



Design Guide

VLT[®] Decentral Drive FCD 302



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1 Introduction

1.1 How to Read the Design Guide

The design guide provides information required for integration of the frequency converter in a diversity of applications.

1.1.1 Additional Resources

- *VLT® Decentral Drive FCD 302 Operating Guide*, for information required to install and commission the frequency converter.
- *VLT® AutomationDrive FC 301/302 Programming Guide*, for information about how to program the unit, including complete parameter descriptions.
- *Modbus RTU Operating Instructions*, for the information required for controlling, monitoring, and programming the frequency converter via the built-in Modbus fieldbus.
- *VLT® PROFIBUS Converter MCA 114 Operating Instructions*, *VLT® EtherNet/IP MCA 121 Installation Guide*, and *VLT® PROFINET MCA 120 Installation Guide*, for information required for controlling, monitoring, and programming the frequency converter via a fieldbus.
- *VLT® Encoder Option MCB 102 Installation Instructions*.
- *VLT® AutomationDrive FC 300, Resolver Option MCB 103 Installation Instructions*.
- *VLT® AutomationDrive FC 300, Safe PLC Interface Option MCB 108 Installation Instructions*.
- *VLT® Brake Resistor MCE 101 Design Guide*.
- *VLT® Frequency Converters Safe Torque Off Operating Guide*.
- Approvals.

Technical literature and approvals are available online at www.danfoss.com/en/search/?filter=type%3Adocumentation%2Csegment%3AAdd.

The following symbols are used in this manual:



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



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



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

The following conventions are used in this manual:

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

1.2 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome. *Table 1.1* shows the document version and the corresponding software version.

Edition	Remarks	Software version
MG04H3xx	EMC-correct Installation has been updated.	7.5x

Table 1.1 Document and Software Version

1.3 Definitions

1.3.1 Frequency Converter

$I_{VLT,MAX}$
Maximum output current.

$I_{VLT,N}$
Rated output current supplied by the frequency converter.

$U_{VLT,MAX}$
Maximum output voltage.

1.3.2 Input

Control command

Start and stop the connected motor with LCP and digital inputs.

Functions are divided into 2 groups.

Functions in group 1 have higher priority than functions in group 2.

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

Table 1.2 Function Groups

1.3.3 Motor

Motor running

Torque generated on output shaft and speed from 0 RPM to maximum speed on motor.

f_{JOG}

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

f_M

Motor frequency.

f_{MAX}

Maximum motor frequency.

f_{MIN}

Minimum motor frequency.

$f_{M,N}$

Rated motor frequency (nameplate data).

I_M

Motor current (actual).

$I_{M,N}$

Rated motor current (nameplate data).

$n_{M,N}$

Nominal motor speed (nameplate data).

n_s

Synchronous motor speed.

$$n_s = \frac{2 \times par. 1 - 23 \times 60 s}{par. 1 - 39}$$

n_{slip}

Motor slip.

$P_{M,N}$

Rated motor power (nameplate data in kW or hp).

$T_{M,N}$

Rated torque (motor).

U_M

Instant motor voltage.

$U_{M,N}$

Rated motor voltage (nameplate data).

Break-away torque

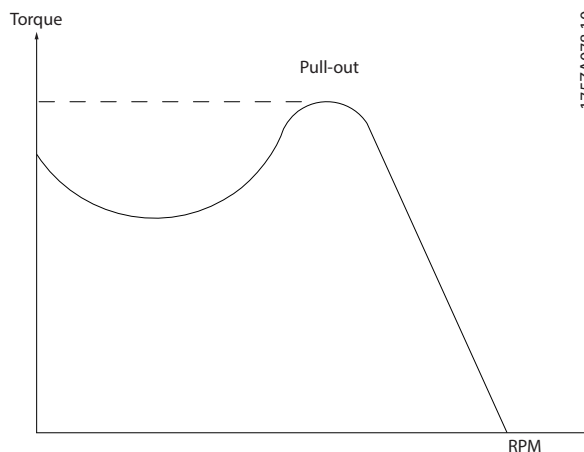


Figure 1.1 Break-away Torque

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 Group 1 control commands - see Table 1.2.

Stop command

A stop command belonging to Group 1 control commands - see Table 1.2.

1.3.4 References

Analog reference

A signal transmitted to the analog inputs 53 or 54 (voltage or current).

Binary reference

A signal transmitted to the serial communication 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.

Pulse reference

A pulse frequency signal transmitted to the digital inputs (terminal 29 or 33).

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 is set in parameter 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 is set in *parameter 3-02 Minimum Reference*.

1.3.5 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, -10 V DC to +10 V DC.

Analog outputs

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

Automatic motor adaptation, AMA

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

Brake resistor

The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative brake power increases the DC-link voltage and a brake chopper ensures that the power is transmitted to the brake resistor.

CT characteristics

Constant torque characteristics used for all applications such as conveyor belts, displacement pumps, and cranes.

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 (maximum 40 mA) signal.

DSP

Digital signal processor.

ETR

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

Hiperface®

Hiperface® is a registered trademark by Stegmann.

Initializing

If initializing is carried out (*parameter 14-22 Operation Mode*), the frequency converter returns to the default setting.

Intermittent duty cycle

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

LCP

The local control panel makes up a complete interface for control and programming of the frequency converter. The control panel is detachable and can be installed up to 3 m (10 ft) from the frequency converter, that is, in a front panel with the installation kit option.

lsb

Least significant bit.

msb

Most significant bit.

MCM

Short for mille circular mil, an American measuring unit for cable cross-section. 1 MCM=0.5067 mm².

Online/offline parameters

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

Process PID

The PID control maintains the required speed, pressure, temperature, and so on, by adjusting the output frequency to match the varying load.

PCD

Process control data.

Power cycle

Switch off the mains until display (LCP) is dark, then turn power on again.

Pulse input/incremental encoder

An external, digital pulse transmitter used for feeding back information on motor speed. The encoder is used in applications where great accuracy in speed control is required.

RCD

Residual current device.

Set-up

Save parameter settings in 4 set-ups. Change between the 4 parameter set-ups and edit 1 set-up, while another set-up is active.

SFAVM

Switching pattern called stator flux-oriented asynchronous vector modulation (*parameter 14-00 Switching Pattern*).

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.

SLC

The SLC (smart logic control) is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC. (See *chapter 4.9.1 Smart Logic Controller*).

STW

Status word.

FC standard bus

Includes RS485 bus with FC protocol or MC protocol. See *parameter 8-30 Protocol*.

THD

Total harmonic distortion states the total contribution of harmonic.

Thermistor

A temperature-dependent resistor placed on the frequency converter or the motor.

Trip

A state entered in fault situations, for example if the frequency converter is subject to an overtemperature or when the frequency converter is protecting the motor, process, or mechanism. The frequency converter prevents a restart until the cause of the fault has disappeared. To cancel the trip state, restart the frequency converter. Do not use the trip state for personal safety.

Trip lock

The frequency converter enters this state in fault situations to protect itself. The frequency converter requires physical intervention, for example when there is a short circuit on the output. A trip lock can only be canceled by disconnecting mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use the trip lock state 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.

60° AVM

60° asynchronous vector modulation
(*parameter 14-00 Switching Pattern*).

Power factor

The power factor is the relation between I_1 and I_{RMS} .

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

The power factor for 3-phase control:

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

The power factor indicates to which extent the frequency converter imposes a load on the mains supply.

The lower the power factor, the higher the I_{RMS} for the same kW performance.

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

In addition, a high-power factor indicates that the different harmonic currents are low.

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

Target position

The final target position specified by positioning commands. The profile generator uses this position to calculate the speed profile.

Commanded position

The actual position reference calculated by the profile generator. The frequency converter uses the commanded position as setpoint for position PI.

Actual position

The actual position from an encoder, or a value that the motor control calculates in open loop. The frequency converter uses the actual position as feedback for position PI.

Position error

Position error is the difference between the actual position and the commanded position. The position error is the input for the position PI controller.

Position unit

The physical unit for position values.

1.4 Safety Precautions

⚠ WARNING

The voltage of the frequency converter is dangerous whenever connected to mains. Correct planning of the installation of the motor, frequency converter, and fieldbus are necessary. Follow the instructions in this manual, and the national and local rules and safety regulations. Failure to follow design recommendations could result in death, serious personal injury, or damage to the equipment once in operation.

⚠ WARNING

HIGH VOLTAGE

Touching the electrical parts may be fatal - even after the equipment has been disconnected from mains. In planning, ensure that other voltage inputs can be disconnected, such as external 24 V DC, load sharing (linkage of DC intermediate circuit), and the motor connection for kinetic back-up. Systems where frequency converters are installed must, if necessary, be equipped with additional monitoring and protective devices according to the valid safety regulations, for example law on mechanical tools, regulations for the prevention of accidents, and so on. Modifications on the frequency converters by means of the operating software are allowed. Failure to follow design recommendations, could result in death or serious injury once the equipment is in operation.

NOTICE!

Hazardous situations have to be identified by the machine builder/integrator who is responsible for taking necessary preventive means into consideration. Additional monitoring and protective devices may be included, always according to valid national safety regulations, for example, law on mechanical tools, regulations for the prevention of accidents.

NOTICE!

Crane, lifts, and hoists:

The controlling of external brakes must always be designed with a redundant system. The frequency converter can in no circumstances be the primary safety circuit. Comply with relevant standards, for example.

Hoists and cranes: IEC 60204-32

Lifts: EN 81

Protection mode

Once a hardware limit on motor current or DC-link voltage is exceeded, the frequency converter enters protection mode. Protection mode means a change of the PWM modulation strategy and a low switching frequency to minimize losses. This continues 10 s after the last fault and increases the reliability and the robustness of the frequency converter while re-establishing full control of the motor.

In hoist applications, protection mode is not usable because the frequency converter is usually unable to leave this mode again and therefore it extends the time before activating the brake - which is not recommended.

The protection mode can be disabled by setting *parameter 14-26 Trip Delay at Inverter Fault* to 0 which means that the frequency converter trips immediately if 1 of the hardware limits is exceeded.

NOTICE!

Disable protection mode in hoisting applications (*parameter 14-26 Trip Delay at Inverter Fault=0*).

⚠ WARNING

DISCHARGE TIME

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

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

Voltage [V]	Minimum waiting time (minutes)		
	4	7	15
200–240	0.25–3.7 kW (0.34–5 hp)	–	5.5–37 kW (7.5–50 hp)
380–500	0.25–7.5 kW (0.34–10 hp)	–	11–75 kW (15–100 hp)
525–600	0.75–7.5 kW (1–10 hp)	–	11–75 kW (15–100 hp)
525–690	–	1.5–7.5 kW (2–10 hp)	11–75 kW (15–100 hp)

Table 1.3 Discharge Time

1.5 CE Labeling

CE labeling is a positive feature when used for its original purpose, that is, to facilitate trade within the EU and EFTA.

However, CE labeling may cover many different specifications. Check what a given CE label specifically covers.

The specifications can vary greatly. A CE label may therefore give the installer a false sense of security when using a frequency converter as a component in a system or an appliance.

Danfoss CE labels the frequency converters in accordance with the Low Voltage Directive. This means that if the frequency converter is installed correctly, compliance with the Low Voltage Directive is achieved. Danfoss issues a declaration of conformity that confirms CE labeling in accordance with the Low Voltage Directive.

The CE label also applies to the EMC directive, if the instructions for EMC-correct installation and filtering are followed. On this basis, a declaration of conformity in accordance with the EMC directive is issued.

The design guide offers detailed instructions for installation to ensure EMC-correct installation.

1.5.1 Conformity

The Machinery Directive (2006/42/EC)

Frequency converters do not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, Danfoss provides information on safety aspects relating to the frequency converter.

What is CE conformity and labeling?

The purpose of CE labeling is to avoid technical trade obstacles within EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Frequency converters are regulated by 2 EU directives:

The Low Voltage Directive (2014/35/EU)

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

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

The EMC Directive (2014/30/EU)

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

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

The frequency converter is most often used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation.

1.5.2 What Is Covered?

The EU EMC Directive 2014/30/EU outline 3 typical situations of using a frequency converter. See below for EMC coverage and CE labeling.

- The frequency converter is sold directly to the end user. The frequency converter is for example sold to a do-it-yourself market. The end user is a layman, installing the frequency converter for use with a hobby machine, a kitchen appliance, and so on. For such applications, the frequency converter must be CE labeled in accordance with the EMC directive.
- The frequency converter is sold for installation in a plant. The plant is built up by professionals of the trade. It could be a production plant or a heating/ventilation plant designed and installed by professionals of the trade. The frequency converter and the finished plant do not have to be CE labeled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. This is ensured by using components, appliances, and systems that are CE labeled under the EMC directive.
- The frequency converter is sold as part of a complete system. The system is marketed as complete, for example an air-conditioning system. The complete system must be CE labeled in accordance with the EMC directive. The manufacturer can ensure CE labeling under the EMC directive either by using CE labeled components or by testing the EMC of the system. If only CE labeled components are used, it is unnecessary to test the entire system.

1.6 Compliance with EMC Directive 2004/108/EC

The frequency converter is mostly used by professionals of the trade as a complex component forming part of a larger appliance, system, or installation.

NOTICE!

The responsibility for the final EMC properties of the appliance, system, or installation rests with the installer.

As an aid to the installer, Danfoss has prepared EMC installation guidelines for the power drive system. The standards and test levels stated for power drive systems are complied with, if the EMC-correct instructions for installation are followed, see *chapter 2.9.4 EMC*.

1.7 Approvals



Table 1.4 FCD 302 Approvals

The frequency converter complies with UL 508C thermal memory retention requirements. For more information, refer to *chapter 3.4.3.2 Motor Thermal Protection*.

1.8 Disposal

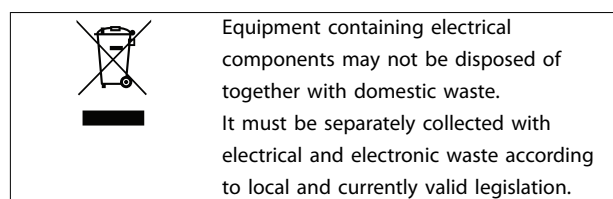


Table 1.5 Disposal Instruction

2 Product Overview and Functions

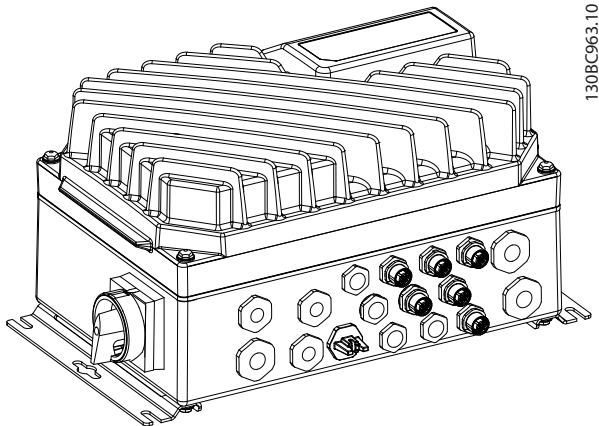


Figure 2.1 Small Unit

relevant creepage/clearance distances. These requirements are described in the EN 61800-5-1 standard.

The components that make up the electrical isolation, as described in Figure 2.3, 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 6 locations (see Figure 2.3).

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

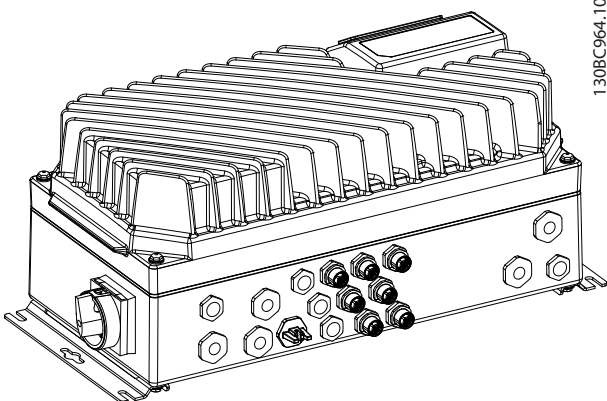
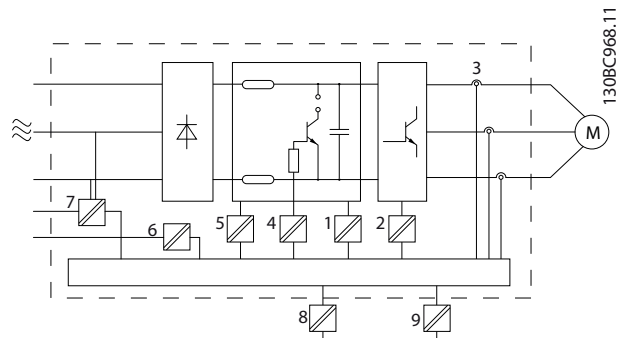


Figure 2.2 Large Unit



1	Power supply (SMPS) including signal isolation of U_{bc} , indicating the voltage of intermediate DC Link circuit.
2	Gate drive that runs the IGBTs (trigger transformers/opto-couplers).
3	Current transducers.
4	Opto-coupler, brake module.
5	Internal inrush, RFI, and temperature measurement circuits.
6	Custom relays.
7	Mechanical brake.
8	Functional galvanic isolation for the 24 V back-up option and for the RS485 standard bus interface.
9	Functional galvanic isolation for the 24 V back-up option and for the RS485 standard bus interface.

Figure 2.3 Galvanic Isolation

2.1 Galvanic Isolation (PELV)

2.1.1 PELV - Protective Extra Low Voltage

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

All control terminals and relay terminals 01–03/04–06 comply with PELV (protective extra low voltage), except for grounded delta leg above 400 V.

Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the

NOTICE!

Installation at high altitude:

380–500 V: At altitudes above 2000 m (6561 ft), contact Danfoss regarding PELV.

2.1.2 Ground Leakage Current

Follow national and local codes regarding protective grounding of equipment with a leakage current >3.5 mA. Frequency converter technology implies high frequency switching at high power. This generates a leakage current in the ground connection. A fault current in the frequency converter at the output power terminals might contain a DC component which can charge the filter capacitors and cause a transient ground current.

The leakage current also depends on the line distortion.

NOTICE!

When a filter is used, turn off *parameter 14-50 RFI Filter* when charging the filter, to avoid that a high leakage current makes the RCD switch.

EN/IEC61800-5-1 (power drive system product standard) requires special care if the leakage current exceeds 3.5 mA. Grounding must be reinforced in 1 of the following ways:

- Ground wire (terminal 95) of at least 10 mm² (7 AWG). This requires a PE adapter (available as an option).
- Two separate ground wires both complying with the dimensioning rules.

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

Using RCDs

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

- Use RCDs of type B, which are capable of detecting AC and DC currents.
- Use RCDs with an inrush delay to prevent faults due to transient ground currents.
- Dimension RCDs according to the system configuration and environmental considerations.

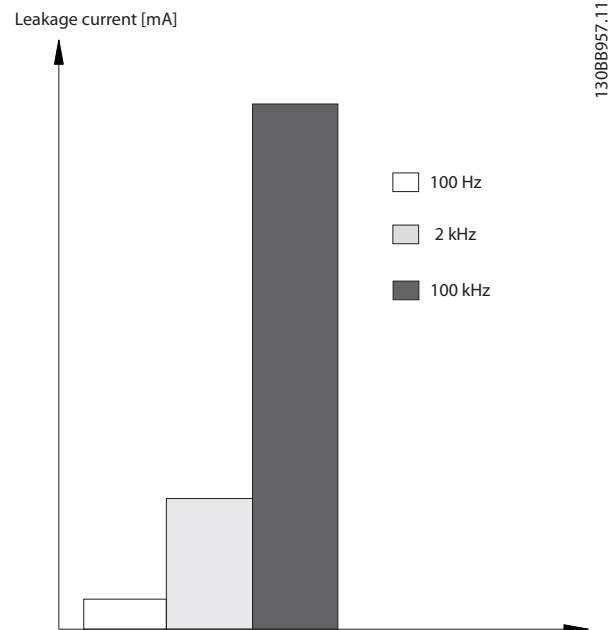


Figure 2.4 Influence of Cut-off Frequency of the RCD

See also *RCD Application Note*.

2.2 Control

A frequency converter rectifies AC voltage from mains into DC voltage. This DC voltage is converted into an AC current with a variable amplitude and frequency.

The motor is supplied with variable voltage, current, and frequency, which enables infinitely variable speed control of 3-phased, standard AC motors and permanent magnet synchronous motors.

The VLT® Decentral Drive FCD 302 frequency converter is designed for installations of multiple smaller frequency converters, especially on conveyor applications, for example, in the food and beverage industries and materials handling. In installations where multiple motors are spread around a facility such as bottling plants, food preparation, packaging plants, and airport baggage handling installations, there may be dozens, perhaps hundreds, of frequency converters, working together but spread over a large physical area. In these cases, cabling costs alone outweigh the cost of the individual frequency converters and it makes sense to get the control closer to the motors.

The frequency converter can control either the speed or the torque on the motor shaft.

Speed control

Two types of speed control:

- Speed open-loop control, which does not require any feedback from the motor (sensorless).
- Speed closed-loop PID control, which requires a speed feedback to an input. A properly optimized speed closed-loop control is more accurate than a speed open-loop control.

Torque control

The torque control function is used in applications where the torque on motor output shaft controls the application as tension control.

- Closed loop in flux mode with encoder feedback comprises motor control based on feedback signals from the system. It improves performance in all 4 quadrants and at all motor speeds.
- Open loop in VVC⁺ mode. The function is used in mechanical robust applications, but the accuracy is limited. Open-loop torque function works only

in 1 speed direction. The torque is calculated on basis of current measurement internal in the frequency converter. See application example *chapter 2.3.1 Control Structure in VVC⁺ Advanced Vector Control*.

Speed/torque reference

The reference to these controls can either be a single reference or be the sum of various references including relatively scaled references. The handling of references is explained in detail in *chapter 2.6 Handling of Reference*.

2.2.1 Control Principle

The frequency converter is compatible with various motor control principles such as U/f special motor mode, VVC⁺, or flux vector motor control.

In addition, the frequency converter is operable with permanent magnet synchronous motors (brushless servo motors) and normal squirrel lift cabin asynchronous motors.

The short circuit behavior depends on the 3 current transducers in the motor phases and the desaturation protection with feedback from the brake.

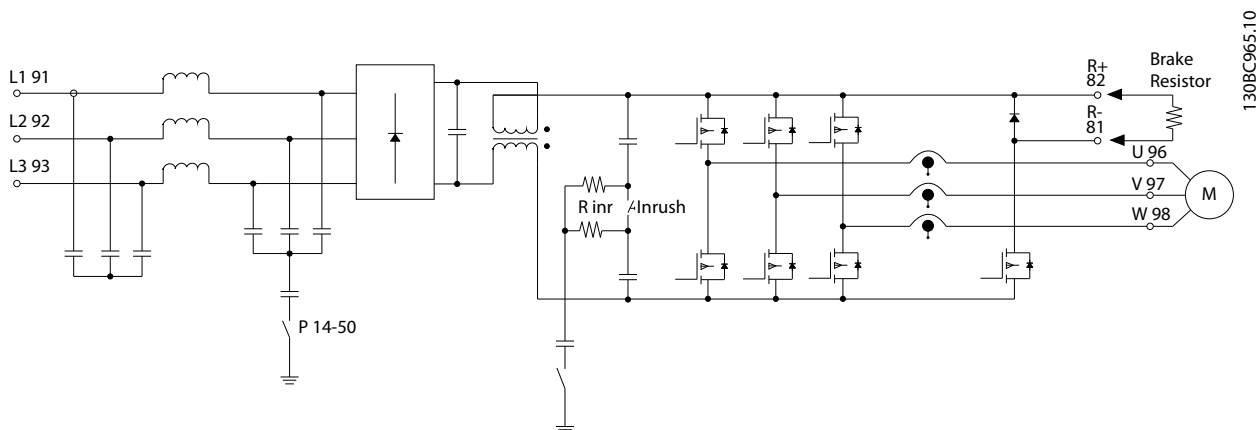


Figure 2.5 Control Principle

2.2.2 Internal Current Control in VVC+ Mode

The frequency converter features an integral current limit control which is activated when the motor current, and thus the torque, is higher than the torque limits set in *parameter 4-16 Torque Limit Motor Mode*, *parameter 4-17 Torque Limit Generator Mode*, and *parameter 4-18 Current Limit*.

When the frequency converter is at the current limit during motor operation or regenerative operation, it reduces torque to below the preset torque limits as quickly as possible without losing control of the motor.

2.3 Control Structures

2.3.1 Control Structure in VVC+ Advanced Vector Control

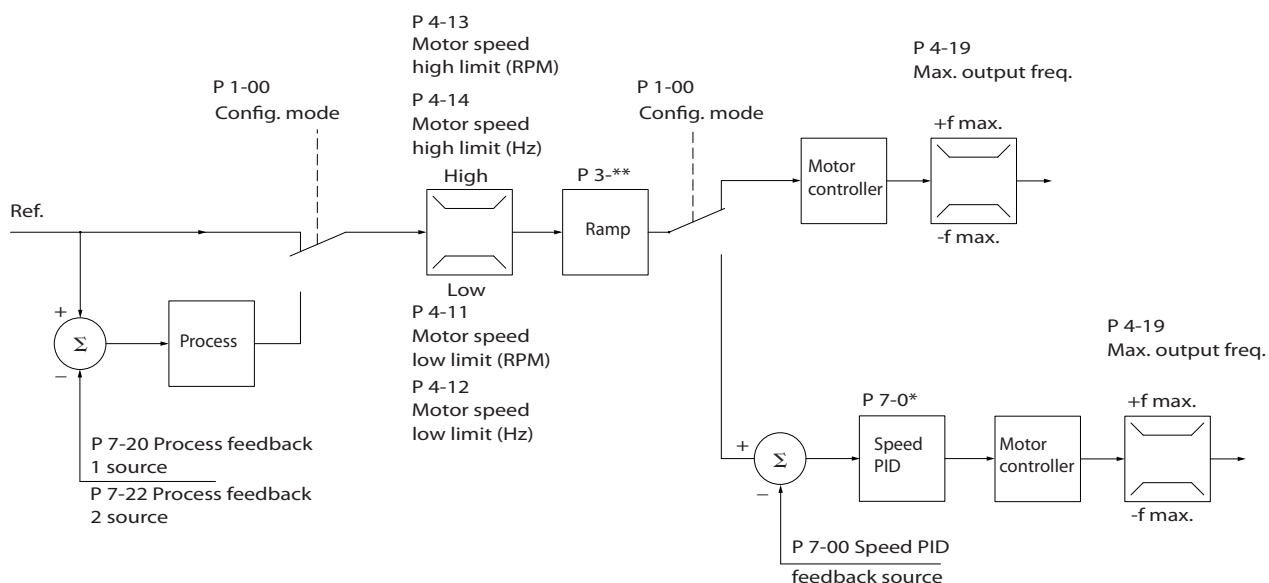


Figure 2.6 Control Structure in VVC+ Open-loop and Closed-loop Configurations

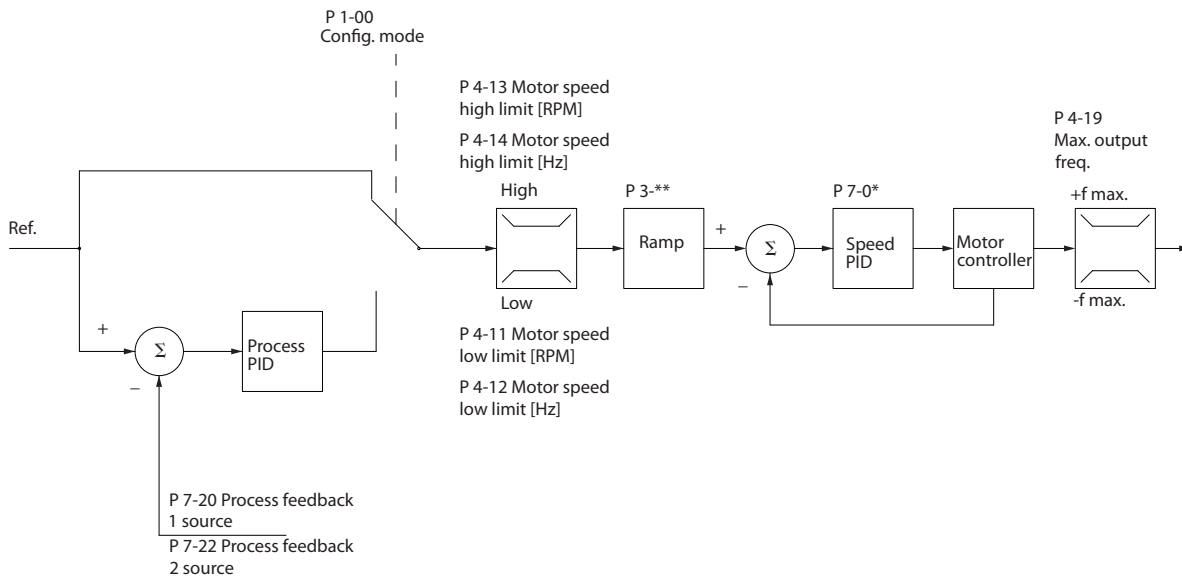
In the configuration shown in *Figure 2.6*, *parameter 1-01 Motor Control Principle* is set to [1] VVC+ and *parameter 1-00 Configuration Mode* is set to [0] Speed open loop. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

If *parameter 1-00 Configuration Mode* is set to [1] Speed closed loop, the resulting reference passes from the ramp limitation and speed limitation into a speed PID control. The speed PID control parameters are in the *parameter group 7-0* Speed PID Ctrl*. The resulting reference from the speed PID control is sent to the motor control limited by the frequency limit.

Select [3] Process in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of, for example, speed or pressure in the controlled application. The process PID parameters are in *parameter group 7-2* Process Ctrl. Feedb* and *parameter group 7-3* Process PID Ctrl*.

2.3.2 Control Structure in Flux Sensorless

Control structure in flux sensorless open-loop and closed-loop configurations.



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Figure 2.7 Control Structure in Flux Sensorless

In the configuration shown, *parameter 1-01 Motor Control Principle* is set to [2] *Flux Sensorless* and *parameter 1-00 Configuration Mode* is set to [0] *Speed open loop*. The resulting reference from the reference handling system is fed through the ramp and speed limitations as determined by the parameter settings indicated.

An estimated speed feedback is generated to the speed PID to control the output frequency. The speed PID must be set with its P, I, and D parameters (*parameter group 7-0* Speed PID Ctrl.*).

Select [3] *Process* in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of speed or pressure in the controlled application. The process PID parameters are in *parameter group 7-2* Process Ctrl. Feedb.* and *parameter group 7-3* Process PID Ctrl.*

2.3.3 Control Structure in Flux with Motor Feedback

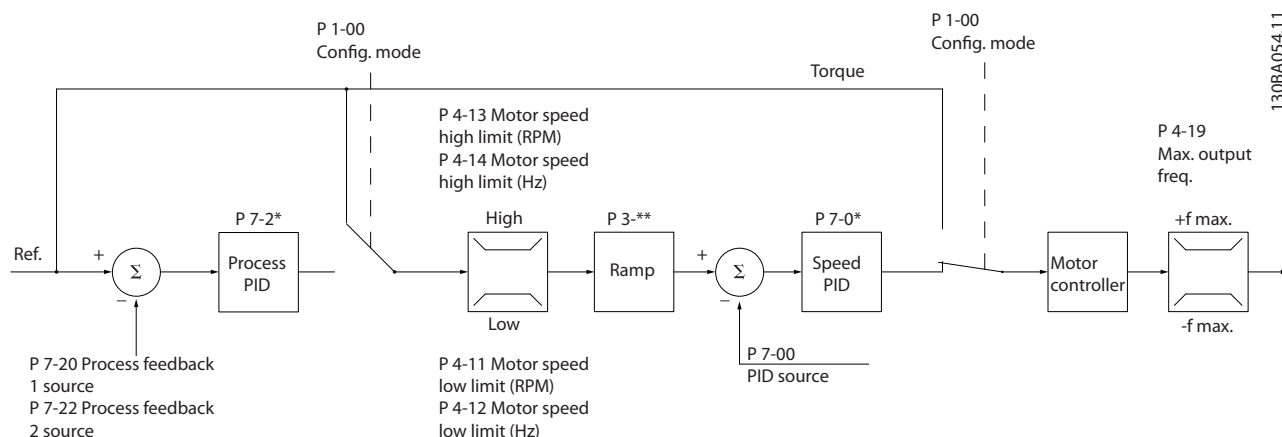


Figure 2.8 Control Structure in Flux with Motor Feedback

In the configuration shown, *parameter 1-01 Motor Control Principle* is set to [3] Flux w motor feedb and *parameter 1-00 Configuration Mode* is set to [1] Speed closed loop.

The motor control in this configuration relies on a feedback signal from an encoder mounted directly on the motor (set in *parameter 1-02 Flux Motor Feedback Source*).

Select [1] Speed closed loop in *parameter 1-00 Configuration Mode* to use the resulting reference as an input for the speed PID control. The speed PID control parameters are located in *parameter group 7-0* Speed PID Ctrl*.

Select [2] Torque in *parameter 1-00 Configuration Mode* to use the resulting reference directly as a torque reference. Torque control can only be selected in the [3] Flux with motor feedback (*parameter 1-01 Motor Control Principle*) configuration. When this mode has been selected, the reference uses the Nm unit. It requires no torque feedback, since the actual torque is calculated based on the current measurement of the frequency converter.

Select [3] Process in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of a process variable (for example, speed) in the controlled application.

2.3.4 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 and digital inputs and fieldbus. If allowed in *parameter 0-40 [Hand on] Key on LCP*, *parameter 0-41 [Off] Key on LCP*, *parameter 0-42 [Auto on] Key on LCP*, and *parameter 0-43 [Reset] Key on LCP*, it is possible to start and stop the frequency converter via the LCP using the [Hand On] and [Off] keys. Alarms can be reset via the [Reset] key. After pressing the [Hand On] key, the frequency converter goes into hand-on mode and follows (as default) the local reference that can be set using the navigation keys on the LCP.

After pressing the [Auto On] key, the frequency converter goes into auto-on mode and follows (as default) the remote reference. In this mode, it is possible to control the frequency converter via the digital inputs and various serial interfaces (RS485, USB, or an optional fieldbus). See more about starting, stopping, changing ramps, parameter set-ups, and so on, in *parameter group 5-1* Digital Inputs* or *parameter group 8-5* Digital/Bus*.

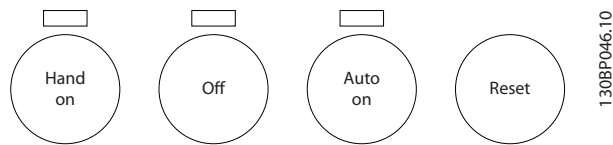


Figure 2.9 LCP Keys

Active reference and configuration mode

The active reference can be either the local reference or the remote reference.

In *parameter 3-13 Reference Site*, the local reference can be permanently selected by selecting [2] Local. For permanent setting of the remote reference, select [1] Remote. By selecting [0] Linked to Hand/Auto (default), the reference site links to the active mode (hand-on mode or auto-on Mode).

