Danfoss

THE REAL DRIVE

Design Guide
VLT® HVAC Basic Drive FC 101

VLT®
HVAC Basic Drive

VLT®
THE REAL DRIVE

Contents

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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 proved for input power characteristics, output for motor control, and ambient operating conditions for the converter.

Also included are safety features, fault condition monitoring, operational status reporting, serial communication capabilities, and programmable options and features. Design details such as site requirements, cables, fuses, control wiring, unit sizes and weights, and other critical information necessary to plan for system integration is also provided.

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
MG18C6xx	Replaces MG18C5xx	2.70

Table 1.1 Document and Software Version

1.3 Safety Symbols

The following symbols are used in this document:

⚠WARNING

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

⚠CAUTION

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

NOTICE

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

1.4 Abbreviations

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

Table 1.2 Abbreviations

1

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 programme, and includes complete parameter descriptions.

- .Danfoss VLT® Energy Box software. Select *PC Software Download* at *www.danfoss.com/BusinessAreas/DrivesSolutions*.
  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 *http://www.danfoss.com/BusinessAreas/DrivesSolutions/Software+MCT10/MCT10+Downloads.htm*.

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

The latest software do not always contain the latest drive updates. Contact the local sales office for the latest drive updates (*.upd files), or download the drive updates from *www.danfoss.com/BusinessAreas/DrivesSolutions/fc101driveupdates*.

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 with LCP and the digital inputs. Functions are divided into 2 groups. Functions in group 1 have higher priority than functions in group 2.	Group 1	Reset, coasting stop, reset and coasting stop, quick-stop, DC braking, stop and the [Off] key.
	Group 2	Start, pulse start, reversing, start reversing, jog and freeze output

Table 1.3 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_{MIN}
The minimum motor frequency.

$f_{M,N}$
The rated motor frequency (nameplate data).

I_M
The motor current.

$I_{M,N}$
The rated motor current (nameplate data).

$n_{M,N}$
The rated motor speed (nameplate data).

$P_{M,N}$
The rated motor power (nameplate data).

U_M
The instantaneous motor voltage.

$U_{M,N}$
The rated motor voltage (nameplate data).

1
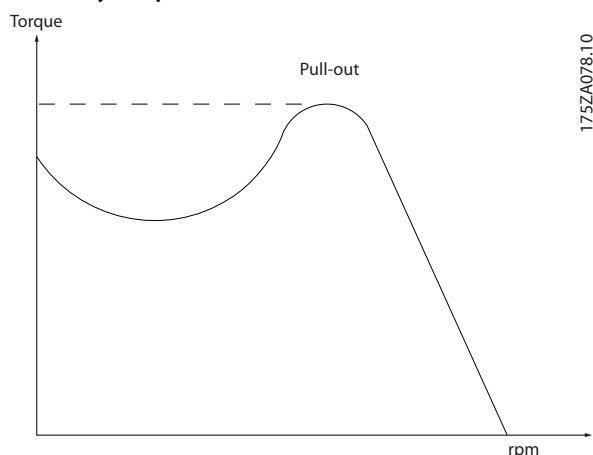
Break-away torque

Illustration 1.1 Break-away Torque

η_VLT

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 1.3*.

Stop command

See *Table 1.3*.

References

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_MAX

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 set in *3-03 Maximum Reference*.

Ref_MIN

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 set in *3-02 Minimum Reference*

Miscellaneous

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

AMA algorithm determines the electrical parameters for the connected motor at standstill.

Digital inputs

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

Digital outputs

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

Relay outputs

The frequency converter features 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 overtemperature of the motor.

Initialising

If initialising is carried out (*14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.
14-22 Operation Mode does not initialise 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 none-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 from the frequency converter, i.e. 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^2.

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.

1

PI controller

The PI controller maintains the desired speed, pressure, temperature, etc. 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, e.g. 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 has disappeared and the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

Trip locked

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 cancelled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is cancelled by activating reset or, in some cases, by being programmed to reset automatically. Trip locked may not be used 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.

$$Power\ factor = \frac{\sqrt{3} \times U \times I_1 \times COS\varphi}{\sqrt{3} \times U \times IRMS}$$

The power factor for 3-phase control:

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

$$IRMS = \sqrt{I_1^2 + I_5^2 + I_7^2 + \ldots + I_n^2}$$

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 minimises 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 1.4*.

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	2006/95/EC; IEC 61800-5-1 (2003)
EMC directive	2004/108/EC
ErP directive	

Table 1.4 EU Directives Applicable to Frequency Converters

Declarations of conformity are available on request.

1

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 2004/108/EC 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 aim of the directive is to increase energy efficiency and the level of protection of the environment, while at the same time 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 UL508C thermal memory retention requirements. For more information, refer to the section *Motor Thermal Protection* in the product specific *design guide*.

1.8.3 C-tick Compliance

Illustration 1.3 C-tick

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 authorised to install, commission, and maintain equipment, systems, and circuits in accordance with pertinent laws and regulations. Additionally, the personnel must be familiar with the instructions and safety measures described in this manual.

2.2 Safety Precautions

⚠WARNING

HIGH VOLTAGE

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

- **Installation, start-up, and maintenance must be performed by qualified personnel only.**

⚠WARNING

UNINTENDED START

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

- **Disconnect the frequency converter from the mains.**

- **Press [Off/Reset] on the LCP before programming parameters.**

- **Ensure that the frequency converter is fully wired and assembled when it is connected to AC mains, DC power supply, or load sharing.**

⚠WARNING

DISCHARGE TIME!

Frequency converters contain DC-link capacitors that can remain charged even when the frequency converter is not powered. To avoid electrical hazards, disconnect AC mains, any permanent magnet type motors, and any remote DC-link power supplies, including battery backups, UPS and DC-link connections to other frequency converters. Wait for the capacitors to fully discharge before performing any service or repair work. The amount of waiting time is listed in *Table 2.1*. Failure to wait the specified time after power has been removed before doing service or repair could result in death or serious injury.

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.**

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3 Product Overview

3.1 Advantages

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.
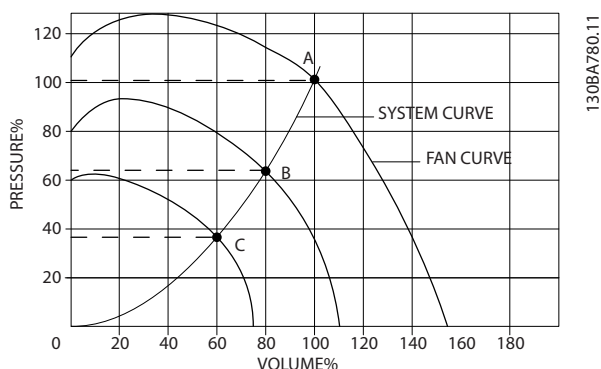
Illustration 3.1 Fan Curves (A, B, and C) for Reduced Fan Volumes
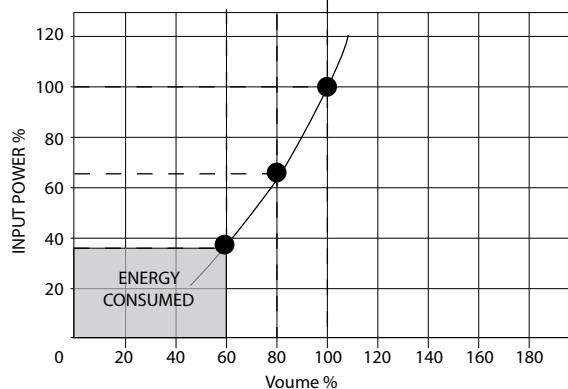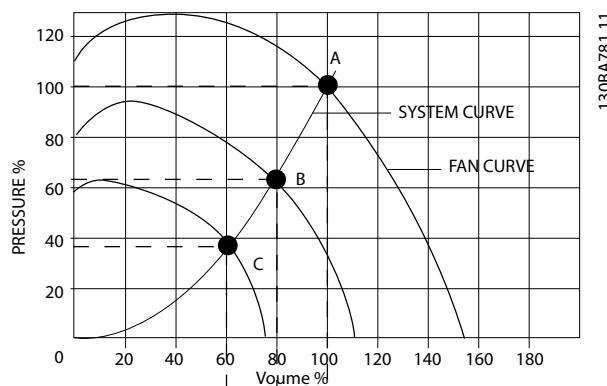
Illustration 3.2 Energy Savings with Frequency Converter Solution

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 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.
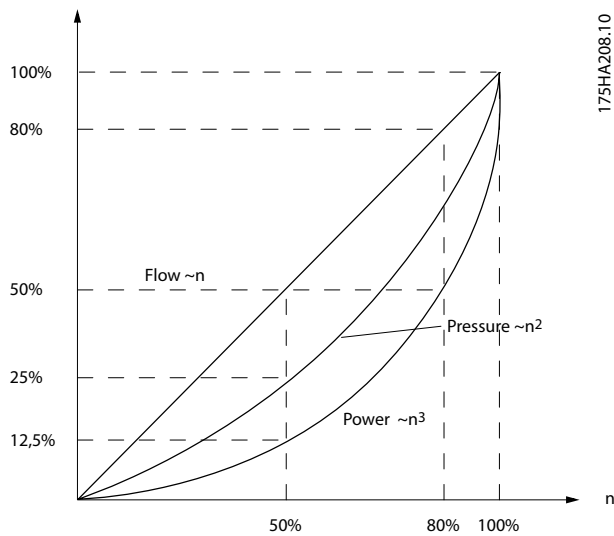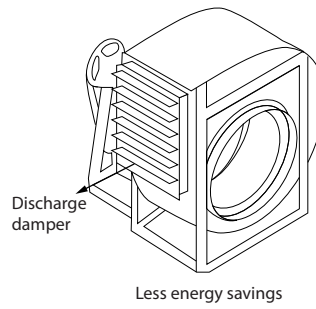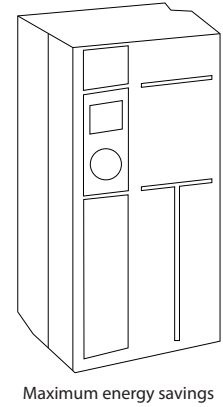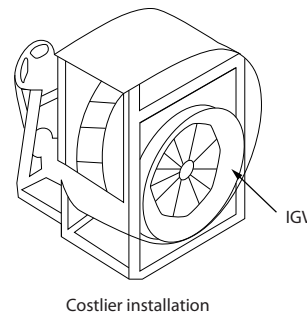
Illustration 3.3 Laws of Proportionally

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

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

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

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

Table 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 i.e. 60%.
As the graph shows, more than 50% energy savings can be achieved in typical applications.

Illustration 3.4 The 3 Common Energy Saving Systems
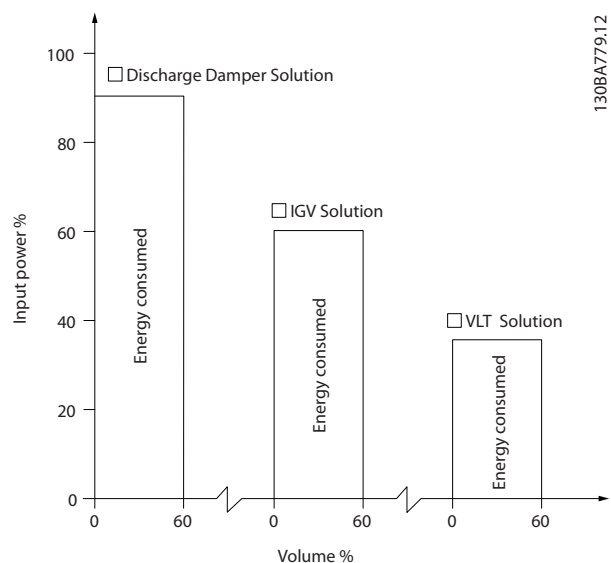
Illustration 3.5 Energy Savings

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.

3

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

Energy savings

$P_{shaft} = P_{shaft\ output}$
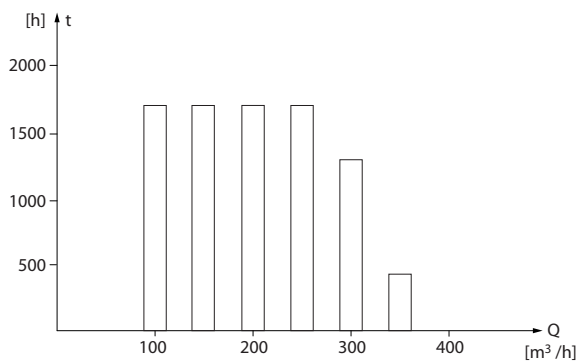
Illustration 3.6 Flow Distribution over 1 Year
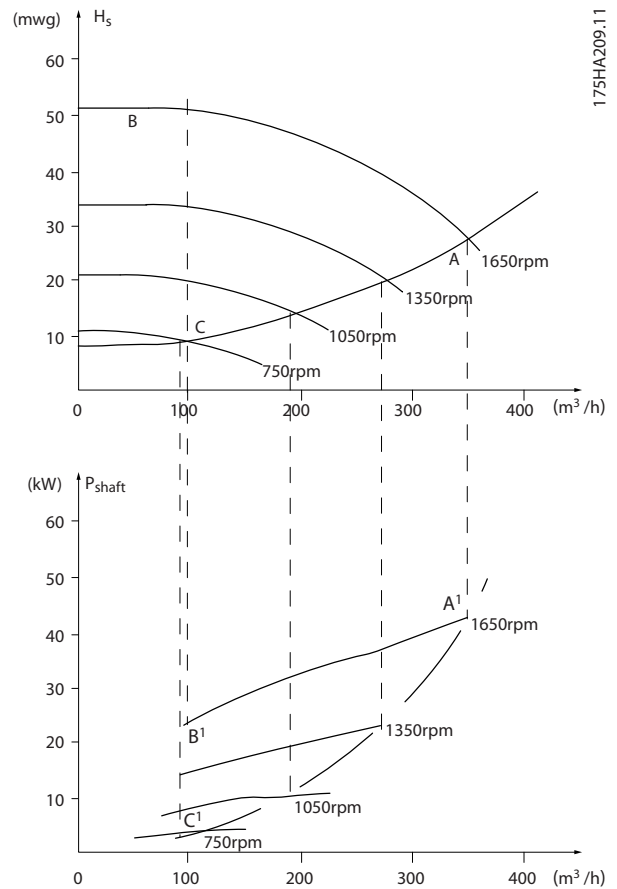
Illustration 3.7 Energy

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

Table 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) utilising 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
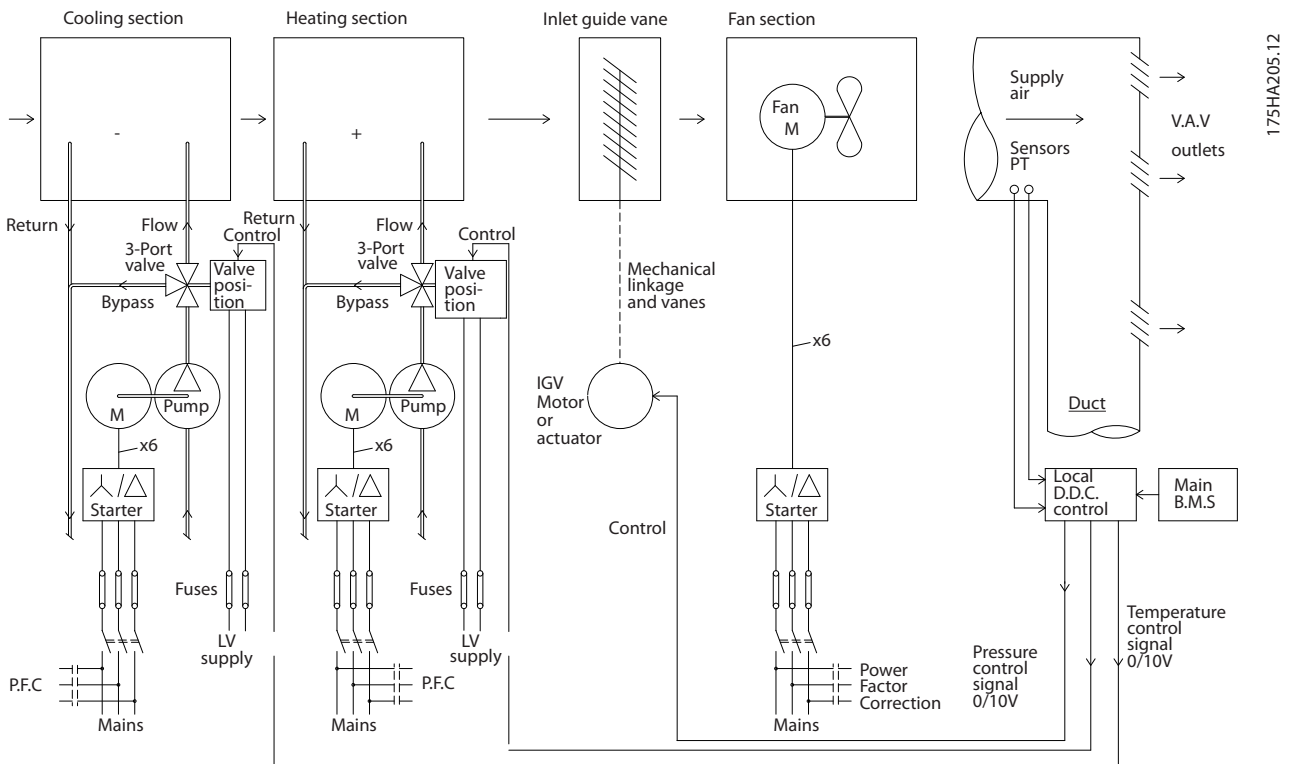
The example in *chapter 3.1.9 Without a Frequency Converter* shows that a lot of equipment is not required when a frequency converter is used. It is possible to calculate the cost of installing the 2 different systems. In the example, the 2 systems can be established at roughly the same price.

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

3.1.9 Without a Frequency Converter

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

16   MG18C602

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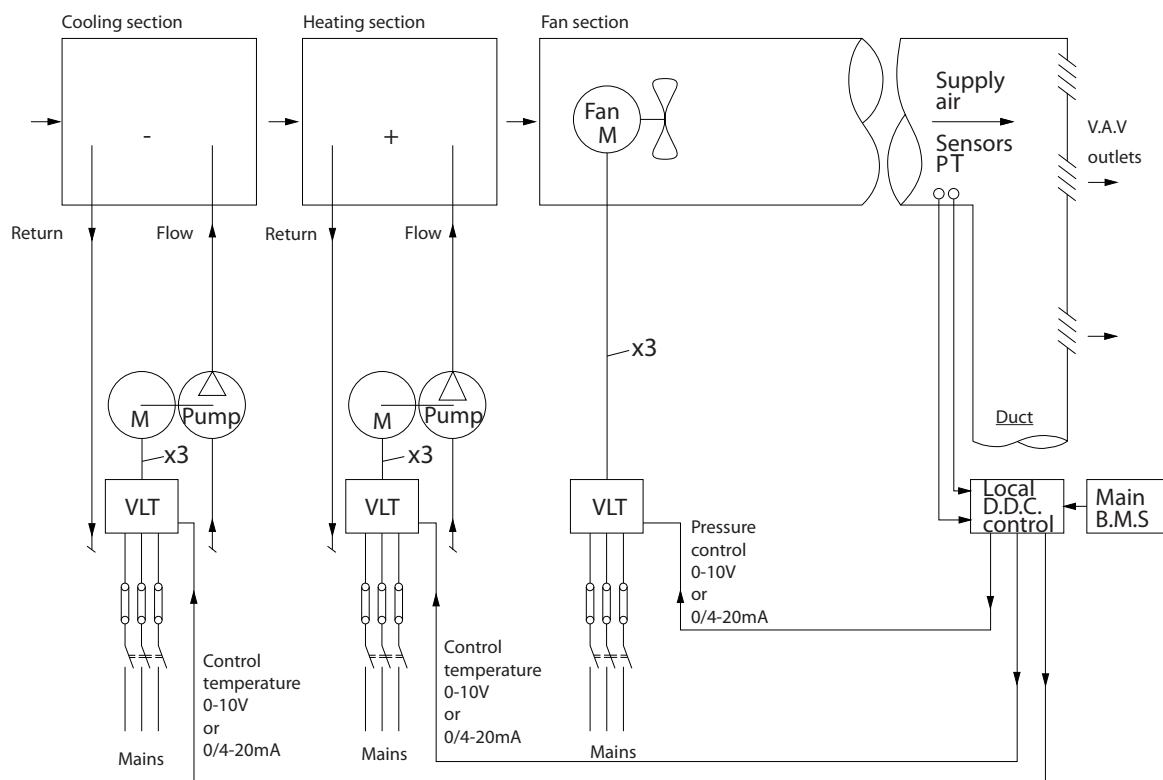
D.D.C.	Direct digital control
E.M.S.	Energy management system
V.A.V.	Variable air volume
Sensor P	Pressure
Sensor T	Temperature

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 satisfy 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 utilising 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 can be used to eliminate the need for additional controllers.
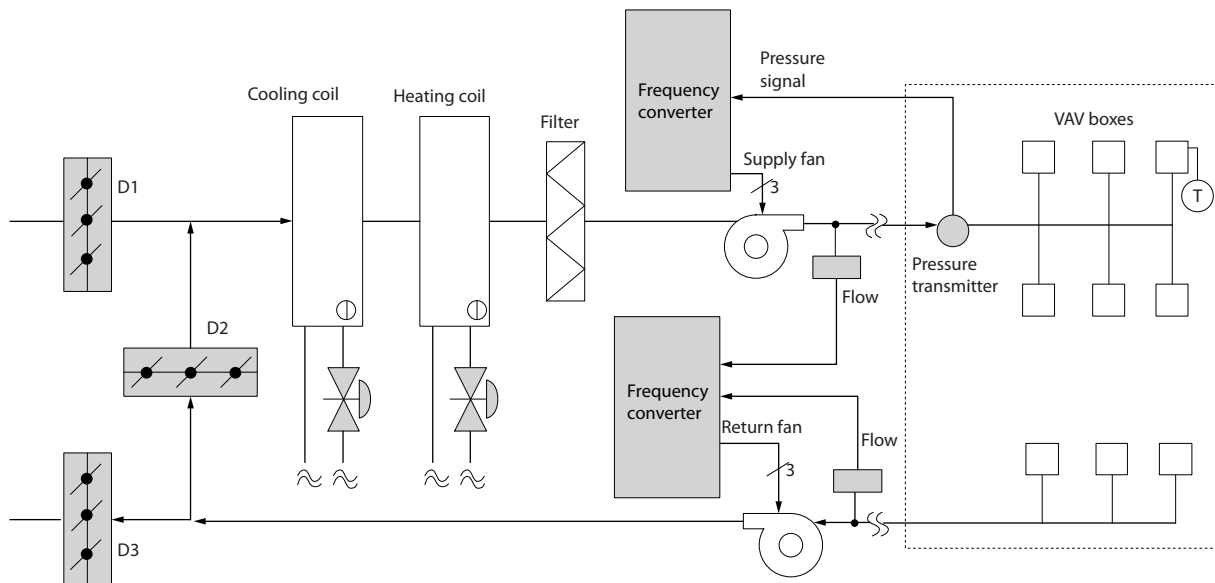
Illustration 3.11 Variable Air Volume

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 utilising 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_2 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_2 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 air flows.

