and the fan running with full speed.

The frequency converter has been tested according to the procedure based on the shown standards, Table 3.4.

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

IEC/EN 60068-2-6	Vibration (sinusoidal) - 1970
IEC/EN 60068-2-64	Vibration, broad-band random

Table 3.4 Standards

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

**CAUTION****INSTALLATION ENVIRONMENTS**

Do not install the frequency converter in environments with airborne liquids, particles, or gases that may affect or damage the electronic components. Failure to take necessary protective measures increases the risk of stoppages, potentially causing equipment damage and personnel injury.

Liquids can be carried through the air and condense in the frequency converter and may cause corrosion of components and metal parts. Steam, oil, and salt water may cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP54. As an extra protection, coated printed circuit boards can be ordered as an option (standard on some power sizes).

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

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

Such chemical reactions rapidly affect and damage the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the frequency converter. An extra protection in such areas is a coating of the printed circuit boards, which can be ordered as an option.

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

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

**3.4 General Aspects of EMC****3.4.1 Overview of EMC Emissions**

Frequency converters (and other electrical devices) generate electronic or magnetic fields that may interfere with their environment. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices.

Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference may take the form of mains harmonics distortion, electrostatic discharges, rapid voltage fluctuations, or high-frequency interference. Electrical devices generate interference along with being affected by interference from other generated sources.

Electrical interference usually arises at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter system in the range 30 MHz to 1 GHz is generated from the inverter, the motor cable, and the motor.

Capacitive currents in the motor cable coupled with a high  $dU/dt$  from the motor voltage generate leakage currents, as shown in *Illustration 3.52*.

The use of a shielded motor cable increases the leakage current (see *Illustration 3.52*) because shielded cables have higher capacitance to ground than unshielded cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current ( $I_1$ ) is carried back to the unit through the shield ( $I_3$ ), there is only a small electro-magnetic field ( $I_4$ ) from the shielded motor cable according to *Illustration 3.52*.

The shield reduces the radiated interference, but increases the low-frequency interference on the mains. Connect the motor cable shield to the frequency converter enclosure as well as on the motor enclosure. This is best done by using integrated shield clamps to avoid twisted shield ends (pigtailed). Pigtailed increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current ( $I_4$ ).

If a shielded cable is used for relay, control cable, signal interface, and brake, mount the shield on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.

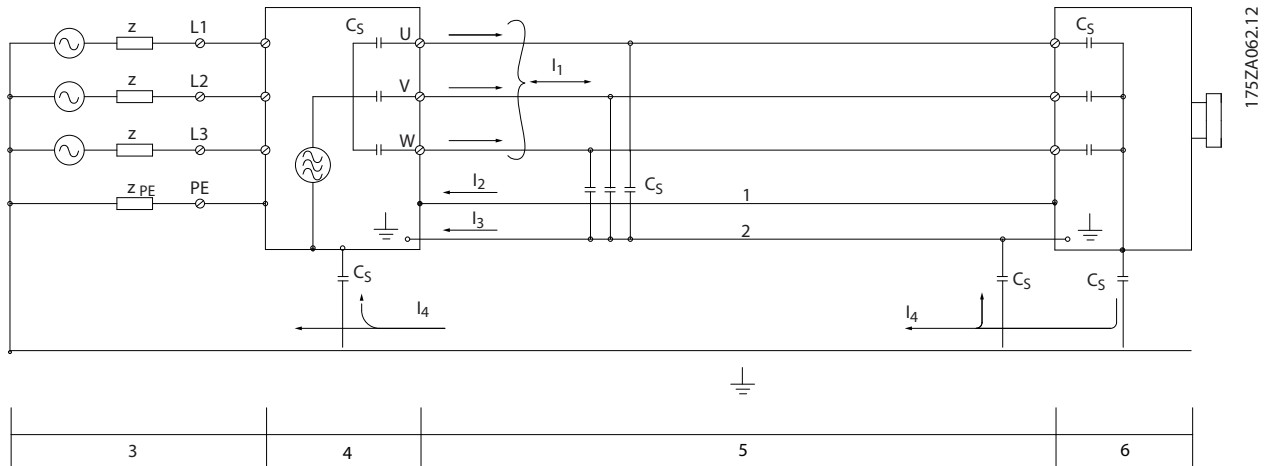
If the shield is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, to convey the shield currents back to the unit. Moreover, ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter chassis.

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

as possible. Avoid placing cables with a sensitive signal level alongside motor and brake cables. Radio interference higher than 50 MHz (airborne) is especially generated by the control electronics.

To reduce the interference level from the entire system (unit+installation), make motor and brake cables as short

3



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

Illustration 3.52 Generation of Leakage Currents

### 3.4.2 Emission Requirements

The EMC product standard for frequency converters defines 4 categories (C1, C2, C3, and C4) with specified requirements for emission and immunity. *Table 3.5* states the definition of the 4 categories and the equivalent classification from EN 55011.

EN/IEC 61800-3 Category	Definition	Equivalent emission class in EN 55011
C1	Frequency converters installed in the 1st environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Frequency converters installed in the 1st environment (home and office) with a supply voltage less than 1000 V, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	Frequency converters installed in the 2nd environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Frequency converters installed in the 2nd environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. Make an EMC plan.

**Table 3.5 Correlation between IEC 61800-3 and EN 55011**

When the generic (conducted) emission standards are used, the frequency converters are required to comply with the limits in *Table 3.6*.

Environment	Generic emission standard	Equivalent emission class in EN 55011
First environment (home and office)	EN/IEC 61000-6-3 Emission standard for residential, commercial and light industrial environments.	Class B
Second environment (industrial environment)	EN/IEC 61000-6-4 Emission standard for industrial environments.	Class A Group 1

**Table 3.6 Correlation between Generic Emission Standards and EN 55011**



### 3.4.3 EMC Emission Test Results

The following test results have been obtained using a system with a frequency converter, a shielded control cable, a control box with potentiometer, and a shielded motor cable.

RFI filter type	Conduct emission. Maximum shielded cable length [m (ft)]						Radiated emission			
	Industrial environment									
EN 55011	Class A Group 2 Industrial environment		Class A Group 1 Industrial environment		Class B Housing, trades and light industries		Class A Group 1 Industrial environment		Class B Housing, trades and light industries	
EN/IEC 61800-3	Category C3 Second environment Industrial		Category C2 First environment Home and office		Category C1 First environment Home and office		Category C2 First environment Home and office		Category C1 First environment Home and office	
	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter	Without external filter	With external filter
<b>H4 RFI filter (EN55011 A1, EN/IEC61800-3 C2)</b>										
0.25–11 kW (0.34–15 hp) 3x200–240 V IP20	–	–	25 (82)	50 (164)	–	20 (66)	Yes	Yes	–	No
0.37–22 kW (0.5–30 hp) 3x380–480 V IP20	–	–	25 (82)	50 (164)	–	20 (66)	Yes	Yes	–	No
<b>H2 RFI filter (EN 55011 A2, EN/IEC 61800-3 C3)</b>										
15–45 kW (20–60 hp) 3x200–240 V IP20	25 (82)	–	–	–	–	–	No	–	No	–
30–90 kW (40–120 hp) 3x380–480 V IP20	25 (82)	–	–	–	–	–	No	–	No	–
0.75–18.5 kW (1–25 hp) 3x380–480 V IP54	25 (82)	–	–	–	–	–	Yes	–	–	–
22–90 kW (30–120 hp) 3x380–480 V IP54	25 (82)	–	–	–	–	–	No	–	No	–
<b>H3 RFI filter (EN55011 A1/B, EN/IEC 61800-3 C2/C1)</b>										
15–45 kW (20–60 hp) 3x200–240 V IP20	–	–	50 (164)	–	20 (66)	–	Yes	–	No	–
30–90 kW (40–120 hp) 3x380–480 V IP20	–	–	50 (164)	–	20 (66)	–	Yes	–	No	–
0.75–18.5 kW (1–25 hp) 3x380–480 V IP54	–	–	25 (82)	–	10 (33)	–	Yes	–	–	–

3

RFI filter type	Conduct emission. Maximum shielded cable length [m (ft)]						Radiated emission			
	Industrial environment									
22–90 kW (30–120 hp) 3x380–480 V IP54	–	–	25 (82)	–	10 (33)	–	Yes	–	No	–

Table 3.7 EMC Emission Test Results

### 3.4.4 Overview of Harmonics Emission

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

	$I_1$	$I_5$	$I_7$
Hz	50	250	350

Table 3.8 Harmonic Currents

The harmonics do not affect the power consumption directly, but increase the heat losses in the installation (transformer, cables). So, in plants with a high percentage of rectifier load, maintain harmonic currents at a low level to avoid overload of the transformer and high temperature in the cables.

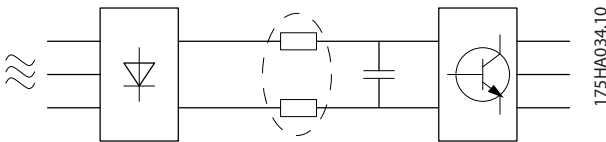


Illustration 3.53 DC-link Coils

#### NOTICE

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

To ensure low harmonic currents, the frequency converter is equipped with DC-link coils as standard. This normally reduces the input current  $I_{RMS}$  by 40%.

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

$$THD \% = \sqrt{U_{\frac{2}{5}}^2 + U_{\frac{2}{7}}^2 + \dots + U_{\frac{2}{N}}^2}$$

( $U_N$  % of U)

### 3.4.5 Harmonics Emission Requirements

#### Equipment connected to the public supply network

Options	Definition
1	IEC/EN 61000-3-2 Class A for 3-phase balanced equipment (for professional equipment only up to 1 kW (1.3 hp) total power).
2	IEC/EN 61000-3-12 Equipment 16–75 A and professional equipment as from 1 kW (1.3 hp) up to 16 A phase current.

Table 3.9 Connected Equipment

### 3.4.6 Harmonics Test Results (Emission)

Power sizes up to PK75 in T4 and P3K7 in T2 complies with IEC/EN 61000-3-2 Class A. Power sizes from P1K1 and up to P18K in T2 and up to P90K in T4 complies with IEC/EN 61000-3-12, Table 4.

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 0.25–11 kW (0.34–15 hp), IP20, 200 V (typical)	32.6	16.6	8.0	6.0
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 0.25–11 kW (0.34–15 hp), 200 V (typical)	39		41.4	
Limit for $R_{scc} \geq 120$	48		46	

Table 3.10 Harmonic Current 0.25–11 kW (0.34–15 hp), 200 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 0.37–22 kW (0.5–30 hp), IP20, 380–480 V (typical)	36.7	20.8	7.6	6.4
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 0.37–22 kW (0.5–30 hp), 380–480 V (typical)	44.4		40.8	
Limit for $R_{scc} \geq 120$	48		46	

Table 3.11 Harmonic Current 0.37–22 kW (0.5–30 hp), 380–480 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 30–90 kW (40–120 hp), IP20, 380–480 V (typical)	36.7	13.8	6.9	4.2
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 30–90 kW (40–120 hp), 380–480 V (typical)	40.6		28.8	
Limit for $R_{scc} \geq 120$	48		46	

Table 3.12 Harmonic Current 30–90 kW (40–120 hp), 380–480 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 2.2–15 kW (3.0–20 hp), IP20, 525–600 V (typical)	48	25	7	5
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 2.2–15 kW (3.0–20 hp), 525–600 V (typical)	55		27	

Table 3.13 Harmonic Current 2.2–15 kW (3.0–20 hp), 525–600 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 18.5–90 kW (25–120 hp), IP20, 525–600 V (typical)	48.8	24.7	6.3	5
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 18.5–90 kW (25–120 hp), 525–600 V (typical)	55.7		25.3	

Table 3.14 Harmonic Current 18.5–90 kW (25–120 hp), 525–600 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 22–90 kW (30–120 hp), IP54, 400 V (typical)	36.3	14	7	4.3
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 22–90 kW (30–120 hp), IP54 400 V (typical)	40.1		27.1	
Limit for $R_{scc} \geq 120$	48		46	

Table 3.15 Harmonic Current 22–90 kW (30–120 hp), 400 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 0.75–18.5 kW (1.0–25 hp), IP54, 380–480 V (typical)	36.7	20.8	7.6	6.4
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 0.75–18.5 kW (1.0–25 hp), IP54, 380–480 V (typical)	44.4		40.8	
Limit for $R_{scc} \geq 120$	48		46	

Table 3.16 Harmonic Current 0.75–18.5 kW (1.0–25 hp), 380–480 V

	Individual harmonic current $I_n/I_1$ (%)			
	$I_5$	$I_7$	$I_{11}$	$I_{13}$
Actual 15–45 kW (20–60 hp), IP20, 200 V (typical)	26.7	9.7	7.7	5
Limit for $R_{scc} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THDi		PWHD	
Actual 15–45 kW (20–60 hp), 200 V (typical)	30.3		27.6	
Limit for $R_{scc} \geq 120$	48		46	

Table 3.17 Harmonic Current 15–45 kW (20–60 hp), 200 V

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

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

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

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

Compliance with various system level guidelines: The harmonic current data in *Table 3.10* to *Table 3.17* are given in accordance with IEC/EN 61000-3-12 with reference to the Power Drive Systems product standard. They may be used as the basis for calculation of the harmonic currents' influence on the power supply system and for the documentation of compliance with relevant regional guidelines: IEEE 519 -1992; G5/4.

### 3.4.7 Immunity Requirements

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

### 3.5 Galvanic Isolation (PELV)

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

All control terminals and relay terminals 01-03/04-06 comply with PELV (protective extra low voltage) (does not apply to grounded delta leg above 440 V).

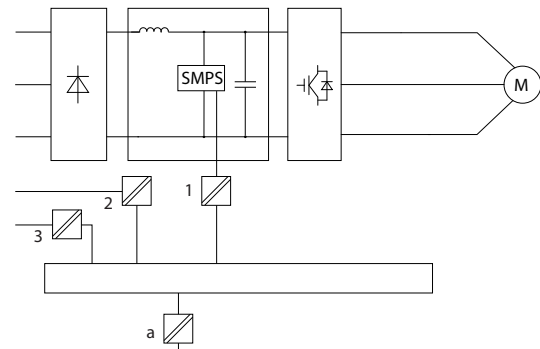
Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the relevant creepage/clearance distances. These requirements are described in the EN 61800-5-1 standard.

The components that make up the electrical isolation, as described, also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.

The PELV galvanic isolation can be shown in *Illustration 3.55*.

To maintain PELV, all connections made to the control terminals must be PELV, for example, thermistors must be reinforced/double insulated.

#### 0.25–22 kW (0.34–30 hp)

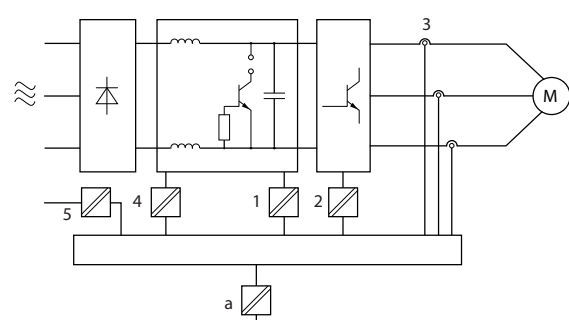


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1	Supply (SMPS)
2	Optocouplers, communication between AOC and BOC
3	Custom relays
a	Control card terminals

Illustration 3.54 Galvanic Isolation

#### 30–90 kW (40–120 hp)



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1	Supply (SMPS) including signal isolation of UDC, indicating the intermediate current voltage
2	Gate drive that runs the IGBTs (trigger transformers/optocouplers)
3	Current transducers
4	Internal soft-charge, RFI, and temperature measurement circuits
5	Custom relays
a	Control card terminals

Illustration 3.55 Galvanic Isolation

The functional galvanic isolation (see *Illustration 3.54*) is for the RS485 standard bus interface.

## CAUTION

### INSTALLATION AT HIGH ALTITUDE

At altitudes above 2000 m (6500 ft), contact Danfoss regarding PELV.

### 3.6 Earth Leakage Current

#### **⚠ WARNING**

##### DISCHARGE TIME

Touching the electrical parts could be fatal - even after the equipment has been disconnected from mains.

Also make sure that other voltage inputs have been disconnected, such as load sharing (linkage of DC-link), and the motor connection for kinetic back-up.

Before touching any electrical parts, wait at least the amount of time indicated in *Table 2.1*.

Shorter time is allowed only if indicated on the nameplate for the specific unit.

#### **⚠ 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**

##### RESIDUAL CURRENT DEVICE PROTECTION

This product can cause a DC current in the protective conductor. Where a residual current device (RCD) is used for protection in case of direct or indirect contact, only an RCD of Type B is allowed on the supply side of this product. Otherwise, apply another protective measure, such as separation from the environment by double or reinforced insulation, or isolation from the supply system by a transformer. See also application note *Protection against Electrical Hazards*.

Protective grounding of the frequency converter and the use of RCDs must always follow national and local regulations.

### 3.7 Extreme Running Conditions

#### Short circuit (motor phase-phase)

Current measurement in each of the 3 motor phases or in the DC-link, protects the frequency converter against short circuits. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off individually when the short circuit current exceeds the allowed value (*alarm 16, Trip Lock*).

For information about protecting the frequency converter against a short circuit at the load sharing and brake outputs, see *chapter 8.3.1 Fuses and Circuit Breakers*.

#### Switching on the output

Switching on the output between the motor and the frequency converter is allowed. The frequency converter is not damaged in any way by switching on the output. However, fault messages may appear.

#### Motor-generated overvoltage

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

- The load drives the motor (at constant output frequency from the frequency converter), that is the load generates energy.
- During deceleration (ramp-down) if the inertia moment is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor, and the installation.
- Incorrect slip compensation setting (*parameter 1-62 Slip Compensation*) may cause higher DC-link voltage.

The control unit may attempt to correct the ramp if *parameter 2-17 Over-voltage Control* is enabled.

The frequency converter turns off to protect the transistors and the DC-link capacitors when a certain voltage level is reached.

#### Mains drop-out

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

### 3.7.1 Motor Thermal Protection (ETR)

Danfoss uses ETR to protect the motor from being overheated. It is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in *Illustration 3.56*.

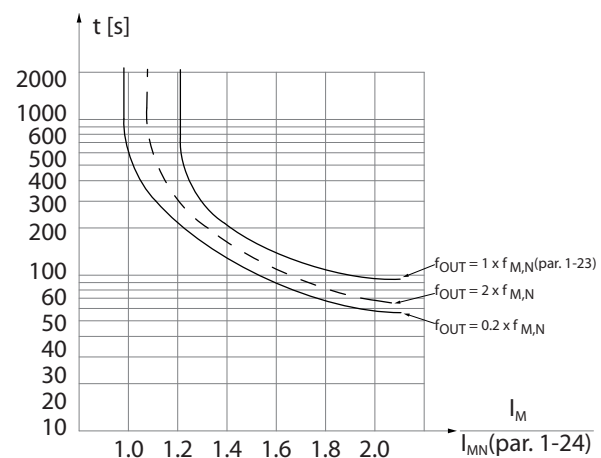


Illustration 3.56 Motor Thermal Protection Characteristic

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The X-axis shows the ratio between  $I_{motor}$  and  $I_{motor}$  nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the frequency converter. The curves show the characteristic nominal speed at twice the nominal speed and at 0.2x the nominal speed.

It is clear that at lower speed the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on actual current and speed.

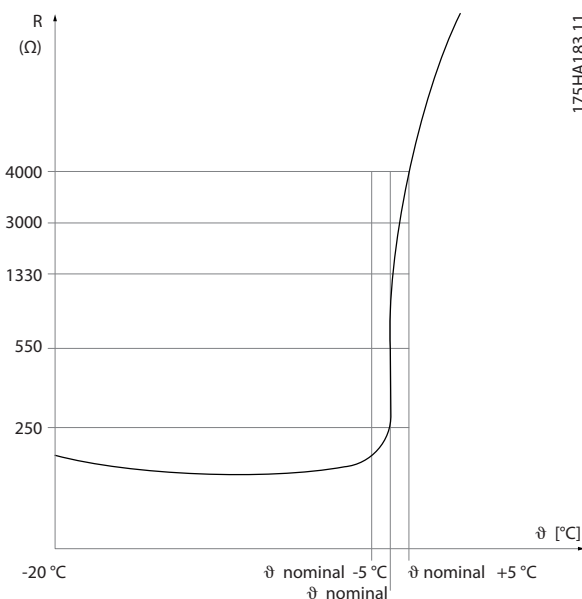
### 3.7.2 Thermistor Inputs

The thermistor cutout value is  $>3\text{ k}\Omega$ .

Integrate a thermistor (PTC sensor) in the motor for winding protection.

Motor protection can be implemented using a range of techniques:

- PTC sensor in motor windings.
- Mechanical thermal switch (Klixon type).
- Electronic thermal relay (ETR).



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Illustration 3.57 Trip due to High Motor Temperature

#### Example with digital input and 10 V power supply

The frequency converter trips when the motor temperature is too high.

Parameter set-up:

Set parameter 1-90 Motor Thermal Protection to [2] Thermistor Trip.

Set parameter 1-93 Thermistor Source to [6] Digital Input 29.

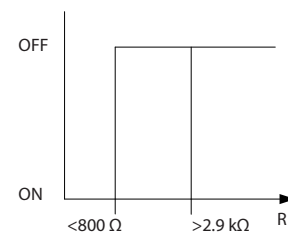
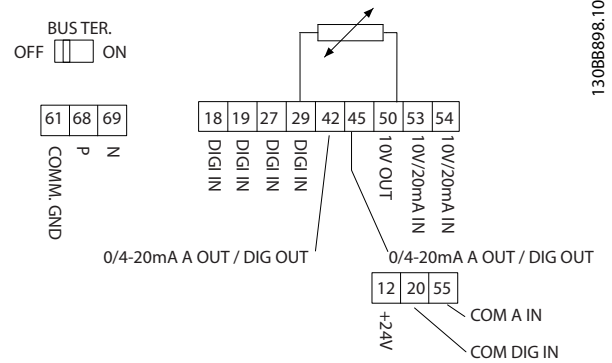


Illustration 3.58 Digital Input/10 V Power Supply

#### Example with analog input and 10 V power supply

The frequency converter trips when the motor temperature is too high.

Parameter set-up:

Set parameter 1-90 Motor Thermal Protection to [2] Thermistor Trip.

Set parameter 1-93 Thermistor Source to [1] Analog Input 53.

**NOTICE**

Do not set Analog Input 54 as reference source.

3

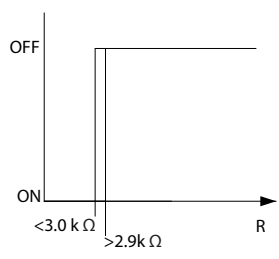
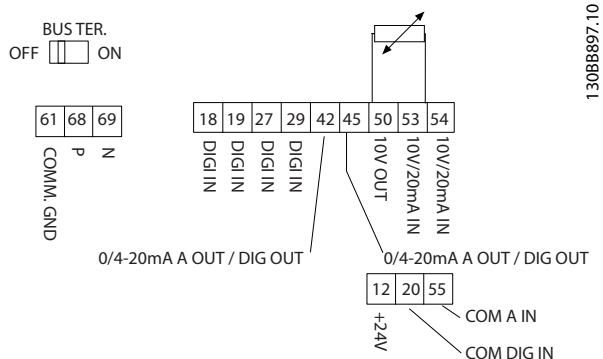


Illustration 3.59 Analog Input/10 V Power Supply

Input	Supply voltage [V]	Threshold cutout values [Ω]
Digital	10	<800⇒2.9 k
Analog	10	<800⇒2.9 k

Table 3.18 Supply Voltage

**NOTICE**

Make sure that the selected supply voltage follows the specification of the used thermistor element.

ETR is activated in parameter 1-90 Motor Thermal Protection.



## 4 Selection and Ordering

### 4.1 Type Code

A type code defines a specific configuration of the VLT® HVAC Basic Drive FC 101 frequency converter. Use *Illustration 4.1* to create a type code string for the desired configuration.

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

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4

Illustration 4.1 Type Code

Description	Position	Possible choice
Product group & FC series	1–6	FC 101
Power rating	7–10	0.25–90 kW (0.34–120 hp) (PK25-P90K)
Number of phases	11	3 phases (T)
Mains voltage	11–12	T2: 200-240 V AC T4: 380-480 V AC T6: 525-600 V AC
Enclosure	13–15	E20: IP20/chassis P20: IP20/chassis with back plate E5A: IP54 P5A: IP54 with back plate
RFI filter	16–17	H1: RFI filter class A1/B H2: RFI filter class A2 H3: RFI filter class A1/B (reduced cable length) H4: RFI filter class A1
Brake	18	X: No brake chopper included
Display	19	A: Alpha numeric local control panel X: No local control panel
Coating PCB	20	X: No coated PCB C: Coated PCB
Mains option	21	X: No mains option
Adaptation	22	X: No adaptation
Adaptation	23	X: No adaptation
Software release	24–27	SXXXX: Latest release - standard software
Software language	28	X: Standard
A options	29–30	AX: No A options
B options	31–32	BX: No B options
C0 options MCO	33–34	CX: No C options
C1 options	35	X: No C1 options
C option software	36–37	XX: No options
D options	38–39	DX: No D0 options

Table 4.1 Type Code Description

## 4.2 Options and Accessories

### 4.2.1 Local Control Panel (LCP)

Ordering number	Description
132B0200	LCP for all IP20 units

Table 4.2 Ordering Number of LCP

Enclosure	IP55 front-mounted
Maximum cable length to unit	3 m (10 ft)
Communication standard	RS485

Table 4.3 Technical Data of LCP

### 4.2.2 Mounting of LCP in Panel Front

#### Step 1

Fit gasket on LCP.

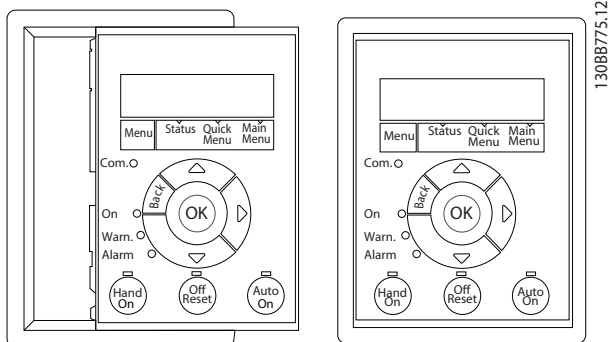
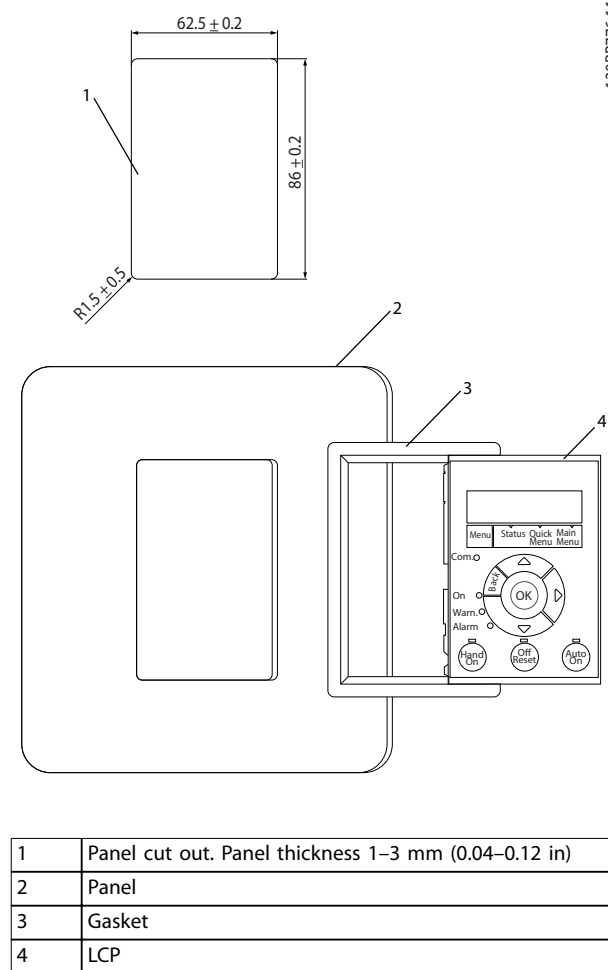


Illustration 4.2 Fit Gasket

#### Step 2

Place LCP on panel, see dimensions of hole on Illustration 4.3.



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

Illustration 4.3 Place LCP on Panel (Front-mounted)

**Step 3**

Place bracket on back of the LCP, then slide down. Tighten screws and connect cable female side to LCP.

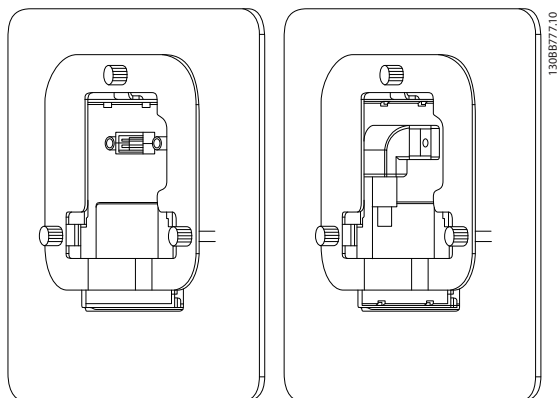


Illustration 4.4 Place Bracket on LCP

**Step 4**

Connect cable to frequency converter.