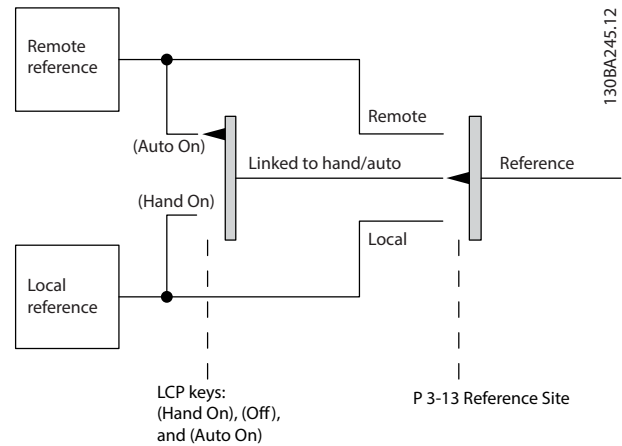
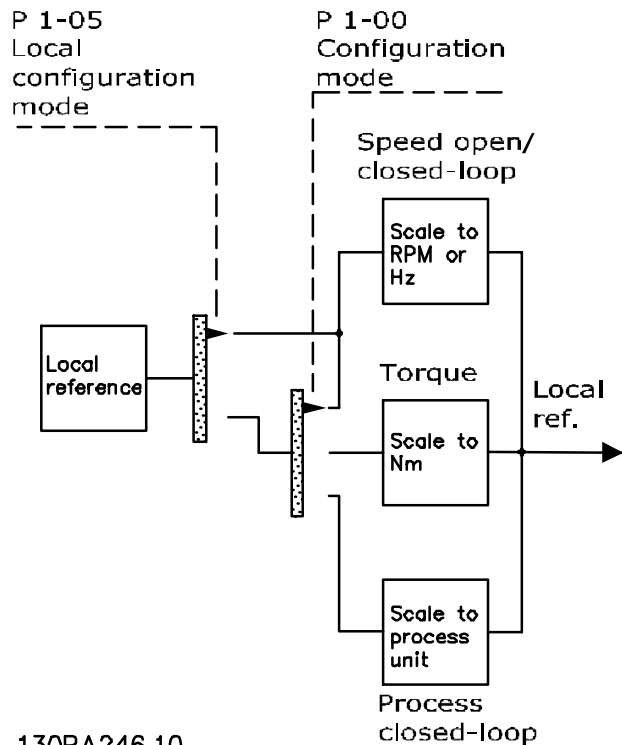


Figure 2.10 Local Handling of Reference



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Figure 2.11 Remote Handling of Reference

LCP keys	Parameter 3-13 Reference Site	Active reference
Hand	Linked to Hand/Auto	Local
Hand⇒Off	Linked to Hand/Auto	Local
Auto	Linked to Hand/Auto	Remote
Auto⇒Off	Linked to Hand/Auto	Remote
All keys	Local	Local
All keys	Remote	Remote

Table 2.1 Conditions for Local/Remote Handling of Reference

Parameter 1-00 Configuration Mode determines what type of application control principle (that is, speed, torque, or process control) is used when the remote reference is active. Parameter 1-05 Local Mode Configuration determines the type of application control principle that is used when the local reference is active. One of them is always active, but both cannot be active at the same time.

2.3.5 Programming of Torque Limit and Stop

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the frequency converter via a standard stop command and simultaneously activate the external electro-mechanical brake.

The example given below, illustrates the programming of the frequency converter connections.

The external brake can be connected to relay 1 or 2. Program parameter 5-01 Terminal 27 Mode to [2] Coast, inverse or [3] Coast and Reset, inverse, and program parameter 5-02 Terminal 29 Mode to [1] Output and [27] Torque limit & stop.

Description

If a stop command is active via terminal 18, and the frequency converter is not at the torque limit, the motor ramps down to 0 Hz.

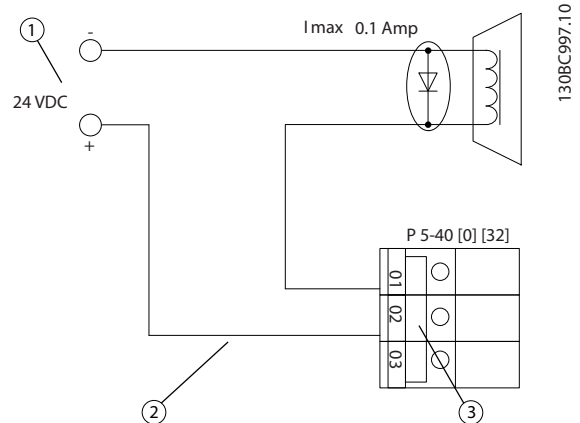
If the frequency converter is at the torque limit and a stop command is activated, parameter 5-31 Terminal 29 digital Output (programmed to [27] torque limit and stop) is activated. The signal to terminal 27 changes from logic 1 to logic 0, and the motor starts to coast. The coast ensures that the hoist stops even if the frequency converter itself cannot handle the required torque (that is, due to excessive overload).

- Start/stop via terminal 18
Parameter 5-10 Terminal 18 Digital Input [8] Start
- Quick stop via terminal 27
Parameter 5-12 Terminal 27 Digital Input [2] Coast Stop, inverse
- Terminal 29 output

Parameter 5-02 Terminal 29 Mode [1] Terminal 29 Mode Output

Parameter 5-31 Terminal 29 digital Output [27] Torque Limit & Stop

- [0] Relay output (relay 1)
Parameter 5-40 Function Relay [32] Mechanical Brake Control



Item	Description
1	External 24 V DC
2	Mechanical brake connection
3	Relay 1

Figure 2.12 Mechanical Brake Control

2.4 PID Control

2.4.1 Speed PID Control

Parameter 1-00 Configu- ration Mode	Parameter 1-01 Motor Control Principle			
	U/f	VVC ⁺	Flux sensorless	Flux w/ encoder feedback
[0] Speed open loop	Not active ¹⁾	Not active ¹⁾	Active	–
[1] Speed closed loop	–	Active	–	Active
[2] Torque	–	–	–	Not active ¹⁾
[3] Process	–	Not active ¹⁾	Active	Active

Table 2.2 Control Configurations where the Speed Control is Active

1) "Not active" means that the specific mode is available, but the speed control is not active in that mode.

NOTICE!

The speed PID control works under the default parameter setting, but tuning the parameters is highly recommended to optimize the motor control performance. The 2 flux motor control principles are particularly dependent on proper tuning to yield their full potential.

2.4.2 Parameters Relevant for Speed Control

Parameter	Description of function	
Parameter 7-00 Speed PID Feedback Source	Select from which input the speed PID should get its feedback.	
Parameter 30-83 Speed PID Proportional Gain	The higher the value - the quicker the control. However, too high value may lead to oscillations.	
Parameter 7-03 Speed PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too low value may lead to oscillations.	
Parameter 7-04 Speed PID Differentiation Time	Provides a gain proportional to the rate of change of the feedback. A setting of 0 disables the differentiator.	
Parameter 7-05 Speed PID Diff. Gain Limit	If there are quick changes in reference or feedback in a given application, which means that the error changes swiftly, the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes and a suitably quick gain for quick changes.	
Parameter 7-06 Speed PID Lowpass Filter Time	A low-pass filter that dampens oscillations on the feedback signal and improves steady state performance. However, too large filter time deteriorates the dynamic performance of the speed PID control. Practical settings of <i>parameter 7-06 Speed PID Lowpass Filter Time</i> taken from the number of pulses per revolution from encoder (PPR):	
	Encoder PPR	Parameter 7-06 Speed PID Lowpass Filter Time
	512	10 ms
	1024	5 ms
	2048	2 ms
4096	1 ms	

Table 2.3 Parameters Relevant for Speed Control

Example of how to program the speed control

In this case, the speed PID control is used to maintain a constant motor speed regardless of the changing load on the motor. The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0–1500 RPM corresponding to 0–10 V over the potentiometer. Starting and stopping is controlled by a switch connected to terminal 18. The speed PID monitors the actual RPM of the motor by using a 24 V (HTL) incremental encoder as feedback. The feedback sensor is an encoder (1024 pulses per revolution) connected to terminals 32 and 33.

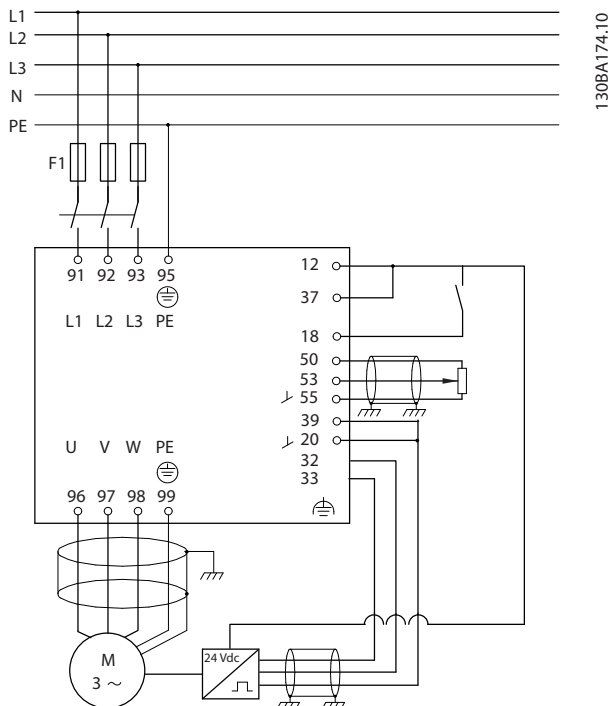


Figure 2.13 Example - Speed Control Connections

The following must be programmed in the order shown (see explanation of settings in the *VLT® AutomationDrive FC 301/FC 302 Programming Guide*)

In the list, it is assumed that all other parameters and switches remain at their default setting.

Function	Parameter	Setting
1) Make sure that the motor runs properly. Do the following:		
Set the motor parameters using nameplate data.	<i>Parameter group 1-2* Motor Data</i>	As specified on motor nameplate.
Perform an automatic motor adaptation.	<i>Parameter 1-29 Auto matic Motor Adaptation (AMA)</i>	[1] Enable complete AMA.
2) Check that the motor is running and that the encoder is attached properly. Do the following:		
Press the [Hand On] LCP key. Check that the motor is running and note in which direction it is turning (referred to as the positive direction).	–	Set a positive reference.
Go to <i>parameter 16-20 Motor Angle</i> . Turn the motor slowly in the positive direction. It must be turned so slowly (only a few RPM) that it can be determined if the value in <i>parameter 16-20 Motor Angle</i> is increasing or decreasing.	<i>Parameter 16-20 Moto r Angle</i>	(Read-only parameter) Note: An increasing value overflows at 65535 and starts again at 0.

Function	Parameter	Setting
If <i>parameter 16-20 Motor Angle</i> is decreasing, then change the encoder direction in <i>parameter 5-71 Terminal 32/33 Encoder Direction</i> .	<i>Parameter 5-71 Terminal 32/33 Encoder Direction</i>	[1] Counterclockwise (if <i>parameter 16-20 Motor Angle</i> is decreasing).
3) Make sure that the frequency converter limits are set to safe values.		
Set acceptable limits for the references.	<i>Parameter 3-02 Minimum Reference</i> <i>Parameter 3-03 Maximum Reference</i>	0 RPM (default). 1500 RPM (default).
Check that the ramp settings are within frequency converter capabilities and allowed application operating specifications.	<i>Parameter 3-41 Ramp 1 Ramp-up Time</i> <i>Parameter 3-42 Ramp 1 Ramp-down Time</i>	Default setting. Default setting.
Set acceptable limits for the motor speed and frequency.	<i>Parameter 4-11 Motor Speed Low Limit [RPM]</i> <i>Parameter 4-13 Motor Speed High Limit [RPM]</i> <i>Parameter 4-19 Max Output Frequency</i>	0 RPM (default). 1500 RPM (default). 60 Hz (default 132 Hz).
4) Configure the speed control and select the motor control principle.		
Activation of speed control.	<i>Parameter 1-00 Configuration Mode</i>	[1] Speed closed loop.
Selection of motor control principle.	<i>Parameter 1-01 Motor Control Principle</i>	[3] Flux w motor feedb.
5) Configure and scale the reference to the speed control.		
Set up analog input 53 as a reference source.	<i>Parameter 3-15 Reference Resource 1</i>	Not necessary (default).
Scale analog input 53 from 0 RPM (0 V) to 1500 RPM (10 V).	<i>Parameter group 6-1* Analog Input 1</i>	Not necessary (default).
6) Configure the 24 V HTL encoder signal as feedback for the motor control and the speed control.		
Set up digital input 32 and 33 as encoder inputs.	<i>Parameter 5-14 Terminal 32 Digital Input</i> <i>Parameter 5-15 Terminal 33 Digital Input</i>	[0] No operation (default).
Select terminal 32/33 as motor feedback.	<i>Parameter 1-02 Flux Motor Feedback Source</i>	Not necessary (default).
Select terminal 32/33 as speed PID feedback.	<i>Parameter 7-00 Speed PID Feedback Source</i>	Not necessary (default).
7) Tune the speed control PID parameters.		
Use the tuning guidelines when relevant or tune manually.	<i>Parameter group 7-0* Speed PID Ctrl.</i>	See the guidelines in <i>chapter 2.4.3 Tuning PID Speed Control</i> .
8) Finished.		
Save the parameter setting to the LCP for safe keeping.	<i>Parameter 0-50 LCP Copy</i>	[1] All to LCP.

Table 2.4 Speed Control Settings

2.4.3 Tuning PID Speed Control

The following tuning guidelines are relevant when using 1 of the flux motor control principles in applications where the load is mainly inertial (with a low amount of friction).

The value of *parameter 30-83 Speed PID Proportional Gain* depends on the combined inertia of the motor and load, and the selected bandwidth can be calculated using the following formula:

$$Par. 7 - 02 = \frac{Total\ inertia\ [kgm^2] \times par. 1 - 25}{Par. 1 - 20 \times 9550} \times Bandwidth\ [rad/s]$$

NOTICE!

Parameter 1-20 Motor Power [kW] is the motor power in [kW] (that is, enter 4 kW instead of 4000 W in the formula).

A practical value for the bandwidth is 20 rad/s. Check the result of the *Parameter 30-83 Speed PID Proportional Gain* calculation against the following formula (not required when using high-resolution feedback such as a SinCos feedback):

$$Par. 7 - 02_{MAX} = \frac{0.01 \times 4 \times Encoder\ Resolution \times Par. 7 - 06}{2 \times \pi} \times Max\ torque\ ripple\ [\%]$$

A good start value for *parameter 7-06 Speed PID Lowpass Filter Time* is 5 ms (lower encoder resolution calls for a higher filter value). Typically, a maximum torque ripple of 3% is acceptable. For incremental encoders, the encoder resolution is found in either *parameter 5-70 Term 32/33 Pulses per Revolution* (24 V HTL on standard frequency converter) or *parameter 17-11 Resolution (PPR)* (5 V TTL on VLT® Encoder Input MCB 102 option).

Generally, the practical maximum limit of *parameter 30-83 Speed PID Proportional Gain* is determined by the encoder resolution and the feedback filter time. But

other factors in the application might limit the *parameter 30-83 Speed PID Proportional Gain* to a lower value.

To minimize the overshoot, *parameter 7-03 Speed PID Integral Time* could be set to approximately 2.5 s (varies with the application).

Parameter 7-04 Speed PID Differentiation Time should be set to 0 until everything else is tuned. If necessary, finish the tuning by experimenting with small increments of this setting.

2.4.4 Process PID Control

The process PID Control can be used to control application parameters that can be measured by a sensor (that is, pressure, temperature, flow) and be affected by the connected motor through a pump, fan, or otherwise.

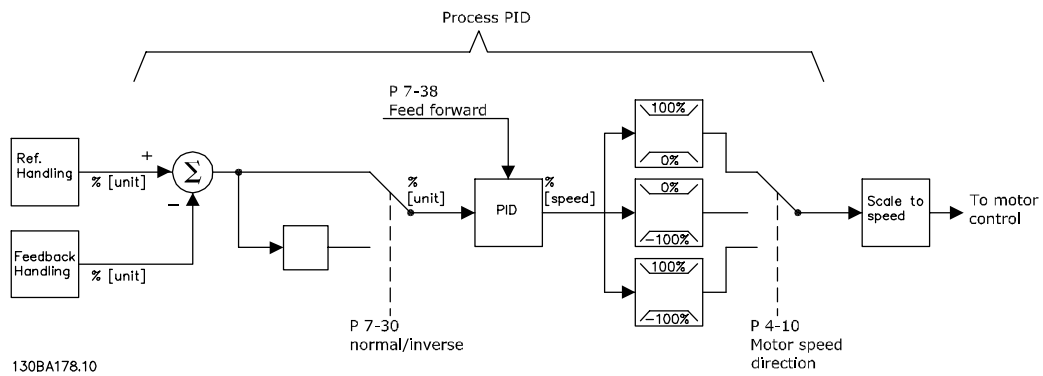
Table 2.5 shows the control configurations where the process control is possible. When a flux vector motor control principle is used, take care also to tune the speed control PID parameters. To see where the speed control is active, refer to *chapter 2.3 Control Structures*.

Parameter 1-00 Configuration Mode	Parameter 1-01 Motor Control Principle			
	U/f	VVC+	Flux sensorles s	Flux with encoder feedback
[3] Process	-	Process	Process & speed	Process & speed

Table 2.5 Process PID Control Settings

NOTICE!

The process PID control works under the default parameter setting, but tuning the parameters is highly recommended to optimize the application control performance. The 2 flux motor control principles are specially dependent on proper speed control PID tuning (before tuning the process control PID) to yield their full potential.



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Figure 2.14 Process PID Control Diagram

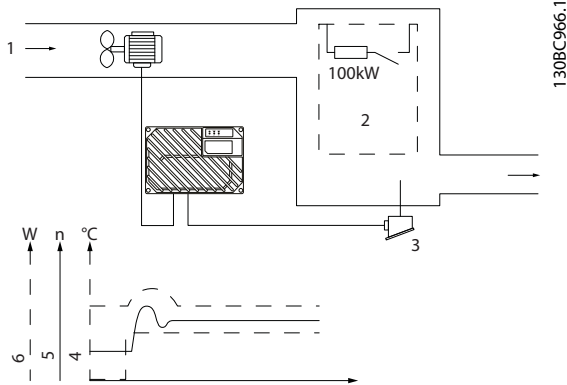
2.4.5 Process Control Relevant Parameters

Parameter	Description of function
<i>Parameter 7-20 Process CL Feedback 1 Resource</i>	Select from which source (that is, analog or pulse input) the process PID should get its feedback.
<i>Parameter 7-22 Process CL Feedback 2 Resource</i>	Optional: Determine if (and from where) the process PID should get an additional feedback signal. If an additional feedback source is selected, the 2 feedback signals are added before being used in the process PID control.
<i>Parameter 7-30 Process PID Normal/Inverse Control</i>	Under [0] <i>Normal operation</i> , the process control responds with an increase of the motor speed if the feedback is getting lower than the reference. In the same situation, but under [1] <i>Inverse operation</i> , the process control responds with a decreasing motor speed instead.
<i>Parameter 7-31 Process PID Anti Windup</i>	The anti-wind-up function ensures that when either a frequency limit or a torque limit is reached, the integrator is set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for with a speed change. This function can be disabled by selecting [0] <i>Off</i> .
<i>Parameter 7-32 Process PID Controller Start Value</i>	In some applications, reaching the required speed/set point can take long time. In such applications, it might be an advantage to set a fixed motor speed from the frequency converter before the process control is activated. This is done by setting a process PID start value (speed) in <i>parameter 7-32 Process PID Controller Start Value</i> .
<i>Parameter 7-33 Process PID Proportional Gain</i>	The higher the value - the quicker the control. However, too large value may lead to oscillations.
<i>Parameter 7-34 Process PID Integral Time</i>	Eliminates steady state speed error. Lower value means quick reaction. However, too small value may lead to oscillations.
<i>Parameter 7-35 Process PID Differentiation Time</i>	Provides a gain proportional to the rate of change of the feedback. A setting of 0 disables the differentiator.
<i>Parameter 7-36 Process PID Differentiation Gain Limit</i>	If there are quick changes in reference or feedback in a given application - which means that the error changes swiftly - the differentiator may soon become too dominant. This is because it reacts to changes in the error. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes.
<i>Parameter 7-38 Process PID Feed Forward Factor</i>	In applications where there is a good (and approximately linear) correlation between the process reference and the motor speed necessary for obtaining that reference, the feed forward factor can be used to achieve better dynamic performance of the process PID control.
<i>Parameter 5-54 Pulse Filter Time Constant #29 (Pulse term. 29), parameter 5-59 Pulse Filter Time Constant #33 (Pulse term. 33), parameter 6-16 Terminal 53 Filter Time Constant (Analog term 53), parameter 6-26 Terminal 54 Filter Time Constant (Analog term. 54)</i>	<p>If there are oscillations of the current/voltage feedback signal, these can be dampened with a low-pass filter. This time constant shows the speed limit of the ripples occurring on the feedback signal.</p> <p>Example: If the low-pass filter has been set to 0.1 s, the limit speed is 10 RAD/s (the reciprocal of 0.1 s), corresponding to $(10/(2 \times \pi))=1.6$ Hz. This means that all currents/voltages that vary by more than 1.6 oscillations per second are dampened by the filter. The control is only carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz.</p> <p>The low-pass filter improves steady state performance but selecting a too large filter time deteriorates the dynamic performance of the process PID control.</p>

Table 2.6 Parameters are Relevant for the Process Control

2.4.6 Example of Process PID Control

Figure 2.15 is an example of a process PID control used in a ventilation system.



Item	Description
1	Cold air
2	Heat generating process
3	Temperature transmitter
4	Temperature
5	Fan speed
6	Heat

Figure 2.15 Process PID Control in Ventilation System

In a ventilation system, the temperature is to be settable from -5 to +35 °C (23-95 °F) with a potentiometer of 0-10 V. The task of the process control is to maintain temperature at a constant preset level.

The control is of the inverse type, which means that when the temperature increases, the ventilation speed is increased as well, to generate more air. When the temperature drops, the speed is reduced. The transmitter used is a temperature sensor with a working range of -10 to +40 °C (14-104 °F), 4-20 mA. Minimum/maximum speed 300/1500 RPM.

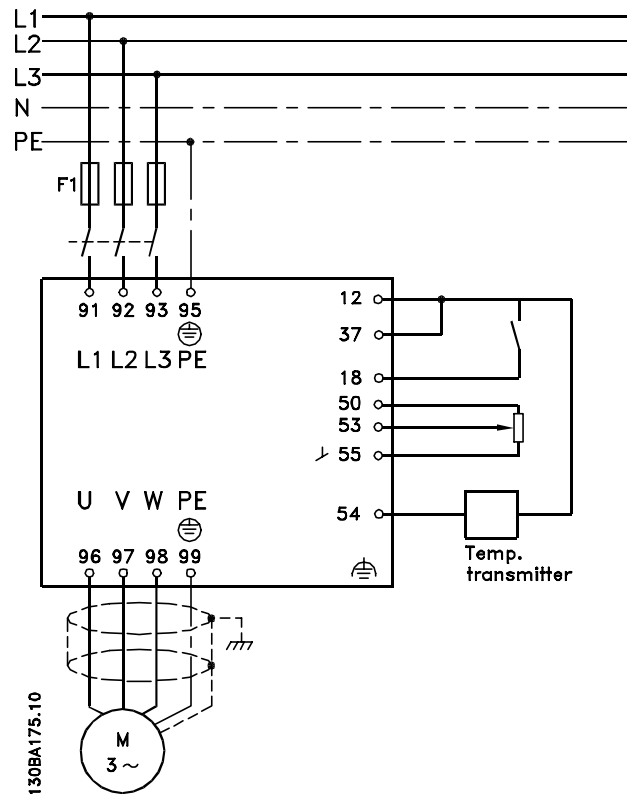


Figure 2.16 Two-wire Transmitter

1. Start/stop via a switch connected to terminal 18.
2. Temperature reference via potentiometer (-5 to 35 °C (23-95 °F), 0-10 V DC) connected to terminal 53.
3. Temperature feedback via transmitter (-10 to 40 °C (14-104 °F), 4-20 mA) connected to terminal 54. Switch S202 set to ON (current input).

2.4.7 Programming Order

Function	Parameter	Setting
Initialize the frequency converter.	<i>Parameter 14-22 Operation Mode</i>	[2] Initialization - make a power-cycle - press reset.
1) Set motor parameters.		
Set the motor parameters according to nameplate data.	<i>Parameter group 1-2* Motor Data</i>	As stated on motor nameplate.
Perform a full AMA.	<i>Parameter 1-29 Automatic Motor Adaptation (AMA)</i>	[1] Enable complete AMA.
2) Check that motor is running in the right direction.		
When the motor is connected to the frequency converter with straight forward phase order as U - U; V- V; W - W, the motor shaft usually turns clockwise seen into shaft end.		
Press [Hand On] LCP key. Check shaft direction by applying a manual reference.		
If the motor turns opposite of the required direction: 1. Change motor direction in <i>parameter 4-10 Motor Speed Direction</i> . 2. Turn off mains - wait for DC link to discharge - switch 2 of the motor phases.	<i>Parameter 4-10 Motor Speed Direction</i>	Select correct motor shaft direction.
Set configuration mode.	<i>Parameter 1-00 Configuration Mode</i>	[3] Process.
Set local mode configuration	<i>Parameter 1-05 Local Mode Configuration</i>	[0] Speed Open Loop.
3) Set reference configuration, that is, the range for handling of reference. Set scaling of analog input in <i>parameter group 6-** Analog In/Out</i>.		
<ul style="list-style-type: none"> Set reference/feedback units. Set minimum reference (10 °C (50 °F)). Set maximum reference (80 °C (176 °F)). If set value is determined from a preset value (array parameter), set other reference sources to no function.	<i>Parameter 3-01 Reference/Feedback Unit</i> <i>Parameter 3-02 Minimum Reference</i> <i>Parameter 3-03 Maximum Reference</i> <i>Parameter 3-10 Preset Reference</i>	[60] °C Unit shown on display. -5 °C. 35 °C. [0] 35%. $Ref = \frac{Par. 3 - 10_{(0)}}{100} \times ((Par. 3 - 03) - (par. 3 - 02)) = 24,5^\circ C$ Parameter 3-14 Preset Relative Reference to parameter 3-18 Relative Scaling Reference Resource, [0] = No function
4) Adjust limits for the frequency converter:		
Set ramp times to an appropriate value as 20 s.	<i>Parameter 3-41 Ramp 1 Ramp-up Time</i> <i>Parameter 3-42 Ramp 1 Ramp-down Time</i>	20 s. 20 s.

Function	Parameter	Setting
<ul style="list-style-type: none"> Set minimum speed limits. Set motor speed maximum limit. Set maximum output frequency. 	Parameter 4-11 Motor Speed Low Limit [RPM] Parameter 4-13 Motor Speed High Limit [RPM] Parameter 4-19 Max Output Frequency	300 RPM. 1500 RPM. 60 Hz.
Set S201 or S202 to wanted analog input function (Voltage (V) or milliamps (I)) NOTICE! Switches are sensitive - Make a power-cycle keeping the default setting of V.		
5) Scale analog inputs used for reference and feedback.		
<ul style="list-style-type: none"> Set terminal 53 low voltage. Set terminal 53 high voltage. Set terminal 54 low feedback value. Set terminal 54 high feedback value. Set feedback source. 	Parameter 6-10 Terminal 53 Low Voltage Parameter 6-11 Terminal 53 High Voltage Parameter 6-24 Terminal 54 Low Ref./Feedb. Value Parameter 6-25 Terminal 54 High Ref./Feedb. Value Parameter 7-20 Process CL Feedback 1 Resource	0 V. 10 V. -5 °C. 35 °C. [2] Analog input 54.
6) Basic PID settings.		
Process PID normal/inverse.	Parameter 7-30 Process PID Normal/Inverse Control	[0] Normal.
Process PID anti-wind-up.	Parameter 7-31 Process PID Anti Windup	[1] On.
Process PID start speed.	Parameter 7-32 Process PID Controller Start Value	300 RPM.
Save parameters to LCP.	Parameter 0-50 LCP Copy	[1] All to LCP.

Table 2.7 Example of Process PID Control Set-up

2.4.8 Process Controller Optimization

The basic settings have now been made. All that needs to be done is to optimize the proportional gain, the integration time, and the differentiation time (*parameter 7-33 Process PID Proportional Gain, parameter 7-34 Process PID Integral Time, parameter 7-35 Process PID Differentiation Time*). In most processes, this can be done by following these guidelines:

1. Start the motor.
2. Set *parameter 7-33 Process PID Proportional Gain* to 0.3 and increase it until the feedback signal again begins to vary continuously. Then reduce the value until the feedback signal has stabilized. Now lower the proportional gain by 40–60%.
3. Set *parameter 7-34 Process PID Integral Time* to 20 s and reduce the value until the feedback signal again begins to vary continuously. Increase the integration time until the feedback signal stabilizes, followed by an increase of 15–50%.
4. Only use *parameter 7-35 Process PID Differentiation Time* for very fast-acting systems only (differentiation time). The typical value is 4 times the set integration time. The differentiator should only be used when the setting of the proportional gain and the integration time has been fully optimized. Make sure that oscillations on the feedback signal are sufficiently dampened by the lowpass filter on the feedback signal.

NOTICE!

If necessary, start/stop can be activated several times to provoke a variation of the feedback signal.

2.4.9 Ziegler Nichols Tuning Method

To tune the PID controls of the frequency converter, Danfoss recommends the Ziegler Nichols tuning method.

NOTICE!

Do not use the Ziegler Nichols Tuning method in applications that could be damaged by the oscillations created by marginally stable control settings.

The criteria for adjusting the parameters are based on evaluating the system at the limit of stability rather than on taking a step response. Increase the proportional gain until observing continuous oscillations (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain (K_u) is called the ultimate gain and is the gain, at which the oscillation is obtained. The period of the oscillation (P_u) (called the ultimate period) is determined as shown in *Figure 2.17* and should be measured when the amplitude of oscillation is small.

1. Select only proportional control, meaning that the integral time is set to the maximum value, while the differentiation time is set to 0.
2. Increase the value of the proportional gain until the point of instability is reached (sustained oscillations) and the critical value of gain, K_u , is reached.
3. Measure the period of oscillation to obtain the critical time constant, P_u .
4. Use *Table 2.8* to calculate the necessary PID control parameters.

The process operator can do the final tuning of the control iteratively to yield satisfactory control.

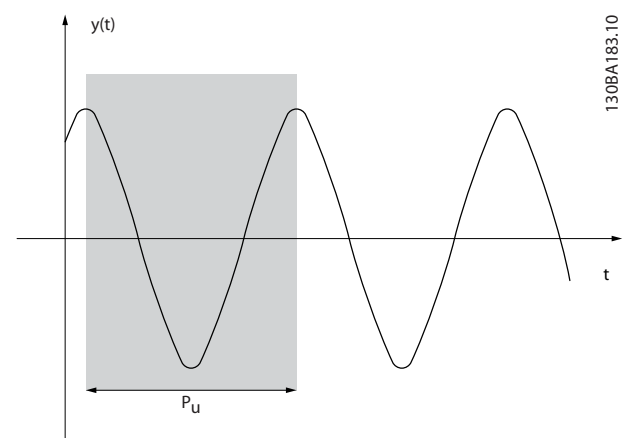


Figure 2.17 Marginally Stable System

Type of control	Proportional gain	Integral time	Differentiation time
PI-control	$0.45 \times K_u$	$0.833 \times P_u$	–
PID tight control	$0.6 \times K_u$	$0.5 \times P_u$	$0.125 \times P_u$
PID some overshoot	$0.33 \times K_u$	$0.5 \times P_u$	$0.33 \times P_u$

Table 2.8 Ziegler Nichols Tuning for Regulator

2.5 Control Cables and Terminals

2.5.1 Control Cable Routing

A 24 V DC external supply can be used as low voltage supply to the control card and any option cards installed. This enables full operation of the LCP (including parameter setting) without connection to mains.

NOTICE!

A warning of low voltage is given when 24 V DC has been connected; however, there is no tripping.

WARNING

ELECTRICAL SHOCK HAZARD

Without galvanic isolation (type PELV), the control terminals impose an electrical shock hazard. Failure to follow the recommendations, may lead to death or serious injury.

- Use 24 V DC supply of type PELV to ensure correct galvanic isolation (type PELV).

2.5.2 DIP Switches

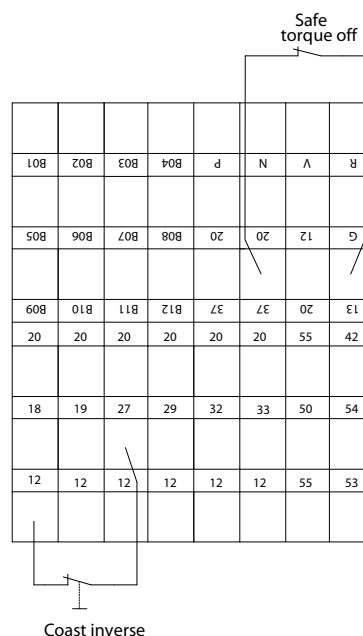
2.5.3 Basic Wiring Example

Connect terminals 27 and 37 to +24 V terminals 12 and 13, as shown in *Figure 2.18*.