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 set-point, the supply fan can decrease its speed. The return fan modulates to maintain a static pressure set-point. 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 utilised 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 one PI controller, which allows monitoring both temperature and air quality. Even if the temperature requirement is satisfied, 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 air flow between the supply and return ducts as well.
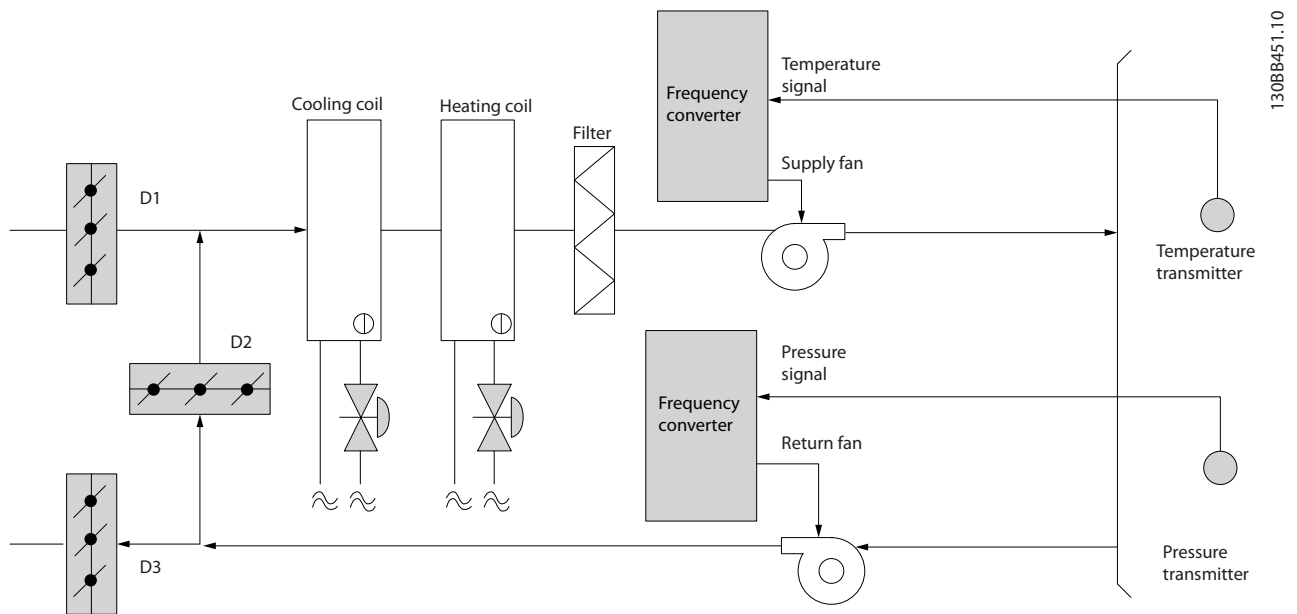
Illustration 3.12 Constant Air Volume

3

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 towers 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 utilised 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 utilising a gear-box to frequency control the tower fan, a minimum speed of 40-50% may be 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 undesireable frequencies that may cause vibrations. These frequencies can easily be avoided by programming the bypass frequency ranges in the frequency converter.
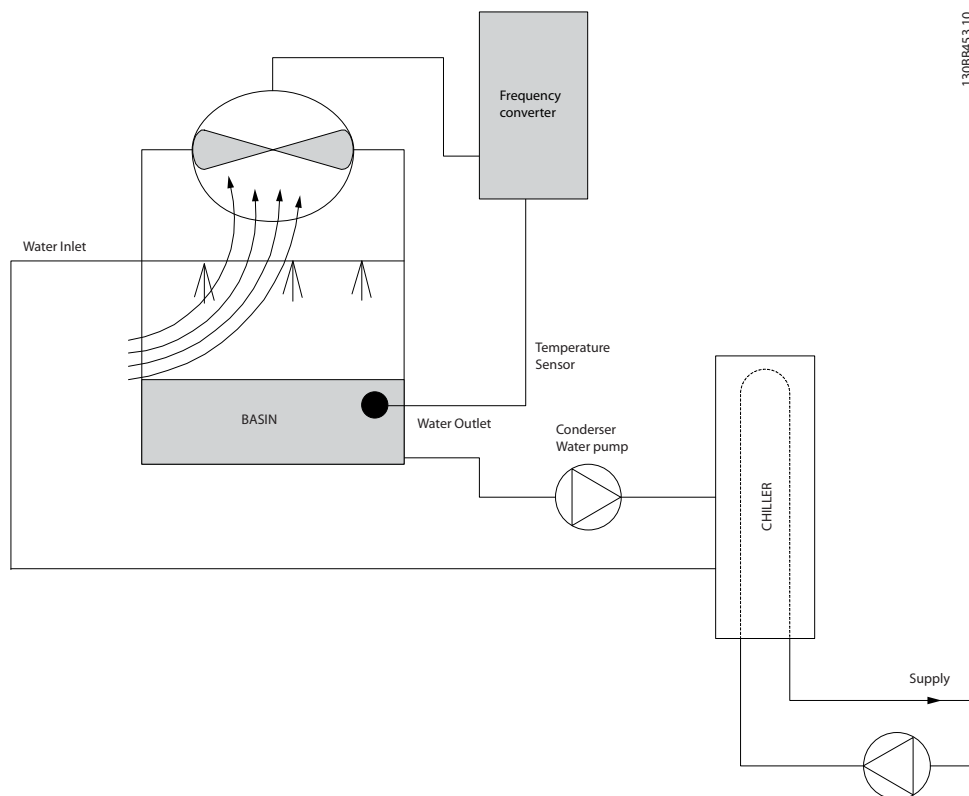
Illustration 3.13 Cooling Tower Fan

3

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.

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.

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.
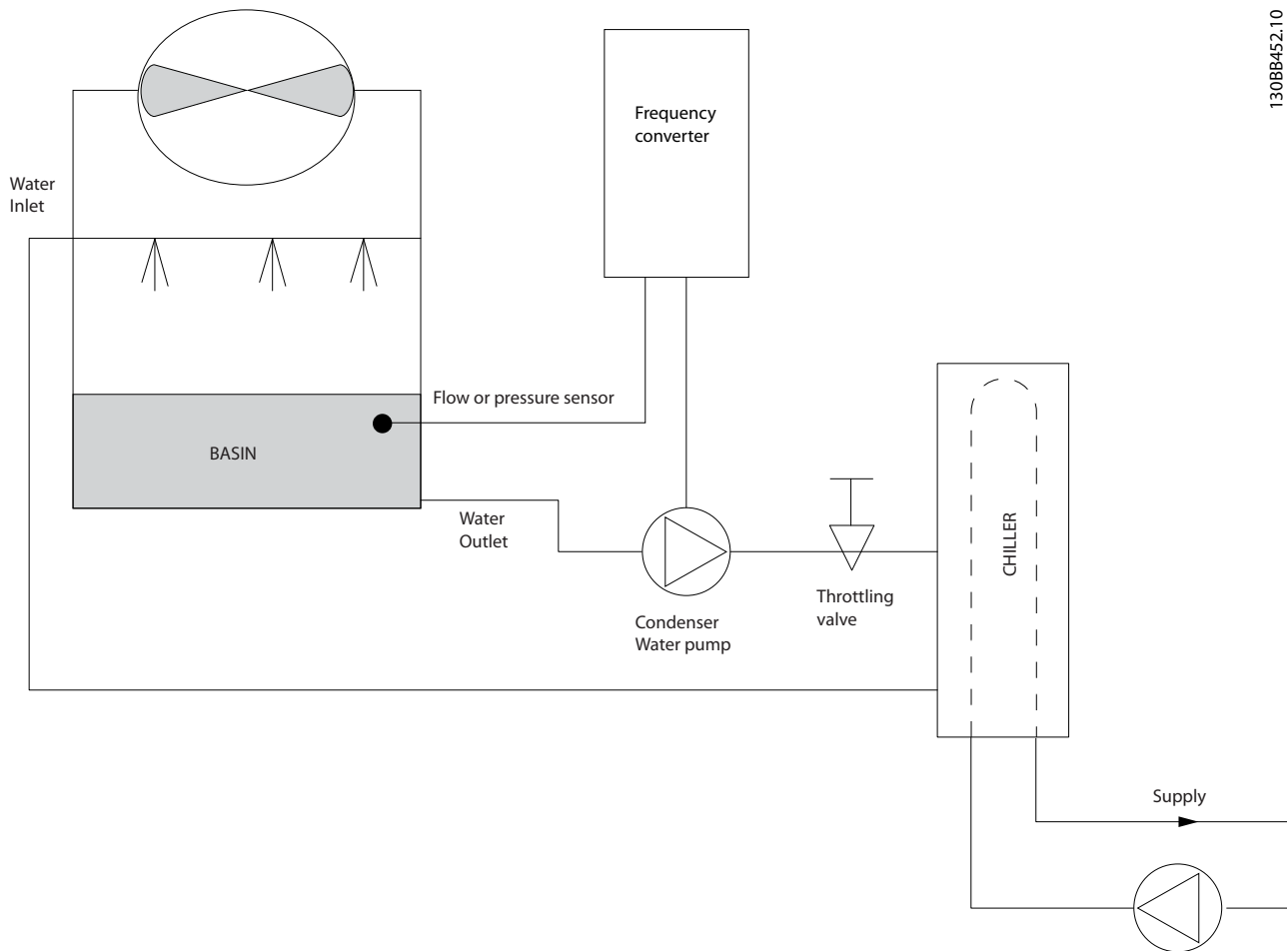
Illustration 3.14 Condenser Pumps

3

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 utilised.

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. In the event the flow rate needs to be increased later in the systems life, the frequency convertercan simply increase the pump speed instead of requiring a new pump impeller.
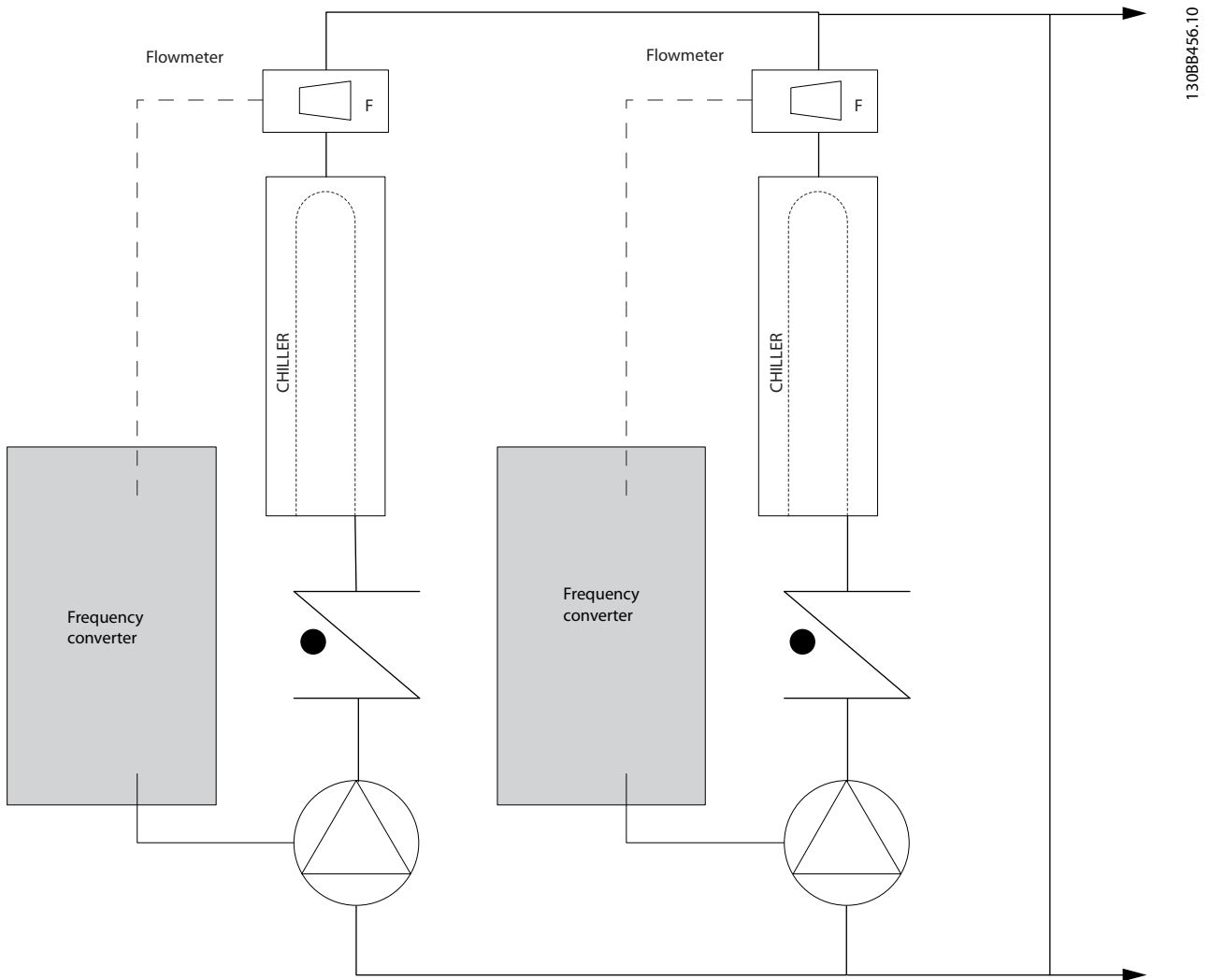
Illustration 3.15 Primary Pumps

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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 hydronically de-couple one 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 realised 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 overpressurisation, 2-way valves can be subjected too.
As the monitored loads are reached, the 2-way valves close down. This increases the differential pressure measured across the load and 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 2-way valve together under design conditions.

NOTICE

When running multiple pumps in parallel, they must run at the same speed to maximise energy savings, either with individual dedicated frequency converters or one frequency converter running multiple pumps in parallel.
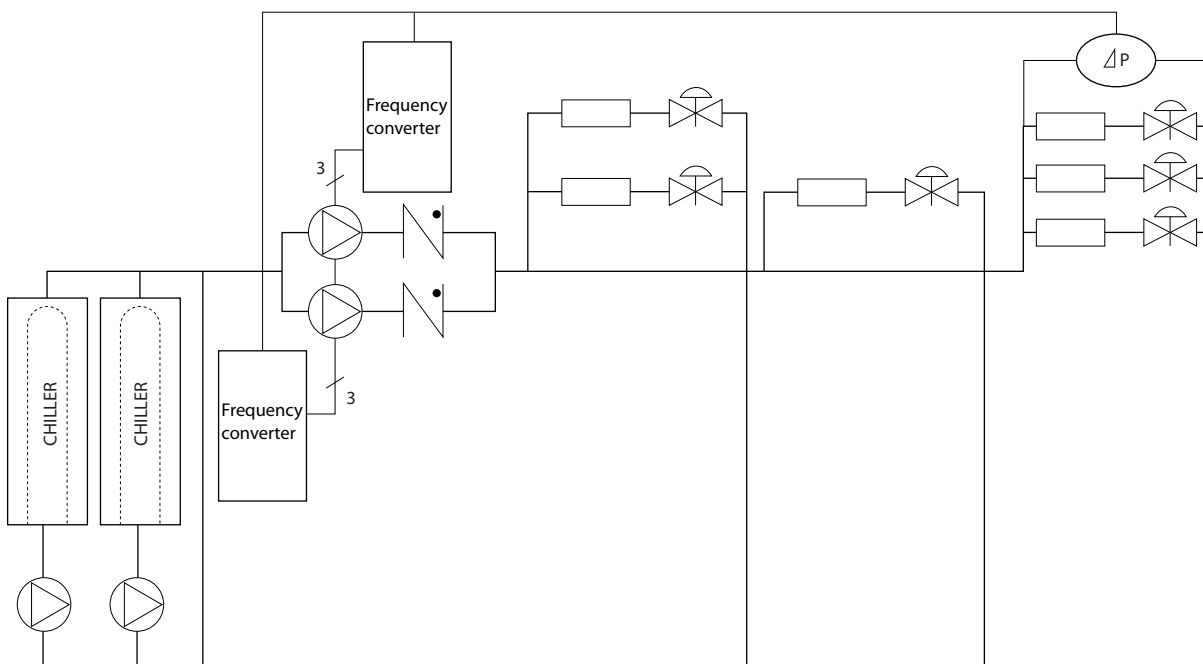
Illustration 3.16 Secondary Pumps

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3.2 Control Structures

Select open or closed loop in *1-00 Configuration Mode.*

3.2.1 Control Structure Open Loop
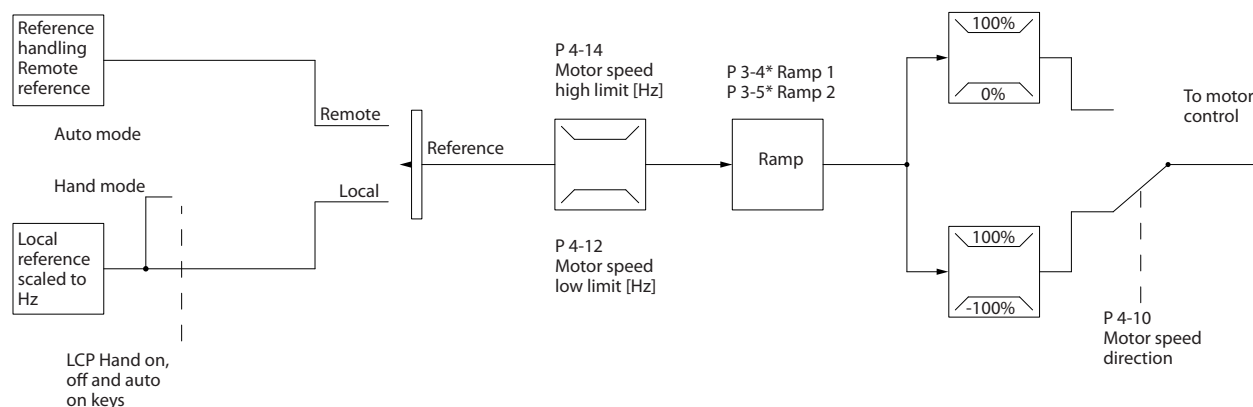
Illustration 3.17 Open Loop Structure

In the configuration shown in *Illustration 3.17*, *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 possibitily for using high-efficient PM motors (permanent magnet motors) in IEC standard enclosure size operated by Danfoss frequency converters.
The commissioning procedure is comparable to the existing one for asynchronous (induction) motors by utilising 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 (e.g. motors).

- Best system efficiency by selecting best components.

- Possible retrofit of existing installations.

- Power range: 45 kW (200 V), 0.37–90 kW (400 V), 90 kW (600 V) for induction motors and 0.37–22 kW (400 V) for PM motors.

Current limitations for PM motors:
- Currently only supported up to 22 kW.

- 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 Rs in the system.

- No stall detection (will be supported from software version 2.80).

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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 *0-40 [Hand on] Key on LCP*, *0-44 [Off/Reset] Key on LCP*, and *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

Local reference forces the configuration mode to open loop, independent on the setting of *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 an integral part of the controlled system. The frequency converter receives a feedback signal from a sensor in the system. It then compares this feedback to a 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 so that the static pressure in a pipe is constant. The desired static pressure value is supplied to the frequency converter as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this to the frequency converter as a feedback signal. If the feedback signal is greater than the setpoint reference, the frequency converter slows down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the frequency converter automatically speeds up to increase the pressure provided by the pump.

Illustration 3.19 Control Structure Closed Loop

While the default values for the frequency converter's closed loop controller often provides satisfactory performance, the control of the system can often be optimised by adjusting some of the closed loop controller's 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*.

Illustration 3.20 Feedback Signal Conversion

3.2.6 Reference Handling

Details for open loop and closed loop operation.
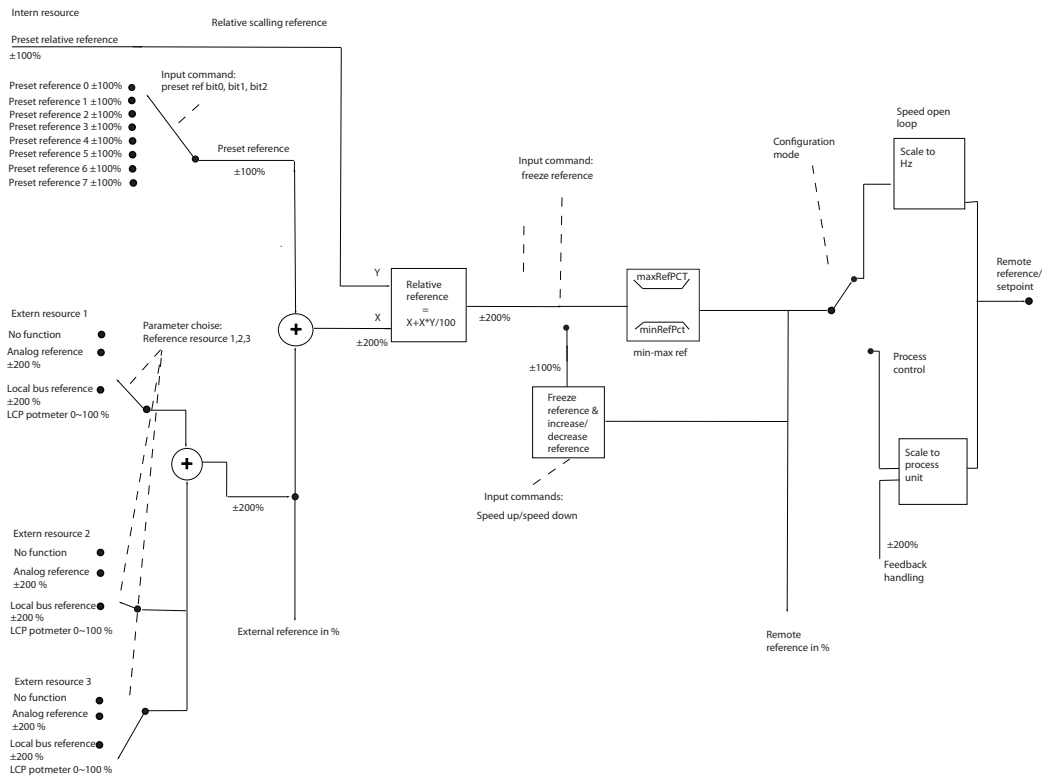
Illustration 3.21 Block Diagram Showing Remote Reference

The remote reference is comprised 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 one of the 3 reference source parameters (*3-15 Reference 1 Source*, *3-16 Reference 2 Source* and *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 by be scaled using *3-14 Preset Relative Reference*.

The scaled reference is calculated as follows:

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

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

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

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3.2.7 Tuning the Drive Closed Loop Controller

Once the frequency converter's closed loop controller has been set up, the performance of the controller should be tested. In many cases, its performance may be acceptable using the default values of *20-93 PI Proportional Gain* and *20-94 PI Integral Time*. However, in some cases it may be helpful to optimise 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 *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. Next, reduce the PI proportional gain until the feedback signal stabilises. Then reduce the proportional gain by 40-60%.

3. Set *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. Next, increase the PI integral time until the feedback signal stabilises. Then increase of 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.

The ambient temperature measured over 24 hours should be at least 5 °C lower than the maximum ambient temperature. If the frequency converter is operated at high ambient temperature, the continuous output current should be decreased.
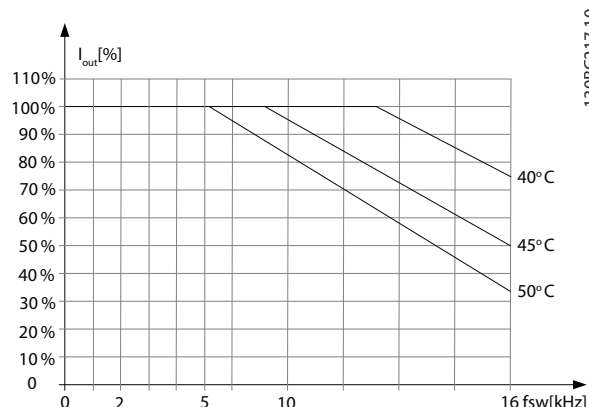
Illustration 3.22 0.25–0.75 kW, 200 V, Enclosure Size H1, IP20
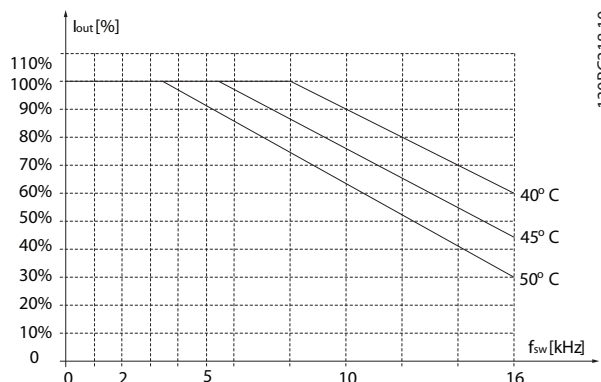
Illustration 3.23 0.37–1.5 kW, 400 V, Enclosure Size H1, IP20
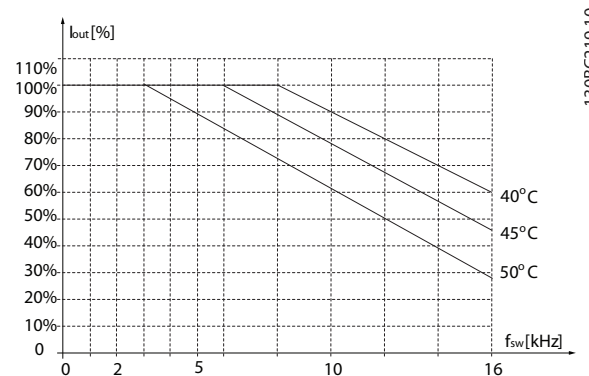
Illustration 3.24 2.2 kW, 200 V, Enclosure Size H2, IP20
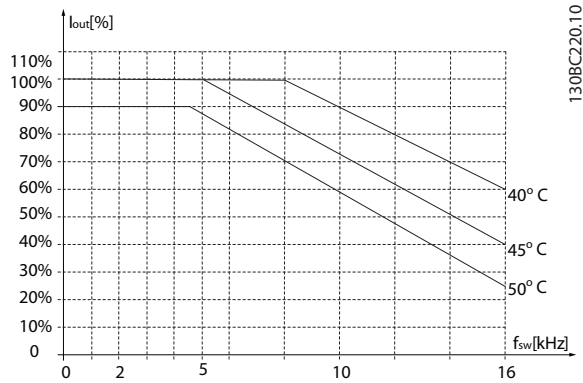
Illustration 3.25 2.2–4.0 kW, 400 V, Enclosure Size H2, IP20
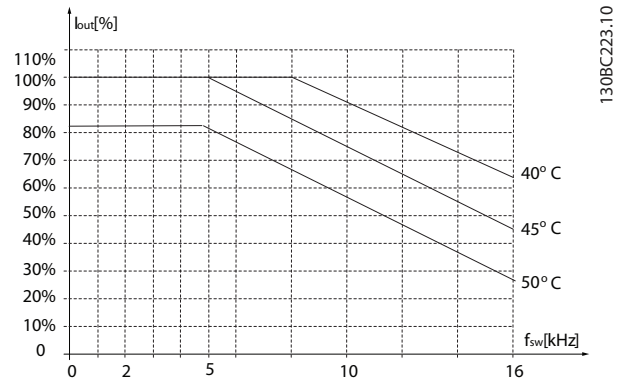
Illustration 3.28 5.5–7.5 kW, 200 V, Enclosure Size H4, IP20
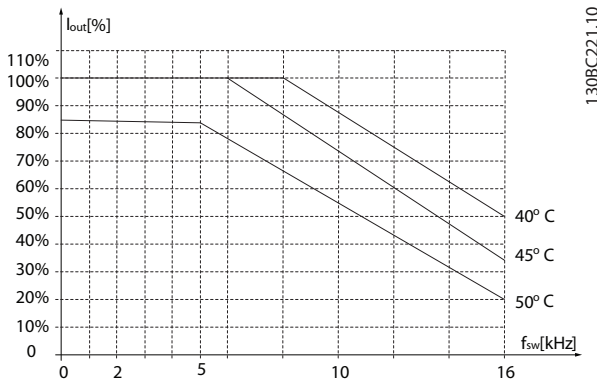
Illustration 3.26 3.7 kW, 200 V, Enclosure Size H3, IP20
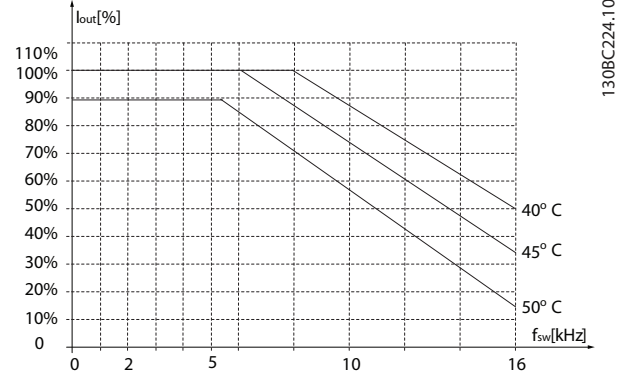
Illustration 3.29 11–15 kW, 400 V, Enclosure Size H4, IP20
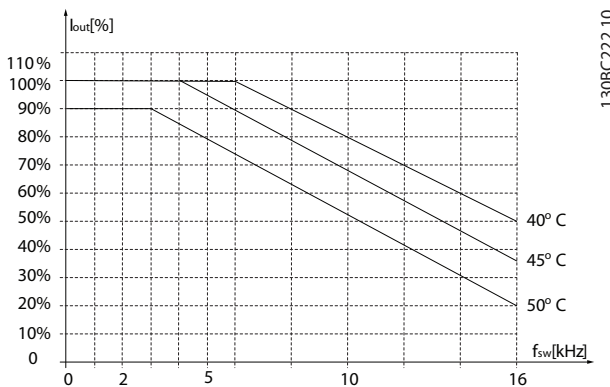
Illustration 3.27 5.5–7.5 kW, 400 V, Enclosure Size H3, IP20
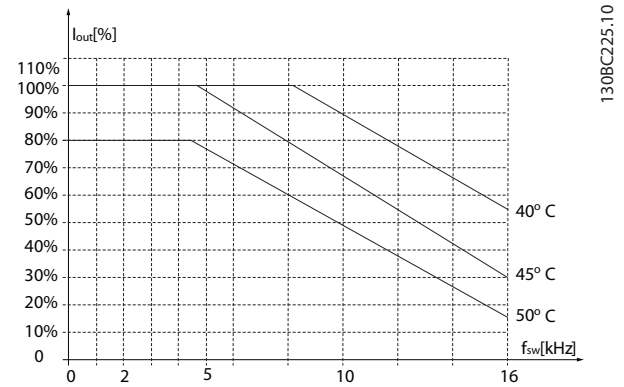
Illustration 3.30 11 kW, 200 V, Enclosure Size H5, IP20

