EN
AG 0101
Drive Optimisation
Guideline for PMSM - CFC Closed-Loop
**Documentation**

**Title:** AG 0101
**Order – No.:** 6047602
**Series:** SK 200E, SK 500E
**Fl series:** SK 200E, SK 210E, SK 220E, SK 230E, SK 205E, SK 215E, SK 225E, SK 235E, SK 520E, SK 530E, SK 535E, SK 540E, SK 545E

**Fl types:**
- **SK 2xxE-111-123-A** (1.1 kW, 1 ~ 220 - 240 V)
- **SK 2xxE-111-323-A** ... **SK 2xxE-112-323-A** (1.1 - 5.5 kW, 3 ~ 220 - 240 V) \(^1\)
- **SK 2xxE-111-340-A** ... **SK 5xxE-551-340-A** (1.1 - 5.5 kW, 3 ~ 380 - 500 V)
- **SK 5xxE-111-323-** ... **SK 5xxE-221-323-** (1.1 - 2.2 kW, 1/3 ~ 230 V)
- **SK 5xxE-301-323-** ... **SK 5xxE-551-323-** (3.0 ~ 5.5 kW, 3 ~ 230 V)
- **SK 5xxE-111-340-** ... **SK 5xxE-551-340-** (1.1 ~ 5.5 kW, 3 ~ 400 V)

\(^1\) Size 4 (5.5) only in the versions SK 2x0E

**Version list**

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<th>Order number</th>
<th>Version</th>
<th>Remarks</th>
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<td>6047602 / 3216</td>
<td>1.0</td>
<td>First edition, based on the manuals BU 0200 GB / 1216, BU 0210 GB / 2509, BU 0500 GB / 0715, BU 0505 GB / 0715, BU 0510 GB / 3911</td>
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Table 1: Version list AG 0101

**Publisher**

Getriebebau NORD GmbH & Co. KG
Getriebebau-Nord-Straße 1 • 22941 Bargteheide, Germany • http://www.nord.com/
Fon +49 (0) 45 32 / 289-0 • Fax +49 (0) 45 32 / 289-2253
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NOTICE

Application

This application example is only valid in combination with the operating instructions of the respective frequency inverters and technology options. This is an essential prerequisite for the availability of all the relevant information required for the safe commissioning of the frequency inverter.

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Information about this guide

This application guide is primarily intended for planners as well as commissioning and service personnel, who are familiar with the use and function of electronic drive technology (motors and frequency inverters) from Getriebebau NORD. The guide is a recommendation for the step-by-step commissioning and parameterisation of the individual controller and function settings as well as the procedure for optimisation of the drive unit or controller.

The information and recommendations relate to currently available drive units and control components or controller settings, preferably standard products from Getriebebau NORD. The guide refers to current drive technology software and hardware versions, which were valid at the time of publication of this guide. Optimisation procedures must be carried out in observance of the current manuals and drive technology data sheets. The versions of the manuals and technical data sheets may differ.

Information and explanations for the use of this application guide are given below.

Structure symbols

Individual section areas and application steps are provided with the following structure symbols in order to provide "familiar" users with graphical or quicker orientation:

<table>
<thead>
<tr>
<th>Identification</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>The Step (1, 2, etc.) serves to provide &quot;familiar&quot; users with a quicker overview for the use of the guide. In places, the steps can also be used as cross-references, or as hyperlinks, see 1.3 &quot;Overview (schematic procedure)&quot;.</td>
</tr>
<tr>
<td>Information</td>
<td>The Information indicates that the following is only stated as information for the corresponding area of the section and provides the user with detailed or helpful additional information.</td>
</tr>
<tr>
<td>Instructions</td>
<td>The Instructions indicate that in the following, the user is required to take action, e.g. for parameterisation, testing or optimisation.</td>
</tr>
<tr>
<td>Information &amp; instructions</td>
<td>Information &amp; Instructions indicate that in the following, helpful additional information as well as the requirement for action by the user is described.</td>
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Fig. 1: List of structure symbols

Cross-references and hyperlinks

For quicker and easier use of the guide, cross-references are prefixed with a symbol 📚. With a mouse click on the cross-reference - see 9.1 "Manuals" the user can directly access the appropriate section, information or the relevant document.

In addition, hyperlinks (e.g. M7000 Electric Motors) are used, with which the user can directly access the relevant manual, data sheet, contact partner, etc. on the Getriebebau NORD homepage.
User symbols

By means of certain hand symbols, etc. the user is presented with important indications of additional information, curves and the objective of the optimisation of the controller.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tr>
<td>🚳</td>
<td>Observance and indication of important additional information</td>
</tr>
<tr>
<td>🌻</td>
<td>Definition and objective of the optimisation to be made</td>
</tr>
<tr>
<td>🌿</td>
<td>Partial success for an optimised curve for optimisation of controllers</td>
</tr>
<tr>
<td>✔️</td>
<td>Objective of an optimum curve for the optimisation of the controller</td>
</tr>
</tbody>
</table>

Fig. 2: List of user symbols

Symbols

- 🚳 Indication of further information
- 🚳 Automatic parameter change
- ← Change to manual parameterisation
- 📱 Check the display
- 🌿 Footnotes / deviations, e.g. device types
- [V] Unit of the parameter value
- [-01] Array No.
- {1} Function No. / Value
- {1 = Off} Description of function, the function number corresponds to the name of the function

Fig. 3: List of symbols

Parameters

The indication of individual parameters has been selected so that parameters which are shown in "bold" type, e.g. Motor list P200 indicate their relevance within a section. If the parameter is not written in "bold" type, e.g. Weak field limit P320, this is only subordinate information, or is not explained further.
Due to certain configurations, the parameters are subject to certain conditions. The relevant / used explanation symbols are listed below:

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
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<td>Third party motor</td>
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<tr>
<td>P240 (P) EMF voltage PMSM [V]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>0</td>
<td>0 → 341</td>
</tr>
<tr>
<td>P241 [-01] Inductance PMSM (d axis) [mH]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>20</td>
<td>20 → 22.6</td>
</tr>
<tr>
<td>P241 [-02] Inductance PMSM (q axis) [mH]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>20</td>
<td>20 → 45.9</td>
</tr>
</tbody>
</table>

1. Parameter number
2. Parameters (P) depend on parameter sets, see Parameter P100, Supervisor parameters (S) depend on the setting, see Parameter P003
3. Array value and description of the array parameter
4. Parameter text: Name / meaning of NORD CON display text
5. Parameter unit
6. Default value (factory setting) of parameter
7. Parameter setting for NORD motors
8. Parameter setting for third party motors
9. Usage symbols, see Symbols

Fig. 4: List of parameter indications

Names of parameters and functions

In the following, for example, a parameter is described with its name, number and with the corresponding selected function (number and name):

Motor list P200 with selection of the function {109 = 3.0 kW 400 V 100T2/4}

1. Parameter name
2. Parameter number
3. Function number
4. Description of function / Name of function or NORD CON display text

Fig. 5: Overview of names of parameters and functions
# Overview for experienced user

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1 Introduction

This guide explains the step-by-step procedure for optimisation of the individual control functions, as well as the parameterisation which is to be carried out in the particular frequency inverters.

Only CFC closed-loop mode is considered, which has the following advantages compared with operation in VFC open-loop mode:

- High torques – Rigidity
- Full torque at speed “zero”
- High speed precision
- Short control times possible

CFC closed-loop mode, also known as servo mode, is an operating mode with speed feedback. Several different control functions are implemented in decentralised SK 2xxE frequency inverters as well as in type SK 5xE control cabinet versions.

This provides the possibility of individually optimising the functional and application-specific requirements of the application which is to be implemented by means of the 4 available controllers.

Fig. 6: Current controller

Parameters: P312, P313, P314

Parameters: P315, P316, P317

Fig. 7: Speed controller

Parameters: P310, P311, P112
This guide for the optimisation of drive units uses the example of a decentralised \textbf{SK 200E-401-340-A} frequency inverter in combination with a \textbf{3.0 kW NORD IE4 synchronous motor (IPMSM, i.e. Interior Permanent Magnet Synchronous Motor)} with \textbf{NORD CON} oscilloscope recordings.

A guide is available to assist in planning and commissioning, which was specially produced for IE4 synchronous motors from Getriebebau NORD. Further details are described in the Technical Information \textnumero\textbf{TI 80_0010}, see \textsect\textbf{9.3 "TIs - Guidelines"}

The correct connection of the components to the control and power terminals, as well as further information about the functions used can be obtained from the relevant manuals, see \textsect\textbf{9.1 "Manuals"}.