Default settings:

27 = [2] Coast inverse parameter 5-10 Terminal 18 Digital Input

37 = Safe Torque Off inverse



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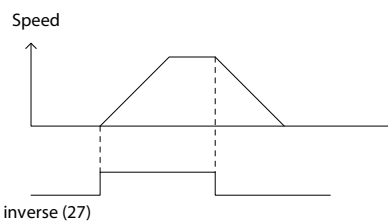


Figure 2.18 Basic Wiring Example

2

2.5.4 Electrical Installation, Control Cables

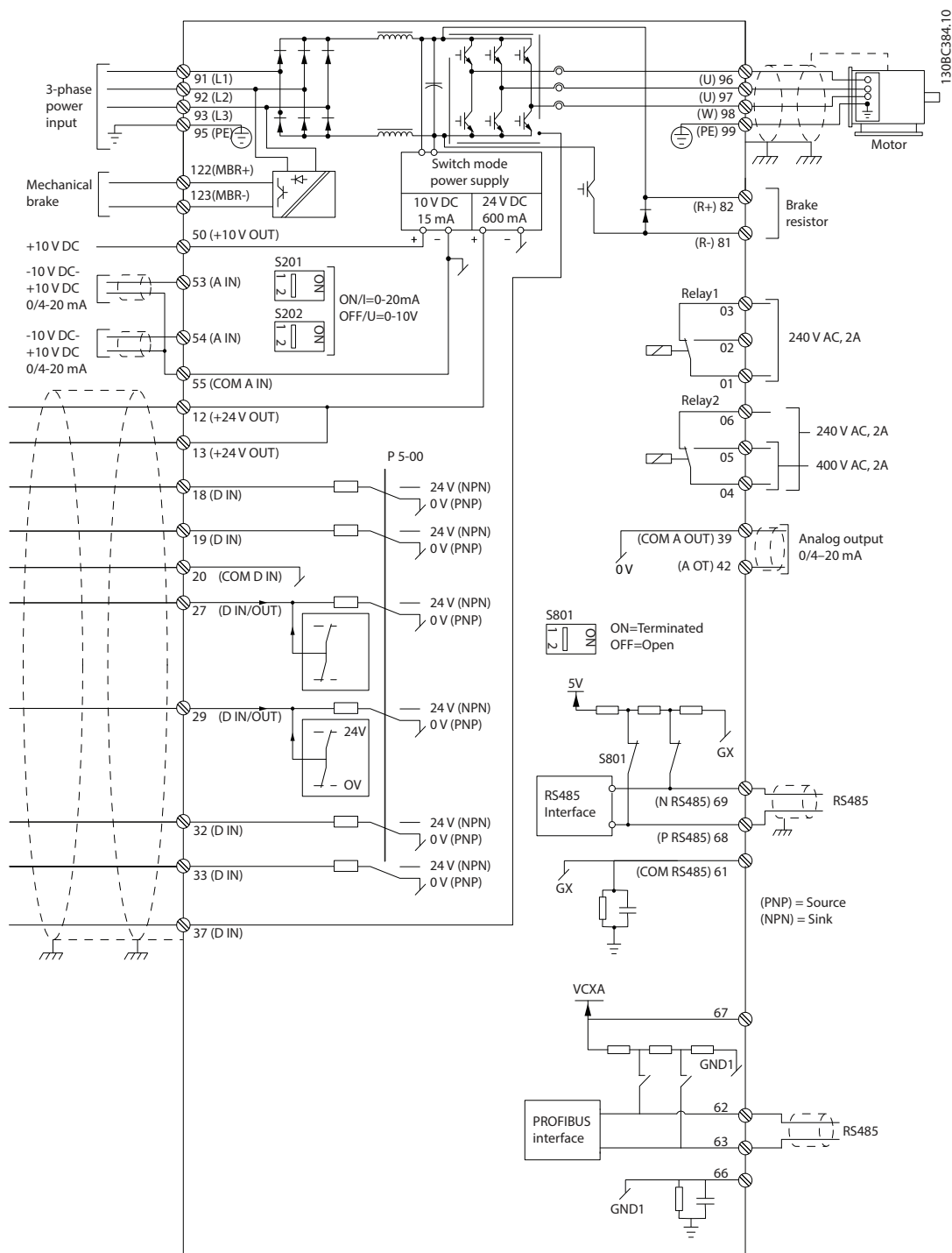


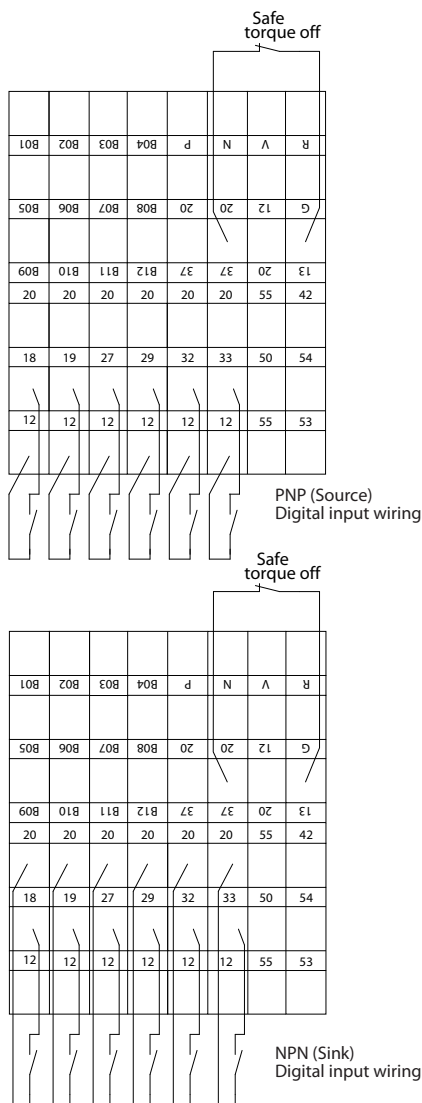
Figure 2.19 Electrical Terminals without Options

A = analog, D = digital

Terminal 37 is used for Safe Torque Off.

Relay 2 has no function when the frequency converter has mechanical brake output.

Long control cables and analog signals may in rare cases result in 50/60 Hz ground loops due to noise from mains supply cables. If this occurs, it may be necessary to break the shield or insert a 100 nF capacitor between shield and chassis. Connect the digital and analog inputs and outputs separately to the common inputs (terminal 20, 55, 39) to avoid ground currents from both groups affecting other groups. For example, switching on the digital input may disturb the analog input signal.



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Figure 2.20 Input Polarity of Control Terminals

NOTICE!

To comply with EMC emission specifications, shielded/ armored cables are recommended. If an unshielded/ unarmored cable is used, see chapter 2.9.7 EMC Test Results for more information.

2.5.5 Relay Output

The relay output with the terminals 01, 02, 03 and 04, 05, 06 has a capacity of maximum 240 V AC, 2 A. Minimum 24 V DC, 10 mA, or 24 V AC, 100 mA can be used for indicating status and warnings. The 2 relays are physically located on the installation card. These are programmable through *parameter group 5-4* Relays*. The relays are Form C, meaning each has 1 normally open contact and 1 normally closed contact on a single throw. The contacts of each relay are rated for a maximum load of 240 V AC at 2 amps.

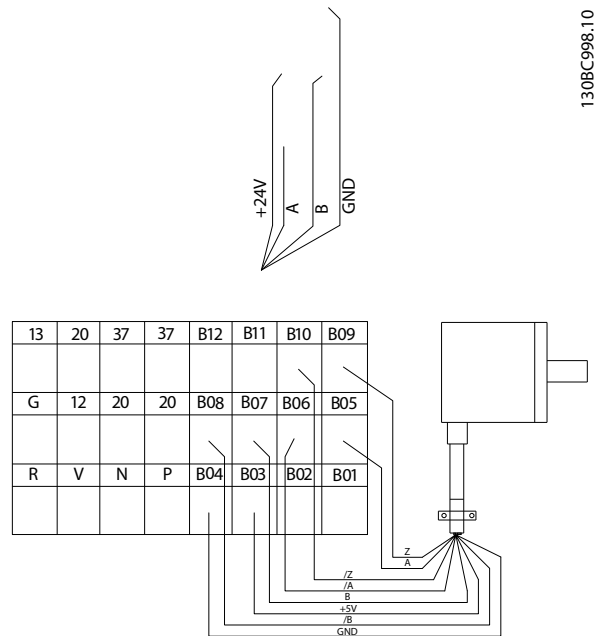
Relay 1

- Terminal 01: Common
- Terminal 02: Normal open 240 V AC
- Terminal 03: Normal closed 240 V AC

Relay 2

- Terminal 04: Common
- Terminal 05: Normal open 240 V AC
- Terminal 06: Normal closed 240 V AC

Relay 1 and relay 2 are programmed in *parameter 5-40 Function Relay*, *parameter 5-41 On Delay, Relay*, and *parameter 5-42 Off Delay, Relay*.



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Figure 2.21 Relay Connection

2.6 Handling of Reference

Local reference

The local reference is active when the frequency converter is operated with [Hand On] key active. Adjust the reference by [▲]/[▼] and [◀]/[▶] arrows, respectively.

Remote reference

The reference handling system for calculating the remote reference is shown in *Figure 2.22*.

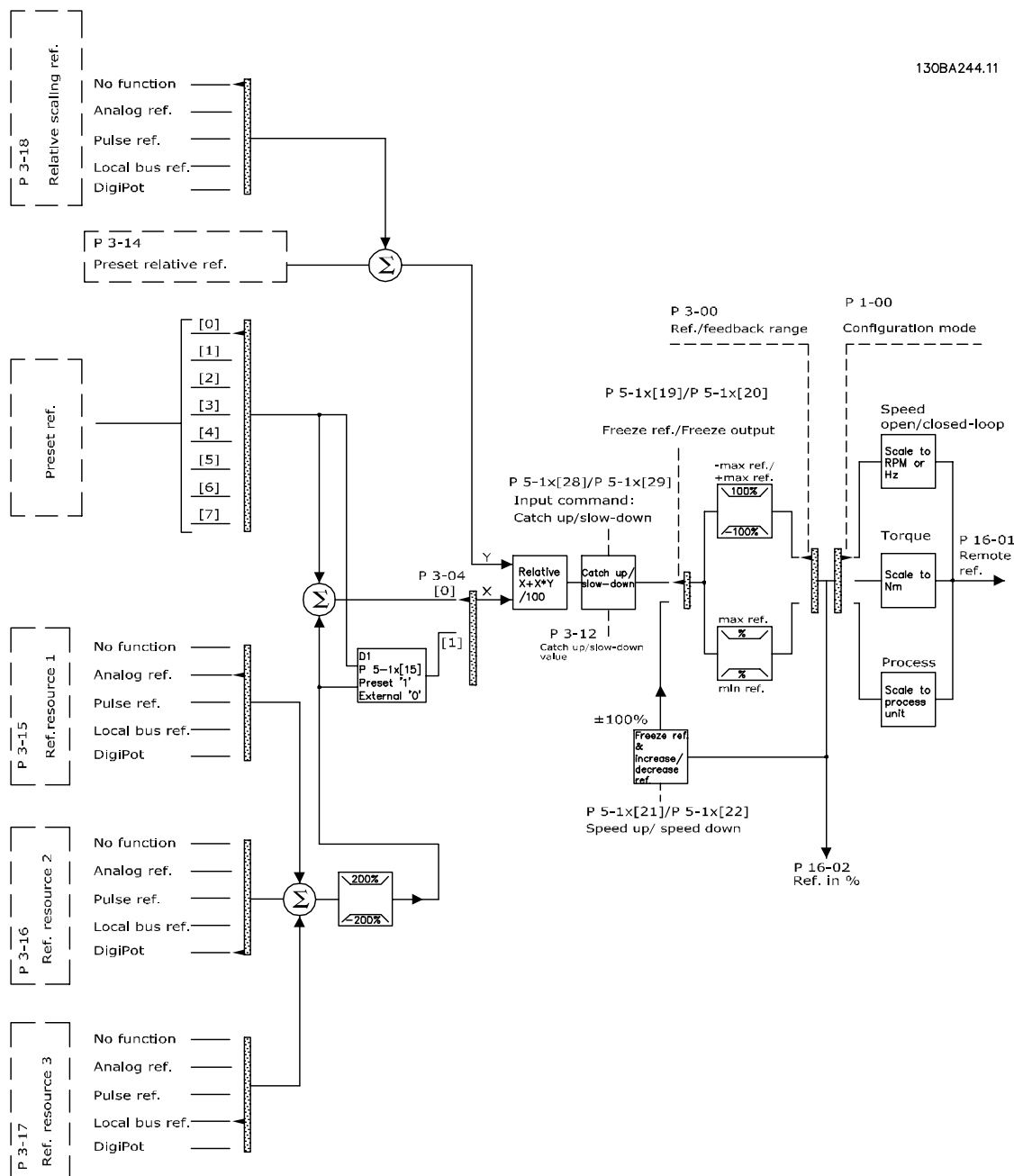


Figure 2.22 Remote Reference

The remote reference is calculated once in every scan interval and initially consists of 2 types of reference inputs:

- X (the external reference): A sum (see *parameter 3-04 Reference Function*) of up to 4 externally selected references. These comprise any combination (determined by the setting of *parameter 3-15 Reference Resource 1*, *parameter 3-16 Reference Resource 2*, and *parameter 3-17 Reference Resource 3*) of a fixed preset reference (*parameter 3-10 Preset Reference*), variable analog references, variable digital pulse references, and various fieldbus references in the unit, which controls the frequency converter ([Hz], [RPM], [Nm] and so on).
- Y (the relative reference): A sum of 1 fixed preset reference (*parameter 3-14 Preset Relative Reference*) and 1 variable analog reference (*parameter 3-18 Relative Scaling Reference Resource*) in [%].

The 2 types of reference inputs are combined in the following formula: Remote reference= $X+X*Y/100\%$. If relative reference is not used, set *parameter 3-18 Relative Scaling Reference Resource* to [0] No function and *parameter 3-14 Preset Relative Reference* to 0%. The catch up/slow down function and the freeze reference function can both be activated by digital inputs on the frequency converter. The functions and parameters are described in the *VLT® AutomationDrive FC 301/FC 302 Programming Guide*.

The scalings of analog references are described in *parameter groups 6-1* Analog Input 1* and *6-2* Analog Input 2*, and the scaling of digital pulse references are described in *parameter group 5-5* Pulse Input*. Reference limits and ranges are set in *parameter group 3-0* Reference Limits*.

2.6.1 Reference Limits

Parameter 3-00 Reference Range, *parameter 3-02 Minimum Reference*, and *parameter 3-03 Maximum Reference* together define the allowed range of the sum of all references. The sum of all references is clamped when necessary. The relation between the resulting reference (after clamping) is shown in *Figure 2.23/Figure 2.24* and the sum of all references is shown in *Figure 2.25*.

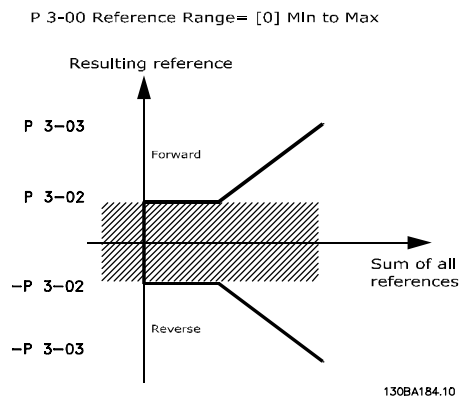


Figure 2.23 Reference Range=[0] Min-Max

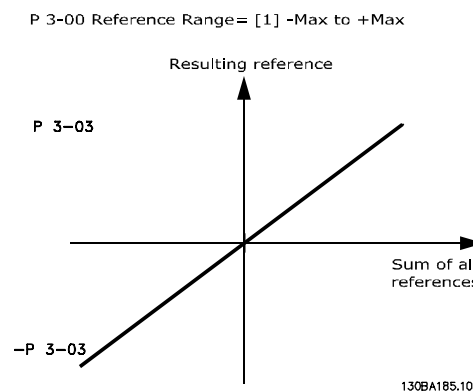


Figure 2.24 Reference Range=[1] -Max-Max

The value of *parameter 3-02 Minimum Reference* cannot be set to less than 0, unless *parameter 1-00 Configuration Mode* is set to [3] Process. In that case, the following relations between the resulting reference (after clamping) and the sum of all references is as shown in *Figure 2.25*.

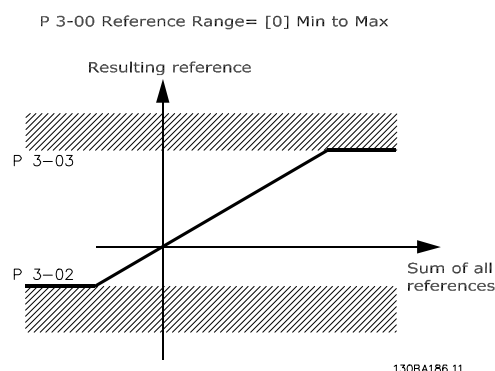


Figure 2.25 Sum of all References

2.6.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

- When *parameter 3-00 Reference Range* is set to [0] *Min-Max* : 0% reference equals 0 [unit] where unit can be any unit, for example RPM, m/s, bar, and so on. 100% reference equals the maximum (abs (*parameter 3-03 Maximum Reference*), abs (*parameter 3-02 Minimum Reference*)).
- When *parameter 3-00 Reference Range*: [1] *-Max to +Max* 0% reference equals 0 [unit] -100% reference equals -Maximum reference 100% reference equals maximum reference.

Bus references are scaled according to the following rules:

- When *parameter 3-00 Reference Range*: [0] *Min to Max*. To obtain maximum resolution on the bus reference the scaling on the bus is: 0% reference equals minimum reference and 100% reference equals maximum reference.
- When *parameter 3-00 Reference Range*: [1] *-Max to +Max* -100% reference equals maximum reference 100% reference equals max reference.

2.6.3 Scaling of Analog and Pulse References and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum endpoints (P1 and P2 in Figure 2.26) are clamped whereas a feedback above or below is not.

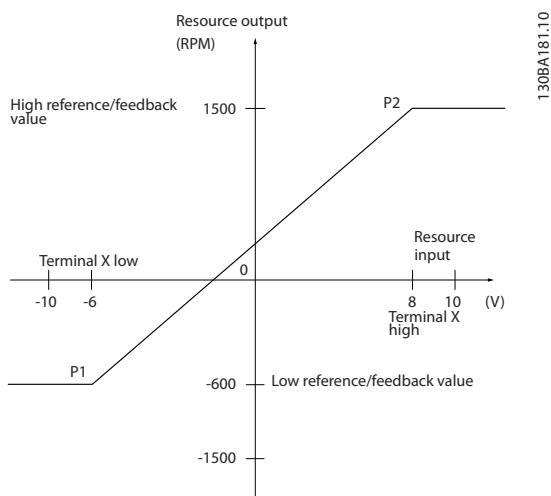


Figure 2.26 Scaling of Analog and Pulse References and Feedback

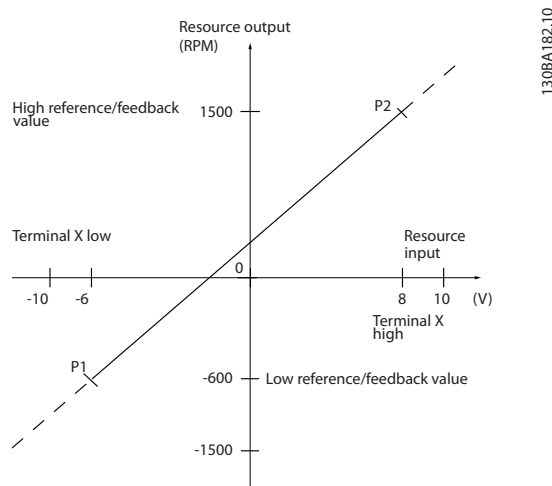


Figure 2.27 Scaling of Reference Output

The endpoints P1 and P2 are defined by the parameters in Table 2.9, depending on which analog or pulse input is used.

	Analog 53 S201=OFF	Analog 53 S201=ON	Analog 54 S202=OFF	Analog 54 S202=ON	Pulse input 29	Pulse input 33
P1=(Minimum input value, minimum reference value)						
Minimum reference value	Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	Parameter 6-24 Terminal 54 Low Ref./Feedb. Value	Parameter 6-24 Terminal 54 Low Ref./Feedb. Value	Parameter 5-52 Term. 29 Low Ref./Feedb. Value	Parameter 5-57 Term. 33 Low Ref./Feedb. Value
Minimum input value	Parameter 6-10 Terminal 53 Low Voltage [V]	Parameter 6-12 Terminal 53 Low Current [mA]	Parameter 6-20 Terminal 54 Low Voltage [V]	Parameter 6-22 Terminal 54 Low Current [mA]	Parameter 5-50 Term. 29 Low Frequency [Hz]	Parameter 5-55 Term. 33 Low Frequency [Hz]
P2=(Maximum input value, maximum reference value)						
Maximum reference value	Parameter 6-15 Terminal 53 High Ref./Feedb. Value	Parameter 6-15 Terminal 53 High Ref./Feedb. Value	Parameter 6-25 Terminal 54 High Ref./Feedb. Value	Parameter 6-25 Terminal 54 High Ref./Feedb. Value	Parameter 5-53 Term. 29 High Ref./Feedb. Value	Parameter 5-58 Term. 33 High Ref./Feedb. Value
Maximum input value	Parameter 6-11 Terminal 53 High Voltage [V]	Parameter 6-13 Terminal 53 High Current [mA]	Parameter 6-21 Terminal 54 High Voltage [V]	Parameter 6-23 Terminal 54 High Current [mA]	Parameter 5-51 Term. 29 High Frequency [Hz]	Parameter 5-56 Term. 33 High Frequency [Hz]

Table 2.9 Input and Reference Endpoint Values

2.6.4 Dead Band Around Zero

Sometimes the reference (in rare cases also the feedback) should have a dead band around zero (that is, to make sure that the machine is stopped when the reference is near 0).

To make the dead band active and to set the amount of dead band, the following settings must be done:

- Either minimum reference value (see Table 2.9 for relevant parameter) or maximum reference value must be 0. In other words, either P1 or P2 must be on the X-axis in Figure 2.28.
- And both points defining the scaling graph are in the same quadrant.

The size of the dead band is defined by either P1 or P2 as shown in Figure 2.28.

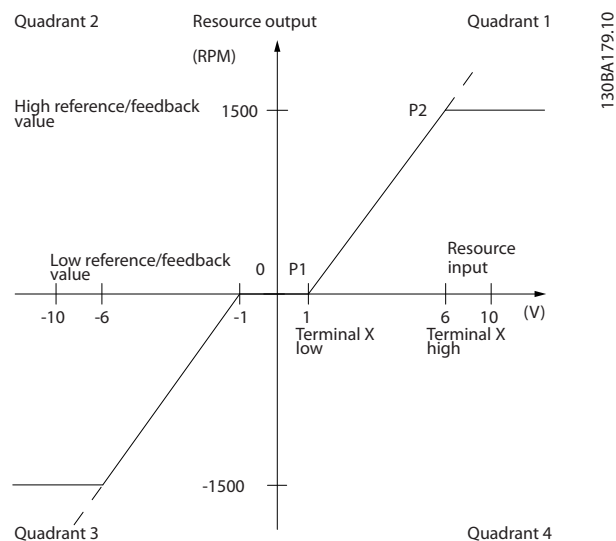


Figure 2.28 Dead Band

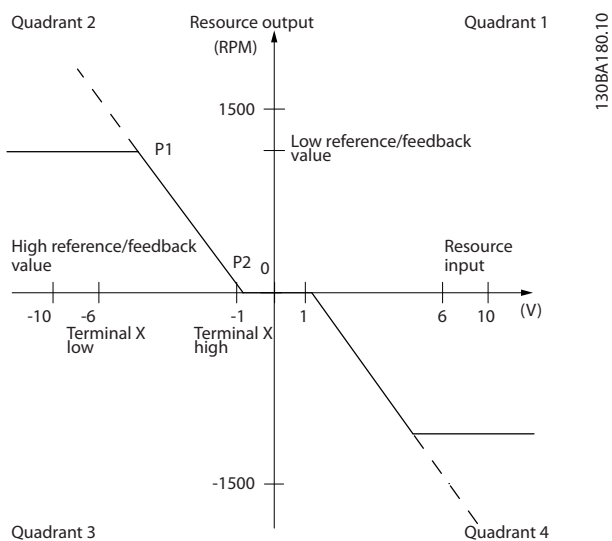


Figure 2.29 Reverse Dead Band

If endpoint 2 is placed in either quadrant 1 or quadrant 4, a reference endpoint of, for example, P1=(1 V, 0 RPM) results in a -1 V to +1 V dead band.

Case 1: Positive reference with dead band, digital input to trigger reverse

This case shows how reference input with limits inside minimum to maximum limits clamps.

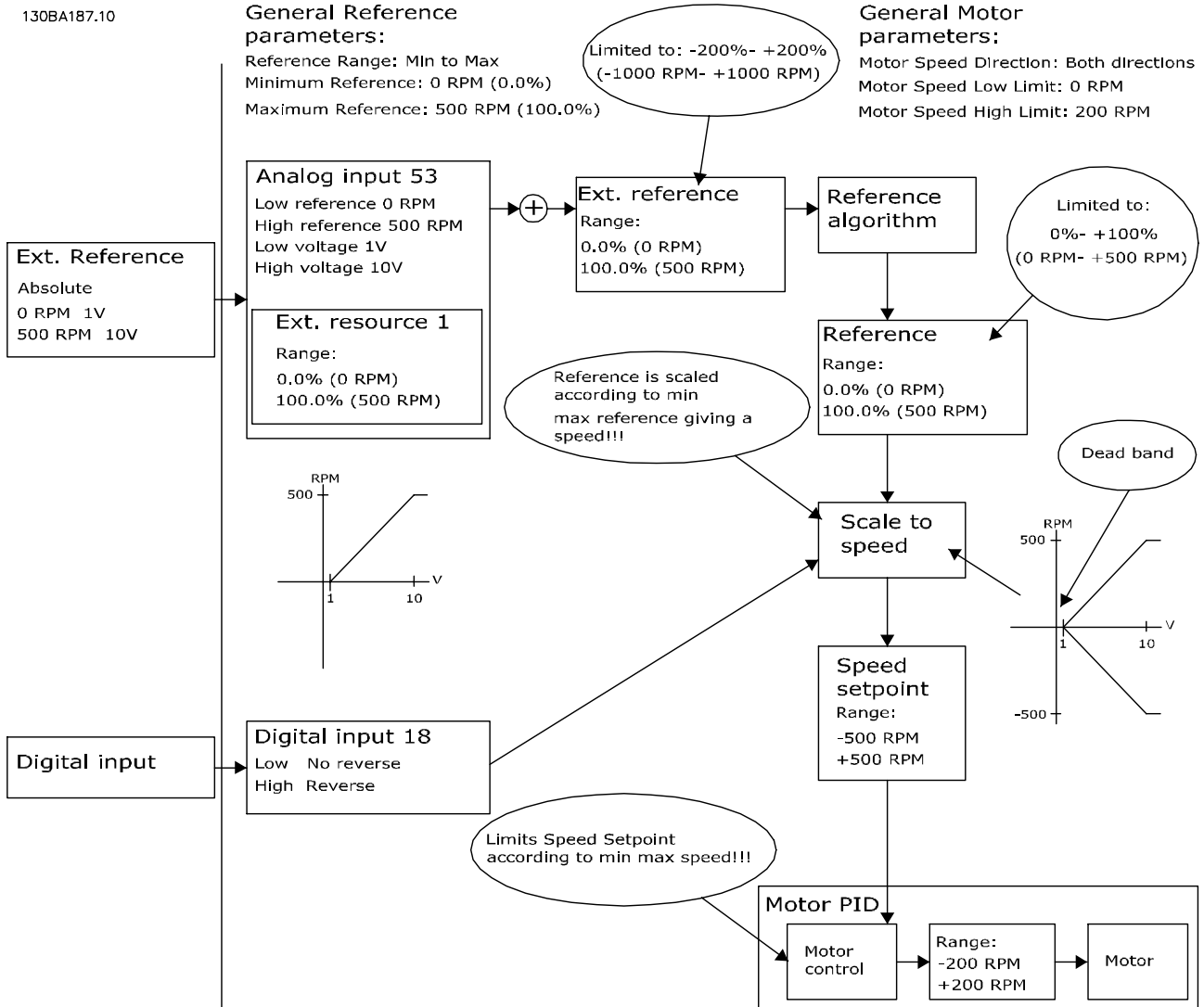


Figure 2.30 Example 1 - Positive Reference

2

Case 2: Positive reference with dead band, digital input to trigger reverse. Clamping rules.

This case shows how reference input with limits outside -maximum to +maximum limits clamps to the inputs low and high limits before addition to external reference. The case also shows how the external reference is clamped to -maximum to +maximum by the reference algorithm.

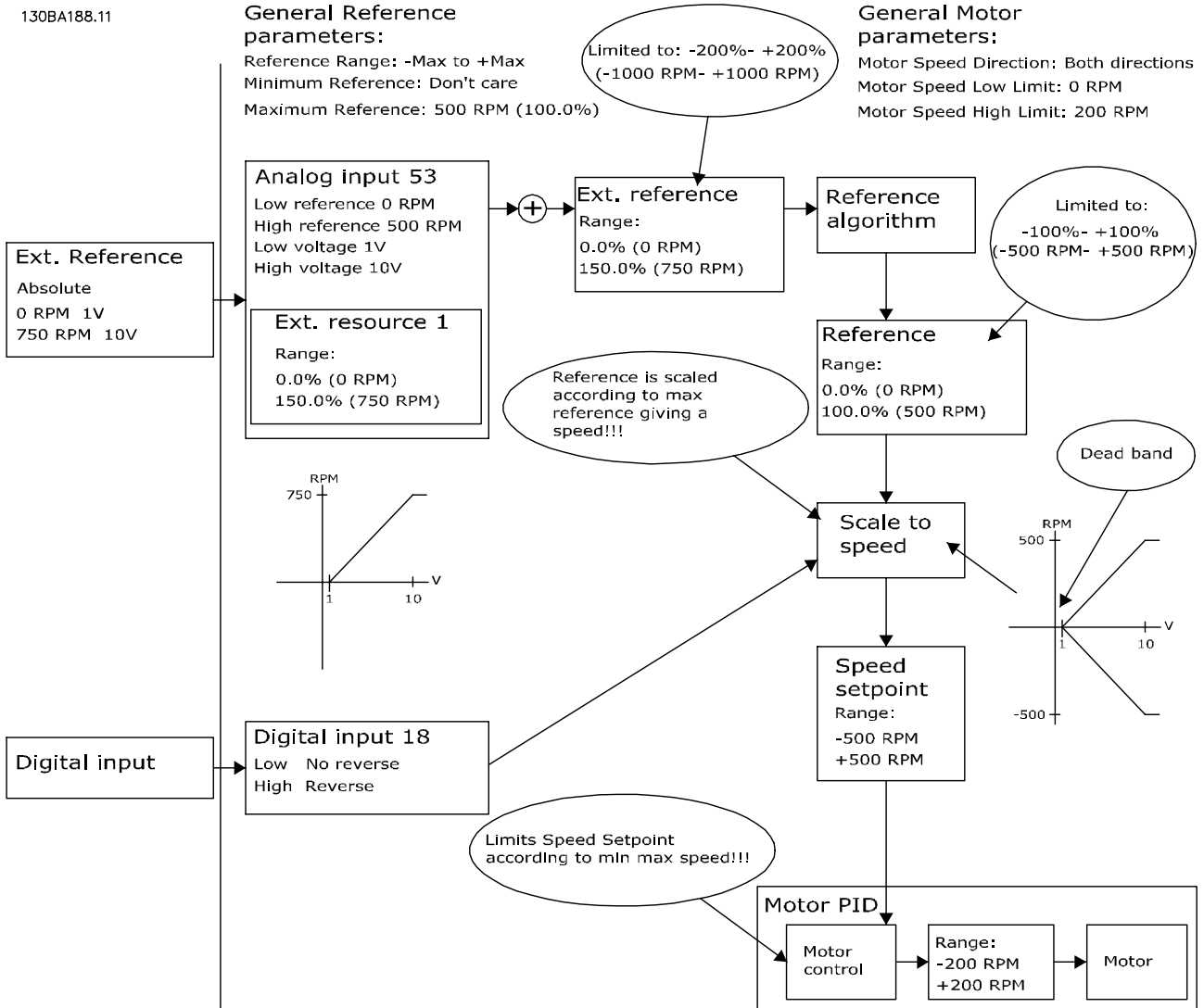


Figure 2.31 Example 2 - Positive Reference

Case 3: Negative to positive reference with dead band, sign determines the direction, -maximum to +maximum

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General Reference parameters:
 Reference Range: -Max to +Max
 Minimum Reference: Don't care
 Maximum Reference: 1000 RPM (100.0%)

General Motor parameters:
 Motor Speed Direction: Both directions
 Motor Speed Low Limit: 0 RPM
 Motor Speed High Limit: 1500 RPM

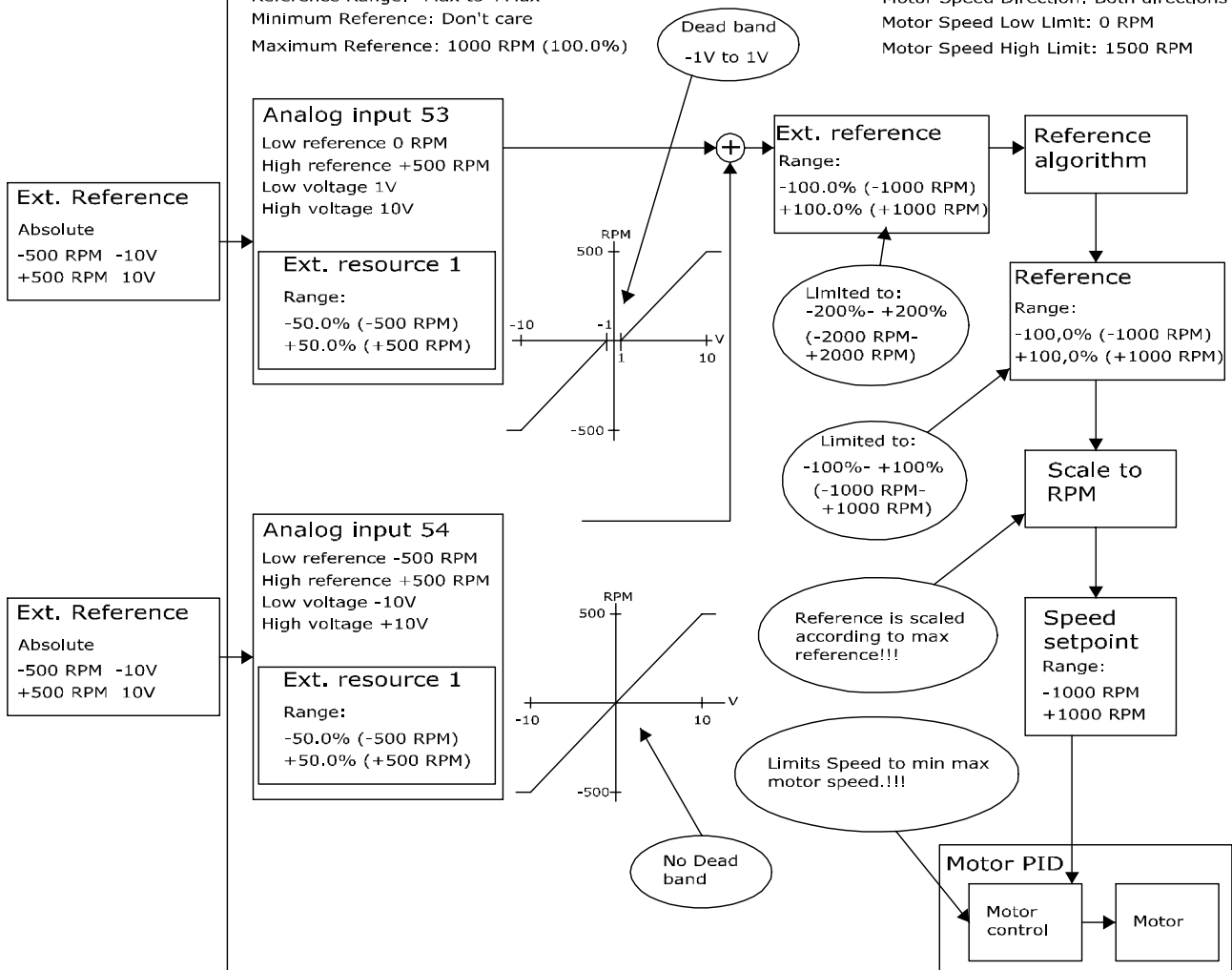


Figure 2.32 Example 3 - Positive to Negative Reference

2.7 Brake Functions

Brake function is applied for braking the load on the motor shaft, either as dynamic brake or static braking.

2.7.1 Mechanical Brake

A mechanical holding brake mounted directly on the motor shaft normally performs static braking. In some applications (usually synchronous permanent motors), the static holding torque holds the motor shaft. The holding brake is either controlled by a PLC, directly by a relay, or a digital output from the frequency converter.

NOTICE!

A frequency converter cannot provide Safe Torque Off control of a mechanical brake. A redundancy circuitry for the brake control must be included in the installation.

2

2.7.1.1 Mechanical Brake Selection Guide and Electrical Circuit Description

VLT® Decentral Drive FCD 302 can be configured with or without a brake (see position 18 in Figure 6.1).