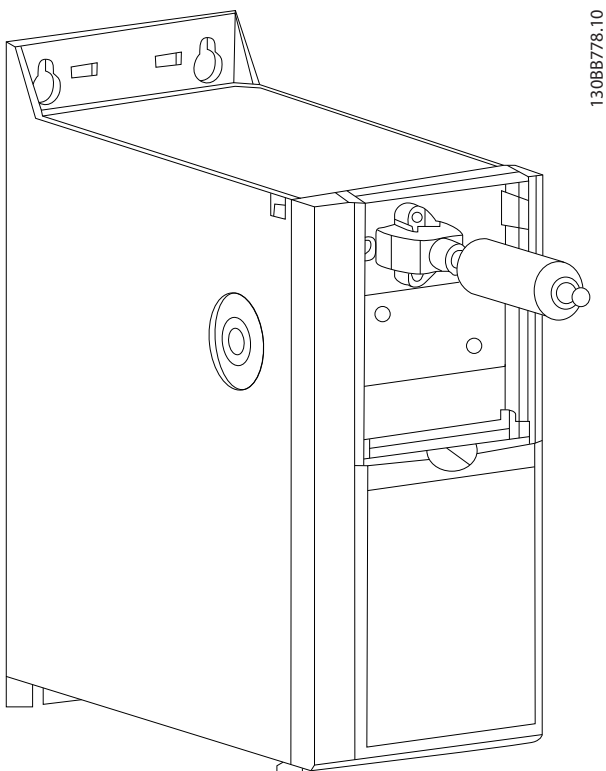


Illustration 4.5 Connect Cable

**NOTICE**

Use the provided thread-cutting screws to fasten the connector to the frequency converter. The tightening torque is 1.3 Nm (11.5 in-lb).

**4.2.3 IP21/NEMA Type 1 Enclosure Kit**

IP21/NEMA Type 1 is an optional enclosure element available for IP20 units.

If the enclosure kit is used, an IP20 unit is upgraded to comply with enclosure IP21/NEMA Type 1.

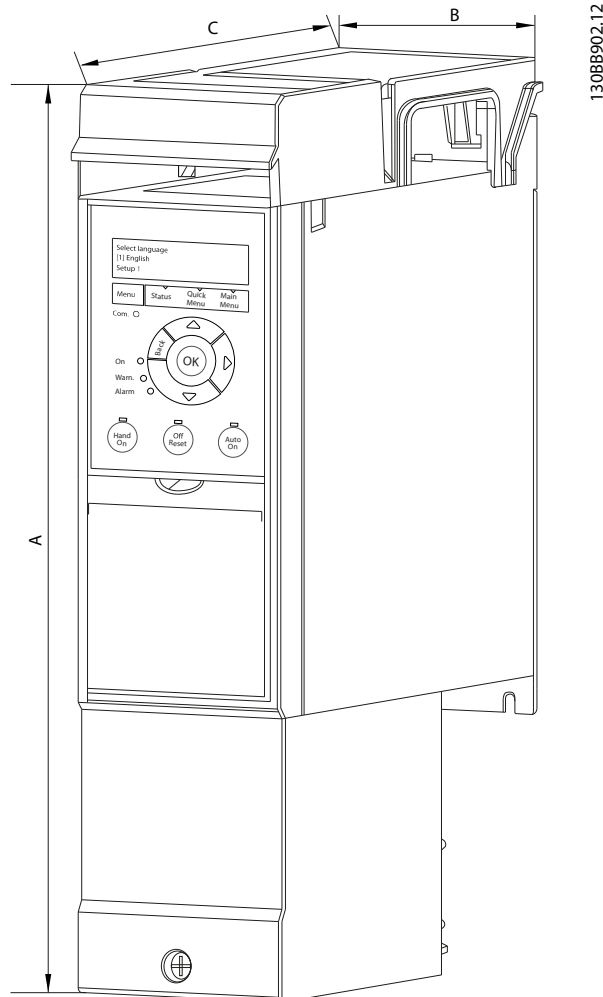


Illustration 4.6 H1-H5 (See Data in Table 4.4)

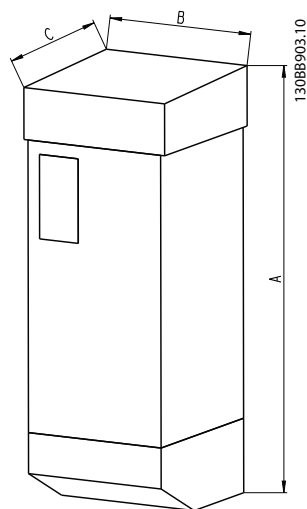


Illustration 4.7 Dimensions (See Data in Table 4.4)

Frame	IP class	Power			Height [mm (in)] A	Width [mm (in)] B	Depth [mm (in)] C	IP21 kit ordering number	NEMA Type 1 kit ordering number
		3x200–240 V [kW (hp)]	3x380–480 V [kW (hp)]	3x525–600 V [kW (hp)]					
H1	IP20	0.25–1.5 (0.34–2.0)	0.37–1.5 (0.5–2.0)	–	293 (11.5)	81 (3.2)	173 (6.8)	132B0212	132B0222
H2	IP20	2.2 (3.0)	2.2–4.0 (3.0–5.4)	–	322 (12.7)	96 (3.8)	195 (7.7)	132B0213	132B0223
H3	IP20	3.7 (5.0)	5.5–7.5 (7.4–10)	–	346 (13.6)	106 (4.2)	210 (8.3)	132B0214	132B0224
H4	IP20	5.5–7.5 (7.4–10)	11–15 (15–20)	–	374 (14.7)	141 (5.6)	245 (9.6)	132B0215	132B0225
H5	IP20	11 (15)	18.5–22 (25–30)	–	418 (16.5)	161 (6.3)	260 (10.2)	132B0216	132B0226
H6	IP20	15–18.5 (20–25)	30–45 (40–60)	18.5–30 (25–40)	663 (26.1)	260 (10.2)	242 (9.5)	132B0217	132B0217
H7	IP20	22–30 (30–40)	55–75 (74–100)	37–55 (50–74)	807 (31.8)	329 (13.0)	335 (13.2)	132B0218	132B0218
H8	IP20	37–45 (50–60)	90 (120)	75–90 (100–120)	943 (37.1)	390 (15.3)	335 (13.2)	132B0219	132B0219
H9	IP20	–	–	2.2–7.5 (3.0–10)	372 (14.6)	130 (5.1)	205 (8.1)	132B0220	132B0220
H10	IP20	–	–	11–15 (15–20)	475 (18.7)	165 (6.5)	249 (9.8)	132B0221	132B0221

Table 4.4 Enclosure Kit Specifications

## 4.2.4 Decoupling Plate

Use the decoupling plate for EMC-correct installation.

Illustration 4.8 shows the decoupling plate on an H3 enclosure.

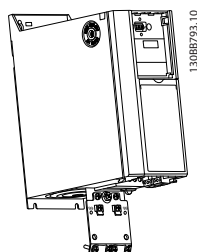


Illustration 4.8 Decoupling Plate

Frame	IP class	Power [kW(hp)]			Decoupling plate ordering numbers
		3x200–240 V	3x380–480 V	3x525–600 V	
H1	IP20	0.25–1.5 (0.33–2.0)	0.37–1.5 (0.5–2.0)	–	132B0202
H2	IP20	2.2 (3.0)	2.2–4 (3.0–5.4)	–	132B0202
H3	IP20	3.7 (5.0)	5.5–7.5 (7.5–10)	–	132B0204
H4	IP20	5.5–7.5 (7.5–10)	11–15 (15–20)	–	132B0205
H5	IP20	11 (15)	18.5–22 (25–30)	–	130B0205
H6	IP20	15–18.5 (20–25)	30 (40)	18.5–30 (25–40)	132B0207
H6	IP20	–	37–45 (50–60)	–	132B0242
H7	IP20	22–30 (30–40)	55 (75)	37–55 (50–75)	132B0208
H7	IP20	–	75 (100)	–	132B0243
H8	IP20	37–45 (50–60)	90 (125)	75–90 (100–125)	132B0209

Table 4.5 Decoupling Plate Specifications

### NOTICE

For enclosure sizes H9 and H10, the decoupling plates are included in the accessory bag.

## 4.3 Ordering Numbers

### 4.3.1 Options and Accessories

	Enclosure size Mains voltage	H1	H2	H3	H4	H5	H6		H7		H8
		[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]	[kW (hp)]
	T2 (200–240 V AC)	0.25–1.5 (0.33–2.0)	2.2 (3.0)	3.7 (5.0)	5.5–7.5 (7.5–10)	11 (15)	15–18.5 (20–25)	–	22–30 (30–40)	–	37–45 (50–60)
	T4 (380–480 V AC)	0.37–1.5 (0.5–2.0)	2.2–4.0 (3.0–5.4)	5.5–7.5 (7.5–10)	11–15 (15–20)	18.5–22 (25–30)	30 (40)	37–45 (50–60)	55 (75)	75 (100)	90 (125)
	T6 (525–600 V AC)	–	–	–	–	–	18.5–30 (25–40)	–	37–55 (50–75)	–	75–90 (100–125)
<b>Description</b>											
LCP <sup>1)</sup>		132B0200									

	Enclosure size Mains voltage	H1 [kW (hp)]	H2 [kW (hp)]	H3 [kW (hp)]	H4 [kW (hp)]	H5 [kW (hp)]	H6 [kW (hp)]		H7 [kW (hp)]		H8 [kW (hp)]
LCP panel mounting kit IP55 including 3 m (9.8 ft) cable		132B0201									
LCP 31 to RJ 45 converter kit		132B0203									
LCP panel mounting kit IP55 without 3 m (9.8 ft) cable		132B0206									
Decoupling plate		132B0202	132B0202	132B0204	132B0205	132B0205	132B0207	132B0242	132B0208	132B0243	132B0209
IP21 option		132B0212	132B0213	132B0214	132B0215	132B0216	132B0217		132B0218		132B0219
NEMA Type 1 Kit		132B0222	132B0223	132B0224	132B0225	132B0226	132B0217		132B0218		132B0219

Table 4.6 Options and Accessories

1) For IP20 units, LCP is ordered separately. For IP54 units, LCP is included in the standard configuration and mounted on the frequency converter.

### 4.3.2 Harmonic Filters

3x380–480 V 50 Hz					
Power [kW (hp)]	Frequency converter input current continuous [A]	Default switching frequency [kHz]	THDi level [%]	Order number filter IP00	Code number filter IP20
22 (30)	41.5	4	4	130B1397	130B1239
30 (40)	57	4	3	130B1398	130B1240
37 (50)	70	4	3	130B1442	130B1247
45 (60)	84	3	3	130B1442	130B1247
55 (74)	103	3	5	130B1444	130B1249
75 (100)	140	3	4	130B1445	130B1250
90 (120)	176	3	4	130B1445	130B1250

Table 4.7 AHF Filters (5% Current Distortion)

3x380–480 V 50 Hz					
Power [kW (hp)]	Frequency converter input current continuous [A]	Default switching frequency [kHz]	THDi level [%]	Order number filter IP00	Code number filter IP20
22 (30)	41.5	4	6	130B1274	130B1111
30 (40)	57	4	6	130B1275	130B1176
37 (50)	70	4	9	130B1291	130B1201
45 (60)	84	3	9	130B1291	130B1201
55 (74)	103	3	9	130B1292	130B1204
75 (100)	140	3	8	130B1294	130B1213
90 (120)	176	3	8	130B1294	130B1213

Table 4.8 AHF Filters (10% Current Distortion)

3x440–480 V 60 Hz					
Power [kW (hp)]	Frequency converter input current Continuous [A]	Default switching frequency [kHz]	THDi level [%]	Order number filter IP00	Code number filter IP20
22 (30)	34.6	4	3	130B1792	130B1757
30 (40)	49	4	3	130B1793	130B1758
37 (50)	61	4	3	130B1794	130B1759
45 (60)	73	3	4	130B1795	130B1760
55 (74)	89	3	4	130B1796	130B1761
75 (100)	121	3	5	130B1797	130B1762
90 (120)	143	3	5	130B1798	130B1763

Table 4.9 AHF Filters (5% Current Distortion)

3x440–480 V 60 Hz					
Power [kW (hp)]	Frequency converter input current continuous [A]	Default switching frequency [kHz]	THDi level [%]	Order number filter IP00	Code number filter IP20
22 (30)	34.6	4	6	130B1775	130B1487
30 (40)	49	4	8	130B1776	130B1488
37 (50)	61	4	7	130B1777	130B1491
45 (60)	73	3	9	130B1778	130B1492
55 (74)	89	3	8	130B1779	130B1493
75 (100)	121	3	9	130B1780	130B1494
90 (120)	143	3	10	130B1781	130B1495

Table 4.10 AHF Filters (10% Current Distortion)

### 4.3.3 External RFI Filter

With external filters listed in *Table 4.11*, the maximum shielded cable length of 50 m (164 ft) according to EN/IEC 61800-3 C2 (EN 55011 A1), or 20 m (65.6 ft) according to EN/IEC 61800-3 C1(EN 55011 B) can be achieved.

4

Power [kW (hp)] Size 380–480 V	Type	A	B	C	D	E	F	G	H	I	J	K	L1	Torque [Nm (in-lb)]	Weight [kg (lb)]	Ordering Number
0.37–2.2 (0.5–3.0)	FN3258-7-45	190	40	70	160	180	20	4.5	1	10.6	M5	20	31	0.7–0.8 (6.2–7.1)	0.5 (1.1)	132B0244
3.0–7.5 (4.0–10)	FN3258-16-45	250	45	70	220	235	25	4.5	1	10.6	M5	22.5	31	0.7–0.8 (6.2–7.1)	0.8 (1.8)	132B0245
11–15 (15–20)	FN3258-30-47	270	50	85	240	255	30	5.4	1	10.6	M5	25	40	1.9–2.2 (16.8–19.5)	1.2 (2.6)	132B0246
18.5–22 (25–30)	FN3258-42-47	310	50	85	280	295	30	5.4	1	10.6	M5	25	40	1.9–2.2 (16.8–19.5)	1.4 (3.1)	132B0247

Table 4.11 RFI Filters - Details

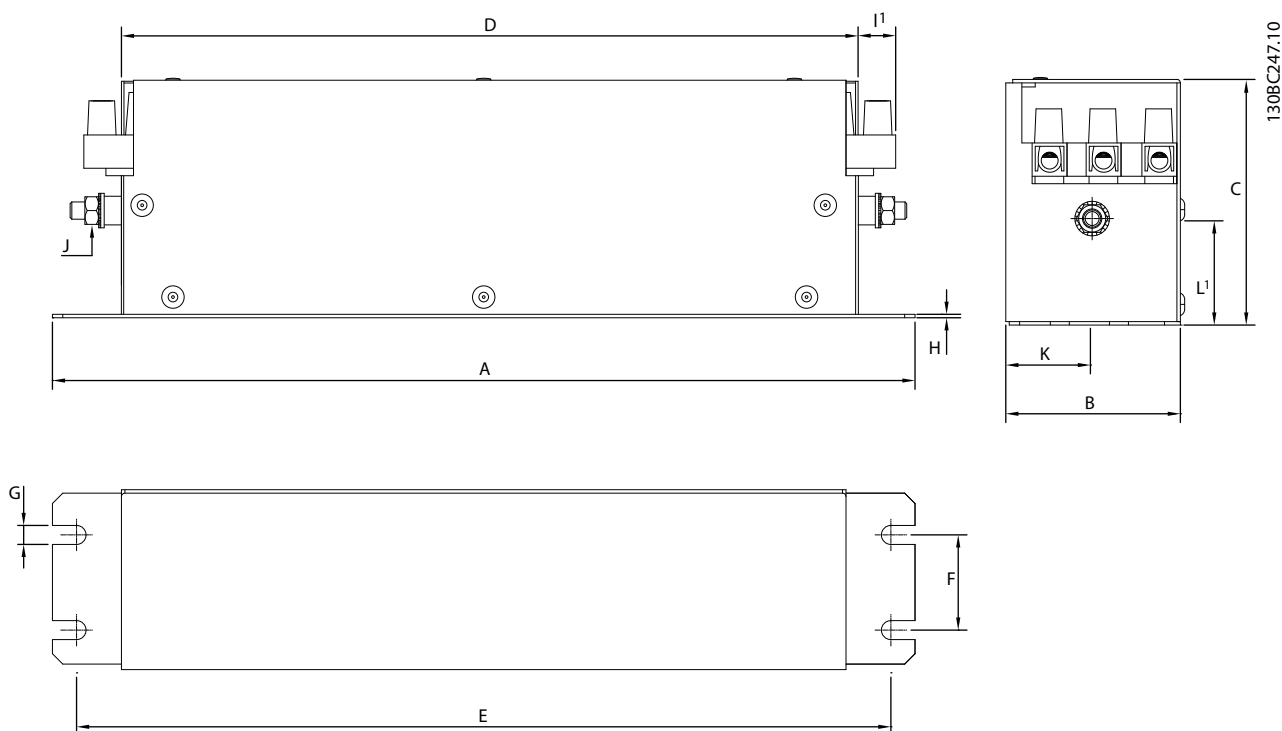


Illustration 4.9 RFI Filter - Dimensions



# 5 Installation

## 5.1 Electrical Installation

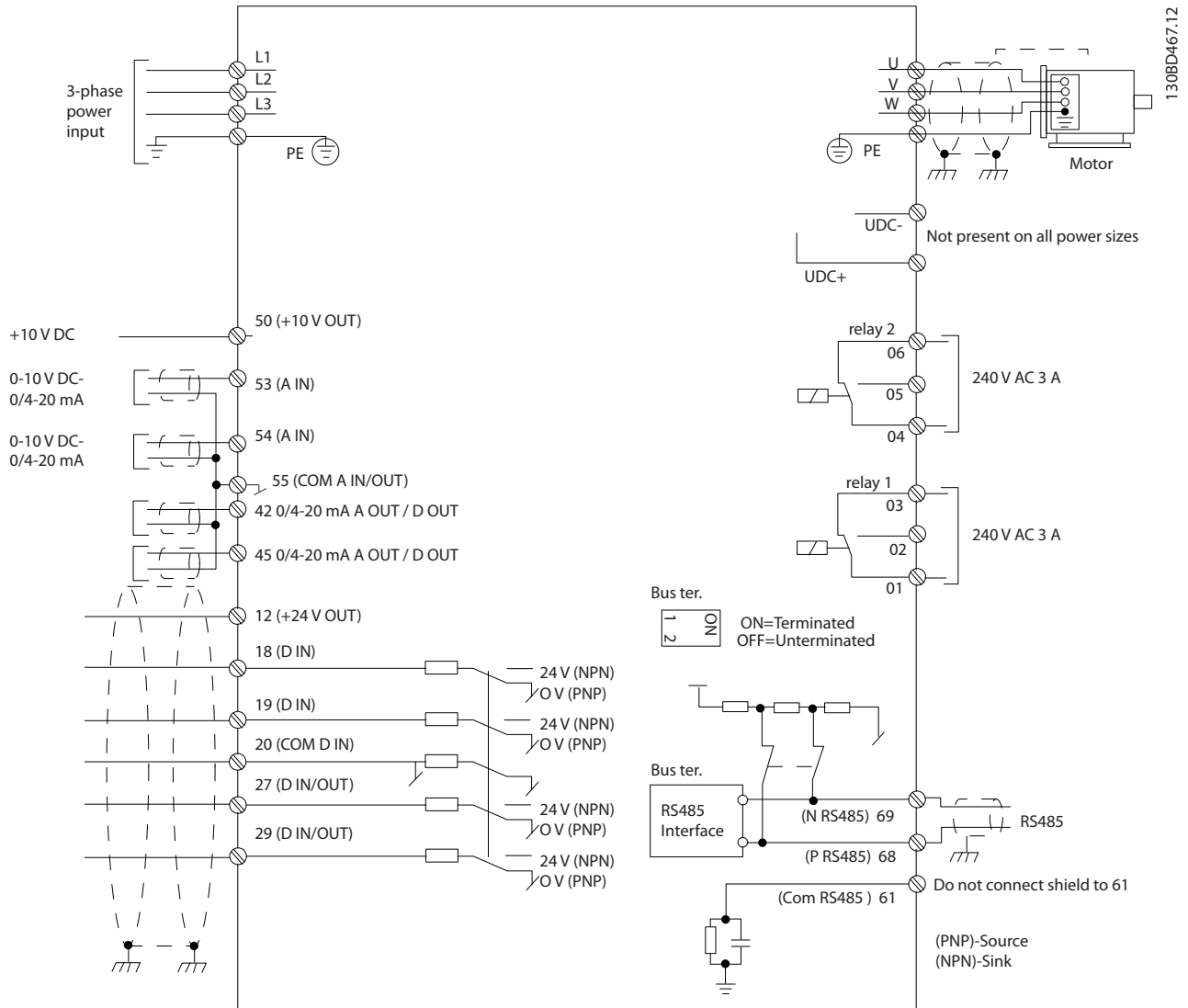


Illustration 5.1 Basic Wiring Schematic Drawing

### NOTICE

There is no access to UDC- and UDC+ on the following units:

- IP20, 380–480 V, 30–90 kW (40–125 hp)
- IP20, 200–240 V, 15–45 kW (20–60 hp)
- IP20, 525–600 V, 2.2–90 kW (3.0–125 hp)
- IP54, 380–480 V, 22–90 kW (30–125 hp)

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

**5**

Enclosure size	IP class	Power [kW (hp)]		Torque [Nm (in-lb)]					
		3x200–240 V	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
H1	IP20	0.25–1.5 (0.33–2.0)	0.37–1.5 (0.5–2.0)	0.8 (7.0)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
H2	IP20	2.2 (3.0)	2.2–4.0 (3.0–5.0)	0.8 (7.0)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
H3	IP20	3.7 (5.0)	5.5–7.5 (7.5–10)	0.8 (7.0)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
H4	IP20	5.5–7.5 (7.5–10)	11–15 (15–20)	1.2 (11)	1.2 (11)	1.2 (11)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
H5	IP20	11 (15)	18.5–22 (25–30)	1.2 (11)	1.2 (11)	1.2 (11)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)
H6	IP20	15–18.5 (20–25)	30–45 (40–60)	4.5 (40)	4.5 (40)	–	0.5 (4.0)	3 (27)	0.5 (4.0)
H7	IP20	22–30 (30–40)	55 (70)	10 (89)	10 (89)	–	0.5 (4.0)	3 (27)	0.5 (4.0)
H7	IP20	–	75 (100)	14 (124)	14 (124)	–	0.5 (4.0)	3 (27)	0.5 (4.0)
H8	IP20	37–45 (50–60)	90 (125)	24 (212) <sup>1)</sup>	24 (212) <sup>1)</sup>	–	0.5 (4.0)	3 (27)	0.5 (4.0)

**Table 5.1 Tightening Torques for Enclosure Sizes H1–H8, 3x200–240 V and 3x380–480 V**

Enclosure size	IP class	Power [kW (hp)]		Torque [Nm (in-lb)]					
		3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay	
I2	IP54	0.75–4.0 (1.0–5.0)	0.8 (7.0)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)	
I3	IP54	5.5–7.5 (7.5–10)	0.8 (7.0)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)	
I4	IP54	11–18.5 (15–25)	1.4 (12)	0.8 (7.0)	0.8 (7.0)	0.5 (4.0)	0.8 (7.0)	0.5 (4.0)	
I6	IP54	22–37 (30–50)	4.5 (40)	4.5 (40)	–	0.5 (4.0)	3 (27)	0.6 (5.0)	
I7	IP54	45–55 (60–70)	10 (89)	10 (89)	–	0.5 (4.0)	3 (27)	0.6 (5.0)	
I8	IP54	75–90 (100–125)	14 (124)/24 (212) <sup>2)</sup>	14 (124)/24 (212) <sup>2)</sup>	–	0.5 (4.0)	3 (27)	0.6 (5.0)	

**Table 5.2 Tightening Torques for Enclosure Sizes I2–I8**

Enclosure size	IP class	Power [kW (hp)]		Torque [Nm (in-lb)]					
		3x525–600 V	Mains	Motor	DC connection	Control terminals	Ground	Relay	
H9	IP20	2.2–7.5 (3.0–10)	1.8 (16)	1.8 (16)	Not recommended	0.5 (4.0)	3 (27)	0.6 (5.0)	
H10	IP20	11–15 (15–20)	1.8 (16)	1.8 (16)	Not recommended	0.5 (4.0)	3 (27)	0.6 (5.0)	
H6	IP20	18.5–30 (25–40)	4.5 (40)	4.5 (40)	–	0.5 (4.0)	3 (27)	0.5 (4.0)	
H7	IP20	37–55 (50–70)	10 (89)	10 (89)	–	0.5 (4.0)	3 (27)	0.5 (4.0)	
H8	IP20	75–90 (100–125)	14 (124)/24 (212) <sup>2)</sup>	14 (124)/24 (212) <sup>2)</sup>	–	0.5 (4.0)	3 (27)	0.5 (4.0)	

**Table 5.3 Tightening Torques for Enclosure Sizes H6–H10, 3x525–600 V**

1) Cable dimensions >95 mm<sup>2</sup>

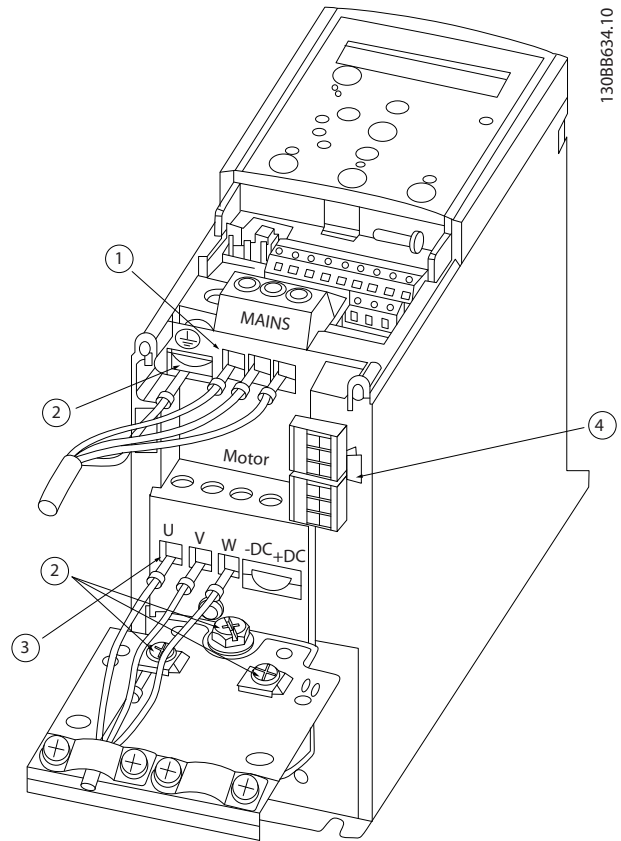
2) Cable dimensions ≤95 mm<sup>2</sup>

### 5.1.1 Mains and Motor Connection

The frequency converter is designed to operate all standard 3-phase asynchronous motors. For maximum cross-section on cables, see *chapter 8.4 General Technical Data*.

- Use a shielded/armored motor cable to comply with EMC emission specifications and connect this cable to both the decoupling plate and the motor.
- Keep the motor cable as short as possible to reduce the noise level and leakage currents.
- For further details on mounting the decoupling plate, see *FC 101 Decoupling Plate Mounting Instruction*.
- Also see *EMC-Correct Installation* in *chapter 5.1.2 EMC-compliant Electrical Installation*.
- For details on how to connect the frequency converter to mains and motor, see *chapter Connecting to Mains and Motor* in the *VLT® HVAC Basic Drive FC 101 Quick Guide*.