If the different names (e.g. connection terminals, parameter structure) are taken into account, this guide can also be used analogously for other performance levels of the decentralised \textbf{SK 2xxE} and \textbf{≥ SK 520E} control cabinet frequency inverter types.
1.1 Introduction to controller optimisation

A controller uses the principle of continuous:

Measuring – Comparison – Provide

![Control loop diagram](Image)

The **value to be controlled** is measured with sensors (e.g. incremental encoders). The value to be controlled is compared with the **setpoint**. The difference is the **deviation**. From the deviation, the value for the adjustment is determined with consideration of the dynamic characteristics of the **control route**.

A control loop is used to bring a specified physical value, the so-called control value, to a required value (setpoint) and to maintain this value, regardless of any disturbances which may occur. To carry out the control task, the momentary value of the control value - the **actual value** - is measured and continuously compared with the setpoint. In case of deviation, adjustment must be made in a suitable manner and a response made as soon as possible. Control technology is used to technically perform this task. This is essentially based on the mathematical description and modelling of the control loop system. Stated simply, the main components of the control loop are the **controller** and the **control route**.

From the deviation, the controller determines the corrective measures required in consideration of the dynamic characteristics of the control route and makes the adjustment accordingly. The control route is the part of the control loop which is controlled by the controller.

(Source: see [www.rn-wissen.de](http://www.rn-wissen.de))

<table>
<thead>
<tr>
<th>Information</th>
<th>Optimisation information</th>
</tr>
</thead>
<tbody>
<tr>
<td>For optimal optimisation of the individual controllers, the following operating conditions should be taken into account in the optimisation procedure.</td>
<td></td>
</tr>
<tr>
<td>• Current control in static operation without load</td>
<td></td>
</tr>
<tr>
<td>• Speed and position control in dynamic operation under load</td>
<td></td>
</tr>
</tbody>
</table>

Application-specific conditions must also be taken into account for the optimisation.
### 1.2 Field-orientated control

To begin with, some information about the motor model or **field oriented control**, also known as current vector control, in the frequency inverter.

With a field-oriented **PMSM model** (Permanent Magnet Synchronous Motor) the 3-phase currents and voltages are stated as space vectors, which consist of the components "d" and "q".

The following diagram shows the orientation of the d component of the rotating coordinate system for the field of the **PMSM** rotor in the space vector or the **vector diagram**.

![Current vector diagram](image)

**Fig. 10: Current vector diagram**

- $I_s$: Line motor current (= Nominal current) [A]
- $I_{sd}$: Weak field current (set by control to 0 = No-load current) [A]
- $I_{sq}$: Torque-forming current (torque current (= rotor current)) [A]

The **current components** $I_{sd}$ (field weakening current / ≈ Actual field current P721) and $I_{sq}$ (torque-forming current, = Act. Torque current P720) are normal to each other. $I_s$ is the total line current (= Actual current P719).

The following simplified relationships result in association with this:

\[
I_s = \sqrt{(I_{sd})^2 + (I_{sq})^2}
\]

CFC Closed-Loop mode: In the basic speed range, up to the rated frequency $I_{sd} = I_o = no load current$.

- $I_o$: Line motor current (P203 / ≈ P719) [A]
- $I_{sd}$: Field weakening current (P209 / ≈ P721) to be set to "0" [A]
- $I_{sq}$: Torque-forming current or rotor current (≈ P720) [A]

#### 1.2.1 Torque calculation

The **torque $M$** is calculated with the following formula:

\[
M ≈ \Phi \cdot I_{sq}
\]

- $M$: Torque [Nm]
- $\Phi$: Magnetic flux [Wb]
- $I_{sq}$: Torque-forming current or rotor current (≈ P720) [A]

In other words, if $I_{sq}$ increases, the **torque $M$** must also increase.
## 1.3 Overview (schematic procedure)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description of procedure / Optimisation procedure</th>
<th>Documentation / Section Further information</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Step 1&quot;</td>
<td><strong>Hardware</strong>&lt;br&gt;Selection, setup and connection&lt;br&gt;– Installation and connection work&lt;br&gt;– Power and control terminals&lt;br&gt;– DIP switches&lt;br&gt;– Motor connection (check Y / ▲)&lt;br&gt;– Synchronous motors (PMSM, IPMSM, SPMSM)&lt;br&gt;– Frequency inverter ↔ Assignment of asynchronous motor&lt;br&gt;– Encoder resolution&lt;br&gt;– Selection of encoder system (IG / AG)&lt;br&gt;– Selection of encoder type: Data for incremental and / or absolute encoders, universal encoders</td>
<td><img src="image1" alt="Manual BU 0200" />&lt;br&gt;<img src="image2" alt="Manual BU 0500" />&lt;br&gt;<img src="image3" alt="Manual BU 0505" /> 2 &quot;Hardware&quot;</td>
</tr>
<tr>
<td>&quot;Step 2&quot;</td>
<td><strong>Basic commissioning / Motor data</strong>&lt;br&gt;Parameterisation according to motor list, type plate and data sheet&lt;br&gt;– NORD CON parameterisation&lt;br&gt;– Modification of operating displays&lt;br&gt;– Adjustment of the maximum frequency (P105)&lt;br&gt;– Selection of motor manufacturer or motor data&lt;br&gt;– Motor list, motor type plate or data sheet (contact the motor manufacturer if necessary)&lt;br&gt;– Motor data / Characteristic curve parameter (P2xx)&lt;br&gt;– NORD- motor or third party motor parameter identification (P220)&lt;br&gt;– Stator resistance (P208), check display&lt;br&gt;– Voltage constant ( k_e ), Stator inductances ( L_d / L_q )&lt;br&gt;– EMF voltage PMSM (P240)&lt;br&gt;– PMSM inductance (P241) [-01] &amp; [-02]&lt;br&gt;– Reluctance angle IPMSM (P243)&lt;br&gt;– Peak current PMSM (P244)&lt;br&gt;– Mass inertia PMSM (P246), Mass inertia&lt;br&gt;– Optimisation of specific motor data for third party motors</td>
<td><img src="image4" alt="NORD CON – Manual BU 0000" />&lt;br&gt;<img src="image5" alt="Manual BU 0200" />&lt;br&gt;<img src="image6" alt="Manual BU 0500" />&lt;br&gt;<img src="image7" alt="Manual BU 0505" /> 3.3 &quot;Motor data&quot;</td>
</tr>
</tbody>
</table>
## 1 Introduction

### Incremental encoder (IG)

Parameterisation, connection and commissioning

- Incremental encoder data
- Control parameter (P3xx)
- Incremental encoder (P301)
- Encoder with zero track
- Sync. 0-pulse (P335)
- Control terminals (P420 [-01] ... [-03])
- Connection, see Manual BU 0210 Technical Data Sheet
- Function test of IG rotary encoder
- Speed feedback / Servo mode (P300)

---

### Absolute encoder (AG)

Parameterisation, connection and commissioning

- CANopen combined absolute encoder with incremental encoder
- Absolute encoder data
- Additional parameter (P5xx) and positioning parameter (P6xx)
- Encoder resolutions (P605)
- Set CANopen parameters (P514 & P515)
- Connection, see Manual BU 0210 Technical Data Sheet
- Function test for CANopen AG encoders

---

### Procedure for determining the start position of the rotor

Selection and parameterisation of rotor position identification

- PMSM control method (P330)
- Encoder offset PMSM (P334)
- Sync. 0-pulse encoder (P335), Incremental encoder

---

### Current control

Torque current controller (P312, P313, P314)
Field current controller (P315, P316, P317)

- Adjust no load current (P209)
- NORD CON Remote control
- NORD CON Oscilloscope trigger, scan time, channel settings, etc.
- Torque current controller P (P312)
- Torque current controller I (P313)
- Field current controller P (P315)
- Field current controller I (P316)
### Drive Optimisation – Guideline for PMSM - CFC Closed-Loop

#### Table 2: Flow chart for procedure

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
</table>
| 5 "Speed control" | - Acceleration time (P102)  
- Jog frequency (P113)  
- NORD CON Remote control  
- NORD CON Oscilloscope trigger, scan time, channel settings, etc.  
- Speed Ctrl P (P310)  
- Speed Ctrl I (P311) |
| 6 "Position control" | - Activate position controller (P600)  
- Travel sensor system (P604 [01] & [02] & [03])  
- Setpoint specification & setpoint mode (P610)  
- Positioning parameters (P607 to P609 & P612)  
- Positions (P613 [01] to [63])  
- NORD CON Control  
- NORD CON device overview trigger, scan time, channel settings, etc.  
- Position controller P (P611) |
| 7 "Reluctance torque" | - Only for IPMSM type third party motors  
- NORD CON Remote control  
- NORD CON device overview as necessary  
- NORD CON Oscilloscope trigger, scan time, channel settings, etc.  
- Operate the motor under normal operating conditions / at the operating point under the nominal load  
- Optimise the reluctance angle IPMSM (P243) |

---

**DANGER!**

The correctness of each individual commissioning step must be checked with a function test. Suitable precautions must be taken to prevent damage to the system or danger to persons if the system behaves incorrectly (e.g. brake control for lifting equipment, mechanical coupling of parallel drives, etc.)
2 Hardware

Step 1

Information

The factory settings of all frequency inverters supplied by Getriebebau NORD are pre-programmed with the default setting for standard applications with 4 pole asynchronous motors (ASM) with the same voltage and power.