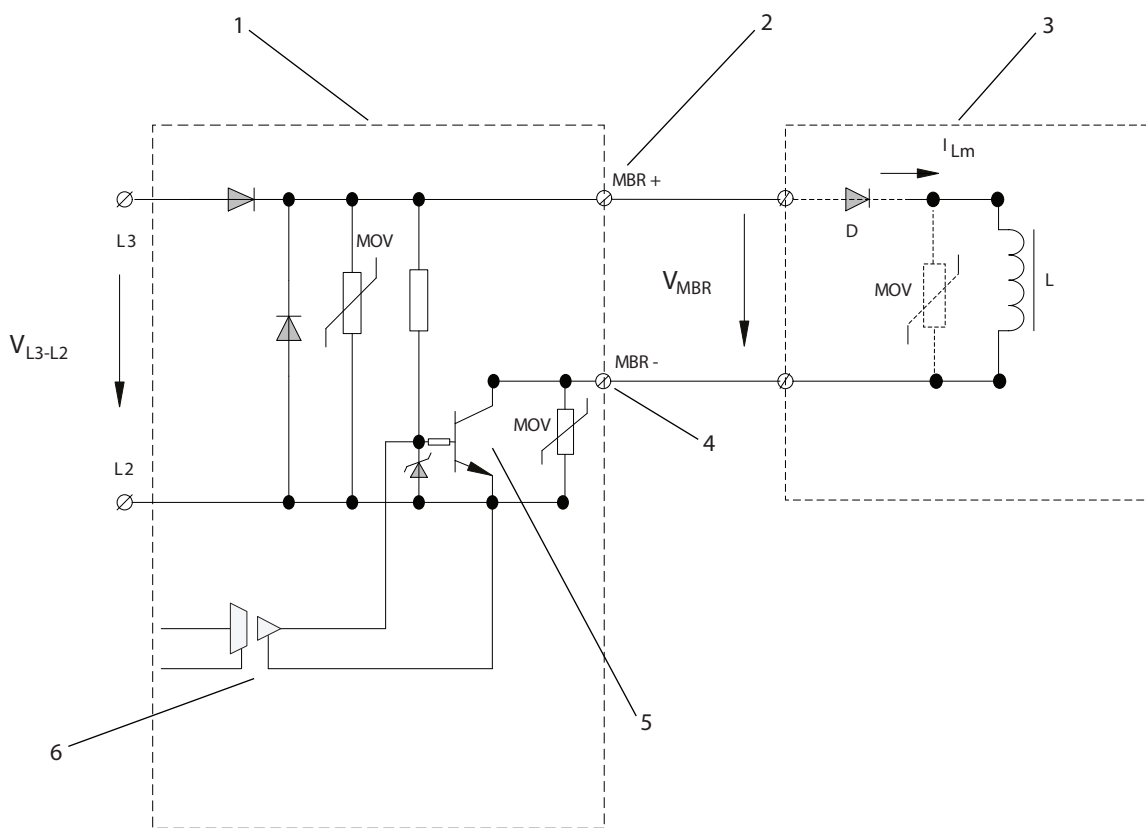
If the inverter part is configured with brake, relay 1 can be configured for various applications, while relay 2 should be reserved only for the mechanical brake. Relay 2 is mounted inside the installation box, but in this configuration state it is not active.

The mechanical brake coil can be powered by a low voltage (of 24 V DC) or from mains line AC voltage.

If the mechanical brake is a 24 V DC type, 1 of the 2 custom relays, relay 1, or a functional relay 2, can be used

within the electrical specification (voltage, current, and so on) or with external relays. If the frequency converter is configured without brake, the internal electrical control signal for relay 2 is active.

If the brake is powered by mains supply, or a mains rectified DC voltage, it is recommended to order the FCD 302 with a mechanical brake. In this case, all the parameter settings for relay 2 now control the internal solid-state switch which gives the output voltage at the MBR+ and MBR- terminals. In some motors, this mechanical brake can be of AC-type or DC-type. If the unit is AC-type, the mechanical brake has an internal diode *D* and the internal MOV, as described in the electrical diagram in Figure 2.33.



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1	Inverter part
2	MBR+ terminal 122
3	Mechanical brake coil
4	MBR- terminal 123
5	Solid state switch
6	Galvanic isolated control circuit

Figure 2.33 Electrical Diagram of Mechanical Brake

The supply voltage is derived from the mains voltage between phases L2 and L3, which is passed through a single pulse diode rectification.

The output voltage of solid-state supply is not a constant value, but rather a pulsed voltage with an average level direct dependent on the mains voltage, as shown in *Figure 2.34*:

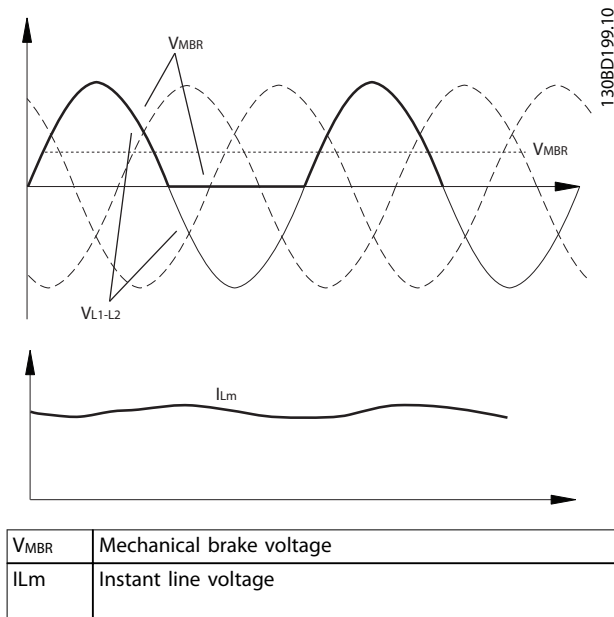


Figure 2.34 Instant Voltage V_{MBR} with its average level of V_{MBR}

This rectified voltage is applied to the mechanical brake inductor, with the smoothed current shape I_{Lm} .

The voltage shown in *Figure 2.33* has the amplitude of the line voltage and an average voltage level calculated as:

$$V_{MBR(DC)} = 0.45 \times V_{AC}$$

Examples:

$$V_{AC} = 400 \text{ V}_{rms} \Rightarrow V_{MBR} = 180 \text{ V}_{DC}$$

$$V_{AC} = 480 \text{ V}_{rms} \Rightarrow V_{MBR} = 216 \text{ V}_{DC}$$

The average level of output voltage is directly determined by the amplitude of the line voltage measured between phases L1 and L2.

NOTICE!

Maximum nominal voltage = 480 AC.

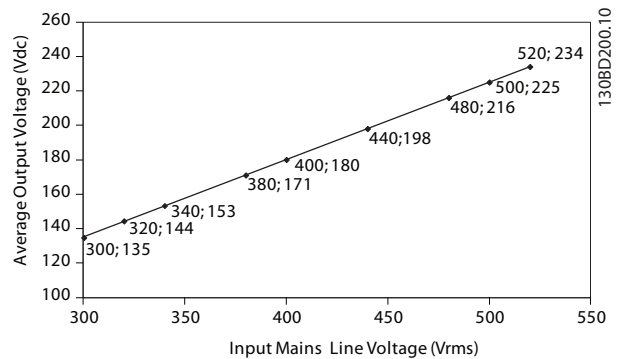


Figure 2.35 Average Output Voltage

It is possible to supply the mechanical brake in the motor with both DC and AC voltage. The output voltage is rectified by the internal diode inside the mechanical brake unit circuit. The average voltage applied to the brake coil remains at the same value.

2.7.1.2 Mechanical Brake Control

For hoisting applications, it is necessary to be able to control an electro-magnetic brake. For controlling the brake, a relay output (relay 1 or relay 2/solid state brake) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed for as long as the frequency converter is unable to hold the motor, for example, because of excess load. For applications with an electro-magnetic brake, select [32] mechanical brake control in 1 of the following parameters:

- Parameter 5-40 Function Relay (Array parameter),
- Parameter 5-30 Terminal 27 Digital Output, or
- Parameter 5-31 Terminal 29 digital Output

When [32] mechanical brake control is selected, the mechanical brake relay stays closed during start until the output current is above a preset level. Select the preset level in parameter 2-20 Release Brake Current. During stop, the mechanical brake closes when the speed is below the level selected in parameter 2-21 Activate Brake Speed [RPM]. When the frequency converter is brought into an alarm condition (that is, an overvoltage situation), or during Safe Torque Off, the mechanical brake immediately cuts in.

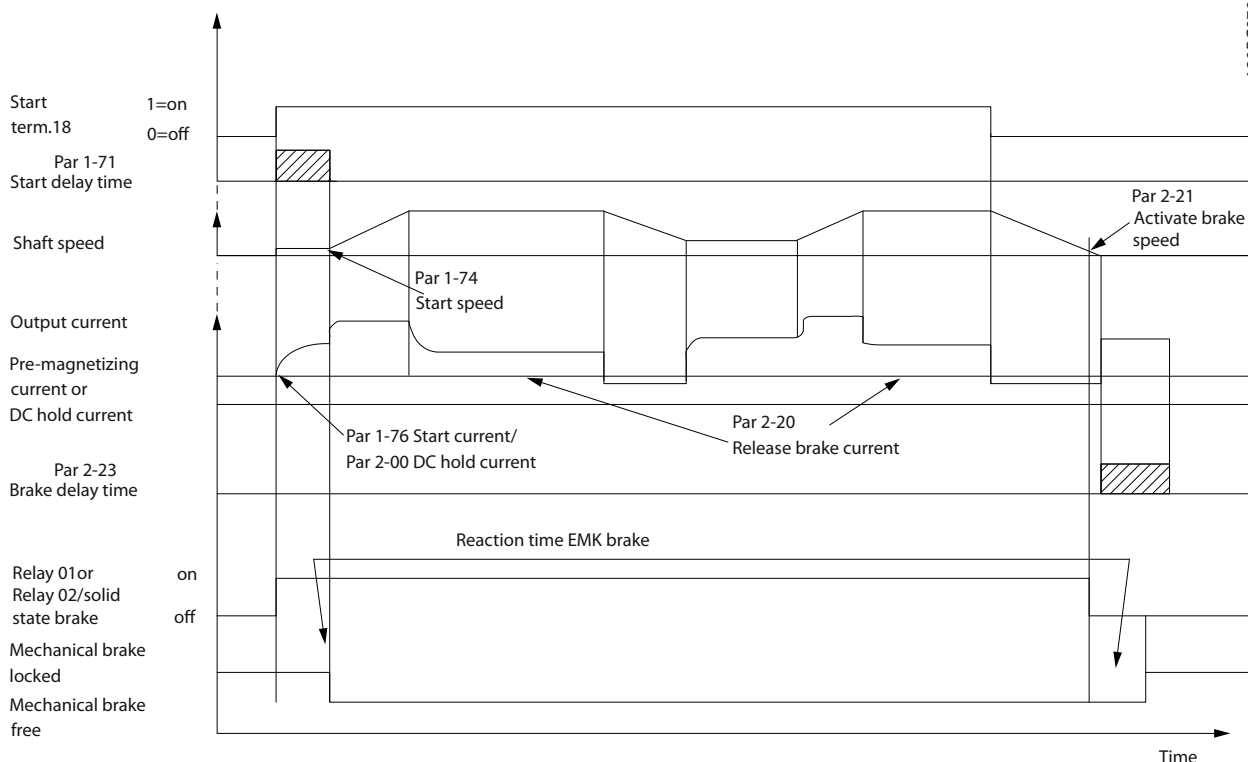


Figure 2.36 Mechanical Brake Control for Hoisting Applications

In hoisting/lowering applications, it must be possible to control an electromechanical brake.

Step-by-step description

- To control the mechanical brake, use any relay output, digital output (terminal 27 or 29), or solid-state brake voltage output (terminals 122–123). Use a suitable contactor when required.
- Ensure that the output is switched off as long as the frequency converter is unable to drive the motor. For example, due to the load being too heavy, or when the motor is not yet mounted.
- Select [32] *mechanical brake control* in *parameter group 5-4* Relays* (or in *parameter group 5-3* Digital Outputs*) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in *parameter 2-20 Release Brake Current*.
- The brake is engaged when the output frequency is lower than a preset limit. Set the limit in *parameter 2-21 Activate Brake Speed [RPM]* or *parameter 2-22 Activate Brake Speed [Hz]* and only

if the frequency converter carries out a stop command.

NOTICE!

Recommendation: For vertical lifting or hoisting applications, ensure that the load can be stopped in an emergency or a malfunction of a single part such as a contactor.

When the frequency converter enters alarm mode or an overvoltage situation, the mechanical brake cuts in.

NOTICE!

For hoisting applications, make sure that the torque limit settings do not exceed the current limit. Set torque limits in *parameter 4-16 Torque Limit Motor Mode* and *parameter 4-17 Torque Limit Generator Mode*. Set current limit in *parameter 4-18 Current Limit*.

Recommendation: Set *parameter 14-25 Trip Delay at Torque Limit* to [0], *parameter 14-26 Trip Delay at Inverter Fault* to [0], and *parameter 14-10 Line Failure* to [3] *Coasting*.

2.7.1.3 Mechanical Brake Cabling

EMC (twisted cables/shielding)

To reduce the electrical noise from the wires between the mechanical brake and the frequency converter, the wires must be twisted.

For enhanced EMC performance, use a metal shield.

Twisted-pair cables, containing both the motor and brake cables, can be used.

2.7.1.4 Hoist Mechanical Brake

For an example of advanced mechanical brake control for hoisting applications, see *chapter 4 Application Examples*.

2.7.2 Dynamic Brake

Dynamic brake established by:

- Resistor brake: A brake IGBT keeps the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor (*parameter 2-10 Brake Function = [1] Resistor Brake*).
- AC brake: The brake energy is distributed in the motor by changing the loss conditions in the motor. The AC brake function cannot be used in applications with high cycling frequency since this overheats the motor (*parameter 2-10 Brake Function = [2] AC Brake*).
- DC brake: An overmodulated DC current added to the AC current works as an eddy current brake (*parameter 2-02 DC Braking Time ≠ 0 s*).

2.7.2.1 Brake Resistors

In certain applications, break down of kinetic energy is required. In this frequency converter, the energy is not fed back to the grid. Instead, the kinetic energy must be transformed to heat, and this is achieved by braking using a brake resistor.

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the frequency converter. If the energy cannot be transported back to the motor, it increases the voltage in the frequency converter DC-line. In applications with frequent braking and/or high inertia loads, this increase may lead to an overvoltage trip in the frequency converter and finally a shutdown. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate, and its physical size. Danfoss brake resistors are available in several types, for internal or external installation to the frequency converter. Code

numbers can be found in *chapter 6.2.1 Ordering Numbers: Accessories*.

2.7.2.2 Selection of Brake Resistor

To handle higher demands by generatoric braking, a brake resistor is necessary. Using a brake resistor ensures that the energy is absorbed in the brake resistor and not in the frequency converter. For more information, see the *VLT® Brake Resistor MCE 101 Design Guide*.

If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated based on the cycle time and braking time also called intermittent duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Figure 2.37* shows a typical braking cycle.

NOTICE!

Motor suppliers often use *S5* when stating the allowed load, which is an expression of intermittent duty cycle.

The intermittent duty cycle for the resistor is calculated as follows:

$$\text{Duty cycle} = t_b / T$$

T = cycle time in s.

t_b is the braking time in s (of the cycle time).

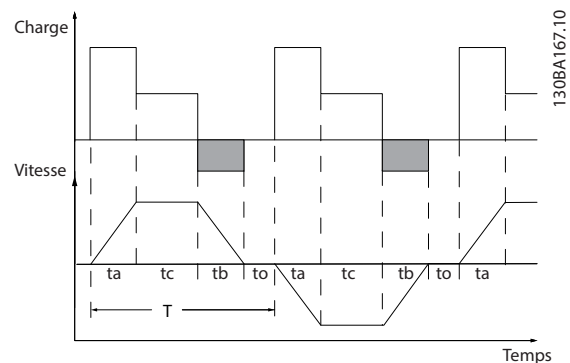


Figure 2.37 Dynamic Brake Cycle Time

	Cycle time [s]	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
3x380-480 V			
PK37-P3K0	120	Continuous	40%

Table 2.10 Braking at High Overload Torque Level

Brake resistors have a duty cycle of 5%, 10%, and 40%. If a 10% duty cycle is applied, the brake resistors are able to absorb brake power for 10% of the cycle time. The remaining 90% of the cycle time is used on dissipating excess heat.

NOTICE!

Ensure that the resistor is designed to handle the required braking time.

The maximum allowed load on the brake resistor is stated as a peak power at a given intermittent duty cycle and can be calculated as:

$$R_{br} [\Omega] = \frac{U_{dc}^2}{P_{peak}}$$

where

$$P_{peak} = P_{motor} \times M_{br} [\%] \times \eta_{motor} \times \eta_{VLT} [W]$$

The brake resistance depends on the DC-link voltage (U_{dc}). The brake function is settled in 4 areas of mains.

Size	Brake active	Warning before cutout	Cutout (trip)
FCD 302 3x380–480 V	778 V	810 V	820 V

Table 2.11 Brake Limit Values

NOTICE!

Check that the brake resistor can cope with a voltage of 820 V - unless brake resistors are used.

Danfoss recommends that the brake resistance R_{rec} guarantees that the frequency converter is able to brake at the highest brake power ($M_{br}(\%)$) of 160%. The formula can be written as:

$$R_{rec} [\Omega] = \frac{U_{dc}^2 \times 100}{P_{motor} \times M_{br}(\%) \times \eta_{VLT} \times \eta_{motor}}$$

η_{motor} is typically at 0.90

η_{VLT} is typically at 0.98

For 480 V frequency converters, R_{rec} at 160% brake power is written as:

$$480V : R_{rec} = \frac{375300}{P_{motor}} [\Omega]$$

NOTICE!

The resistance in the brake resistor circuit should not exceed the limits recommended by Danfoss. If a brake resistor with a higher ohmic value is selected, the 160% brake power may not be achieved because there is a risk that the frequency converter cuts out for safety reasons.

NOTICE!

If a short circuit in the brake transistor occurs, power dissipation in the brake resistor is only prevented by using a mains switch or contactor to disconnect the mains for the frequency converter (The contactor can be controlled by the frequency converter).

NOTICE!

Do not touch the brake resistor as it can get very hot while/after braking. The brake resistor must be placed in a secure environment to avoid fire risk.

2.7.2.3 Brake Resistors 10 W

For frequency converters equipped with the dynamic brake option, 1 brake IGBT along with terminals 81 (R-) and 82 (R+) is included in each inverter module for connecting a brake resistor(s).

An internal 10 W brake resistor can be mounted in the installation box (bottom part). This optional resistor is suitable for applications where braking IGBT is only active for very short duty cycles, for example to avoid warning and trip events.

For internal brake resistor use:

Brake resistor 1750 Ω 10 W/ 100%	For mounting inside installation box, below motor terminals.
Brake resistor 350 Ω 10 W/ 100%	For mounting inside installation box, below motor terminals.

Table 2.12 Brake Resistors 10 W

2.7.2.4 Brake Resistor 40%

Placing the brake resistor externally has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the frequency converter from overheating if the brake resistor is overloaded.

Number	Function	
81 (optional function)	R-	Brake resistor terminals
82 (optional function)	R+	

Table 2.13 Brake Resistors 40%

- The connection cable to the brake resistor must be shielded/armored. Connect the shield to the metal cabinet of the frequency converter and to the metal cabinet of the brake resistor with cable clamps.
- Dimension the cross-section of the brake cable to match the brake torque.

2.7.2.5 Control with Brake Function

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/digital output can be used for protecting the brake resistor against overloading in connection with a fault in the frequency converter.

In addition, the brake makes it possible to readout the momentary power and the mean power for the latest 120 s. The brake can also monitor the energizing power and make sure that it does not exceed a limit selected in *parameter 2-12 Brake Power Limit (kW)*. In *parameter 2-13 Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in *parameter 2-12 Brake Power Limit (kW)*.

NOTICE!

Monitoring the brake power is not a safety function; a thermal switch is required for that purpose. The brake resistor circuit is not ground leakage protected.

Overvoltage control (OVC) (exclusive brake resistor) can be selected as an alternative brake function in *parameter 2-17 Over-voltage Control*. This function is active for all units. The function ensures that a trip can be avoided if the DC-link voltage increases. This is done by increasing the output frequency to limit the voltage from the DC link. It is a very useful function to avoid unnecessary tripping of the frequency converter, for example when the ramp-down time is too short. In this situation, the ramp-down time is extended.

NOTICE!

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

2.7.2.6 Brake Resistor Cabling

EMC (twisted cable/shielding)

To reduce the electrical noise from the wires between the brake resistor and the frequency converter, the wires must be twisted.

For enhanced EMC performance, use a metal shield.

2.8 Safe Torque Off

To run STO, additional wiring for the frequency converter is required. Refer to *VLT® Frequency Converters Safe Torque Off Operating Guide* for further information.

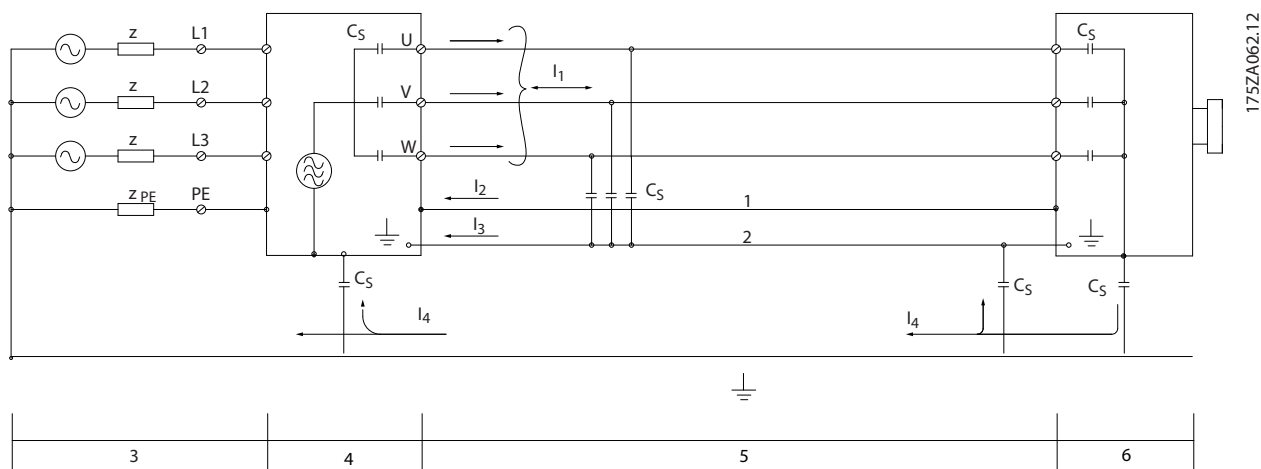
2.9 EMC

2.9.1 General Aspects of EMC Emissions

Burst transient is usually conducted 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. The use of a shielded motor cable increases the leakage current (see *Figure 2.38*) because shielded cables have higher capacitance to ground than unshielded cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below approximately 5 MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), there is only a small electro-magnetic field (I_4) from the shielded motor cable.

The shield reduces the radiated interference but increases the low-frequency interference on the mains. Connect the motor cable shield to the frequency converter and motor enclosures. Use integrated shield clamps to avoid twisted shield ends (pigtailed). Twisted shield ends increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4). When a shielded cable is used for fieldbus relay, control cable, signal interface, or brake, ensure that the shield is mounted on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.

2



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

Figure 2.38 Example - Leakage Current

Mounting plates, when used, must be constructed of metal to ensure that the shield currents are conveyed back to the unit. Ensure good electrical contact from the mounting plate through the mounting screws to the chassis of the frequency converter.

When unshielded cables are used, some emission requirements are not fulfilled. However, the immunity requirements are observed.

To reduce the interference level from the entire system (unit+installation), keep motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor and brake cables. Radio interference frequency above 50 MHz (airborne) is generated by the control electronics in particular.

2.9.2 Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC 61800-3:2004 the EMC requirements depend on the intended use of the frequency converter. Four categories are defined in the EMC product standard. The definitions of the 4 categories together with the requirements for mains supply voltage conducted emissions are given in *Table 2.14*.

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

Table 2.14 Emission Requirements

When the generic emission standards are used, the frequency converters are required to comply with the limits in *Table 2.15*.

Environment	Generic standard	Conducted emission requirement according to the limits given in EN 55011
First environment (home and office)	EN/IEC 61000-6-3 Emission standard for residential, commercial, and light industrial environments.	Class B
Second environment (Industrial environment)	EN/IEC 61000-6-4 Emission standard for industrial environments.	Class A Group 1

Table 2.15 Emission Limit Classes

2

2.9.3 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.

To document immunity against burst transient from electrical phenomena, the following immunity tests have been made on a system consisting of a frequency converter (with options if relevant), a shielded control cable, and a control box with potentiometer, motor cable, and motor.

:

The tests were performed in accordance with the following basic standards

- **EN 61000-4-2 (IEC 61000-4-2):** Electrostatic discharges (ESD): Simulation of electrostatic discharges from human beings.
- **EN 61000-4-3 (IEC 61000-4-3):** Incoming electromagnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment and mobile communications equipment.
- **EN 61000-4-4 (IEC 61000-4-4):** Burst transients: Simulation of interference brought about by switching a contactor, relay, or similar devices.
- **EN 61000-4-5 (IEC 61000-4-5):** Surge transients: Simulation of transients brought about for example, by lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6):** RF common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See Table 2.16.

Voltage range: 200–240 V, 380–480 V					
Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4 kV CM	2 kV/2 Ω DM 4kV/12 Ω CM	—	—	10 V _{RMS}
Motor	4 kV CM	4 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Brake	4 kV CM	4 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Load sharing	4 kV CM	4 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Control wires	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Standard bus	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Relay wires	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
Application and fieldbus options	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
LCP cable	2 kV CM	2 kV/2 Ω ¹⁾	—	—	10 V _{RMS}
External 24 V DC	2 V CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	—	—	10 V _{RMS}
Enclosure	—	—	8 kV AD 6 kV CD	10 V/m	—

Table 2.16 EMC Immunity

1) Injection on cable shield

AD: Air Discharge

CD: Contact Discharge

CM: Common Mode

DM: Differential Mode

2.9.4 EMC

2.9.4.1 EMC-correct Installation

The following is a guideline to good engineering practice when installing frequency converters. Follow these guidelines to comply with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment*, for example industrial networks, or in an installation with its own transformer. Deviation from these guidelines is allowed but not recommended. See also *chapter 1.5.1 CE Labeling*, *chapter 2.9.1 General Aspects of EMC Emissions*, and *chapter 2.9.7 EMC Test Results*.

Good engineering practice to ensure EMC-correct electrical installation:

- Use only braided shielded/armored motor cables and braided shielded/armored control cables. The shield should provide a minimum coverage of 80%. The shield material must be metal, not limited to but typically copper, aluminum, steel, or lead. There are no special requirements for the mains cable.
- Installations using rigid metal conduits are not required to use shielded cable, but the motor cable must be installed in conduit separate from the control and mains cables. Full connection of the conduit from the frequency converter to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the shield/armor/conduit to ground at both ends for motor cables and for control cables. Sometimes, it is not possible to connect the shield in both ends. If so, connect the shield at the frequency converter.
- Avoid terminating the shield/armor with twisted ends (pigtailed). It increases the high frequency impedance of the shield, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable glands instead.
- Avoid using unshielded/unarmored motor or control cables inside cabinets housing the frequency converter(s), whenever this can be avoided.

Leave the shield as close to the connectors as possible.

Figure 2.39 shows an example of an EMC-correct electrical installation of the *VLT[®] Decentral Drive FCD 302*. The frequency converter is connected to a PLC, which is installed in a separate cabinet. Other ways of doing the installation may have just as good an EMC performance, provided the above guidelines are followed.

If the installation is not carried out according to the guidelines, and if unshielded cables and control wires are used, then certain emission requirements are not fulfilled, although the immunity requirements are fulfilled. See *chapter 2.9.7 EMC Test Results*.

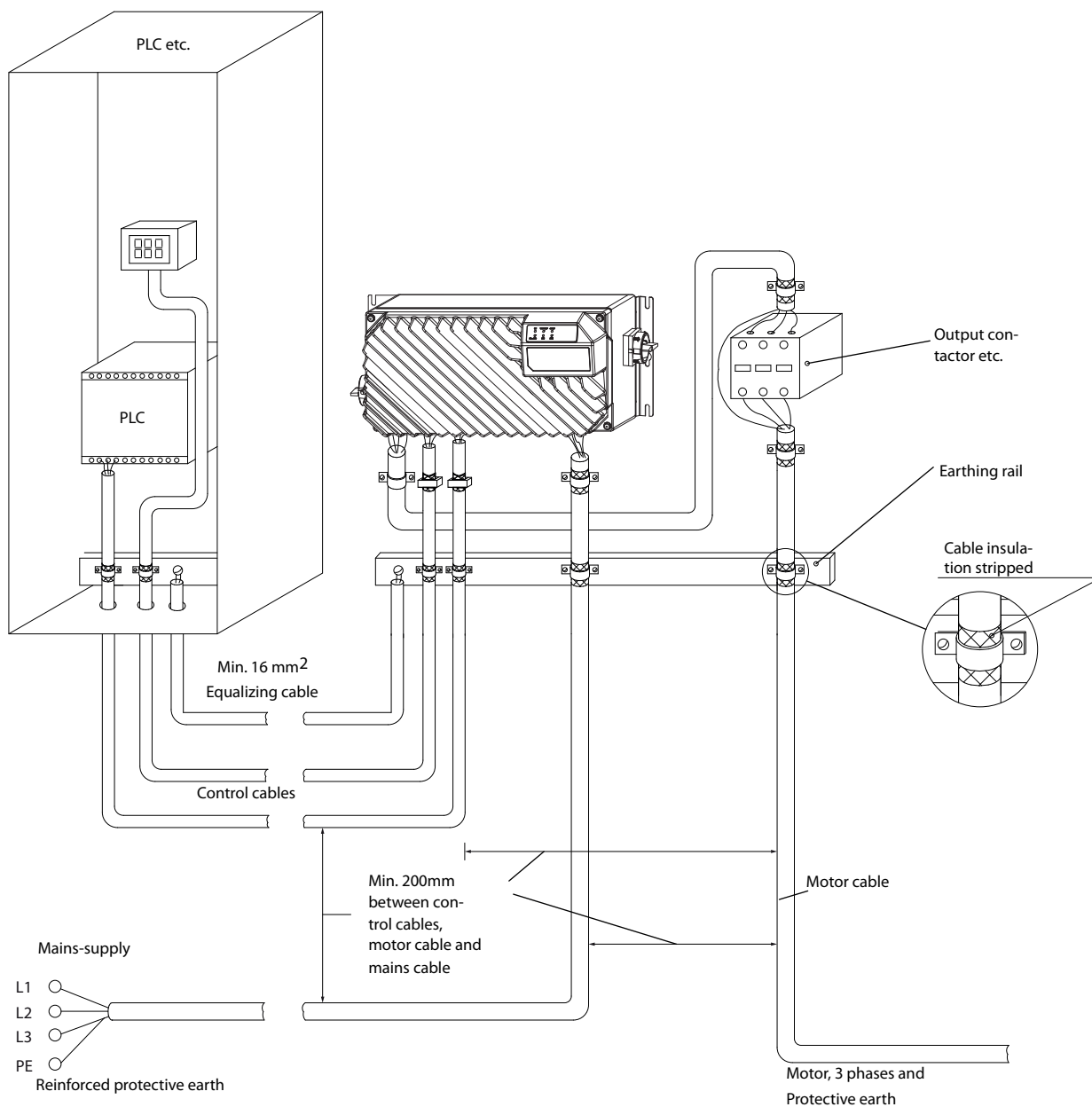


Figure 2.39 EMC-correct Electrical Installation of a Frequency Converter

A minimum distance of 200 mm (7.87 in) is required between the fieldbus cable and the motor cable and also between fieldbus cable and the mains cable. If this cannot be achieved, use the optional PE grounding plug on the underside of the VLT® Decentral Drive FCD 302.

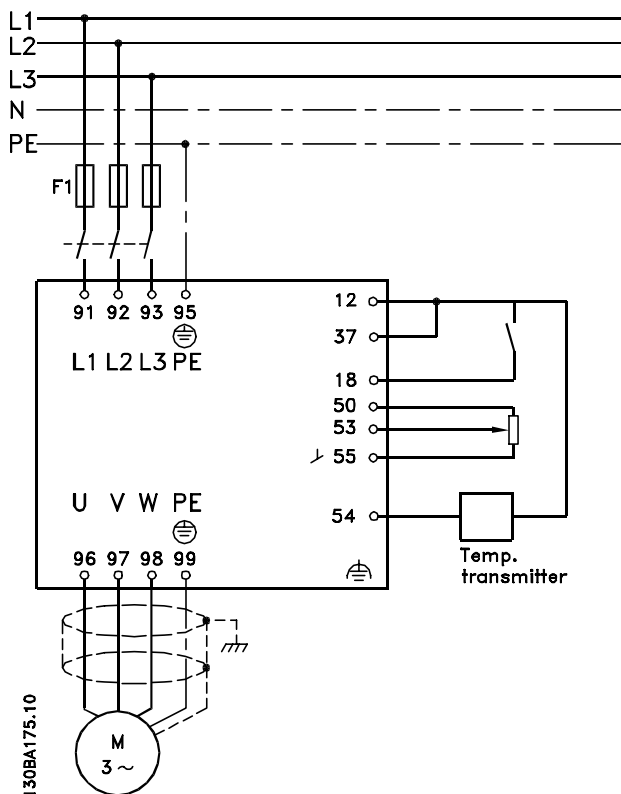


Figure 2.40 Connection of Mains Diagram

Electrical safety ground connections

To obtain the electrical safety, always connect the safety ground on the dedicated connections inside the VLT® Decentral Drive FCD 302 installation box. See Figure 2.41.

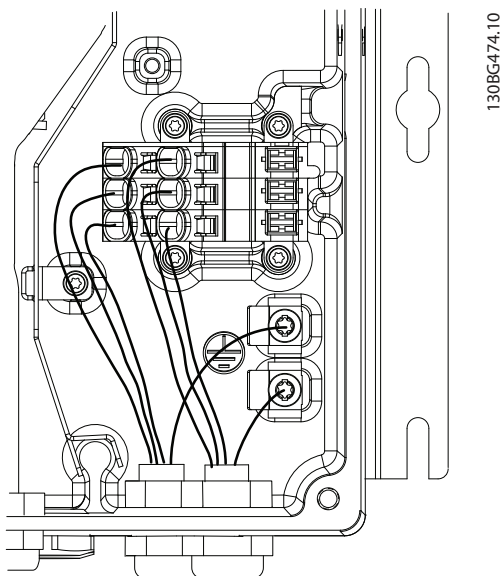


Figure 2.41 Electrical Safety Ground Connections

Equalizing cable

As the shield of the communication cable needs to be connected to ground by each drive/device, there is a risk of having current in the communication cable. This might lead to communication problems as the equalizing current can interfere with the communication. To reduce currents in the shield of the communication cable, always apply a short grounding cable between units that are connected to the same communication cable. Danfoss recommend using minimum 16 mm² (6 AWG) equalizing cable and install the equalizing cable parallel with the communication cable.

For good equalizing between VLT® Decentral Drive FCD 302 in a decentral installation, use the external equalizing terminal from Danfoss (ordering number 130B5833).