Relays and terminals on enclosure sizes H1–H5



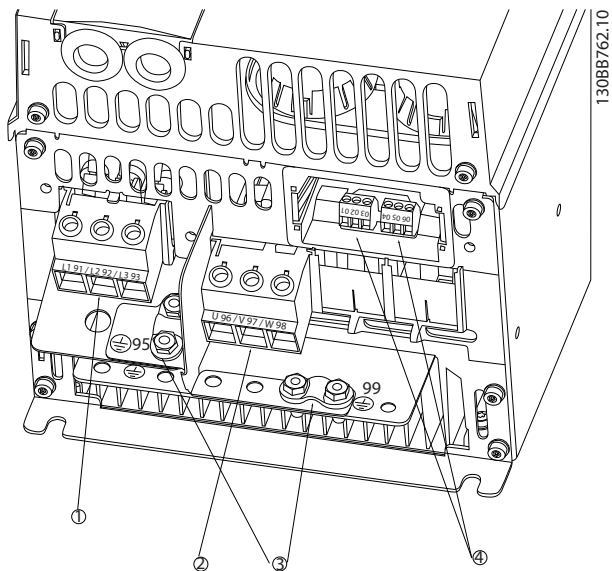
5

1	Mains
2	Ground
3	Motor
4	Relays

**Illustration 5.2 Enclosure Sizes H1–H5**  
 IP20, 200–240 V, 0.25–11 kW (0.33–15 hp)  
 IP20, 380–480 V, 0.37–22 kW (0.5–30 hp)

5

Relays and terminals on enclosure size H6

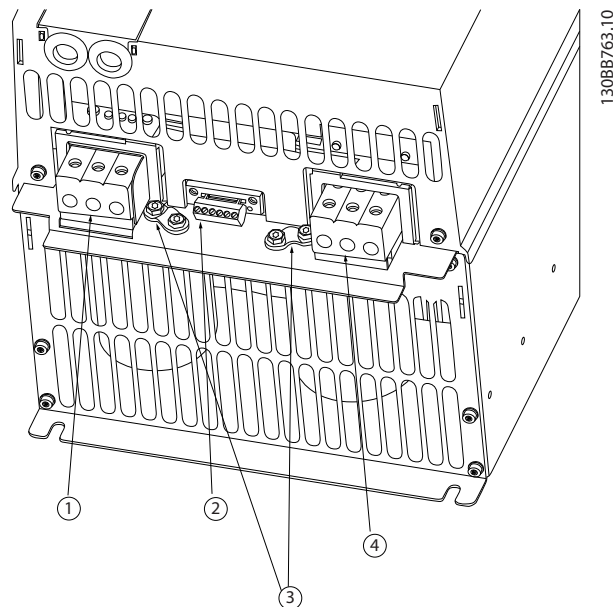


1	Mains
2	Motor
3	Ground
4	Relays

Illustration 5.3 Enclosure Size H6

- IP20, 380–480 V, 30–45 kW (40–60 hp)
- IP20, 200–240 V, 15–18.5 kW (20–25 hp)
- IP20, 525–600 V, 22–30 kW (30–40 hp)

Relays and terminals on enclosure size H7

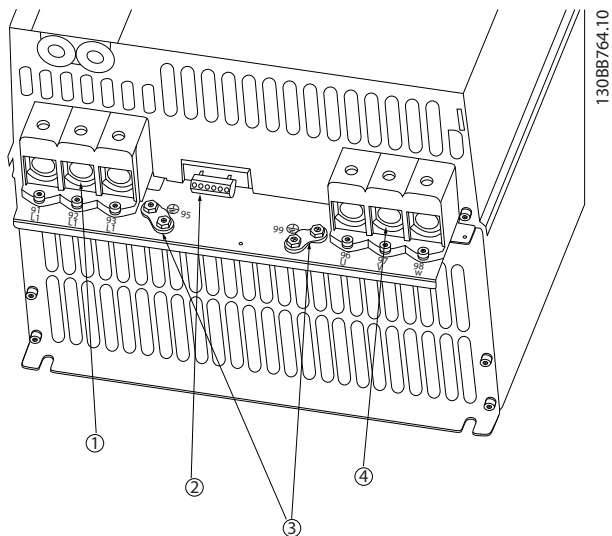


1	Mains
2	Relays
3	Ground
4	Motor

Illustration 5.4 Enclosure Size H7

- IP20, 380–480 V, 55–75 kW (70–100 hp)
- IP20, 200–240 V, 22–30 kW (30–40 hp)
- IP20, 525–600 V, 45–55 kW (60–70 hp)

**Relays and terminals on enclosure size H8**



1	Mains
2	Relays
3	Ground
4	Motor

**Illustration 5.5 Enclosure Size H8**

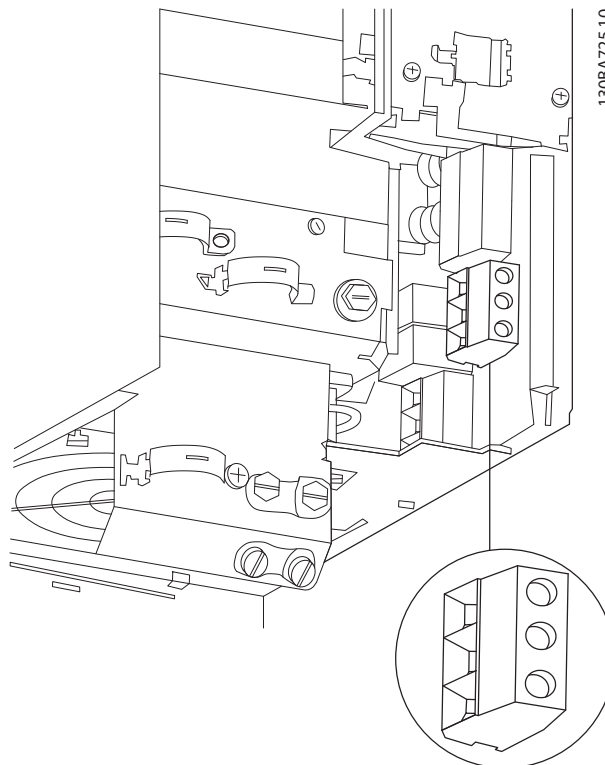
IP20, 380–480 V, 90 kW (125 hp)

IP20, 200–240 V, 37–45 kW (50–60 hp)

IP20, 525–600 V, 75–90 kW (100–125 hp)

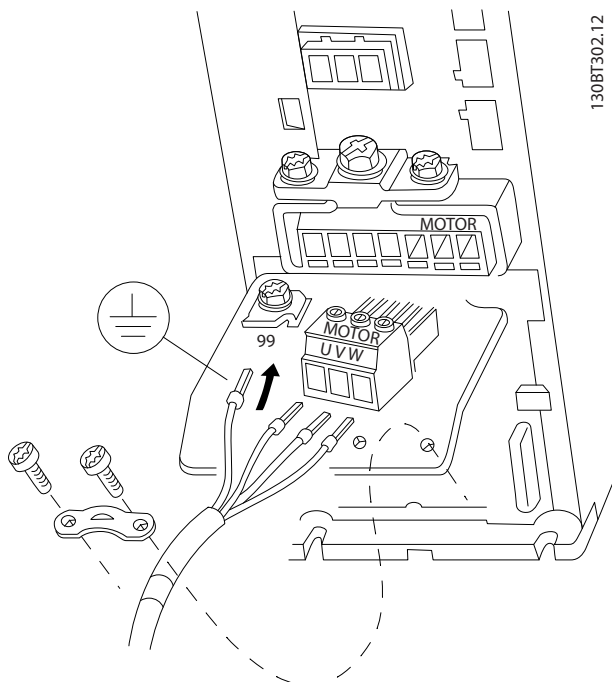
Make sure that the mains cables for enclosure size H9 is connected correctly, for details, see *chapter Connecting to Mains and Motor* in the *VLT® HVAC Basic Drive FC 101 Quick Guide*. Use the tightening torques described in *chapter 5.1.1 Electrical Installation in General*.

**Relays and terminals on enclosure size H10**



5

**Mains and motor connection for enclosure size H9**



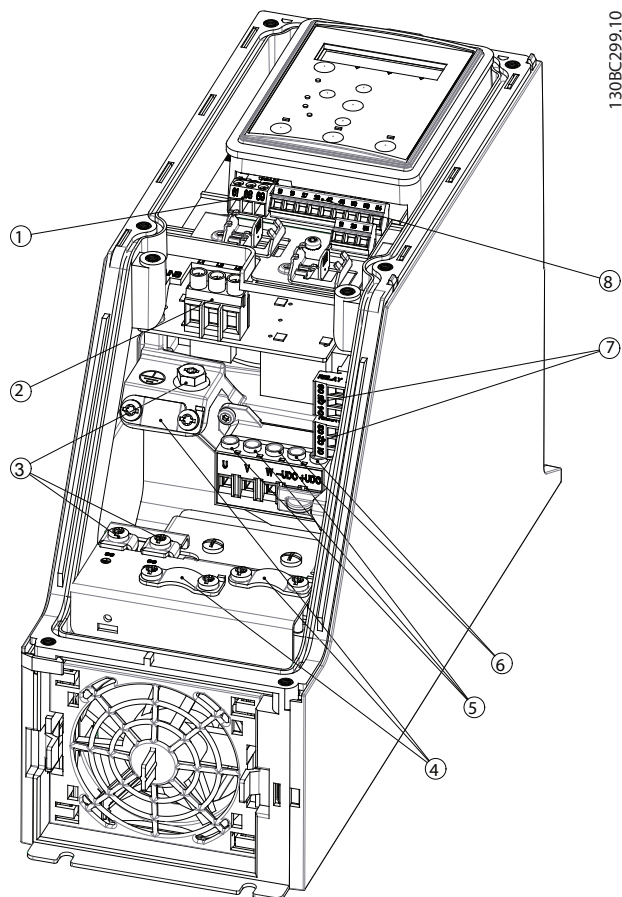
**Illustration 5.6 Motor Connection for Enclosure Size H9**

IP20, 600 V, 2.2–7.5 kW (3.0–10 hp)

**Illustration 5.7 Enclosure Size H10**

IP20, 600 V, 11–15 kW (15–20 hp)

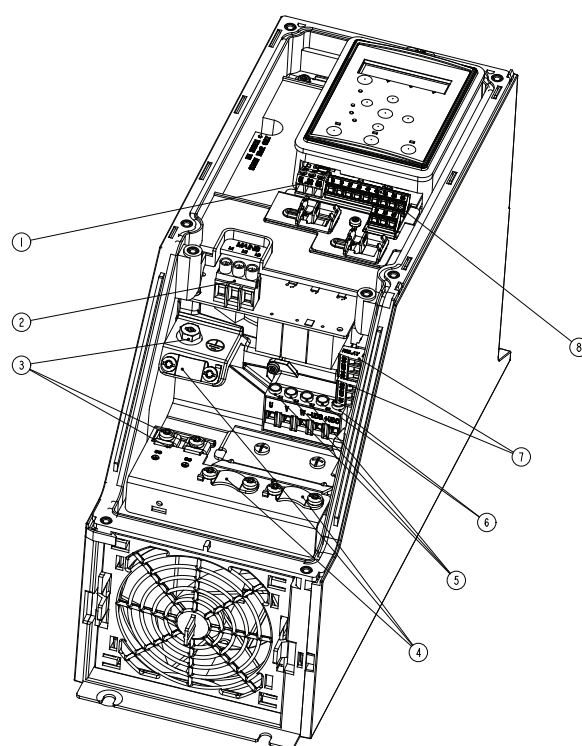
Enclosure size I2



1	RS485
2	Mains
3	Ground
4	Cable clamps
5	Motor
6	UDC
7	Relays
8	I/O

Illustration 5.8 Enclosure Size I2  
IP54, 380–480 V, 0.75–4.0 kW (1.0–5.0 hp)

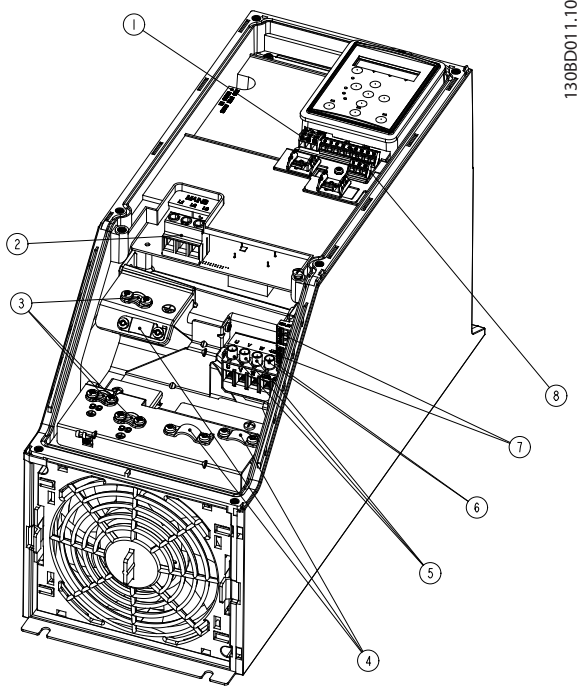
Enclosure size I3



1	RS485
2	Mains
3	Ground
4	Cable clamps
5	Motor
6	UDC
7	Relays
8	I/O

Illustration 5.9 Enclosure Size I3  
IP54, 380–480 V, 5.5–7.5 kW (7.5–10 hp)

Enclosure size I4



130BD011.10

1	RS485
2	Mains
3	Ground
4	Cable clamps
5	Motor
6	UDC
7	Relays
8	I/O

Illustration 5.10 Enclosure Size I4  
IP54, 380–480 V, 0.75–4.0 kW (1.0–5.0 hp)

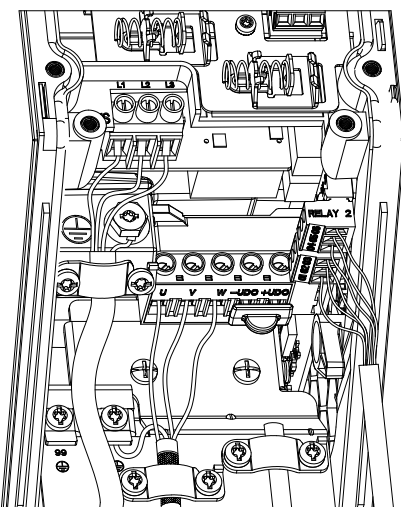
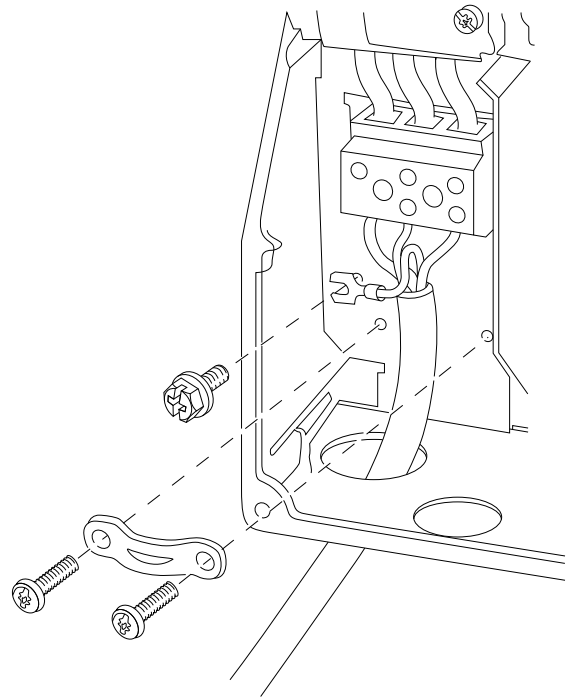


Illustration 5.11 IP54 Enclosure Sizes I2, I3, I4

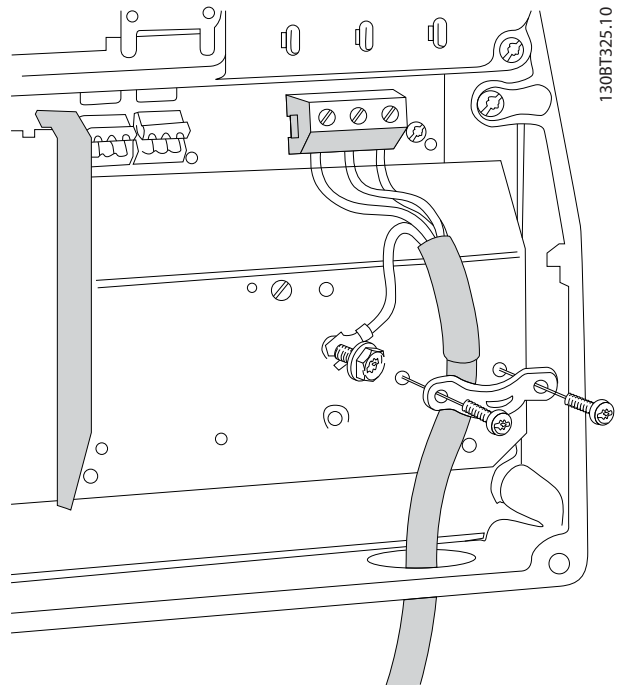
130BC203.10

Enclosure size I6



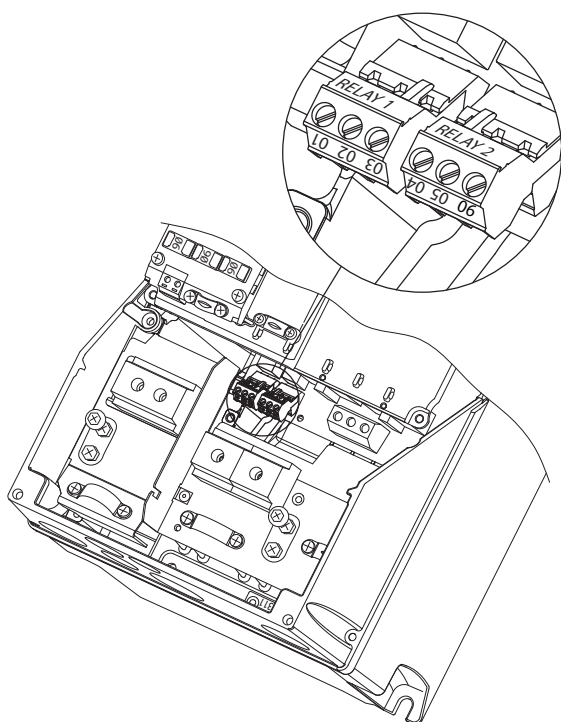
130BT326.10

Illustration 5.12 Mains Connection for Enclosure Size I6  
IP54, 380–480 V, 22–37 kW (30–50 hp)



130BT325.10

Illustration 5.13 Motor Connection for Enclosure Size I6  
IP54, 380–480 V, 22–37 kW (30–50 hp)



130BA215:10

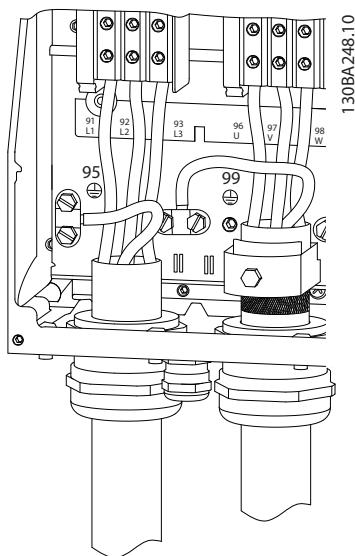
### 5.1.2 EMC-compliant Electrical Installation

Pay attention to the following recommendations to ensure EMC-correct electrical installation.

- Use only shielded/armored motor cables and shielded/armored control cables.
- Connect the shield to ground at both ends.
- Avoid installation with twisted shield ends (pigtailed), because this may affect the shielding effect at high frequencies. Use the cable clamps provided instead.
- It is important to ensure good electrical contact from the installation plate through the installation screws to the metal cabinet of the frequency converter.
- Use starwashers and galvanically conductive installation plates.
- Do not use unshielded/unarmored motor cables in the installation cabinets.

Illustration 5.14 Relays on Enclosure Size I6  
IP54, 380–480 V, 22–37 kW (30–50 hp)

#### Enclosure sizes I7, I8



130BA248:10

Illustration 5.15 Enclosure Sizes I7, I8  
IP54, 380–480 V, 45–55 kW (60–70 hp)  
IP54, 380–480 V, 75–90 kW (100–125 hp)



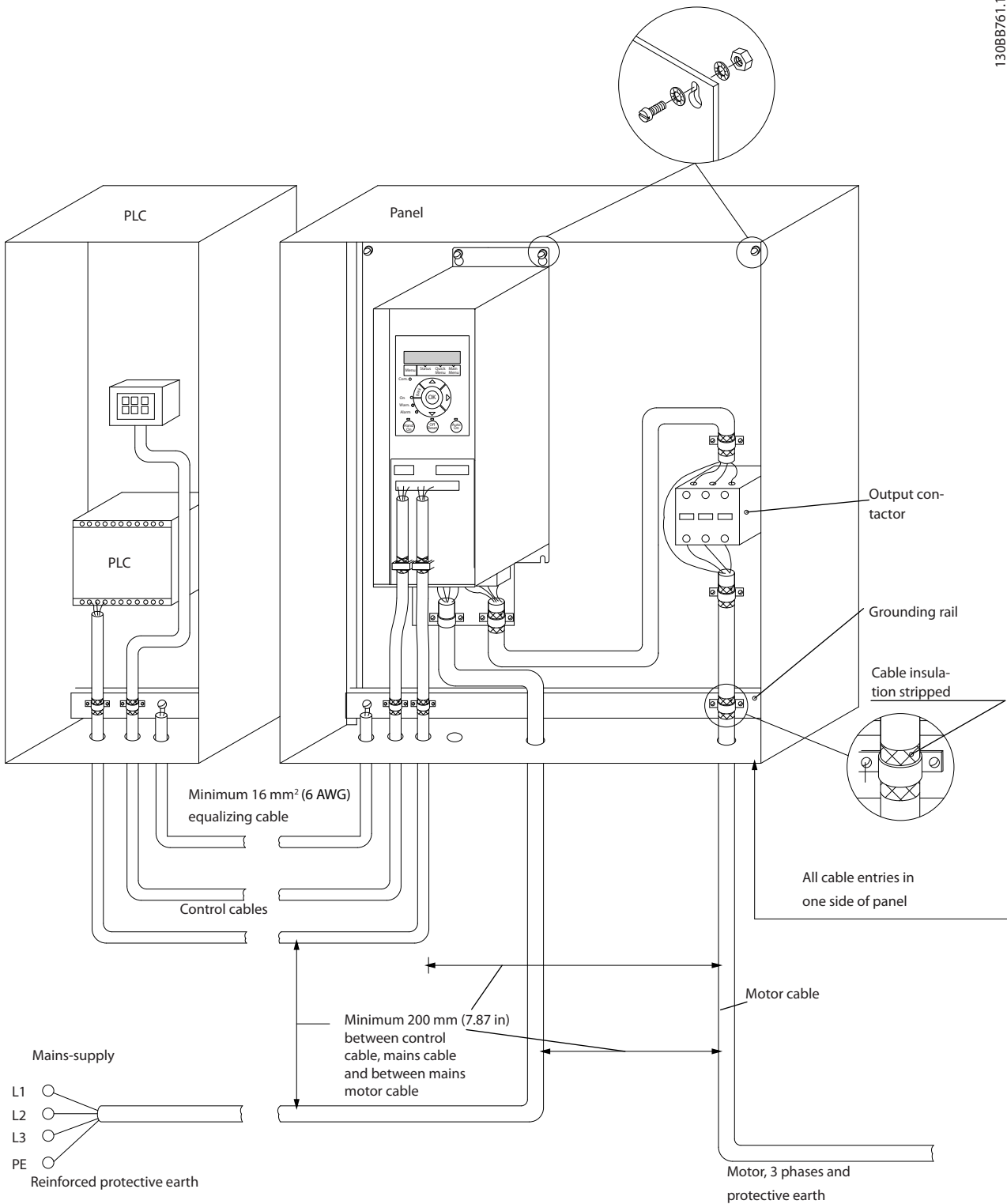


Illustration 5.16 EMC-correct Electrical Installation

**NOTICE**

For North America, use metal conduits instead of shielded cables.

### 5.1.3 Control Terminals

Refer to *VLT® HVAC Basic Drive FC 101 Quick Guide* and make sure that the terminal cover is removed correctly.

*Illustration 5.17* shows all the frequency converter control terminals. Applying start (terminal 18), connection between terminals 12-27, and an analog reference (terminal 53 or 54, and 55) make the frequency converter run.

The digital input mode of terminal 18, 19, and 27 is set in *parameter 5-00 Digital Input Mode* (PNP is default value). Digital input 29 mode is set in *parameter 5-03 Digital Input 29 Mode* (PNP is default value).

5

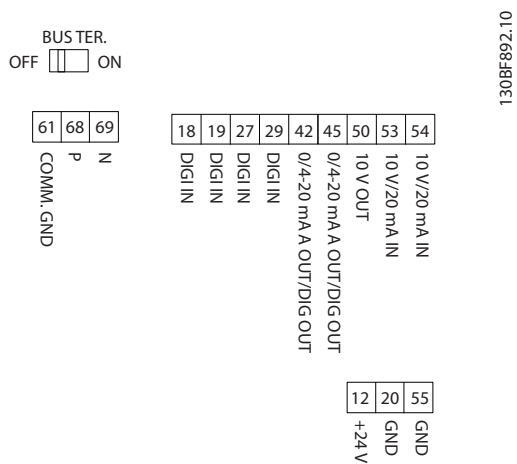


Illustration 5.17 Control Terminals

# 6 Programming

## 6.1 Introduction

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. Refer to *chapter 1.5 Additional Resources* for more details about the software.

## 6.2 Local Control Panel (LCP)

The LCP is divided into 4 functional sections.

- A. Display
- B. Menu key
- C. Navigation keys and indicator lights
- D. Operation keys and indicator lights

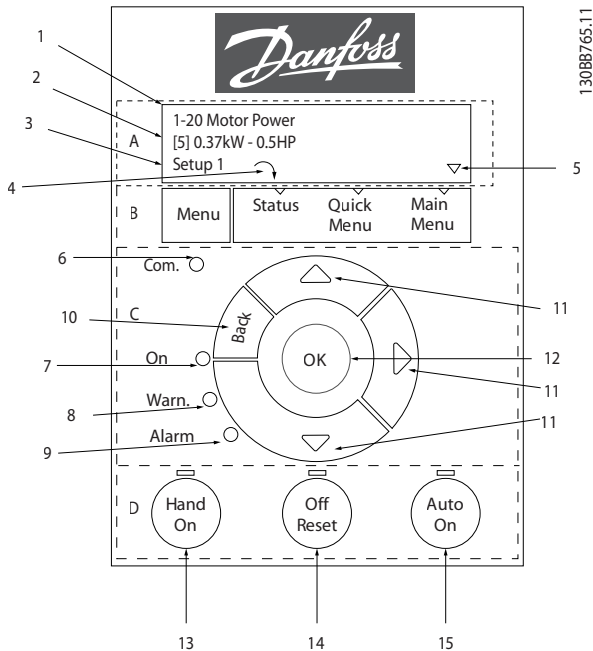


Illustration 6.1 Local Control Panel (LCP)

### A. Display

The LCD display is illuminated with 2 alphanumeric lines. All data is shown on the LCP.

Illustration 6.1 describes the information that can be read from the display.

1	Parameter number and name.
2	Parameter value.
3	Set-up number shows the active set-up and the edit set-up. If the same set-up acts as both active and edit set-up, only that set-up number is shown (factory setting). When active and edit set-up differ, both numbers are shown in the display (set-up 12). The number flashing indicates the edit set-up.
4	Motor direction is shown to the bottom left of the display – indicated by a small arrow pointing either clockwise or counterclockwise.
5	The triangle indicates if the LCP is in Status, Quick Menu, or Main Menu.

Table 6.1 Legend to Illustration 6.1, Part I

### B. Menu key

Press [Menu] to select among Status, Quick Menu, or Main Menu.

### C. Navigation keys and indicator lights

6	Com. LED: Flashes during bus communication.
7	Green LED/On: Control section is working correctly.
8	Yellow LED/Warn.: Indicates a warning.
9	Flashing Red LED/Alarm: Indicates an alarm.
10	[Back]: For moving to the previous step or layer in the navigation structure.
11	[▲] [▼] [▶]: For navigating among parameter groups and parameters, and within parameters. They can also be used for setting local reference.
12	[OK]: For selecting a parameter and for accepting changes to parameter settings.

Table 6.2 Legend to Illustration 6.1, Part II

### D. Operation keys and indicator lights

	[Hand On]: Starts the motor and enables control of the frequency converter via the LCP.
13	<b>NOTICE</b> [2] Coast inverse is the default option for parameter 5-12 Terminal 27 Digital Input. If there is no 24 V supply to terminal 27, [Hand On] does not start the motor. Connect terminal 12 to terminal 27.
14	[Off/Reset]: Stops the motor (Off). If in alarm mode, the alarm is reset.
15	[Auto On]: The frequency converter is controlled either via control terminals or serial communication.

Table 6.3 Legend to Illustration 6.1, Part III

## 6.3 Menus

### 6.3.1 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*.
- Motor Speed [RPM], *parameter 16-17 Speed [RPM]*.

The wizard is shown after power-up until any parameter has been changed. The wizard can always be accessed again through the quick menu. Press [OK] to start the wizard. Press [Back] to return to the status view.

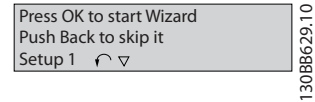


Illustration 6.3 Start-up/Quit Wizard

6

### 6.3.2 Quick Menu

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

- Wizard for open loop applications. See *Illustration 6.4* for details.
- Wizard for closed loop applications. See *Illustration 6.5* for details.
- Motor set-up. See *Table 6.6* for details.
- Changes made.

The built-in wizard menu guides the installer through the set-up of the frequency converter in a clear and structured manner for open-loop applications, closed-loop applications, and quick motor settings.