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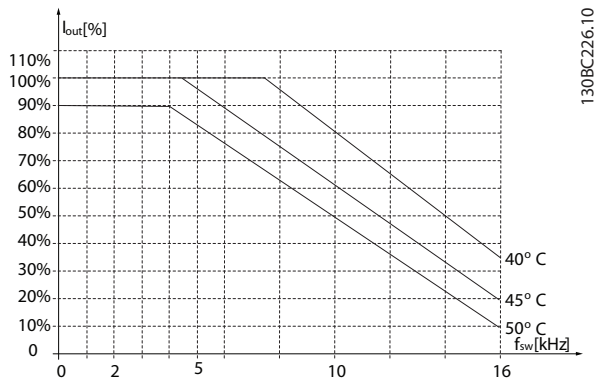
Illustration 3.31 18.5–22 kW, 400 V, Enclosure Size H5, IP20
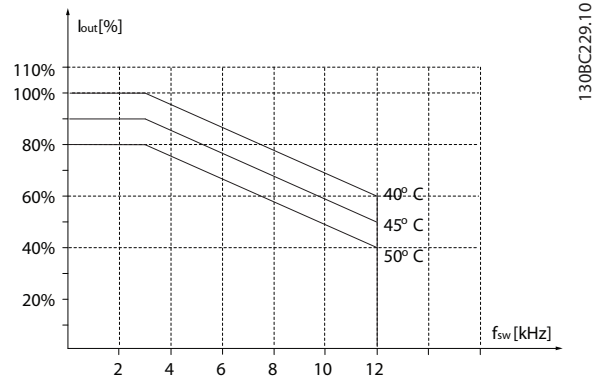
Illustration 3.34 45 kW, 400 V, Enclosure Size H6, IP20
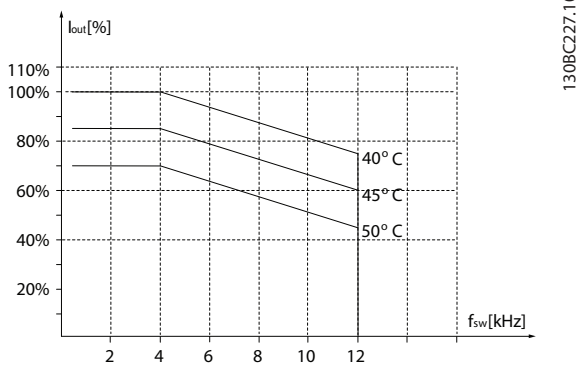
Illustration 3.32 15–18.5 kW, 200 V, Enclosure Size H6, IP20
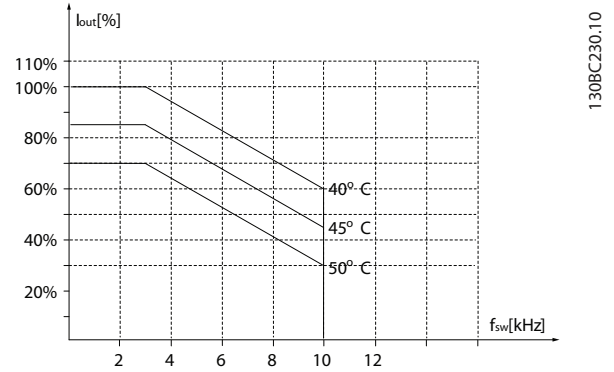
Illustration 3.35 22–30 kW, 600 V, Enclosure Size H6, IP20
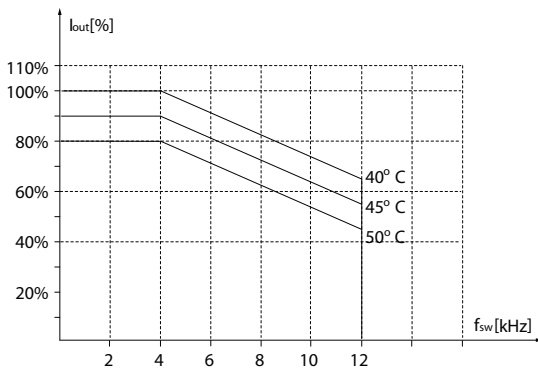
Illustration 3.33 400 V IP20 H6, 30–37 kW
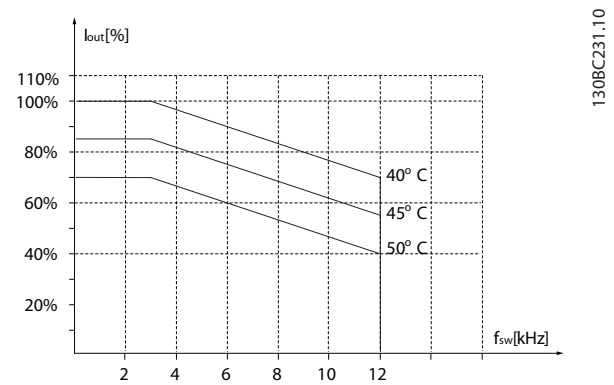
Illustration 3.36 22–30 kW, 200 V, Enclosure Size H7, IP20

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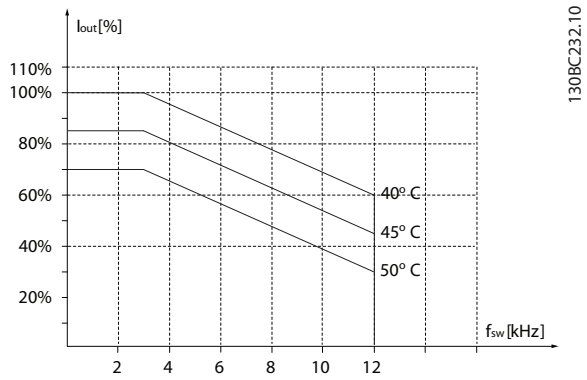
Illustration 3.37 55–75 kW, 400 V, Enclosure Size H7, IP20
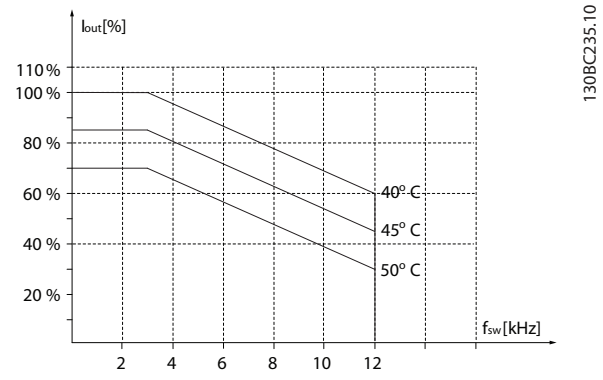
Illustration 3.40 90 kW, 400 V, Enclosure Size H8, IP20
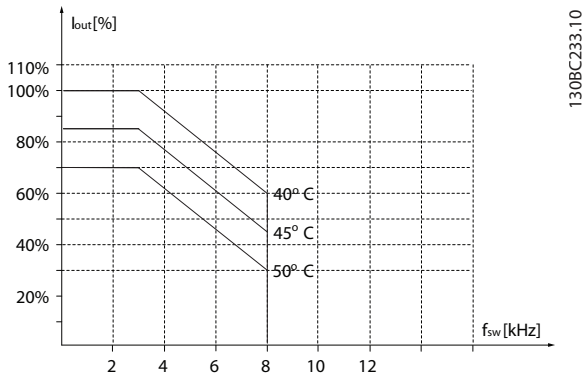
Illustration 3.38 45–55 kW, 600 V, Enclosure Size H7, IP20
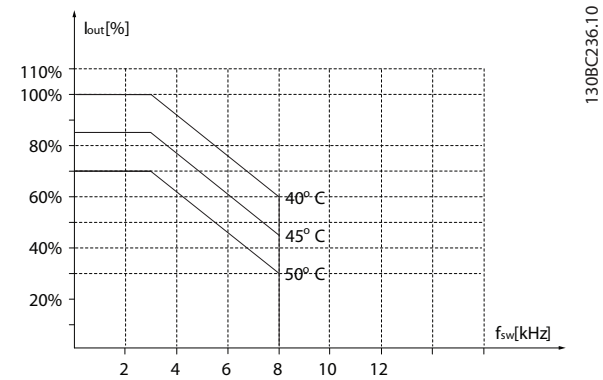
Illustration 3.41 75–90 kW, 600 V, Enclosure Size H8, IP20
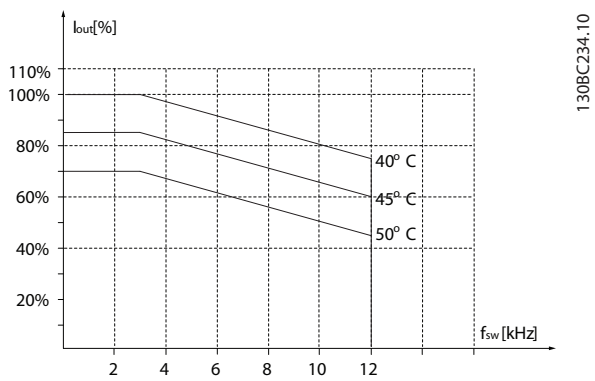
Illustration 3.39 37–45 kW, 200 V, Enclosure Size H8, IP20
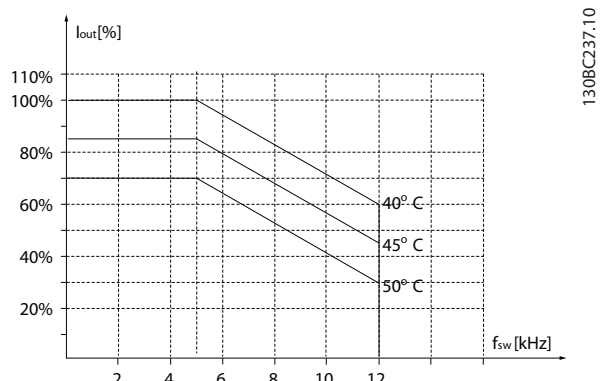
Illustration 3.42 2.2–3 kW, 600 V, Enclosure Size H9, IP20

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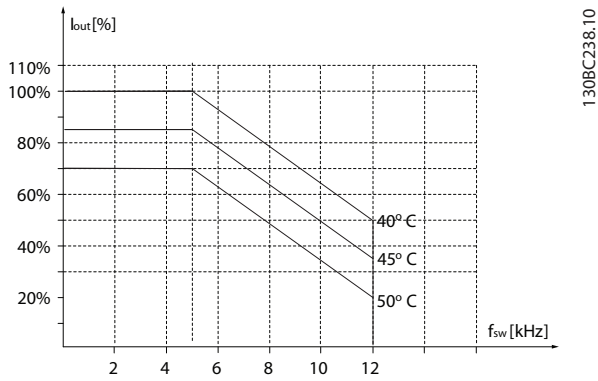
Illustration 3.43 5.5–7.5 kW, 600 V, Enclosure Size H9, IP20

Illustration 3.44 11–15 kW, 600 V, Enclosure Size H10, IP20

Illustration 3.45 0.75–4.0 kW, 400 V, Enclosure Size I2, IP54

Illustration 3.46 5.5–7.5 kW, 400 V, Enclosure Size I3, IP54

Illustration 3.47 11–18.5 kW, 400 V, Enclosure Size I4, IP54
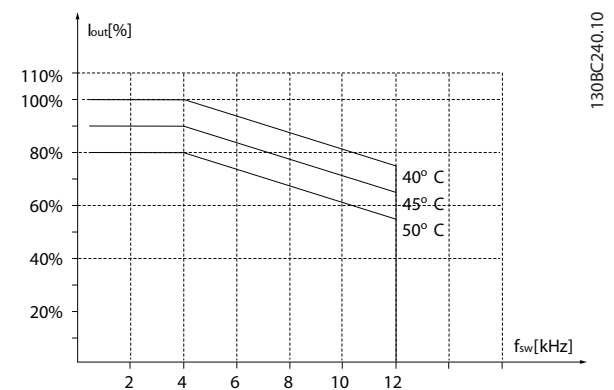
Illustration 3.48 22–30 kW, 400 V, Enclosure Size I6, IP54

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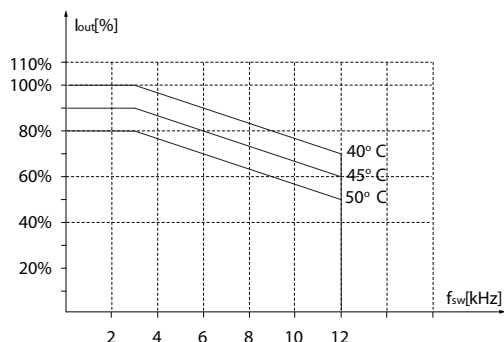
Illustration 3.49 37 kW, 400 V, Enclosure Size I6, IP54
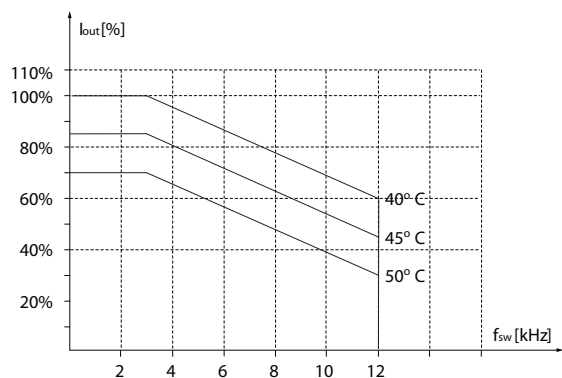
Illustration 3.50 45–55 kW, 400 V, Enclosure Size I7, IP54
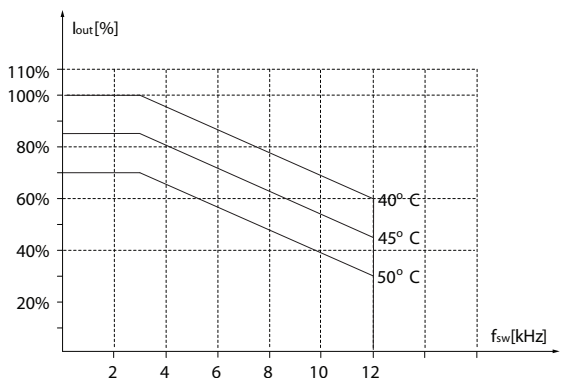
Illustration 3.51 75–90 kW, 400 V, Enclosure Size I8, IP54

If the motor or the equipment driven by the motor - e.g. 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 *14-03 Overmodulation* to *[0] Off*.

- Switching pattern and switching frequency parameter group *14-0* Inverter Switching*.

- *1-64 Resonance Dampening*.

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

1. DC intermediate circuit coils.

2. Integral fan.

3. RFI filter choke.

Enclosure size	Level [dBA]
H1	57.3
H2	59.5
H3	53.8
H4	64
H5	63.7
H6	71.5
H7	67.5 (75 kW 71.5 dB)
H8	73.5
H9	60
H10	62.9
I2	50.2
I3	54
I4	60.8
I6	70
I7	62
I8	65.6

Table 3.3 Typical Values Measured at a Distance of 1 m from the Unit

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

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

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

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

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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 causes chemical processes on the frequency converter components.

Such chemical reactions rapidly affects and damages the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the frequency converter. 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 instal-lation 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, 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 screened motor cable increases the leakage current (see *Illustration 3.52*) because screened cables have higher capacitance to ground than unscreened cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the screen (I_3), there is only a small electro-magnetic field (I_4) from the screened motor cable according to *Illustration 3.52*.

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

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

If the screen is to be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, to convey the screen 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 unscreened cables, some emission requirements are not complied with, although most immunity requirements are observed.

To reduce the interference level from the entire system (unit+installation), make motor and brake cables as short 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.
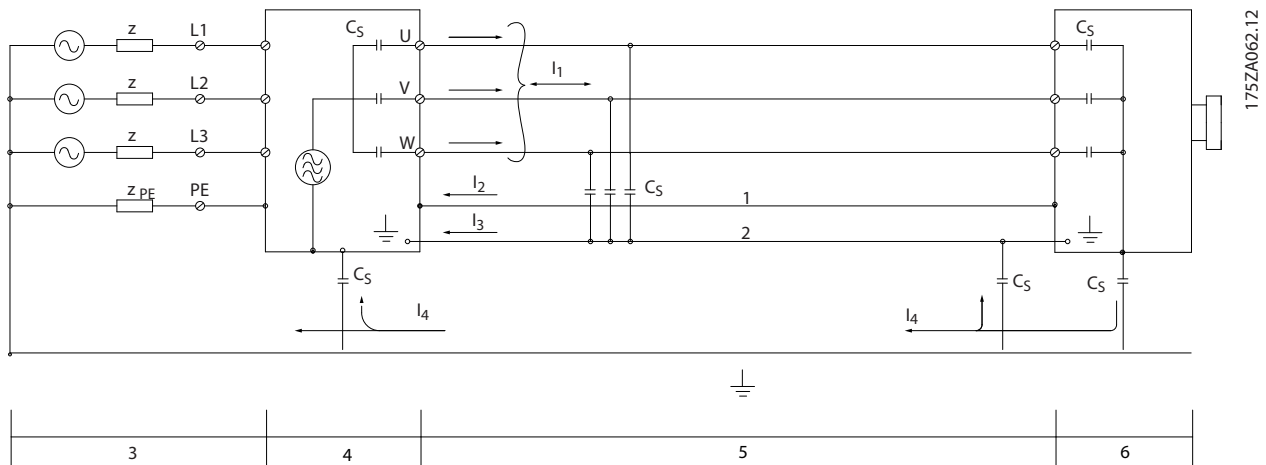
1	Ground wire	2	Screen	3	AC mains supply
4	Frequency converter	5	Screened motor cable	6	Motor

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 first environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Frequency converters installed in the first environment (home and office) with a supply voltage less than 1000 V, which are neither plug-in nor movable and are intended to be installed and commissioned by a professional.	Class A Group 1
C3	Frequency converters installed in the second environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Frequency converters installed in the second environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. 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 screened control cable, a control box with potentiometer, and a screened motor cable.

RFI filter type	Conduct emission. Maximum shielded cable length [m]						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**
H4 RFI filter (EN55011 A1, EN/IEC61800-3 C2)										
0.25–11 kW 3x200–240 V IP20	–	–	25	50	–	20	Yes	Yes	–	No
0.37–22 kW 3x380–480 V IP20	–	–	25	50	–	20	Yes	Yes	–	No
H2 RFI filter (EN 55011 A2, EN/IEC 61800-3 C3)										
15–45 kW 3x200–240 V IP20	25	–	–	–	–	–	No	–	No	–
30–90 kW 3x380–480 V IP20	25	–	–	–	–	–	No	–	No	–
0.75–18.5 kW 3x380–480 V IP54	25	–	–	–	–	–	Yes	–	–	–
22–90 kW 3x380–480 V IP54	25	–	–	–	–	–	No	–	No	–
H3 RFI filter (EN55011 A1/B, EN/IEC 61800-3 C2/C1)										
15–45 kW 3x200–240 V IP20	–	–	50	–	20	–	Yes	–	No	–
30–90 kW 3x380–480 V IP20	–	–	50	–	20	–	Yes	–	No	–
0.75–18.5 kW 3x380–480 V IP54	–	–	25	–	10	–	Yes	–	–	–
22–90 kW 3x380–480 V IP54	–	–	25	–	10	–	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.
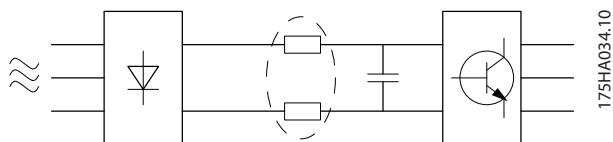
Illustration 3.53 Intermediate Circuit Coils

> ⚠️ *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 intermediate circuit 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 is calculated based on the individual voltage harmonics using this formula:

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

(U_N% of U)

3.4.5 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 total power).
2	IEC/EN 61000-3-12 Equipment 16-75 A and professional equipment as from 1 kW 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, IP20, 200 V (typical)	32.6	16.6	8.0	6.0
Limit for $R_{sce} \geq 120$	40	25	15	10
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 0.25–11 kW, 200 V (typical)	39		41.4	
Limit for $R_{sce} \geq 120$	48		46	

Table 3.10 Harmonic Current 0.25–11 kW, 200 V

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

Table 3.11 Harmonic Current 0.37–22 kW, 380-480 V

3

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

Table 3.12 Harmonic Current 30–90 kW, 380–480 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 2.2–15 kW, IP20, 525–600 V (typical)	48	25	7	5
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 2.2–15 kW, 525–600 V (typical)	55		27	

Table 3.13 Harmonic Current 2.2–15 kW, 525–600 V

	Individual harmonic current I_n/I_1 (%)			
	I_5	I_7	I_{11}	I_{13}
Actual 18.5–90 kW, IP20, 525–600 V (typical)	48.8	24.7	6.3	5
	Harmonic current distortion factor (%)			
	THD		PWHD	
Actual 18.5–90 kW, 525–600 V (typical)	55.7		25.3	

Table 3.14 Harmonic Current 18.5–90 kW, 525–600 V

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

Table 3.15 Harmonic Current 22–90 kW, 400 V

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

Table 3.16 Harmonic Current 0.75–18.5 kW, 380–480 V

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

Table 3.17 Harmonic Current 15–45 kW, 200 V

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

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

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

It is the responsibility of the installer or user of the equipment to ensure, by consultation with the distribution network operator if necessary, that the equipment is connected only to a supply with a short-circuit power S_{sc} greater than or equal to 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 consequently 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 creapage/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, e.g. thermistor must be reinforced/double insulated.

0.25–22 kW
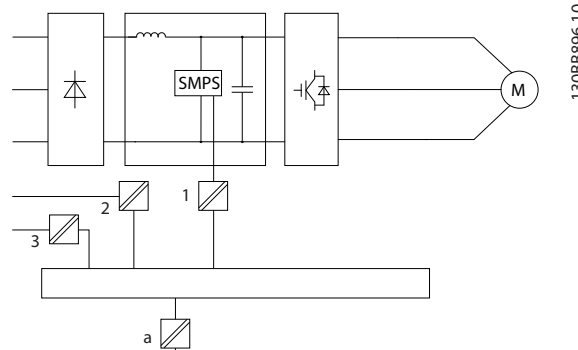
1	Power supply (SMPS)
2	Optocouplers, communication between AOC and BOC
3	Custom relays
a	Control card terminals

Illustration 3.54 Galvanic Isolation

30–90 kW
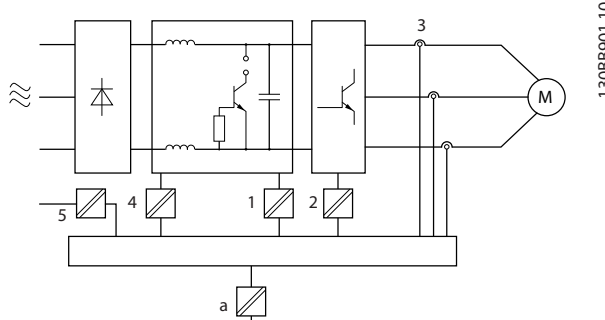
1	Power supply (SMPS) incl. signal isolation of UDC, indicating the intermediate current voltage
2	Gate drive that runs the IGBTs (trigger transformers/opto-couplers)
3	Current transducers
4	Internal soft-charge, RFI and temperature measurement circuits
5	Custom relays
a	Control card terminals

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, contact Danfoss regarding PELV.

3

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 intermediate circuit), as well as 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.

NOTICE

LEAKAGE CURRENT

The earth leakage current from the frequency converter exceeds 3.5 mA. To ensure that the ground cable has a good mechanical connection to the ground connection, the cable cross section must be at least 10 mm² Cu or 16 mm² Al or 2 rated earth wires terminated separately.

⚠️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, another protective measure shall be applied, 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 circuts. 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 permitted 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 5.2.4 Fuses and Circuit Breakers*.

Switching on the output
Switching on the output between the motor and the frequency converter is fully permitted. 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 intermediate circuit 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 moment of inertia is high, the friction is low and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor and the installation.