In addition, the motor data for all IE4 synchronous motors (IPMSM) produced by NORD for the power range from 1.1 kW to 5.5 kW are saved in the frequency inverter. For use with permanently excited synchronous motors from other manufacturers, the data from the type plate or data sheet of the motor must be entered.

In principle, the frequency inverters are operable in this configuration and can be further configured according to the requirements of the application. This includes settings such as the encoder system, ramp times and interfaces and possibly the bus system configuration.

Configuration can be carried out to a limited extent with the integrated DIP switches (see 9.1 "Manuals").

Configuration via DIP switch

Mixing of DIP switch configuration and (software) parametrisation should be avoided. DIP switch settings for the frequency inverter have priority over parameter settings.

2.1 System components

For this guide, a 4 kW frequency inverter / 3 kW motor combination was used for the test setup.

<table>
<thead>
<tr>
<th>Number</th>
<th>Designation</th>
<th>Nominal ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frequency inverter SK200E</td>
<td>SK 200E-401-340-A</td>
</tr>
<tr>
<td>1</td>
<td>SK 200E connection unit</td>
<td>SK TI4-2-200-3</td>
</tr>
<tr>
<td>1</td>
<td>3.0 kW or 4.0 kW, synchronous motor (IPMSM),IE4, 4-pole</td>
<td>SK 100 T2/4 BRE40 TF IG+AG</td>
</tr>
<tr>
<td>1</td>
<td>CANopen absolute encoder with incremental track / AG4</td>
<td>Resolution 8192/4096 pulses</td>
</tr>
<tr>
<td>1</td>
<td>External brake resistor, 400 Ω, 100 W</td>
<td>SK BRE4-1-400-100</td>
</tr>
</tbody>
</table>

Table 3: System components

With these system components, examples of the individual optimisations of the controllers are illustrated in the following sections on the basis of NORD CON oscilloscope images.

Version status

Due to software updates, the parameters described in this guide may differ from those in the firmware version for the frequency inverter which is used. Because of this, care should be taken that both the current NORD CON version and the software version of the latest firmware version (see 9.1 Software version parameter P707) correspond to that of the frequency inverter.

IE4 synchronous motors produced by Getriebebau NORD have only been implemented as of NORD CON Version V2.3.
2.2 Synchronous motors (PMSM / IPMSM)

Synchronous motors PMSM (Permanent Magnet Synchronous Motor), like Getriebebau NORD IE4 synchronous motors IPMSM (Interior Permanent Magnet Synchronous Motor) are energy-saving drives, which may only be operated with frequency inverters!

At present, Getriebebau NORD supplies synchronous motors with efficiency class IE4 in the power range from 1.1 kW to 5.5 kW.

### NOTICE

Mains operation

Synchronous motors and IE4 motors produced by Getriebebau NORD must not be operated directly from the mains! A safety label on the drive unit explicitly warns the user of this.

Failure to comply with this may cause damage to the synchronous motor due to impermissible currents in the components.

The specific NORD synchronous motors are equipped with permanent magnets which are located in the rotor package. These are inserted in recesses and are known as so-called IPMSMs. Due to their high efficiency, they offer the advantage of energy saving, especially for applications with long operating times (S1 operation).

None of the IE4 synchronous motors from Getriebebau NORD are servo motors.

Due to the control response times and the electrical time constants, their dynamic behaviour is definitely comparable with motors (ASM) with efficiency class IE1 and IE2.

Motors specific to NORD (i.e. so-called NORD motors) with efficiency class IE4 do not have any slip. They are designed for various nominal speeds or operating points:

1. 2100 rpm at 70 Hz, 400 V in Y or 230 V in ▲
2. 3000 rpm at 100 Hz, 400 V in ▲

### Information

Third party motors

Synchronous motors or brands from other manufacturers (i.e. so-called third party motors) can be operated by frequency inverters manufactured by Getriebebau NORD.

However, in general all frequency inverter – synchronous motor combinations should be checked in advance by Getriebebau NORD!
2.3 Frequency inverter - motor assignment

Synchronous motors (PMSM) and IE4 synchronous motors (IPMSM) from Getriebebau NORD can be operated with either decentralised SK 2xxE frequency inverters or the control cabinet versions SK 5xxE with all performance levels.

As with asynchronous motors, the selected allocation of the frequency inverter to the synchronous motor (PMSM / IPMSM) is primarily made according to the power and the current.

<table>
<thead>
<tr>
<th>Frequency inverter power</th>
<th>≥</th>
<th>Nominal motor power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal frequency inverter current</td>
<td>≥</td>
<td>Nominal motor current</td>
</tr>
</tbody>
</table>

**NOTICE**

Drive unit load

The assignment of synchronous motors to the particular frequency inverters applies for operation up to the nominal speed.

Higher speeds and overloads require special planning or consultation with Getriebebau NORD.

Failure to comply with this may cause damage to the motor or the gear unit due to impermissible loads on the components.

---

**Information**

### Third party motors

In principle, IE4 synchronous motors from Getriebebau NORD can be operated with frequency inverters from other manufacturers. However, the customer is responsible for the success of commissioning. Also, the performance of the motor, or the achievement of efficiencies which correspond to the IE4 classification depends on the frequency inverter and its function and settings.
2.4 Encoder resolution selection

For the correct selection of the rotary encoder with regard to the maximum resolution, the maximum limiting frequency should be taken into account using the following rule-of-thumb:

\[
\frac{f_{\text{max}} \times 60}{n_{\text{max}}} = \text{Encoder resolution}
\]

\[
\frac{205000 \ [Hz] \times 60 \ [s]}{n_{\text{max}} \ [rpm]} \geq \text{Encoder resolution} "\text{[Pulse number}_{\text{max}}]\"
\]

\[
\frac{205000 \ [Hz] \times 60 \ [s]}{1500 \ [rpm]} = 8200 \quad 8200 \geq 8192 \text{ Pulses} \quad \text{Encoder resolution } (n_{\text{max}} = 1500 \ \text{rpm})
\]

\[
\frac{205000 \ [Hz] \times 60 \ [s]}{3000 \ [rpm]} = 4100 \quad 4100 \geq 4096 \text{ Pulses} \quad \text{Encoder resolution } (n_{\text{max}} = 3000 \ \text{rpm})
\]

- \(f_{\text{max}}\): maximum limiting frequency for digital inputs \([Hz]\)
- \(n_{\text{max}}\): maximum speed of motor \([rpm]\)

All standard encoders defined by Getriebebau NORD, i.e. the recommended encoder systems and types enable "safe" operation within a very wide adjustment range (e.g. 0 to 100 Hz). I.e. the minimum Pulse number\(_{\text{min}}\) has already been taken into account with regard to encoder resolution.
2.5 Selection of the incremental encoder (IG)

The correct selection, parameterisation and connection of an HTL- incremental encoder (IG) to a decentralised SK 2xxE frequency inverter as well as a TTL incremental encoder or sine wave encoder (e.g. SIN/COS encoder) to an SK 53xE or SK 54xE control cabinet frequency inverter are described in greater detail in previous or further sections.