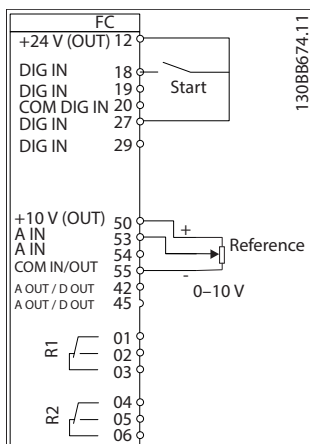


Illustration 6.2 Frequency Converter Wiring

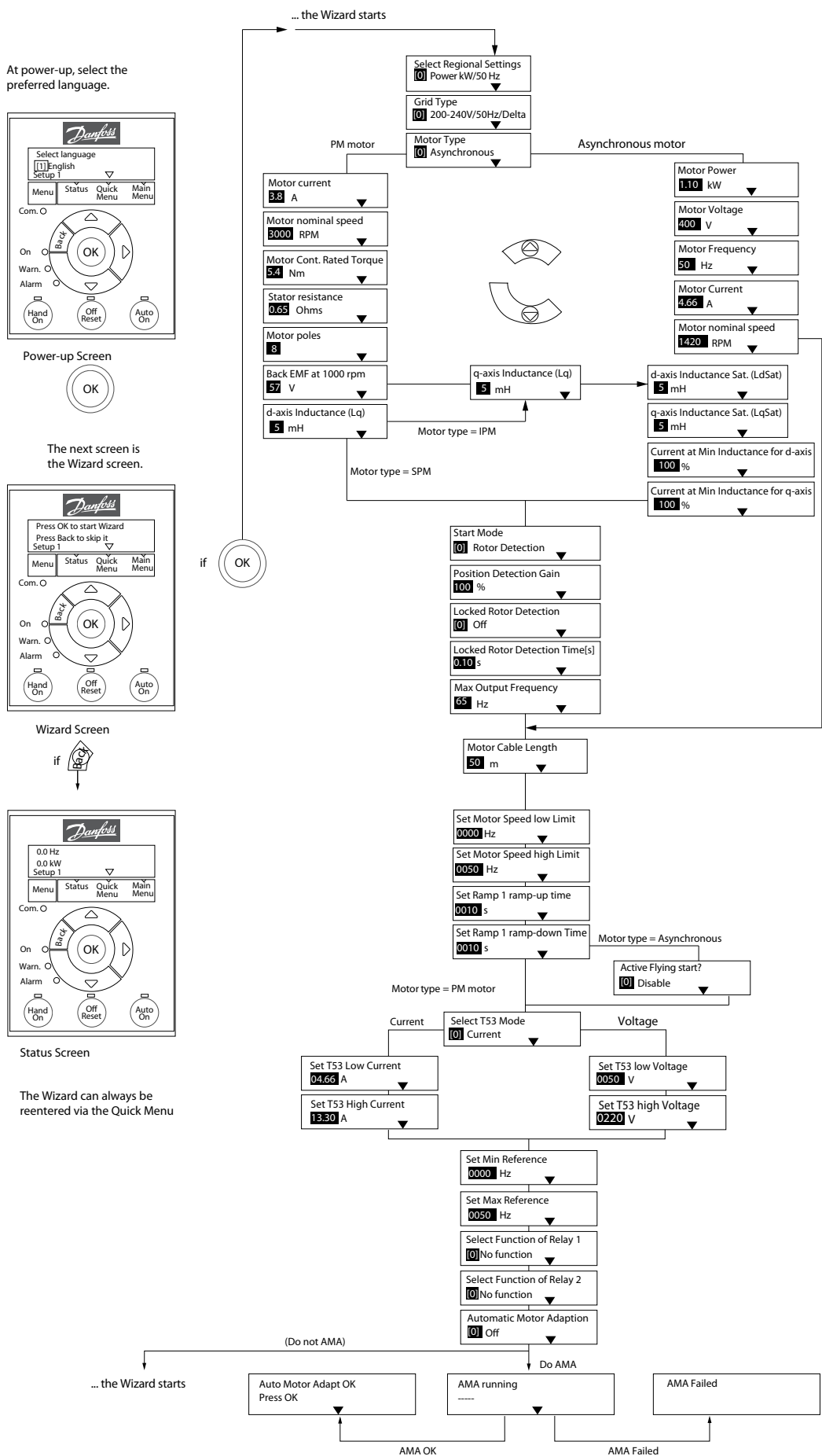


Illustration 6.4 Set-up Wizard for Open-loop Applications

Set-up Wizard for Open-loop Applications

Parameter	Option	Default	Usage
Parameter 0-03 Regional Settings	[0] International [1] US	[0] International	–
Parameter 0-06 GridType	[0] 200–240 V/50 Hz/IT-grid [1] 200–240 V/50 Hz/Delta [2] 200–240 V/50 Hz [10] 380–440 V/50 Hz/IT-grid [11] 380–440 V/50 Hz/Delta [12] 380–440 V/50 Hz [20] 440–480 V/50 Hz/IT-grid [21] 440–480 V/50 Hz/Delta [22] 440–480 V/50 Hz [30] 525–600 V/50 Hz/IT-grid [31] 525–600 V/50 Hz/Delta [32] 525–600 V/50 Hz [100] 200–240 V/60 Hz/IT-grid [101] 200–240 V/60 Hz/Delta [102] 200–240 V/60 Hz [110] 380–440 V/60 Hz/IT-grid [111] 380–440 V/60 Hz/Delta [112] 380–440 V/60 Hz [120] 440–480 V/60 Hz/IT-grid [121] 440–480 V/60 Hz/Delta [122] 440–480 V/60 Hz [130] 525–600 V/60 Hz/IT-grid [131] 525–600 V/60 Hz/Delta [132] 525–600 V/60 Hz	Size related	Select the operating mode for restart after reconnection of the frequency converter to mains voltage after power-down.

Parameter	Option	Default	Usage
Parameter 1-10 Motor Construction	*[0] Asynchron [1] PM, non-salient SPM [3] PM, salient IPM	[0] Asynchron	<p>Setting the parameter value might change these parameters:</p> <ul style="list-style-type: none"> <li>• Parameter 1-01 Motor Control Principle.</li> <li>• Parameter 1-03 Torque Characteristics.</li> <li>• Parameter 1-08 Motor Control Bandwidth.</li> <li>• Parameter 1-14 Damping Gain.</li> <li>• Parameter 1-15 Low Speed Filter Time Const.</li> <li>• Parameter 1-16 High Speed Filter Time Const.</li> <li>• Parameter 1-17 Voltage filter time const.</li> <li>• Parameter 1-20 Motor Power.</li> <li>• Parameter 1-22 Motor Voltage.</li> <li>• Parameter 1-23 Motor Frequency.</li> <li>• Parameter 1-24 Motor Current.</li> <li>• Parameter 1-25 Motor Nominal Speed.</li> <li>• Parameter 1-26 Motor Cont. Rated Torque.</li> <li>• Parameter 1-30 Stator Resistance (Rs).</li> <li>• Parameter 1-33 Stator Leakage Reactance (X1).</li> <li>• Parameter 1-35 Main Reactance (Xh).</li> <li>• Parameter 1-37 d-axis Inductance (Ld).</li> <li>• Parameter 1-38 q-axis Inductance (Lq).</li> <li>• Parameter 1-39 Motor Poles.</li> <li>• Parameter 1-40 Back EMF at 1000 RPM.</li> <li>• Parameter 1-44 d-axis Inductance Sat. (LdSat).</li> <li>• Parameter 1-45 q-axis Inductance Sat. (LqSat).</li> <li>• Parameter 1-46 Position Detection Gain.</li> <li>• Parameter 1-48 Current at Min Inductance for d-axis.</li> <li>• Parameter 1-49 Current at Min Inductance for q-axis.</li> <li>• Parameter 1-66 Min. Current at Low Speed.</li> <li>• Parameter 1-70 Start Mode.</li> <li>• Parameter 1-72 Start Function.</li> <li>• Parameter 1-73 Flying Start.</li> <li>• Parameter 1-80 Function at Stop.</li> <li>• Parameter 1-82 Min Speed for Function at Stop [Hz].</li> <li>• Parameter 1-90 Motor Thermal Protection.</li> <li>• Parameter 2-00 DC Hold/Motor Preheat Current.</li> <li>• Parameter 2-01 DC Brake Current.</li> <li>• Parameter 2-02 DC Braking Time.</li> <li>• Parameter 2-04 DC Brake Cut In Speed.</li> <li>• Parameter 2-10 Brake Function.</li> <li>• Parameter 4-14 Motor Speed High Limit [Hz].</li> <li>• Parameter 4-19 Max Output Frequency.</li> <li>• Parameter 4-58 Missing Motor Phase Function.</li> <li>• Parameter 14-65 Speed Derate Dead Time Compensation.</li> </ul>

Parameter	Option	Default	Usage
Parameter 1-20 Motor Power	0.12–110 kW/0.16–150 hp	Size related	Enter the motor power from the nameplate data.
Parameter 1-22 Motor Voltage	50–1000 V	Size related	Enter the motor voltage from the nameplate data.
Parameter 1-23 Motor Frequency	20–400 Hz	Size related	Enter the motor frequency from the nameplate data.
Parameter 1-24 Motor Current	0.01–10000.00 A	Size related	Enter the motor current from the nameplate data.
Parameter 1-25 Motor Nominal Speed	50–9999 RPM	Size related	Enter the motor nominal speed from the nameplate data.
Parameter 1-26 Motor Cont. Rated Torque	0.1–1000.0 Nm	Size related	This parameter is available when <i>parameter 1-10 Motor Construction</i> is set to options that enable permanent magnet motor mode. <b>NOTICE</b> Changing this parameter affects the settings of other parameters.
Parameter 1-29 Automatic Motor Adaption (AMA)	See <i>parameter 1-29 Automatic Motor Adaption (AMA)</i> .	Off	Performing an AMA optimizes motor performance.
Parameter 1-30 Stator Resistance (Rs)	0.000–99.990 Ω	Size related	Set the stator resistance value.
Parameter 1-37 d-axis Inductance (Ld)	0.000–1000.000 mH	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor datasheet.
Parameter 1-38 q-axis Inductance (Lq)	0.000–1000.000 mH	Size related	Enter the value of the q-axis inductance.
Parameter 1-39 Motor Poles	2–100	4	Enter the number of motor poles.
Parameter 1-40 Back EMF at 1000 RPM	10–9000 V	Size related	Line-line RMS back EMF voltage at 1000 RPM.
Parameter 1-42 Motor Cable Length	0–100 m	50 m	Enter the motor cable length.
Parameter 1-44 d-axis Inductance Sat. (LdSat)	0.000–1000.000 mH	Size related	This parameter corresponds to the inductance saturation of Ld. Ideally, this parameter has the same value as <i>parameter 1-37 d-axis Inductance (Ld)</i> . However, if the motor supplier provides an induction curve, enter the induction value, which is 200% of the nominal current.
Parameter 1-45 q-axis Inductance Sat. (LqSat)	0.000–1000.000 mH	Size related	This parameter corresponds to the inductance saturation of Lq. Ideally, this parameter has the same value as <i>parameter 1-38 q-axis Inductance (Lq)</i> . However, if the motor supplier provides an induction curve, enter the induction value, which is 200% of the nominal current.
Parameter 1-46 Position Detection Gain	20–200%	100%	Adjusts the height of the test pulse during position detection at start.
Parameter 1-48 Current at Min Inductance for d-axis	20–200%	100%	Enter the inductance saturation point.
Parameter 1-49 Current at Min Inductance for q-axis	20–200%	100%	This parameter specifies the saturation curve of the d- and q-inductance values. From 20–100% of this parameter, the inductances are linearly approximated due to <i>parameter 1-37 d-axis Inductance (Ld)</i> , <i>parameter 1-38 q-axis Inductance (Lq)</i> , <i>parameter 1-44 d-axis Inductance Sat. (LdSat)</i> , and <i>parameter 1-45 q-axis Inductance Sat. (LqSat)</i> .
Parameter 1-70 Start Mode	[0] Rotor Detection [1] Parking	[0] Rotor Detection	Select the PM motor start mode.



Parameter	Option	Default	Usage
Parameter 1-73 Flying Start	[0] Disabled [1] Enabled	[0] Disabled	Select [1] Enabled to enable the frequency converter to catch a motor spinning due to mains drop-out. Select [0] Disabled if this function is not required. When this parameter is set to [1] Enabled, parameter 1-71 Start Delay and parameter 1-72 Start Function are not functional. Parameter 1-73 Flying Start is active in VVC <sup>+</sup> mode only.
Parameter 3-02 Minimum Reference	-4999.000–4999.000	0	The minimum reference is the lowest value obtainable by summing all references.
Parameter 3-03 Maximum Reference	-4999.000–4999.000	50	The maximum reference is the highest obtainable by summing all references.
Parameter 3-41 Ramp 1 Ramp Up Time	0.05–3600.00 s	Size related	If asynchronous motor is selected, the ramp-up time is from 0 to rated parameter 1-23 Motor Frequency. If PM motor is selected, the ramp-up time is from 0 to parameter 1-25 Motor Nominal Speed.
Parameter 3-42 Ramp 1 Ramp Down Time	0.05–3600.00 s	Size related	For asynchronous motors, the ramp-down time is from rated parameter 1-23 Motor Frequency to 0. For PM motors, the ramp-down time is from parameter 1-25 Motor Nominal Speed to 0.
Parameter 4-12 Motor Speed Low Limit [Hz]	0.0–400.0 Hz	0 Hz	Enter the minimum limit for low speed.
Parameter 4-14 Motor Speed High Limit [Hz]	0.0–400.0 Hz	100 Hz	Enter the maximum limit for high speed.
Parameter 4-19 Max Output Frequency	0.0–400.0 Hz	100 Hz	Enter the maximum output frequency value. If parameter 4-19 Max Output Frequency is set lower than parameter 4-14 Motor Speed High Limit [Hz], parameter 4-14 Motor Speed High Limit [Hz] is set equal to parameter 4-19 Max Output Frequency automatically.
Parameter 5-40 Function Relay	See parameter 5-40 Function Relay.	[9] Alarm	Select the function to control output relay 1.
Parameter 5-40 Function Relay	See parameter 5-40 Function Relay.	[5] Drive running	Select the function to control output relay 2.
Parameter 6-10 Terminal 53 Low Voltage	0.00–10.00 V	0.07 V	Enter the voltage that corresponds to the low reference value.
Parameter 6-11 Terminal 53 High Voltage	0.00–10.00 V	10 V	Enter the voltage that corresponds to the high reference value.
Parameter 6-12 Terminal 53 Low Current	0.00–20.00 mA	4 mA	Enter the current that corresponds to the low reference value.
Parameter 6-13 Terminal 53 High Current	0.00–20.00 mA	20 mA	Enter the current that corresponds to the high reference value.
Parameter 6-19 Terminal 53 mode	[0] Current [1] Voltage	[1] Voltage	Select if terminal 53 is used for current or voltage input.
Parameter 30-22 Locked Rotor Protection	[0] Off [1] On	[0] Off	–
Parameter 30-23 Locked Rotor Detection Time [s]	0.05–1 s	0.10 s	–

Table 6.4 Set-up Wizard for Open-loop Applications

Set-up Wizard for Closed-loop Applications

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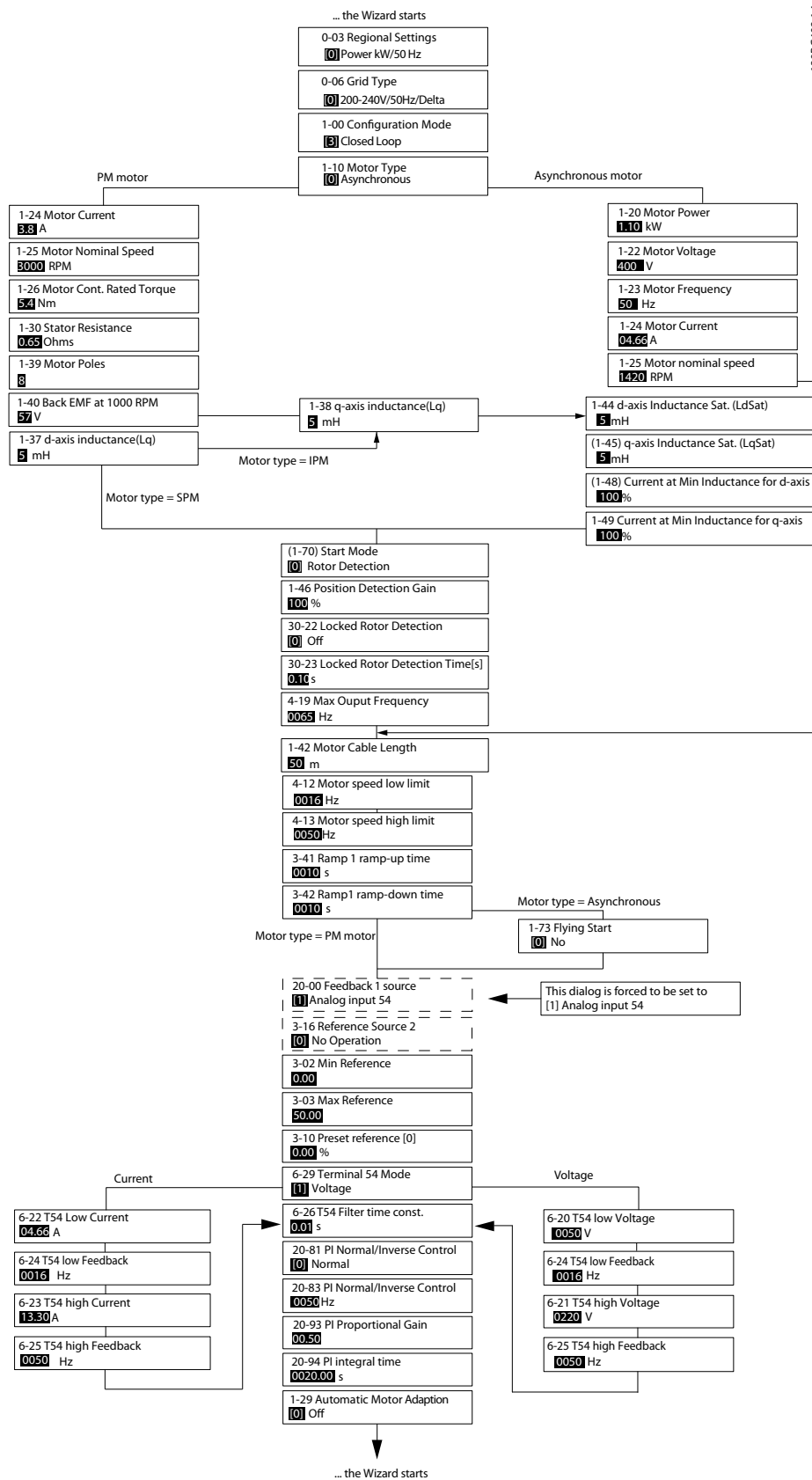


Illustration 6.5 Set-up Wizard for Closed-loop Applications

Parameter	Range	Default	Usage
<i>Parameter 0-03 Regional Settings</i>	<i>[0] International [1] US</i>	<i>[0] International</i>	–
<i>Parameter 0-06 GridType</i>	<i>[0]–[132] see Table 6.4.</i>	<i>Size selected</i>	Select the operating mode for restart after reconnection of the frequency converter to mains voltage after power-down.
<i>Parameter 1-00 Configuration Mode</i>	<i>[0] Open loop [3] Closed loop</i>	<i>[0] Open loop</i>	Select <i>[3] Closed loop</i> .

Parameter	Range	Default	Usage
Parameter 1-10 Motor Construction	*[0] Asynchron [1] PM, non-salient SPM [3] PM, salient IPM	[0] Asynchron	<p>Setting the parameter value might change these parameters:</p> <ul style="list-style-type: none"> <li>• Parameter 1-01 Motor Control Principle.</li> <li>• Parameter 1-03 Torque Characteristics.</li> <li>• Parameter 1-08 Motor Control Bandwidth.</li> <li>• Parameter 1-14 Damping Gain.</li> <li>• Parameter 1-15 Low Speed Filter Time Const.</li> <li>• Parameter 1-16 High Speed Filter Time Const.</li> <li>• Parameter 1-17 Voltage filter time const.</li> <li>• Parameter 1-20 Motor Power.</li> <li>• Parameter 1-22 Motor Voltage.</li> <li>• Parameter 1-23 Motor Frequency.</li> <li>• Parameter 1-24 Motor Current.</li> <li>• Parameter 1-25 Motor Nominal Speed.</li> <li>• Parameter 1-26 Motor Cont. Rated Torque.</li> <li>• Parameter 1-30 Stator Resistance (Rs).</li> <li>• Parameter 1-33 Stator Leakage Reactance (X1).</li> <li>• Parameter 1-35 Main Reactance (Xh).</li> <li>• Parameter 1-37 d-axis Inductance (Ld).</li> <li>• Parameter 1-38 q-axis Inductance (Lq).</li> <li>• Parameter 1-39 Motor Poles.</li> <li>• Parameter 1-40 Back EMF at 1000 RPM.</li> <li>• Parameter 1-44 d-axis Inductance Sat. (LdSat).</li> <li>• Parameter 1-45 q-axis Inductance Sat. (LqSat).</li> <li>• Parameter 1-46 Position Detection Gain.</li> <li>• Parameter 1-48 Current at Min Inductance for d-axis.</li> <li>• Parameter 1-49 Current at Min Inductance for q-axis.</li> <li>• Parameter 1-66 Min. Current at Low Speed.</li> <li>• Parameter 1-70 Start Mode.</li> <li>• Parameter 1-72 Start Function.</li> <li>• Parameter 1-73 Flying Start.</li> <li>• Parameter 1-80 Function at Stop.</li> <li>• Parameter 1-82 Min Speed for Function at Stop [Hz].</li> <li>• Parameter 1-90 Motor Thermal Protection.</li> <li>• Parameter 2-00 DC Hold/Motor Preheat Current.</li> <li>• Parameter 2-01 DC Brake Current.</li> <li>• Parameter 2-02 DC Braking Time.</li> <li>• Parameter 2-04 DC Brake Cut In Speed.</li> <li>• Parameter 2-10 Brake Function.</li> <li>• Parameter 4-14 Motor Speed High Limit [Hz].</li> <li>• Parameter 4-19 Max Output Frequency.</li> <li>• Parameter 4-58 Missing Motor Phase Function.</li> <li>• Parameter 14-65 Speed Derate Dead Time Compensation.</li> </ul>

Parameter	Range	Default	Usage
Parameter 1-20 Motor Power	0.09–110 kW	Size related	Enter the motor power from the nameplate data.
Parameter 1-22 Motor Voltage	50–1000 V	Size related	Enter the motor voltage from the nameplate data.
Parameter 1-23 Motor Frequency	20–400 Hz	Size related	Enter the motor frequency from the nameplate data.
Parameter 1-24 Motor Current	0–10000 A	Size related	Enter the motor current from the nameplate data.
Parameter 1-25 Motor Nominal Speed	50–9999 RPM	Size related	Enter the motor nominal speed from the nameplate data.
Parameter 1-26 Motor Cont. Rated Torque	0.1–1000.0 Nm	Size related	This parameter is available when <i>parameter 1-10 Motor Construction</i> is set to options that enable permanent magnet motor mode. <b>NOTICE</b> Changing this parameter affects the settings of other parameters.
Parameter 1-29 Automatic Motor Adaption (AMA)		Off	Performing an AMA optimizes motor performance.
Parameter 1-30 Stator Resistance (Rs)	0–99.990 Ω	Size related	Set the stator resistance value.
Parameter 1-37 d-axis Inductance (Ld)	0.000–1000.000 mH	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor datasheet.
Parameter 1-38 q-axis Inductance (Lq)	0.000–1000.000 mH	Size related	Enter the value of the q-axis inductance.
Parameter 1-39 Motor Poles	2–100	4	Enter the number of motor poles.
Parameter 1-40 Back EMF at 1000 RPM	10–9000 V	Size related	Line-line RMS back EMF voltage at 1000 RPM.
Parameter 1-42 Motor Cable Length	0–100 m	50 m	Enter the motor cable length.
Parameter 1-44 d-axis Inductance Sat. (LdSat)	0.000–1000.000 mH	Size related	This parameter corresponds to the inductance saturation of Ld. Ideally, this parameter has the same value as <i>parameter 1-37 d-axis Inductance (Ld)</i> . However, if the motor supplier provides an induction curve, enter the induction value, which is 200% of the nominal current.
Parameter 1-45 q-axis Inductance Sat. (LqSat)	0.000–1000.000 mH	Size related	This parameter corresponds to the inductance saturation of Lq. Ideally, this parameter has the same value as <i>parameter 1-38 q-axis Inductance (Lq)</i> . However, if the motor supplier provides an induction curve, enter the induction value, which is 200% of the nominal current.
Parameter 1-46 Position Detection Gain	20–200%	100%	Adjusts the height of the test pulse during position detection at start.
Parameter 1-48 Current at Min Inductance for d-axis	20–200%	100%	Enter the inductance saturation point.
Parameter 1-49 Current at Min Inductance for q-axis	20–200%	100%	This parameter specifies the saturation curve of the d- and q-inductance values. From 20–100% of this parameter, the inductances are linearly approximated due to <i>parameter 1-37 d-axis Inductance (Ld)</i> , <i>parameter 1-38 q-axis Inductance (Lq)</i> , <i>parameter 1-44 d-axis Inductance Sat. (LdSat)</i> , and <i>parameter 1-45 q-axis Inductance Sat. (LqSat)</i> .
Parameter 1-70 Start Mode	[0] Rotor Detection [1] Parking	[0] Rotor Detection	Select the PM motor start mode.
Parameter 1-73 Flying Start	[0] Disabled [1] Enabled	[0] Disabled	Select [1] Enabled to enable the frequency converter to catch a spinning motor in, for example, fan applications. When PM is selected, this parameter is enabled.

Parameter	Range	Default	Usage
Parameter 3-02 Minimum Reference	-4999.000–4999.000	0	The minimum reference is the lowest value obtainable by summing all references.
Parameter 3-03 Maximum Reference	-4999.000–4999.000	50	The maximum reference is the highest value obtainable by summing all references.
Parameter 3-10 Preset Reference	-100–100%	0	Enter the setpoint.
Parameter 3-41 Ramp 1 Ramp Up Time	0.05–3600.0 s	Size related	Ramp-up time from 0 to rated <i>parameter 1-23 Motor Frequency</i> for asynchronous motors. Ramp-up time from 0 to <i>parameter 1-25 Motor Nominal Speed</i> for PM motors.
Parameter 3-42 Ramp 1 Ramp Down Time	0.05–3600.0 s	Size related	Ramp-down time from rated <i>parameter 1-23 Motor Frequency</i> to 0 for asynchronous motors. Ramp-down time from <i>parameter 1-25 Motor Nominal Speed</i> to 0 for PM motors.
Parameter 4-12 Motor Speed Low Limit [Hz]	0.0–400.0 Hz	0.0 Hz	Enter the minimum limit for low speed.
Parameter 4-14 Motor Speed High Limit [Hz]	0.0–400.0 Hz	100 Hz	Enter the maximum limit for high speed.
Parameter 4-19 Max Output Frequency	0.0–400.0 Hz	100 Hz	Enter the maximum output frequency value. If <i>parameter 4-19 Max Output Frequency</i> is set lower than <i>parameter 4-14 Motor Speed High Limit [Hz]</i> , <i>parameter 4-14 Motor Speed High Limit [Hz]</i> is set equal to <i>parameter 4-19 Max Output Frequency</i> automatically.
Parameter 6-20 Terminal 54 Low Voltage	0.00–10.00 V	0.07 V	Enter the voltage that corresponds to the low reference value.
Parameter 6-21 Terminal 54 High Voltage	0.00–10.00 V	10.00 V	Enter the voltage that corresponds to the high reference value.
Parameter 6-22 Terminal 54 Low Current	0.00–20.00 mA	4.00 mA	Enter the current that corresponds to the low reference value.
Parameter 6-23 Terminal 54 High Current	0.00–20.00 mA	20.00 mA	Enter the current that corresponds to the high reference value.
Parameter 6-24 Terminal 54 Low Ref./Feedb. Value	-4999–4999	0	Enter the feedback value that corresponds to the voltage or current set in <i>parameter 6-20 Terminal 54 Low Voltage/parameter 6-22 Terminal 54 Low Current</i> .
Parameter 6-25 Terminal 54 High Ref./Feedb. Value	-4999–4999	50	Enter the feedback value that corresponds to the voltage or current set in <i>parameter 6-21 Terminal 54 High Voltage/parameter 6-23 Terminal 54 High Current</i> .
Parameter 6-26 Terminal 54 Filter Time Constant	0.00–10.00 s	0.01	Enter the filter time constant.
Parameter 6-29 Terminal 54 mode	[0] Current [1] Voltage	[1] Voltage	Select if terminal 54 is used for current or voltage input.
Parameter 20-81 PI Normal/Inverse Control	[0] Normal [1] Inverse	[0] Normal	Select [0] <i>Normal</i> to set the process control to increase the output speed when the process error is positive. Select [1] <i>Inverse</i> to reduce the output speed.
Parameter 20-83 PI Start Speed [Hz]	0–200 Hz	0 Hz	Enter the motor speed to be attained as a start signal for commencement of PI control.
Parameter 20-93 PI Proportional Gain	0.00–10.00	0.01	Enter the process controller proportional gain. Quick control is obtained at high amplification. However, if amplification is too high, the process may become unstable.
Parameter 20-94 PI Integral Time	0.1–999.0 s	999.0 s	Enter the process controller integral time. Obtain quick control through a short integral time, though if the integral time is too short, the process becomes unstable. An excessively long integral time disables the integral action.
Parameter 30-22 Locked Rotor Protection	[0] Off [1] On	[0] Off	–

Parameter	Range	Default	Usage
<i>Parameter 30-23 Locked Rotor Detection Time [s]</i>	0.05–1.00 s	0.10 s	–

**Table 6.5 Set-up Wizard for Closed-loop Applications**

### Motor set-up

The motor set-up wizard guides users through the needed motor parameters.