- Incorrect slip compensation setting (*1-62 Slip Compensation*) may cause higher DC link voltage.

The control unit may attempt to correct the ramp if *2-17 Over-voltage Control* is enabled.
The frequency converter turns off to protect the transistors and the intermediate circuit capacitors when a certain voltage level is reached.

Mains drop-out
During a mains drop-out, the frequency converter keeps running until the intermediate circuit 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*.
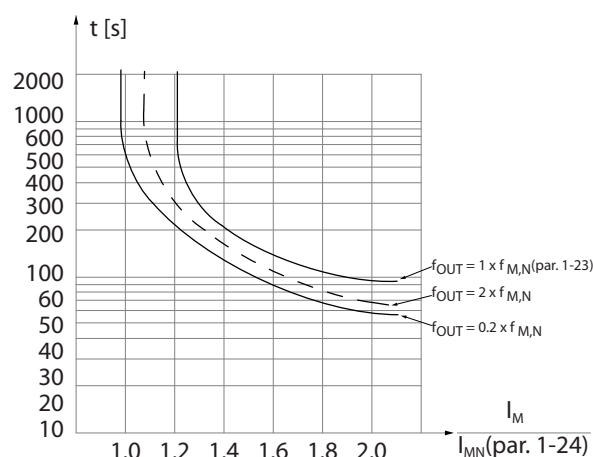
Illustration 3.56 Motor Thermal Protection Characteristic

3

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 are showing 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 cut-out value is >3 kΩ.

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).
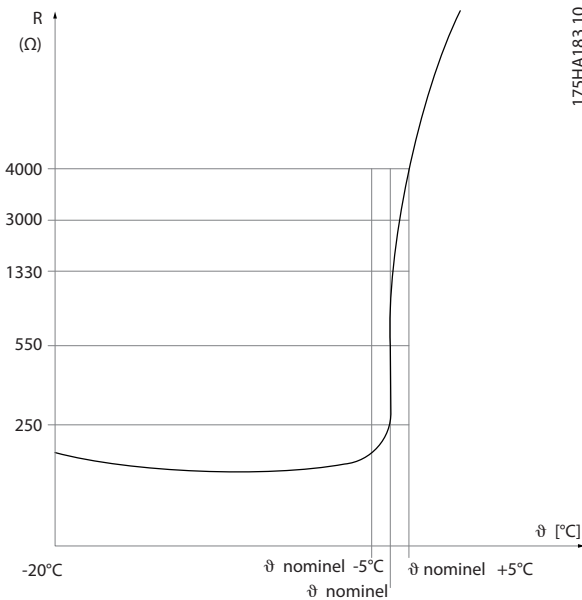
Illustration 3.57 Trip due to High Motor Temperature

Using a digital input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[6] Digital Input 29*
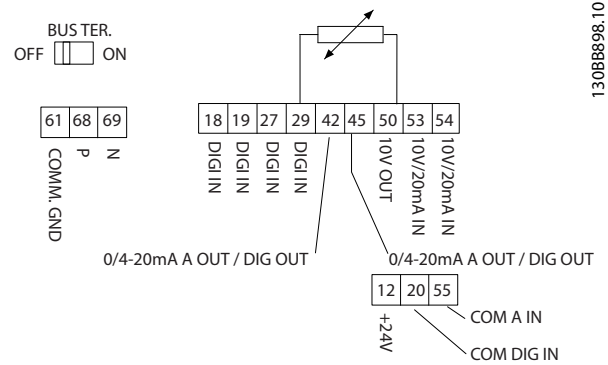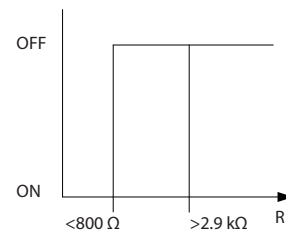
Illustration 3.58 Digital Input/10 V Power Supply

Using an analog input and 10 V as power supply:
Example: The frequency converter trips when the motor temperature is too high.
Parameter set-up:
Set *1-90 Motor Thermal Protection* to *[2] Thermistor Trip*
Set *1-93 Thermistor Source* to *[1] Analog Input 53*

NOTICE

Do not set *Analog Input 54* as reference source.
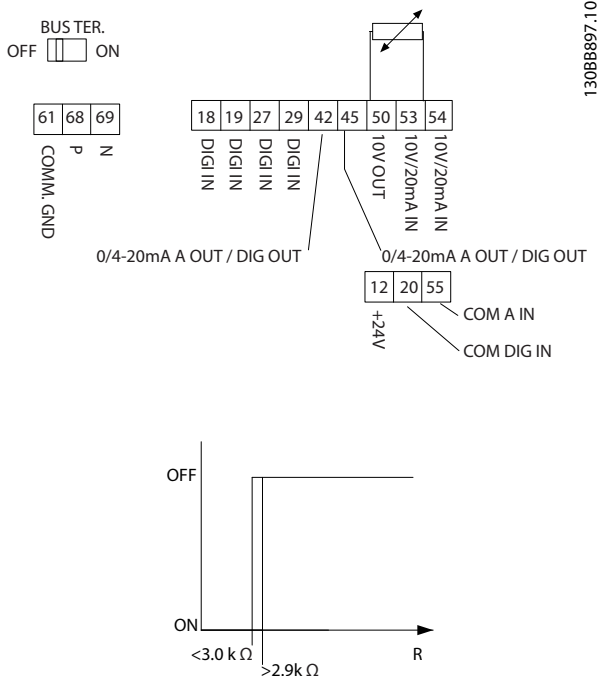
Illustration 3.59 Analog Input/10 V Power Supply

Input	Supply voltage [V]	Threshold cut-out 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 *1-90 Motor Thermal Protection*.

4 Selection and Ordering

4.1 Type Code

A type code defines a specific configuration of the 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	

130BB899.10

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 (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.
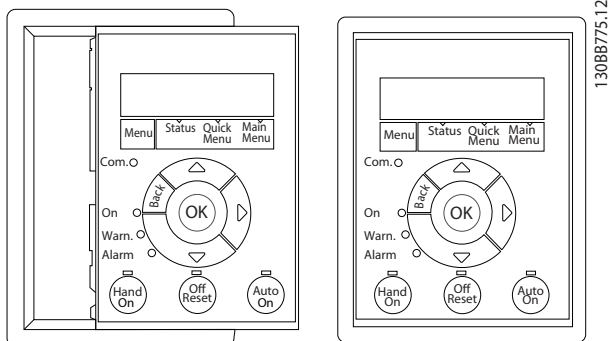
Illustration 4.2 Fit Gasket

Step 2
Place LCP on panel, see dimensions of hole on
Illustration 4.3.
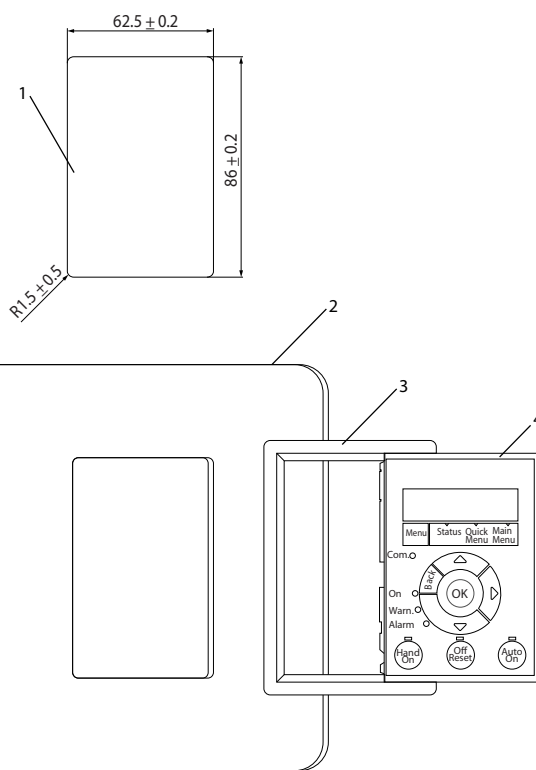
Illustration 4.3 Place LCP on Panel (Front-mounted)

Step 3
Place bracket on back of the LCP, then slide down.
Tighten screws and connect cable female side to LCP.
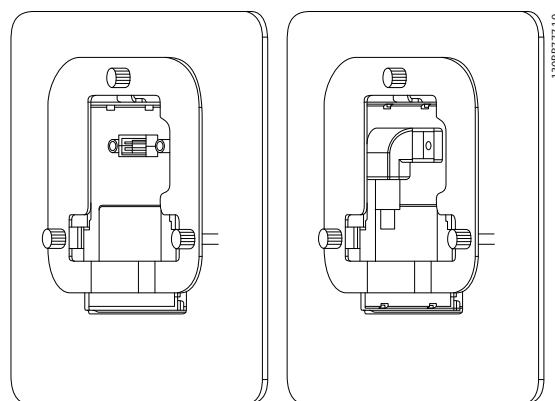
Illustration 4.4 Place Bracket on LCP

Step 4

Connect cable to frequency converter.
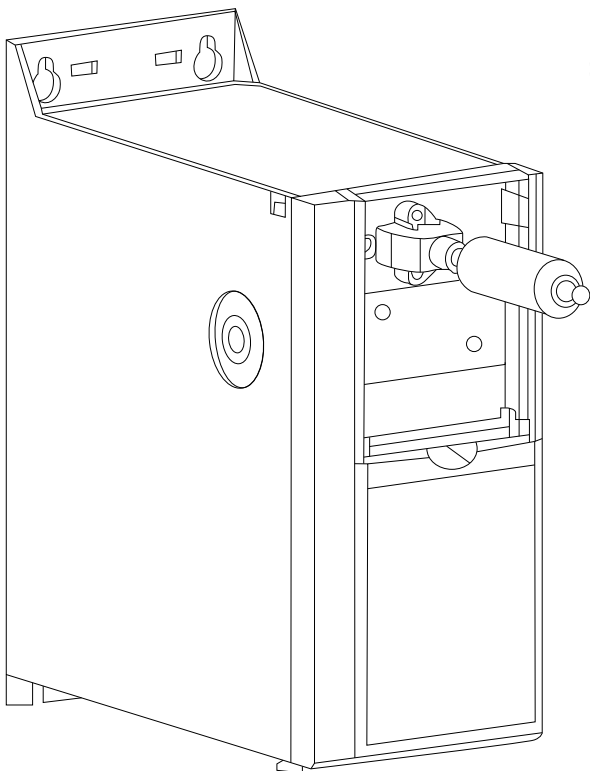
Illustration 4.5 Connect Cable

NOTICE

Use the provided thread-cutting screws to fasten the connector to the frequency converter. The tightening torque is 1.3 Nm.

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.
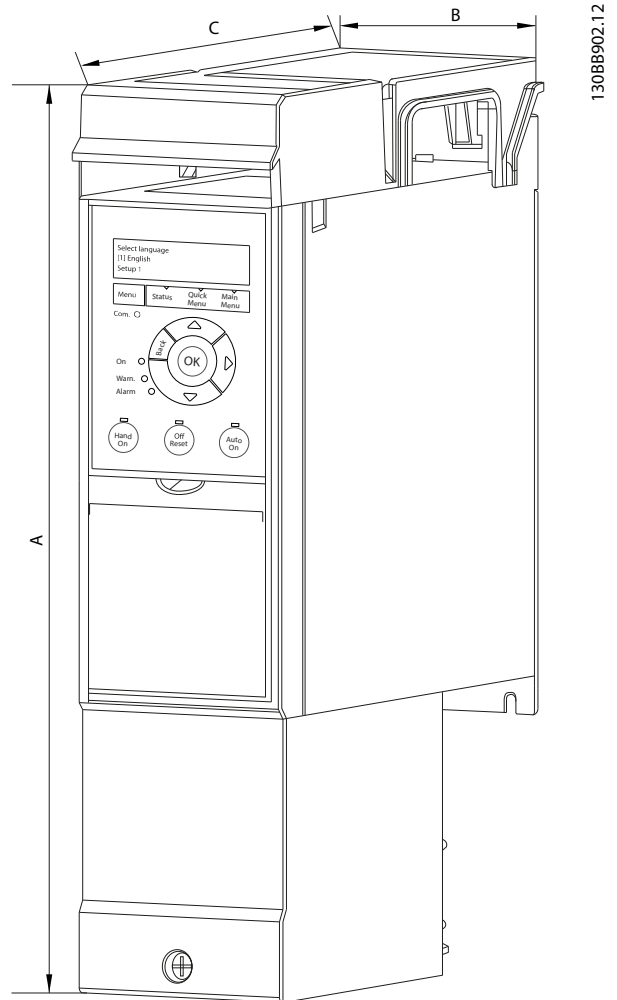
Illustration 4.6 H1–H5 (See Data in *Table 4.4*)
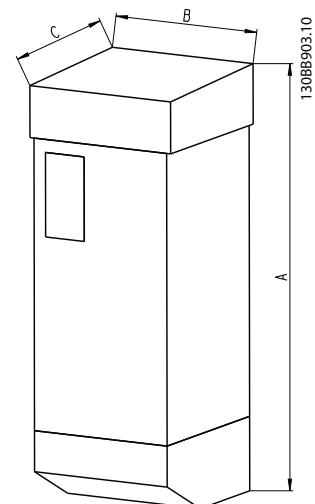
Illustration 4.7 Dimensions (See Data in *Table 4.4*)

Frame	IP class	Power			Height [mm] A	Width [mm] B	Depth [mm] C	IP21 kit ordering number	NEMA Type 1 kit ordering number
		3x200-240 V [kW]	3x380-480 V [kW]	3x525-600 V [kW]					
H1	IP20	0.25-1.5	0.37-1.5		293	81	173	132B0212	132B0222
H2	IP20	2.2	2.2-4		322	96	195	132B0213	132B0223
H3	IP20	3.7	5.5-7.5		346	106	210	132B0214	132B0224
H4	IP20	5.5-7.5	11-15		374	141	245	132B0215	132B0225
H5	IP20	11	18.5-22		418	161	260	132B0216	132B0226
H6	IP20	15-18.5	30-45	18.5-30	663	260	242	132B0217	132B0217
H7	IP20	22-30	55-75	37-55	807	329	335	132B0218	132B0218
H8	IP20	37-45	90	75-90	943	390	335	132B0219	132B0219
H9	IP20			2.2-7.5	372	130	205	132B0220	132B0220
H10	IP20			11-15	475	165	249	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.
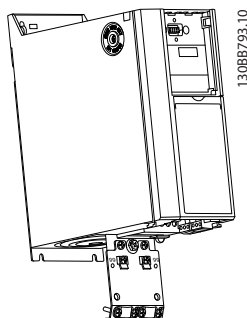
Illustration 4.8 Decoupling Plate

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)	0.37–1.5 (0.5–2)	–	132B0202
H2	IP20	2.2 (3)	2.2–4 (3–5.4)	–	132B0202
H3	IP20	3.7 (5)	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 [kW(hp)]	H2 [kW(hp)]	H3 [kW(hp)]	H4 [kW(hp)]	H5 [kW(hp)]	H6 [kW(hp)]		H7 [kW(hp)]		H8 [kW(hp)]
	T2 (200–240 V AC)	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)	0.37–1.5 (0.5–2)	2.2–4 (3–5.4)	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)
Description											
LCP[1]						132B0200					
LCP panel mounting kit IP55 including 3 m cable						132B0201					
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]	Frequency converter input current continuous [A]	Default switching frequency [kHz]	THID level [%]	Order number filter IP00	Code number filter IP20
22	41.5	4	4	130B1397	130B1239
30	57	4	3	130B1398	130B1240
37	70	4	3	130B1442	130B1247
45	84	3	3	130B1442	130B1247
55	103	3	5	130B1444	130B1249
75	140	3	4	130B1445	130B1250
90	176	3	4	130B1445	130B1250

Table 4.7 AHF Filters (5% Current Distortion)

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

Table 4.8 AHF Filters (10% Current Distortion)

4

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

Table 4.9 AHF Filters (5% Current Distortion)

3x440–480 V 60 Hz					
Power [kW]	**Frequency converter input current continuous [A]**	**Default switching frequency [kHz]**	**THID level [%]**	**Order number filter IP00**	**Code number filter IP20**
22	34.6	4	6	130B1775	130B1487
30	49	4	8	130B1776	130B1488
37	61	4	7	130B1777	130B1491
45	73	3	9	130B1778	130B1492
55	89	3	8	130B1779	130B1493
75	121	3	9	130B1780	130B1494
90	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 screened cable length of 50 m according to EN/IEC 61800-3 C2 (EN 55011 A1), or 20 m according to EN/IEC 61800-3 C1(EN 55011 B) can be achieved.

Power [kW] Size 380–480 V	Type	A	B	C	D	E	F	G	H	I	J	K	L1	Torque [Nm]	Weight [kg]	Ordering Number
0.37–2.2	FN3258-7-45	190	40	70	160	180	20	4.5	1	10.6	M5	20	31	0.7–0.8	0.5	132B0244
3–7.5	FN3258-16-45	250	45	70	220	235	25	4.5	1	10.6	M5	22.5	31	0.7–0.8	0.8	132B0245
11–15	FN3258-30-47	270	50	85	240	255	30	5.4	1	10.6	M5	25	40	1.9–2.2	1.2	132B0246
18.5–22	FN3258-42-47	310	50	85	280	295	30	5.4	1	10.6	M5	25	40	1.9–2.2	1.4	132B0247

Table 4.11 RFI Filters - Details
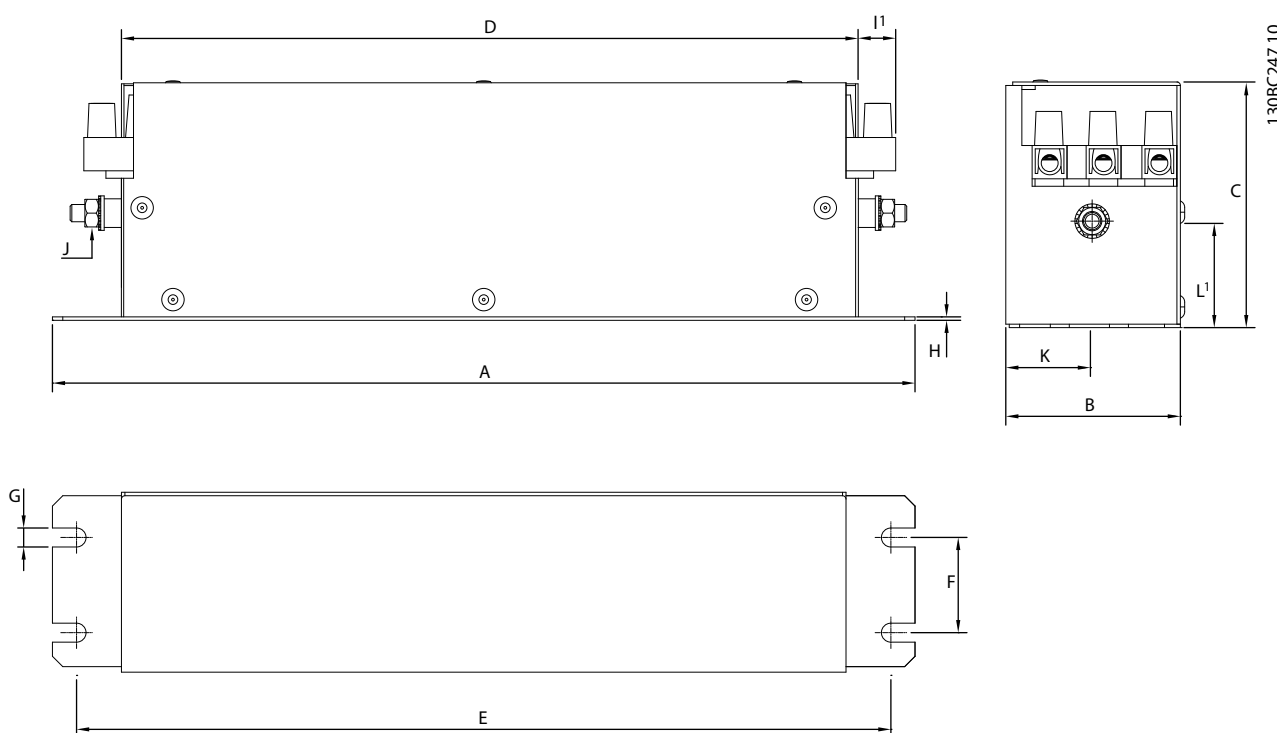
Illustration 4.9 RFI Filter - Dimensions

5 Installation

5.1 Mechanical Dimensions

5.1.1 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 5.1 Clearance Required for Cooling

NOTICE

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

5.1.2 Frequency Converter Dimensions

Enclosure		Power [kW(hp)]			Height [mm(in)]			Width [mm(in)]		Depth [mm(in)]	Mounting hole [mm(in)]			Max. weight
Size	IP class	3x200–240 V	3x380–480 V	3x525–600 V	A	A¹⁾	a	B	b	C	d	e	f	kg(lb)
H1	IP20	0.25–1.5 (0.33–2)	0.37–1.5 (0.5–2)	–	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)	2.2–4.0 (3–5)	–	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)	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 (3–10)	269 (10.6)	374 (14.7)	257 (10.1)	130 (5.1)	110 (4.3)	205 (8)	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. When installing in an application, it is necessary to allow space above and below the units for cooling. The amount of space for free air passage is listed in Table 5.1.

Table 5.3 Dimensions, Enclosure Sizes H1–H10

5

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[1]	a	B	b	C	d	e	f	kg(lb)
I2	IP54	–	0.75–4.0 (1–5)	–	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)	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. When installing in an application it is necessary to allow space above and below the units for cooling. The amount of space for free air passage is listed in *Table 5.1*.

Table 5.4 Dimensions, Enclosure Sizes I2–I8

5.1.3 Shipping Dimensions

Enclosure size Mains voltage	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	I2	I3	I4	I6	I7	I8
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)								
380–480 V AC [kW(hp)]	0.37–1.5 (0.5–2)	2.2–4 (3–5.4)	5.5–7.5 (7.5–10)	11–15 (15–20)	18.5–22 (25–30)	30–45 (40–60)	55–75 (73–100)	90 (125)			0.75–4 (1–5)	5.5–7.5 (7.5–10)	11–18.5 (15–25)	22–37 (30–50)	45–55 (60–70)	75–90 (100–125)
3x525–600 V AC) [kW(hp)]					18.5–30 (30–40)	37–55 (60–70)	75–90 (100–125)	2.2–7.5 (3.0–10)	11–15 (15–20)							
IP protection rating	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)	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)	28.3 (62.4)	41.5 (91.5)	60.5 (133.8)
Shipping dimensions																
Height [mm(in)]	255 (10.0)	300 (11.8)	330 (13.0)	380 (15.0)	420 (16.5)	850 (33.5)	850 (33.5)	850 (33.5)	380 (15.0)	500 (19.7)	440 (17.3)	470 (18.5)	588 (23.2)	850 (33.5)	850 (33.5)	950 (37.4)
Width [mm(in)]	154 (6.1)	170 (6.7)	188 (7.4)	250 (9.8)	290 (11.4)	370 (14.6)	410 (16.1)	490 (19.3)	290 (11.4)	330 (13.0)	200 (7.9)	240 (9.4)	285 (11.2)	370 (14.6)	410 (16.1)	490 (19.3)
Depth [mm(in)]	235 (9.3)	260 (10.2)	282 (11.1)	375 (14.8)	375 (14.8)	460 (18.1)	540 (21.3)	490 (19.3)	200 (7.9)	350 (13.8)	300 (11.8)	330 (13.0)	385 (15.2)	460 (18.1)	540 (21.3)	490 (19.3)

Table 5.5 Shipping Dimensions

5.1.4 Field Mounting

For field mounting, IP21/NEMA Type 1 kits are recommended.

5.2 Electrical Installation

5.2.1 Electrical Wiring
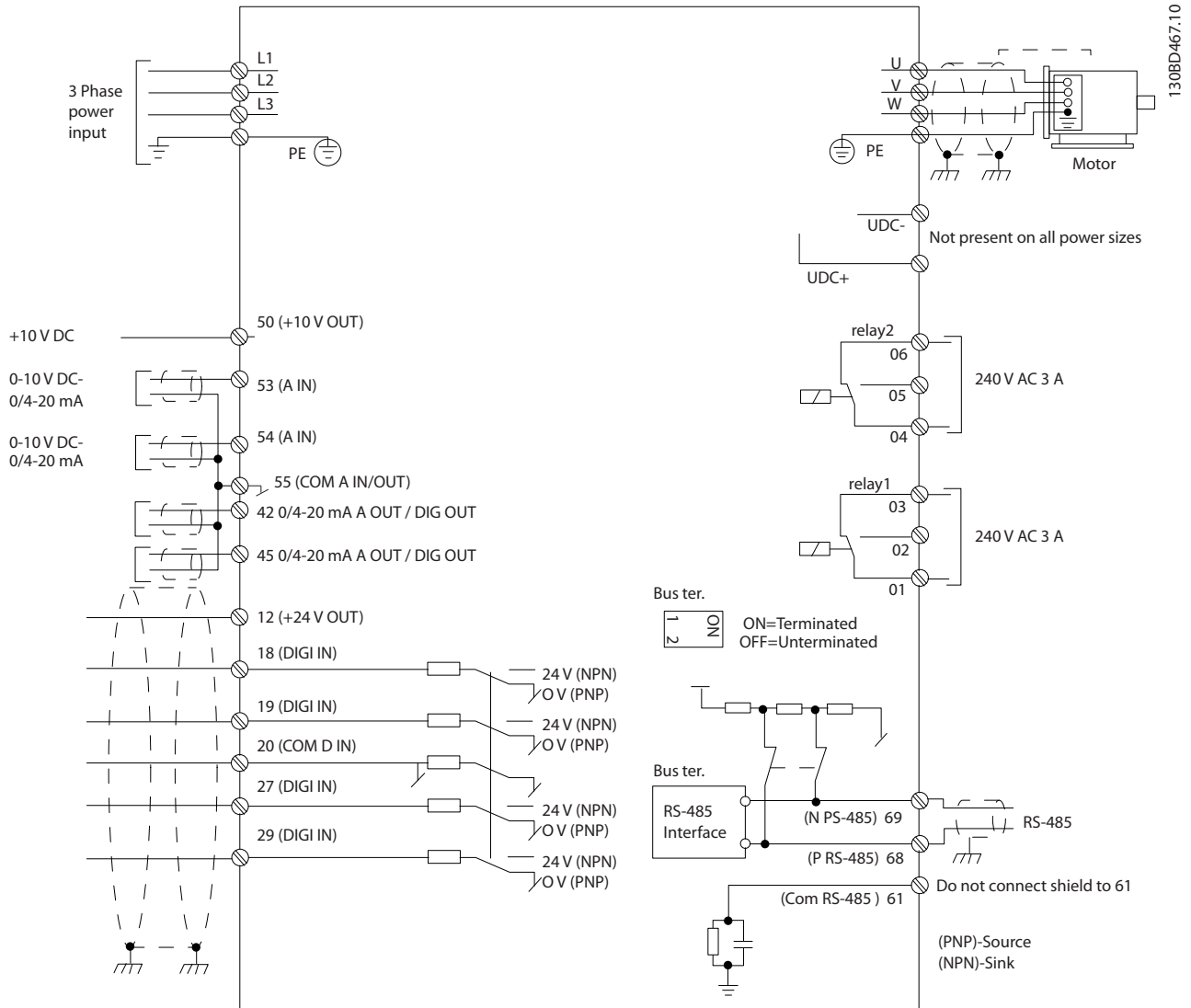
Illustration 5.1 Basic Wiring Schematic Drawing

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 (3–125 HP)
IP54, 380–480 V, 22–90 kW (30–125 HP)

5.2.2 Electrical Installation in General

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.