Various encoders with a cable length of 1.5 m are defined as **standard incremental encoders** by Getriebebau NORD:

![Fig. 11: Standard incremental encoders](image)

**Table 4: Standard incremental encoders**

<table>
<thead>
<tr>
<th>FI type</th>
<th>Part no. Supplier</th>
<th>Designation</th>
<th>Power supply</th>
<th>Incremental encoder resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK 2xxE</td>
<td>19551021 Fritz Kübler GmbH</td>
<td>IG 42 10-30 V HTL 4096 D12 5820 1,5 m</td>
<td>10 … 30 V HTL / Push-pull</td>
<td>4096 pulses</td>
</tr>
<tr>
<td>SK 53xE</td>
<td>19551022 Fritz Kübler GmbH</td>
<td>IG 41 10-30 V TTL 4096 D12 5820 1,5 m</td>
<td>10 … 30 V TTL / RS422</td>
<td>4096 pulses</td>
</tr>
<tr>
<td>SK 54xE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Taking into account the **maximum limiting frequency** for the selection of the encoder, the **highest possible resolution** should be selected and if possible, an encoder system with a **power supply** of 10 … 30 V should be used.

Technical data for the incremental encoder, e.g. the relevant resolution, interface, etc. can be obtained from catalogue **M7000 Electric Motors** and Section **9.3.1 “TIs – Incremental encoder (IG)”**.

Detailed information for the connection of:

- **HTL incremental encoder** to SK 2xxE
- **TTL incremental encoder** to ≥ SK 53xE
- **SIN/COS encoder** to SK 54xE

can be obtained from the relevant manuals **BU 0200, BU 0500 und BU 0505**.

Information regarding the **POSICON** function is provided in the supplementary manuals BU 0210 and BU 0510, see Section **9.1 "Manuals”**.
Testing the encoder function

After completion of connection and basic commissioning the correct function of the incremental encoder should always be checked. Detailed information and warnings for the testing and activation of the encoder are provided in Section 3.5.3 "Function test of rotary encoders (IG)".

For activation of the speed feedback (CFC closed loop mode) under the tab "Control parameters" the parameter Servo mode P300 must be set to Function (1 = On (CFC closed-loop)).

2.6 Selection of absolute encoders

The correct selection, parameterisation and connection of a CANopen absolute encoder to a decentralised SK 2xxE or ≥ SK 53xE control cabinet frequency inverter are different. In addition, for position control, further types of absolute encoder can be connected to SK 54xE control cabinet frequency inverters. Other encoder systems such as SSI, BISS, Endat and Hiperface encoders can be connected to its universal interface or terminal bar X14.

Several multturn CANopen encoders are defined as standard combined absolute encoders by Getriebebau NORD:

![Image of absolute encoders]

Several multturn CANopen encoders are defined as standard combined absolute encoders by Getriebebau NORD:

![Image of absolute encoders]

Taking into account the maximum limiting frequency for the selection of the encoder, the highest possible resolution should be selected and if possible, an encoder system with a power supply of 10 ... 30 V should be used.

<table>
<thead>
<tr>
<th>FI type</th>
<th>NORD data</th>
<th>Absolute encoder resolution</th>
<th>Incremental encoder resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>SK 2xxE</td>
<td>Part no.</td>
<td>Supplier</td>
<td>Type</td>
</tr>
<tr>
<td>19551886</td>
<td>19556994</td>
<td>Fritz Kübler GmbH</td>
<td>AG4</td>
</tr>
<tr>
<td>Baumer IVO GmbH &amp; Co. KG</td>
<td>19556994</td>
<td>AG6</td>
<td>AG&amp;IG IVO CANOPEN</td>
</tr>
<tr>
<td>SK 53xE</td>
<td>SK 54xE</td>
<td>Fritz Kübler GmbH</td>
<td>AG1</td>
</tr>
<tr>
<td>Baumer IVO GmbH &amp; Co. KG</td>
<td>19556995</td>
<td>AG3</td>
<td>AG&amp;IG IVO CANOPEN</td>
</tr>
</tbody>
</table>

Table 5: Standard absolute encoders
Technical data for the incremental encoder, e.g. the relevant type, interface, etc. can be obtained from catalogue M7000 Electric Motors and Section 9.3.2 "TIs - CANopen absolute encoder (AG)".

Detailed information for the connection and parameterisation of standard combination absolute encoders with a CANopen interface can be obtained from the supplementary manuals BU 0210 und BU 0510, see Section 9.1 "Manuals".

**NOTICE**

Installation of rotary encoders

It is essential that the combination absolute encoder (single and multiturn with integral incremental track) is mounted on the end of the motor shaft.

Other types of absolute encoder (e.g. Type AG1 / Part no. 19551881 / Kübler Type 8.5888.0421.2102. S010.K014) must not necessarily be mounted on the end of the motor shaft.

In this case, the speed ratio in the frequency inverter must be parameterised with the aid of the Ratio P607 and the Reduction Ratio P608. Otherwise, inaccuracy of the speed (incremental track) and / or the position control may result.

For an absolute encoder, the encoder system must be parameterised in the Parameter Travel measurement system P604, and the corresponding resolutions / pulse numbers and the encoder type (Single or Multiturn) must be parameterised in the parameter Absolute encoder P605.

For detailed information, please refer to the relevant manual for the frequency inverter, see 9.1 "Manuals" or Section 3.6.1 "Parameterisation of CANopen encoders (absolute encoders)".

**Information**

Activating the position control

For positioning / position control (CFC Closed Loop mode) the position control must be activated with the parameter Position control P600 or the required function (selection of ramp type) must be parameterised in the tab "Positioning parameters". For further details of activation of the position control, see 6.4.2 "Activating the position control".
3 Basic Commissioning

Step 2

Information

If the frequency inverter is not in the state as delivered, a reset of all parameters should generally be carried out via the parameter Factory Setting P523 before basic commissioning is carried out. This parameter can be found under the tab "Additional Parameters".

All parameters which are not explicitly mentioned in this guide should therefore be left in the factory or default setting. For more detailed information, please refer to the relevant manual for the frequency inverter, see § 9.1 "Manuals".

Parameterisation

Other application-specific settings, e.g. Deceleration time P103 (Brake reaction time P107 and Brake delay off P114) are not described in this guide and must be adjusted independently by the user! For optimisation of the controller only the Acceleration time P102, for the speed control, and the Deceleration time P103, need to be adjusted.

Several other parameters must be changed for the optimisation of the particular controller, in order to obtain informative oscilloscope recordings.

Notice

After completion of the individual controller optimisations these parameters must be re-adjusted according to the particular requirements of the application.

Function restrictions

The following frequency inverter functions for the parameters are only available to users to a limited extent or not at all for synchronous motor applications:

- Shut-down mode P108
  - Function (3 = Instant d.c. braking)
  - Function (5 = Combi. braking)

- Flying start P520
  - Function (1 - 4 = All functions) *

* Only available as of software version ≥ 2.1 R0 for SK 2xxE, ≥ 3.1 R0 for SK 5xxE or ≥ 2.3 R0 for SK 54xE

An incorrect parameterisation of this function is not used for the operation of the drive unit or is automatically not activated by the frequency inverter, even though it has been parameterised.
3 Basic Commissioning

3.1 Operating display settings

For optimisation of the relevant controller, the following two parameters must be checked or set in advance.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATING DISPLAYS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P001</td>
<td>Select of disp.value</td>
<td>0*</td>
<td>0 → 2 (Setpoint frequency [Hz])</td>
</tr>
<tr>
<td>P003</td>
<td>Supervisor-Code</td>
<td>1 **</td>
<td>1 → 3 (all parameters visible) only for SK 2xxE</td>
</tr>
</tbody>
</table>

* 0 corresponds to the actual frequency [Hz]

** 1 corresponds to all parameters visible except P3xx / P6xx

In general, optimisation of the speed and position controllers should be made in dynamic operation under load conditions with specification of a setpoint. Because of this, the Select of disp.value P001 should be changed from the function \(0 = \text{Actual frequency}\) to \(2 = \text{Setpoint frequency}\). The setpoint frequency is displayed in \([\text{Hz}]\).

In contrast, optimisation of the current controller should be made in static operation without load and without specification of a setpoint.

### Information

<table>
<thead>
<tr>
<th>Supervisor-Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>The tabs Control Parameters P3xx and Positioning P6xx are only enabled and therefore made visible for decentralised SK 2xxE frequency inverters by means of Supervisor-code P003 (3 = \text{all parameters visible}). In the NORD CON display, all tabs are always visible.</td>
</tr>
<tr>
<td>For control cabinet SK 5xxE frequency inverters all tabs are enabled or displayed in the factory setting (1 = \text{all parameters visible}).</td>
</tr>
</tbody>
</table>

3.2 Further settings

For the operation of synchronous motors with nominal frequencies > 50 Hz, setting of the following parameters is mandatory.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASIC PARAMETERS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P105 (P)</td>
<td>Maximum frequency [Hz]</td>
<td>50.0</td>
<td>50.0 → 70.0</td>
</tr>
</tbody>
</table>

Due to the "changed" motor data of a synchronous motor or the higher Nominal frequency P201, a change must be made to the value in the parameter Maximum frequency P105.