2.9.4.2 Use of EMC-correct Cables

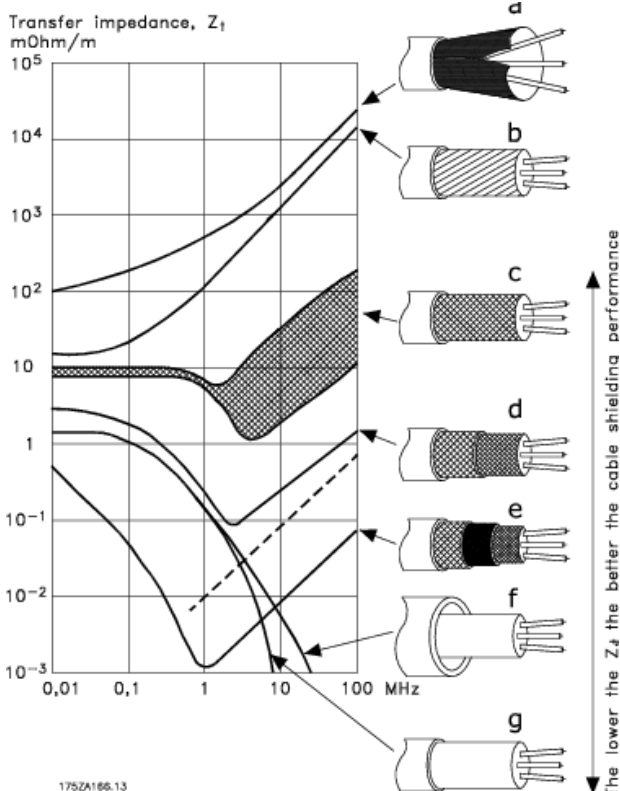
Danfoss recommends braided shielded/armored cables to optimize EMC immunity of the control cables and emission from the motor cables.

The ability of a cable to reduce the in- and outgoing radiation of electric noise depends on the transfer impedance (Z_T). The shield of a cable is normally designed to reduce the transfer of electric noise; however, a shield with a lower transfer impedance (Z_T) value is more effective than a shield with a higher transfer impedance (Z_T).

Transfer impedance (Z_T) is rarely stated by cable manufacturers but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable.

Transfer impedance (Z_T) can be assessed based on the following factors:

- The conductivity of the shield material.
- The contact resistance between the individual shield conductors.
- The shield coverage, that is, the physical area of the cable covered by the shield - often stated as a percentage value.
- Shield type, that is, braided or twisted pattern.



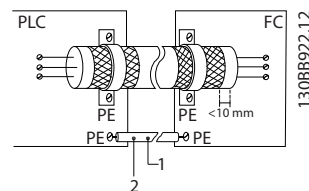
a.	Aluminum-clad with copper wire
b.	Twisted copper wire or armored steel wire cable
c.	Single-layer braided copper wire with varying percentage shield coverage. This is the typical reference cable
d.	Double-layer braided copper wire
e.	Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer
f.	Cable that runs in copper tube or steel tube
g.	Lead cable with 1.1 mm (0.04 inch) wall thickness

Figure 2.42 Transfer Impedance

2.9.4.3 Grounding of Shielded Control Cables

Correct shielding

The preferred method usually is to secure control cables and cables with shielding clamps provided at both ends to ensure best possible high frequency cable contact. If the ground potential between the frequency converter and the PLC is different, electric noise may occur that disturbs the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 16 mm² (6 AWG).



1	Minimum 16 mm ² (6 AWG)
2	Equalizing cable

Figure 2.43 Shielding of Control Cables

50/60 Hz ground loops

With very long control cables, ground loops may occur. To eliminate ground loops, connect 1 end of the shield-to-ground with a 100 nF capacitor (keeping leads short).

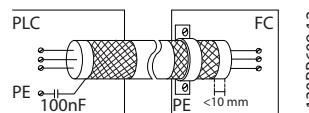
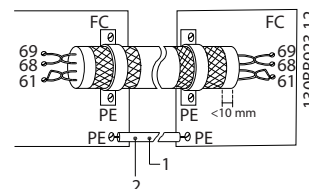


Figure 2.44 Shielding for 50/60 Hz Ground Loops

Avoid EMC noise on serial communication

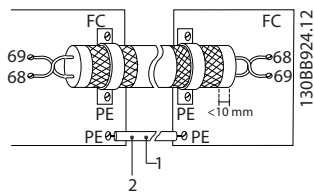
This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown in Figure 2.45.



1	Minimum 16 mm ² (6 AWG)
2	Equalizing cable

Figure 2.45 Shielding for EMC Noise Reduction, Serial Communication

Alternatively, the connection to terminal 61 can be omitted:



1	Minimum 16 mm ² (6 AWG)
2	Equalizing cable

Figure 2.46 Shielding for EMC Noise Reduction, Serial Communication, without Terminal 61

2.9.4.4 RFI Switch

Mains supply isolated from ground

When the frequency converter is supplied from an isolated mains source (IT mains, floating delta, and grounded delta) or TT/TN-S mains with grounded leg, set the RFI switch to [Off] via *parameter 14-50 RFI 1* on the frequency converter. Otherwise, set *parameter 14-50 RFI 1* to [On].

For further information, refer to:

- IEC 364-3.
- Application note *VLT® on IT mains*. It is important to use isolation monitors that are capable for use together with power electronics (IEC 61557-8).

2.9.5 Mains Supply Interference/Harmonics

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 up into sine-wave currents with different frequencies, that is, different harmonic currents I_N with 50 Hz as the basic frequency:

Harmonic currents	I_1	I_5	I_7
Hz	50 Hz	250 Hz	350 Hz

Table 2.17 Harmonic Currents

The harmonics do not affect the power consumption directly but increase the heat losses in the installation (transformer, cables). Therefore, 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.

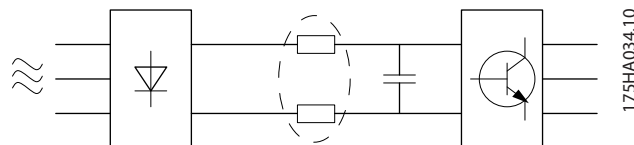


Figure 2.47 DC-link Coils

NOTICE!

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

	Input current
I_{RMS}	1.0
I_1	0.9
I_5	0.4
I_7	0.2
I_{11-49}	<0.1

Table 2.18 Harmonic Currents Compared to the RMS Input Current

To ensure low harmonic currents, the frequency converter is equipped with DC-link coils as standard. DC coils reduce the total harmonic distortion (THD) to 40%.

2.9.5.1 Effect of Harmonics in a Power Distribution System

In *Figure 2.48*, a transformer is connected on the primary side to a point of common coupling PCC1 on the medium voltage supply. The transformer has an impedance Z_{xfr} and feeds a number of loads. The point of common coupling where all loads are connected together is PCC2. Each load is connected through cables that have an impedance Z_1 , Z_2 , Z_3 .

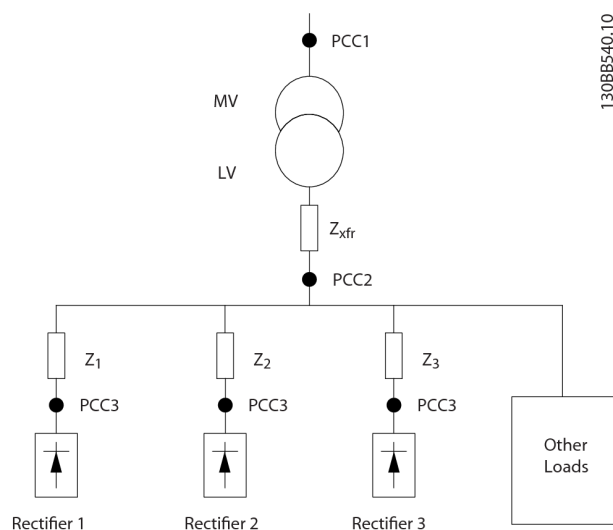


Figure 2.48 Small Distribution System

Harmonic currents drawn by non-linear loads cause distortion of the voltage because of the voltage drop on the impedances of the distribution system. Higher impedances result in higher levels of voltage distortion.

Current distortion relates to apparatus performance and it relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the load's harmonic performance. To predict the distortion in the PCC, the configuration of the distribution system and relevant impedances must be known.

A commonly used term for describing the impedance of a grid is the short circuit ratio R_{sce} , defined as the ratio between the short circuit apparent power of the supply at the PCC (S_{sc}) and the rated apparent power of the load (S_{equ}).

$$R_{sce} = \frac{S_{sc}}{S_{equ}}$$

where $S_{sc} = \frac{U^2}{Z_{supply}}$ and $S_{equ} = U \times I_{equ}$

The negative effect of harmonics is twofold

- Harmonic currents contribute to system losses (in cabling, transformer).
- Harmonic voltage distortion causes disturbance to other loads and increase losses in other loads.

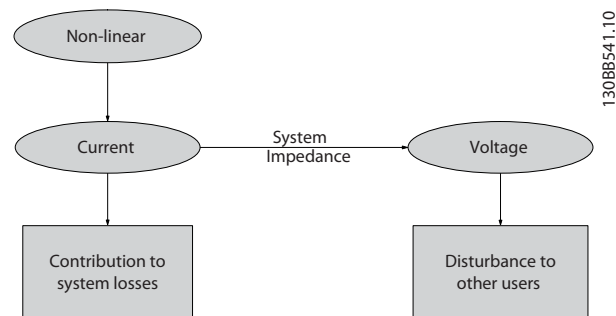


Figure 2.49 Negative Effects of Harmonics

2.9.5.2 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be:

- Application-specific requirements.
- Standards that must be observed.

The application-specific requirements are related to a specific installation where there are technical reasons for limiting the harmonics.

Example: A 250 kVA transformer with 2 110 kW motors connected is sufficient if 1 of the motors is connected directly online and the other is supplied through a frequency converter. However, the transformer is undersized if a frequency converter supplies both motors. Using extra means of harmonic reduction within the installation or selecting low harmonic frequency converter variants makes it possible for both motors to run with frequency converters.

There are various harmonic mitigation standards, regulations, and recommendations. Different standards apply in different geographical areas and industries. The following standards are the most common:

- IEC61000-3-2
- IEC61000-3-12
- IEC61000-3-4
- IEEE 519
- G5/4

See the *VLT® Advanced Harmonic Filter AHF 005 & AHF 010 Design Guide* for specific details on each standard.

2.9.5.3 Harmonic Mitigation

In cases where extra harmonic suppression is required, Danfoss offers a wide range of mitigation equipment.

These are:

- VLT® 12-pulse frequency converters.
- VLT® AHF filters.
- VLT® Low Harmonic Drives.
- VLT® Advanced Active Filters.
- The grid (background distortion, mains unbalance, resonance, and type of supply (transformer/generator))
- Application (load profile, number of loads, and load size)
- Local/national requirements/regulations (IEEE 519, IEC, G5/4, and so on)
- Total cost of ownership (initial cost, efficiency, maintenance, and so on)

The selection of the right solution depends on several factors:

2.9.5.4 Harmonic Calculation

Determining the degree of voltage pollution on the grid and needed precaution is done with the Danfoss VLT® Harmonic Calculation MCT 31 software. The free tool MCT 31 can be downloaded from www.danfoss.com. The software is built with a focus on user-friendliness and limited to involve only system parameters that are normally accessible.

2.9.6 Residual Current Device

Use RCD relays, multiple protective earthing, or grounding as extra protection to comply with local safety regulations. If a ground fault appears, a DC content may develop in the faulty current.

If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up using RCDs.

2.9.7 EMC Test Results

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

RFI filter type		Conducted emission			Radiated emission	
		Class B	Class A Group 1	Class A Group 2	Class B	Class A Group 1
Standards and requirements	EN 55011	Housing, trades, and light industries	Industrial environment	Industrial environment	Housing, trades, and light industries	Industrial environment
	EN/IEC 61800-3	Category C1	Category C2	Category C3	Category C1	Category C2
		First environment Home and office	First environment Home and office	Second environment Industrial	First environment Home and office	First environment Home and office
H1						
FCD 302	0.37–3 kW (0.5–4 hp)	No	10 m (32.8 ft)	10 m (32.8 ft)	No	Yes

Table 2.19 EMC Test Results (Emission, Immunity)

3 System Integration

3

3.1 Ambient Conditions

3.1.1 Air Humidity

The frequency converter meets the IEC/EN 60068-2-3 standard, EN 50178 section 9.4.2.2 at 50 °C (122 °F).

3.1.2 Aggressive Environments

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

NOTICE!

The frequency converter should not be installed in environments with airborne liquids, particles, or gases capable of affecting and damaging the electronic components. Failure to take the necessary protective measures increases the risk of stoppages, thus reducing the life of the frequency converter.

Degree of protection as per IEC 60529

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

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

NOTICE!

Mounting frequency converters in aggressive environments increases the risk of stoppages and considerably reduces the life of the frequency converter.

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

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

3.1.3 Vibration and Shock

The frequency converter has been tested according to the procedure based on the shown standards:

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

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

3.1.4 Acoustic Noise

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

- DC intermediate circuit coils.
- RFI filter choke.

VLT® Decentral Drive FCD 302 has no significant audible noise. Refer to *chapter 7 Specifications* for acoustic noise data.

3.2 Mounting Positions

The VLT® Decentral Drive FCD 302 consists of 2 parts:

- The installation box
- The electronic part

Standalone mounting

- The holes on the rear of the installation box are used to fix mounting brackets.
- Ensure that the strength of the mounting location can support the unit weight.
- Make sure that the proper mounting screws or bolts are used.

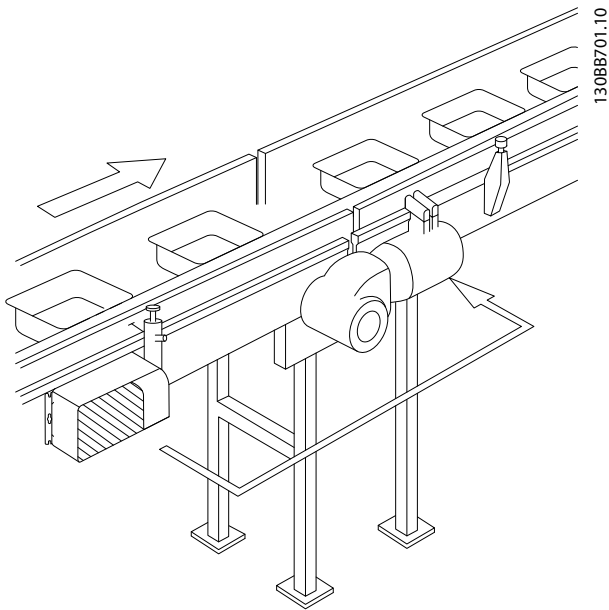


Figure 3.1 FCD 302 Stand-alone Mounted with Mounting Brackets

3.2.1 Mounting Positions for Hygienic Installation

The VLT® Decentral Drive FCD 302 is designed according to the EHEDG guidelines, suitable for installation in environments with high focus on ease of cleaning.

Mount the FCD 302 vertically on a wall or machine frame, to ensure that liquids drain off the enclosure. Orient the unit so the cable glands are located at the base.

Use cable glands designed to meet hygienic application requirements, for example Rittal HD 2410.110/120/130. Hygienic-purpose cable glands ensure optimal ease of cleaning the installation.

NOTICE!

Only frequency converters configured as hygienic enclosure designation, FCD 302 P XXX T4 W69, have the EHEDG certification.

Allowed mounting positions

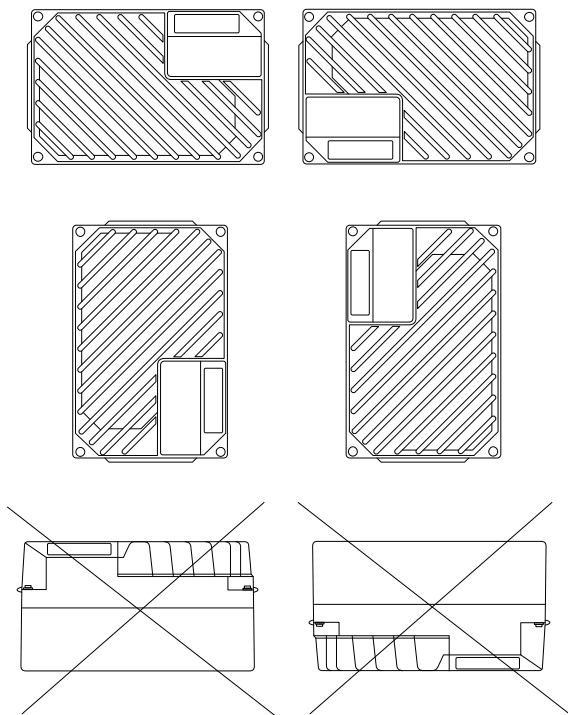


Figure 3.2 Allowed Mounting Positions for Standard Applications

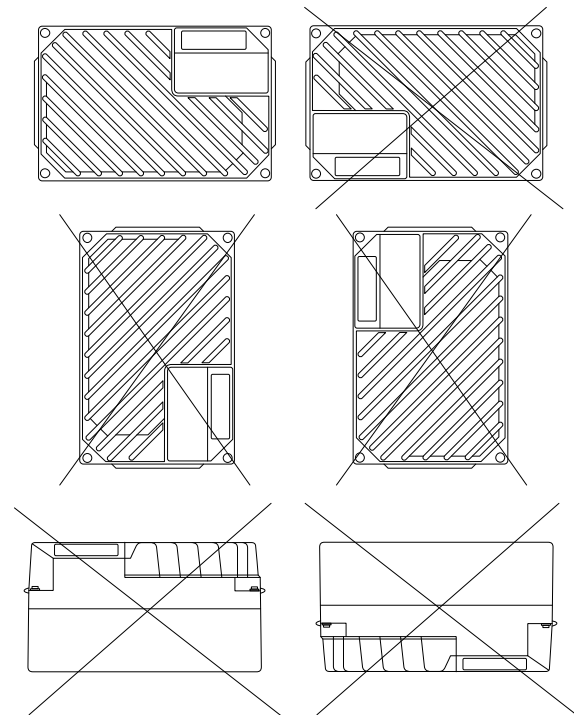


Figure 3.3 Allowed Mounting Positions for Hygienic Applications

3.3 Electrical Input: Mains-side Dynamics

3.3.1 Connections

3.3.1.1 Cables General

NOTICE!

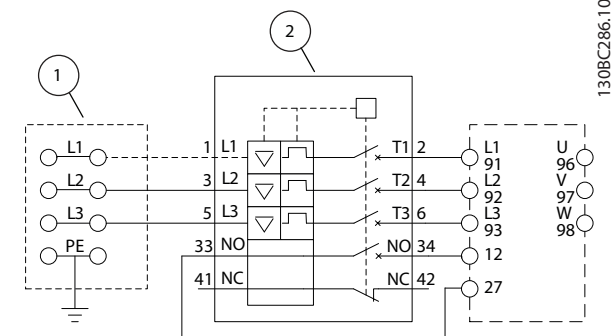
Cables general

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. Copper (75 °C (175 °F)) conductors are recommended.

3.3.1.2 Connection to Mains and Grounding

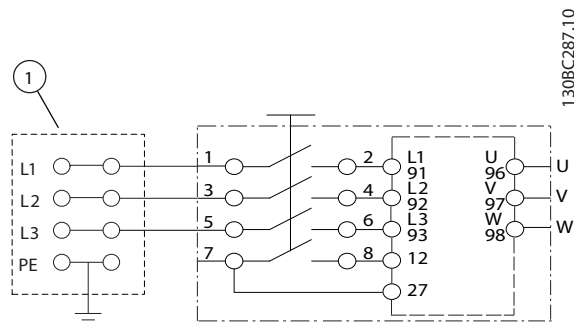
For installation instructions and location of terminals, refer to *VLT® Decentral Drive FCD 302 Operating Guide*.

Connection of mains



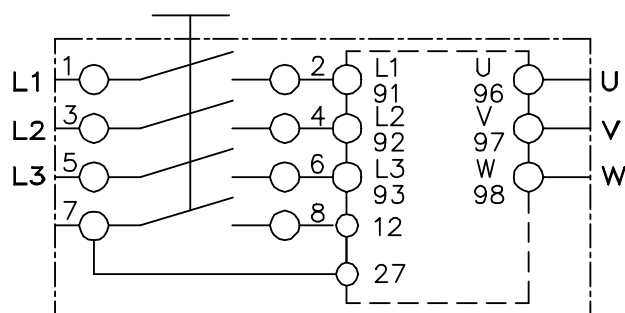
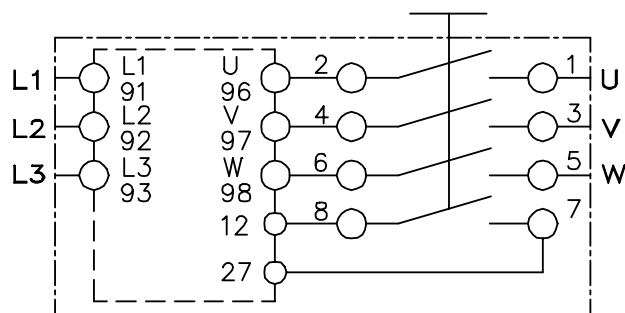
1	Looping terminals
2	Circuit breaker

Figure 3.4 Large Unit only: Circuit Breaker and Mains Disconnect



1	Looping terminals
---	-------------------

Figure 3.5 Large Unit only: Service Switch at Mains with Looping Terminals



195NA288.10

Figure 3.6 Motor and Connection of Mains with Service Switch

For both small and large units, the service switch is optional. The switch is shown mounted on the motor side. Alternatively, the switch can be on the mains side, or omitted.

For the large unit, the circuit breaker is optional. The large unit can be configured with either service switch or circuit breaker, not both. *Figure 3.6* is not configurable in practice, but shows the respective positions of components only.

Usually, the power cables for mains are unshielded cables.

3.3.1.3 Relay Connection

To set relay output, see *parameter group 5-4* Relays*.

Number	Description
01-02	Make (normally open)
01-03	Break (normally closed)
04-05	Make (normally open)
04-06	Break (normally closed)

Table 3.1 Relay Settings

For location of relay terminals, refer to *VLT® Decentral Drive FCD 302 Operating Guide*.

3.3.2 Fuses and Circuit Breakers

3.3.2.1 Fuses

Fuses and/or circuit breakers are recommended protection on the supply side, if a component break-down inside the frequency converter (first fault) occurs.

NOTICE!

Using fuses and/or circuit breakers is mandatory in order to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

NOTICE!

Personnel and property must be protected against the consequence of component break-down internally in the frequency converter.

Branch circuit protection

To protect the installation against electrical and fire hazard, all branch circuits in an installation, switchgear, machines, and so on, must be protected against short circuit and overcurrent according to national/international regulations.

NOTICE!

The recommendations given do not cover branch circuit protection for UL.

Short-circuit protection

Danfoss recommends using the fuses/circuit breakers mentioned below to protect service personnel and property in case of component break-down in the frequency converter.

3.3.2.2 Recommendations

CAUTION

In the event of malfunction, failure to follow the recommendation may result in personnel risk and damage to the frequency converter and other equipment.

The following sections list the recommended rated current. Danfoss recommends fuse type gG and Danfoss CB (Danfoss - CTI-25M) circuit breakers. Other types of circuit breakers may be used if they limit the energy into the frequency converter to a level equal to or lower than the Danfoss CB types.

Follow the recommendations for fuses and circuit breakers to ensure that any damage to the frequency converter is internal only.

For further information, see *Application Note Fuses and Circuit Breakers*.

3.3.2.3 CE Compliance

Use of fuses or circuit breakers is mandatory to comply with IEC 60364.

Danfoss recommends fuse size up to gG-25. This fuse size is suitable for use on a circuit capable of delivering 100000 A_{rms} (symmetrical), 480 V. With the proper fusing, the frequency converter short-circuit current rating (SCCR) is 100000 A_{rms} .

3.3.2.4 UL Compliance

Fuses or circuit breakers are mandatory to comply with NEC 2009. To meet UL/cUL requirements, use the pre-fuses in *Table 7.2*, and comply with the conditions listed in *chapter 7.2 Electrical Data and Wire Sizes*.

The current and voltage ratings are also valid for UL.

3.4 Electrical Output: Motor-side Dynamics

3.4.1 Motor Connection

NOTICE!

To comply with EMC emission specifications, shielded/armored cables are recommended.

See *chapter 7.3 General Specifications* for correct dimensioning of motor cable cross-section and length.

Shielding of cables

Avoid installation with twisted shield ends (pigtailed). They spoil the shielding effect at higher frequencies. If it is necessary to break the shield to install a motor isolator or motor contactor, the shield must be continued at the lowest possible HF impedance.

Connect the motor cable shield to both the decoupling plate of the frequency converter and to the metal housing of the motor.

Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the frequency converter.

If it is necessary to split the shield to install a motor isolator or motor relay, the shield must be continued with the lowest possible HF impedance.

Cable length and cross-section

The frequency converter has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance - and thus the leakage current - may increase, and the cable length must be reduced correspondingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

All types of 3-phase asynchronous standard motors can be connected to the frequency converter. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor nameplate for correct connection mode and voltage.

For installation of mains and motor cables, refer to *VLT® Decentral Drive FCD 302 Operating Guide*.

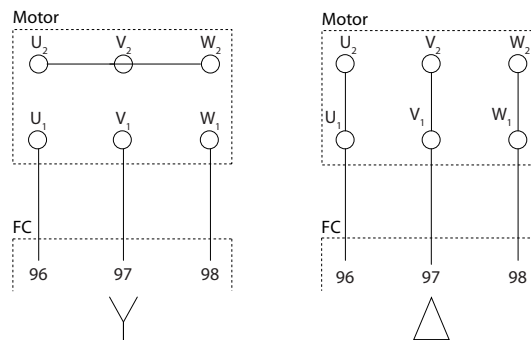


Figure 3.7 Star - Delta Grounding Connections

NOTICE!

In motors without phase insulation paper or other insulation reinforcement suitable for operation with voltage supply (such as a frequency converter), fit a sine-wave filter on the output of the frequency converter.

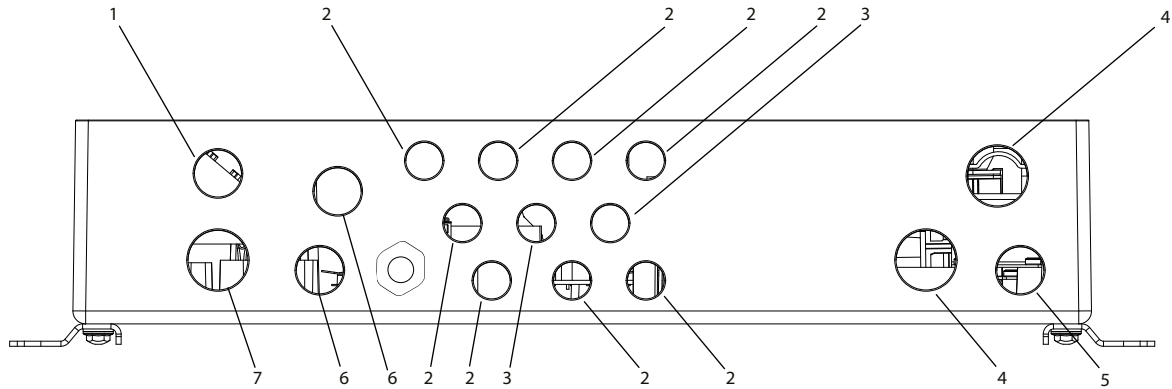
Terminal number	96	97	98	99	
	U	V	W	PE ¹⁾	Motor voltage 0–100% of mains voltage. 3 wires out of motor.
	U1	V1	W1	PE ¹⁾	Delta-connected. 6 wires out of motor.
	W2	U2	V2		
	U1	V1	W1	PE ¹⁾	Star-connected U2, V2, W2. U2, V2, and W2 to be interconnected separately.

Table 3.2 Motor Connection Terminals

1) Protective earth connection

175ZA114.11

The VLT® Decentral Drive FCD 302 is also available as a real NPT version in 2 different variants.



1308C981.10

	Metric	NPT 1 for USA	NPT 2 for USA
1	Brake M20	1/2" NPT	1/2" NPT
2	8xM16	8xM16	3/8" NPT (except ground plug, which is M16)
3	2xM20	2xM20	1/2" NPT
4	Mains cables M25	3/4" NPT	3/4" NPT
5	M20	M20	1/2" NPT
6	24 V M20	1/2" NPT	1/2" NPT
7	Motor M25	3/4" NPT	3/4" NPT

Figure 3.8 Cable Entry Holes - Large Unit

3.4.2 Mains Disconnectors

The frequency converter is available with optional

- Service switch on mains side or motor side or
- Built-in circuit breaker on the mains side (large unit only)

Specify the requirement when ordering.

Figure 3.9 and Figure 3.10 show examples of configuration for the large unit.

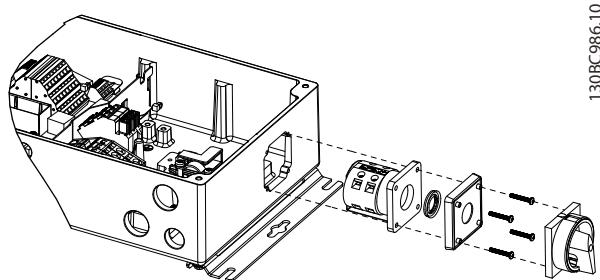


Figure 3.9 Location of Service Switch, Mains Side, Large Unit (IP66/Type 4X indoor)

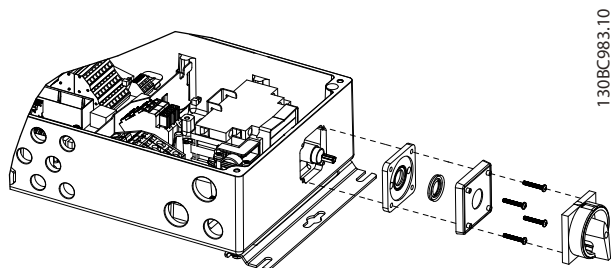


Figure 3.10 Location of Circuit Breaker, Mains Side, Large Unit

- Terminal U/T1/96 connected to U-phase.
- Terminal V/T2/97 connected to V-phase.
- Terminal W/T3/98 connected to W-phase.

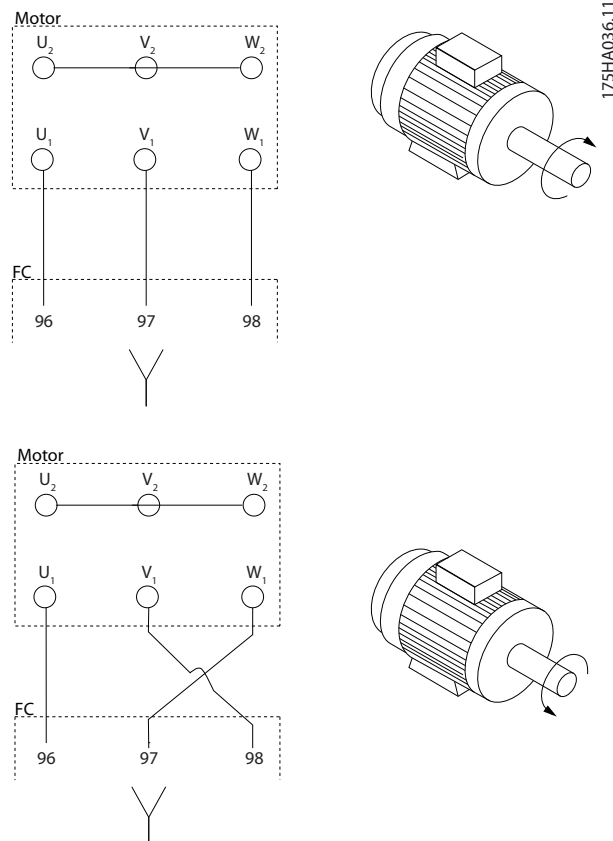


Figure 3.11 Motor Connection - Direction of Rotation

3.4.3 Additional Motor Information

3.4.3.1 Motor Cable

The motor must be connected to terminals U/T1/96, V/T2/97, W/T3/98. Ground to terminal 99. All types of 3-phase asynchronous standard motors can be used with a frequency converter unit. The factory setting is for clockwise rotation with the frequency converter output connected as shown in Table 3.3:

Terminal number	Function
96, 97, 98, 99	Mains U/T1, V/T2, W/T3 Ground

Table 3.3 Motor Connection - Factory Setting

The direction of rotation can be changed by switching 2 phases in the motor cable or by changing the setting of parameter 4-10 Motor Speed Direction.

Motor rotation check can be performed using parameter 1-28 Motor Rotation Check and following the steps shown in the display.

3.4.3.2 Motor Thermal Protection

The electronic thermal relay in the frequency converter has received UL approval for single motor overload protection, when parameter 1-90 Motor Thermal Protection is set for ETR Trip and parameter 1-24 Motor Current is set to the rated motor current (see motor nameplate).

3.4.3.3 Parallel Connection of Motors

The frequency converter can control several parallel-connected motors. When using parallel motor connection, observe the following:

- Recommended to run applications with parallel motors in U/F mode *parameter 1-01 Motor Control Principle* [0]. Set the U/F graph in *parameter 1-55 U/f Characteristic - U* and *parameter 1-56 U/f Characteristic - F*.
- VVC⁺ mode may be used in some applications.
- The total current consumption of the motors must not exceed the rated output current I_{INV} for the frequency converter.
- If motor sizes are widely different in winding resistance, starting problems may occur due to too low motor voltage at low speed.
- The electronic thermal relay (ETR) of the frequency inverter cannot be used as motor overload protection for the individual motor. Provide further motor overload protection with for example thermistors in each motor winding or individual thermal relays. Circuit breakers are not suitable as protection device.

NOTICE!

Installations with cables connected in a common joint as shown in the first example in the picture is only recommended for short cable lengths.

NOTICE!

When motors are connected in parallel, *parameter 1-02 Flux Motor Feedback Source* cannot be used, and *parameter 1-01 Motor Control Principle* must be set to *Special motor characteristics (U/f)*.

The total motor cable length specified in *chapter 7 Specifications*, is valid as long as the parallel cables are kept short (less than 10 m (32.8 ft) each).

3.4.3.4 Motor Insulation

For motor cable lengths \leq the maximum cable length listed in *chapter 7.3 General Specifications*, the following motor insulation ratings are recommended because the peak voltage can be up to twice the DC-link voltage, 2.8 times the mains voltage, due to transmission line effects in the motor cable. If a motor has lower insulation rating, it is recommended to use a dU/dt or sine-wave filter.

Nominal mains voltage	Motor insulation
$U_N \leq 420$ V	Standard $U_{LL} = 1300$ V
420 V $< U_N \leq 500$ V	Reinforced $U_{LL} = 1600$ V

Table 3.4 Mains Voltage and Motor Insulation

3.4.3.5 Motor Bearing Currents

To minimize DE (Drive End) bearing and shaft currents proper grounding of the frequency converter, motor, driven machine, and motor to the driven machine is required.

Standard mitigation strategies

1. Use an insulated bearing.
2. Apply rigorous installation procedures:
 - 2a Ensure that the motor and load motor are aligned.
 - 2b Strictly follow the EMC Installation guideline.
 - 2c Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads.
 - 2d Provide a good high frequency connection between the motor and the frequency converter, for instance via a shielded cable which has a 360° connection in the motor and the frequency converter.
 - 2e Make sure that the impedance from the frequency converter to the building ground is lower than the grounding impedance of the machine. This can be difficult for pumps.
 - 2f Make a direct ground connection between the motor and load motor.
3. Lower the IGBT switching frequency.
4. Modify the inverter waveform, 60° AVFM vs. SFVFM.
5. Install a shaft grounding system or use an isolating coupling.
6. Apply conductive lubrication.
7. Use minimum speed settings if possible.
8. Try to ensure that the mains voltage is balanced to ground. This can be difficult for IT, TT, TN-CS, or grounded leg systems.
9. Use a dU/dt or sinus filter.