Power [kW(hp)]				Torque [Nm(in-lb]					
Enclosure size	IP class	3x200–240 V	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
H1	IP20	0.25–1.5 (0.33–2)	0.37–1.5 (0.5–2)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
H2	IP20	2.2 (3)	2.2–4.0 (3–5)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
H3	IP20	3.7 (5)	5.5–7.5 (7.5–10)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
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)	0.8 (7)	0.5 (4)
H5	IP20	11 (15)	18.5–22 (25–30)	1.2 (11)	1.2 (11)	1.2 (11)	0.5 (4)	0.8 (7)	0.5 (4)
H6	IP20	15–18.5 (20–25)	30–45 (40–60)	4.5 (40)	4.5 (40)	–	0.5 (4)	3 (27)	0.5 (4)
H7	IP20	22–30 (30–40)	55 (70)	10 (89)	10 (89)	–	0.5 (4)	3 (27)	0.5 (4)
H7	IP20	–	75 (100)	14 (124)	14 (124)	–	0.5 (4)	3 (27)	0.5 (4)
H8	IP20	37–45 (50–60)	90 (125)	24 (212)[1]	24 (212)[1]	–	0.5 (4)	3 (27)	0.5 (4)

Table 5.6 Tightening Torques for Enclosure Sizes H1–H8, 3x200–240 V & 3x380–480 V

Power [kW(hp)]			Torque [Nm(in-lb]					
Enclosure size	IP class	3x380–480 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
I2	IP54	0.75–4.0 (1–5)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
I3	IP54	5.5–7.5 (7.5–10)	0.8 (7)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
I4	IP54	11–18.5 (15–25)	1.4 (12)	0.8 (7)	0.8 (7)	0.5 (4)	0.8 (7)	0.5 (4)
I6	IP54	22–37 (30–50)	4.5 (40)	4.5 (40)	–	0.5 (4)	3 (27)	0.6 (5)
I7	IP54	45–55 (60–70)	10 (89)	10 (89)	–	0.5 (4)	3 (27)	0.6 (5)
I8	IP54	75–90 (100–125)	14 (124)/24 (212)[2]	14 (124)/24 (212)[2]	–	0.5 (4)	3 (27)	0.6 (5)

Table 5.7 Tightening Torques for Enclosure Sizes I1–I8

Power [kW]			Torque [Nm(in-lb)]					
Enclosure size	IP class	3x525–600 V	Mains	Motor	DC connection	Control terminals	Ground	Relay
H9	IP20	2.2–7.5 (3–10)	1.8 (16)	1.8 (16)	not recommended	0.5 (4)	3 (27)	0.6 (5)
H10	IP20	11–15 (15–20)	1.8 (16)	1.8 (16)	not recommended	0.5 (4)	3 (27)	0.6 (5)
H6	IP20	18.5–30 (25–40)	4.5 (40)	4.5 (40)	–	0.5 (4)	3 (27)	0.5 (4)
H7	IP20	37–55 (50–70)	10 (89)	10 (89)	–	0.5 (4)	3 (27)	0.5 (4)
H8	IP20	75–90 (100–125)	14 (124)/24 (212)[2]	14 (124)/24 (212)[2]	–	0.5 (4)	3 (27)	0.5 (4)

Table 5.8 Tightening Torques for Enclosure Sizes H6–H10, 3x525–600 V

1) Cable dimensions >95 mm^2

2) Cable dimensions ≤95 mm^2

5.2.3 Connecting to Mains and Motor

The frequency converter is designed to operate all standard 3-phase asynchronous motors. For maximum cross-section on cables, see *chapter 8.2 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 De-coupling Plate Mounting Instruction*.

- Also see *chapter 5.2.5 EMC-compliant Electrical Installation*.

1. Mount the ground cables to the ground terminal.

2. Connect the motor to terminals U, V, and W, and tighten the screws according to the torques specified in *chapter 5.2.2 Electrical Installation in General*.

3. Connect the mains supply to terminals L1, L2, and L3, and tighten the screws according to the torques specified in *chapter 5.2.2 Electrical Installation in General*.

Relays and terminals on enclosure sizes H1-H5
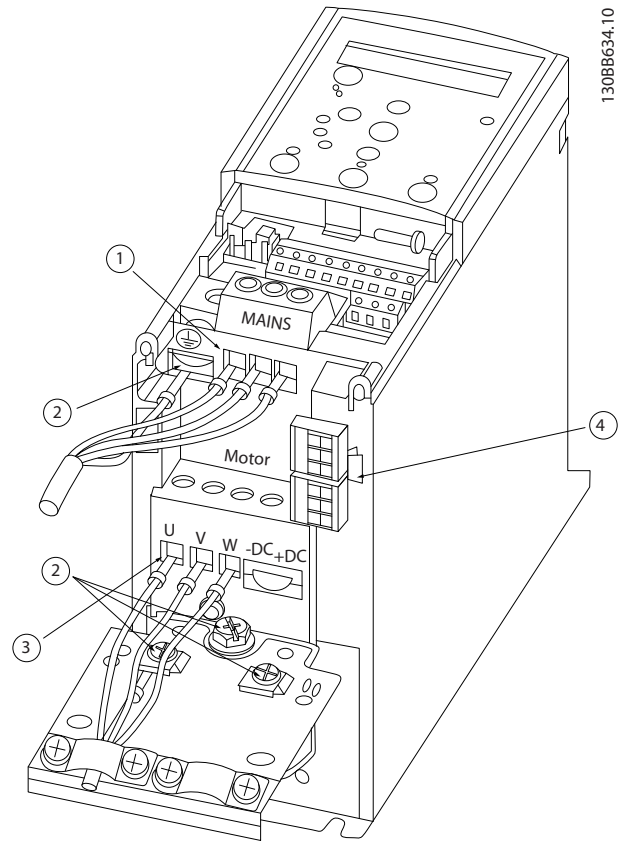
1	Mains
2	Ground
3	Motor
4	Relays

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)

Relays and terminals on enclosure size H6

Relays and terminals on enclosure size H7
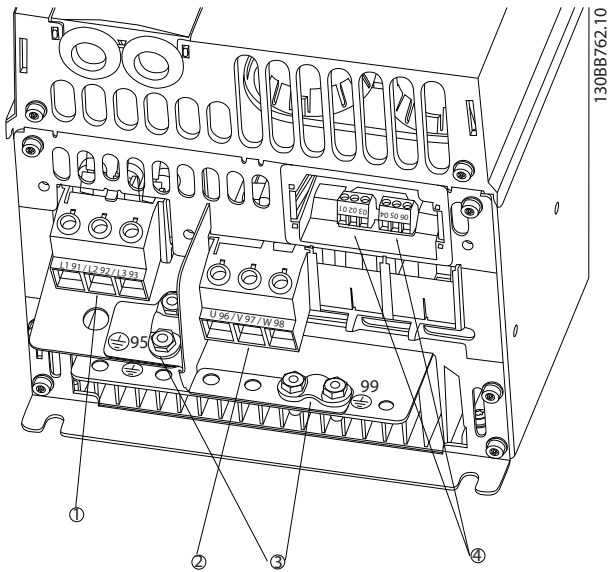
1	Mains
2	Motor
3	Ground
4	Relays

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)
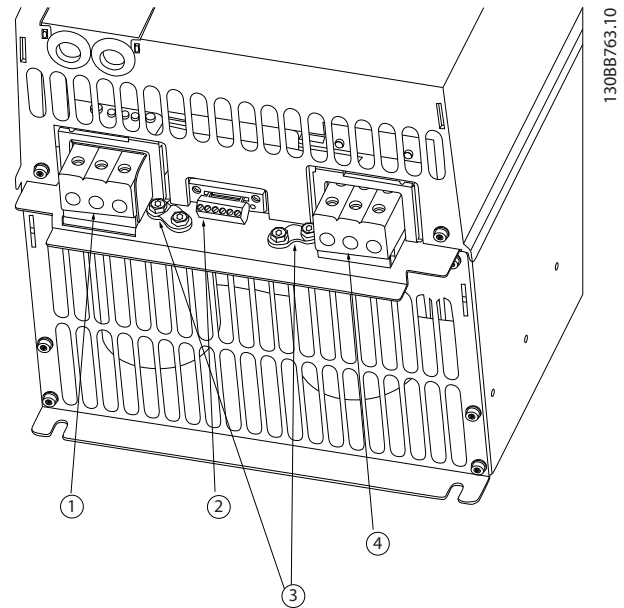
1	Mains
2	Relays
3	Ground
4	Motor

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
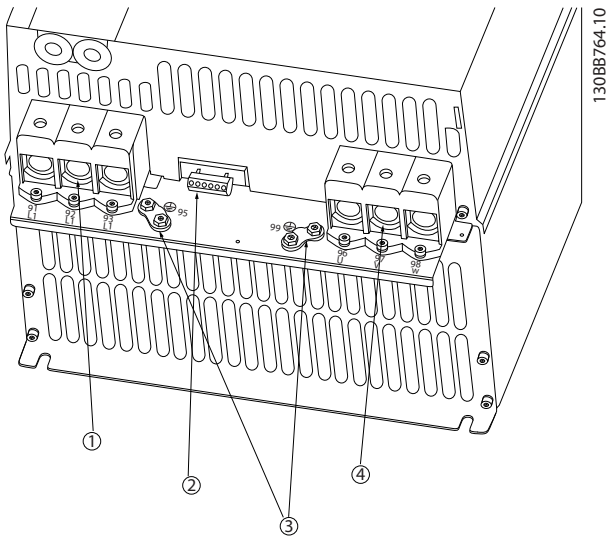
1	Mains
2	Relays
3	Ground
4	Motor

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)

Connecting to mains and motor for enclosure size H9
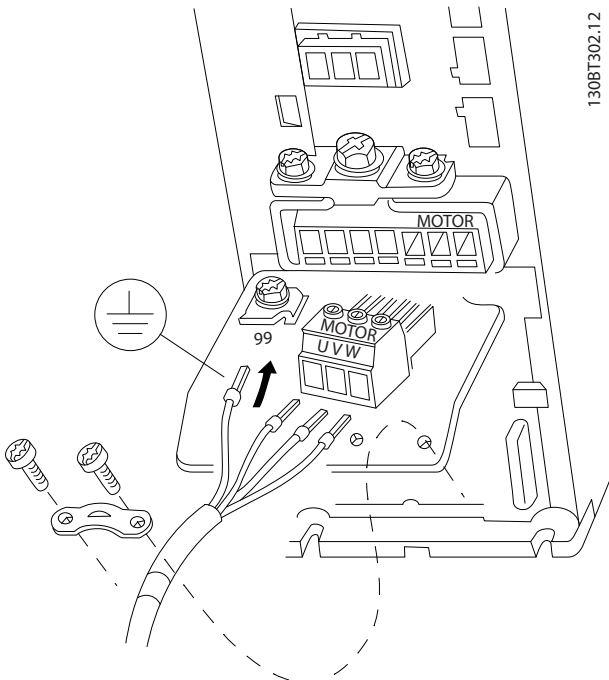
Illustration 5.6 Connecting the Frequency Converter to the Motor, Enclosure Size H9
IP20, 600 V, 2.2–7.5 kW (3–10 hp)

Complete the following steps to connect the mains cables for enclosure size H9. Use the tightening torques described in *chapter 5.2.2 Electrical Installation in General*.

1. Slide the mounting plate into place and tighten the 2 screws, as shown in *Illustration 5.7*.
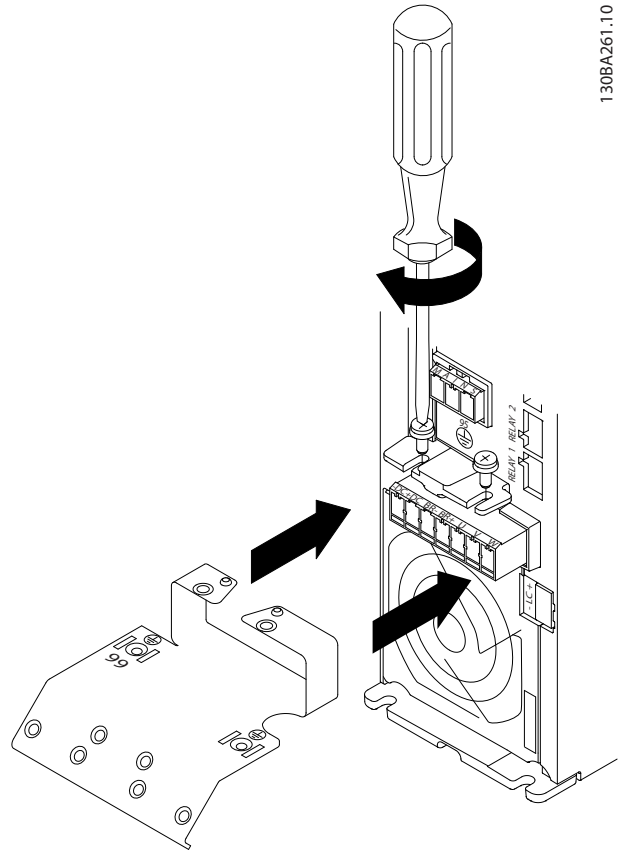
Illustration 5.7 Mounting the Mounting Plate

2. Mount the ground cable, as shown in *Illustration 5.8*.
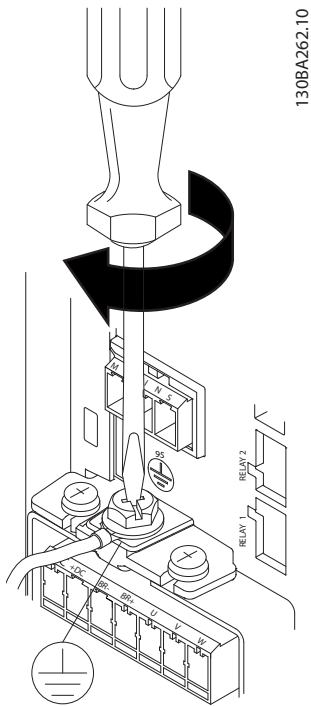
Illustration 5.8 Mounting the Ground Cable

3. Insert the mains cables to the mains plug and tighten the screws, as shown in *Illustration 5.9*.
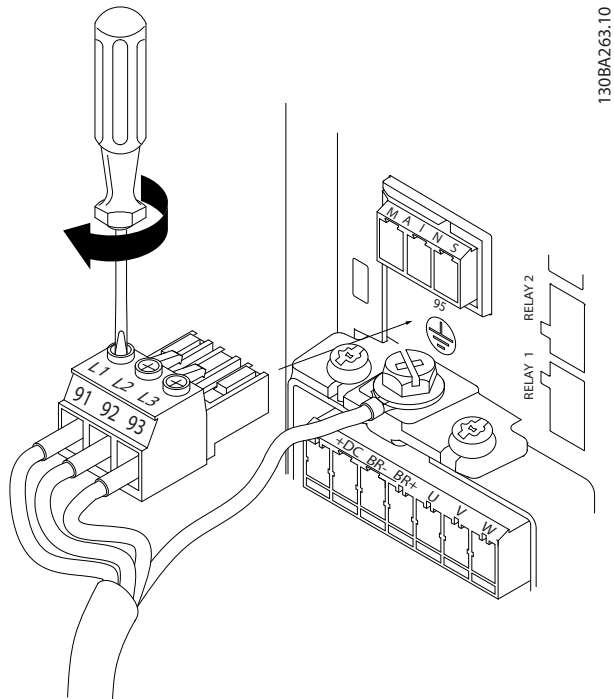
Illustration 5.9 Mounting the Mains Plug

4. Mount the support bracket across the mains cables and tighten the screws, as shown in *Illustration 5.10*.
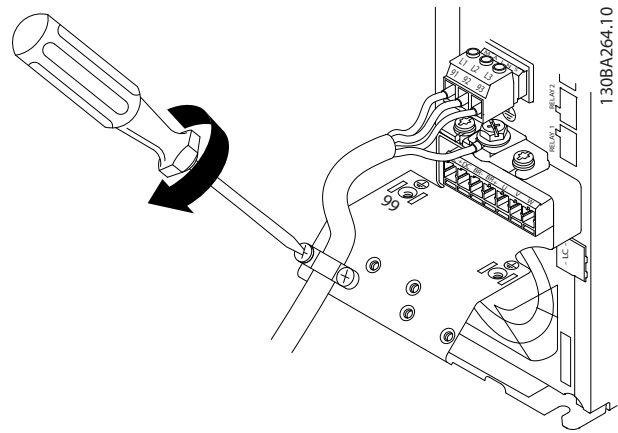
Illustration 5.10 Mounting the Support Bracket

Relays and terminals on enclosure size H10
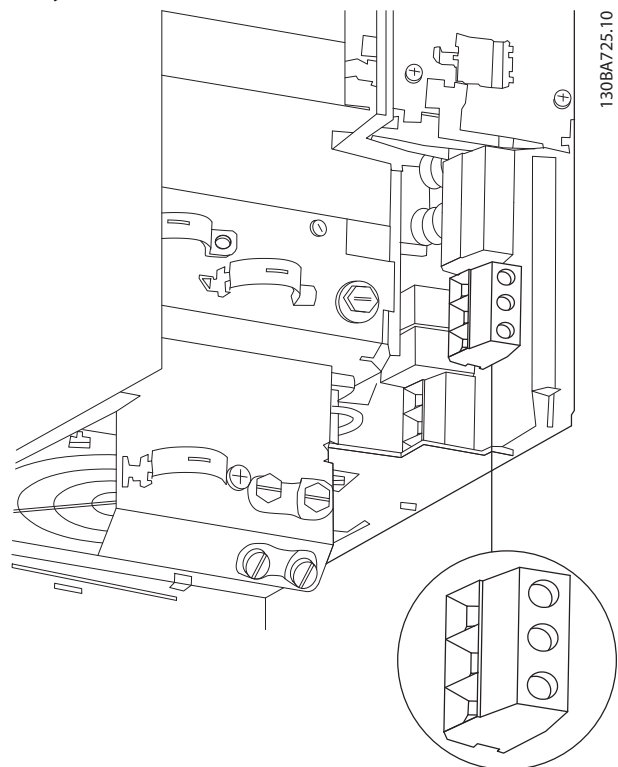
Illustration 5.11 Enclosure Size H10
IP20, 600 V, 11–15 kW (15–20 hp)

5

5

Enclosure size I2
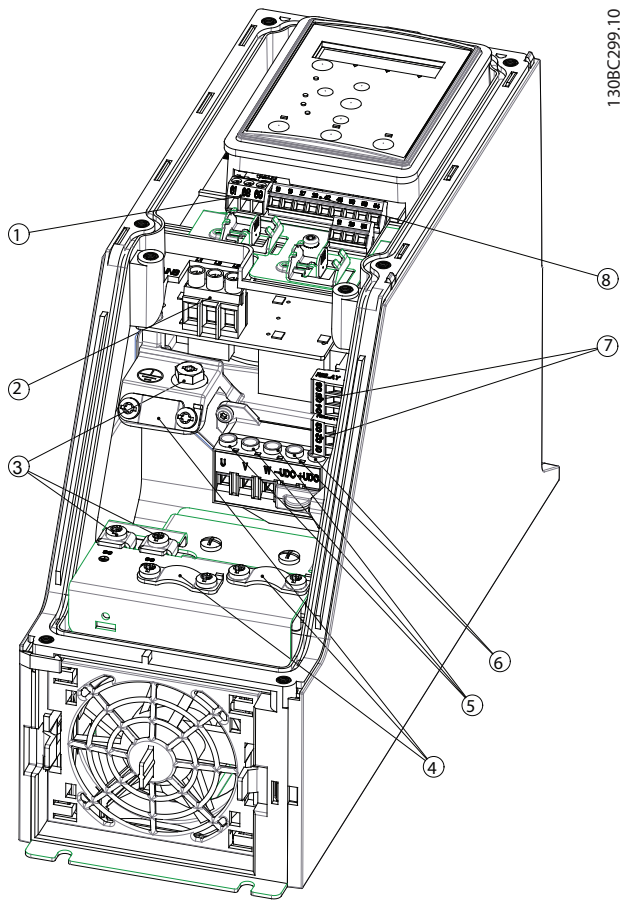
Enclosure size I3

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

Illustration 5.12 Enclosure Size I2
IP54, 380–480 V, 0.75–4.0 kW (1–5 hp)
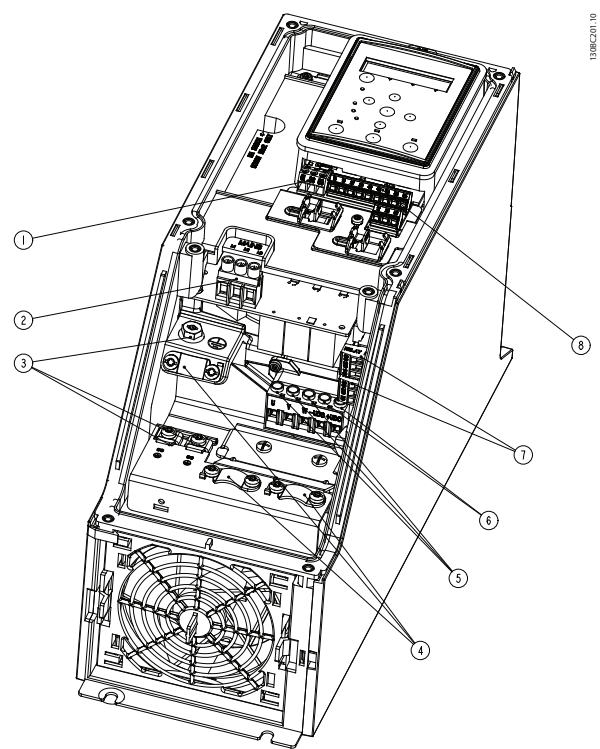
1	RS-485
2	Mains
3	Ground
4	Cable clamps
5	Motor
6	UDC
7	Relays
8	I/O

Illustration 5.13 Enclosure Size I3
IP54, 380–480 V, 5.5–7.5 kW (7.5–10 hp)

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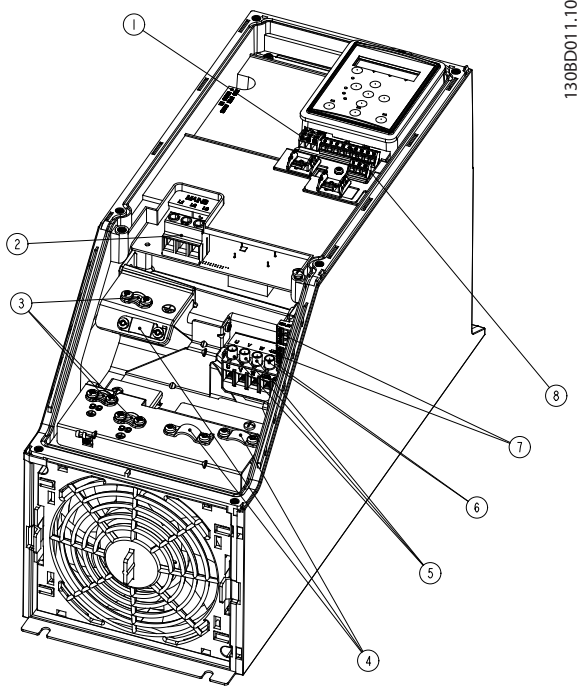
Enclosure size I4

130BD011.10

1	RS-485
2	Mains
3	Ground
4	Cable clamps
5	Motor
6	UDC
7	Relays
8	I/O

Illustration 5.14 Enclosure Size I4
IP54, 380–480 V, 0.75–4.0 kW (1–5 hp)
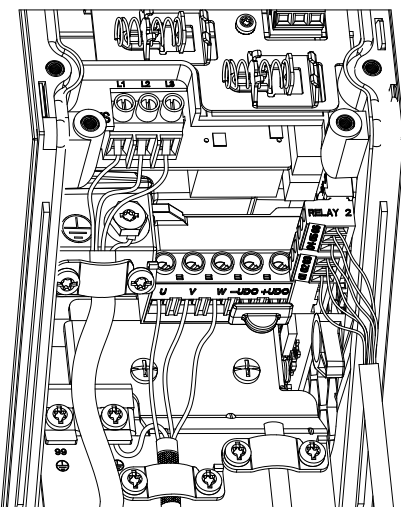
130BC203.10