Depending on the selected operating mode and the requirements of the application, the value of the Maximum frequency P105 may also vary according to the specific application. The selected value should not be larger than the value for the Nominal frequency P201 so that the motor is not operated in the weak field range.
3.3 Motor data

In principle, the windings of a Getriebebau NORD IE4 synchronous motor (IPMSM) or PMSM and SPMSM drives from other manufacturers can be wired in 2 ways (Y / ▲), depending on the mains voltage. Depending on the circuit, synchronous motors can be operated using with or without a frequency inverter on different mains connections (including 230 V, 50 Hz and 400 V, 50 Hz) and therefore usually have several different V/f characteristic curves.

Fig. 13: Examples of motor type plates

Getriebebau NORD

Third party brand (Source: KOLLMORGEN *)

*AKM Operating Instructions, Edition 2014

Fig. 14: Examples of data sheets
3 Basic Commissioning

The motor data are parameterised in the frequency inverter in the tab "Motor data / Characteristic curve parameters" in parameters P201 - P209. In contrast to asynchronous motors, for synchronous motors further specific motor data are relevant or must be parameterised. There are various methods of writing these motor-specific data for a synchronous motor in the parameters P240 - P247.

The selection of the input method depends on whether the motor is an IE4 synchronous motor from Getriebebau NORD or a synchronous motor from a different manufacturer.

The following two methods are available for the parameterisation of synchronous motors:

1. **NORD motors (IE4 synchronous motors (IPMSM))**
   - Selection using the parameter Motor list P200 and the function \(109 = 3.0 \text{ kW} 400 \text{ V} 100\text{T2/4}\), with **automatic** entry of the motor data in parameters (P201 - P209 and P240- P246)
   - Measurement of the stator resistance \(R_s\) using Par.-identification P220 and selection of the function \(1 = \text{Identification } R_s\)

2. **Third party motors** (synchronous motors (SPMSM) from other manufacturers)
   - Adopt the data from the **motor type plate** and / or the **data sheet**
   - **Manual** entry of the motor data in parameter (P201 - P207 and P240- P246)
   - Measurement of the stator resistance \(R_s\) using Para. identification P220 and selection of the function \(1 = \text{Identification } R_s\)
   - With subsequent **optimisation** of the motor data for the parameters (P240, P241, P246), see 3.4 "Optimisation of motor data"

If the motor data of the **synchronous motor** for the parameters **Stator resistance** \(R_s\), **Stator inductance** \(L_d\) and \(L_q\) are not known, there is the further possibility of determining the data by means of **Motor identification**:

- **Parameter identification** with parameter Par.-identification P220 and selection of the function \(2 = \text{identification motor}\)
  - Only applies for **synchronous motors** from other manufacturers / **third party brands** if none of the motor data for the **third party motor** are known
  - Only applies for NORD motors for (field test devices, special motors, etc.)
  - Only the **Stator resistance** \(R_s\) in the parameter **Stator resistance** P208 and the **Stator inductance** \(L_d\) in the parameter Inductance P241 [-01] are determined.
  - The **Stator inductance** \(L_q\) in the parameter Inductance P241 [-02] is calculated from \(L_d\)
  - Subsequent optimisation of the specific motor data
### 3.3.1 Motor lists

If the motor is from Getriebbau NORD it can be selected using the parameter Motor list P200 from a list of the available 4-pole IE4 synchronous motors (IPMSM). With the selection of the motor type, the corresponding parameters P201 - P209 and P240 - P246 are set automatically.

#### Information

The motor data which are saved in the frequency inverter are only for IE1 asynchronous motors and IE4 synchronous motors manufactured by Getriebbau NORD. The values have been calculated from the specific data sheets for the motor or the details on the type plate.

The Motor cos phi P206 is also stated or pre-set via the Motor list P200, but is not relevant for synchronous motors.

After entry of the motor data via the Motor list P200, the No load current P209 is only always parameterised automatically to the value "0" for IE4 synchronous motors.

#### Course of action

In the parameter Motor list P200 the following functions are available for selection, e.g. for a Getriebbau NORD SK100 T2/4 IE4 synchronous motor:

- Function {103} = 2.2 kW / 230 V ⇒ 230 V frequency inverter
  - Motor connected in Y, nominal speed 1500 rpm
- Function {108} = 3.0 kW / 230 V ⇒ 230 V frequency inverter
  - Motor connected in ▲, nominal speed 2100 rpm
- Function {109} = 3.0 kW / 400 V ⇒ 400 V frequency inverter
  - Motor connected in Y, nominal speed 2100 rpm
- Function {113} = 4.0 kW / 400 V ⇒ 400 V frequency inverter
  - Motor connected in ▲, nominal speed 3000 rpm

With the selection of function {109 = 3.0 kW 400 V 100T2/4} the following motor data / characteristic curve parameters are only set automatically for NORD motors:

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P200 (P) Motor list</td>
<td></td>
<td>0</td>
<td>☑ 0 → 109 (3.0 kW 400 V 100T2/4)</td>
</tr>
<tr>
<td>P201 (P) Nominal frequency [Hz]</td>
<td>50.0*</td>
<td>☑ 50.0 → 70.0</td>
<td></td>
</tr>
<tr>
<td>P202 (P) Nominal speed [rpm]</td>
<td>1445*</td>
<td>☑ 1445 → 2100</td>
<td></td>
</tr>
<tr>
<td>P203 (P) Nominal current [A]</td>
<td>8.3*</td>
<td>☑ 8.3 → 5.4</td>
<td></td>
</tr>
<tr>
<td>P204 (P) Nominal voltage [V]</td>
<td>400*</td>
<td>☑ 400 → 385</td>
<td></td>
</tr>
<tr>
<td>P205 (P) Nominal power [kW]</td>
<td>4*</td>
<td>☑ 4 → 3</td>
<td></td>
</tr>
<tr>
<td>P206 (P) Cos phi</td>
<td>0.8*</td>
<td>☑ 0.8 → 0.92</td>
<td></td>
</tr>
<tr>
<td>P207 (P) Star Delta con.</td>
<td>1*</td>
<td>☑ 1 → 0 (Star)</td>
<td></td>
</tr>
<tr>
<td>P208 (P) Stator resistance [Ω]</td>
<td>3.44*</td>
<td>☑ 3.44 → 1.44 (measured)</td>
<td></td>
</tr>
<tr>
<td>P209 (P) No load current [A]</td>
<td>4.4*</td>
<td>☑ 4.4 → 0 **</td>
<td></td>
</tr>
<tr>
<td>P220 (P) Par.-identification</td>
<td>0</td>
<td>☑ 0 → 1 (Identification Rs)</td>
<td></td>
</tr>
</tbody>
</table>
### MOTOR DATA/ CHARACTERISTIC CURVE PARAMETERS

<table>
<thead>
<tr>
<th>Parameter No.</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P240 (P)</td>
<td>EMF voltage PMSM [V]</td>
<td>0</td>
<td>☑ 0 → 341</td>
</tr>
<tr>
<td>P241 [-01]</td>
<td>Inductance PMSM (d axis) [mH]</td>
<td>20</td>
<td>☑ 20 → 22.6</td>
</tr>
<tr>
<td>P241 [-02]</td>
<td>Inductance PMSM (q axis) [mH]</td>
<td>20</td>
<td>☑ 20 → 45.9</td>
</tr>
<tr>
<td>P243 (P)</td>
<td>Reluctance angle IPMSM [°]</td>
<td>0</td>
<td>☑ 0 → 10</td>
</tr>
<tr>
<td>P244 (P)</td>
<td>Peak current PMSM [A]</td>
<td>5 ***</td>
<td>☑ 5 → 14</td>
</tr>
<tr>
<td>P246 (P)</td>
<td>Mass Inertia PMSM [kg*cm²]</td>
<td>5</td>
<td>☑ 5 → 45.8</td>
</tr>
<tr>
<td>P247 (P)</td>
<td>Changeover frequency VFC PMSM [%]</td>
<td>25</td>
<td>☑ 25 (leave as set)</td>
</tr>
</tbody>
</table>

* dependent on F1 power or parameters P200/P220
** ☑ To "0" for IE4 synchronous motors from Getriebebau NORD
导购 To "0" for synchronous motors from other manufacturers
*** Depending on the frequency inverter, SK 5xxE factory setting = 20

The **Stator resistance P208** should always be measured and set with the automatic stator resistance measurement and should then be checked, see **Par.-identification P220** and the function {1 = Identification Rs}.