3.4.4 Extreme Running Conditions

Short circuit (motor phase – phase)

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

To protect the frequency converter against a short circuit at the load sharing and brake outputs, see the design guidelines.

Switching on the output

Switching on the output between the motor and the frequency converter is fully allowed. No damage to the frequency converter can occur by switching on the output. However, fault messages can appear.

Motor-generated overvoltage

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

- The load drives the motor (at constant output frequency from the frequency converter), that is, the load generates energy.
- During deceleration (ramp-down), if the inertia moment is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter, the motor, and the installation.
- Incorrect slip compensation setting can cause higher DC-link voltage.
- Back EMF from PM motor operation. When coasted at high RPM, the PM motor back EMF can potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. The frequency converter is designed to prevent the occurrence of back EMF: The value of *parameter 4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *parameter 1-40 Back EMF at 1000 RPM*, *parameter 1-25 Motor Nominal Speed*, and *parameter 1-39 Motor Poles*. When motor overspeed is possible (for example, due to excessive windmilling effects), then a brake resistor is recommended.

NOTICE!

The frequency converter must be equipped with a brake chopper.

When possible, the control unit may attempt to correct the ramp (*parameter 2-17 Over-voltage Control*).

The inverter turns off when a certain voltage level is reached, to protect the transistors and the DC link capacitors.

See *parameter 2-10 Brake Function* and *parameter 2-17 Over-voltage Control* to select the method used for controlling the DC-link voltage level.

NOTICE!

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

Mains drop-out

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

Static overload in VVC+ mode

When the frequency converter is overloaded, the controls reduce the output frequency to reduce the load. Overload is defined as reaching the torque limit set in *parameter 4-16 Torque Limit Motor Mode/parameter 4-17 Torque Limit Generator Mode*. For extreme overload, a current acts to ensure the frequency converter cuts out after approximately 5–10 seconds.

Operation within the torque limit is limited in time (0–60 seconds) in *parameter 14-25 Trip Delay at Torque Limit*.

3.4.4.1 Motor Thermal Protection

To protect the application from serious damage, the frequency converter offers several dedicated features:

Torque limit

The torque limit feature protects the motor from being overloaded independent of the speed. Select torque limit settings in *parameter 4-16 Torque Limit Motor Mode* and/or *parameter 4-17 Torque Limit Generator Mode*. Set the time to trip for the torque limit warning in *parameter 14-25 Trip Delay at Torque Limit*.

Current limit

Set the current limit in *parameter 4-18 Current Limit*. Set the time before the current limit warning trips in *parameter 14-24 Trip Delay at Current Limit*.

Minimum speed limit

Parameter 4-11 Motor Speed Low Limit [RPM] or *parameter 4-12 Motor Speed Low Limit [Hz]* limit the operating speed range to for instance between 30 and 50/60 Hz. Maximum speed limit: *Parameter 4-13 Motor*

Speed High Limit [RPM] or parameter 4-19 Max Output Frequency limit the maximum output speed the frequency converter can provide.

ETR (electronic thermal relay)

The ETR function measures actual current, speed, and time to calculate motor temperature and protect the motor from being overheated (warning or trip). An external thermistor input is also available. ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in Figure 3.12.

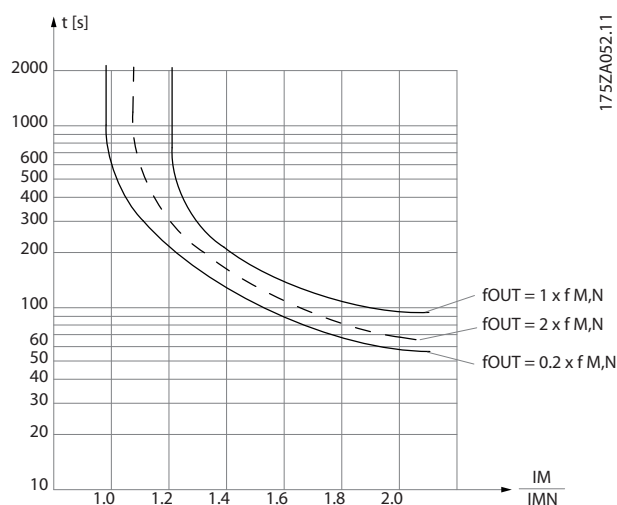


Figure 3.12 ETR Functions

In Figure 3.12 the X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cut off and trips the frequency converter. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed. At lower speed the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from overheating even at low speed. The ETR feature calculates the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in parameter 16-18 Motor Thermal in the frequency converter.

3.5 Final Test and Set-up

3.5.1 High-voltage Test

Carry out a high-voltage test by short-circuiting terminals U, V, W, L₁, L₂, and L₃. Energize maximum 2.15 kV DC for 380–500 V frequency converters for 1 s between this short circuit and the chassis.

The limits for the high-voltage test are:

- LVD (CE) = 1500 V AC = 2150 V DC
- UL = (2 x 500) + 1000 = 2000 V AC = 2850 V DC

⚠ WARNING

HIGH LEAKAGE CURRENT

When running high-voltage tests of the entire installation, leakage currents can be high. Failure to follow recommendations could result in death or serious injury.

- Interrupt the mains and motor connection if the leakage currents are too high.

3.5.2 Grounding

The following basic issues need to be considered when installing a frequency converter to obtain electro-magnetic compatibility (EMC).

- Safety grounding: Note that the frequency converter has a high leakage current and must be grounded appropriately for safety reasons. Apply local safety regulations.
- High frequency grounding: Keep the ground wire connections as short as possible.

Connect the different ground systems at the lowest possible conductor impedance. The lowest possible conductor impedance is obtained by keeping the conductor as short as possible and by using the greatest possible surface area.

The metal cabinets of the different devices are mounted on the cabinet rear plate using the lowest possible HF impedance. This avoids having different HF voltages for the individual devices and avoids the risk of radio interference currents running in connection cables that may be used between the devices. The radio interference has been reduced.

To obtain a low HF impedance, use the fastening bolts of the devices as HF connection to the rear plate. It is necessary to remove insulating paint or similar from the fastening points.

3.5.3 Safety Grounding Connection

The frequency converter has a high leakage current and must be grounded appropriately for safety reasons according to IEC 61800-5-1.

⚠ 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.

3.5.4 Final Set-up Check

Follow these steps to check the set-up and ensure that the frequency converter is running.

1. Locate the motor nameplate.

NOTICE!

The motor is either star- (Y) or delta- connected (Δ). This information is located on the motor nameplate data.

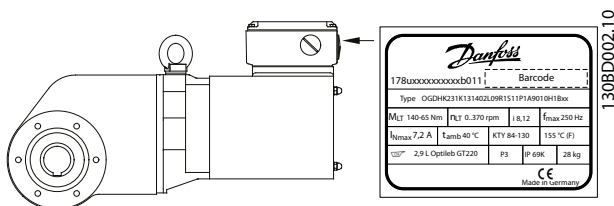


Figure 3.13 Location of Motor Nameplate

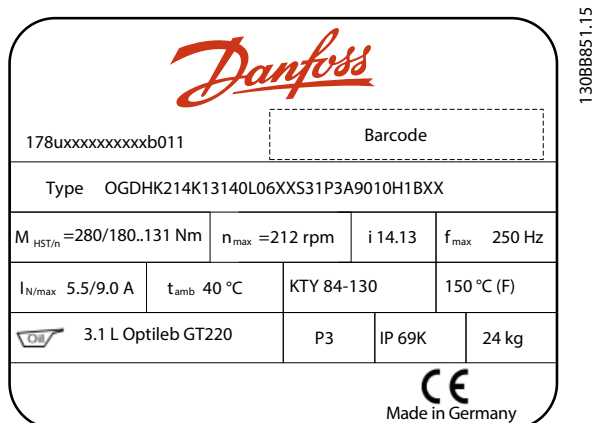


Figure 3.14 Nameplate

2. Check the motor nameplate data in this parameter list.
To access this list, press the [Quick Menu] key on the LCP and select "Q2 Quick Set-up".
 - 2a Parameter 1-20 Motor Power [kW].
Parameter 1-21 Motor Power [HP].
 - 2b Parameter 1-22 Motor Voltage.
 - 2c Parameter 1-23 Motor Frequency.
 - 2d Parameter 1-24 Motor Current.
 - 2e Parameter 1-25 Motor Nominal Speed.
3. Select OGD motor data.
 - 3a Set 1-11 Motor Model to 'Danfoss OGD LA10'.
4. Set speed limit and ramp times.
Set up the desired limits for speed and ramp time:
 - 4a Parameter 3-02 Minimum Reference.
 - 4b Parameter 3-03 Maximum Reference.
 - 4c Parameter 4-11 Motor Speed Low Limit [RPM] or parameter 4-12 Motor Speed Low Limit [Hz].
 - 4d Parameter 4-13 Motor Speed High Limit [RPM] or parameter 4-14 Motor Speed High Limit [Hz].
 - 4e Parameter 3-41 Ramp 1 Ramp-up Time.
 - 4f Parameter 3-42 Ramp 1 Ramp-down Time.

4 Application Examples

4.1 Overview

The examples in this section are intended as a quick reference for common applications.

- Parameter settings are the regional default values unless otherwise indicated (selected in parameter 0-03 Regional Settings).
- Parameters associated with the terminals and their settings are shown next to the drawings.
- Where switch settings for analog terminals A53 or A54 are required, these are also shown.

NOTICE!

A jumper wire may be required between terminal 12 (or 13) and terminal 27 for the frequency converter to operate when using factory default programming values. Refer to VLT® Frequency Converters Safe Torque Off Operating Instructions for further information

4.2 AMA

4.2.1 AMA with T27 Connected

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
+24 V	13		
D IN	18		
D IN	19		
COM	20		
D IN	27	Parameter 5-12 Terminal 27 Digital Input	[2]* Coast inverse
D IN	29		
D IN	32	* = Default value	
D IN	33	Notes/comments: Parameter group 1-2* Motor Data must be set according to motor.	
D IN	37		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.1 AMA with T27 Connected

4.2.2 AMA without T27 Connected

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
+24 V	13		
D IN	18		
D IN	19		
COM	20		
D IN	27	Parameter 5-12 Terminal 27 Digital Input	[0] No operation
D IN	29		
D IN	32	* = Default value	
D IN	33	Notes/comments: Parameter group 1-2* Motor Data must be set according to motor.	
D IN	37		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.2 AMA without T27 Connected

4.3 Analog Speed Reference

4.3.1 Voltage Analog Speed Reference

		Parameters	
FC		Function	Setting
+10 V	50	Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
A IN	53		
A IN	54	Parameter 6-11 Terminal 53 High Voltage	10 V*
A IN	54		
COM	55	Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
A OUT	42		
COM	39	Parameter 6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
		* = Default value	
		Notes/comments:	

Table 4.3 Voltage Analog Speed Reference

4

4.3.2 Current Analog Speed Reference

Parameters	
Function	Setting
Parameter 6-12 Terminal 53 Low Current	4 mA*
Parameter 6-13 Terminal 53 High Current	20 mA*
Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
Parameter 6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
* = Default value	
Notes/comments:	

Table 4.4 Current Analog Speed Reference

4.3.3 Speed Reference (Using a Manual Potentiometer)

Parameters	
Function	Setting
Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
Parameter 6-11 Terminal 53 High Voltage	10 V*
Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
Parameter 6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
* = Default value	
Notes/comments:	

Table 4.5 Speed Reference (Using a Manual Potentiometer)

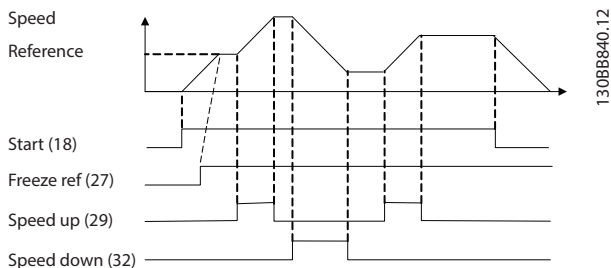


Figure 4.1 Speed Up/Speed Down

4.3.4 Speed Up/Speed Down

Parameters	
Function	Setting
Parameter 5-10 Terminal 18 Digital Input	[8] Start*
Parameter 5-12 Terminal 27 Digital Input	[19] Freeze Reference
Parameter 5-13 Terminal 29 Digital Input	[21] Speed Up
Parameter 5-14 Terminal 32 Digital Input	[22] Speed Down
* = Default value	
Notes/comments:	

Table 4.6 Speed Up/Speed Down

4.4 Start/Stop Applications

4.4.1 Start/Stop Command with Safe Torque Off

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 5-10 Terminal 18 Digital Input	[8] Start*
+24 V	13		
D IN	18	Parameter 5-12 Terminal 27 Digital Input	[0] No operation
D IN	19		
COM	20	Parameter 5-19 Terminal 37 Safe Stop	[1] Safe Alarm
D IN	27		
D IN	29	*=Default value	
D IN	32	Notes/comments: If parameter 5-12 Terminal 27 Digital Input is set to [0] No operation, a jumper wire to terminal 27 is not needed.	
D IN	33		
D IN	37		
+10	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.7 Start/Stop Command with Safe Torque Off

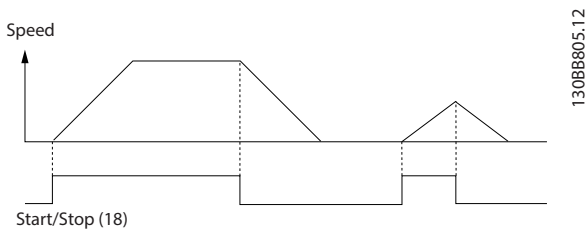


Figure 4.2 Start/Stop Command with Safe Torque Off

4.4.2 Pulse Start/Stop

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 5-10 Terminal 18 Digital Input	[9] Latched Start
+24 V	13		
D IN	18	Parameter 5-12 Terminal 27 Digital Input	[6] Stop Inverse
D IN	19		
COM	20	*=Default value	
D IN	27	Notes/comments: If parameter 5-12 Terminal 27 Digital Input is set to [0] No operation, a jumper wire to terminal 27 is not needed.	
D IN	29		
D IN	32		
D IN	33		
D IN	37		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 4.8 Pulse Start/Stop

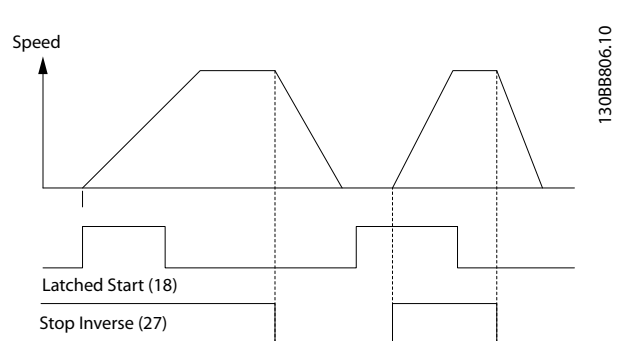


Figure 4.3 Pulse Start/Stop

4

4.4.3 Start/Stop with Reversing and 4 Preset Speeds

		Parameters	
		Function	Setting
		Parameter 5-10 Terminal 18 Digital Input	[8] Start
		Parameter 5-11 Terminal 19 Digital Input	[10] Reversing*
		Parameter 5-12 Terminal 27 Digital Input	[0] No operation
		Parameter 5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
		Parameter 5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
		Parameter 3-10 Preset Reference	
		Preset ref. 0	25%
		Preset ref. 1	50%
		Preset ref. 2	75%
		Preset ref. 3	100%
		* = Default value	
		Notes/comments:	

Table 4.9 Start/Stop with Reversing and 4 Preset Speeds

4.5 Bus and Relay Connection

4.5.1 External Alarm Reset

		Parameters	
		Function	Setting
		Parameter 5-11 Terminal 19 Digital Input	[1] Reset
		* = Default value	
		Notes/comments:	

Table 4.10 External Alarm Reset

4.5.2 RS485 Network Connection

		Parameters	
		Function	Setting
		Parameter 8-30 P <i>rotocol</i>	[0] FC*
		Parameter 8-31 A <i>ddress</i>	1*
		Parameter 8-32 B <i>aud Rate</i>	9600*
		*=-Default value	
		Notes/comments: Select protocol, address, and baud rate in the above mentioned parameters.	

Table 4.11 RS485 Network Connection

4.5.3 Motor Thermistor

NOTICE!

Thermistors must use reinforced or double insulation to meet insulation requirements.

		Parameters	
		Function	Setting
		Parameter 1-90 <i>Motor Thermal Protection</i>	[2] Thermistor trip
		Parameter 1-93 T <i>hermistor Source</i>	[1] Analog input 53
		Notes/comments: If only a warning is desired, parameter 1-90 Motor Thermal Protection should be set to [1] Thermistor warning.	

Table 4.12 Motor Thermistor

4.5.4 Using SLC to Set a Relay

		Parameters																																					
		Function	Setting																																				
<table border="1"> <tr><th colspan="2">FC</th></tr> <tr><td>+24 V</td><td>12</td></tr> <tr><td>+24 V</td><td>13</td></tr> <tr><td>D IN</td><td>18</td></tr> <tr><td>D IN</td><td>19</td></tr> <tr><td>COM</td><td>20</td></tr> <tr><td>D IN</td><td>27</td></tr> <tr><td>D IN</td><td>29</td></tr> <tr><td>D IN</td><td>32</td></tr> <tr><td>D IN</td><td>33</td></tr> <tr><td>D IN</td><td>37</td></tr> <tr><td colspan="2"> </td></tr> <tr><td>+10 V</td><td>50</td></tr> <tr><td>A IN</td><td>53</td></tr> <tr><td>A IN</td><td>54</td></tr> <tr><td>COM</td><td>55</td></tr> <tr><td>A OUT</td><td>42</td></tr> <tr><td>COM</td><td>39</td></tr> </table>	FC		+24 V	12	+24 V	13	D IN	18	D IN	19	COM	20	D IN	27	D IN	29	D IN	32	D IN	33	D IN	37			+10 V	50	A IN	53	A IN	54	COM	55	A OUT	42	COM	39	130BB839.10	Parameter 4-30 Motor Feedback Loss Function	[1] Warning
	FC																																						
	+24 V	12																																					
	+24 V	13																																					
	D IN	18																																					
	D IN	19																																					
	COM	20																																					
	D IN	27																																					
	D IN	29																																					
	D IN	32																																					
	D IN	33																																					
	D IN	37																																					
	+10 V	50																																					
	A IN	53																																					
	A IN	54																																					
COM	55																																						
A OUT	42																																						
COM	39																																						
Parameter 4-31 Motor Feedback Speed Error	100 RPM																																						
Parameter 4-32 Motor Feedback Loss Timeout	5 s																																						
Parameter 7-00 Speed PID Feedback Source	[2] MCB 102																																						
Parameter 17-11 Resolution (PPR)	1024*																																						
Parameter 13-00 SL Controller Mode	[1] On																																						
Parameter 13-01 Start Event	[19] Warning																																						
Parameter 13-02 Stop Event	[44] Reset key																																						
Parameter 13-10 Comparator Operand	[21] Warning no.																																						
Parameter 13-11 Comparator Operator	[1] ≈*																																						
Parameter 13-12 Comparator Value	90																																						
Parameter 13-51 SL Controller Event	[22] Comparator 0																																						
Parameter 13-52 SL Controller Action	[32] Set digital out A low																																						
Parameter 5-40 Function Relay	[80] SL digital output A																																						

Table 4.13 Using Smart Logic Controller to Set a Relay

	*=Default value
	Notes/comments: If the limit in the feedback monitor is exceeded, warning 90 Feedback Mon. is issued. The SLC monitors warning 90 and if the warning becomes true, relay 1 is triggered. External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 s, the frequency converter continues and the warning disappears. But relay 1 is still triggered until pressing [Reset] on the LCP.

Table 4.14 Using Smart Logic Controller to Set a Relay

4.6 Brake Application

4.6.1 Mechanical Brake Control

		Parameters																																					
		Function	Setting																																				
<table border="1"> <tr><th colspan="2">FC</th></tr> <tr><td>+24 V</td><td>12</td></tr> <tr><td>+24 V</td><td>13</td></tr> <tr><td>D IN</td><td>18</td></tr> <tr><td>D IN</td><td>19</td></tr> <tr><td>COM</td><td>20</td></tr> <tr><td>D IN</td><td>27</td></tr> <tr><td>D IN</td><td>29</td></tr> <tr><td>D IN</td><td>32</td></tr> <tr><td>D IN</td><td>33</td></tr> <tr><td>D IN</td><td>37</td></tr> <tr><td colspan="2"> </td></tr> <tr><td>+10 V</td><td>50</td></tr> <tr><td>A IN</td><td>53</td></tr> <tr><td>A IN</td><td>54</td></tr> <tr><td>COM</td><td>55</td></tr> <tr><td>A OUT</td><td>42</td></tr> <tr><td>COM</td><td>39</td></tr> </table>	FC		+24 V	12	+24 V	13	D IN	18	D IN	19	COM	20	D IN	27	D IN	29	D IN	32	D IN	33	D IN	37			+10 V	50	A IN	53	A IN	54	COM	55	A OUT	42	COM	39	130BB841.10	Parameter 5-40 Function Relay	[32] Mech. brake ctrl
	FC																																						
	+24 V	12																																					
	+24 V	13																																					
	D IN	18																																					
	D IN	19																																					
	COM	20																																					
	D IN	27																																					
	D IN	29																																					
	D IN	32																																					
D IN	33																																						
D IN	37																																						
+10 V	50																																						
A IN	53																																						
A IN	54																																						
COM	55																																						
A OUT	42																																						
COM	39																																						
Parameter 5-10 Terminal 18 Digital Input	[8] Start*																																						
Parameter 5-11 Terminal 19 Digital Input	[11] Start reversing																																						
Parameter 1-71 Start Delay	0.2																																						
Parameter 1-72 Start Function	[5] VVC+/ FLUX Clockwise																																						
Parameter 1-76 Start Current	I _{m,n}																																						
Parameter 2-20 Release Brake Current	Application dependent																																						
Parameter 2-21 Activate Brake Speed [RPM]	Half of nominal slip of the motor																																						

Table 4.15 Mechanical Brake Control

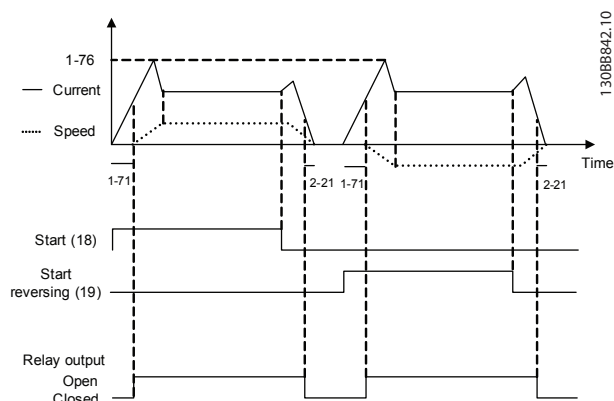


Figure 4.4 Mechanical Brake Control

4.6.2 Hoist Mechanical Brake

The VLT® Decentral Drive FCD 302 features a mechanical brake control designed for hoisting applications. The hoist mechanical brake is activated via option [6] *Hoist Mech. Brake Rel* in *parameter 1-72 Start Function*. The main difference compared to the regular mechanical brake control, where a relay function monitoring the output current is used, is that the hoist mechanical brake function has direct control over the brake relay. This means that instead of setting a current for release of the brake, the torque is applied against the closed brake before release is defined. Because the torque is defined directly, the set-up is more straightforward for hoisting applications.

Set *parameter 2-28 Gain Boost Factor* to obtain a quicker control when releasing the brake. The hoist mechanical brake strategy is based on a 3-step sequence, where motor control and brake release are synchronized to obtain the smoothest possible brake release.

3-step sequence

1. Pre-magnetize the motor
To ensure that there is a hold on the motor and to verify that it is mounted correctly, the motor is first pre-magnetized.
2. Apply torque against the closed brake
When the load is held by the mechanical brake, its size cannot be determined, only its direction. The moment the brake opens, the load must be taken over by the motor. To facilitate the takeover, a user-defined torque, set in *parameter 2-26 Torque Ref*, is applied in hoisting direction. This is used to restore the speed controller that finally takes over the load. To reduce wear on the gearbox due to backlash, the torque is acceded.
3. Release brake
When the torque reaches the value set in *parameter 2-26 Torque Ref*, the brake is released. The value set in *parameter 2-25 Brake Release Time* determines the delay before the load is released. To react as quickly as possible on the load-step that follows brake release, increase the proportional gain to boost the speed PID control.

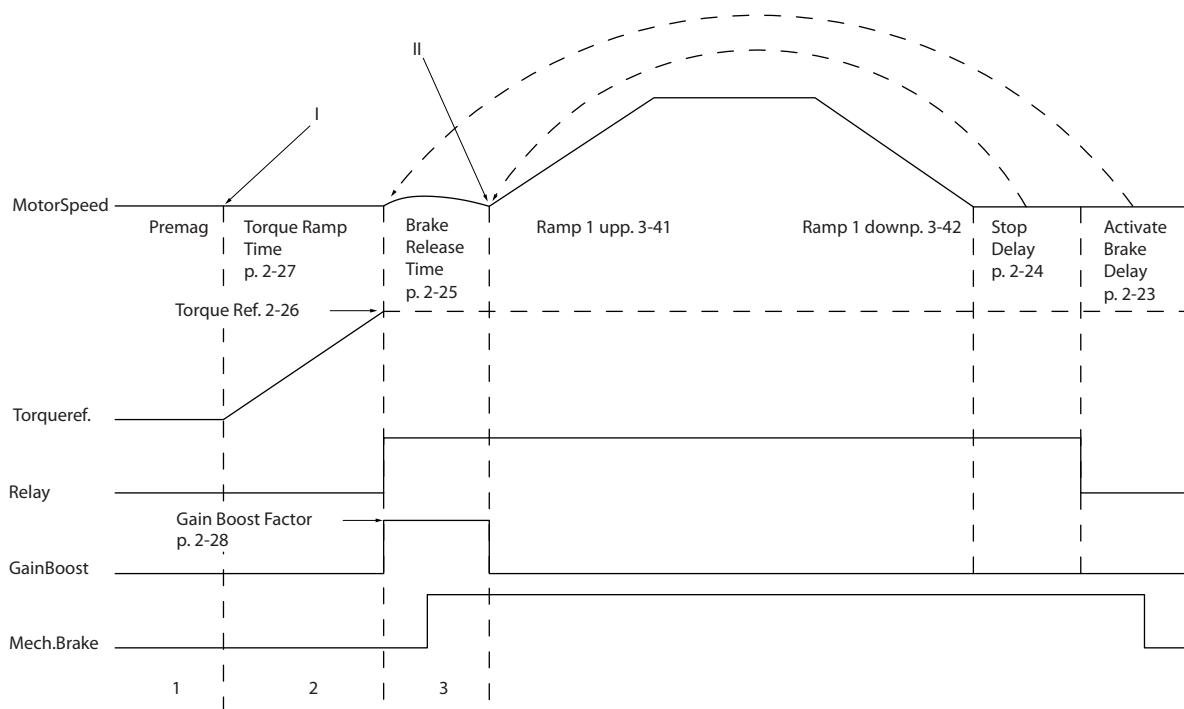


Figure 4.5 Brake Release Sequence for Hoist Mechanical Brake Control

- I) *Activate Brake Delay*: The frequency converter starts again from the *mechanical brake engaged* position.
- II) *Stop delay*: When the time between successive starts is shorter than the setting in *parameter 2-24 Stop Delay*, the frequency converter starts without applying the mechanical brake (for example, reversing).

Both relays 1 and 2 can be used to control the brake.

4.7 Encoder

The purpose of this guideline is to ease the set-up of encoder connection to the frequency converter. Before setting up the encoder, the basic settings for a closed-loop speed control system is shown.

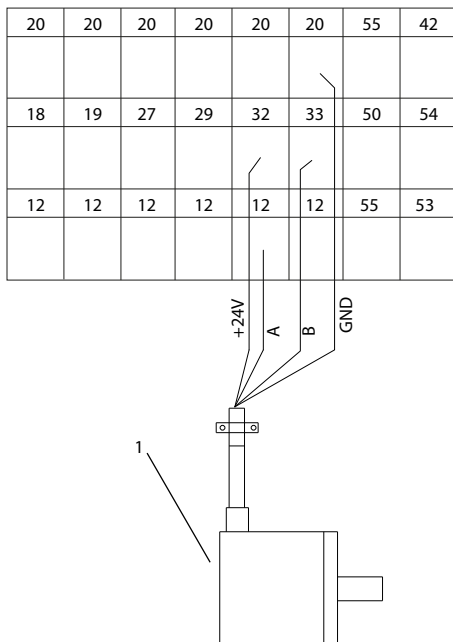


Figure 4.6 Encoder Connection to the Frequency Converter

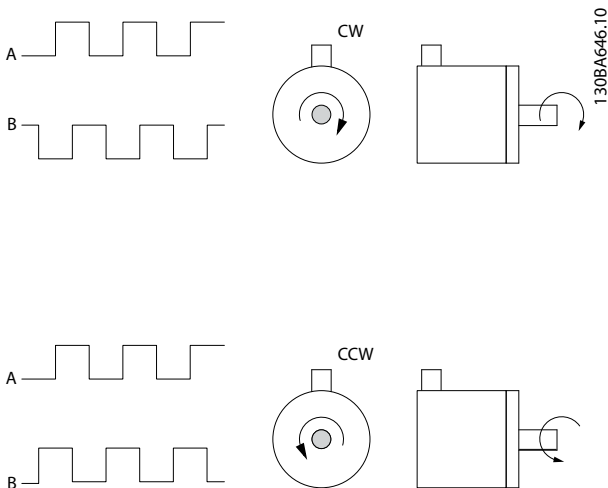


Figure 4.7 24 V Incremental Encoder with Maximum Cable Length 5 m (16.4 ft)

4.7.1 Encoder Direction

The direction of the encoder is determined by which order the pulses are entering the frequency converter.

- Clockwise direction means channel A is 90 electrical degrees before channel B.
- Counterclockwise direction means channel B is 90 electrical degrees before A.

The direction is determined by looking into the shaft end.

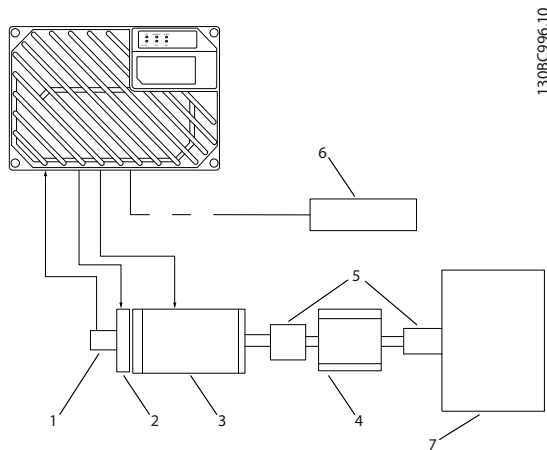
4.8 Closed-loop Drive System

A closed-loop drive system usually comprises elements such as:

- Motor.
- Additional equipment:
 - Gearbox
 - Mechanical Brake
- Frequency converter.
- Encoder as feedback system.
- Brake resistor for dynamic brake.
- Transmission.
- Load.

Applications demanding mechanical brake control usually needs a brake resistor.

4



Item	Description
1	Encoder
2	Mechanical brake
3	Motor
4	Gearbox
5	Transmission
6	Brake resistor
7	Load

Figure 4.8 Basic Set-up for Closed-loop Speed Control

4.9 Smart Logic Control

Smart logic control (SLC) is essentially a sequence of user-defined actions (see *parameter 13-52 SL Controller Action [x]*) executed by the SLC when the associated user-defined event (see *parameter 13-51 SL Controller Event [x]*) is evaluated as true by the SLC.

The condition for an event can be a particular status or that the output from a logic rule or a comparator operand becomes true. This leads to an associated action as illustrated in *Figure 4.9*.

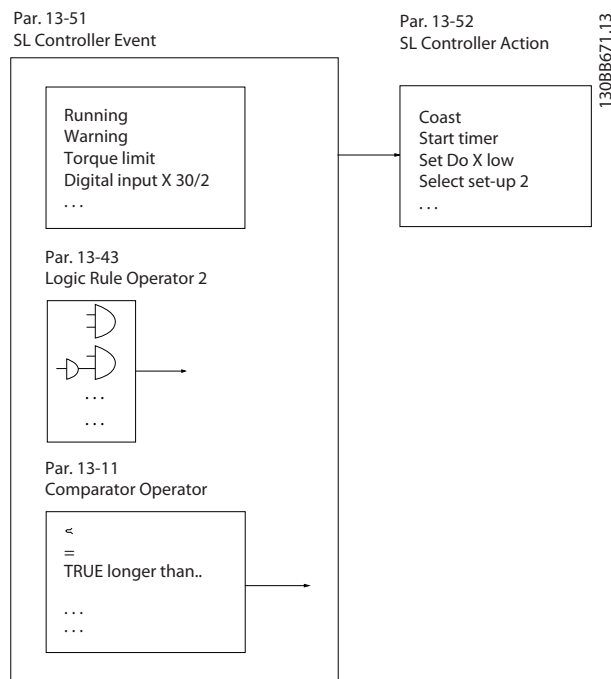


Figure 4.9 Current Control Status/Event and Action

Events and actions are each numbered and linked together in pairs (states). This means that when event [0] is fulfilled (attains the value true), action [0] is executed. After this, the conditions of event [1] is evaluated and if evaluated true, action [1] is executed, and so on. Only 1 event is evaluated at any time. If an event is evaluated as false, nothing happens (in the SLC) during the current scan interval and no other events are evaluated. This means that when the SLC starts, it evaluates event [0] (and only event [0]) each scan interval. Only when event [0] is evaluated true, the SLC executes action [0] and starts evaluating event. It is possible to program from 1 to 20 events and actions.

When the last event/action has been executed, the sequence starts over again from event [0]/action [0]. *Figure 4.10* shows an example with 3 event/actions.

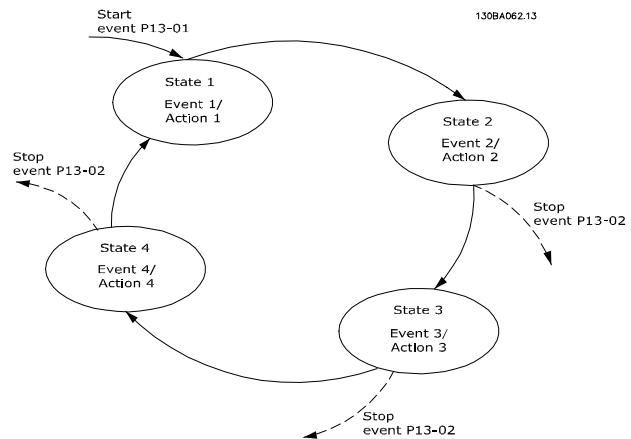


Figure 4.10 Example - Internal Current Control

Comparators

Comparators are used for comparing continuous variables (that is, output frequency, output current, analog input, and so forth) to fixed preset values.