Illustration 5.15 IP54 Enclosure Sizes I2, I3, I4, IP54

Enclosure size I6
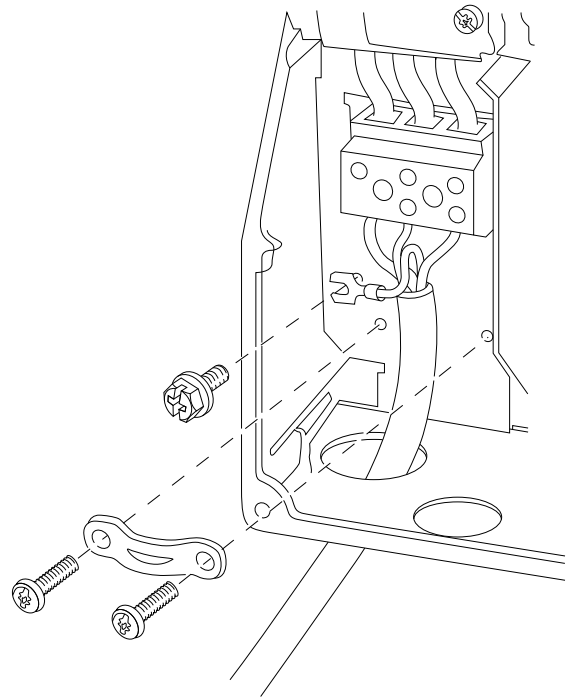
130BT326.10

Illustration 5.16 Connecting to Mains for Enclosure Size I6
IP54, 380–480 V, 22–37 kW (30–50 hp)
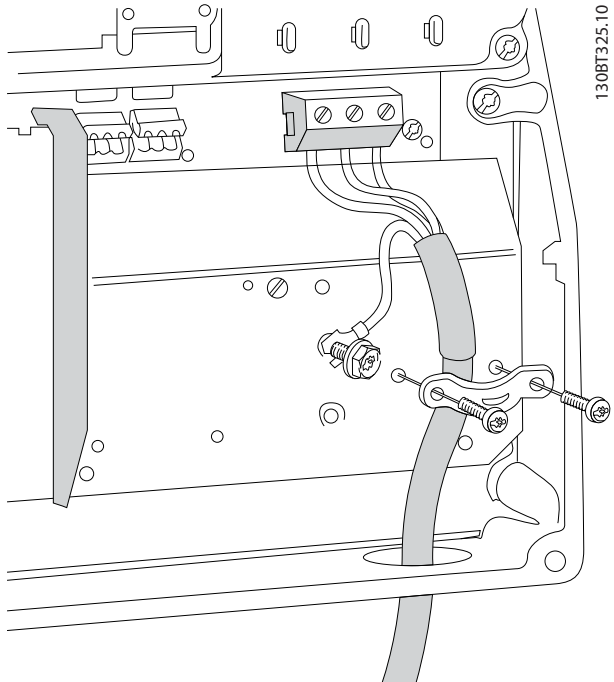
130BT325.10

Illustration 5.17 Connecting to Motor for Enclosure Size I6
IP54, 380–480 V, 22–37 kW (30–50 hp)
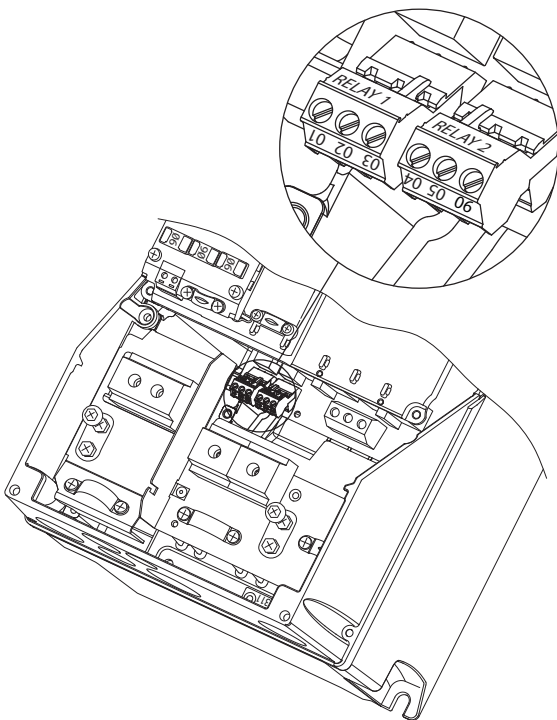
Illustration 5.18 Relays on Enclosure Size I6
IP54, 380–480 V, 22–37 kW (30–50 hp)

Enclosure sizes I7, I8
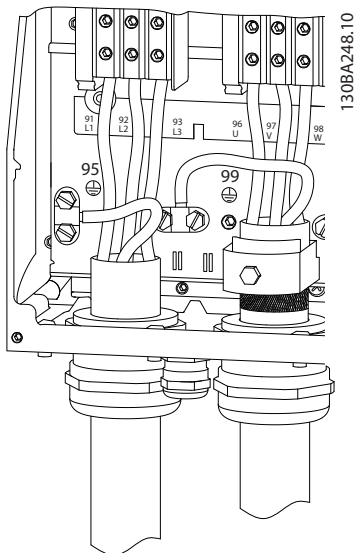
Illustration 5.19 Enclosure Sizes I7, I8
IP54, 380–480 V, 45–55 kW (60–70 hp)
IP54, 380–480 V, 75–90 kW (100–125 hp)

5.2.4 Fuses and Circuit Breakers

Branch circuit protection
To protect the installation against electrical and fire hazards, all branch circuits in an installation, switch gear, machines etc., must be short-circuit and overcurrent protected according to national and local regulations.

Short-circuit protection
Danfoss recommends using the fuses and circuit breakers listed in *Table 5.9* to protect service personnel or other equipment in case of an internal failure in the unit or short-circuit on 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
Use the circuit breakers or fuses listed in *Table 5.9*, to ensure compliance with UL or IEC 61800-5-1.
Circuit breakers must be designed for protection in a circuit capable of supplying a maximum of 10000 A_{rms} (symmetrical), 480 V maximum.

⚠WARNING

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
3x200–240 V IP20							
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)			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
1.5 (2)			FRS-R-10	KTN-R10	JKS-10	JJN-10	10
2.2 (3)			FRS-R-15	KTN-R15	JKS-15	JJN-15	16
3.7 (5)			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
3x380–480 V IP20							
0.37 (0.5)			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
0.75 (1)			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
1.5 (2)			FRS-R-10	KTS-R10	JKS-10	JJS-10	10
2.2 (3)			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
3 (4)			FRS-R-15	KTS-R15	JKS-15	JJS-15	16
4 (5)			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
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
3x525–600 V IP20							
2.2 (3)			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
3 (4)			FRS-R-20	KTS-R20	JKS-20	JJS-20	20
3.7 (5)			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	KTN-R80	JKS-80	JJS-80	80
22 (30)			FRS-R-80	KTN-R80	JKS-80	JJS-80	80
30 (40)			FRS-R-80	KTN-R80	JKS-80	JJS-80	80

	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
37 (50)	Cutler-Hammer JGE3125FFG	Cutler-Hammer JGE3125FFG	FRS-R-125	KTN-R125	JKS-125	JJS-125	125
45 (60)			FRS-R-125	KTN-R125	JKS-125	JJS-125	125
55 (70)			FRS-R-125	KTN-R125	JKS-125	JJS-125	125
75 (100)	Cutler-Hammer JGE3200FAG	Cutler-Hammer JGE3200FAG	FRS-R-200	KTN-R200	JKS-200	JJS-200	200
90 (125)			FRS-R-200	KTN-R200	JKS-200	JJS-200	200
3x380–480 V IP54							
0.75 (1)		PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
1.5 (2)		PKZM0-16	FRS-R-10	KTS-R-10	JKS-10	JJS-10	16
2.2 (3)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
3 (4)		PKZM0-16	FRS-R-15	KTS-R-15	JKS-15	JJS-15	16
4 (5)		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)			FRS-R-80	KTS-R-80	JKS-80	JJS-80	125
30 (40)	Moeller NZMB1-A125		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 5.9 Circuit Breakers and Fuses

 MG18C602

5.2.5 EMC-compliant Electrical Installation

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

- Use only screened/armoured motor cables and screened/armoured control cables.

- Connect the screen to ground at both ends.

- Avoid installation with twisted screen ends (pigtails), because this may affect the screening 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 unscreened/unarmoured motor cables in the installation cabinets.

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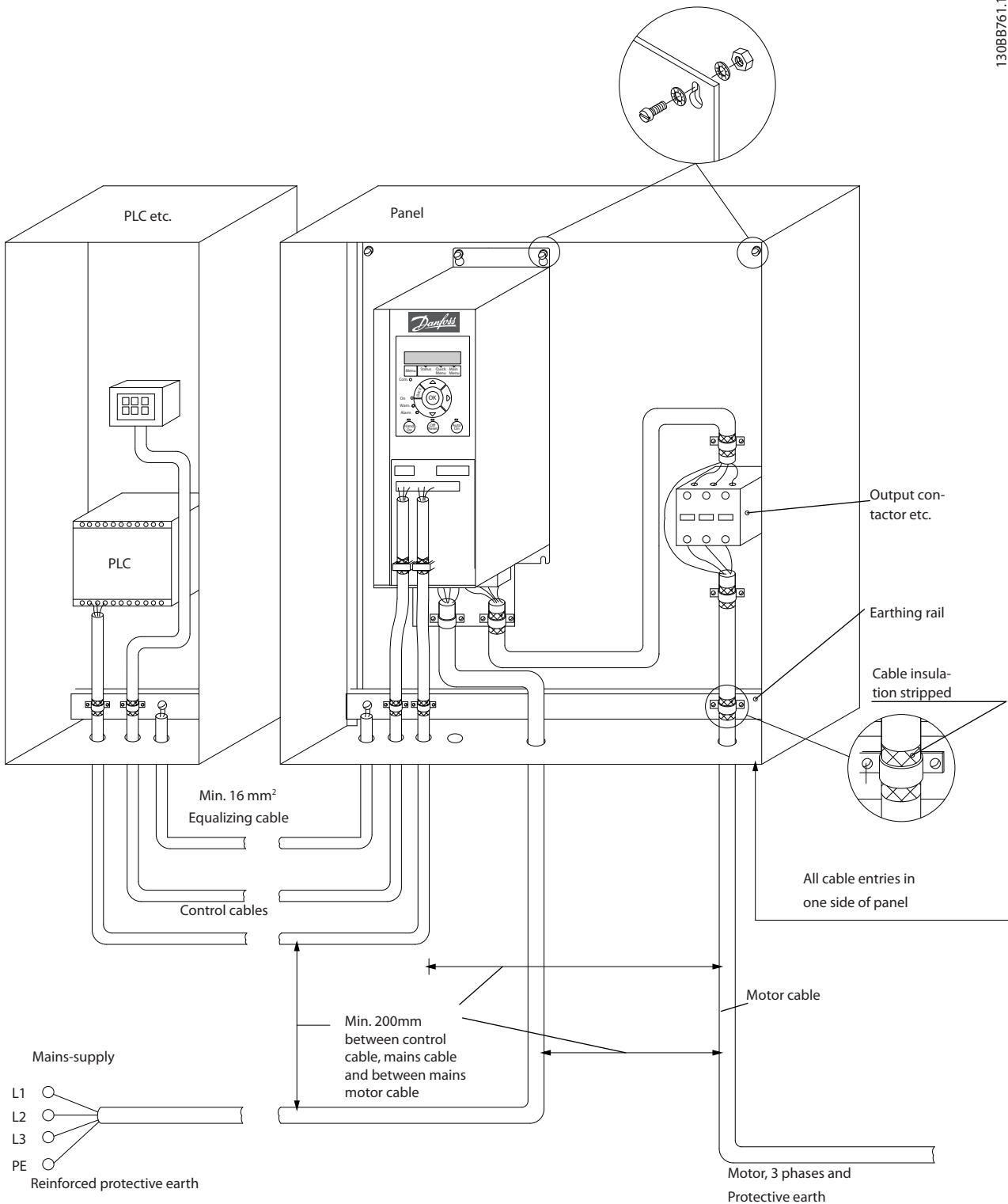
Illustration 5.20 EMC-correct Electrical Installation

NOTICE

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

5.2.6 Control Terminals

Remove the terminal cover to access the control terminals.

Use a flat-edged screwdriver to push down the lock lever of the terminal cover under the LCP, then remove the terminal cover, as shown in *Illustration 5.21*.

For IP54 units, remove the front cover before removing the terminal cover.
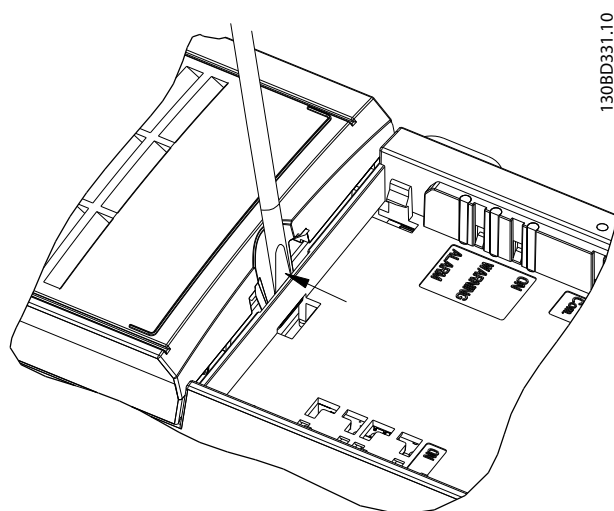
Illustration 5.21 Removing the Terminal Cover

Illustration 5.22 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 *5-00 Digital Input Mode* (PNP is default value). Digital input 29 mode is set in *5-03 Digital Input 29 Mode* (PNP is default value).
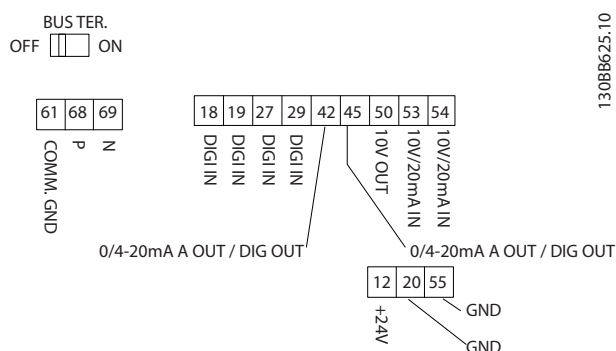
Illustration 5.22 Control Terminals

6 Programming

6.1 Introduction

The frequency converter can also be programmed from a PC via the RS485 COM port by installing the MCT 10 Set-up Software. Refer to *chapter 1.5.1 MCT 10 Set-up Software Support* 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 (LEDs)
- D. Operation keys and indicator lights (LEDs)
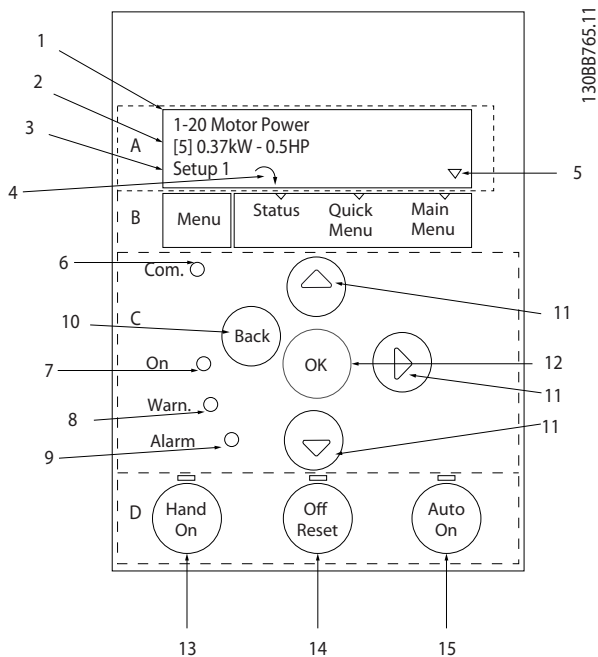
Illustration 6.1 Local Control Panel (LCP)

A. Display
The LCD-display is back-lit with 2 alphanumeric lines. All data is displayed 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 between Status, Quick Menu or Main Menu.

C. Navigation keys and indicator lights (LEDs)

6	Com LED: Flashes when bus communication is communicating.
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, 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 (LEDs)

13	[Hand On]: Starts the motor and enables control of the frequency converter via the LCP. **NOTICE** *[2] coast inverse* **is the default option for** *5-12 Terminal 27 Digital Input*. **This means that [Hand On] does not start the motor if there is no 24 V supply to terminal 27. Connect terminal 12 to terminal 27.**
14	[Off/Reset]: Stops the motor (Off). If in Alarm mode, the alarm is reset.
15	[Auto On]: 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], *16-13 Frequency*.

- Motor Current [A], *16-14 Motor current*.

- Motor Speed Reference in Percentage [%], *16-02 Reference [%]*.

- Feedback, *16-52 Feedback[Unit]*.

- Motor Power [kW] (if *0-03 Regional Settings* is set to *[1] North America*, Motor Power is shown in the unit of hp instead of kW), *16-10 Power [kW]* for kW, *16-11 Power [hp]* for hp.

- Custom Readout *16-09 Custom Readout*.

6.3.2 Quick Menu

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

- Wizard for open loop applications. See *Illustration 6.4* for details.

- Closed loop set-up wizard. 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 and closed-loop applications and quick motor settings.
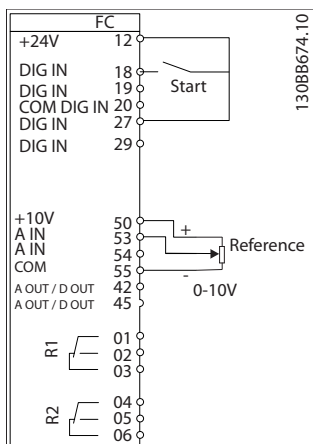
Illustration 6.2 Frequency Converter Wiring
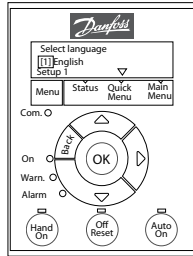
The wizard is displayed after power-up until any parameter has been changed. The wizard can always be accessed again through the Quick Menu. Press [OK] to start the wizard. Press [Back] to return to the status screen.

Illustration 6.3 Start-up/Quit Wizard
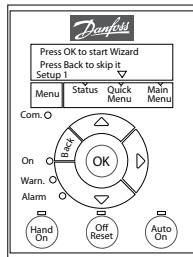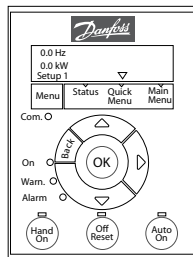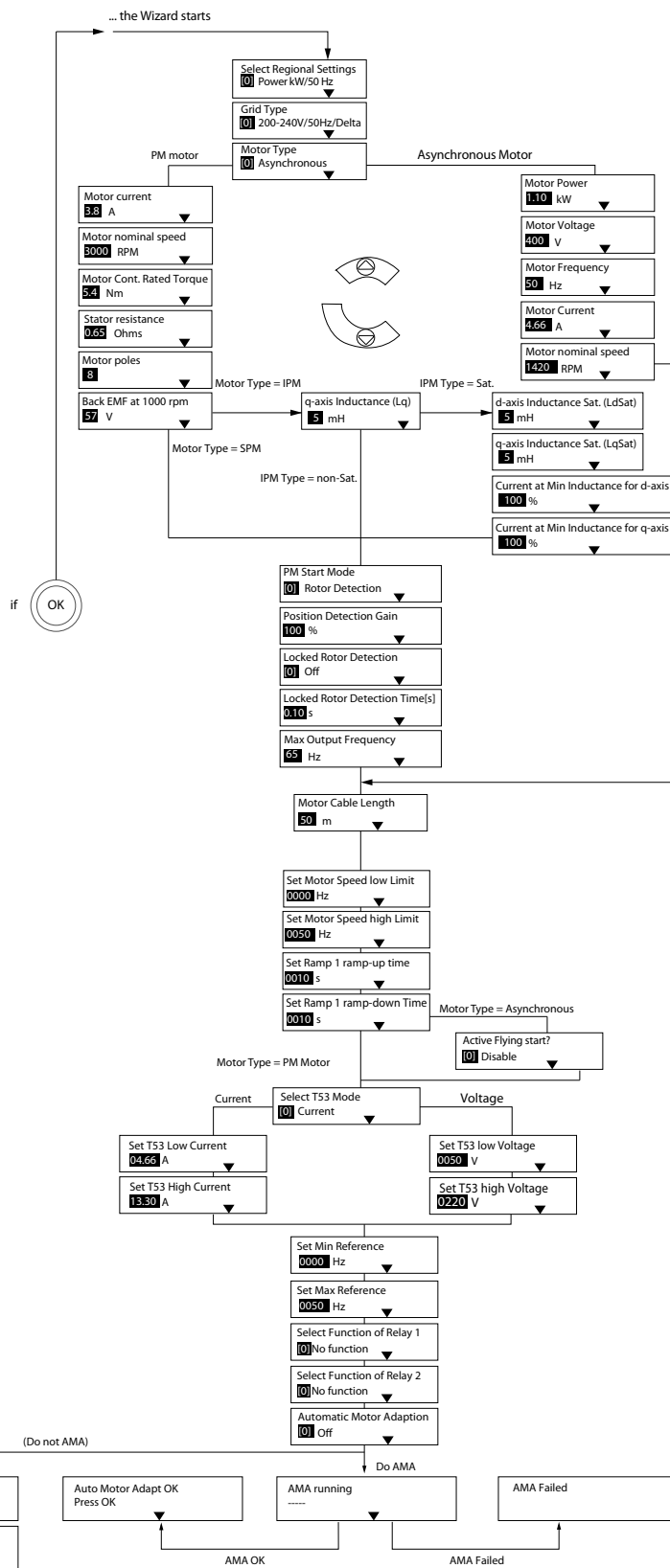
Illustration 6.4 Set-up Wizard for Open-loop Applications

1-46 Position Detection Gain and *1-70 PM Start Mode* are
available in software version 2.80 and subsequent versions.

Set-up Wizard for Open-loop Applications

Parameter	Option	Default	Usage
0-03 Regional Settings	[0] International [1] US	0	
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 upon reconnection of the frequency converter to mains voltage after power down.

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Parameter	Option	Default	Usage
1-10 Motor Construction	*[0] Asynchron [1] PM, non-salient SPM [2] PM, salient IPM, non Sat. [3] PM, salient IPM, Sat.	[0] Asynchron	Setting the parameter value might change these parameters: *1-01 Motor Control Principle* *1-03 Torque Characteristics* *1-14 Damping Gain* *1-15 Low Speed Filter Time Const.* *1-16 High Speed Filter Time Const.* *1-17 Voltage filter time const.* *1-20 Motor Power [kW]* *1-22 Motor Voltage* *1-23 Motor Frequency* *1-24 Motor Current* *1-25 Motor Nominal Speed* *1-26 Motor Cont. Rated Torque* *1-30 Stator Resistance (Rs)* *1-33 Stator Leakage Reactance (X1)* *1-35 Main Reactance (Xh)* *1-37 d-axis Inductance (Ld)* *1-38 q-axis Inductance (Lq)* *1-39 Motor Poles* *1-40 Back EMF at 1000 RPM* *1-44 d-axis Inductance Sat. (LdSat)* *1-45 q-axis Inductance Sat. (LqSat)* *1-46 Position Detection Gain* *1-48 Current at Min Inductance for d-axis* *1-49 Current at Min Inductance for q-axis* *1-66 Min. Current at Low Speed* *1-70 PM Start Mode* *1-72 Start Function* *1-73 Flying Start* *4-14 Motor Speed High Limit [Hz]* *4-19 Max Output Frequency* *4-58 Missing Motor Phase Function* *14-65 Speed Derate Dead Time Compensation*
1-20 Motor Power	0.12–110 kW/0.16–150 hp	Size related	Enter the motor power from the nameplate data.
1-22 Motor Voltage	50.0–1000.0 V	Size related	Enter the motor voltage from the nameplate data.
1-23 Motor Frequency	20.0–400.0 Hz	Size related	Enter the motor frequency from the nameplate data.
1-24 Motor Current	0.01–10000.00 A	Size related	Enter the motor current from the nameplate data.
1-25 Motor Nominal Speed	50.0–9999.0 RPM	Size related	Enter the motor nominal speed from the nameplate data.

Parameter	Option	Default	Usage
1-26 Motor Cont. Rated Torque	0.1–1000.0 Nm	Size related	This parameter is available when *1-10 Motor Construction* is set to options that enable permanent motor mode. **NOTICE** **Changing this parameter affects the settings of other parameters.**
1-29 Automatic Motor Adaption (AMA)	See *1-29 Automatic Motor Adaption (AMA)*	Off	Performing an AMA optimises motor performance.
1-30 Stator Resistance (Rs)	0.000–99.990 Ohm	Size related	Set the stator resistance value.
1-37 d-axis Inductance (Ld)	0–1000 mH	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The d-axis inductance cannot be found by performing an AMA.
1-38 q-axis Inductance (Lq)	0–1000 mH	Size related	Enter the value of the q-axis inductance.
1-39 Motor Poles	2–100	4	Enter the number of motor poles.
1-40 Back EMF at 1000 RPM	10–9000 V	Size related	Line-line RMS back-EMF voltage at 1000 RPM.
1-42 Motor Cable Length	0–100 m	50 m	Enter the motor cable length.
1-44 d-axis Inductance Sat. (LdSat)	0–1000 mH	Size related	This parameter corresponds to the inductance saturation of Ld. Ideally, this parameter has the same value as *1-37 d-axis Inductance (Ld)*. However, if the motor supplier provides an induction curve, the induction value @ 200% of isNom should be entered here.
1-45 q-axis Inductance Sat. (LqSat)	0–1000 mH	Size related	This parameter corresponds to the inductance saturation of Lq. Ideally, this parameter has the same value as *1-38 q-axis Inductance (Lq)*. However, if the motor supplier provides an induction curve, the induction value @ 200% of isNom should be entered here.
1-46 Position Detection Gain	20–200%	100%	Adjusts the height of the test pulse during position detection at start.
1-48 Current at Min Inductance for d-axis	20–200 %	100%	Enter the inductance saturation point.