### Information

The measured value or the value to be entered for the **Stator resistance P208** of a line (if this is available) should always be relative to an **ambient temperature** of approx. **20 °C**.

For IE4 synchronous motors manufactured by Getriebebau NORD, the value of the stator resistance is also stamped on the motor type plate.

The parameter **Mass inertia P246** describes the moment of inertia of the drive machine. The factory setting of **5 kg*cm²** is **sufficient for most applications**.

However, for highly dynamic applications, the mass inertia for the entire drive system should ideally be parameterised.

This results in an improvement of the dynamic characteristics. The values should be obtained from the technical data sheets or by an enquiry to the manufacturer.

### NORD – Motor type plates / Data sheet

The motor data can be obtained from the motor type plate, see ☐ 3.3 "Motor data" and / or the manufacturer's data sheet. The manufacturer's motor data should be parameterised accordingly in the tab "Motor data / Characteristic curve parameters".

### NORD motors

In **general** only the motor data for should be selected by means of the **motor type** via the parameter **Motor list P200**, e.g. function {109 = 3.0 kW 400 V}.
If a NORD motor is not selected with the aid of the parameter Motor list P200, the motor data must be parameterised according to the type plate or from the data sheet. The No Load Current P209 must then always be explicitly parameterised manually, to the value "0" by the user.

The specific motor values for the Voltage constant $k_v$, the Stator resistance $R_s$ and the Stator inductances $L_d$ and $L_q$ are listed in the data sheet or stamped on the motor type plate. The parameter Reluctance angle IPMSM P243 must be parameterised to the value 10°. The values for the two parameters Peak current PMSM P244 and Mass inertia PMSM P246 must also be adjusted according to the data sheet or the details from the manufacturer.
3.3.3 Third party motor type plates / Data sheets

This Section only applies for third party motors or synchronous motors from other manufacturers.
For applications with a NORD motor, this section can be completely ignored!

For synchronous motors from other manufacturers or other brands, there is only the possibility of obtaining the motor data from the motor type plate or from the manufacturer's data sheet. The motor data must be entered or parameterised in the frequency inverter in the tab "Motor data / Characteristic curve parameters" with parameters P201 - P209. In contrast to asynchronous motors, for synchronous motors further specific motor data are relevant or must be parameterised. The additional motor data values for the specific manufacturer must be entered in the parameters P240 - P246 by the user.

NOTICE

Motors from other manufacturers

The selection or pre-setting of the motor data (P2xxx) for third party motors must not be made via the parameter Motor list P200, e.g. with the function \( \{109 = 3.0 \text{ kW}, 400 \text{ V}, 100 \text{T2/4}\} \)! Otherwise the calculation of the PMSM model will be based on "false" motor data values. As these are data for the synchronous motor which are specific to the particular manufacturer, the manufacturer of the drive should always be contacted in case of doubt.

The specific motor values for the Voltage constant \( k_v \), the Stator resistance \( R_s \) and the Stator inductances \( L_d \) and \( L_q \) are listed in the data sheet or stamped on the motor type plate.

If in the case of a third party motor the Nominal current P203 is not stated on the motor type plate or in the manufacturer's data sheet, this can be calculated according to the following formula:

\[
I_N = \frac{M_N}{K_{Trms}} \triangleq P_{203} = \frac{M_N}{K_{Trms}}
\]

- \( I_N \): Nominal current [A]
- \( P_{203} \): Nominal torque [Nm]
- \( M_N \): Nominal current [A]
- \( K_{Trms} \): Torque constant [Nm/A]

Information

The Motor cos phi P206 may also be stated by the manufacturer, but is not relevant for synchronous motors. From the entry of the Nominal frequency P201 and the Nominal speed P202 the number of pole pairs is determined automatically. For synchronous motors, there may be occasionally deviations. Please contact the Getriebebau NORD Service department.

The No load current P209 for synchronous motors from other manufacturers, i.e. in general for all third party motors, must always be manually \( \Diamond \) parameterised to the value "0" by the user.

The parameter Reluctance angle IPMSM P243 must be set according to the manufacturer's details. The values for the two parameters Peak current PMSM P244 and Mass inertia PMSM P246 must also be adjusted according to the data sheet or the details from the manufacturer.
### 7.6 Technical Data AKM5

<table>
<thead>
<tr>
<th>$U_{N}$</th>
<th>Data</th>
<th>Symbol [Unit]</th>
<th>51E</th>
<th>51G</th>
<th>51H</th>
<th>51K</th>
<th>52E</th>
<th>52G</th>
<th>52H</th>
<th>52K</th>
<th>52M</th>
</tr>
</thead>
<tbody>
<tr>
<td>75VDC</td>
<td>Rated speed</td>
<td>$n_{n} \text{ [rpm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated torque</td>
<td>$M_{n} \text{ [Nm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated power</td>
<td>$P_{n} \text{ [kW]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>115V</td>
<td>Rated speed</td>
<td>$n_{n} \text{ [rpm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated torque</td>
<td>$M_{n} \text{ [Nm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated power</td>
<td>$P_{n} \text{ [kW]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>230V</td>
<td>Rated speed</td>
<td>$n_{n} \text{ [rpm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated torque</td>
<td>$M_{n} \text{ [Nm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated power</td>
<td>$P_{n} \text{ [kW]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>400V</td>
<td>Rated speed</td>
<td>$n_{n} \text{ [rpm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated torque</td>
<td>$M_{n} \text{ [Nm]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rated power</td>
<td>$P_{n} \text{ [kW]}$</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

#### Mechanical data
- Rotor moment of inertia: $J_{r} \text{ [kgm}^2\text{]}$ 3.4 0.7
- Pole number: 10 10
- Static friction torque: $M_{s} \text{ [Nm]}$ 0.02 0.04
- Thermal time constant: $t_{th} \text{ [min]}$ 20 24
- Weight standard: $G \text{ [kg]}$ 4.2 5.8
- Radial load permitted: $F_{r} \text{ [N]}$ (179)
- Axial load permitted: $F_{a} \text{ [N]}$ (179)

#### Power cable acc. EN50204-1 2006 Table 6, Column B2
- Minimum cross section: $mm^2$ 1 1 1 1 1 1 1 1

* Rated data with reference Tange Aluminium 305mm * 305mm * 12.7mm
** Dealing in case of built-in Encoder 8% with built-in Encoder and Brake 10%
An SK 540E-221-323-A frequency inverter and a synchronous motor from the firm Kollmorgen, with the designation AKM5 were used for the test setup.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P201 (P)</td>
<td>Nominal frequency [Hz]</td>
<td>50.0*</td>
<td>50.0 → 208.3</td>
</tr>
<tr>
<td>P202 (P)</td>
<td>Nominal speed [rpm]</td>
<td>1440*</td>
<td>1440 → 2500</td>
</tr>
<tr>
<td>P203 (P)</td>
<td>Nominal current [A]</td>
<td>5.2*</td>
<td>5.2 → 1.5</td>
</tr>
<tr>
<td>P204 (P)</td>
<td>Nominal voltage [V]</td>
<td>400*</td>
<td>400 (leave as set)</td>
</tr>
<tr>
<td>P205 (P)</td>
<td>Nominal power [kW]</td>
<td>2.2*</td>
<td>2.2 → 1.04</td>
</tr>
<tr>
<td>P206 (P)</td>
<td>Cos phi</td>
<td>0.74*</td>
<td>0.74 (leave as set)</td>
</tr>
<tr>
<td>P207 (P)</td>
<td>Star Delta con.</td>
<td>0*</td>
<td>0 (leave as set)</td>
</tr>
<tr>
<td>P208 (P)</td>
<td>Stator resistance [Ω]</td>
<td>2.43*</td>
<td>2.43 → 4.45 (measured)</td>
</tr>
<tr>
<td>P209 (P)</td>
<td>No load current [A]</td>
<td>3.8*</td>
<td>3.8 → 0 **</td>
</tr>
<tr>
<td>P220 (P)</td>
<td>Par.-identification</td>
<td>0</td>
<td>0 → 1 (Identification Rs)</td>
</tr>
<tr>
<td>P240 (P)</td>
<td>EMF voltage PMSM [V]</td>
<td>0</td>
<td>0 → 275</td>
</tr>
<tr>
<td>P241 [-01]</td>
<td>Inductance PMSM (d axis) [mH]</td>
<td>20</td>
<td>20 → 8.5</td>
</tr>
<tr>
<td>P241 [-02]</td>
<td>Inductance PMSM (q axis) [mH]</td>
<td>20</td>
<td>20 → 18.3</td>
</tr>
<tr>
<td>P243 (P)</td>
<td>Reluctance angle IPMSM [°]</td>
<td>0</td>
<td>0 (leave as set)</td>
</tr>
<tr>
<td>P244 (P)</td>
<td>Peak current PMSM [A]</td>
<td>20 ***</td>
<td>20 → 8.2</td>
</tr>
<tr>
<td>P246 (P)</td>
<td>Mass Inertia PMSM [kg*cm²]</td>
<td>5</td>
<td>5 → 3.4</td>
</tr>
</tbody>
</table>