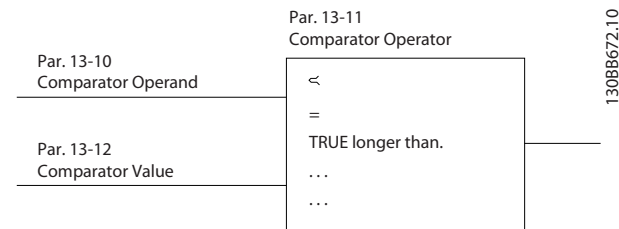


Figure 4.11 Comparators

Logic rules

Combine up to 3 boolean inputs (true/false inputs) from timers, comparators, digital inputs, status bits, and events using the logical operators AND, OR, and NOT.

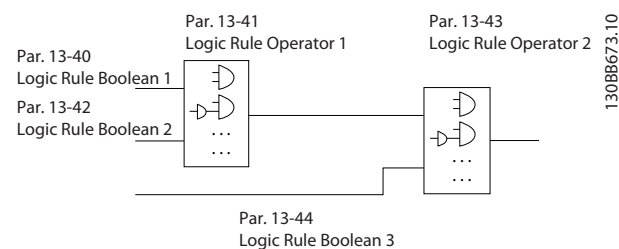


Figure 4.12 Logic Rules

Application example

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 4-30 Motor Feedback Loss Function	[1] Warning
+24 V	13		
D IN	18	Parameter 4-31 Motor Feedback Speed Error	100 RPM
D IN	19		
COM	20	Parameter 4-32 Motor Feedback Loss Timeout	5 s
D IN	27		
D IN	29	Parameter 7-00 S peed PID Feedback Source	[2] MCB 102
D IN	32		
D IN	33	Parameter 17-11 Resolution (PPR)	1024*
D IN	37		
+10 V	50	Parameter 13-00 SL Controller Mode	[1] On
A IN	53		
A IN	54	Parameter 13-01 Start Event	[19] Warning
COM	55		
A OUT	42	Parameter 13-02 Stop Event	[44] Reset key
COM	39		
	01	Parameter 13-10 Comparator Operand	[21] Warning no.
	02		
	03	Parameter 13-11 Comparator Operator	[1] ≈*
	04		
	05	Parameter 13-12 Comparator Value	90
	06		
		Parameter 13-51 SL Controller Event	[22] Comparator 0
		Parameter 13-52 SL Controller Action	[32] Set digital out A low
		Parameter 5-40 F unction Relay	[80] SL digital output A

Table 4.16 Using SLC to Set a Relay

	*=Default value
	Notes/comments: If the limit in the feedback monitor is exceeded, warning 90 Feedback Mon. is issued. The SLC monitors warning 90 and if the warning becomes true, relay 1 is triggered. External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 s, the frequency converter continues and the warning disappears. But relay 1 is still triggered until pressing [Reset] on the LCP.

Table 4.17 Using SLC to Set a Relay

5 Special Conditions

Under some special conditions, where the operation of the frequency converter is challenged, consider derating. In some conditions, derating must be done manually. In other conditions, the frequency converter automatically performs a degree of derating when necessary. This is done to ensure the performance at critical stages where the alternative could be a trip.

5.1 Manual Derating

Manual derating must be considered for:

- Air pressure – relevant for installation at altitudes above 1000 m (3280 ft)
- Motor speed – at continuous operation at low RPM in constant torque applications
- Ambient temperature – relevant for ambient temperatures above 40 °C (104 °F)

Contact Danfoss for the application note for tables and elaboration. Only the case of running at low motor speeds is elaborated here.

5.1.1 Derating for Low Air Pressure

The cooling capability of air is decreased at lower air pressure.

Below 1000 m (3280 ft) altitude no derating is necessary. But above 1000 m (3280 ft) the ambient temperature (T_{AMB}) or maximum output current (I_{out}) should be derated in accordance with the diagram in *Figure 5.1*.

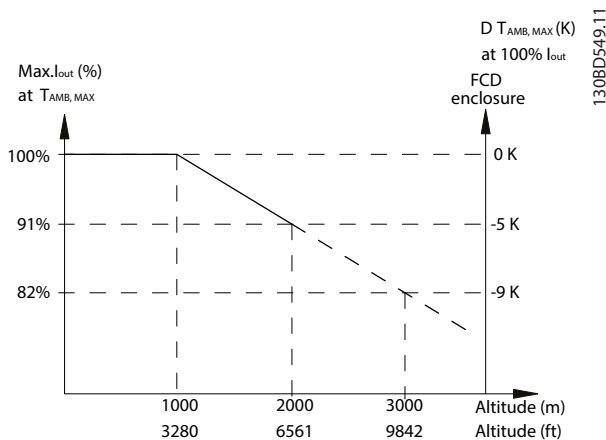


Figure 5.1 Derating of output current versus altitude at $T_{AMB,MAX}$ for VLT® Decentral Drive FCD 302. At altitudes above 2000 m (6561 ft), contact Danfoss regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and by that ensuring 100% output current at high altitudes. As an example of how to read the graph, the situation at 2000 m (6561 ft) is elaborated for a 3 kW (4 hp) frequency converter with $T_{AMB,MAX} = 40$ °C (104 °F). At a temperature of 36 °C (96.8 °F) ($T_{AMB,MAX} - 3.3$ K), 91% of the rated output current is available. At a temperature of 41.7 °C (107 °F), 100% of the rated output current is available.

5.1.2 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate.

The level of heating depends on the load on the motor, and the operating speed and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speed due to less cooling air from the motor integral fan.

Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with extra air-cooling (or a motor designed for this type of operation may be used).

An alternative is to reduce the load level of the motor by selecting a larger motor. However, the design of the frequency converter puts a limit to the motor size.

Variable (quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for extra cooling or derating of the motor.

5.1.3 Ambient Temperature

Graphs are presented individually for 60° AVM and SFAVM. 60° AVM only switches 2/3 of the time whereas SFAVM switches throughout the whole period. The maximum switching frequency is 16 kHz for 60° AVM and 10 kHz for SFAVM. The discrete switching frequencies are presented in Table 5.1.

Switching pattern	Discrete switching frequencies												
	2	2.5	3	3.5	4	5	6	7	8	10	12	14	16
60° AVM	2	2.5	3	3.5	4	5	6	7	8	10	12	14	16
SFAVM	2	2.5	3	3.5	4	5	6	7	8	10	-	-	-

Table 5.1 Discrete Switching Frequencies

5.1.3.1 Power Size 0.37–0.75 kW

60° AVM - Pulse width modulation

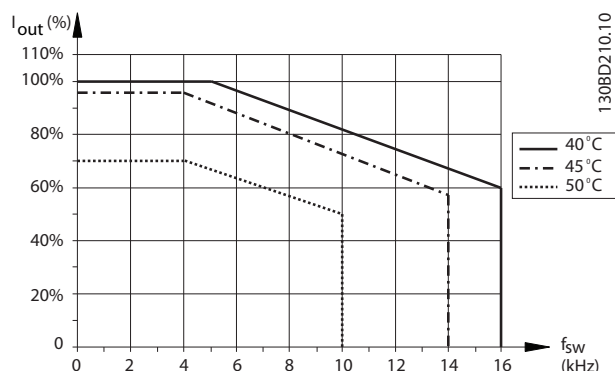


Figure 5.2 Derating of I_{out} for different $T_{AMB, MAX}$ for FCD 302 0.37–0.55–0.75 kW, using 60° AVM

SFAVM - Stator frequency asynchron vector modulation

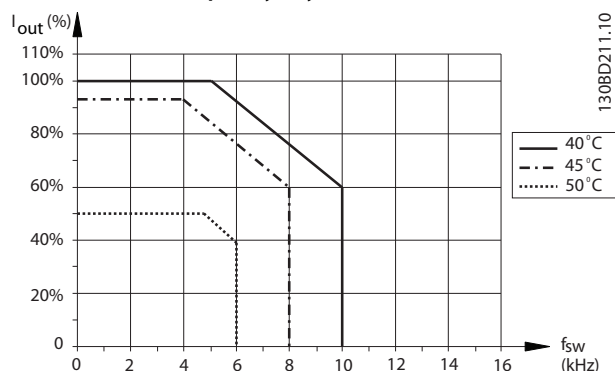


Figure 5.3 Derating of I_{out} for different $T_{AMB, MAX}$ for FCD 302 0.37–0.55–0.75 kW, using SFAVM

5.1.3.2 Power Size 1.1–1.5 kW

60° AVM - Pulse width modulation

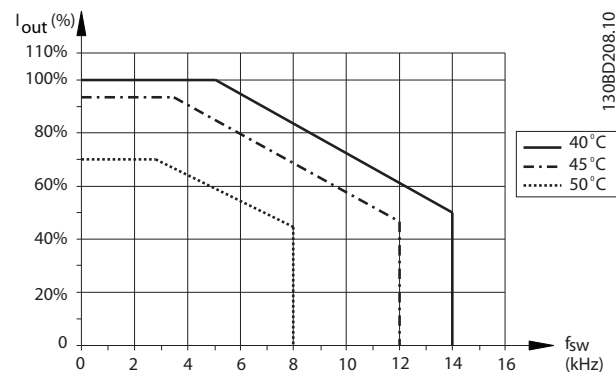


Figure 5.4 Derating of I_{out} for different $T_{AMB, MAX}$ for FCD 302 1.1–1.5 kW, using 60° AVM

SFAVM - Stator frequency asynchron vector modulation

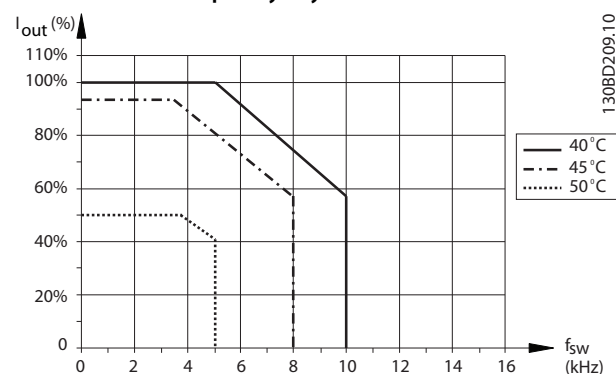


Figure 5.5 Derating of I_{out} for different $T_{AMB, MAX}$ for FCD 302 1.1–1.5 kW, using SFAVM

5.1.3.3 Power Size 2.2–3.0 kW

60° AVM - Pulse width modulation

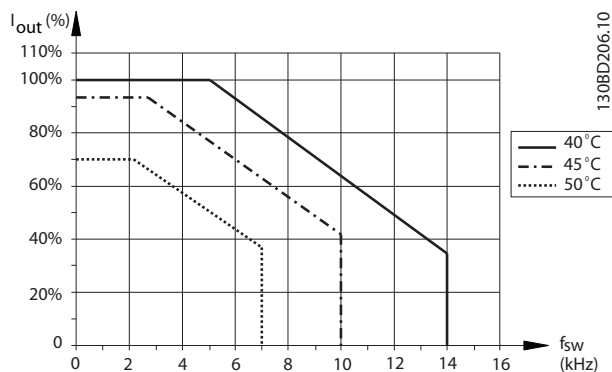


Figure 5.6 Derating of I_{out} for different T_{AMB, MAX} for FCD 302 2.2–3.0 kW, using 60° AVM

SFAVM - Stator frequency asynchron vector modulation

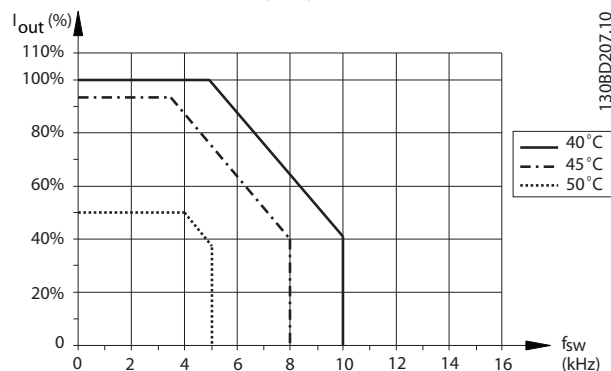


Figure 5.7 Derating of I_{out} for different T_{AMB, MAX} for FCD 302 2.2–3.0 kW, using SFAVM

5

5.2 Automatic Derating

The frequency converter constantly checks for critical levels:

- Critical high temperature on the control card or heat sink
- High motor load
- High DC-link voltage
- Low motor speed

As a response to a critical level, the frequency converter adjusts the switching frequency. For critical high internal temperatures and low motor speed, the frequency converter can also force the PWM pattern to SFAVM.

NOTICE!

The automatic derating is different when *parameter 14-55 Output Filter* is set to [2] *Sine-Wave Filter Fixed*.

The automatic derating is made up of contributions from separate functions that evaluate the need. Their interrelationship is illustrated in *Figure 5.9*.

NOTICE!

In sine-wave filter fixed mode, the structure is different. See chapter 5.2.1 Sine-Wave Filter Fixed Mode.

5

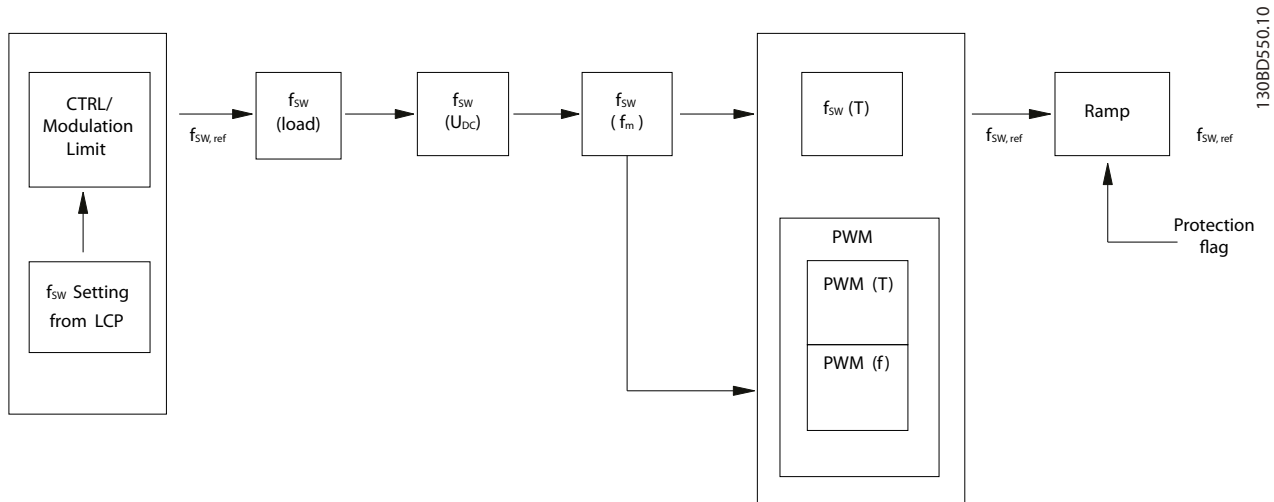


Figure 5.8 Automatic Derating Function Block

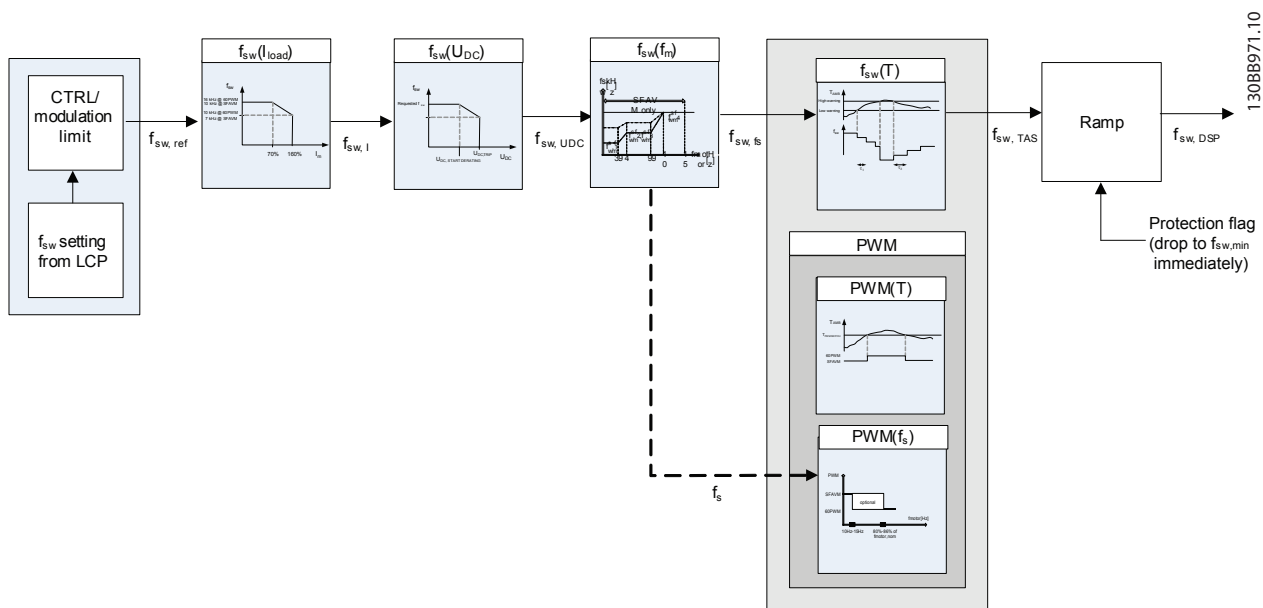
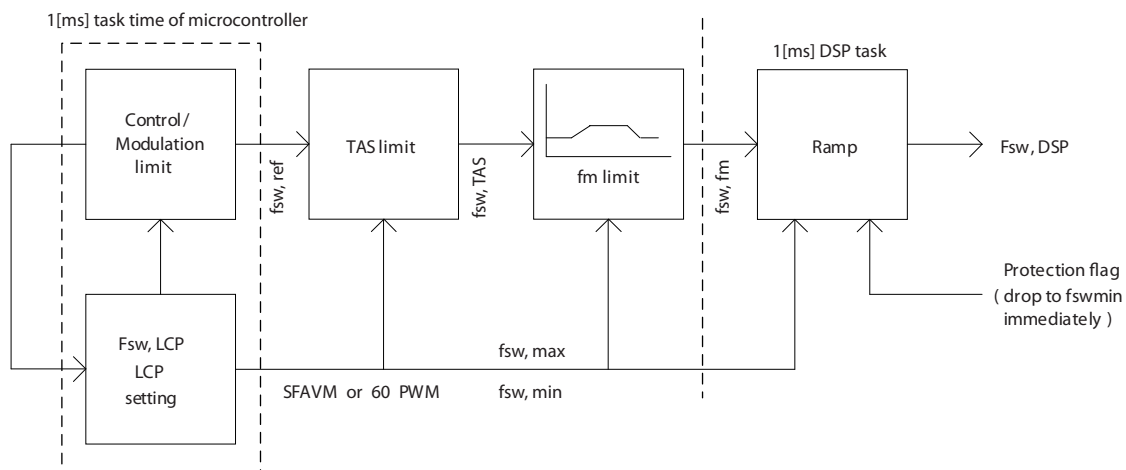


Figure 5.9 Interrelationship Between the Automatic Derating Contributions

The switching frequency is first derated due to motor current, followed by DC-link voltage, motor frequency, and then temperature. If multiple deratings occur on the same iteration, the resulting switching frequency would be the same as though only the most significant derating occurred by itself (the deratings are not cumulative). Each of these functions is presented in the following sections.

5.2.1 Sine-Wave Filter Fixed Mode

If the frequency converter is running with a fixed frequency sine-wave filter, the switching frequency is not derated due to motor current or DC-link voltage. The switching frequency is still derated due to motor frequency and temperature; however the order of these 2 operations is reversed. It should be noted that, in this situation, the function for derating based on motor frequency does nothing unless the frequency converter's LC_Low_Speed_Derate_Enable PUD parameter is set to true. Also, the function for derating due to temperature is slightly different. In sine filter fixed mode, a different protection mode switching frequency is sent to the DSP.



130BB972.11

Figure 5.10 The Switching Frequency Limiting Algorithm when the Frequency Converter is Operating with a Fixed Frequency Sine-wave Filter

5.2.2 Overview Table

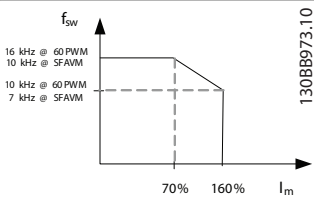
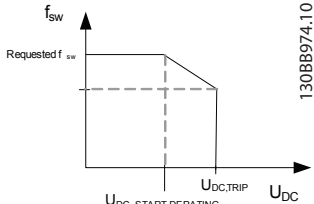
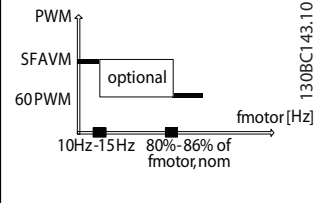
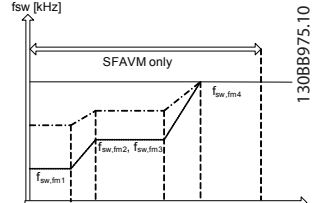
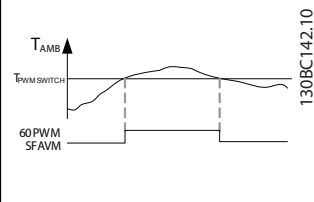
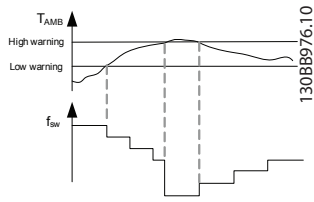
Background for derating	PWM - Functions that adjust the switching pattern	f _{sw} – Functions that derate the switching frequency
I _{load} ↑	No automatic derating	 130BB973.10
U _{dc} ↑	No automatic derating	 130BB974.10
f _s	 130BC143.10	 130BB975.10
T ↑	 130BC142.10	 130BB976.10

Table 5.2 Overview - Derating

5.2.3 High Motor Load

The switching frequency is automatically adjusted according to the motor current. When a certain percentage of the nominal HO motor load is reached, the switching frequency is derated. This percentage is individual for each enclosure size and a value that is coded in the EEPROM along with the other points that limit the derating.

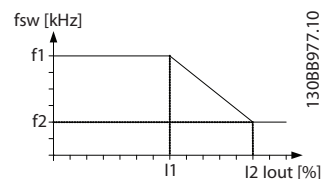


Figure 5.11 Derating of Switching Frequency According to Motor Load. f1, f2, I1, and I2 are Coded in EEPROM.

In EEPROM, the limits depend on the modulation mode. In 60° AVM, f1 and f2 are higher than for SFAVM. I1 and I2 are independent of modulation mode.

5.2.4 High Voltage on the DC link

The switching frequency is automatically adjusted according to the voltage on the DC link. When the DC link reaches a certain magnitude, the switching frequency is derated. The points that limit the derating are individual for each enclosure size and are coded in the EEPROM.

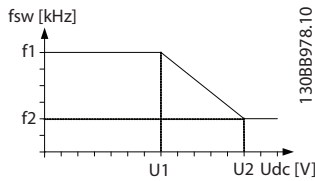


Figure 5.12 Derating of Switching Frequency According to Voltage on the DC link. f1, f2, U1, and U2 are Coded in EEPROM.

In EEPROM the limits depend on the modulation mode. In 60° AVM, f1 and f2 are higher than for SFAVM. U1 and U2 are independent of the modulation mode.

5.2.5 Low Motor Speed

The option of PWM strategy depends on the stator frequency. To prevent that the same IGBT is conducting for too long (thermal consideration), fm, switch1 is specified as the minimum stator frequency for 60° PWM, whereas fm, switch2 is specified as the maximum stator frequency for SFAVM to protect the frequency converter. 60° PWM helps to reduce the inverter loss above fm, switch1 as the switch loss is reduced by 1/3 by changing from SFAVM to 60° AVM.

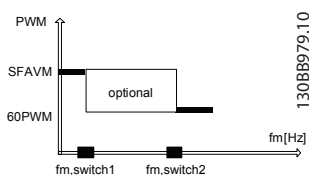


Figure 5.13 Reducing Inverter Loss

The shape of the average temperature is constant regardless of the stator frequency. The peak temperature, however, follows the shape of the output power for small stator frequencies and goes towards the average temperature for increasing stator frequency. This results in higher temperature variations for small stator frequencies. This means that the expected lifetime of the component decreases for small stator frequencies if no compensation

is used. Therefore, for low values of the stator frequency where the temperature variations are large, the switching frequency can be reduced to lower the peak temperature and thereby the temperature variations.

For VT-applications, the load current is relatively small for small stator frequencies and the temperature variations are thus not as large as for the CT-applications. For this reason, also the load current is considered.

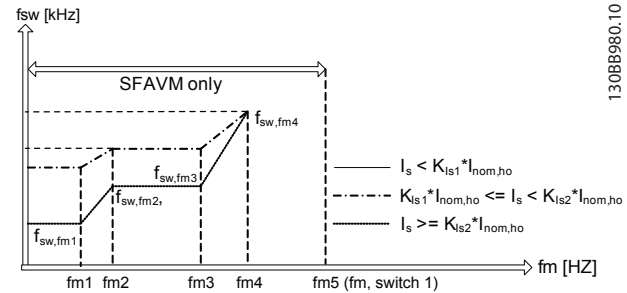


Figure 5.14 Switching Frequency (fsw) Variation for Different Stator Frequencies (fm)

The points that limit the derating are individual for each enclosure size and are coded in the EEPROM.

NOTICE!

The VLT® Decentral Drive FCD 302 never derates the current automatically. Automatic derating refers to adaptation of the switching frequency and pattern.

For VT-applications, the load current is considered before derating the switching frequency at low motor speed.

5.2.6 High Internal

The switching frequency is derated based on both control card- and heat sink temperature. This function may sometimes be referred to as the temperature adaptive switching frequency function (TAS).

NOTICE!

Figure 5.15 shows 1 temperature affecting the derating. In fact there are 2 limiting temperatures: Control card temperature and heat sink temperature. Both have their own set of control temperatures.

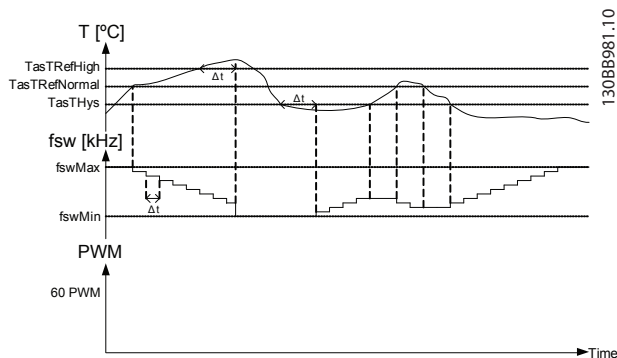


Figure 5.15 Switching Frequency Derating due to High Temperature

NOTICE!

dt is 10 s when the control card is too hot but 0 s when the heat sink is too hot (more critical).

The high warning can only be violated for a certain time before the frequency converter trips.

5.2.7 Current

The final derating function is a derating of the output current due to high temperatures. This calculation takes place after the calculations for derating the switching frequency. This results in an attempt to lower the temperatures by first lowering the switching frequency, and then lowering the output current. Current derating is only performed if the unit is programmed to derate in overtemperature situations. If the user has selected a trip function for overtemperature situations, the current derate factor is not lowered.

5.3 Derating for Running at Low Speed

When a motor is connected to a frequency converter, it is necessary to check that the cooling of the motor is adequate.

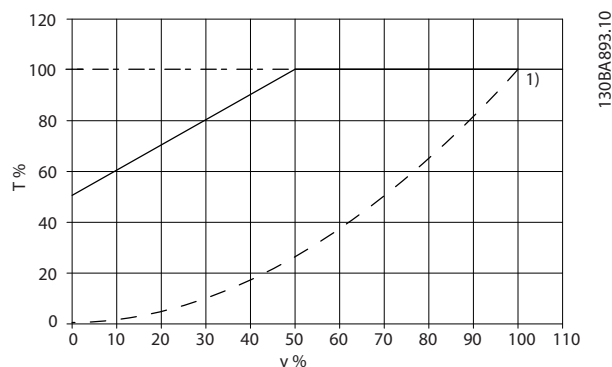
The level of heating depends on the load on the motor, the operating speed, and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In constant torque applications, a motor may overheat at low speeds due to less cooling air from the motor integral fan. Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with extra air-cooling (or a motor designed for this type of operation may be used). An alternative is to reduce the load level of the motor by selecting a larger motor. However, the design of the frequency converter puts a limit to the motor size.

Variable (quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, the torque is proportional to the square of the speed and the power is proportional to the cube of the speed. In these applications, there is no need for extra cooling or derating of the motor. In Figure 5.16, the typical VT curve is below the maximum torque with derating and maximum torque with forced cooling at all speeds.



Item	Description
————	Maximum torque
-----	Typical torque at VT load

Figure 5.16 VT Applications - Maximum Load for a Standard Motor at 40 °C (104 °F)

NOTICE!

Oversynchronous speed operation results in decrease of the available motor torque, inversely proportional to the increase in speed. Consider this during the design phase to avoid motor overload.

6 Type Code and Selection Guide

6.1 Type Code Description

Position	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	39	39	
	F	C	D	3	0	2	P				T	4				H	1												X	A		B		X	X	X	X	X	D	

130BB797.10

Position	Description	Choices/options	
01-03	Product group	FCD	Decentral Drive
04-06	Frequency converter series	302	Advanced performance
07-10	Power size	PK37	0.37 kW/0.5 hp
		PK55	0.55 kW/0.75 hp
		PK75	0.75 kW/1.0 hp
		P1K1	1.1 kW/1.5 hp
		P1K5	1.5 kW/2.0 hp
		P2K2	2.2 kW/3.0 hp
		P3K0	3.0 kW/4.0 hp (large unit only)
		PXXX	Installation box only (without power section)
11-12	Phases, mains voltage	T	3-phase
		4	380-480 V AC
13-15	Enclosure	B66	Standard Black - IP66/Type 4X
		W66	Standard White - IP66/Type 4X
		W69	Hygienic White - IP66K/Type 4X
16-17	RFI filter	H1	RFI filter class A1/C2
18	Brake	X	No brake
		S	Brake chopper + mechanical brake supply
19	Hardware configuration	1	Complete product, small unit, standalone mount
		3	Complete product, large unit, standalone mount
		X	Drive part, small unit (no installation box)
		Y	Drive part, large unit (no installation box)
		R	Installation box, small unit, standalone mount (no drive part)
T	Installation box, large unit, standalone mount (no drive part)		
20	Brackets	X	No brackets
		E	Flat brackets
		F	40 mm brackets
21	Threads	X	No installation box
		M	Metric threads
22	Switch option	X	No switch option
		E	Service switch on mains input
		F	Service switch on motor output
		L	Circuit breaker & mains disconnect, looping terminals (large unit only)
		K	Service switch on mains input with extra looping terminals (large unit only)
23	Display	X	No display connector (No installation box)
		C	With display connector

Position	Description	Choices/options	
24	Sensor plugs	X	No sensor plugs
		E	Direct mount 4xM12: 4 digital inputs
		F	Direct mount 6xM12: 4 digital inputs, 2 relay outputs
25	Motor plug	X	No motor plug
26	Mains plug	X	No mains plug
27	Fieldbus plug	X	No fieldbus plug
		E	M12 Ethernet
		P	M12 PROFIBUS
28	Reserved	X	For future use
29–30	A option	AX	No A option
		A0	PROFIBUS DP
		AN	EtherNet/IP
		AL	PROFINET
31–32	B option	BX	No B option
		BR	Encoder option
		BU	Resolver option
		BZ	Safety PLC Interface
33–37	Reserved	XXXXX	For future use
38–39	D option	DX	No D option
		D0	24 V DC back-up input

Figure 6.1 Type Code Description

Not all choices/options are available for each VLT® Decentral Drive FCD 302 variant. To verify if the appropriate version is available, consult the Drive Configurator on the Internet: vltconfig.danfoss.com/.

NOTICE!

A and D options for FCD 302 are integrated into the control card. Do not use pluggable options for frequency converters. Future retrofit requires exchange of the entire control card. B options are pluggable, using the same concept as for frequency converters.

6.2 Ordering Numbers

6.2.1 Ordering Numbers: Accessories

Accessories	Description	Ordering number
Mounting brackets extended	40 mm brackets	130B5771
Mounting brackets	Flat brackets	130B5772
LCP cable	Preconfectedion cable to be used between inverter and LCP	130B5776
Brake resistor 1750 Ω 10 W/100%	For mounting inside installation box below motor terminals	130B5778
Brake resistor 350 Ω 10 W/100%	For mounting inside installation box below motor terminals	130B5780
VLT® Control Panel LCP 102	Graphical LCP for programming and readout	130B1078
Venting membrane, goretex	Preventing condensation inside enclosure	175N2116
Stainless chassis kit, M16	Stainless Steel	130B5833

Table 6.1 Ordering Numbers: Accessories

6.2.2 Ordering Numbers: Spare Parts

Spare parts	Description	Ordering number
Protection cover	Plastic protection cover for inverter part	130B5770
Gasket	Gasket between installation box and inverter part	130B5773
Accessory bag	Spare cable clamps and screws for shield termination	130B5774
Service switch	Spare switch for mains or motor disconnect	130B5775
LCP plug	Spare plug for mounting in installation box	130B5777
Main termination board	For mounting in installation box	130B5779
M12 sensor plugs	Set of two M12 sensor plugs for mounting in cable gland hole	130B5411
Control card	Control card with 24 V back-up	130B5783
Control card PROFIBUS	Control card PROFIBUS with 24 V back-up	130B5781
Control card Ethernet	Control card Ethernet with 24 V back-up	130B5788
Control card PROFINET	Control card PROFINET with 24 V back-up	130B5794

Table 6.2 Ordering Numbers: Spare Parts

The packaging contains:

- Accessories bag, supplied only with order of installation box. Contents:
 - 2 cable clamps
 - Bracket for motor/loads cables
 - Elevation bracket for cable clamp
 - Screw 4 mm x 20 mm
 - Thread forming 3.5 mm x 8 mm
- Documentation

Depending on options fitted, the box contains 1 or 2 bags and 1 or more booklets.

6.3 Options and Accessories

Danfoss offers a wide range of options and accessories for the frequency converter.

6.3.1 Fieldbus Options

Select the fieldbus option when ordering the frequency converter. All fieldbus options are included on the control card. No separate A option is available.

To change the fieldbus option later, change out the control card. The following control cards with different fieldbus options are available. All control cards have 24 V back-up as standard.

Item	Ordering number
Control card PROFIBUS	130B5781
Control card Ethernet	130B5788
Control card PROFINET	130B5794

Table 6.3 Control Cards with Fieldbus Options

6.3.2 VLT® Encoder Input MCB 102

The encoder module can be used as feedback source for closed-loop flux control (*parameter 1-02 Flux Motor Feedback Source*) and closed-loop speed control (*parameter 7-00 Speed PID Feedback Source*). Configure the encoder option in *parameter group 17-** Position Feedback*.

The encoder option MCB 102 is used for:

- VVC⁺ closed-loop.
- Flux vector speed control.

- Flux vector torque control.
- Permanent magnet motor.

Supported encoder types:

- Incremental encoder: 5 V TTL type, RS422, maximum frequency: 410 kHz
- Incremental encoder: 1Vpp, sine-cosine
- Hiperface® Encoder: Absolute and Sine-Cosine (Stegmann/SICK)
- EnDat encoder: Absolute and Sine-Cosine (Heidenhain) Supports version 2.1
- SSI encoder: Absolute
- Encoder monitor: The 4 encoder channels (A, B, Z, and D) are monitored, open, and short circuit can be detected. There is a green LED for each channel which lights up when the channel is OK.

NOTICE!