Parameter	Range	Default	Usage
<i>Parameter 0-03 Regional Settings</i>	[0] <i>International</i> [1] <i>US</i>	0	–
<i>Parameter 0-06 GridType</i>	[0]–[132] see <i>Table 6.4.</i>	Size related	Select the operating mode for restart after reconnection of the frequency converter to mains voltage after power-down.

Parameter	Range	Default	Usage
Parameter 1-10 Motor Construction	*[0] Asynchron [1] PM, non-salient SPM [3] PM, salient IPM	[0] Asynchron	<p>Setting the parameter value might change these parameters:</p> <ul style="list-style-type: none"> <li>• Parameter 1-01 Motor Control Principle.</li> <li>• Parameter 1-03 Torque Characteristics.</li> <li>• Parameter 1-08 Motor Control Bandwidth.</li> <li>• Parameter 1-14 Damping Gain.</li> <li>• Parameter 1-15 Low Speed Filter Time Const.</li> <li>• Parameter 1-16 High Speed Filter Time Const.</li> <li>• Parameter 1-17 Voltage filter time const.</li> <li>• Parameter 1-20 Motor Power.</li> <li>• Parameter 1-22 Motor Voltage.</li> <li>• Parameter 1-23 Motor Frequency.</li> <li>• Parameter 1-24 Motor Current.</li> <li>• Parameter 1-25 Motor Nominal Speed.</li> <li>• Parameter 1-26 Motor Cont. Rated Torque.</li> <li>• Parameter 1-30 Stator Resistance (Rs).</li> <li>• Parameter 1-33 Stator Leakage Reactance (X1).</li> <li>• Parameter 1-35 Main Reactance (Xh).</li> <li>• Parameter 1-37 d-axis Inductance (Ld).</li> <li>• Parameter 1-38 q-axis Inductance (Lq).</li> <li>• Parameter 1-39 Motor Poles.</li> <li>• Parameter 1-40 Back EMF at 1000 RPM.</li> <li>• Parameter 1-44 d-axis Inductance Sat. (LdSat).</li> <li>• Parameter 1-45 q-axis Inductance Sat. (LqSat).</li> <li>• Parameter 1-46 Position Detection Gain.</li> <li>• Parameter 1-48 Current at Min Inductance for d-axis.</li> <li>• Parameter 1-49 Current at Min Inductance for q-axis.</li> <li>• Parameter 1-66 Min. Current at Low Speed.</li> <li>• Parameter 1-70 Start Mode.</li> <li>• Parameter 1-72 Start Function.</li> <li>• Parameter 1-73 Flying Start.</li> <li>• Parameter 1-80 Function at Stop.</li> <li>• Parameter 1-82 Min Speed for Function at Stop [Hz].</li> <li>• Parameter 1-90 Motor Thermal Protection.</li> <li>• Parameter 2-00 DC Hold/Motor Preheat Current.</li> <li>• Parameter 2-01 DC Brake Current.</li> <li>• Parameter 2-02 DC Braking Time.</li> <li>• Parameter 2-04 DC Brake Cut In Speed.</li> <li>• Parameter 2-10 Brake Function.</li> <li>• Parameter 4-14 Motor Speed High Limit [Hz].</li> <li>• Parameter 4-19 Max Output Frequency.</li> <li>• Parameter 4-58 Missing Motor Phase Function.</li> <li>• Parameter 14-65 Speed Derate Dead Time Compensation.</li> </ul>



Parameter	Range	Default	Usage
Parameter 1-20 Motor Power	0.12–110 kW/0.16–150 hp	Size related	Enter the motor power from the nameplate data.
Parameter 1-22 Motor Voltage	50–1000 V	Size related	Enter the motor voltage from the nameplate data.
Parameter 1-23 Motor Frequency	20–400 Hz	Size related	Enter the motor frequency from the nameplate data.
Parameter 1-24 Motor Current	0.01–10000.00 A	Size related	Enter the motor current from the nameplate data.
Parameter 1-25 Motor Nominal Speed	50–9999 RPM	Size related	Enter the motor nominal speed from the nameplate data.
Parameter 1-26 Motor Cont. Rated Torque	0.1–1000.0 Nm	Size related	This parameter is available when <i>parameter 1-10 Motor Construction</i> is set to options that enable permanent magnet motor mode. <b>NOTICE</b> Changing this parameter affects the settings of other parameters.
Parameter 1-30 Stator Resistance (Rs)	0–99.990 Ω	Size related	Set the stator resistance value.
Parameter 1-37 d-axis Inductance (Ld)	0.000–1000.000 mH	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor datasheet.
Parameter 1-38 q-axis Inductance (Lq)	0.000–1000.000 mH	Size related	Enter the value of the q-axis inductance.
Parameter 1-39 Motor Poles	2–100	4	Enter the number of motor poles.
Parameter 1-40 Back EMF at 1000 RPM	10–9000 V	Size related	Line-line RMS back EMF voltage at 1000 RPM.
Parameter 1-42 Motor Cable Length	0–100 m	50 m	Enter the motor cable length.
Parameter 1-44 d-axis Inductance Sat. (LdSat)	0.000–1000.000 mH	Size related	This parameter corresponds to the inductance saturation of Ld. Ideally, this parameter has the same value as <i>parameter 1-37 d-axis Inductance (Ld)</i> . However, if the motor supplier provides an induction curve, enter the induction value, which is 200% of the nominal current.
Parameter 1-45 q-axis Inductance Sat. (LqSat)	0.000–1000.000 mH	Size related	This parameter corresponds to the inductance saturation of Lq. Ideally, this parameter has the same value as <i>parameter 1-38 q-axis Inductance (Lq)</i> . However, if the motor supplier provides an induction curve, enter the induction value, which is 200% of the nominal current.
Parameter 1-46 Position Detection Gain	20–200%	100%	Adjusts the height of the test pulse during position detection at start.
Parameter 1-48 Current at Min Inductance for d-axis	20–200%	100%	Enter the inductance saturation point.
Parameter 1-49 Current at Min Inductance for q-axis	20–200%	100%	This parameter specifies the saturation curve of the d- and q-inductance values. From 20–100% of this parameter, the inductances are linearly approximated due to <i>parameter 1-37 d-axis Inductance (Ld)</i> , <i>parameter 1-38 q-axis Inductance (Lq)</i> , <i>parameter 1-44 d-axis Inductance Sat. (LdSat)</i> , and <i>parameter 1-45 q-axis Inductance Sat. (LqSat)</i> .
Parameter 1-70 Start Mode	[0] Rotor Detection [1] Parking	[0] Rotor Detection	Select the PM motor start mode.
Parameter 1-73 Flying Start	[0] Disabled [1] Enabled	[0] Disabled	Select [1] Enabled to enable the frequency converter to catch a spinning motor.
Parameter 3-41 Ramp 1 Ramp Up Time	0.05–3600.0 s	Size related	Ramp-up time from 0 to rated <i>parameter 1-23 Motor Frequency</i> .
Parameter 3-42 Ramp 1 Ramp Down Time	0.05–3600.0 s	Size related	Ramp-down time from rated <i>parameter 1-23 Motor Frequency</i> to 0.

Parameter	Range	Default	Usage
Parameter 4-12 Motor Speed Low Limit [Hz]	0.0–400.0 Hz	0.0 Hz	Enter the minimum limit for low speed.
Parameter 4-14 Motor Speed High Limit [Hz]	0.0–400.0 Hz	100.0 Hz	Enter the maximum limit for high speed.
Parameter 4-19 Max Output Frequency	0.0–400.0 Hz	100.0 Hz	Enter the maximum output frequency value. If <i>parameter 4-19 Max Output Frequency</i> is set lower than <i>parameter 4-14 Motor Speed High Limit [Hz]</i> , <i>parameter 4-14 Motor Speed High Limit [Hz]</i> is set equal to <i>parameter 4-19 Max Output Frequency</i> automatically.
Parameter 30-22 Locked Rotor Protection	[0] Off [1] On	[0] Off	–
Parameter 30-23 Locked Rotor Detection Time [s]	0.05–1.00 s	0.10 s	–

Table 6.6 Motor Set-up Wizard Settings

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**Changes made**

The changes made function lists all parameters changed from default settings.

- The list shows only parameters that have been changed in the current edit set-up.
- Parameters that have been reset to default values are not listed.
- The message *Empty* indicates that no parameters have been changed.

**Changing parameter settings**

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

**The main menu accesses all parameters**

1. Press the [Menu] key until the indicator in the display is placed above Main Menu.
2. Press [▲] [▼] to browse through the parameter groups.
3. Press [OK] to select a parameter group.
4. Press [▲] [▼] to browse through the parameters in the specific group.
5. Press [OK] to select the parameter.
6. Press [▲] [▼] to set/change the parameter value.
7. Press [OK] to accept the change.

**6.3.3 Main Menu**

Press [Menu] to access the main menu and program 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. The quick menu provides the simplest and quickest access to the typically required parameters.

**6.4 Quick Transfer of Parameter Settings between Multiple Frequency Converters**

When the set-up of a frequency converter is completed, store the data in the LCP or on a PC via MCT 10 Set-up Software.

**Data transfer from the frequency converter to the LCP**

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

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

**Data transfer from the LCP to the frequency converter**

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

**6.5 Readout and Programming of Indexed Parameters**

Select the parameter, press [OK], and press [▲]/[▼] to scroll through the indexed values. To change the parameter value, select the indexed value and press [OK]. Change the value by pressing [▲]/[▼]. Press [OK] to accept the new setting. Press [Cancel] to abort. Press [Back] to leave the parameter.

**6.6 Initialization to Default Settings**

There are 2 ways to initialize the frequency converter to the default settings.

**Recommended initialization**

1. Select *parameter 14-22 Operation Mode*.
2. Press [OK].
3. Select [2] *Initialisation* and Press [OK].
4. Power off the frequency converter and wait until the display turns off.
5. Reconnect the mains supply. The frequency converter is now reset, except for the following parameters:
  - *Parameter 1-06 Clockwise Direction*
  - *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 8-37 Maximum Inter-char 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 to parameter 15-05 Over Volt's*
  - *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*
- *Parameter 18-10 FireMode Log:Event*

**2-finger initialization**

The other way to initialize the frequency converter to default settings is through 2-finger initialization:

1. Power off the frequency converter.
2. Press [OK] and [Menu].
3. Power up the frequency converter while still pressing the keys for 10 s.
4. The frequency converter is now reset, except for the following parameters:

- *Parameter 1-06 Clockwise Direction*
- *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*
- *Parameter 18-10 FireMode Log:Event*

Initialization of parameters is confirmed by *alarm 80, Drive initialised* in the display after the power cycle.

## 7 RS485 Installation and Set-up

### 7.1 RS485

#### 7.1.1 Overview

RS485 is a 2-wire bus interface compatible with multi-drop network topology, that is, nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to 1 network segment. Repeaters divide network segments.

#### **NOTICE**

Each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments.

7

Terminate each segment at both ends, using either the termination switch (S801) of the frequency converters or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling, and follow good common installation practice.

Low-impedance ground connection of the shield at every node is important. Connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable gland. Apply potential-equalizing cables to maintain the same ground potential throughout the network - particularly in installations with long cables.

To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the frequency converter, always use shielded motor cable.

Cable	Shielded twisted pair (STP)
Impedance [ $\Omega$ ]	120
Cable length [m (ft)]	Maximum 1200 (3937) (including drop lines). Maximum 500 (1640) station-to-station.

Table 7.1 Cable Specifications

#### 7.1.2 Network Connection

Connect the frequency converter to the RS485 network as follows (see also *Illustration 7.1*):

1. Connect signal wires to terminal 68 (P+) and terminal 69 (N-) on the main control board of the frequency converter.
2. Connect the cable shield to the cable clamps.

#### **NOTICE**

To reduce noise between conductors, use shielded, twisted-pair cables.

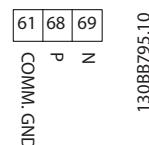


Illustration 7.1 Network Connection

#### 7.1.3 Frequency Converter Hardware Set-up

Use the terminator dip switch on the main control board of the frequency converter to terminate the RS485 bus.

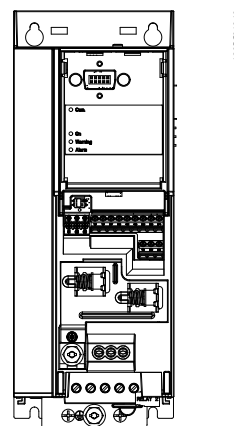


Illustration 7.2 Terminator Switch Factory Setting

The factory setting for the dip switch is OFF.

### 7.1.4 Parameter Settings for Modbus Communication

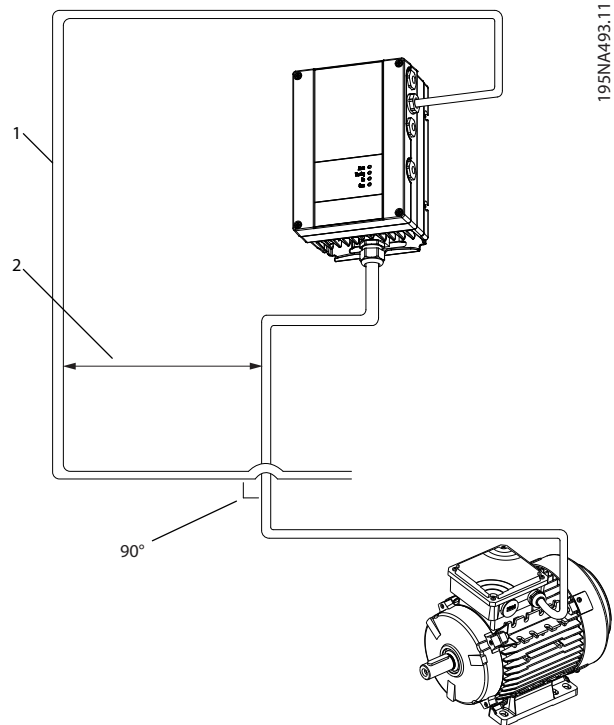
Parameter	Function
Parameter 8-30 Protocol	Select the application protocol to run for the RS485 interface.
Parameter 8-31 Address	Set the node address. <b>NOTICE</b> The address range depends on the protocol selected in parameter 8-30 Protocol.
Parameter 8-32 Baud Rate	Set the baud rate. <b>NOTICE</b> The default baud rate depends on the protocol selected in parameter 8-30 Protocol.
Parameter 8-33 Parity / Stop Bits	Set the parity and number of stop bits. <b>NOTICE</b> The default selection depends on the protocol selected in parameter 8-30 Protocol.
Parameter 8-35 Minimum Response Delay	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.
Parameter 8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.
Parameter 8-37 Maximum Inter-character delay	If transmission is interrupted, specify a maximum delay time between 2 received bytes to ensure timeout. <b>NOTICE</b> The default selection depends on the protocol selected in parameter 8-30 Protocol.

Table 7.2 Modbus Communication Parameter Settings

### 7.1.5 EMC Precautions

**NOTICE**

Observe relevant national and local regulations regarding protective ground connection. Failure to ground the cables properly can result in communication degradation and equipment damage. To avoid coupling of high frequency noise between the cables, keep the RS485 communication cable away from motor and brake resistor cables. Normally, a distance of 200 mm (8 in) is sufficient. Maintain the greatest possible distance between the cables, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS485 cable must cross motor and brake resistor cables at an angle of 90°.



1	Fieldbus cable
2	Minimum 200 mm (8 in) distance

Illustration 7.3 Minimum Distance between Communication and Power Cables

## 7.2 FC Protocol

### 7.2.1 Overview

The FC protocol, also referred to as FC bus or standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master-slave principle for communications via a serial bus.

One master and a maximum of 126 slaves can be connected to the bus. The master selects the individual slaves via an address character in the telegram. A slave itself can never transmit without first being requested to do so, and direct message transfer between the individual slaves is not possible. Communications occur in the half-duplex mode.

The master function cannot be transferred to another node (single-master system).

The physical layer is RS485, thus utilizing the RS485 port built into the frequency converter. The FC protocol supports different telegram formats:

- A short format of 8 bytes for process data.
- A long format of 16 bytes that also includes a parameter channel.
- A format used for texts.

### 7.2.2 FC with Modbus RTU

The FC protocol provides access to the control word and bus reference of the frequency converter.

The control word allows the Modbus master to control several important functions of the frequency converter:

- Start.
- Stop of the frequency converter in various ways:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change of the active set-up.
- Control of the 2 relays built into the frequency converter.

The bus reference is commonly used for speed control. It is also possible to access the parameters, read their values, and where possible, write values to them. Accessing the parameters offers a range of control options, including controlling the setpoint of the frequency converter when its internal PI controller is used.

## 7.3 Parameter Settings to Enable the Protocol

To enable the FC protocol for the frequency converter, set the following parameters.

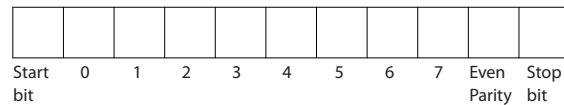
Parameter	Setting
Parameter 8-30 Protocol	FC
Parameter 8-31 Address	1–126
Parameter 8-32 Baud Rate	2400–115200
Parameter 8-33 Parity / Stop Bits	Even parity, 1 stop bit (default)

Table 7.3 Parameters to Enable the Protocol

## 7.4 FC Protocol Message Framing Structure

### 7.4.1 Content of a Character (Byte)

Each character transferred begins with a start bit. Then 8 data bits are transferred, corresponding to a byte. Each character is secured via a parity bit. This bit is set at 1 when it reaches parity. Parity is when there is an equal number of 1s in the 8 data bits and the parity bit in total. A stop bit completes a character, thus consisting of 11 bits in all.



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Illustration 7.4 Content of a Character

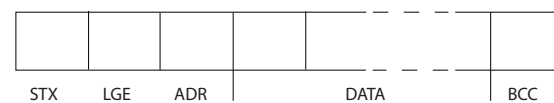
### 7.4.2 Telegram Structure

Each telegram has the following structure:

- Start character (STX) = 02 hex.
- A byte denoting the telegram length (LGE).
- A byte denoting the frequency converter address (ADR).

Several data bytes (variable, depending on the type of telegram) follow.

A data control byte (BCC) completes the telegram.



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Illustration 7.5 Telegram Structure

### 7.4.3 Telegram Length (LGE)

The telegram length is the number of data bytes plus the address byte ADR and the data control byte BCC.

4 data bytes	LGE = 4+1+1 = 6 bytes
12 data bytes	LGE = 12+1+1 = 14 bytes
Telegrams containing texts	10 <sup>1</sup> +n bytes

**Table 7.4 Length of Telegrams**

1) The 10 represents the fixed characters, while the n is variable (depending on the length of the text).

### 7.4.4 Frequency Converter Address (ADR)

#### Address format 1–126

- Bit 7 = 1 (address format 1–126 active).
- Bit 0–6 = frequency converter address 1–126.
- Bit 0–6 = 0 broadcast.

The slave returns the address byte unchanged to the master in the response telegram.

### 7.4.5 Data Control Byte (BCC)

The checksum is calculated as an XOR-function. Before the first byte in the telegram is received, the calculated checksum is 0.

### 7.4.6 The Data Field

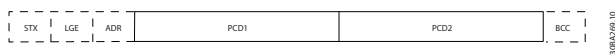
The structure of data blocks depends on the type of telegram. There are 3 telegram types, and the type applies for both control telegrams (master⇒slave) and response telegrams (slave⇒master).

The 3 types of telegram are:

#### Process block (PCD)

The PCD is made up of a data block of 4 bytes (2 words) and contains:

- Control word and reference value (from master to slave).
- Status word and present output frequency (from slave to master).



**Illustration 7.6 Process Block**

#### Parameter block

The parameter block is used to transfer parameters between master and slave. The data block is made up of 12 bytes (6 words) and also contains the process block.



**Illustration 7.7 Parameter Block**

#### Text block

The text block is used to read or write texts via the data block.

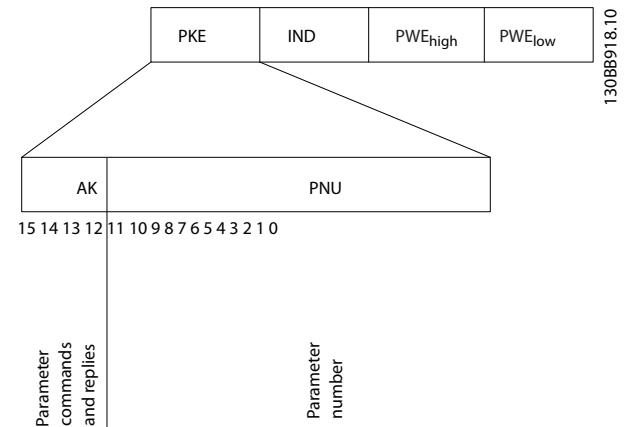


**Illustration 7.8 Text Block**

### 7.4.7 The PKE Field

The PKE field contains 2 subfields:

- Parameter command and response (AK)
- Parameter number (PNU)



**Illustration 7.9 PKE Field**

Bits 12–15 transfer parameter commands from master to slave and return processed slave responses to the master.

Parameter commands master⇒slave				
Bit number				Parameter command
15	14	13	12	
0	0	0	0	No command.
0	0	0	1	Read parameter value.
0	0	1	0	Write parameter value in RAM (word).
0	0	1	1	Write parameter value in RAM (double word).
1	1	0	1	Write parameter value in RAM and EEPROM (double word).
1	1	1	0	Write parameter value in RAM and EEPROM (word).
1	1	1	1	Read text.

Table 7.5 Parameter Commands

Response slave⇒master				
Bit number				Response
15	14	13	12	
0	0	0	0	No response.
0	0	0	1	Parameter value transferred (word).
0	0	1	0	Parameter value transferred (double word).
0	1	1	1	Command cannot be performed.
1	1	1	1	Text transferred.

Table 7.6 Response

If the command cannot be performed, the slave sends *0111 Command cannot be performed* response and issues the following fault reports in *Table 7.7*.

Fault code	FC specification
0	Illegal parameter number.
1	Parameter cannot be changed.
2	Upper or lower limit is exceeded.
3	Subindex is corrupted.
4	No array.
5	Wrong data type.
6	Not used.
7	Not used.
9	Description element is not available.
11	No parameter write access.
15	No text available.
17	Not applicable while running.
18	Other errors.
100	–
>100	–
130	No bus access for this parameter.
131	Write to factory set-up is not possible.
132	No LCP access.
252	Unknown viewer.
253	Request is not supported.
254	Unknown attribute.
255	No error.

Table 7.7 Slave Report

## 7.4.8 Parameter Number (PNU)

Bit numbers 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in *chapter 6 Programming*.

## 7.4.9 Index (IND)

The index is used with the parameter number to read/write access parameters with an index, for example, *parameter 15-30 Alarm Log: Error Code*. The index consists of 2 bytes: a low byte and a high byte.

Only the low byte is used as an index.

## 7.4.10 Parameter Value (PWE)

The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the slave.

When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains several data options, for example



*parameter 0-01 Language*, select the data value by entering the value in the PWE block. Serial communication is only capable of reading parameters containing data type 9 (text string).

*Parameter 15-40 FC Type to parameter 15-53 Power Card Serial Number* contain data type 9.

For example, read the unit size and mains voltage range in *parameter 15-40 FC Type*. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the 2<sup>nd</sup> byte of the telegram (LGE). When using text transfer, the index character indicates whether it is a read or a write command.

To read a text via the PWE block, set the parameter command (AK) to F hex. The index character high-byte must be 4.

### 7.4.11 Data Types Supported by the Frequency Converter

Unsigned means that there is no operational sign in the telegram.

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string

Table 7.8 Data Types

### 7.4.12 Conversion

The *programming guide* contains the descriptions of attributes of each parameter. Parameter values are transferred as whole numbers only. Conversion factors are used to transfer decimals.

*Parameter 4-12 Motor Speed Low Limit [Hz]* has a conversion factor of 0.1. To preset the minimum frequency to 10 Hz, transfer the value 100. A conversion factor of 0.1 means that the value transferred is multiplied by 0.1. The value 100 is thus perceived as 10.0.

Conversion index	Conversion factor
74	3600
2	100
1	10
0	1
-1	0.1
-2	0.01
-3	0.001
-4	0.0001
-5	0.00001

Table 7.9 Conversion

### 7.4.13 Process Words (PCD)

The block of process words is divided into 2 blocks of 16 bits, which always occur in the defined sequence.

PCD 1	PCD 2
Control telegram (master→slave control word)	Reference value
Control telegram (slave→master) status word	Present output frequency

Table 7.10 Process Words (PCD)

## 7.5 Examples

### 7.5.1 Writing a Parameter Value

Change *parameter 4-14 Motor Speed High Limit [Hz]* to 100 Hz.

Write the data in EEPROM.

PKE = E19E hex - Write single word in *parameter 4-14 Motor Speed High Limit [Hz]*:

- IND = 0000 hex.
- PWEHIGH = 0000 hex.
- PWELOW = 03E8 hex.

Data value 1000, corresponding to 100 Hz, see *chapter 7.4.12 Conversion*.

The telegram looks like *Illustration 7.10*.

E19E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

Illustration 7.10 Telegram

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**NOTICE**

Parameter 4-14 Motor Speed High Limit [Hz] is a single word, and the parameter command for write in EEPROM is E. Parameter 4-14 Motor Speed High Limit [Hz] is 19E in hexadecimal.

The response from the slave to the master is shown in Illustration 7.11.

119E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

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Illustration 7.11 Response from Master

7.5.2 Reading a Parameter Value

Read the value in parameter 3-41 Ramp 1 Ramp Up Time.

PKE = 1155 hex - Read parameter value in parameter 3-41 Ramp 1 Ramp Up Time:

- IND = 0000 hex.
- PWE<sub>HIGH</sub> = 0000 hex.
- PWE<sub>LOW</sub> = 0000 hex.

1155	H	0000	H	0000	H	0000	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

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Illustration 7.12 Telegram

If the value in parameter 3-41 Ramp 1 Ramp Up Time is 10 s, the response from the slave to the master is shown in Illustration 7.13.

1155	H	0000	H	0000	H	03E8	H
PKE		IND		PWE <sub>high</sub>		PWE <sub>low</sub>	

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Illustration 7.13 Response

3E8 hex corresponds to 1000 decimal. The conversion index for parameter 3-41 Ramp 1 Ramp Up Time is -2, that is, 0.01.

Parameter 3-41 Ramp 1 Ramp Up Time is of the type Unsigned 32.

7.6 Modbus RTU Overview

7.6.1 Introduction

Danfoss assumes that the installed controller supports the interfaces in this document, and strictly observes all requirements and limitations stipulated in the controller and frequency converter.

The built-in Modbus RTU (remote terminal unit) is designed to communicate with any controller that supports the interfaces defined in this document. It is assumed that the user has full knowledge of the capabilities and limitations of the controller.

7.6.2 Overview

Regardless of the type of physical communication networks, this section describes the process that a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of telegram fields.

During communications over a Modbus RTU network, the protocol:

- Determines how each controller learns its device address.
- Recognizes a telegram addressed to it.
- Determines which actions to take.
- Extracts any data or other information contained in the telegram.

If a reply is required, the controller constructs the reply telegram and sends it.

Controllers communicate using a master/slave technique in which only the master can initiate transactions (called queries). Slaves respond by supplying the requested data to the master, or by acting as requested in the query. The master can address individual slaves, or initiate a broadcast telegram to all slaves. Slaves return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master.

The Modbus RTU protocol establishes the format for the master query by providing the following information:

- The device (or broadcast) address.
- A function code defining the requested action.
- Any data to be sent.
- An error-checking field.

The response telegram of the slave device is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and

an error-checking field. If an error occurs in receipt of the telegram, or if the slave is unable to perform the requested action, the slave constructs and sends an error message. Alternatively, a timeout occurs.

### 7.6.3 Frequency Converter with Modbus RTU

The frequency converter communicates in Modbus RTU format over the built-in RS485 interface. Modbus RTU provides access to the control word and bus reference of the frequency converter.

The control word allows the Modbus master to control several important functions of the frequency converter:

- Start.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change the active set-up.
- Control built-in relay of the frequency converter.

The bus reference is commonly used for speed control. It is also possible to access the parameters, read their values, and, where possible, write values to them. Accessing the parameters offers a range of control options, including controlling the setpoint of the frequency converter when its internal PI controller is used.