* depending on FI power or parameters P200 / P220

** 🎧 To “0” for synchronous motors from other manufacturers

*** Depending on the frequency inverter, SK 2xxE factory setting = 5

After entry of the motor data parameters, optimisation of the other motor data should only be carried out for third party motors.

The stator resistance should be measured with the Identification motor, see 🎧 Par.-identification P220 and the function (1 = Identification Rs). After this, optimisation of the other motor data should be carried out according to Section 🎧 3.4 "Optimisation of motor data”.

The Voltage constant $k_e$, which states the value for the inductive reactance voltage of the synchronous motor is stated on the motor type plate and in the data sheet. The voltage constant $k_e$ states the voltage induced by the field (from the rotor to the stator) relative to the speed of the motor.
**EMF voltage PMSM P240**

The EMF voltage PMSM P240 is calculated according to the following formula, using the Voltage constant $k_e$:

\[
EMF \text{ voltage PMSM} = k_e \cdot n_N = P_{240} = k_e \cdot P_{202}
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_e$</td>
<td>Voltage constant</td>
<td>[mV/min]</td>
</tr>
<tr>
<td>$n_N$</td>
<td>Nominal speed</td>
<td>[rpm]</td>
</tr>
<tr>
<td>$P_{202}$</td>
<td>Nominal motor speed</td>
<td>[rpm]</td>
</tr>
<tr>
<td>$P_{240}$</td>
<td>EMF- voltage PMSM</td>
<td>[V]</td>
</tr>
</tbody>
</table>

The calculated value for the EMF voltage PMSM P240 and the values for the stator inductances $L_d$ and $L_q$ obtained from the data sheet or the motor type plate must be parameterised accordingly in the frequency inverter.

**Inductance PMSM (P241)**

- [-01] for d-axis $\triangleq$ Stator inductance $L_d$
- [-02] for q-axis $\triangleq$ Stator inductance $L_q$

For third party motors, the values for the two stator inductances $L_d$ and $L_q$, in parameter Inductance PMSM P241 [-01] and [-02] can be determined by means of the parameter identification, see $\equiv$ Par.-identification P220 by selecting the function {2 = identification motor}.

As the stator inductance of the d-axis is not equal to that of the q-axis,

\[
L_d \neq L_q \quad \text{Inductance PMSM P241 [-01]} \neq \text{Inductance PMSM P241 [-02]}
\]

for IE4 synchronous motors produced by Getriebebau NORD (NORD motors) and third party IPMSM motors, the Reluctance torque or the parameter Reluctance angle IPMSM P243 must also be taken into account.

**Reluctance angle IPMSM P243**

The Reluctance angle IPMSM P243, states the additional angle which results from the anisotropy (dependence on direction) of the inductance in the d- and q-axis.

**Information**

For applications with SPMSM (Surface Permanent Magnet Synchronous Motors), i.e. synchronous motors with surface magnets, the parameter Reluctance angle IPMSM P243 must be set to “0°” or left in the factory setting (0°).

The motor-specific reluctance angle (10° for IE4 synchronous motors from Getriebebau NORD) should always be determined experimentally under load conditions for third party motors. For further details see Section 9.1 "Manuals". For IE4 synchronous motors from Getriebebau NORD the value of 10° is set automatically 0°, with the selection of the synchronous motor from the Motor list P200.
After completion of the basic commissioning of IPMSM drives from other manufacturers, the drive should be run under a constant load (> 0.5 x Mn) in CFC Closed-Loop mode (see Servo mode P301 with the function {1 = On (CFC Closed-Loop)}).

For detailed information, please refer to the relevant manual for the frequency inverter, see 7 "Reluctance torque".

**Peak current PMSM P244**

The peak current of the drive system is entered in the parameter Peak current PMSM P244. This parameter serves as a type of motor protection and prevents demagnetisation of the drive. This value must be obtained from the manufacturer or from the motor type plate or data sheet.

**Mass Inertia PMSM P246**

The mass inertia of the drive system is entered in the parameter Mass inertia PMSM P246. The factory setting of 5 kg*cm² is sufficient for most applications. For highly dynamic applications, e.g. dynamic conveyor systems, the actual value should ideally be determined and entered.

The values for synchronous motors should be obtained from manufacturer's technical data or by an enquiry to the manufacturer. The portion of the external centrifugal mass (e.g. gear unit, machine) must be calculated or may alternatively be determined experimentally.

Correct setting of the parameter Mass inertia PMSM P246 results in an improvement of the dynamic characteristics of the drive unit.

For detailed information, please refer to the relevant manual for the frequency inverter, see 9.1 "Manuals".
3.3.4 Motor identification

If the motor data for the Stator resistance $R_S$ and the Stator inductance $L_d$ and $L_q$ are not known, e.g. neither the data sheet nor the motor type plate are available, there is the possibility of determining these motor data automatically by means of a motor identification.

However, to do this, the motor data for the parameters:

- Nominal frequency P201
- Nominal speed P202 approx. values, as this depends on the number of pole pairs (2 / 4)
- Nominal voltage P204
- Nominal power P205
- Star Delta con. P207

must be known to the user and parameterised in the frequency inverter under the tab "Motor data / Characteristic curve parameters".

Nominal frequency P201

The nominal motor frequency is calculated from the Nominal speed P202 according to the following formula:

$$f = \frac{n \times p}{60} \triangleq P_{201} = \frac{P_{202} \times p}{60}$$

- $f$: Frequency [Hz]
- $n$: Speed [rpm]
- $p$: Number of pole pairs [-]
- $P_{201}$: Nominal frequency / Frequency [Hz]
- $P_{202}$: Nominal current [rpm]

The calculated value is entered in the parameter Nominal frequency P201.

Para. Identification P220

By means of the parameter Par.-identification P220 there is the possibility of determining the motor data for the Stator resistance $R_S$ and the Stator inductance $L_d$ and $L_q$ automatically $\triangleright$.

Information

Parameter identification SK 5xxE

With SK 5xxE frequency inverters, for the Par.-identification P220 the function $\{2 = \text{Identification motor}\}$ is only possible for frequency inverter / motor combinations $\leq 7.5$ kW (for 400 V) or $\leq 4.0$ kW (for 230 V).

For SK 5xxE applications $\geq 11.0$ kW the function $\{2 = \text{identification motor}\}$ is not approved.

For decentralised SK 2xxE frequency inverters the function $\{2 = \text{identification motor}\}$ is possible for the entire power range.

The Par.-identification P220 must be carried out when the motor is cold ($15 \degree C \geq T_{\text{Motor}} \leq 25 \degree C$).
The following two functions can be selected:

- Function (1) Identification $R_S$:
  For the Identification $R_S$ only the Stator resistance P208 is determined by multiple measurements.

- Function (2) identification motor:
  By means of the motor identification the Stator resistance $R_S$ and the Stator inductance $L_d$ of synchronous motors is only measured when the motor is at a standstill. The $L_q$ value is calculated from the $L_d$ value.

  The stator values which are determined are automatically entered into the parameters Stator resistance P208 and Inductance PMSM P241 [-01] + [-02].

For NORD motors, for the Par.-identification P220 or for measurement of the Stator resistance (see parameter Stator resistance P208) preferably on the function (2 = Identification $R_S$) should be used!

---

**Information**

**Stator resistance and stator inductance value**

After the measurement is complete, the determined stator resistance is entered or displayed automatically in the parameter Stator resistance P208.