The LEDs are not visible when mounted in a VLT® Decentral Drive FCD 302 frequency converter. Reaction in case of an encoder error can be selected in *parameter 17-61 Feedback Signal Monitoring: [0] Disabled, [1] Warning, or [2] Trip*.

The encoder option kit contains:

- Encoder Option MCB 102
- Cable to connect customer terminals to control card

Connector Designation X31	Incremental Encoder (refer to Graphic A)	SinCos Encoder HIPERFACE® (refer to Graphic B)	EnDat Encoder	SSI Encoder	Description
1	NC	–	–	24 V ¹⁾	24 V output (21–25 V, I _{max} :125 mA)
2	NC	8 VCC	–	–	8 V output (7–12 V, I _{max} : 200 mA)
3	5 VCC	–	5 VCC	5 V ¹⁾	5 V output (5 V ±5%, I _{max} : 200 mA)
4	GND	–	GND	GND	GND
5	A input	+COS	+COS	–	A input
6	A inv input	REFCOS	REFCOS	–	A inv input
7	B input	+SIN	+SIN	–	B input
8	B inv input	REFSIN	REFSIN	–	B inv input
9	Z input	+Data RS485	Clock out	Clock out	Z input OR +Data RS485
10	Z inv input	-Data RS485	Clock out inv.	Clock out inv.	Z input OR -Data RS485
11	NC	NC	Data in	Data in	Future use
12	NC	NC	Data in inv.	Data in inv.	Future use
Maximum 5 V on X31.5–12		–	–	–	–

Table 6.4 Encoder Option MCB 102 Connection Terminals

1) Supply for encoder: See data on encoder.

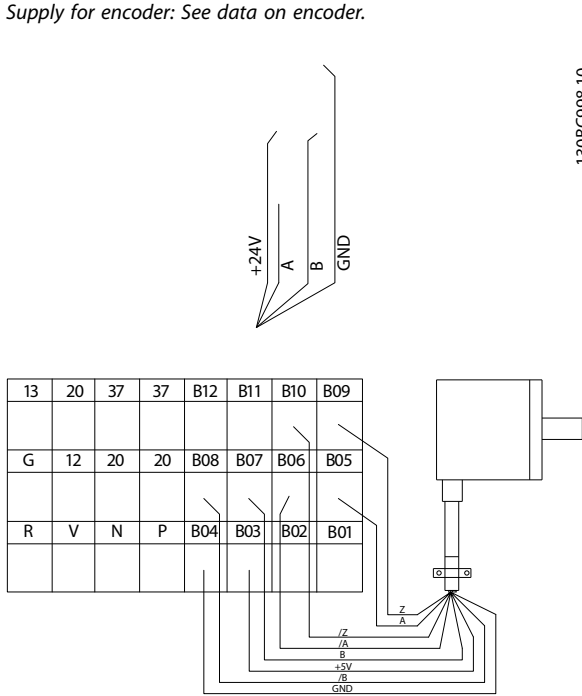


Figure 6.2 Connections for 5 V Incremental Encoder

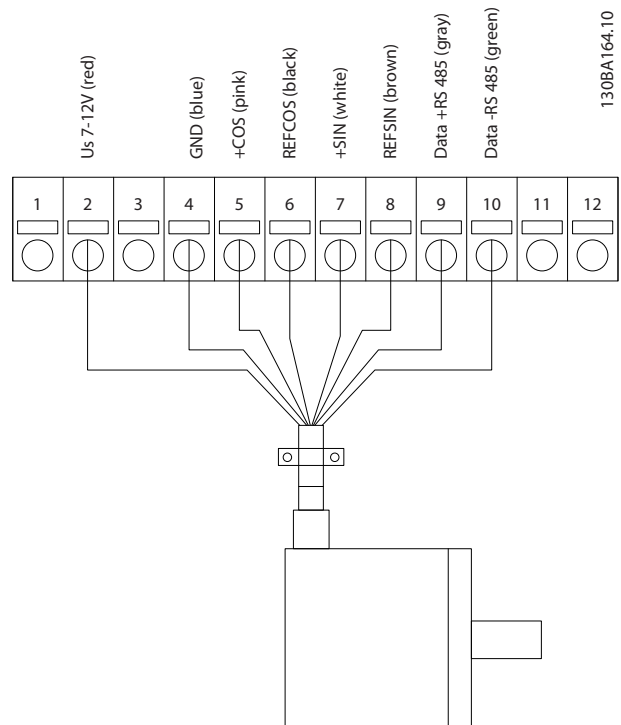
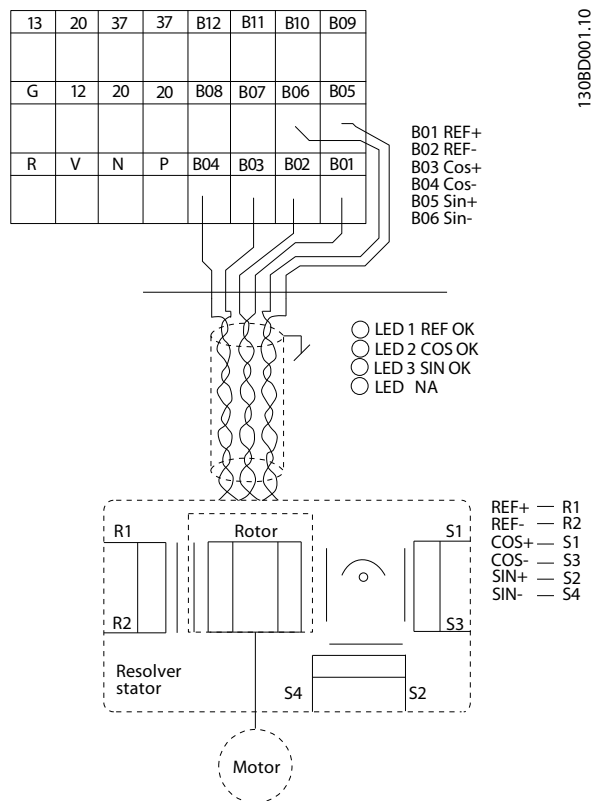
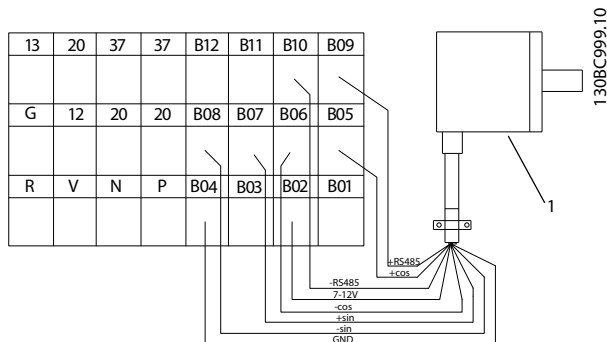


Figure 6.3 Connections for HIPERFACE® Encoder - 1

Maximum cable length 10 m (32.8 ft)



Item	Description
1	HIPERFACE® encoder

Figure 6.4 Connections for HIPERFACE® Encoder - 2

6.3.3 VLT® Resolver Input MCB 103

The MCB 103 is used for interfacing resolver motor feedback to the frequency converter. Resolvers are used basically as motor feedback device for permanent magnet brushless synchronous motors.

The resolver option kit comprises:

- MCB 103 Resolver Option.
- Cable to connect customer terminals to control card.

Find the relevant parameters in *parameter group 17-5** Resolver Interface.

MCB 103 supports a various number of resolver types.

Resolver poles	Parameter 17-50 Poles: 2 *2
Resolver input voltage	Parameter 17-51 Input Voltage: 2.0–8.0 V_{rms} *7.0 V_{rms}
Resolver input frequency	Parameter 17-52 Input Frequency: 2–15 kHz *10.0 kHz
Transformation ratio	Parameter 17-53 Transformation Ratio: 0.1–1.1 *0.5
Secondary input voltage	Maximum 4 V_{rms}
Secondary load	Approximately 10 k Ω

Table 6.5 Resolver Option MCB 103 Specifications

Figure 6.5 Connections for Resolver Option MCB 103

NOTICE!

The Resolver Option MCB 103 can only be used with rotor-supplied resolver types. Stator-supplied resolvers cannot be used.

NOTICE!

LED indicators are not visible at the resolver option.

LED indicators

- LED 1 is on when the reference signal is OK to resolver.
- LED 2 is on when the cosine signal is OK from resolver.
- LED 3 is on when the sine signal is OK from resolver.

The LEDs are active when *parameter 17-61 Feedback Signal Monitoring* is set to [1] Warning or [2] Trip.

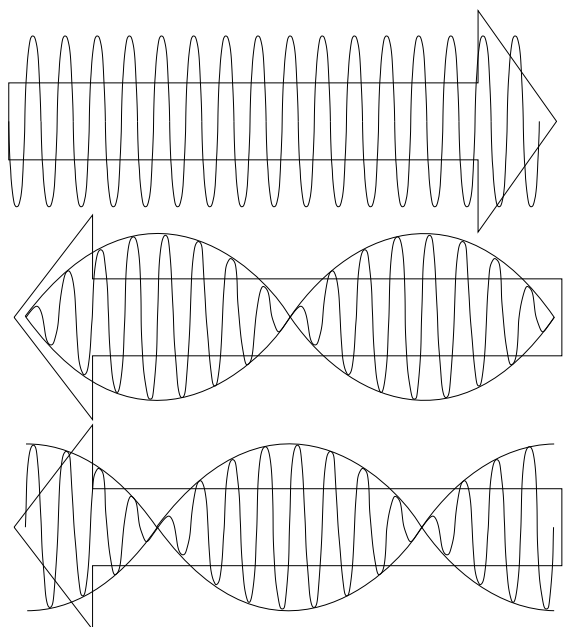


Figure 6.6 Resolver Signals

Set-up example

In this example, a permanent magnet (PM) motor is used with resolver as speed feedback. A PM motor must usually operate in flux mode.

Wiring

The maximum cable length is 150 m (492 ft) when a twisted pair type of cable is used.

NOTICE!

Shield and separate the resolver cables from the motor cables.

NOTICE!

The shield of the resolver cable must be correctly connected to the decoupling plate and connected to chassis (ground) on the motor side.

NOTICE!

Always use shielded motor cables and brake chopper cables.

Parameter 1-00 Configuration Mode	[1] Speed closed loop
Parameter 1-01 Motor Control Principle	[3] Flux with feedback
Parameter 1-10 Motor Construction	[1] PM, non-salient SPM
Parameter 1-24 Motor Current	Nameplate
Parameter 1-25 Motor Nominal Speed	Nameplate
Parameter 1-26 Motor Cont. Rated Torque	Nameplate
AMA is not possible on PM motors	
Parameter 1-30 Stator Resistance (Rs)	Motor datasheet
Parameter 30-80 d-axis Inductance (Ld)	Motor datasheet (mH)
Parameter 1-39 Motor Poles	Motor datasheet
Parameter 1-40 Back EMF at 1000 RPM	Motor datasheet
Parameter 1-41 Motor Angle Offset	Motor datasheet (usually 0)
Parameter 17-50 Poles	Resolver datasheet
Parameter 17-51 Input Voltage	Resolver datasheet
Parameter 17-52 Input Frequency	Resolver datasheet
Parameter 17-53 Transformation Ratio	Resolver datasheet
Parameter 17-59 Resolver Interface	[1] Enabled

Table 6.6 Parameters to Adjust

6.3.4 VLT® 24 V DC Supply MCB 107

24 V DC external supply

A 24 V DC external supply can be installed for low voltage supply to the control card and any option card installed. This enables full operation of the LCP (including the parameter setting) without connection to mains.

24 V DC external supply specification

Input voltage range	24 V DC \pm 15% (maximum 37 V in 10 s)
Maximum input current	2.2 A
Average input current	0.9 A
Maximum cable length	75 m
Input capacitance load	<10 μ F
Power-up delay	<0.6 s

The inputs are protected.

Terminal numbers

- Terminal 35: - 24 V DC external supply.
- Terminal 36: + 24 V DC external supply.

7 Specifications

7.1 Mechanical Dimensions

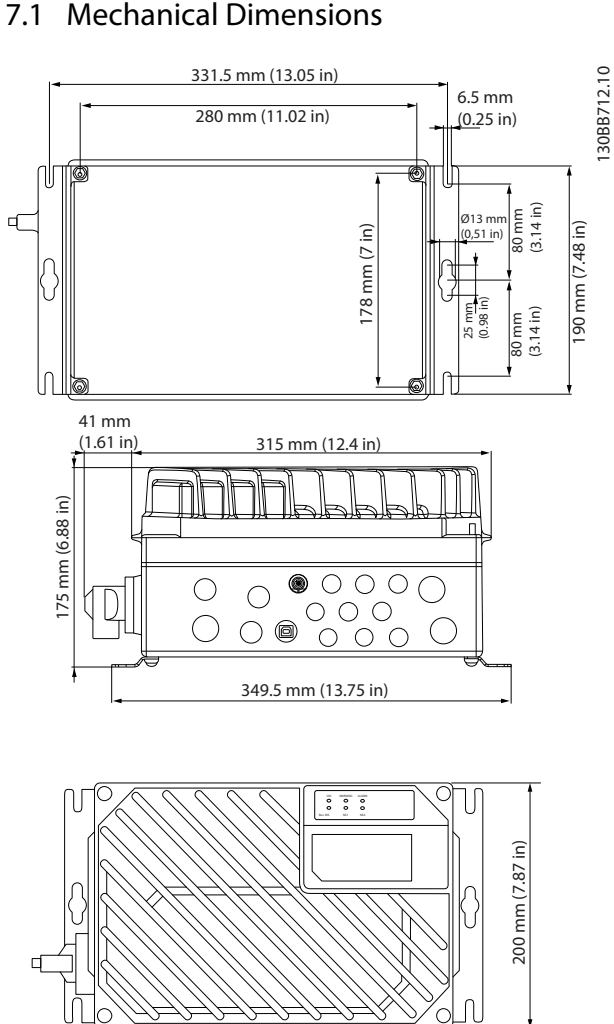
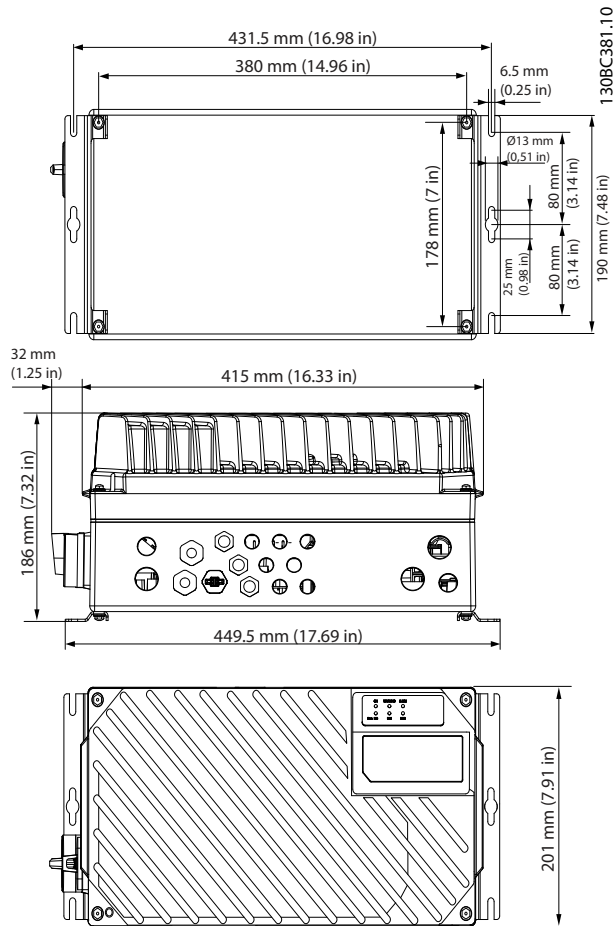


Figure 7.1 Small Unit



Motor side	1xM20, 1xM25
Control side	2xM20, 9xM16 ¹⁾
Mains side	2xM25
¹⁾ Also used for 4xM12/6xM12 sensor/actuator sockets.	

Figure 7.2 Large Unit

7.2 Electrical Data and Wire Sizes

7.2.1 Overview

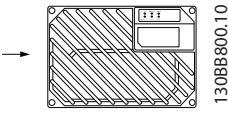
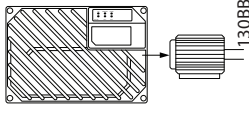
Mains supply 3x380–480 V AC									
Frequency converter		PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0	
Rated shaft output [kW]		0.37	0.55	0.75	1.1	1.5	2.2	3.0	
Rated shaft output [hp]		0.5	0.75	1.0	1.5	2.0	3.0	4.0	
Maximum input current									
 130BB800.10	Continuous (3x380–440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5	
	Intermittent (3x380–440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4	
	Continuous (3x441–480 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7	
	Intermittent (3x441–480 V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1	
	Recommended maximum fuse size (non-UL)	gG-25							
	Built-in circuit breaker (large unit)	CTI-25M Danfoss part number: 047B3151							
	Recommended circuit breaker Danfoss CTI-25M (small and large unit) part number:								
	0.37, 0.55 kW	Danfoss part number: 047B3148							
	0.75, 1.1 kW	Danfoss part number: 047B3149							
	1.5 kW, 2.2 kW, and 3 kW	Danfoss part number: 047B3151							
	Recommended circuit breaker Danfoss CTI-45MB ¹⁾ (small unit) part number:								
	0.55, 0.75 kW	Danfoss part number: 047B3160							
	1.1 kW	Danfoss part number: 047B3161							
	1.5 kW	Danfoss part number: 047B3162							
	2.2 kW	Danfoss part number: 047B3163							
	Power loss at maximum load [W] ²⁾	35	42	46	58	62	88	116	
	Efficiency ³⁾	0.93	0.95	0.96	0.96	0.97	0.97	0.97	
Weight, small unit [kg]	9.8 (21.6 lb)							–	
Weight, large unit [kg]	13.9 (30.6 lb)								
Output current									
 130BB799.10	Continuous (3x380–440 V) [A]	1.3	1.8	2.4	3.0	4.1	5.2	7.2	
	Intermittent (3x380–440 V) [A]	2.1	2.9	3.8	4.8	6.6	8.3	11.5	
	Continuous (3x441–480 V) [A]	1.2	1.6	2.1	3.0	3.4	4.8	6.3	
	Intermittent (3x441–480 V) [A]	1.9	2.6	3.4	4.8	5.4	7.7	10.1	
	Continuous kVA (400 V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0	
	Continuous kVA (460 V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0	
	Maximum cable size: (Mains, motor, brake) [mm ² /AWG]	Solid cable 6/10 Flexible cable 4/12							

Table 7.1 VLT® Decentral Drive FCD 302 Shaft Output, Output Current, and Input Current

1) Type CTI-45MB circuit breakers are not available for 3 kW (4 hp) units.

2) Applies for dimensioning of frequency converter cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/.

3) Efficiency measured at nominal current. For energy efficiency class, see chapter 7.3 General Specifications. For part load losses, see drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/.

7.2.2 UL/cUL Approved Pre-fuses

- American wire gauge. Maximum cable cross-section is the largest cable cross-section that can be attached to the terminals. Always observe national and local regulations.
- Type gG pre-fuses must be used. To maintain UL/cUL, use pre-fuses of these types (see *Table 7.2*).
- Measured using a 10 m (32.8 ft) shielded/armored motor cable with a rated load and rated frequency.

Recommended maximum pre-fuse size 25 A

Brand	Fuse type	UL File number	UL Category (CCN code)
Bussmann	FWH- ¹⁾	E91958	JFHR2
Bussmann	KTS-R ¹⁾	E4273	RK1/JDDZ
Bussmann	JKS- ¹⁾	E4273	J/JDDZ
Bussmann	JJS- ¹⁾	E4273	T/JDDZ
Bussmann	FNQ-R- ¹⁾	E4273	CC/JDDZ
Bussmann	KTK-R- ¹⁾	E4273	CC/JDDZ
Bussmann	LP-CC- ¹⁾	E4273	CC/JDDZ
SIBA	5017906- ¹⁾	E180276	RK1/JDDZ
Littelfuse	KLS-R ¹⁾	E81895	RK1/JDDZ
Ferraz Shawmut	ATM-R ¹⁾	E2137	CC/JDDZ
Ferraz Shawmut	A6K-R ¹⁾	E2137	RK1/JDDZ
Ferraz Shawmut	HSJ ¹⁾	E2137	J/HSJ

Table 7.2 VLT® Decentral Drive FCD 302 Pre-fuses Meeting UL/cUL Requirements

1) 5 A (0.37 kW/0.5 hp), 7 A (0.55 kW/0.37 hp), 9 A (0.75 kW/1 hp), 12 A (1.1 kW/1.5 hp), 15 A (1.5 kW/2 hp), 20 A (2.2 kW/3 hp), 25 A (3 kW/4 hp)

7.2.3 VLT® Decentral Drive FCD 302 DC Voltage Levels

DC voltage level	380–480 V units (V DC)
Inverter undervoltage disable	373
Undervoltage warning	410
Inverter undervoltage re-enable (warning reset)	398
Overvoltage warning (without brake)	778
Dynamic brake turn on	778
Inverter overvoltage re-enable (warning reset)	795
Overvoltage warning (with brake)	810
Overvoltage trip	820

Table 7.3 FCD 302 DC Voltage Level

Fuses

The unit is suitable for use on a circuit capable of delivering not more than 100000 RMS symmetrical Amperes, 500 V maximum.

Circuit breaker

The unit is suitable for use on a circuit capable of delivering not more than 10000 RMS symmetrical Amperes, 500 V maximum.

7.3 General Specifications

Mains supply (L1, L2, L3)¹⁾

Supply voltage	380–480 V ±10% ²⁾
Supply frequency	50/60 Hz ± 5%
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 ($\cos \phi$)	Near unity (> 0.98)
Switching on input supply L1, L2, L3 (power-ups)	Maximum 2 times/minute

1) The unit is suitable for use on a circuit capable of delivering not more than 100000 RMS symmetrical Amperes, 480 V maximum.

2) Mains voltage low/mains drop-out:

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

Motor output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–590 Hz
Output frequency in flux mode	0–300 Hz
Switching on output	Unlimited
Ramp times	0.01–3600 s

Torque characteristics

Starting torque (constant torque)	Maximum 160% for 60 s ¹⁾
Starting torque	Maximum 180% up to 0.5 s ¹⁾
Overload torque (constant torque)	Maximum 160% for 60 s ¹⁾
Starting torque (variable torque)	Maximum 110% for 60 s ¹⁾
Overload torque (variable torque)	Maximum 110% for 60 s ¹⁾

1) Percentage relates to the nominal torque.

Cable lengths and cross-sections for control cables¹⁾

Maximum motor cable length, shielded	10 m (32.8 ft)
Maximum motor cable length, unshielded, without fulfilling emission specification	10 m (32.8 ft)
Maximum cross-section to control terminals, flexible/ rigid wire without cable end sleeves	1.5 mm ² /16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves	1.5 mm ² /16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	1.5 mm ² /16 AWG
Minimum cross-section to control terminals	0.25 mm ² /24 AWG

1) Power cables, see tables in chapter 7.2 Electrical Data and Wire Sizes.

Protection and features

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the frequency converter trips if the temperature reaches a predefined level.
- The frequency converter is protected against short circuits on motor terminals U, V, W.
- If a mains phase is missing, the frequency converter trips or issues a warning (depending on the load).
- Monitoring of the DC-link voltage ensures that the frequency converter trips if the DC-link voltage is too low or too high.
- The frequency converter constantly checks for critical levels of internal temperature, load current, high voltage on the DC link, and low motor speeds. As a response to a critical level, the frequency converter can adjust the switching frequency and/or change the switching pattern to ensure the performance of the frequency converter.

Digital inputs

Programmable digital inputs	4 (6) ¹⁾
Terminal number	18, 19, 27 ¹⁾ , 29 ¹⁾ , 32, 33
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 ²⁾	>19 V DC
Voltage level, logic 1 NPN ²⁾	<14 V DC
Maximum voltage on input	28 V DC
Pulse frequency range	0–110 kHz
(Duty cycle) Minimum pulse width	4.5 ms
Input resistance, R _i	Approximately 4 kΩ

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

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

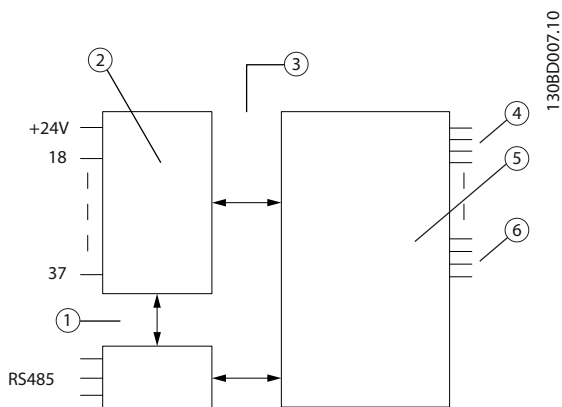
Safe Torque Off terminal 37 (terminal 37 is fixed PNP logic)

Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<4 V DC
Voltage level, logic 1 PNP	20 V DC
Nominal input current at 24 V	50 mA rms
Nominal input current at 20 V	60 mA rms
Input capacitance	400 nF

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202=OFF (U)
Voltage level	-10 V to +10 V (scaleable)
Input resistance, R _i	Approximately 10 kΩ
Maximum voltage	±20 V
Current mode	Switch S201/switch S202=ON (I)
Current level	0/4–20 mA (scaleable)
Input resistance, R _i	Approximately 200Ω
Maximum current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Maximum error 0.5% of full scale
Bandwidth	100 Hz

The analog inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.



Item	Description
1	Functional isolation
2	Control
3	PELV isolation
4	Mains
5	High voltage
6	Motor

Figure 7.3 Analog Inputs

Pulse/encoder inputs

Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29, 33 ¹⁾ /32 ²⁾ , 33 ²⁾
Maximum frequency at terminal 29, 32, 33	110 kHz (Push-pull driven)
Maximum frequency at terminal 29, 32, 33	5 kHz (open collector)
Minimum frequency at terminal 29, 32, 33	4 Hz
Voltage level	See <i>Digital Inputs</i> in this section
Maximum voltage on input	28 V DC
Input resistance, R _i	Approximately 4 kΩ
Pulse input accuracy (0.1–1 kHz)	Maximum error: 0.1% of full scale
Encoder input accuracy (1–110 kHz)	Maximum error: 0.05% of full scale

The pulse and encoder inputs (terminals 29, 32, 33) are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

1) Pulse inputs are 29 and 33

2) Encoder inputs: 32=A, and 33=B

Analog output

Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4 to 20 mA
Maximum load GND - analog output less than	500 Ω
Accuracy on analog output	Maximum error: 0.5% of full scale
Resolution on analog output	12 bit

The analog output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control card, RS485 serial communication

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

The RS485 serial communication circuit is functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

Digital output

Programmable digital/pulse outputs	2
Terminal number	27, 29 ¹⁾
Voltage level at digital/frequency output	0–24 V
Maximum output current (sink or source)	40 mA
Maximum load at frequency output	1 k Ω
Maximum capacitive load at frequency output	10 nF
Minimum output frequency at frequency output	0 Hz
Maximum output frequency at frequency output	32 kHz
Accuracy of frequency output	Maximum error: 0.1% of full scale
Resolution of frequency outputs	12 bit

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

The digital output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control card, 24 V DC output

Terminal number	12, 13
Output voltage	24 V +1, -3 V
Maximum load	600 mA

The 24 V DC supply is galvanically isolated from the supply voltage (PELV), but has the same ground potential as the analog and digital inputs and outputs.

Relay outputs

Programmable relay outputs	2
Relay 01 terminal number	1-3 (break), 1-2 (make)
Maximum terminal load (AC-1) ¹⁾ on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ (Inductive load @ $\cos\phi$ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 1-2 (NO), 1-3 (NC) (Resistive load)	48 V DC, 1 A
Maximum terminal load (DC-13) ¹⁾ (Inductive load)	24 V DC, 0.1 A
Relay 02 terminal number	4-6 (break), 4-5 (make)
Maximum terminal load (AC-1) ¹⁾ on 4-5 (NO) (Resistive load) ²⁾³⁾ Overvoltage cat. II	240 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ on 4-5 (NO) (Inductive load @ $\cos\phi$ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 4-5 (NO) (Resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) ¹⁾ on 4-5 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) ¹⁾ on 4-6 (NC) (Resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ (Inductive load @ $\cos\phi$ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 4-6 (NO), 4-5 (NC) (Resistive load)	48 V DC, 1 A
Maximum terminal load (DC-13) ¹⁾ (Inductive load)	24 V DC, 0.1 A
Minimum terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24 V DC 10 mA, 24 V AC 20 mA

1) IEC 60947 part 4 and 5

The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).

2) Overvoltage Category II

3) UL applications 300 V AC 2A

Control card, 10 V DC output

Terminal number	\pm 50
Output voltage	10.5 V \pm 0.5 V
Maximum load	15 mA

The 10 V DC supply is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control characteristics

Resolution of output frequency at 0–590 Hz	±0.003 Hz
Repeat accuracy of precise start/stop (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤2 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed control range (closed loop)	1:1000 of synchronous speed
Speed accuracy (open loop)	30–4000 RPM: error ±8 RPM
Speed accuracy (closed loop), depending on resolution of feedback device	0–6000 RPM: error ±0.15 RPM
Torque control accuracy (speed feedback)	Maximum error ±5% of rated torque

All control characteristics are based on a 4-pole asynchronous motor.

Control card performance

Scan interval	1 ms
---------------	------

Surroundings

Enclosure rating	IP66/Type 4X (indoor)
Vibration test for units with no circuit breaker	1.7 g RMS
Mounts unit with integrated circuit breaker on a level, vibration-proof, and torsionally rigid support structure	
Maximum relative humidity	5–95% (IEC 60 721-3-3; Class 3K3 (non-condensing) during operation)
Ambient temperature	Maximum 40 °C (75 °F) (24-hour average maximum 35 °C (95 °F))
Temperature during storage/transport	-25 to +65/70 °C (-13 to +149/158 °F)

Derating for high ambient temperature

Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced performance	-10 °C (14 °F)
Maximum altitude above sea level	1000 m (3280.8 ft)
Energy efficiency class ¹⁾	IE2

Derating for high altitude

1) Determined according to EN 50598-2 at:

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

Control card, USB serial communication

USB standard	1.1 (Full speed)
USB plug	USB type B plug

Connection to PC is carried out via a standard host/device USB cable.

The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

*The USB ground connection is **not** galvanically isolated from protection ground. Use only an isolated laptop as PC connection to the USB connector on the frequency converter.*

7.4 Efficiency

Efficiency of the frequency converter (η_{VLT})

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

This also means that the efficiency of the frequency converter does not change even if other U/f characteristics are selected. However, the U/f characteristics influence the efficiency of the motor.

The efficiency declines a little when the switching frequency is set to a value of above 5 kHz. The efficiency is also slightly reduced if the mains voltage is 480 V.

Efficiency calculation

Calculate the efficiency of the frequency converter at different loads based on the following graph. The factor in this graph must be multiply by the specific efficiency factor listed in *Table 7.1*:

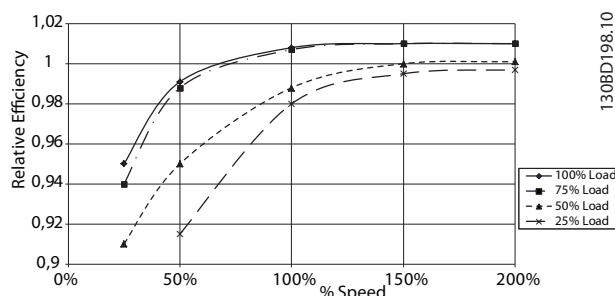


Figure 7.4 Typical Efficiency Curves

Example: Assume a 3.0 kW, 380–480 V AC at 75% load at 50% speed. The graph is showing 0.99 - the rated efficiency for a 3.0 kW, FCD 302 is 0.97. The actual efficiency is then: $0.99 \times 0.97 = 0.96$.

Efficiency of the motor (η_{MOTOR})

The efficiency of a motor connected to the frequency converter depends on magnetising level. In general, the efficiency is just as good as with mains operation. The efficiency of the motor depends on the type of motor.

In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant, both when it is controlled by the frequency converter and when it runs directly on mains.

In small motors, the influence from the U/f characteristic on efficiency is marginal.

In general, the switching frequency does not affect the efficiency of small motors. Motors with low internal impedance (for example, PM motors with a very high-power factor) require relatively high switching frequency to maintain the sine shape of the current. The resulting

increase in switching losses can decrease the efficiency of the frequency converter.

Efficiency of the system (η_{SYSTEM})

To calculate the system efficiency, the efficiency of the frequency converter (η_{VLT}) is multiplied by the efficiency of the motor (η_{MOTOR}):

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

7.5 dU/dt Conditions

NOTICE!

380–690 V

To avoid premature aging of motors (without phase insulation paper or other insulation reinforcement) not designed for operation of the frequency converter, Danfoss strongly recommend fitting a dU/dt filter or a sine-wave filter on the output of the frequency converter. For further information about dU/dt and sine-wave filters, see the *Output Filters Design Guide*.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a dU/dt ratio depending on:

- The motor cable (type, cross-section, length, shielded, or unshielded)
- Inductance

The natural induction causes an overshoot U_{PEAK} in the motor voltage before it stabilizes itself at a level depending on the voltage in the DC link. The rise time and the peak voltage U_{PEAK} affect the service life of the motor. If the peak voltage is too high, especially motors without phase coil insulation are affected. When the motor cable is short (a few meters), the rise time and peak voltage are lower.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The frequency converter complies with the demands of IEC 60034-25 regarding motors designed to be controlled by frequency converters. The frequency converter also complies with IEC 60034-17 regarding Norm motors controlled by frequency converters. The measured values from the laboratory tests are detailed in *Table 7.4, Table 7.5, Table 7.6, Table 7.7, and Table 7.8:*

Inverter measurements FCD 302: P0K37T4 & FCD 302: P0K55T4

Motor cable length [m] (ft)	Mains voltage [V _{rms}]	Rise time [μs]	U _{peak} [kV]	dU/dt [V/μs]
10 (32.8 ft)	480	0.25	0.662	2118.40

Table 7.4 FCD 302: P0K37T4 & FCD 302: P0K55T4
Inverter measurements FCD 302: P0K75T4

Motor cable length [m] (ft)	Mains voltage [V _{rms}]	Rise time [μs]	U _{peak} [kV]	dU/dt [V/μs]
10 (32.8 ft)	480	0.22	0.66	2118.40

Table 7.5 FCD 302: P0K75T4
Inverter measurements FCD 302: P1K1T4 & FCD 302: P1K5T4

Motor cable length [m] (ft)	Mains voltage [V _{rms}]	Rise time [μs]	U _{peak} [kV]	dU/dt [V/μs]
10 (32.8 ft)	480	0.22	0.66	2400

Table 7.6 FCD 302: P1K1T4 & FCD 302: P1K5T4
Inverter measurements FCD 302: P2K2T4

Motor cable length [m] (ft)	Mains voltage [V _{rms}]	Rise time [μs]	U _{peak} [kV]	dU/dt [V/μs]
10 (32.8 ft)	480	0.142	0.685	3859.15

Table 7.7 FCD 302: P2K2T4
Inverter measurements FCD 302: P3K0T4

Control Structure in Motor cable length [m] (ft)	Mains voltage [V _{rms}]	Rise time [μs]	U _{peak} [kV]	dU/dt [V/μs]
10 (32.8 ft)	480	0.202	0.68	2693.07

Table 7.8 FCD 302: P3K0T4

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