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Parameter	Option	Default	Usage
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% to 100% of this parameter, the inductances are linearly approximated due to parameters 1-37, 1-38, 1-44, and 1-45.
1-70 PM Start Mode	[0] Rotor Detection [1] Parking	[0] Rotor Detection	–
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select *[1] Enable* to enable the frequency converter to catch a motor spinning due to mains drop-out. Select *[0] Disable* if this function is not required. When this parameter is set to *[1] Enable*, *1-71 Start Delay* and *1-72 Start Function* have no function. *1-73 Flying Start* is active in VVC⁺ mode only.
3-02 Minimum Reference	-4999–4999	0	The minimum reference is the lowest value obtainable by summing all references.
3-03 Maximum Reference	-4999–4999	50	The maximum reference is the lowest obtainable by summing all references.
3-41 Ramp 1 Ramp Up Time	0.05–3600.0 s	Size related	Ramp-up time from 0 to rated *1-23 Motor Frequency* if asynchron motor is selected; ramp-up time from 0 to *1-25 Motor Nominal Speed* if PM motor is selected.
3-42 Ramp 1 Ramp Down Time	0.05–3600.0 s	Size related	Ramp-down time from rated *1-23 Motor Frequency* to 0 if asynchron motor is selected; ramp-down time from *1-25 Motor Nominal Speed* to 0 if PM motor is selected.
4-12 Motor Speed Low Limit [Hz]	0.0–400 Hz	0 Hz	Enter the minimum limit for low speed.
4-14 Motor Speed High Limit [Hz]	0.0–400 Hz	100 Hz	Enter the maximum limit for high speed.
4-19 Max Output Frequency	0–400	100 Hz	Enter the maximum output frequency value.
5-40 Function Relay [0] Function relay	See *5-40 Function Relay*	Alarm	Select the function to control output relay 1.
5-40 Function Relay [1] Function relay	See *5-40 Function Relay*	Drive running	Select the function to control output relay 2.
6-10 Terminal 53 Low Voltage	0–10 V	0.07 V	Enter the voltage that corresponds to the low reference value.
6-11 Terminal 53 High Voltage	0–10 V	10 V	Enter the voltage that corresponds to the high reference value.
6-12 Terminal 53 Low Current	0–20 mA	4 mA	Enter the current that corresponds to the low reference value.
6-13 Terminal 53 High Current	0–20 mA	20 mA	Enter the current that corresponds to the high reference value.

Parameter	Option	Default	Usage
6-19 Terminal 53 mode	[0] Current [1] Voltage	1	Select if terminal 53 is used for current- or voltage input.
30-22 Locked Rotor Detection	[0] Off [1] On	[0] Off	–
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

130BC402.10

1 | 0-03 Regional Settings
[0] Power kW/50 Hz

2 | 0-06 Grid Type
[0] 200-240V/50Hz/Delta

3 | 1-00 Configuration Mode
[3] Closed Loop

4 | 1-10 Motor Type
[0] Asynchronous

PM motor — Asynchronous Motor

10 | 1-24 Motor Current
3.8 A

11 | 1-25 Motor nominal speed
3000 RPM

12 | 1-26 Motor Cont. Rated Torque
5.4 Nm

13 | 1-30 Stator resistance
0.65 Ohms

14 | 1-39 Motor poles
8

15 | 1-40 Back EMF at 1000 rpm
57 V

16 | 1-37 d-axis inductance(Ld)
5 mH

17 | 4-19 Max Ouput Frequency
0065 Hz

5 | 1-20 Motor Power
1.10 kW

6 | 1-22 Motor Voltage
0050 V

7 | 1-23 Motor frequency
0050 Hz

8 | 1-24 Motor current
04.66 A

9 | 1-25 Motor nominal speed
1420 RPM

18 | 4-12 Motor speed low limit
0016 Hz

19 | 4-13 Motor speed high limit
0050 Hz

20 | 3-41 Ramp 1 ramp-up time
0003 s

21 | 3-42 Ramp1 ramp-down time
0003 s

MotorType = Asynchronous

22 | 1-73 Flying Start
[0] No

MotorType = PM Motor

22a | 20-00 Feedback 1 source
[1] Analog input 54

This dialog is forced to be set to
[1] Analog input 54

22b | 3-16 Reference Source 2
[0] No Operation

23 | 3-02 Min Reference
0.00

24 | 3-03 Max Reference
50.00

25 | 3-10 Preset reference [0]
0.00 %

Current — 26 | 6-29 Terminal 54 Mode
[1] Voltage — Voltage

31 | 6-22 T54 Low Current
04.66 A

32 | 6-24 T54 low Feedback
0016 Hz

33 | 6-23 T54 high Current
13.30 A

34 | 6-25 T54 high Feedback
0050 Hz

35 | 6-26 T54 Filter time const.
0.01 s

36 | 20-81 PI Normal/Inverse Control
[0] Normal

37 | 20-83 PI Normal/Inverse Control
0050 Hz

38 | 20-93 PI Proportional Gain
00.50

39 | 20-94 PI integral time
0020.00 s

40 | 1-29 Automatic Motor Adaption
[0] Off

27 | 6-20 T54 low Voltage
0050 V

28 | 6-24 T54 low Feedback
0016 Hz

29 | 6-21 T54 high Voltage
0220 V

30 | 6-25 T54 high Feedback
0050 Hz

Illustration 6.5 Set-up Wizard for Closed-loop Applications

1-46 Position Detection Gain and *1-70 PM Start Mode* are available in software version 2.80 and subsequent versions.

Parameter	Range	Default	Usage
0-03 Regional Settings	[0] International [1] US	0	–
0-06 GridType	[0] -[132] see *Table 6.4*.	Size selected	Select the operating mode for restart upon reconnection of the frequency converter to mains voltage after power down.
1-00 Configuration Mode	[0] Open loop [3] Closed loop	0	Select *[3] Closed loop*.
1-10 Motor Construction	*[0] Asynchron [1] PM, non-salient SPM [2] PM, salient IPM, non Sat. [3] PM, salient IPM, Sat.	[0] Asynchron	Setting the parameter value might change these parameters: *1-01 Motor Control Principle* *1-03 Torque Characteristics* *1-14 Damping Gain* *1-15 Low Speed Filter Time Const.* *1-16 High Speed Filter Time Const.* *1-17 Voltage filter time const.* *1-20 Motor Power [kW]* *1-22 Motor Voltage* *1-23 Motor Frequency* *1-24 Motor Current* *1-25 Motor Nominal Speed* *1-26 Motor Cont. Rated Torque* *1-30 Stator Resistance (Rs)* *1-33 Stator Leakage Reactance (X1)* *1-35 Main Reactance (Xh)* *1-37 d-axis Inductance (Ld)* *1-38 q-axis Inductance (Lq)* *1-39 Motor Poles* *1-40 Back EMF at 1000 RPM* *1-44 d-axis Inductance Sat. (LdSat)* *1-45 q-axis Inductance Sat. (LqSat)* *1-46 Position Detection Gain* *1-48 Current at Min Inductance for d-axis* *1-49 Current at Min Inductance for q-axis* *1-66 Min. Current at Low Speed* *1-72 Start Function* *1-73 Flying Start* *4-14 Motor Speed High Limit [Hz]* *4-19 Max Output Frequency* *4-58 Missing Motor Phase Function* *14-65 Speed Derate Dead Time Compensation*
1-20 Motor Power	0.09–110 kW	Size related	Enter the motor power from the nameplate data.
1-22 Motor Voltage	50–1000 V	Size related	Enter the motor voltage from the nameplate data.
1-23 Motor Frequency	20–400 Hz	Size related	Enter the motor frequency from the nameplate data.
1-24 Motor Current	0–10000 A	Size related	Enter the motor current from the nameplate data.
1-25 Motor Nominal Speed	50–9999 RPM	Size related	Enter the motor nominal speed from the nameplate data.

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Parameter	Range	Default	Usage
1-26 Motor Cont. Rated Torque	0.1–1000.0 Nm	Size related	This parameter is available when*1-10 Motor Construction* is set to options that enable permanent motor mode. **NOTICE** **Changing this parameter affects the settings of other parameters.**
1-29 Automatic Motor Adaption (AMA)		Off	Performing an AMA optimises motor performance.
1-30 Stator Resistance (Rs)	0–99.990 Ohm	Size related	Set the stator resistance value.
1-37 d-axis Inductance (Ld)	0–1000 mH	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The d-axis inductance cannot be found by performing an AMA.
1-38 q-axis Inductance (Lq)	0–1000 mH	Size related	Enter the value of the q-axis inductance.
1-39 Motor Poles	2–100	4	Enter the number of motor poles.
1-40 Back EMF at 1000 RPM	10–9000 V	Size related	Line-line RMS back-EMF voltage at 1000 RPM.
1-42 Motor Cable Length	0–100 m	50 m	Enter the motor cable length.
1-44 d-axis Inductance Sat. (LdSat)	0–1000 mH	Size related	This parameter corresponds to the inductance saturation of Ld. Ideally, this parameter has the same value as *1-37 d-axis Inductance (Ld)*. However, if motor supplier provides an induction curve, the induction value @ 200% of isNom should be entered here.
1-45 q-axis Inductance Sat. (LqSat)	0–1000 mH	Size related	This parameter corresponds to the inductance saturation of Lq. Ideally, this parameter has the same value as *1-38 q-axis Inductance (Lq)*. However, if motor supplier provides an induction curve, the induction value @ 200% of isNom should be entered here.
1-46 Position Detection Gain	20–200%	100%	Adjusts the height of the test pulse during position detection at start.
1-48 Current at Min Inductance for d-axis	20–200 %	100%	Enter the inductance saturation point.
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% to 100% of this parameter, the inductances are linearly approximated due to parameters 1-37, 1-38, 1-44, and 1-45.
1-70 PM Start Mode	[0] Rotor Detection [1] Parking	[0] Rotor Detection	–
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select *[1] Enable* to enable the frequency converter to catch a spinning motor, i.e. fan applications. When PM is selected, *1-73 Flying Start* is enabled.

Parameter	Range	Default	Usage
3-02 Minimum Reference	-4999–4999	0	The minimum reference is the lowest value obtainable by summing all references.
3-03 Maximum Reference	-4999–4999	50	The maximum reference is the highest value obtainable by summing all references.
3-10 Preset Reference	-100–100%	0	Enter the setpoint.
3-41 Ramp 1 Ramp Up Time	0.05–3600.0 s	Size related	Ramp-up time from 0 to rated *1-23 Motor Frequency* if asynchron motor is selected; ramp-up time from 0 to *1-25 Motor Nominal Speed* if PM motor is selected.
3-42 Ramp 1 Ramp Down Time	0.05–3600.0 s	Size related	Ramp-down time from rated *1-23 Motor Frequency* to 0 if asynchron motor is selected; ramp-down time from *1-25 Motor Nominal Speed* to 0 if PM motor is selected.
4-12 Motor Speed Low Limit [Hz]	0–400 Hz	0.0 Hz	Enter the minimum limit for low speed.
4-14 Motor Speed High Limit [Hz]	0–400 Hz	100 Hz	Enter the minimum limit for high speed.
4-19 Max Output Frequency	0–400	100 Hz	Enter the maximum output frequency value.
6-20 Terminal 54 Low Voltage	0–10 V	0.07 V	Enter the voltage that corresponds to the low reference value.
6-21 Terminal 54 High Voltage	0–10 V	10 V	Enter the voltage that corresponds to the low high reference value.
6-22 Terminal 54 Low Current	0–20 mA	4 mA	Enter the current that corresponds to the high reference value.
6-23 Terminal 54 High Current	0–20 mA	20 mA	Enter the current that corresponds to the high reference value.
6-24 Terminal 54 Low Ref./Feedb. Value	-4999–4999	0	Enter the feedback value that corresponds to the voltage or current set in *6-20 Terminal 54 Low Voltage/6-22 Terminal 54 Low Current*.
6-25 Terminal 54 High Ref./Feedb. Value	-4999–4999	50	Enter the feedback value that corresponds to the voltage or current set in *6-21 Terminal 54 High Voltage/ 6-23 Terminal 54 High Current*.
6-26 Terminal 54 Filter Time Constant	0–10 s	0.01	Enter the filter time constant.
6-29 Terminal 54 mode	[0] Current [1] Voltage	1	Select if terminal 54 is used for current- or voltage input.
20-81 PI Normal/ Inverse Control	[0] Normal [1] Inverse	0	Select *[0] Normal* to set the process control to increase the output speed when the process error is positive. Select *[1] Inverse* to reduce the output speed.
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.
20-93 PI Proportional Gain	0–10	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.

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Parameter	Range	Default	Usage
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.
30-22 Locked Rotor Detection	[0] Off [1] On	[0] Off	–
30-23 Locked Rotor Detection Time [s]	0.05–1 s	0.10 s	–

Table 6.5 Set-up Wizard for Closed-loop Applications

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

Parameter	Range	Default	Usage
0-03 Regional Settings	[0] International [1] US	0	–
0-06 GridType	[0] -[132] see *Table 6.4*	Size selected	Select the operating-mode for restart upon reconnection of the frequency converter to mains voltage after power down.
1-10 Motor Construction	*[0] Asynchron [1] PM, non-salient SPM [2] PM, salient IPM, non Sat. [3] PM, salient IPM, Sat.	[0] Asynchron	–
1-20 Motor Power	0.12–110 kW/0.16–150 hp	Size related	Enter the motor power from the nameplate data.
1-22 Motor Voltage	50–1000 V	Size related	Enter the motor voltage from the nameplate data.
1-23 Motor Frequency	20–400 Hz	Size related	Enter the motor frequency from the nameplate data.
1-24 Motor Current	0.01–10000.00 A	Size related	Enter the motor current from the nameplate data.
1-25 Motor Nominal Speed	50–9999 RPM	Size related	Enter the motor nominal speed from the nameplate data.
1-26 Motor Cont. Rated Torque	0.1–1000.0 Nm	Size related	This parameter is available when *1-10 Motor Construction* is set to options that enable permanent motor mode. **NOTICE** **Changing this parameter affects the settings of other parameters.**
1-30 Stator Resistance (Rs)	0–99.990 Ohm	Size related	Set the stator resistance value.
1-37 d-axis Inductance (Ld)	0–1000 mH	Size related	Enter the value of the d-axis inductance. Obtain the value from the permanent magnet motor data sheet. The d-axis inductance cannot be found by performing an AMA.
1-38 q-axis Inductance (Lq)	0–1000 mH	Size related	Enter the value of the q-axis inductance.
1-39 Motor Poles	2–100	4	Enter the number of motor poles.

Parameter	Range	Default	Usage
1-40 Back EMF at 1000 RPM	10–9000 V	Size related	Line-line RMS back-EMF voltage at 1000 RPM.
1-42 Motor Cable Length	0–100 m	50 m	Enter the motor cable length.
1-44 d-axis Inductance Sat. (LdSat)	0–1000 mH	Size related	This parameter corresponds to the inductance saturation of Ld. Ideally, this parameter has the same value as 1-37 d-axis Inductance (Ld). However, if the motor supplier provides an induction curve, the induction value @ 200% of isNom should be entered here.
1-45 q-axis Inductance Sat. (LqSat)	0–1000 mH	Size related	This parameter corresponds to the inductance saturation of Lq. Ideally, this parameter has the same value as 1-38 q-axis Inductance (Lq). However, if the motor supplier provides an induction curve, the induction value @ 200% of isNom should be entered here.
1-46 Position Detection Gain	20–200%	100%	Adjusts the height of the test pulse during position detection at start.
1-48 Current at Min Inductance for d-axis	20–200 %	100%	Enter the inductance saturation point.
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% to 100% of this parameter, the inductances are linearly approximated due to parameters 1-37, 1-38, 1-44, and 1-45.
1-70 PM Start Mode	[0] Rotor Detection [1] Parking	[0] Rotor Detection	–
1-73 Flying Start	[0] Disabled [1] Enabled	0	Select [1] Enable to enable the frequency converter to catch a spinning motor.
3-41 Ramp 1 Ramp Up Time	0.05–3600.0 s	Size related	Ramp-up time from 0 to rated 1-23 Motor Frequency.
3-42 Ramp 1 Ramp Down Time	0.05–3600.0 s	Size related	Ramp-down time from rated 1-23 Motor Frequency to 0.
4-12 Motor Speed Low Limit [Hz]	0–400 Hz	0.0 Hz	Enter the minimum limit for low speed.
4-14 Motor Speed High Limit [Hz]	0–400 Hz	100 Hz	Enter the maximum limit for high speed.
4-19 Max Output Frequency	0–400	100 Hz	Enter the maximum output frequency value.
30-22 Locked Rotor Detection	[0] Off [1] On	[0] Off	–
30-23 Locked Rotor Detection Time [s]	0.05–1 s	0.10 s	–

Table 6.6 Motor Set-up Wizard Settings

Changes Made

The *Changes Made* function lists all parameters changed from default settings.

- The list shows only parameters which have been changed in the current edit set-up.

- Parameters which have been reset to default values are not listed.

- The message *Empty* indicates that no parameters have been changed.

Changing parameter settings

1. Press the [Menu] key to enter the Quick Menu until indicator in display is placed above Quick Menu.

2. Press [▲] [▼] to select the wizard, closed-loop set-up, motor set-up, or changes made, then press [OK].

3. Press [▲] [▼] to browse through the parameters in the Quick Menu.

4. Press [OK] to select a parameter.

5. Press [▲] [▼] to change the value of a parameter setting.

6. Press [OK] to accept the change.

7. 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 indicator in 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.

6.3.3 Main Menu

Press [Main Menu] to access and programme of all parameters. The Main Menu parameters can be accessed readily unless a password has been created via *0-60 Main Menu Password*.

For the majority of VLT® HVAC Basic Drive applications it is not necessary to access the Main Menu parameters. The Quick Menu provides the simplest and quickest access to the typical required parameters.

The Main Menu accesses all parameters.

1. Press [Menu] until indicator in 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.

Press [Back] to go back 1 level.

6.4 Quick Transfer of Parameter Settings between Multiple Frequency Converters

Once the set-up of a frequency converter is complete, Danfoss recommends to store the data in the LCP or on a PC via MCT 10 Set-up Software.

Data transfer from frequency converter to LCP:

1. Stop the motor, and wait for the discharge time specified in *Table 2.1*.

2. Go to *0-50 LCP Copy*.

3. Press [OK].

4. Select *[1] All to LCP*.

5. Press [OK].

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

Data transfer from LCP to frequency converter:

1. Stop the motor, and wait for the discharge time specified in *Table 2.1*.

2. Go to *0-50 LCP Copy*

3. Press [OK]

4. Select *[2] All from LCP*

5. 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 Initialise the Frequency Converter to Default Settings in two Ways

Recommended initialisation (via *14-22 Operation Mode*)

1. Select *14-22 Operation Mode*.

2. Press [OK].

3. Select *[2] Initialisation* and Press [OK].

4. Cut off the mains supply and wait until the display turns off.

5. Reconnect the mains supply - the frequency converter is now reset.

Except the following parameters:
- *8-30 Protocol*
- *8-31 Address*
- *8-32 Baud Rate*
- *8-33 Parity / Stop Bits*
- *8-35 Minimum Response Delay*
- *8-36 Maximum Response Delay*
- *8-37 Maximum Inter-char delay*
- *8-70 BACnet Device Instance*
- *8-72 MS/TP Max Masters*
- *8-73 MS/TP Max Info Frames*
- *8-74 "I am" Service*
- *8-75 Intialisation Password*
- *15-00 Operating hours* to *15-05 Over Volt's*
- *15-03 Power Up's*
- *15-04 Over Temp's*
- *15-05 Over Volt's*
- *15-30 Alarm Log: Error Code*
- *15-4* Drive identification parameters*
- *1-06 Clockwise Direction*

2-finger initialisation

1. Power off the frequency converter.

2. Press [OK] and [Menu].

3. Power up the frequency converter while still pressing the keys above for 10 s.

6

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

- *15-00 Operating hours*
- *15-03 Power Up's*
- *15-04 Over Temp's*
- *15-05 Over Volt's*
- 15-4* rive identification parameters

Initialisation of parameters is confirmed by AL80 in the display after the power cycle.

6

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 one 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.

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

Low-impedance ground connection of the screen at every node is important. Connect a large surface of the screen to ground, for example with a cable clamp or a conductive cable gland. Apply potential-equalising 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 screened motor cable.

Cable	Screened twisted pair (STP)
Impedance [Ω]	120
Cable length [m]	Maximum 1200 (including drop lines)
	Maximum 500 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 screen to the cable clamps.

NOTICE

Screened, twisted-pair cables are recommended to reduce noise between conductors.
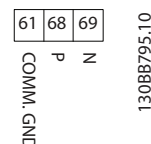
Illustration 7.1 Network Connection

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.
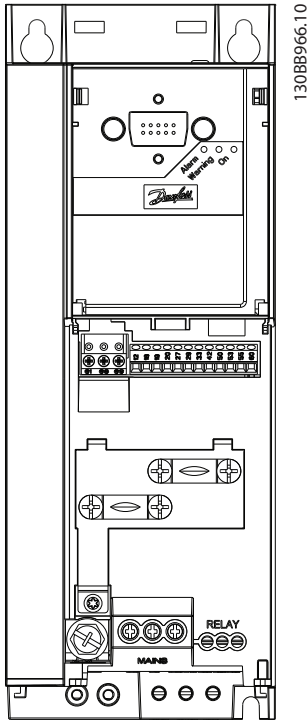
Illustration 7.2 Terminator Switch Factory Setting

The factory setting for the dip switch is OFF.

7.1.4 Parameter Settings for Modbus Communication

Parameter	Function
8-30 Protocol	Select the application protocol to run for the RS485 interface.
8-31 Address	Set the node address. **NOTICE** **The address range depends on the protocol selected in *8-30 Protocol*.**
8-32 Baud Rate	Set the baud rate. **NOTICE** **The default baud rate depends on the protocol selected in *8-30 Protocol*.**
8-33 Parity / Stop Bits	Set the parity and number of stop bits. **NOTICE** **The default selection depends on the protocol selected in *8-30 Protocol*.**
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.
8-36 Maximum Response Delay	Specify a maximum delay time between transmitting a request and receiving a response.
8-37 Maximum Inter-char delay	If transmission is interrupted, specify a maximum delay time between 2 received bytes to ensure time-out. **NOTICE** **The default selection depends on the protocol selected in *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, the RS485 communication cable must be kept away from motor and brake resistor cables. Normally, a distance of 200 mm (8 inches) 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°.
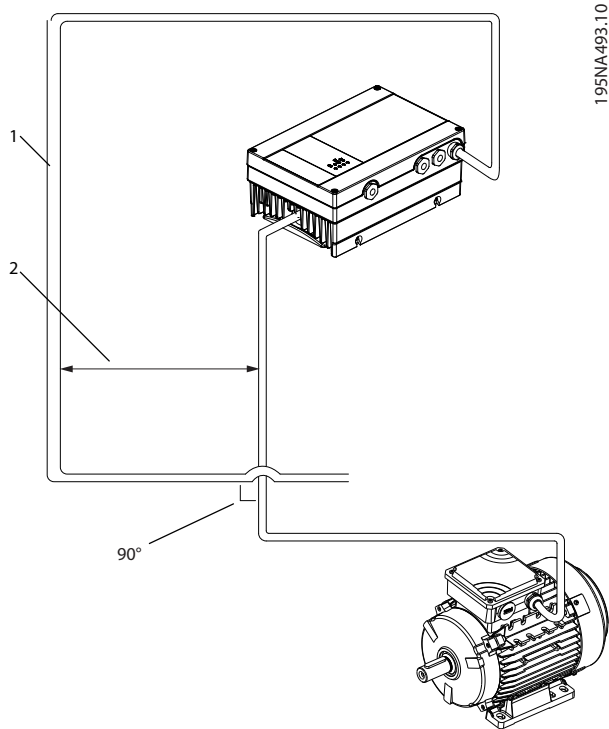
1	Fieldbus cable
2	Minimum 200 mm (8 in) distance

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 utilising 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. This permits 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

Set the following parameters to enable the FC protocol for the frequency converter.

Parameter	Setting
8-30 Protocol	FC
8-31 Address	1–126
8-32 Baud Rate	2400–115200
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.

| Start bit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Even Parity | Stop bit |
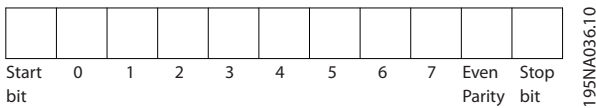
Illustration 7.4 Content of a Character

7.4.2 Telegram Structure

Each telegram has the following structure:

1.   Start character (STX)=02 hex.

2.   A byte denoting the telegram length (LGE).

3.   A byte denoting the frequency converter address (ADR).

A number of data bytes (variable, depending on the type of telegram) follows.

A data control byte (BCC) completes the telegram.

| STX | LGE | ADR | DATA | BCC |

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[1]+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).

| STX | LGE | ADR | PCD1 | PCD2 | BCC |
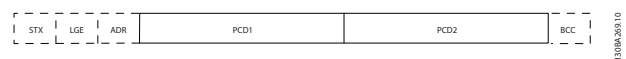
Illustration 7.6 Process Block

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.

| STX | LGE | ADR | PKE | IND | PWE$_{high}$ | PWE$_{low}$ | PCD1 | PCD2 | BCC |

Illustration 7.7 Parameter Block

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

| STX | LGE | ADR | PKE | IND | Ch1 | Ch2 | Chn | PCD1 | PCD2 | BCC |
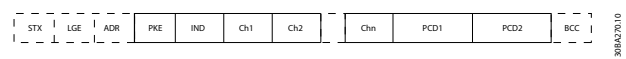
Illustration 7.8 Text Block

7.4.7 The PKE Field

The PKE field contains 2 subfields:

- Parameter command and response (AK)

- Parameter number (PNU)
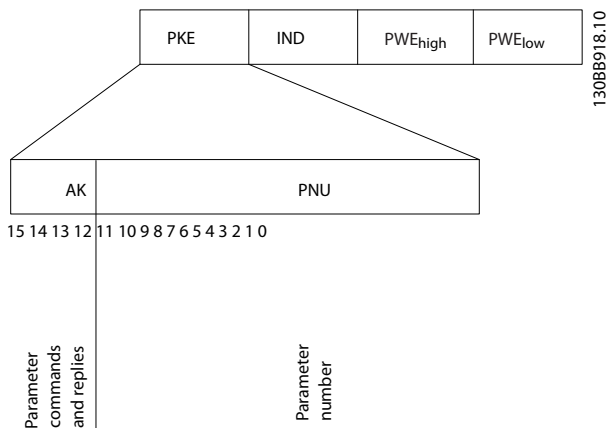
Illustration 7.9 PKE Field

Bit numbers 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 this response:
0111 Command cannot be performed
- and issues the following fault report in the parameter value:

Error 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, *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, e.g. *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).