## 7.7 Network Configuration

To enable Modbus RTU on the frequency converter, set the following parameters:

Parameter	Setting
Parameter 8-30 Protocol	Modbus RTU
Parameter 8-31 Address	1–247
Parameter 8-32 Baud Rate	2400–115200
Parameter 8-33 Parity / Stop Bits	Even parity, 1 stop bit (default)

Table 7.11 Network Configuration

## 7.8 Modbus RTU Message Framing Structure

### 7.8.1 Introduction

The controllers are set up to communicate on the Modbus network using RTU (remote terminal unit) mode, with each byte in a telegram containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 7.12*.

Start bit	Data byte						Stop/parity	Stop

Table 7.12 Format for Each Byte

Coding system	8-bit binary, hexadecimal 0–9, A–F. 2 hexadecimal characters contained in each 8-bit field of the telegram.
Bits per byte	<ul style="list-style-type: none"> <li>• 1 start bit.</li> <li>• 8 data bits, least significant bit sent first.</li> <li>• 1 bit for even/odd parity; no bit for no parity.</li> <li>• 1 stop bit if parity is used; 2 bits if no parity.</li> </ul>
Error check field	Cyclic redundancy check (CRC).

Table 7.13 Byte Details

### 7.8.2 Modbus RTU Telegram Structure

The transmitting device places a Modbus RTU telegram into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the telegram, read the address portion, determine which device is addressed (or all devices, if the telegram is broadcast), and to recognize when the telegram is completed. Partial telegrams are detected and errors set as a result. Characters for transmission must be in hexadecimal 00–FF format in each field. The frequency converter continuously monitors the network bus, also during silent intervals. When the first field (the address field) is received, each frequency converter or device decodes it to determine which device is being addressed. Modbus RTU telegrams addressed to 0 are broadcast telegrams. No response is permitted for broadcast telegrams. A typical telegram frame is shown in *Table 7.14*.

Start	Address	Function	Data	CRC check	End
T1-T2-T3-T4	8 bits	8 bits	N x 8 bits	16 bits	T1-T2-T3-T4

Table 7.14 Typical Modbus RTU Telegram Structure

### 7.8.3 Start/Stop Field

Telegrams start with a silent period of at least 3.5 character intervals. The silent period is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the telegram. A new telegram can begin after this period.

Transmit the entire telegram frame as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete telegram and assumes that the next byte is the address field of a new telegram. Similarly, if a new telegram begins before 3.5 character intervals after a previous telegram, the receiving device considers it a continuation of the previous telegram. This behavior causes a timeout (no response from the slave), since the value in the final CRC field is not valid for the combined telegrams.

### 7.8.4 Address Field

The address field of a telegram frame contains 8 bits. Valid slave device addresses are in the range of 0–247 decimal. The individual slave devices are assigned addresses in the range of 1–247. 0 is reserved for broadcast mode, which all slaves recognize. A master addresses a slave by placing the slave address in the address field of the telegram. When the slave sends its response, it places its own address in this address field to let the master know which slave is responding.

### 7.8.5 Function Field

The function field of a telegram frame contains 8 bits. Valid codes are in the range of 1–FF. Function fields are used to send telegrams between master and slave. When a telegram is sent from a master to a slave device, the function code field tells the slave what kind of action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response).

For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the slave places a unique code into the data field of the response telegram. This code tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 7.8.11 Function Codes Supported by Modbus RTU* and *chapter 7.8.12 Modbus Exception Codes*.

### 7.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00–FF hexadecimal. These digits are made up of 1 RTU character. The data field of telegrams sent from a master to a slave device contains additional information which the slave must use to perform accordingly.

The information can include items such as:

- Coil or register addresses.
- The quantity of items to be handled.
- The count of actual data bytes in the field.

### 7.8.7 CRC Check Field

Telegrams include an error-checking field, operating based on a cyclic redundancy check (CRC) method. The CRC field checks the contents of the entire telegram. It is applied regardless of any parity check method used for the individual characters of the telegram. The transmitting device calculates the CRC value and appends the CRC as the last field in the telegram. The receiving device recalculates a CRC during receipt of the telegram and compares the calculated value to the actual value received in the CRC field. 2 unequal values result in bus timeout. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. After the implementation, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte sent in the telegram.

### 7.8.8 Coil Register Addressing

In Modbus, all data is organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2 byte word (that is 16 bits). All data addresses in Modbus telegrams are referenced to 0. The 1st occurrence of a data item is addressed as item number 0. For example: The coil known as coil 1 in a programmable controller is addressed as coil 0000 in the data address field of a Modbus telegram. Coil 127 decimal is addressed as coil 007Ehex (126 decimal).

Holding register 40001 is addressed as register 0000 in the data address field of the telegram. The function code field already specifies a holding register operation. Therefore, the 4XXXX reference is implicit. Holding register 40108 is addressed as register 006Bhex (107 decimal).

Coil number	Description	Signal direction
1–16	Frequency converter control word (see <i>Table 7.16</i> ).	Master to slave
17–32	Frequency converter speed or setpoint reference range 0x0–0xFFFF (-200% ... ~200%).	Master to slave
33–48	Frequency converter status word (see <i>Table 7.17</i> ).	Slave to master
49–64	Open-loop mode: Frequency converter output frequency. Closed-loop mode: Frequency converter feedback signal.	Slave to master
65	Parameter write control (master to slave).	Master to slave
	0 = Parameter changes are written to the RAM of the frequency converter.	
	1 = Parameter changes are written to the RAM and EEPROM of the frequency converter.	
66–65536	Reserved.	–

**Table 7.15 Coil Register**

Coil	0	1
01	Preset reference lsb	
02	Preset reference msb	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze frequency	No freeze frequency
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up lsb	
15	–	
16	No reversing	Reversing

**Table 7.16 Frequency Converter Control Word (FC Profile)**

Coil	0	1
33	Control not ready	Control ready
34	Frequency converter not ready	Frequency converter ready
35	Coast stop	Safety closed
36	No alarm	Alarm
37	Not used	Not used
38	Not used	Not used
39	Not used	Not used
40	No warning	Warning
41	Not at reference	At reference
42	Hand mode	Auto mode
43	Out of frequency range	In frequency range
44	Stopped	Running
45	Not used	Not used
46	No voltage warning	Voltage exceeds
47	Not in current limit	Current limit
48	Thermal level is OK	Thermal level exceeds

**Table 7.17 Frequency Converter Status Word (FC Profile)**

Bus address	Bus register <sup>1)</sup>	PLC register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
1	2	40002	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
2	3	40003	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–
5	6	40006	Modbus configuration	Read/Write	TCP only. Reserved for Modbus TCP ( <i>parameter 12-28 Store Data Values</i> and <i>parameter 12-29 Store Always</i> - stored in, for example, EEPROM).
6	7	40007	Last fault code	Read only	Fault code received from parameter database, refer to WHAT 38295 for details.
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details.
8	9	40009	Index pointer	Read/Write	Subindex of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	<i>Parameter 0-01 Language</i>	Dependent on parameter access	<i>Parameter 0-01 Language</i> (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map.
19	20	40020	Free	–	–
29	30	40030	<i>Parameter 0-03 Regional Settings</i>	Dependent on parameter access	<i>Parameter 0-03 Regional Settings</i> 20 bytes space reserved for parameter in Modbus map.

**Table 7.18 Address/Registers**

1) Value written in the Modbus RTU telegram must be 1 or less than the register number. For example, Read Modbus Register 1 by writing value 0 in the telegram.

### 7.8.9 Access via PCD write/read

The advantage of using the PCD write/read configuration is that the controller can write or read more data in 1 telegram. Up to 63 registers can be read or written to via the function code read holding register or write multiple registers in 1 telegram. The structure is also flexible so that only 2 registers can be written to and 10 registers can be read from the controller.

The PCD write list is data sent from the controller to the frequency converter, the data includes control word, reference, and application dependent data like minimum reference and ramp times, and so on.

#### **NOTICE**

**The control word and reference is always sent in the list from the controller to the frequency converter.**

The PCD write list is set up in *parameter 8-42 PCD Write Configuration*.

The PCD read list is data sent from the frequency converter to the controller like status word, main actual value, and application dependent data like running hours, motor current, and alarm word.

#### **NOTICE**

**The status word and main actual value is always sent in the list from the frequency converter to the controller.**

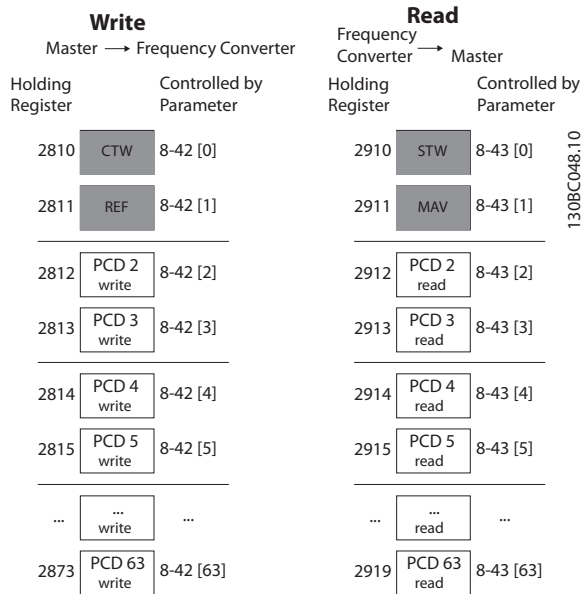


Illustration 7.14 Accessing via PCD write/read

**NOTICE**

The boxes marked in grey are not changeable, they are default values.

**NOTICE**

The 32 bit parameters must be mapped inside the 32 bit boundaries (PCD2 & PCD3 or PCD4 & PCD5, and so on.), where the parameter number is mapped twice to parameter 8-42 PCD Write Configuration or parameter 8-43 PCD Read Configuration.

7.8.10 How to Control the Frequency Converter

This section describes codes which can be used in the function and data fields of a Modbus RTU telegram.

7.8.11 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the following function codes in the function field of a telegram.

Function	Function code (hex)
Read coils	1
Read holding registers	3
Write single coil	5
Write single register	6
Write multiple coils	F
Write multiple registers	10
Get comm. event counter	B
Report slave ID	11
Read write multiple registers	17

Table 7.19 Function Codes

Function	Function code	Subfunction code	Subfunction
Diagnostics	8	1	Restart communication.
		2	Return diagnostic register.
		10	Clear counters and diagnostic register.
		11	Return bus message count.
		12	Return bus communication error count.
		13	Return slave error count.
		14	Return slave message count.

Table 7.20 Function Codes

7.8.12 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to chapter 7.8.5 Function Field.

Code	Name	Meaning
1	Illegal function	The function code received in the query is not an allowable action for the server (or slave). This may be because the function code is only applicable to newer devices and was not implemented in the unit selected. It could also indicate that the server (or slave) is in the wrong state to process a request of this type, for example because it is not configured and is being asked to return register values.

Code	Name	Meaning
2	Illegal data address	The data address received in the query is not an allowable address for the server (or slave). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 succeeds, while a request with offset 96 and length 5 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or slave). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the Modbus protocol is unaware of the significance of any value of any register.
4	Slave device failure	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

Table 7.21 Modbus Exception Codes

## 7.9 How to Access Parameters

### 7.9.1 Parameter Handling

The PNU (parameter number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10 x parameter number) decimal. Example: Reading *parameter 3-12 Catch up/slow Down Value* (16 bit): The holding register 3120 holds the parameters value. A value of 1352 (decimal) means that the parameter is set to 12.52%.

Reading *parameter 3-14 Preset Relative Reference* (32 bit): The holding registers 3410 and 3411 hold the parameters values. A value of 11300 (decimal), means that the parameter is set to 1113.00.

For information on the parameters, size, and conversion index, see *chapter 6 Programming*.

### 7.9.2 Storage of Data

The coil 65 decimal determines whether data written to the frequency converter is stored in EEPROM and RAM (coil 65 = 1), or only in RAM (coil 65 = 0).

### 7.9.3 IND (Index)

Some parameters in the frequency converter are array parameters, for example *parameter 3-10 Preset Reference*. Since the Modbus does not support arrays in the holding registers, the frequency converter has reserved the holding register 9 as pointer to the array. Before reading or writing an array parameter, set the holding register 9. Setting holding register to the value of 2 causes all following read/write to array parameters to be to the index 2.

### 7.9.4 Text Blocks

Parameters stored as text strings are accessed in the same way as the other parameters. The maximum text block size is 20 characters. If a read request for a parameter is for more characters than the parameter stores, the response is truncated. If the read request for a parameter is for fewer characters than the parameter stores, the response is space filled.

### 7.9.5 Conversion Factor

A parameter value can only be transferred as a whole number. To transfer decimals, use a conversion factor.

### 7.9.6 Parameter Values

#### Standard data types

Standard data types are int 16, int 32, uint 8, uint 16, and uint 32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 hex read holding registers. Parameters are written using the function 6 hex preset single register for 1 register (16 bits), and the function 10 hex preset multiple registers for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

#### Non-standard data types

Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 hex read holding registers and written using function 10 hex preset multiple registers. Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

## 7.10 Examples

The following examples show various Modbus RTU commands.

### 7.10.1 Read Coil Status (01 hex)

#### Description

This function reads the ON/OFF status of discrete outputs (coils) in the frequency converter. Broadcast is never supported for reads.



### Query

The query telegram specifies the starting coil and quantity of coils to be read. Coil addresses start at 0, that is, coil 33 is addressed as 32.

Example of a request to read coils 33–48 (status word) from slave device 01.

Field name	Example (hex)
Slave address	01 (frequency converter address)
Function	01 (read coils)
Starting address HI	00
Starting address LO	20 (32 decimals) coil 33
Number of points HI	00
Number of points LO	10 (16 decimals)
Error check (CRC)	–

Table 7.22 Query

### Response

The coil status in the response telegram is packed as 1 coil per bit of the data field. Status is indicated as: 1 = ON; 0 = OFF. The lsb of the first data byte contains the coil addressed in the query. The other coils follow toward the high-order end of this byte, and from low order to high order in subsequent bytes.

If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte are padded with values 0 (toward the high-order end of the byte). The byte count field specifies the number of complete bytes of data.

Field name	Example (hex)
Slave address	01 (frequency converter address)
Function	01 (read coils)
Byte count	02 (2 bytes of data)
Data (coils 40–33)	07
Data (coils 48–41)	06 (STW = 0607hex)
Error check (CRC)	–

Table 7.23 Response

### **NOTICE**

Coils and registers are addressed explicitly with an offset of -1 in Modbus.

For example, coil 33 is addressed as coil 32.

## 7.10.2 Force/Write Single Coil (05 hex)

### Description

This function forces the coil to either ON or OFF. When broadcast, the function forces the same coil references in all attached slaves.

### Query

The query telegram specifies the coil 65 (parameter write control) to be forced. Coil addresses start at 0, that is, coil 65 is addressed as 64. Force data = 00 00 hex (OFF) or FF 00 hex (ON).

Field name	Example (hex)
Slave address	01 (Frequency converter address)
Function	05 (write single coil)
Coil address HI	00
Coil address LO	40 (64 decimal) Coil 65
Force data HI	FF
Force data LO	00 (FF 00 = ON)
Error check (CRC)	–

Table 7.24 Query

### Response

The normal response is an echo of the query, returned after the coil state has been forced.

Field name	Example (hex)
Slave address	01
Function	05
Force data HI	FF
Force data LO	00
Quantity of coils HI	00
Quantity of coils LO	01
Error check (CRC)	–

Table 7.25 Response

## 7.10.3 Force/Write Multiple Coils (0F hex)

### Description

This function forces each coil in a sequence of coils to either on or off. When broadcasting, the function forces the same coil references in all attached slaves.

### Query

The query telegram specifies the coils 17–32 (speed setpoint) to be forced.

### **NOTICE**

Coil addresses start at 0, that is, coil 17 is addressed as 16.

Field name	Example (hex)
Slave address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil address HI	00
Coil address LO	10 (coil address 17)
Quantity of coils HI	00
Quantity of coils LO	10 (16 coils)
Byte count	02
Force data HI (Coils 8–1)	20
Force data LO (Coils 16–9)	00 (reference = 2000 hex)
Error check (CRC)	–

Table 7.26 Query

### Response

The normal response returns the slave address, function code, starting address, and quantity of coils forced.

Field name	Example (hex)
Slave address	01 (frequency converter address)
Function	0F (write multiple coils)
Coil address HI	00
Coil address LO	10 (coil address 17)
Quantity of coils HI	00
Quantity of coils LO	10 (16 coils)
Error check (CRC)	–

Table 7.27 Response

## 7.10.4 Read Holding Registers (03 hex)

### Description

This function reads the contents of holding registers in the slave.

### Query

The query telegram specifies the starting register and quantity of registers to be read. Register addresses start at 0, that is, registers 1–4 are addressed as 0–3.

Example: Read *parameter 3-03 Maximum Reference*, register 03030.

Field name	Example (hex)
Slave address	01
Function	03 (Read holding registers)
Starting address HI	0B (Register address 3029)
Starting address LO	D5 (Register address 3029)
Number of points HI	00
Number of points LO	02 – ( <i>parameter 3-03 Maximum Reference</i> is 32 bits long, that is, 2 registers)
Error check (CRC)	–

Table 7.28 Query

### Response

The register data in the response telegram is packed as 2 bytes per register, with the binary contents right justified within each byte. For each register, the 1<sup>st</sup> byte contains the high-order bits, and the 2<sup>nd</sup> contains the low-order bits.

Example: hex 000088B8 = 35.000 = 35 Hz.

Field name	Example (hex)
Slave address	01
Function	03
Byte count	04
Data HI (register 3030)	00
Data LO (register 3030)	16
Data HI (register 3031)	E3
Data LO (register 3031)	60
Error check (CRC)	–

Table 7.29 Response

## 7.10.5 Preset Single Register (06 hex)

### Description

This function presets a value into a single holding register.

### Query

The query telegram specifies the register reference to be preset. Register addresses start at 0, that is, register 1 is addressed as 0.

Example: Write to *parameter 1-00 Configuration Mode*, register 1000.

Field name	Example (hex)
Slave address	01
Function	06
Register address HI	03 (register address 999)
Register address LO	E7 (register address 999)
Preset data HI	00
Preset data LO	01
Error check (CRC)	–

Table 7.30 Query

### Response

The normal response is an echo of the query, returned after the register contents have been passed.

Field name	Example (hex)
Slave address	01
Function	06
Register address HI	03
Register address LO	E7
Preset data HI	00
Preset data LO	01
Error check (CRC)	–

Table 7.31 Response

### 7.10.6 Preset Multiple Registers (10 hex)

#### Description

This function presets values into a sequence of holding registers.

#### Query

The query telegram specifies the register references to be preset. Register addresses start at 0, that is, register 1 is addressed as 0. Example of a request to preset 2 registers (set *parameter 1-24 Motor Current* to 738 (7.38 A)):

Field name	Example (hex)
Slave address	01
Function	10
Starting address HI	04
Starting address LO	07
Number of registers HI	00
Number of registers LO	02
Byte count	04
Write data HI (Register 4: 1049)	00
Write data LO (Register 4: 1049)	00
Write data HI (Register 4: 1050)	02
Write data LO (Register 4: 1050)	E2
Error check (CRC)	-

Table 7.32 Query

#### Response

The normal response returns the slave address, function code, starting address, and quantity of registers preset.

Field name	Example (hex)
Slave address	01
Function	10
Starting address HI	04
Starting address LO	19
Number of registers HI	00
Number of registers LO	02
Error check (CRC)	-

Table 7.33 Response

### 7.10.7 Read/Write Multiple Registers (17 hex)

#### Description

This function code performs a combination of 1 read operation and 1 write operation in a single MODBUS transaction. The write operation is performed before read.

#### Query

The query message specifies the starting address and number of holding registers to be read as well as the starting address, number of holding registers, and the data to be written. Holding registers are addressed starting at zero. Example of a request to set *parameter 1-24 Motor Current* to 738 (7.38 A) and read *parameter 3-03 Maximum Reference* which has value 50000 (50,000 Hz):

Field name	Example (hex)
Slave address	01
Function	17
Reading starting address HI	0B (Register address 3029)
Read starting address LO	D5 (Register address 3029)
Quantity to read HI	00
Quantity to read LO	02 (Parameter 3-03 Maximum Reference is 32 bits long, that is, 2 registers)
Write starting address HI	04 (Register address 1239)
Write starting address LO	D7 (Register address 1239)
Quantity to write HI	00
Quantity to write LO	02
Write byte count	04
Write registers value HI	00
Write registers value LO	00
Write registers value HI	02
Write registers value LO	0E
Error check (CRC)	-

Table 7.34 Query

#### Response

The normal response contains the data from the group of registers that were read. The byte count field specifies the quantity of bytes to follow in the read data field.

Field name	Example (hex)
Slave address	01
Function	17
Byte count	04
Read registers value HI	00
Read registers value LO	00
Read registers value HI	C3
Read registers value LO	50
Error check (CRC)	-

Table 7.35 Response

## 7.11 Danfoss FC Control Profile

### 7.11.1 Control Word According to FC Profile (8-10 Protocol = FC Profile)

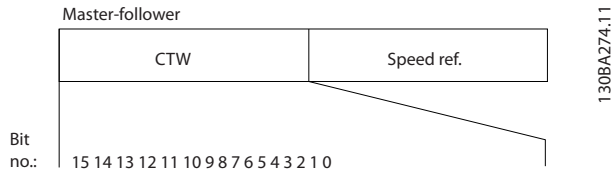


Illustration 7.15 Control Word According to FC Profile

Bit	Bit value = 0	Bit value = 1
00	Reference value	External selection lsb
01	Reference value	External selection msb
02	DC brake	Ramp
03	Coasting	No coasting
04	Quick stop	Ramp
05	Hold output frequency	Use ramp
06	Ramp stop	Start
07	No function	Reset
08	No function	Jog
09	Ramp 1	Ramp 2
10	Data invalid	Data valid
11	Relay 01 open	Relay 01 active
12	Relay 02 open	Relay 02 active
13	Parameter set-up	Selection lsb
15	No function	Reverse

Table 7.36 Control Word According to FC Profile

#### Explanation of the control bits

##### Bits 00/01

Bits 00 and 01 are used to select among the 4 reference values, which are preprogrammed in *parameter 3-10 Preset Reference* according to *Table 7.37*.

Programmed reference value	Parameter	Bit 01	Bit 00
1	<i>Parameter 3-10 Preset Reference</i> [0]	0	0
2	<i>Parameter 3-10 Preset Reference</i> [1]	0	1
3	<i>Parameter 3-10 Preset Reference</i> [2]	1	0
4	<i>Parameter 3-10 Preset Reference</i> [3]	1	1

Table 7.37 Control Bits

#### NOTICE

In *parameter 8-56 Preset Reference Select*, define how bit 00/01 gates with the corresponding function on the digital inputs.

##### Bit 02, DC brake

Bit 02 = 0: Leads to DC braking and stop. Set braking current and duration in *parameter 2-01 DC Brake Current* and *parameter 2-02 DC Braking Time*.

Bit 02 = 1: Leads to ramping.

##### Bit 03, Coasting

Bit 03 = 0: The frequency converter immediately releases the motor (the output transistors are shut off), and it coasts to a standstill.

Bit 03 = 1: If the other starting conditions are met, the frequency converter starts the motor.

In *parameter 8-50 Coasting Select*, define how bit 03 gates with the corresponding function on a digital input.

##### Bit 04, Quick stop

Bit 04 = 0: Makes the motor speed ramp down to stop (set in *parameter 3-81 Quick Stop Ramp Time*).

##### Bit 05, Hold output frequency

Bit 05 = 0: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs programmed to [21] *Speed up* and [22] *Speed down* (*parameter 5-10 Terminal 18 Digital Input* to *parameter 5-13 Terminal 29 Digital Input*).

#### NOTICE

If freeze output is active, the frequency converter can only be stopped in 1 of the following ways:

- Bit 03 coast stop.
- Bit 02 DC brake.
- Digital input programmed to [5] *DC brake inverse*, [2] *Coast inverse*, or [3] *Coast and reset inv* (*parameter 5-10 Terminal 18 Digital Input* to *parameter 5-13 Terminal 29 Digital Input*).

##### Bit 06, Ramp stop/start

Bit 06 = 0: Causes a stop and makes the motor speed ramp down to stop via the selected ramp-down parameter.

Bit 06 = 1: If the other starting conditions are met, bit 06 allows the frequency converter to start the motor.

In *parameter 8-53 Start Select*, define how bit 06 ramp stop/start gates with the corresponding function on a digital input.

##### Bit 07, Reset

Bit 07 = 0: No reset.

Bit 07 = 1: Resets a trip. Reset is activated on the leading signal edge, that is, when changing from logic 0 to logic 1.

##### Bit 08, Jog

Bit 08 = 1: *Parameter 3-11 Jog Speed [Hz]* determines the output frequency.

##### Bit 09, Selection of ramp 1/2

Bit 09 = 0: Ramp 1 is active (*parameter 3-41 Ramp 1 Ramp Up Time* to *parameter 3-42 Ramp 1 Ramp Down Time*).

Bit 09 = 1: Ramp 2 (*parameter 3-51 Ramp 2 Ramp Up Time* to *parameter 3-52 Ramp 2 Ramp Down Time*) is active.

**Bit 10, Data not valid/Data valid**

Tell the frequency converter whether to use or ignore the control word.

Bit 10 = 0: The control word is ignored.

Bit 10 = 1: The control word is used. This function is relevant because the telegram always contains the control word, regardless of the telegram type. If the control word is not needed when updating or reading parameter, turn it off.

**Bit 11, Relay 01**

Bit 11 = 0: Relay not activated.

Bit 11 = 1: Relay 01 activated if [36] Control word bit 11 is selected in parameter 5-40 Function Relay.

**Bit 12, Relay 02**

Bit 12 = 0: Relay 02 is not activated.

Bit 12 = 1: Relay 02 is activated if [37] Control word bit 12 is selected in parameter 5-40 Function Relay.

**Bit 13, Set-up selection**

Use bit 13 to select from the 2 menu set-ups according to Table 7.38.

Set-up	Bit 13
1	0
2	1

Table 7.38 Menu Set-ups

The function is only possible when [9] Multi set-ups is selected in parameter 0-10 Active Set-up.

To define how bit 13 gates with the corresponding function on the digital inputs, use parameter 8-55 Set-up Select.

**Bit 15 Reverse**

Bit 15 = 0: No reversing.

Bit 15 = 1: Reversing. In the default setting, reversing is set to digital in parameter 8-54 Reversing Select. Bit 15 causes reversing only when serial communication, [2] Logic OR or [3] Logic AND is selected.

**7.11.2 Status Word According to FC Profile (STW)**

Set parameter 8-30 Protocol to [0] FC.

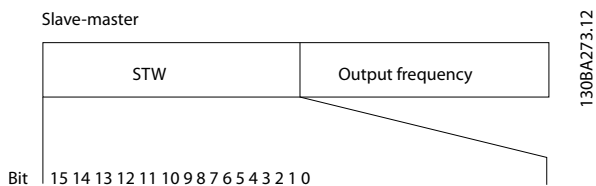


Illustration 7.16 Status Word

Bit	Bit = 0	Bit = 1
00	Control not ready	Control ready
01	Frequency converter not ready	Frequency converter ready
02	Coasting	Enable
03	No error	Trip
04	No error	Error (no trip)
05	Reserved	-
06	No error	Triplock
07	No warning	Warning
08	Speed ≠ reference	Speed = reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Frequency converter OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Current OK	Current exceeded
15	Thermal level OK	Thermal level exceeded

Table 7.39 Status Word According to FC Profile

**Explanation of the status bits**

**Bit 00, Control not ready/ready**

Bit 00 = 0: The frequency converter trips.

Bit 00 = 1: The frequency converter controls are ready but the power component does not necessarily receive any supply (if there is 24 V external supply to controls).

**Bit 01, Frequency converter ready**

Bit 01 = 0: The frequency converter is not ready.

Bit 01 = 1: The frequency converter is ready for operation, but the coasting command is active via the digital inputs or via serial communication.

**Bit 02, Coast stop**

Bit 02 = 0: The frequency converter releases the motor.

Bit 02 = 1: The frequency converter starts the motor with a start command.

**Bit 03, No error/trip**

Bit 03 = 0: The frequency converter is not in fault mode.

Bit 03 = 1: The frequency converter trips. To re-establish operation, press [Reset].

**Bit 04, No error/error (no trip)**

Bit 04 = 0: The frequency converter is not in fault mode.

Bit 04 = 1: The frequency converter shows an error but does not trip.

**Bit 05, Not used**

Bit 05 is not used in the status word.

**Bit 06, No error/triplock**

Bit 06 = 0: The frequency converter is not in fault mode.

Bit 06 = 1: The frequency converter is tripped and locked.

**Bit 07, No warning/warning**

Bit 07 = 0: There are no warnings.

Bit 07 = 1: A warning has occurred.

**Bit 08, Speed  $\neq$  reference/speed = reference**

Bit 08 = 0: The motor runs, but the present speed is different from the preset speed reference. It might happen when the speed ramps up/down during start/stop.

Bit 08 = 1: The motor speed matches the preset speed reference.

**Bit 09, Local operation/bus control**

Bit 09 = 0: [Off/Reset] is activated on the control unit or [2] *Local* in *parameter 3-13 Reference Site* is selected. It is not possible to control the frequency converter via serial communication.

Bit 09 = 1: It is possible to control the frequency converter via the fieldbus/serial communication.

**Bit 10, Out of frequency limit**

Bit 10 = 0: The output frequency has reached the value in *parameter 4-12 Motor Speed Low Limit [Hz]* or *parameter 4-14 Motor Speed High Limit [Hz]*.

Bit 10 = 1: The output frequency is within the defined limits.

**Bit 11, No operation/in operation**

Bit 11 = 0: The motor is not running.

Bit 11 = 1: The frequency converter has a start signal without coast.

**Bit 12, Frequency converter OK/stopped, auto start**

Bit 12 = 0: There is no temporary overtemperature on the frequency converter.

Bit 12 = 1: The frequency converter stops because of overtemperature but the unit does not trip and resumes operation once the overtemperature normalizes.

**Bit 13, Voltage OK/limit exceeded**

Bit 13 = 0: There are no voltage warnings.

Bit 13 = 1: The DC voltage in the frequency converter's DC link is too low or too high.

**Bit 14, Current OK/limit exceeded**

Bit 14 = 0: The motor current is lower than the current limit selected in *parameter 4-18 Current Limit*.

Bit 14 = 1: The current limit in *parameter 4-18 Current Limit* is exceeded.

**Bit 15, Thermal level OK/limit exceeded**

Bit 15 = 0: The timers for motor thermal protection and thermal protection are not exceeded 100%.

Bit 15 = 1: 1 of the timers exceeds 100%.

### 7.11.3 Bus Speed Reference Value

Speed reference value is transmitted to the frequency converter in a relative value in %. The value is transmitted in the form of a 16-bit word. The integer value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted using 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

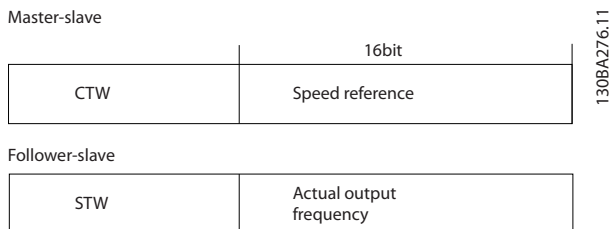


Illustration 7.17 Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

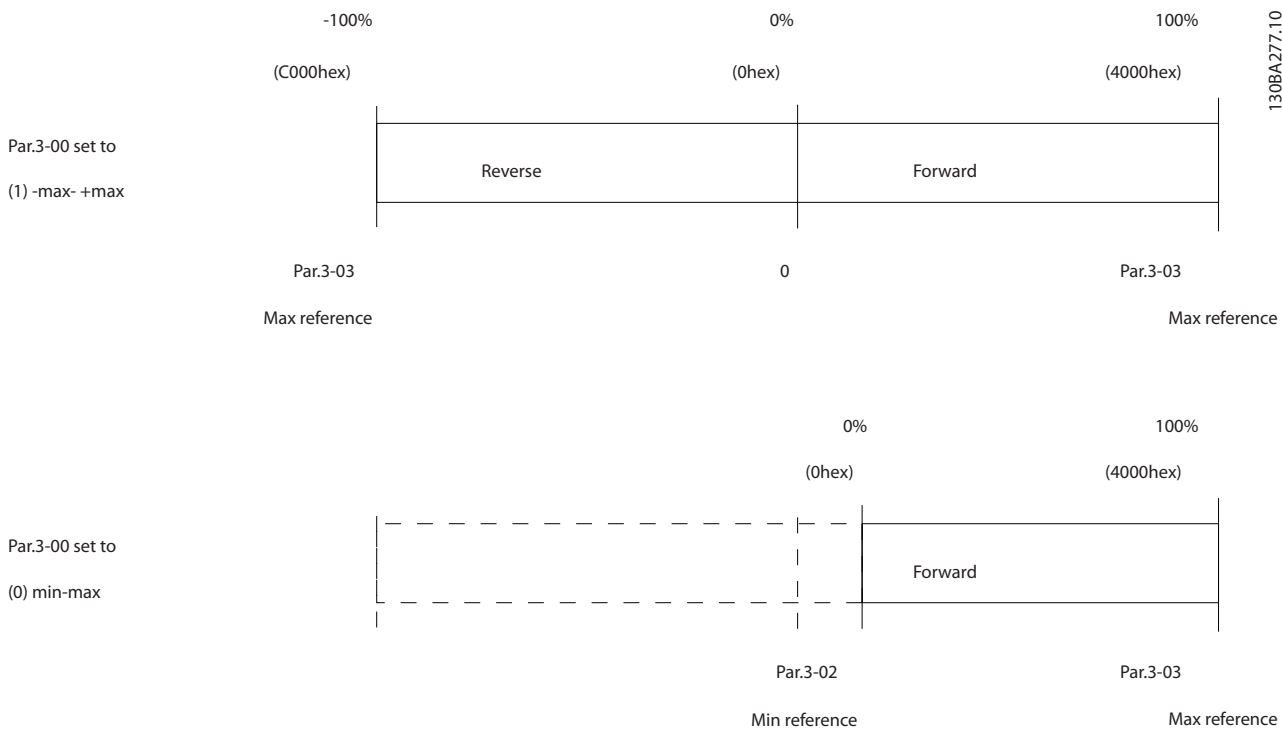


Illustration 7.18 Reference and MAV

## 8 General Specifications

### 8.1 Mechanical Dimensions

#### 8.1.1 Side-by-side Installation

The frequency converter can be mounted side by side but requires the clearance above and below for cooling.

Size	IP class	Power [kW (hp)]			Clearance above/below [mm (in)]
		3x200–240 V	3x380–480 V	3x525–600 V	
H1	IP20	0.25–1.5 (0.33–2)	0.37–1.5 (0.5–2)	–	100 (4)
H2	IP20	2.2 (3)	2.2–4 (3–5)	–	100 (4)
H3	IP20	3.7 (5)	5.5–7.5 (7.5–10)	–	100 (4)
H4	IP20	5.5–7.5 (7.5–10)	11–15 (15–20)	–	100 (4)
H5	IP20	11 (15)	18.5–22 (25–30)	–	100 (4)
H6	IP20	15–18.5 (20–25)	30–45 (40–60)	18.5–30 (25–40)	200 (7.9)
H7	IP20	22–30 (30–40)	55–75 (70–100)	37–55 (50–70)	200 (7.9)
H8	IP20	37–45 (50–60)	90 (125)	75–90 (100–125)	225 (8.9)
H9	IP20	–	–	2.2–7.5 (3–10)	100 (4)
H10	IP20	–	–	11–15 (15–20)	200 (7.9)
I2	IP54	–	0.75–4.0 (1–5)	–	100 (4)
I3	IP54	–	5.5–7.5 (7.5–10)	–	100 (4)
I4	IP54	–	11–18.5 (15–25)	–	100 (4)
I6	IP54	–	22–37 (30–50)	–	200 (7.9)
I7	IP54	–	45–55 (60–70)	–	200 (7.9)
I8	IP54	–	75–90 (100–125)	–	225 (8.9)

Table 8.1 Clearance Required for Cooling

#### **NOTICE**

With IP21/NEMA Type1 option kit mounted, a distance of 50 mm (2 in) between the units is required.



8.1.2 Frequency Converter Dimensions

Enclosure		Power [kW (hp)]		Height [mm (in)]			Width [mm (in)]		Depth [mm (in)]	Mounting hole [mm (in)]			Maximum weight	
Size	IP class	3x200-240 V	3x380-480 V	3x525-600 V	A	A <sup>1)</sup>	a	B	b	C	d	e	f	kg (lb)
H1	IP20	0.25-1.5 (0.33-2.0)	0.37-1.5 (0.5-2.0)	-	195 (7.7)	273 (10.7)	183 (7.2)	75 (3.0)	56 (2.2)	168 (6.6)	9 (0.35)	4.5 (0.18)	5.3 (0.21)	2.1 (4.6)
H2	IP20	2.2 (3.0)	2.2-4.0 (3.0-5.0)	-	227 (8.9)	303 (11.9)	212 (8.3)	90 (3.5)	65 (2.6)	190 (7.5)	11 (0.43)	5.5 (0.22)	7.4 (0.29)	3.4 (7.5)
H3	IP20	3.7 (5.0)	5.5-7.5 (7.5-10)	-	255 (10.0)	329 (13.0)	240 (9.4)	100 (3.9)	74 (2.9)	206 (8.1)	11 (0.43)	5.5 (0.22)	8.1 (0.32)	4.5 (9.9)
H4	IP20	5.5-7.5 (7.5-10)	11-15 (15-20)	-	296 (11.7)	359 (14.1)	275 (10.8)	135 (5.3)	105 (4.1)	241 (9.5)	12.6 (0.50)	7 (0.28)	8.4 (0.33)	7.9 (17.4)
H5	IP20	11 (15)	18.5-22 (25-30)	-	334 (13.1)	402 (15.8)	314 (12.4)	150 (5.9)	120 (4.7)	255 (10)	12.6 (0.50)	7 (0.28)	8.5 (0.33)	9.5 (20.9)
H6	IP20	15-18.5 (20-25)	30-45 (40-60)	18.5-30 (25-40)	518 (20.4)	595 (23.4)/635 (25), 45 kW	495 (19.5)	239 (9.4)	200 (7.9)	242 (9.5)	-	8.5 (0.33)	15 (0.6)	24.5 (54)
H7	IP20	22-30 (30-40)	55-75 (70-100)	37-55 (50-70)	550 (21.7)	630 (24.8)/690 (27.2), 75 kW	521 (20.5)	313 (12.3)	270 (10.6)	335 (13.2)	-	8.5 (0.33)	17 (0.67)	36 (79)
H8	IP20	37-45 (50-60)	90 (125)	75-90 (100-125)	660 (26)	800 (31.5)	631 (24.8)	375 (14.8)	330 (13)	335 (13.2)	-	8.5 (0.33)	17 (0.67)	51 (112)
H9	IP20	-	-	2.2-7.5 (3.0-10)	269 (10.6)	374 (14.7)	257 (10.1)	130 (5.1)	110 (4.3)	205 (8.0)	11 (0.43)	5.5 (0.22)	9 (0.35)	6.6 (14.6)
H10	IP20	-	-	11-15 (15-20)	399 (15.7)	419 (16.5)	380 (15)	165 (6.5)	140 (5.5)	248 (9.8)	12 (0.47)	6.8 (0.27)	7.5 (0.30)	12 (26.5)

1) Including decoupling plate  
The dimensions are only for the physical units.  
**NOTICE**  
When installing in an application, allow space above and below the units for cooling. The amount of space for free air passage is listed in Table 8.1.



Enclosure		Power [kW (hp)]		Height [mm (in)]		Width [mm (in)]		Depth [mm (in)]		Mounting hole [mm (in)]			Maximum weight	
Size	IP class	3x200-240 V	3x380-480 V	3x525-600 V	A	A <sup>1)</sup>	a	B	b	C	d	e	f	kg (lb)
I2	IP54	-	0.75-4.0 (1.0-5.0)	-	332 (13.1)	-	318.5 (12.53)	115 (4.5)	74 (2.9)	225 (8.9)	11 (0.43)	5.5 (0.22)	9 (0.35)	5.3 (11.7)
I3	IP54	-	5.5-7.5 (7.5-10)	-	368 (14.5)	-	354 (13.9)	135 (5.3)	89 (3.5)	237 (9.3)	12 (0.47)	6.5 (0.26)	9.5 (0.37)	7.2 (15.9)
I4	IP54	-	11-18.5 (15-25)	-	476 (18.7)	-	460 (18.1)	180 (7.0)	133 (5.2)	290 (11.4)	12 (0.47)	6.5 (0.26)	9.5 (0.37)	13.8 (30.42)
I6	IP54	-	22-37 (30-50)	-	650 (25.6)	-	624 (24.6)	242 (9.5)	210 (8.3)	260 (10.2)	19 (0.75)	9 (0.35)	9 (0.35)	27 (59.5)
I7	IP54	-	45-55 (60-70)	-	680 (26.8)	-	648 (25.5)	308 (12.1)	272 (10.7)	310 (12.2)	19 (0.75)	9 (0.35)	9.8 (0.39)	45 (99.2)
I8	IP54	-	75-90 (100-125)	-	770 (30)	-	739 (29.1)	370 (14.6)	334 (13.2)	335 (13.2)	19 (0.75)	9 (0.35)	9.8 (0.39)	65 (143.3)

1) Including decoupling plate

The dimensions are only for the physical units.

**NOTICE**

When installing in an application, allow space above and below the units for cooling. The amount of space for free air passage is listed in Table 8.1.

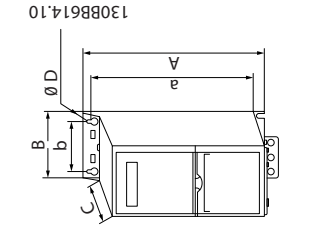
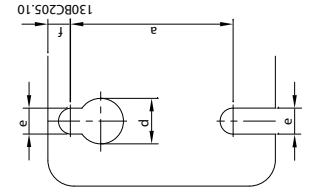
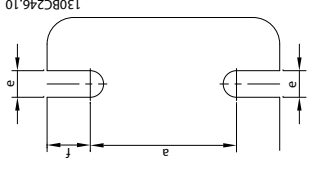


Table 8.3 Dimensions, Enclosure Sizes I2-I8

### 8.1.3 Shipping Dimensions

Enclosure frame size Mains voltage	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	I2	I3	I4	I5	I6	I7	I8	
T2 (200–240 V AC) [kW/hp]	0.25–1.5/ 0.33–2	2.2/3	3.7/5	5.5–7.5/ 7.5–10	11/15	15–18.5/ 20–25	22–30/ 30–40	37–45/ 50–60	–	–	–	–	–	–	–	–	–	–
T4 (380–480 V AC) [kW/hp]	0.37–1.5/ 0.5–2	2.2–4/ 3–5.5	5.5–7.5/ 7.5–10	11–15/ 15–20	18.5–22/ 25–30	30–45/ 40–60	55–75/ 75–100	90/ 125	–	–	0.75– 4.0/ 1.0–5.0	5.5–7.5/ 7.5–10	11–18.5/ 15–25	11–18.5/ 15–25	22–37/ 30–50	45–55/ 60–70	75–90/ 100–125	–
T6 (525–600 V AC) [kW/hp]	–	–	–	–	–	18.5–30/ 25–40	37–55/ 50–75	75–90/ 100–125	2.2–7.5/ 3–10	11–15/ 15–20	–	–	–	–	–	–	–	–
IP frame																		
IP20									IP54									
Maximum weight [kg (lb)]	2.1 (4.6)	3.4 (7.5)	4.5 (9.9)	7.9 (17.4)	9.5 (20.9)	24.5 (54.0)	36 (79.4)	51 (112.4)	6.6 (14.6)	11.5 (25.4)	6.1 (13.4)	7.8 (17.2)	13.8 (30.4)	23.3 (51.4)	28.3 (62.4)	41.5 (91.5)	60.5 (133.4)	
Height [mm/in]	265/ 10.4	300/ 11.8	280/ 11.0	380/ 15.0	395/ 15.6	850/ 33.5	850/ 33.5	850/ 33.5	380/ 15.0	500/ 19.7	310/ 12.2	325/ 12.8	390/ 15.4	850/ 33.5	850/ 33.5	850/ 33.5	950/ 37.4	
Width [mm/in]	230/ 9.1	265/ 10.4	155/ 6.1	200/ 7.9	233/ 9.2	370/ 15.6	410/ 16.1	490/ 19.3	290/ 11.4	330/ 13.0	205/ 8.1	230/ 9.1	295/ 11.6	370/ 15.6	370/ 15.6	410/ 16.1	490/ 19.3	
Depth [mm/in]	135/ 5.3	155/ 6.1	320/ 12.6	315/ 12.4	380/ 15.0	460/ 18.1	540/ 21.3	490/ 19.3	200/ 7.9	350/ 13.8	435/ 17.1	480/ 18.9	635/ 25.0	460/ 18.1	460/ 18.1	540/ 21.3	490/ 19.3	

Table 8.4 Dimensions

### 8.1.4 Field Mounting

If the environment, air quality or surroundings require extra protection, an IP21/NEMA Type 1 kit can be additional ordered and mounted on the drive or the drive can be ordered and delivered in an IP54 version.

**NOTICE**

The IP20, IP21, and IP54 versions are not suitable for outdoor mounting.

## 8.2 Mains Supply Specifications

### 8.2.1 3x200–240 V AC

Frequency converter	PK25	PK37	PK75	P1K5	P2K2	P3K7	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K
Typical shaft output [kW]	0.25	0.37	0.75	1.5	2.2	3.7	5.5	7.5	11.0	15.0	18.5	22.0	30.0	37.0	45.0
Typical shaft output [hp]	0.33	0.5	1.0	2.0	3.0	5.0	7.5	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0
Enclosure protection rating IP20	H1	H1	H1	H1	H2	H3	H4	H4	H5	H6	H6	H7	H7	H8	H8
Maximum cable size in terminals (mains, motor) [mm <sup>2</sup> (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)	16 (6)	35 (2)	35 (2)	50 (1)	50 (1)	95 (0)	120 (4/0)
<b>Output current</b>															
<b>40 °C (104 °F) ambient temperature</b>															
Continuous (3x200–240 V) [A]	1.5	2.2	4.2	6.8	9.6	15.2	22.0	28.0	42.0	59.4	74.8	88.0	115.0	143.0	170.0
Intermittent (3x200–240 V) [A]	1.7	2.4	4.6	7.5	10.6	16.7	24.2	30.8	46.2	65.3	82.3	96.8	126.5	157.3	187.0
<b>Maximum input current</b>															
Continuous (3x200–240 V) [A]	1.1	1.6	2.8	5.6	8.6/7.2	14.1/12.0	21.0/18.0	28.3/24.0	41.0/38.2	52.7	65.0	76.0	103.7	127.9	153.0
Intermittent (3x200–240 V) [A]	1.2	1.8	3.1	6.2	9.5/7.9	15.5/13.2	23.1/19.8	31.1/26.4	45.1/42.0	58.0	71.5	83.7	114.1	140.7	168.3
Maximum mains fuses	See chapter 8.3.1 Fuses and Circuit Breakers.														
Estimated power loss [W], Best case/typical <sup>1)</sup>	12/14	15/18	21/26	48/60	80/102	97/120	182/204	229/268	369/386	512	697	879	1149	1390	1500
Weight enclosure protection rating IP20 [kg (lb)]	2.0 (4.4)	2.0 (4.4)	2.0 (4.4)	2.1 (4.6)	3.4 (7.5)	4.5 (9.9)	7.9 (17.4)	7.9 (17.4)	9.5 (20.9)	24.5 (54)	24.5 (54)	36.0 (79.4)	36.0 (79.4)	51.0 (112.4)	51.0 (112.4)
Efficiency [%], best case/typical <sup>2)</sup>	97.0/96.5	97.3/96.8	98.0/97.6	97.6/97.0	97.1/96.3	97.9/97.4	97.3/97.0	98.5/97.1	97.2/97.1	97.0	97.1	96.8	97.1	97.1	97.3
<b>Output current</b>															
<b>50 °C (122 °F) ambient temperature</b>															
Continuous (3x200–240 V) [A]	1.5	1.9	3.5	6.8	9.6	13.0	19.8	23.0	33.0	41.6	52.4	61.6	80.5	100.1	119
Intermittent (3x200–240 V) [A]	1.7	2.1	3.9	7.5	10.6	14.3	21.8	25.3	36.3	45.8	57.6	67.8	88.6	110.1	130.9

Table 8.5 3x200–240 V AC, 0.25–45 kW (0.33–60 hp)

1) Applies for 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 50598-2, refer to [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](http://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.4.12 Ambient Conditions. For part load losses, see [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](http://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

8.2.2 3x380–480 V AC

Frequency converter	PK37	PK75	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5	P11K	P15K
Typical shaft output [kW]	0.37	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11.0	15.0
Typical shaft output [hp]	0.5	1.0	2.0	3.0	4.0	5.0	7.5	10.0	15.0	20.0
Enclosure protection rating IP20	H1	H1	H1	H2	H2	H2	H3	H3	H4	H4
Maximum cable size in terminals (mains, motor) [mm <sup>2</sup> (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)
<b>Output current - 40 °C (104 °F) ambient temperature</b>										
Continuous (3x380–440 V)[A]	1.2	2.2	3.7	5.3	7.2	9.0	12.0	15.5	23.0	31.0
Intermittent (3x380–440 V) [A]	1.3	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34.0
Continuous (3x441–480 V) [A]	1.1	2.1	3.4	4.8	6.3	8.2	11.0	14.0	21.0	27.0
Intermittent (3x441–480 V) [A]	1.2	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7
<b>Maximum input current</b>										
Continuous (3x380–440 V) [A]	1.2	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9
Intermittent (3x380–440 V) [A]	1.3	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9
Continuous (3x441–480 V) [A]	1.0	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7
Intermittent (3x441–480 V) [A]	1.1	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2
Maximum mains fuses	See chapter 8.3.1 Fuses and Circuit Breakers.									
Estimated power loss [W], best case/typical <sup>1)</sup>	13/15	16/21	46/57	46/58	66/83	95/118	104/131	159/198	248/274	353/379
Weight enclosure protection rating IP20 [kg (lb)]	2.0 (4.4)	2.0 (4.4)	2.1 (4.6)	3.3 (7.3)	3.3 (7.3)	3.4 (7.5)	4.3 (9.5)	4.5 (9.9)	7.9 (17.4)	7.9 (17.4)
Efficiency [%], best case/typical <sup>2)</sup>	97.8/97.3	98.0/97.6	97.7/97.2	98.3/97.9	98.2/97.8	98.0/97.6	98.4/98.0	98.2/97.8	98.1/97.9	98.0/97.8
<b>Output current - 50 °C (122 °F) ambient temperature</b>										
Continuous (3x380–440 V) [A]	1.04	1.93	3.7	4.85	6.3	8.4	10.9	14.0	20.9	28.0
Intermittent (3x380–440 V) [A]	1.1	2.1	4.07	5.4	6.9	9.2	12.0	15.4	23.0	30.8
Continuous (3x441–480 V) [A]	1.0	1.8	3.4	4.4	5.5	7.5	10.0	12.6	19.1	24.0
Intermittent (3x441–480 V) [A]	1.1	2.0	3.7	4.8	6.1	8.3	11.0	13.9	21.0	26.4

Table 8.6 3x380–480 V AC, 0.37–15 kW (0.5–20 hp), Enclosure Sizes H1–H4

1) Applies for 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 50598-2, refer to [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](https://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

2) Typical: under rated condition.

Best case: the optimal condition is adopt, such as the higher input voltage and lower switching frequency.

Frequency converter	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	18.5	22.0	30.0	37.0	45.0	55.0	75.0	90.0
Typical shaft output [hp]	25.0	30.0	40.0	50.0	60.0	70.0	100.0	125.0
Enclosure protection rating IP20	H5	H5	H6	H6	H6	H7	H7	H8
Maximum cable size in terminals (mains, motor) [mm <sup>2</sup> (AWG)]	16 (6)	16 (6)	35 (2)	35 (2)	35 (2)	50 (1)	95 (0)	120 (250MCM)
<b>Output current - 40 °C (104 °F) ambient temperature</b>								
Continuous (3x380–440 V)[A]	37.0	42.5	61.0	73.0	90.0	106.0	147.0	177.0
Intermittent (3x380–440 V) [A]	40.7	46.8	67.1	80.3	99.0	116.0	161.0	194.0
Continuous (3x441–480 V) [A]	34.0	40.0	52.0	65.0	80.0	105.0	130.0	160.0
Intermittent (3x441–480 V) [A]	37.4	44.0	57.2	71.5	88.0	115.0	143.0	176.0
<b>Maximum input current</b>								
Continuous (3x380–440 V) [A]	35.2	41.5	57.0	70.0	84.0	103.0	140.0	166.0
Intermittent (3x380–440 V) [A]	38.7	45.7	62.7	77.0	92.4	113.0	154.0	182.0
Continuous (3x441–480 V) [A]	29.3	34.6	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3x441–480 V) [A]	32.2	38.1	54.1	66.7	79.8	97.5	132.9	157.0
Maximum mains fuses	See chapter 8.3.1 Fuses and Circuit Breakers.							
Estimated power loss [W], best case/typical <sup>1)</sup>	412/456	475/523	733	922	1067	1133	1733	2141
Weight enclosure protection rating IP20 [kg (lb)]	9.5 (20.9)	9.5 (20.9)	24.5 (54)	24.5 (54)	24.5 (54)	36.0 (79.4)	36.0 (79.4)	51.0 (112.4)
Efficiency [%], best case/typical <sup>2)</sup>	98.1/97.9	98.1/97.9	97.8	97.7	98	98.2	97.8	97.9
<b>Output current - 50 °C (122 °F) ambient temperature</b>								
Continuous (3x380–440 V) [A]	34.1	38.0	48.8	58.4	72.0	74.2	102.9	123.9
Intermittent (3x380–440 V) [A]	37.5	41.8	53.7	64.2	79.2	81.6	113.2	136.3
Continuous (3x441–480 V) [A]	31.3	35.0	41.6	52.0	64.0	73.5	91.0	112.0
Intermittent (3x441–480 V) [A]	34.4	38.5	45.8	57.2	70.4	80.9	100.1	123.2

**Table 8.7 3x380–480 V AC, 18.5–90 kW (25–125 hp), Enclosure Sizes H5–H8**

1) Applies for 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 50598-2, refer to [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](https://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.4.12 Ambient Conditions. For part load losses, see [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](https://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

Frequency converter	PK75	P1K5	P2K2	P3K0	P4K0	P5K5	P7K5	P11K	P15K	P18K
Typical shaft output [kW]	0.75	1.5	2.2	3.0	4.0	5.5	7.5	11	15	18.5
Typical shaft output [hp]	1.0	2.0	3.0	4.0	5.0	7.5	10.0	15	20	25
Enclosure protection rating IP54	I2	I2	I2	I2	I2	I3	I3	I4	I4	I4
Maximum cable size in terminals (mains, motor) [mm <sup>2</sup> (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)	16 (6)
<b>Output current</b>										
<b>40 °C (104 °F) ambient temperature</b>										
Continuous (3x380–440 V) [A]	2.2	3.7	5.3	7.2	9.0	12.0	15.5	23.0	31.0	37.0
Intermittent (3x380–440 V) [A]	2.4	4.1	5.8	7.9	9.9	13.2	17.1	25.3	34.0	40.7
Continuous (3x441–480 V) [A]	2.1	3.4	4.8	6.3	8.2	11.0	14.0	21.0	27.0	34.0
Intermittent (3x441–480 V) [A]	2.3	3.7	5.3	6.9	9.0	12.1	15.4	23.1	29.7	37.4
<b>Maximum input current</b>										
Continuous (3x380–440 V) [A]	2.1	3.5	4.7	6.3	8.3	11.2	15.1	22.1	29.9	35.2
Intermittent (3x380–440 V) [A]	2.3	3.9	5.2	6.9	9.1	12.3	16.6	24.3	32.9	38.7
Continuous (3x441–480 V) [A]	1.8	2.9	3.9	5.3	6.8	9.4	12.6	18.4	24.7	29.3
Intermittent (3x441–480 V) [A]	2.0	3.2	4.3	5.8	7.5	10.3	13.9	20.2	27.2	32.2
Maximum mains fuses	See chapter 8.3.1 Fuses and Circuit Breakers.									
Estimated power loss [W], best case/typical <sup>1)</sup>	21/ 16	46/ 57	46/ 58	66/ 83	95/ 118	104/ 131	159/ 198	248/ 274	353/ 379	412/ 456
Weight enclosure protection rating IP54 [kg (lb)]	5.3 (11.7)	5.3 (11.7)	5.3 (11.7)	5.3 (11.7)	5.3 (11.7)	7.2 (15.9)	7.2 (15.9)	13.8 (30.4)	13.8 (30.4)	13.8 (30.4)
Efficiency [%], best case/typical <sup>2)</sup>	98.0/ 97.6	97.7/ 97.2	98.3/ 97.9	98.2/ 97.8	98.0/ 97.6	98.4/ 98.0	98.2/ 97.8	98.1/ 97.9	98.0/ 97.8	98.1/ 97.9
<b>Output current - 50 °C (122 °F) ambient temperature</b>										
Continuous (3x380–440 V) [A]	1.93	3.7	4.85	6.3	7.5	10.9	14.0	20.9	28.0	33.0
Intermittent (3x380–440 V) [A]	2.1	4.07	5.4	6.9	9.2	12.0	15.4	23.0	30.8	36.3
Continuous (3x441–480 V) [A]	1.8	3.4	4.4	5.5	6.8	10.0	12.6	19.1	24.0	30.0
Intermittent (3x441–480 V) [A]	2.0	3.7	4.8	6.1	8.3	11.0	13.9	21.0	26.4	33.0

Table 8.8 3x380–480 V AC, 0.75–18.5 kW (1–25 hp), Enclosure Sizes I2–I4

1) Applies for 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 50598-2, refer to [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](http://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.4.12 Ambient Conditions. For part load losses, see [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](http://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).