15-40 FC Type to *15-53 Power Card Serial Number* contain data type 9.
For example, read the unit size and mains voltage range in *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 second 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 various attributes of each parameter are displayed in the chapter *Parameter Lists* in the *Programming Guide*. Parameter values are transferred as whole numbers only. Conversion factors are therefore used to transfer decimals.

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 *4-14 Motor Speed High Limit [Hz]* to 100 Hz. Write the data in EEPROM.

PKE=E19E hex - Write single word in *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 this:

E19E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE$_{high}$		PWE$_{low}$	

Illustration 7.10 Telegram

NOTICE

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

The response from the slave to the master is:

119E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE high		PWE low	

Illustration 7.11 Response from Master

7.5.2 Reading a Parameter Value

Read the value in *3-41 Ramp 1 Ramp Up Time*

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

- IND=0000 hex.
- PWE_HIGH=0000 hex.
- PWE_LOW=0000 hex.

1155	H	0000	H	0000	H	0000	H
PKE		IND		PWE high		PWE low	

Illustration 7.12 Telegram

If the value in *3-41 Ramp 1 Ramp Up Time* is 10 s, the response from the slave to the master is:

1155	H	0000	H	0000	H	03E8	H
PKE		IND		PWE high		PWE low	

Illustration 7.13 Response

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

Regardless of the type of physical communication networks, this section describes the process 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 message fields.
During communications over a Modbus RTU network, the protocol determines:

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

If a reply is required, the controller constructs the reply message 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 taking the action requested in the query.
The master can address individual slaves, or initiate a broadcast message 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's query by providing the device (or broadcast) address, a function code defining the requested action, any data to be sent, and an error-checking field. The slave's response message 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 message, or if the slave is unable to perform the requested action, the slave constructs an error message, and send it in response, or a time-out 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.

- 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 a variety of preset speeds.

- Run in reverse.

- Change the active set-up.

- Control the frequency converter's built-in relay.

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. This permits 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
8-30 Protocol	Modbus RTU
8-31 Address	1–247
8-32 Baud Rate	2400–115200
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 message 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 message.
Bits Per Byte	• 1 start bit.

• 8 data bits, least significant bit sent first.

• 1 bit for even/odd parity; no bit for no parity.

• 1 stop bit if parity is used; 2 bits if no parity. |
| Error Check Field | Cyclical redundancy check (CRC). |

Table 7.13 Byte Details

7.8.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognise when the message is completed. Partial messages are detected and errors set as a result. Characters for transmission must be in hexadecimal 00 to 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 messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message 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 Message Structure

7.8.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals. This 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 message. A new message can begin after this period. The entire message frame must be transmitted 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 message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message. This causes a time-out (no response from the slave), since the value in the final CRC field is not valid for the combined messages.

7.8.4 Address Field

The address field of a message 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 recognise.) A master addresses a slave by placing the slave address in the address field of the message. 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 message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and slave. When a message 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 message. This tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter 7.8.10 Function Codes Supported by Modbus RTU* and *chapter 7.8.10 Modbus Exception Codes*

7.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00 to FF hexadecimal. These are made up of one RTU character. The data field of messages sent from a master to slave device contains additional information which the slave must use to take the action defined by the function code. This can include items such as coil or register addresses, the quantity of items to be handled, and the count of actual data bytes in the field.

7.8.7 CRC Check Field

Messages include an error-checking field, operating based on a cyclical redundancy check (CRC) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The CRC value is calculated by the transmitting device, which appends the CRC as the last field in the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the actual value received in the CRC field. If the 2 values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. When this is done, 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 message.

7.8.8 Coil Register Addressing

In Modbus, all data are organised 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 messages are referenced to zero. The first occurrence of a data item is addressed as item number zero. 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 message. 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 message. 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).

7

Coil Number	Description	Signal Direction
1-16	Frequency converter control word (see *Table 7.16*)	Master to slave
17-32	Frequency converter speed or set-point reference Range 0x0-0xFFFF (-200% ... ~200%)	Master to slave
33-48	Frequency converter status word (see *Table 7.17*)	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) 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.	Master to slave
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 freq.	No freeze freq.
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	Coasting 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 freq. range	In frequency range
44	Stopped	Running
45	Not used	Not used
46	No voltage warning	Voltage warning
47	Not in current limit	Current limit
48	No thermal warning	Thermal warning

Table 7.17 Frequency Converter Status Word (FC Profile)

Bus adress	Bus register[1]	PLC Register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for Legacy Drives VLT 5000 and VLT 2800.
1	2	40002	Reserved	–	Reserved for Legacy Drives VLT 5000 and VLT 2800.
2	3	40003	Reserved	–	Reserved for Legacy Drives VLT 5000 and VLT 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–
5	6	40006	Modbus conf	Read/Write	TCP only. Reserved for Modbus TCP (p12-28 and 12-29 - stored in Eeprom etc.).
6	7	40007	Last error code	Read only	Error code recieved 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	Sub index of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	FC par. 0-01	Dependent on parameter access	Parameter 0-01 (Modbus Register=10 parameter number 20 bytes space reserved pr parameter in Modbus map.
19	20	40020	FC par. 0-02	Dependent on parameter access	Parameter 0-02 20 bytes space reserved pr parameter in Modbus map.
29	30	40030	FC par. xx-xx	Dependent on parameter access	Parameter 0-03 20 bytes space reserved pr parameter in Modbus map.

Table 7.18 Adress/Registers

1) Value written in Modbus RTU telegram must be one or less than register number. E.g. Read Modbus Register 1 by writing value 0 in telegram.

7.8.9 How to Control the Frequency Converter

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

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

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

Table 7.19 Function Codes

Function	Function Code	Sub-function code	Sub-function
Diagnostics	8	1	Restart communication
		2	Return diagnostic register
		10	Clear counters and diagnostic register
		11	Return bus message count
		12	Return bus communi- cation error count
		13	Return slave error count
		14	Return slave message count

Table 7.20 Function Codes

7

MG18C602   95

7.8.10 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.
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 would succeed, 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 specifically 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 particular value of any particular 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 *3-12 Catch up/slow Down Value* (16bit): The holding register 3120 holds the parameters value. A value of 1352 (Decimal), means that the parameter is set to 12.52%

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

For information on the parameters, size and converting index, consult the product relevant programming guide.

7.9.2 Storage of Data

The coil 65 decimal determines whether data written to the frequency converter are 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 e.g. *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. Use a conversion factor to transfer decimals.

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 illustrate 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 message specifies the starting coil and quantity of coils to be read. Coil addresses start at zero, 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
No. of Points HI	00
No. of Points LO	10 (16 decimals)
Error Check (CRC)	-

Table 7.22 Query

Response
The coil status in the response message 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-orderin subsequent bytes.
If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte is padded with zeros (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 off-set of -1 in Modbus.
I.e. 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 message specifies the coil 65 (parameter write control) to be forced. Coil addresses start at zero, that is, coil 65 is addressed as 64. Force Data=00 00hex (OFF) or FF 00hex (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 message specifies the coils 17 to 32 (speed set-point) to be 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)
Byte Count	02
Force Data HI (Coils 8-1)	20
Force Data LO (Coils 16-9)	00 (ref.=2000 hex)
Error Check (CRC)	-

Table 7.26 Query

7

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 message specifies the starting register and quantity of registers to be read. Register addresses start at zero, that is, registers 1-4 are addressed as 0-3.

Example: Read *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)
No. of Points HI	00
No. of Points LO	02 - (*3-03 Maximum Reference* is 32 bits long, i.e. 2 registers)
Error Check (CRC)	-

Table 7.28 Query

Response

The register data in the response message are packed as 2 bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high-order bits and the second 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 message specifies the register reference to be preset. Register addresses start at zero, that is, register 1 is addressed as 0.

Example: Write to *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 message specifies the register references to be preset. Register addresses start at zero, that is, register 1 is addressed as 0. Example of a request to preset 2 registers (set *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
No. of Registers HI	00
No. 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
No. of Registers HI	00
No. of registers LO	02
Error Check (CRC)	-

Table 7.33 Response

7.11 Danfoss FC Control Profile

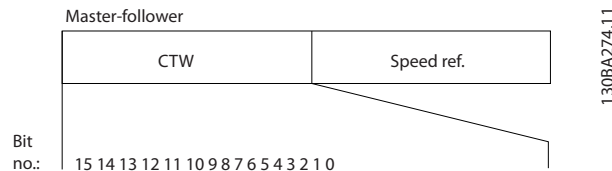### 7.11.1 Control Word According to FC Profile (8-10 Protocol = FC profile)

Illustration 7.14 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 7.34 Control Word According to FC Profile

Explanation of the control bits

Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *3-10 Preset Reference* according to the *Table 7.35*.

Programmed ref. value	Parameter	Bit 01	Bit 00
1	*3-10 Preset Reference* [0]	0	0
2	*3-10 Preset Reference* [1]	0	1
3	*3-10 Preset Reference* [2]	1	0
4	*3-10 Preset Reference* [3]	1	1

Table 7.35 Control Bits

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NOTICE

Make a selection in *8-56 Preset Reference Select* **to 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 *2-01 DC Brake Current* and *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: The frequency converter starts the motor if the other starting conditions are met.

Make a selection in *8-50 Coasting Select* to 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 *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 (*5-10 Terminal 18 Digital Input* to *5-13 Terminal 29 Digital Input*) programmed to *Speed up=21* and *Slow down=22*.

NOTICE

If Freeze output is active, the frequency converter can only be stopped by the following:

- **Bit 03 Coasting stop.**
- **Bit 02 DC braking.**
- **Digital input (*5-10 Terminal 18 Digital Input* to *5-13 Terminal 29 Digital Input*) programmed to *DC braking=5*, *Coasting stop=2*, or *Reset and coasting stop=3*.**

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: Permits the frequency converter to start the motor, if the other starting conditions are met.

Make a selection in *8-53 Start Select* to 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 signal's leading edge, that is, when changing from logic 0 to logic 1.

Bit 08, Jog

Bit 08=1: The output frequency is determined by *3-11 Jog Speed [Hz]*.

Bit 09, Selection of ramp 1/2

Bit 09=0: Ramp 1 is active (*3-41 Ramp 1 Ramp Up Time* to *3-42 Ramp 1 Ramp Down Time*).
Bit 09=1: Ramp 2 (*3-51 Ramp 2 Ramp Up Time* to *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. Turn off the control word if not wanting to use it when updating or reading parameters.

Bit 11, Relay 01

Bit 11=0: Relay not activated.
Bit 11=1: Relay 01 activated provided that *Control word bit 11=36* is selected in *5-40 Function Relay*.

Bit 12, Relay 02

Bit 12=0: Relay 02 is not activated.
Bit 12=1: Relay 02 is activated provided that *Control word bit 12=37* is chosen in *5-40 Function Relay*.

Bit 13, Selection of set-up

Use bit 13 to select from the 2 menu set-ups according to *Table 7.36*.

Set-up	Bit 13
1	0
2	1

The function is only possible when *Multi Set-Ups=9* is selected in *0-10 Active Set-up*.

Make a selection in *8-55 Set-up Select* to define how bit 13 gates with the corresponding function on the digital inputs.

Bit 15 Reverse

Bit 15=0: No reversing.
Bit 15=1: Reversing. In the default setting, reversing is set to digital in *8-54 Reversing Select*. Bit 15 causes reversing only when serial communication, *[2] Logic OR* or *[3] Logic AND* is selected.

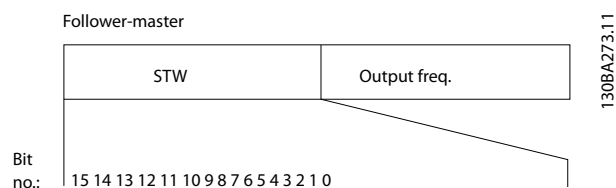## 7.11.2 Status Word According to FC Profile (STW) (*8-30 Protocol* = FC profile)

Illustration 7.15 Status Word

Bit	Bit=0	Bit=1
00	Control not ready	Control ready
01	Drive not ready	Drive 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	Drive OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 7.36 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 power supply (in case of external 24 V supply to controls).

Bit 01, Drive 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, Coasting 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 reference/speed=reference
Bit 08=0: The motor runs but the present speed is different from the preset speed reference. It might for example, be the case 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 activate on the control unit or *local control* in *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 *4-12 Motor Speed Low Limit [Hz]* or *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, Drive OK/stopped, autostart
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 normalises.

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 intermediate circuit is too low or too high.

Bit 14, Torque OK/limit exceeded
Bit 14=0: The motor current is lower than the current limit selected in *4-18 Current Limit*.
Bit 14=1: The current limit in *4-18 Current Limit* is exceeded.

Bit 15, Timer OK/limit exceeded
Bit 15=0: The timers for motor thermal protection and thermal protection are not exceeded 100%.
Bit 15=1: One of the timers exceeds 100%.

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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; in integers (0-32767) the value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted by means of 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.
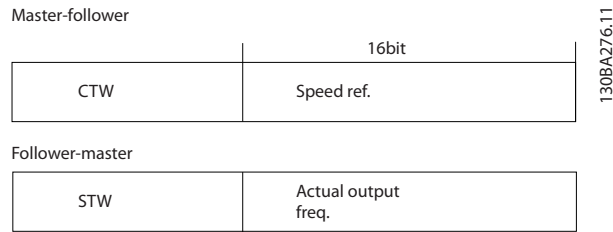

Illustration 7.16 Actual Output Frequency (MAV)
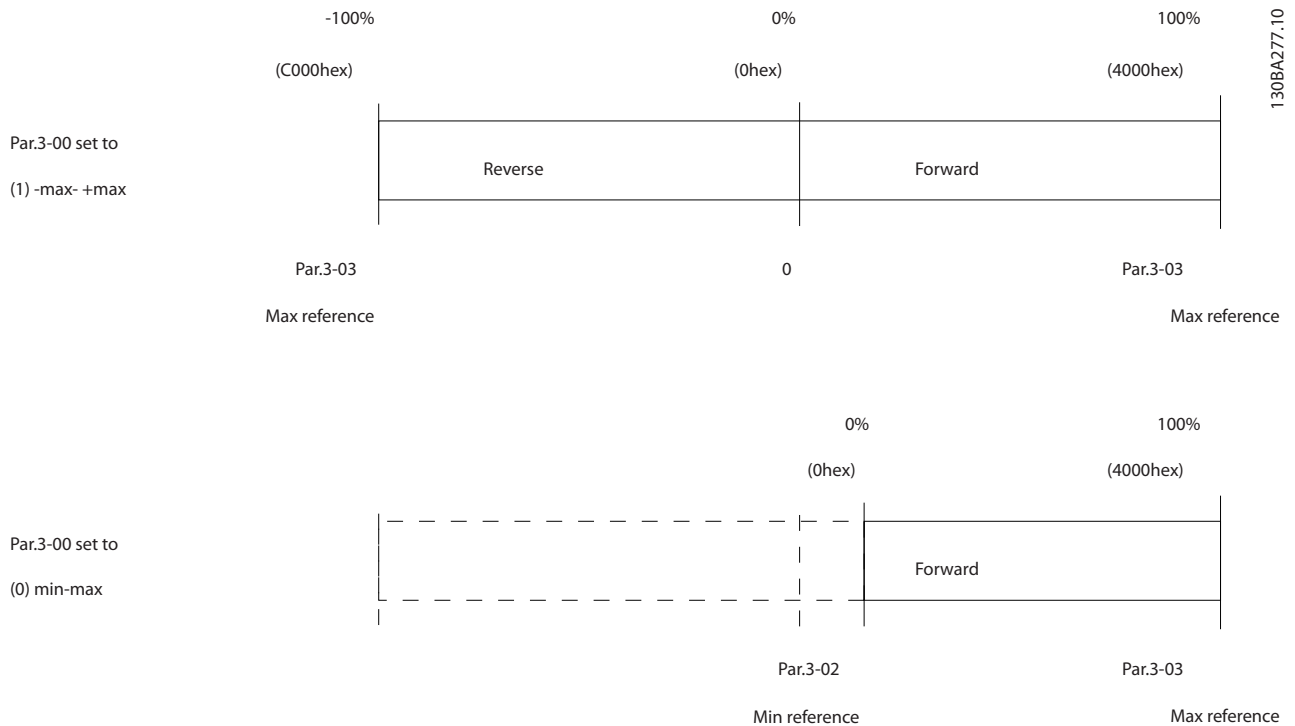
The reference and MAV are scaled as follows:

Illustration 7.17 Reference and MAV

8 General Specifications

8.1 Mains Supply Specifications

8.1.1 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
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^2 (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)
Output current															
40 °C (104 °F) ambient temperature															
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
Maximum input current															
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 5.2.4 Fuses and Circuit Breakers*														
Estimated power loss [W], Best case/typical[1]	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[2]	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
Output current															
50 °C (122 °F) ambient temperature															
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 8.1 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 www.danfoss.com/vltenergyefficiency.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.2.13 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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8.1.2 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
Protection rating IP20	H1	H1	H1	H2	H2	H2	H3	H3	H4	H4
Maximum cable size in terminals (mains, motor) [mm² (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)
Output current - 40 °C (104 °F) ambient temperature										
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
Maximum input current										
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 5.2.4 Fuses and Circuit Breakers*									
Estimated power loss [W], best case/typical[1]	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[2]	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
Output current - 50 °C (122 °F) ambient temperature										
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 8.2 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 www.danfoss.com/vltenergyefficiency.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.2.13 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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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
Protection rating IP20	H5	H5	H6	H6	H6	H7	H7	H8
Maximum cable size in terminals (mains, motor) [mm² (AWG)]	16 (6)	16 (6)	35 (2)	35 (2)	35 (2)	50 (1)	95 (0)	120 (250MCM)
Output current - 40 °C (104 °F) ambient temperature								
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
Maximum input current								
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								
Estimated power loss [W], best case/typical[1]	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[2]	98.1/97.9	98.1/97.9	97.8	97.7	98	98.2	97.8	97.9
Output current - 50 °C (122 °F) ambient temperature								
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 8.3 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 www.danfoss.com/vltenergyefficiency.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.2.13 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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Frequency converter	PK75	P1K5	P2K2	P3K0	P4KO	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
Protection rating IP54	I2	I2	I2	I2	I2	I3	I3	I4	I4	I4
Maximum cable size in terminals (mains, motor) [mm² (AWG)]	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	4 (10)	16 (6)	16 (6)	16 (6)
Output current										
40 °C (104 °F) ambient temperature										
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
Maximum input current										
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 5.2.4 Fuses and Circuit Breakers*									
Estimated power loss [W], best case/typical[1]	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[2]	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
Output current - 50 °C (122 °F) ambient temperature										
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 8.4 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 www.danfoss.com/vltenergyefficiency.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.2.13 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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
Protection rating IP54	I6	I6	I6	I7	I7	I8	I8
Maximum cable size in terminals (mains, motor) [mm^2 (AWG)]	35 (2)	35 (2)	35 (2)	50 (1)	50 (1)	95 (3/0)	120 (4/0)
Output current							
40 °C (104 ° F) ambient temperature							
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
Maximum input current							
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
Maximum mains fuses							
Estimated power loss [W], best case/typical[1]	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[2]	98.0	97.8	97.6	98.3	98.2	98.1	98.3
Output current - 50 °C (122 °F) ambient temperature							
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 8.5 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 www.danfoss.com/vltenergyefficiency.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.2.13 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

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8.1.3 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
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) [mm² (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)
Output current - 40 °C (104 ° F) ambient temperature															
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
Maximum input current															
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 5.2.4 Fuses and Circuit Breakers*														
Estimated power loss [W], best case/typical[1]	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[2]	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
Output current - 50 °C (122 °F) ambient temperature															
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 8.6 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 www.danfoss.com/vltenergyefficiency.

2) Efficiency measured at nominal current. For energy efficiency class, see chapter 8.2.13 Ambient Conditions. For part load losses, see www.danfoss.com/vltenergyefficiency.

8.2 General Technical Data

8.2.1 Protection and Features

- Electronic thermal motor protection against overload.

- Temperature monitoring of the heat sink ensures that the frequency converter trips in case of 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 intermediate circuit voltage ensures that the frequency converter trips when the intermediate circuit voltage is too low or too high.

- The frequency converter is protected against ground faults on motor terminals U, V, W.

8.2.2 Mains Supply (L1, L2, L3)

Supply voltage	200–240 V ±10%
Supply voltage	380–480 V ±10%
Supply voltage	525–600 V ±10%
Supply frequency	50/60 Hz
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor (λ)	≥0.9 nominal at rated load
Displacement power factor (cosφ) near unity	(>0.98)
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H1–H5, I2, I3, I4	Maximum 2 times/min.
Switching on the input supply L1, L2, L3 (power-ups) enclosure sizes H6–H8, I6–I8	Maximum 1 time/min.
Environment according to EN 60664-1	overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than 100000 A_{rms} symmetrical Amperes, 240/480 V maximum.

8.2.3 Motor Output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–200 Hz (VVC$^+$), 0–400 Hz (u/f)
Switching on output	Unlimited
Ramp times	0.05-3600 s

8.2.4 Cable Lengths and Cross-sections

Maximum motor cable length, screened/armoured (EMC correct installation)	See *chapter 3.4.3 EMC Emission Test Results*
Maximum motor cable length, unscreened/unarmoured	50 m
Maximum cross section to motor, mains[1]	
Cross-section DC terminals for filter feedback on enclosure sizes H1–H3, I2, I3, I4	4 mm^2/11 AWG
Cross-section DC terminals for filter feedback on enclosure sizes H4–H5	16 mm^2/6 AWG
Maximum cross-section to control terminals, rigid wire	2.5 mm^2/14 AWG
Maximum cross-section to control terminals, flexible cable	2.5 mm^2/14 AWG
Minimum cross-section to control terminals	0.05 mm^2/30 AWG

1) See *chapter 8.1.2 3x380–480 V AC* for more information

8.2.5 Digital Inputs

Programmable digital inputs	4
Terminal number	18, 19, 27, 29
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN	>19 V DC
Voltage level, logic 1 NPN	<14 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	Approximately 4 kΩ
Digital input 29 as 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.)

8.2.6 Analog Inputs

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

8.2.7 Analog Output

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

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

8.2.8 Digital Output

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

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

8.2.9 Control Card, RS485 Serial Communication

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

8.2.10 Control Card, 24 V DC Output

Terminal number	12
Maximum load	80 mA

8.2.11 Relay Output

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

1) IEC 60947 parts 4 and 5.

8.2.12 Control Card, 10 V DC Output

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

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8.2.13 Ambient Conditions

Enclosure	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[1]	See maximum output current at 40/50 °C in *chapter 8.1.2 3x380–480 V AC*
Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	-20 °C
Minimum ambient temperature at reduced performance	-10 °C
Temperature during storage/transport	-30 to +65/70 °C
Maximum altitude above sea level without derating	1000 m
Maximum altitude above sea level with derating	3000 m
Derating for high altitude, see	
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
EMC standards, Immunity	EN 61800-3, EN 61000-3-12, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6
Energy efficiency class	IE2

1) Refer to special conditions in the design guide for:

- *Derating for high ambient temperature.*

- *Derating for high altitude.*

2) Determined according to EN50598-2 at:

- *Rated load.*

- *90% rated frequency.*

- *Switching frequency factory setting.*

- *Switching pattern factory setting.*

8.3 dU/Dt

	Cable length [m(ft)]	AC line voltage [V]	Rise time [μsec]	V$_{peak}$ [kV]	dU/dt [kV/μsec]
	5 (16)	240	0.121	0.498	3.256
200 V 0.25 kW	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
	5 (16)	240	0.121	0.498	3.256
200 V 0.37 kW	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
	5 (16)	240	0.121	0.498	3.256
200 V 0.75 kW	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
	5 (16)	240	0.121	0.498	3.256
200 V 1.5 kW	25 (82)	240	0.182	0.615	2.706
	50 (164)	240	0.258	0.540	1.666
	5 (16)	240	0.18	0.476	2.115
200 V 2.2 kW	25 (82)	240	0.230	0.615	2.141
	50 (164)	240	0.292	0.566	1.550

	Cable length [m(ft)]	AC line voltage [V]	Rise time [µsec]	V_{peak} [kV]	dU/dt [kV/µsec]

	Cable length [m(ft)]	AC line voltage [V]	Rise time [µsec]	V_{peak} [kV]	dU/dt [kV/µsec]
200 V 3.7 kW	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	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	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	36 (118)	240	0.176	0.56	2.545
	50 (164)	240	0.216	0.599	2.204
400 V 0.37 kW	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	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	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	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	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 (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	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	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 11 kW	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	5 (16)	400	0.139	0.864	4.955
	50 (82)	400	0.338	1.008	2.365
400 V 18.5 kW	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	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

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	Cable length [m(ft)]	AC line voltage [V]	Rise time [μsec]	V~peak~ [kV]	dU/dt [kV/μsec]
400 V 30 kW	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	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	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	10 (33)	400	0.46	1.12	1.948
		480	0.468	1.3	2.222
400 V 75 kW	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	10 (33)	400	0.402	1.108	2.155
		400	0.408	1.288	2.529
		400	0.424	1.368	2.585
600 V 7.5 kW	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

Table 8.7 dU/Dt Data

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