Frequency converter	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	22.0	30.0	37.0	45.0	55.0	75.0	90.0
Typical shaft output [hp]	30.0	40.0	50.0	60.0	70.0	100.0	125.0
Enclosure protection rating IP54	I6	I6	I6	I7	I7	I8	I8
Maximum cable size in terminals (mains, motor) [mm <sup>2</sup> (AWG)]	35 (2)	35 (2)	35 (2)	50 (1)	50 (1)	95 (3/0)	120 (4/0)
<b>Output current</b>							
<b>40 °C (104 ° F) ambient temperature</b>							
Continuous (3x380–440 V) [A]	44.0	61.0	73.0	90.0	106.0	147.0	177.0
Intermittent (3x380–440 V) [A]	48.4	67.1	80.3	99.0	116.6	161.7	194.7
Continuous (3x441–480 V) [A]	40.0	52.0	65.0	80.0	105.0	130.0	160.0
Intermittent (3x441–480 V) [A]	44.0	57.2	71.5	88.0	115.5	143.0	176.0
<b>Maximum input current</b>							
Continuous (3x380–440 V) [A]	41.8	57.0	70.3	84.2	102.9	140.3	165.6
Intermittent (3x380–440 V) [A]	46.0	62.7	77.4	92.6	113.1	154.3	182.2
Continuous (3x441–480 V) [A]	36.0	49.2	60.6	72.5	88.6	120.9	142.7
Intermittent (3x441–480 V) [A]	39.6	54.1	66.7	79.8	97.5	132.9	157.0
<b>Maximum mains fuses</b>							
Estimated power loss [W], best case/typical <sup>1)</sup>	496	734	995	840	1099	1520	1781
Weight enclosure protection rating IP54 [kg (lb)]	27 (59.5)	27 (59.5)	27 (59.5)	45 (99.2)	45 (99.2)	65 (143.3)	65 (143.3)
Efficiency [%], best case/typical <sup>2)</sup>	98.0	97.8	97.6	98.3	98.2	98.1	98.3
<b>Output current - 50 °C (122 °F) ambient temperature</b>							
Continuous (3x380–440 V) [A]	35.2	48.8	58.4	63.0	74.2	102.9	123.9
Intermittent (3x380–440 V) [A]	38.7	53.9	64.2	69.3	81.6	113.2	136.3
Continuous (3x441–480 V) [A]	32.0	41.6	52.0	56.0	73.5	91.0	112.0
Intermittent (3x441–480 V) [A]	35.2	45.8	57.2	61.6	80.9	100.1	123.2

**Table 8.9 3x380–480 V AC, 22–90 kW (30–125 hp), Enclosure Sizes I6–I8**

1) Applies for 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 50598-2, refer to [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](https://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.4.12 Ambient Conditions. For part load losses, see [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](https://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

8.2.3 3x525–600 V AC

Frequency converter	P2K2	P3K0	P3K7	P5K5	P7K5	P11K	P15K	P18K	P22K	P30K	P37K	P45K	P55K	P75K	P90K
Typical shaft output [kW]	2.2	3.0	3.7	5.5	7.5	11.0	15.0	18.5	22.0	30.0	37	45.0	55.0	75.0	90.0
Typical shaft output [hp]	3.0	4.0	5.0	7.5	10.0	15.0	20.0	25.0	30.0	40.0	50.0	60.0	70.0	100.0	125.0
Enclosure protection rating IP20	H9	H9	H9	H9	H9	H10	H10	H6	H6	H6	H7	H7	H7	H8	H8
Maximum cable size in terminals (mains, motor) [mm <sup>2</sup> (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	10 (8)	10 (8)	35 (2)	35 (2)	35 (2)	50 (1)	50 (1)	50 (1)	95 (0)	120 (4/0)
<b>Output current - 40 °C (104 °F) ambient temperature</b>															
Continuous (3x525–550 V) [A]	4.1	5.2	6.4	9.5	11.5	19.0	23.0	28.0	36.0	43.0	54.0	65.0	87.0	105.0	137.0
Intermittent (3x525–550 V) [A]	4.5	5.7	7.0	10.5	12.7	20.9	25.3	30.8	39.6	47.3	59.4	71.5	95.7	115.5	150.7
Continuous (3x551–600 V) [A]	3.9	4.9	6.1	9.0	11.0	18.0	22.0	27.0	34.0	41.0	52.0	62.0	83.0	100.0	131.0
Intermittent (3x551–600 V) [A]	4.3	5.4	6.7	9.9	12.1	19.8	24.2	29.7	37.4	45.1	57.2	68.2	91.3	110.0	144.1
<b>Maximum input current</b>															
Continuous (3x525–550 V) [A]	3.7	5.1	5.0	8.7	11.9	16.5	22.5	27.0	33.1	45.1	54.7	66.5	81.3	109.0	130.9
Intermittent (3x525–550 V) [A]	4.1	5.6	6.5	9.6	13.1	18.2	24.8	29.7	36.4	49.6	60.1	73.1	89.4	119.9	143.9
Continuous (3x551–600 V) [A]	3.5	4.8	5.6	8.3	11.4	15.7	21.4	25.7	31.5	42.9	52.0	63.3	77.4	103.8	124.5
Intermittent (3x551–600 V) [A]	3.9	5.3	6.2	9.2	12.5	17.3	23.6	28.3	34.6	47.2	57.2	69.6	85.1	114.2	137.0
Maximum mains fuses	See chapter 8.3.1 Fuses and Circuit Breakers.														
Estimated power loss [W], best case/typical <sup>1)</sup>	65	90	110	132	180	216	294	385	458	542	597	727	1092	1380	1658
Weight enclosure protection rating IP54 [kg (lb)]	6.6 (14.6)	6.6 (14.6)	6.6 (14.6)	6.6 (14.6)	6.6 (14.6)	11.5 (25.3)	11.5 (25.3)	24.5 (54)	24.5 (54)	24.5 (54)	36.0 (79.3)	36.0 (79.3)	36.0 (79.3)	51.0 (112.4)	51.0 (112.4)
Efficiency [%], best case/typical <sup>2)</sup>	97.9	97	97.9	98.1	98.1	98.4	98.4	98.4	98.4	98.5	98.5	98.7	98.5	98.5	98.5
<b>Output current - 50 °C (122 °F) ambient temperature</b>															
Continuous (3x525–550 V) [A]	2.9	3.6	4.5	6.7	8.1	13.3	16.1	19.6	25.2	30.1	37.8	45.5	60.9	73.5	95.9
Intermittent (3x525–550 V) [A]	3.2	4.0	4.9	7.4	8.9	14.6	17.7	21.6	27.7	33.1	41.6	50.0	67.0	80.9	105.5
Continuous (3x551–600 V) [A]	2.7	3.4	4.3	6.3	7.7	12.6	15.4	18.9	23.8	28.7	36.4	43.3	58.1	70.0	91.7
Intermittent (3x551–600 V) [A]	3.0	3.7	4.7	6.9	8.5	13.9	16.9	20.8	26.2	31.6	40.0	47.7	63.9	77.0	100.9

Table 8.10 3x525–600 V AC, 2.2–90 kW (3–125 hp), Enclosure Sizes H6–H10

1) Applies for 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 50598-2, refer to [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](http://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.4.12 Ambient Conditions. For part load losses, see [drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/](http://drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/).

### 8.3 Fuses and Circuit Breakers

#### Branch circuit protection

To prevent fire hazards, protect the branch circuits in an installation - switch gear, machines, and so on - against short circuits and overcurrent. Follow national and local regulations.

#### Short-circuit protection

Danfoss recommends using the fuses and circuit breakers listed in *Table 8.11* to protect service personnel or other equipment in case of an internal failure in the unit or a short circuit on the DC link. The frequency converter provides full short-circuit protection in case of a short circuit on the motor.

#### Overcurrent protection

Provide overload protection to avoid overheating of the cables in the installation. Overcurrent protection must always be carried out according to local and national

regulations. Circuit breakers and fuses must be designed for protection in a circuit capable of supplying a maximum of 100000  $A_{rms}$  (symmetrical), 480 V maximum.

#### UL/Non-UL compliance

To ensure compliance with UL or IEC 61800-5-1, use the circuit breakers or fuses listed in *Table 8.11*.

Circuit breakers must be designed for protection in a circuit capable of supplying a maximum of 10000  $A_{rms}$  (symmetrical), 480 V maximum.

#### **NOTICE**

**In the event of malfunction, failure to follow the protection recommendation may result in damage to the frequency converter.**

	Circuit breaker		Fuse				
	UL	Non-UL	UL				Non-UL
			Bussmann	Bussmann	Bussmann	Bussmann	Maximum fuse
Power [kW (hp)]			Type RK5	Type RK1	Type J	Type T	Type G
<b>3x200–240 V IP20</b>							
0.25 (0.33)	-	-	FRS-R-10	KTN-R10	JKS-10	JJN-10	10
0.37 (0.5)			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
0.75 (1.0)			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
1.5 (2.0)			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
2.2 (3.0)			FRS-R-15	KTN-R15	JKS-15	JJN-15	16
3.7 (5.0)			FRS-R-25	KTN-R25	JKS-25	JJN-25	25
5.5 (7.5)			FRS-R-50	KTN-R50	JKS-50	JJN-50	50
7.5 (10)			FRS-R-50	KTN-R50	JKS-50	JJN-50	50
11 (15)			FRS-R-80	KTN-R80	JKS-80	JJN-80	65
15 (20)	Cutler-Hammer EGE3100FFG	Moeller NZMB1- A125	FRS-R-100	KTN-R100	JKS-100	JJN-100	125
18.5 (25)			FRS-R-100	KTN-R100	JKS-100	JJN-100	125
22 (30)	Cutler-Hammer JGE3150FFG	Moeller NZMB1- A160	FRS-R-150	KTN-R150	JKS-150	JJN-150	160
30 (40)			FRS-R-150	KTN-R150	JKS-150	JJN-150	160
37 (50)	Cutler-Hammer JGE3200FFG	Moeller NZMB1- A200	FRS-R-200	KTN-R200	JKS-200	JJN-200	200
45 (60)			FRS-R-200	KTN-R200	JKS-200	JJN-200	200
<b>3x380–480 V IP20</b>							
0.37 (0.5)	-	-	FRS-R-10	KTS-R10	JKS-10	JJS-10	10
0.75 (1.0)			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
1.5 (2.0)			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
2.2 (3.0)			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
3.0 (4.0)			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
4.0 (5.0)			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
5.5 (7.5)			FRS-R-25	KTS-R25	JKS-25	JJS-25	25
7.5 (10)			FRS-R-25	KTS-R25	JKS-25	JJS-25	25
11 (15)			FRS-R-50	KTS-R50	JKS-50	JJS-50	50
15 (20)			FRS-R-50	KTS-R50	JKS-50	JJS-50	50
18.5 (25)			FRS-R-80	KTS-R80	JKS-80	JJS-80	65
22 (30)			FRS-R-80	KTS-R80	JKS-80	JJS-80	65

	Circuit breaker		Fuse				
	UL	Non-UL	UL				Non-UL
			Bussmann	Bussmann	Bussmann	Bussmann	Maximum fuse
Power [kW (hp)]			Type RK5	Type RK1	Type J	Type T	Type G
30 (40)	Cutler-Hammer EGE3125FFG	Moeller NZMB1- A125	FRS-R-125	KTS-R125	JKS-R125	JJS-R125	80
37 (50)			FRS-R-125	KTS-R125	JKS-R125	JJS-R125	100
45 (60)			FRS-R-125	KTS-R125	JKS-R125	JJS-R125	125
55 (70)	Cutler-Hammer JGE3200FFG	Moeller NZMB1- A200	FRS-R-200	KTS-R200	JKS-R200	JJS-R200	150
75 (100)			FRS-R-200	KTS-R200	JKS-R200	JJS-R200	200
90 (125)	Cutler-Hammer JGE3250FFG	Moeller NZMB2- A250	FRS-R-250	KTS-R250	JKS-R250	JJS-R250	250
<b>3x525-600 V IP20</b>							
2.2 (3)	-	-	FRS-R-20	KTS-R20	JKS-20	JJS-20	20
3.0 (4.0)			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
3.7 (5.0)			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
5.5 (7.5)			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
7.5 (10)			FRS-R-20	KTS-R20	JKS-20	JJS-20	30
11 (15)	-	-	FRS-R-30	KTS-R30	JKS-30	JJS-30	35
15 (20)			FRS-R-30	KTS-R30	JKS-30	JJS-30	35
18.5 (25)	Cutler-Hammer EGE3080FFG	Cutler-Hammer EGE3080FFG	FRS-R-80	KTS-R80	JKS-80	JJS-80	80
22 (30)			FRS-R-80	KTS-R80	JKS-80	JJS-80	80
30 (40)			FRS-R-80	KTS-R80	JKS-80	JJS-80	80
37 (50)	Cutler-Hammer JGE3125FFG	Cutler-Hammer JGE3125FFG	FRS-R-125	KTS-R125	JKS-125	JJS-125	125
45 (60)			FRS-R-125	KTS-R125	JKS-125	JJS-125	125
55 (70)			FRS-R-125	KTS-R125	JKS-125	JJS-125	125
75 (100)	Cutler-Hammer JGE3200FAG	Cutler-Hammer JGE3200FAG	FRS-R-200	KTS-R200	JKS-200	JJS-200	200
90 (125)		-	FRS-R-200	KTS-R200	JKS-200	JJS-200	200
<b>3x380-480 V IP54</b>							
0.75 (1.0)	-	PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
1.5 (2.0)		PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
2.2 (3.0)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
3.0 (4.0)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
4.0 (5.0)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
5.5 (7.5)		PKZM0-25	FRS-R-25	KTS-R-25	JKS-25	JJS-25	25
7.5 (10)		PKZM0-25	FRS-R-25	KTS-R-25	JKS-25	JJS-25	25
11 (15)		PKZM4-63	FRS-R-50	KTS-R-50	JKS-50	JJS-50	63
15 (20)		PKZM4-63	FRS-R-50	KTS-R-50	JKS-50	JJS-50	63
18.5 (25)		PKZM4-63	FRS-R-80	KTS-R-80	JKS-80	JJS-80	63
22 (30)	Moeller NZMB1-A125	-	FRS-R-80	KTS-R-80	JKS-80	JJS-80	125
30 (40)			FRS-R-125	KTS-R-125	JKS-125	JJS-125	125
37 (50)			FRS-R-125	KTS-R-125	JKS-125	JJS-125	125
45 (60)	Moeller NZMB2-A160	-	FRS-R-125	KTS-R-125	JKS-125	JJS-125	160
55 (70)			FRS-R-200	KTS-R-200	JKS-200	JJS-200	160
75 (100)	Moeller NZMB2-A250	-	FRS-R-200	KTS-R-200	JKS-200	JJS-200	200
90 (125)			FRS-R-250	KTS-R-250	JKS-200	JJS-200	200

Table 8.11 Circuit Breakers and Fuses

## 8.4 General Technical Data

### Protection and features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the frequency converter trips if there is overtemperature.
- The frequency converter is protected against short circuits between motor terminals U, V, W.
- When a motor phase is missing, the frequency converter trips and issues an alarm.
- When a mains phase is missing, the frequency converter trips or issues a warning (depending on the load).
- Monitoring of the 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, W.

### 8.4.1 Mains Supply (L1, L2, L3)

Supply voltage	200–240 V $\pm$ 10%
Supply voltage	380–480 V $\pm$ 10%
Supply voltage	525–600 V $\pm$ 10%
Supply frequency	50/60 Hz
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor ( $\lambda$ )	$\geq$ 0.9 nominal at rated load
Displacement power factor ( $\cos\phi$ ) near unity	(>0.98)
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H1–H5, I2, I3, I4	Maximum 1 time/30 s
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H6–H10, I6–I8	Maximum 1 time/minute
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2
The unit is suitable for use on a circuit capable of delivering not more than 100000 A <sub>rms</sub> symmetrical Amperes, 240/480 V maximum.	

### 8.4.2 Motor Output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–400 Hz
Switching on output	Unlimited
Ramp times	0.05–3600 s

### 8.4.3 Cable Length and Cross-section

Maximum motor cable length, shielded/armored (EMC-correct installation)	See chapter 3.4.3 EMC Emission Test Results
Maximum motor cable length, unshielded/unarmored	50 m (164 ft)
Maximum cross-section to motor, mains <sup>1)</sup>	
Cross-section DC terminals for filter feedback on enclosure sizes H1–H3, I2, I3, I4	4 mm <sup>2</sup> /11 AWG
Cross-section DC terminals for filter feedback on enclosure sizes H4–H5	16 mm <sup>2</sup> /6 AWG
Maximum cross-section to control terminals, rigid wire	2.5 mm <sup>2</sup> /14 AWG
Maximum cross-section to control terminals, flexible cable	2.5 mm <sup>2</sup> /14 AWG
Minimum cross-section to control terminals	0.05 mm <sup>2</sup> /30 AWG

1) See chapter 8.2.2 3x380–480 V AC for more information.

### 8.4.4 Digital Inputs

Programmable digital inputs	4
Terminal number	18, 19, 27, 29
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN	>19 V DC
Voltage level, logic 1 NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R <sub>i</sub>	Approximately 4 kΩ
Digital input 29 as thermistor input	Fault: >2.9 kΩ and no fault: <800 Ω
Digital input 29 as pulse input	Maximum frequency 32 kHz push-pull-driven & 5 kHz (O.C.)

### 8.4.5 Analog Inputs

Number of analog inputs	2
Terminal number	53, 54
Terminal 53 mode	Parameter 16-61 Terminal 53 Setting: 1 = voltage, 0 = current
Terminal 54 mode	Parameter 16-63 Terminal 54 Setting: 1 = voltage, 0 = current
Voltage level	0–10 V
Input resistance, R <sub>i</sub>	Approximately 10 kΩ
Maximum voltage	20 V
Current level	0/4–20 mA (scalable)
Input resistance, R <sub>i</sub>	<500 Ω
Maximum current	29 mA
Resolution on analog input	10 bit

### 8.4.6 Analog Output

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

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

### 8.4.7 Digital Output

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

1) Terminals 27 and 29 can also be programmed as input.

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

The digital outputs are galvanically isolated from the supply voltage (PELV) and other high voltage terminals.

### 8.4.8 Control Card, RS485 Serial Communication

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

### 8.4.9 Control Card, 24 V DC Output

Terminal number	12
Maximum load	80 mA

### 8.4.10 Relay Output

Programmable relay outputs	2
Relay 01 and 02 (enclosure size H1–H5 & I2–I4)	01–03 (NC), 01–02 (NO), 04–06 (NC), 04–05 (NO)
Maximum terminal load (AC-1) <sup>1)</sup> on 01–02/04–05 (NO) (resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15) <sup>1)</sup> on 01–02/04–05 (NO) (inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 01–02/04–05 (NO) (resistive load)	30 V DC, 2 A
Maximum terminal load (DC-13) <sup>1)</sup> on 01–02/04–05 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) <sup>1)</sup> on 01–03/04–06 (NC) (resistive load)	250 V AC, 3 A
Maximum terminal load (AC-15) <sup>1)</sup> on 01–03/04–06 (NC) (inductive load @ cosφ 0.4)	250 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 01–03/04–06 (NC) (resistive load)	30 V DC, 2 A
Minimum terminal load on 01–03 (NC), 01–02 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

1) IEC 60947 parts 4 and 5. Endurance of the relay varies with different load type, switching current, ambient temperature, driving configuration, working profile, and so forth. It is recommended to mount a snubber circuit when connecting inductive loads to the relays.

Programmable relay outputs	
Relay 01 terminal number (enclosure size H9)	01–03 (NC), 01–02 (NO)
Maximum terminal load (AC-1) <sup>1)</sup> on 01–03 (NC), 01–02 (NO) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) <sup>1)</sup> (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 01–02 (NO), 01–03 (NC) (resistive load)	60 V DC, 1 A
Maximum terminal load (DC-13) <sup>1)</sup> (inductive load)	24 V DC, 0.1 A
Relay 01 and 02 terminal number (enclosure size H6, H7, H8, H9 (relay 2 only), H10, and I6–I8)	01–03 (NC), 01–02 (NO), 04–06 (NC), 04–05 (NO)
Maximum terminal load (AC-1) <sup>1)</sup> on 04–05 (NO) (resistive load) <sup>2)3)</sup>	400 V AC, 2 A
Maximum terminal load (AC-15) <sup>1)</sup> on 04–05 (NO) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A

Maximum terminal load (DC-1) <sup>1)</sup> on 04–05 (NO) (resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) <sup>1)</sup> on 04–05 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) <sup>1)</sup> on 04–06 (NC) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) <sup>1)</sup> on 04–06 (NC) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>1)</sup> on 04–06 (NC) (resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13) <sup>1)</sup> on 04–06 (NC) (inductive load)	24 V DC, 0.1 A
Minimum terminal load on 01–03 (NC), 01–02 (NO), 04–06 (NC), 04–05 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

1) IEC 60947 parts 4 and 5. Endurance of the relay varies with different load type, switching current, ambient temperature, driving configuration, working profile, and so forth. It is recommended to mount a snubber circuit when connecting inductive loads to the relays.

2) Overvoltage Category II.

3) UL applications 300 V AC 2 A.

### 8.4.11 Control Card, 10 V DC Output

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

### 8.4.12 Ambient Conditions

Enclosure protection rating	IP20, IP54
Enclosure kit available	IP21, TYPE 1
Vibration test	1.0 g
Maximum relative humidity	5–95% (IEC 60721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60721-3-3), coated (standard) enclosure sizes H1–H5	Class 3C3
Aggressive environment (IEC 60721-3-3), non-coated enclosure sizes H6–H10	Class 3C2
Aggressive environment (IEC 60721-3-3), coated (optional) enclosure sizes H6–H10	Class 3C3
Aggressive environment (IEC 60721-3-3), non-coated enclosure sizes I2–I8	Class 3C2
Test method according to IEC 60068-2-43 H2S (10 days)	
Ambient temperature	See maximum output current at 40/50 °C (104/122°F) in chapter 8.2.2 3x380–480 V AC.
Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced performance, enclosure sizes H1–H5 and I2–I4	-20 °C (-4 °F)
Minimum ambient temperature at reduced performance, enclosure sizes H6–H10 and I6–I8	-10 °C (14 °F)
Temperature during storage/transport	-30 to +65/70 °C (-22 to +149/158°F)
Maximum altitude above sea level without derating	1000 m (3281 ft)
Maximum altitude above sea level with derating	3000 m (9843 ft)
Safety standards	EN/IEC 61800-5-1, UL 508C
EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011, IEC 61800-3
	EN 61800-3, EN 61000-3-12, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4,
EMC standards, Immunity	EN 61000-4-5, EN 61000-4-6
Energy efficiency class <sup>1)</sup>	IE2

1) Determined according to EN 50598-2 at:

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



### 8.5 dU/Dt

	Cable length [m (ft)]	AC line voltage [V]	Rise time [µsec]	V <sub>peak</sub> [kV]	dU/dt [kV/µsec]
200 V 0.25 kW (0.34 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 0.37 kW (0.5 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 0.75 kW (1.0 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 1.5 kW (2.0 hp)	5 (16)	240	0.121	0.498	3.256
	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
200 V 2.2 kW (3.0 hp)	5 (16)	240	0.18	0.476	2.115
	25 (82)	240	0.230	0.615	2.141
	50 (164)	240	0.292	0.566	1.550
200 V 3.7 kW (5.0 hp)	5 (16)	240	0.168	0.570	2.714
	25 (82)	240	0.205	0.615	2.402
	50 (164)	240	0.252	0.620	1.968
200 V 5.5 kW (7.4 hp)	5 (16)	240	0.128	0.445	2.781
	25 (82)	240	0.224	0.594	2.121
	50 (164)	240	0.328	0.596	1.454
200 V 7.5 kW (10 hp)	5 (16)	240	0.18	0.502	2.244
	25 (82)	240	0.22	0.598	2.175
	50 (164)	240	0.292	0.615	1.678
200 V 11 kW (15 hp)	36 (118)	240	0.176	0.56	2.545
	50 (164)	240	0.216	0.599	2.204
400 V 0.37 kW (0.5 hp)	5 (16)	400	0.160	0.808	4.050
	25 (82)	400	0.240	1.026	3.420
	50 (164)	400	0.340	1.056	2.517
400 V 0.75 kW (1.0 hp)	5 (16)	400	0.160	0.808	4.050
	25 (82)	400	0.240	1.026	3.420
	50 (164)	400	0.340	1.056	2.517
400 V 1.5 kW (2.0 hp)	5 (16)	400	0.160	0.808	4.050
	25 (82)	400	0.240	1.026	3.420
	50 (164)	400	0.340	1.056	2.517
400 V 2.2 kW (3.0 hp)	5 (16)	400	0.190	0.760	3.200
	25 (82)	400	0.293	1.026	2.801
	50 (164)	400	0.422	1.040	1.971
400 V 3.0 kW (4.0 hp)	5 (16)	400	0.190	0.760	3.200
	25 (82)	400	0.293	1.026	2.801
	50 (164)	400	0.422	1.040	1.971
400 V 4.0 kW (5.4 hp)	5 (16)	400	0.190	0.760	3.200
	25 (82)	400	0.293	1.026	2.801
	50 (164)	400	0.422	1.040	1.971
400 V 5.5 kW (7.4 hp)	5 (16)	400	0.168	0.81	3.857
	25 (82)	400	0.239	1.026	3.434
	50 (164)	400	0.328	1.05	2.560
400 V 7.5 kW (10 hp)	5 (16)	400	0.168	0.81	3.857
	25 (82)	400	0.239	1.026	3.434
	50 (164)	400	0.328	1.05	2.560

	Cable length [m (ft)]	AC line voltage [V]	Rise time [ $\mu$ sec]	V <sub>peak</sub> [kV]	dU/dt [kV/ $\mu$ sec]
400 V 11 kW (15 hp)	5 (16)	400	0.116	0.69	4.871
	25 (82)	400	0.204	0.985	3.799
	50 (164)	400	0.316	1.01	2.563
400 V 15 kW (20 hp)	5 (16)	400	0.139	0.864	4.955
	50 (82)	400	0.338	1.008	2.365
400 V 18.5 kW (25 hp)	5 (16)	400	0.132	0.88	5.220
	25 (82)	400	0.172	1.026	4.772
	50 (164)	400	0.222	1.00	3.603
400 V 22 kW (30 hp)	5 (16)	400	0.132	0.88	5.220
	25 (82)	400	0.172	1.026	4.772
	50 (164)	400	0.222	1.00	3.603
400 V 30 kW (40 hp)	10 (33)	400	0.376	0.92	1.957
	50 (164)	400	0.536	0.97	1.448
	100 (328)	400	0.696	0.95	1.092
	150 (492)	400	0.8	0.965	0.965
	10 (33)	480	0.384	1.2	2.5
	50 (164)	480	0.632	1.18	1.494
	100 (328)	480	0.712	1.2	1.348
	150 (492)	480	0.832	1.17	1.125
	10 (33)	500	0.408	1.24	2.431
	50 (164)	500	0.592	1.29	1.743
	100 (328)	500	0.656	1.28	1.561
	150 (492)	500	0.84	1.26	1.2
400 V 37 kW (50 hp)	10 (33)	400	0.276	0.928	2.69
	50 (164)	400	0.432	1.02	1.889
	10 (33)	480	0.272	1.17	3.441
	50 (164)	480	0.384	1.21	2.521
	10 (33)	500	0.288	1.2	3.333
	50 (164)	500	0.384	1.27	2.646
400 V 45 kW (60 hp)	10 (33)	400	0.3	0.936	2.496
	50 (164)	400	0.44	0.924	1.68
	100 (328)	400	0.56	0.92	1.314
	150 (492)	400	0.8	0.92	0.92
	10 (33)	480	0.3	1.19	3.173
	50 (164)	480	0.4	1.15	2.3
	100 (328)	480	0.48	1.14	1.9
	150 (492)	480	0.72	1.14	1.267
	10 (33)	500	0.3	1.22	3.253
	50 (164)	500	0.38	1.2	2.526
	100 (328)	500	0.56	1.16	1.657
	150 (492)	500	0.74	1.16	1.254
400 V 55 kW (74 hp)	10 (33)	400	0.46	1.12	1.948
		480	0.468	1.3	2.222
400 V 75 kW (100 hp)	10 (33)	400	0.502	1.048	1.673
		480	0.52	1.212	1.869
		500	0.51	1.272	1.992
400 V 90 kW (120 hp)	10 (33)	400	0.402	1.108	2.155
		400	0.408	1.288	2.529
		400	0.424	1.368	2.585

	Cable length [m (ft)]	AC line voltage [V]	Rise time [ $\mu$ sec]	V <sub>peak</sub> [kV]	dU/dt [kV/ $\mu$ sec]
600 V 7.5 kW (10 hp)	5 (16)	525	0.192	0.972	4.083
	50 (164)	525	0.356	1.32	2.949
	5 (16)	600	0.184	1.06	4.609
	50 (164)	600	0.42	1.49	2.976

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