In case of "incorrect" resistance values, the setting for the "Star Delta con. P207" and the motor connection in the connection terminal box should be checked.

The determined stator inductance value $L_d$ for the d-axis is entered into the parameter Inductance PMSM P241 [-01] automatically on completion of the measurement. The inductance value $L_q$ for the q-axis is calculated from the determined stator inductance $L_d$ of the d-axis and is entered directly into the parameter Inductance PMSM P241 [-02].

For IPMSM applications (Interior Permanent Magnet Synchronous Motor) approximately corresponds to the calculated inductance value $L_q$ in the parameter array Inductance PMSM P241 [-02].

For SPMSM applications (Surface Permanent Magnet Synchronous Motor) the inductance values of both axis components ($L_d = L_q$) must be parameterised identically, i.e. for parameterisation the values in the two parameter arrays Inductivity PMSM P241 [-02] = Inductivity PMSM P241 [-01] must be set to the same value.
3.3.5 Schematic circuit diagram

In general, all of the data which are necessary for control are calculated from the details on the type plate (3.3 "Motor data") or the data sheet from the specific manufacturer. The required data refer to the data in the schematic circuit diagram for the PMSMs.

For the Para. identification P220 only the Stator resistance \( R_s \) and the Stator inductance \( L_d \) or \( L_q \) of the SCD are determined on the basis of measurement signals.

To some extent, the data from the schematic circuit diagram which are required for control depend on the temperature (motor and ambient temperature). A correction of the values at higher motor temperatures is made automatically by the controller.

If the stator resistance is measured at higher ambient temperatures or after longer operation of the motor, "incorrect" starting values result for the automatic temperature correction.

### Information

### Displayed measurement values

If the motor data are determined with Par.-identification P220 and the function \( \{1 = \text{identification R}_s \} \), the Stator resistance value \( R_s \) can be checked in the parameter Stator resistance P208 as well as in the parameter Select of disp.value P001.

If the function \( \{2 = \text{identification motor} \} \) is selected for the Par.-identification P220 the values for the stator inductances \( L_d \) and \( L_q \) are only displayed in the parameter Inductance PMSM P241 [-01] and [-02].

In the tab "Operating Displays" the corresponding values form the schematic circuit diagram which are to be displayed after the frequency inverter is enabled can be selected under the parameter Select of disp.valueP001. On the other hand, values which are calculated from the motor data, as well as other data for the schematic circuit diagram cannot be displayed.

### 3.4 Optimisation of motor data

#### Instructions

The motor data for synchronous motors are in principle specific to the motor or manufacturer. The designations of the further motor data differ to some extent in the manufacturer's data sheets or on the type plates of third party motors.

For operation of third party motors with frequency inverters from Getriebebau NORD it is recommended, that the user always carries out a further optimisation of individual, motor-specific parameters, i.e. the following parameters, after basic commissioning of the synchronous motor (entry of the motor data from the motor type plate / data sheet).

These parameters can be found in the tab "Motor data / Characteristic curve parameters and must be optimised accordingly.

- EMF voltage PMSM P240
- Inductance PMSM P241
- Reluctance angle IPMSM P243
- Mass inertia PMSM P246

The reluctance torque should only be optimised as necessary by the user for third party IPMSM motors. The procedure for optimising the parameter Reluctance angle IPMSM P243 is described in Section 7 "Reluctance torque".

On the other hand, the mass inertia should only be optimised in certain circumstances or for application-specific circumstances.
3 Basic Commissioning

3.4.1 NORD motors

The motor data for IE4 synchronous motors from Getriebebau NORD, see parameter Motor list P200, are already implemented in the system software in the motor list of the two frequency inverter series SK 2xxE and SK 5xxE.

Optimisation of the specific motor data for Getriebebau NORD IE1, IE4 synchronous motors is only necessary, or must be carried out by the user in exceptional cases or for special applications.

In general, this applies for all NORD motors (e.g. field test drive units, special versions, etc.), which are not included in the Motor list P200.

For special applications, special motors and in case of application problems, we recommend that you contact the Service department of Getriebebau NORD.

3.4.2 Third party motors

Third party motors or third party brands are specific to the motor or manufacturer and for operation with frequency inverters from Getriebebau NORD should always be further optimised after entry of the motor data (from the motor type plate / data sheet).

Optimisation should be carried out on completion of basic commissioning, see 3 "Basic Commissioning" and after

- Parameterisation of motor data from the motor type plate or data sheet
- Motor identification with Par.-identification P220 function {1 = Identification Rs} by the user.
3.4.3 EMF constant

The EMF constant or the EMF voltage PMSM P240 can be calculated with the Voltage constant $k_v$ and subsequently optimised, see 3.3.2 "NORD – Motor type plates / Data sheet".

The EMF constant or the parameter EMF voltage PMSM P240 of a synchronous motor can not be identified when the motor is at a standstill. However, the value can be determined experimentally and optimised with the drive operating without a load.

The following procedure should be followed for optimisation of the EMF voltage PMSM P240:

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOTOR DATA/ CHARACTERISTIC CURVE PARAMETERS</td>
<td>Third party motor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P209 (P)</td>
<td>No load current [A]</td>
<td>4.4*</td>
<td>$\therefore 3.8 \rightarrow 0$</td>
</tr>
<tr>
<td>P240 (P)</td>
<td>EMF voltage PMSM [V]</td>
<td>0</td>
<td>$\therefore 275 \rightarrow$ optimal</td>
</tr>
<tr>
<td>P247 (P)</td>
<td>Changeover frequency VFC PMSM [%]</td>
<td>25</td>
<td>$\therefore 25$ (leave as set)</td>
</tr>
<tr>
<td>Speed control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P300 (P)</td>
<td>Servo mode</td>
<td>0 (Off = VFC Open-Loop)</td>
<td>$\therefore 0$ (leave as set)</td>
</tr>
</tbody>
</table>

* $\therefore$ To "0" for IE4 synchronous motors from Getriebebau NORD
$\therefore$ To "0" for synchronous motors from other manufacturers

For synchronous motors which are running without load, the EMF constant can be optimised with the following specifications by means of the "disabled" parameter Servo Mode P300, i.e. function (0 = Off (VFC Open-Loop)):

- No load current P209 = "0" and
- Adequate setpoint specification, i.e. Setpoint frequency > Switch-over frequency.VFC PMSM P247

The objective is to determine the optimum value for the parameter EMF voltage P240.

The "correct" value for the EMF constant has been found when the Actual current P719 under no-load conditions reaches "0" or almost "0".
The following diagram shows the optimum setting for the EMF voltage PMSM P240:

![Diagram showing optimum setting for EMF voltage PMSM P240](image)

**Fig. 17: Diagram for optimum current / EMF constant**

Start with smaller setpoint specifications / setpoint frequencies and carry out optimisation of the **EMF voltage PMSM P240**. After this, the **setpoint frequency** is increased up to shortly before the **weak field range** and then fine adjustment is carried out.
### 3.4.4 Stator inductance

After adoption of the stator inductances from the manufacturer's data sheets, see 3.3.2 "NORD – Motor type plates / Data sheet", the **Stator inductance** $L_d$ should be optimised.

The **Stator inductance** $L_d$ or the parameter **Inductance PMSM P241 [-01]** of a synchronous motor can **not** be optimised if the **drive is at a standstill**.

The value for $L_d$ can and **may** only be determined experimentally after the correct determination of the EMF constant, with the **drive running under no-load conditions**.

The following procedure should be followed for optimisation of the **Inductance PMSM P241 [-01]**:

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MOTOR DATA/ CHARACTERISTIC CURVE PARAMETERS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P203 (P)</td>
<td>Nominal current [A]</td>
<td>8.3</td>
<td>$\ominus$ 5.2 → 1.5</td>
</tr>
<tr>
<td>P209 (P)</td>
<td>No load current [A]</td>
<td>4.4*</td>
<td>$\ominus$ 0 → 1.5</td>
</tr>
<tr>
<td>P241 [-01]</td>
<td>Inductance PMSM (d axis) [mH]</td>
<td>20</td>
<td>$\ominus$ 8.5 → optimal</td>
</tr>
<tr>
<td>P241 [-02]</td>
<td>Inductance PMSM (q axis) [mH]</td>
<td>20</td>
<td>$\ominus$ 18.3 → calculated **</td>
</tr>
<tr>
<td>P247 (P)</td>
<td>Changeover frequency VFC PMSM [%]</td>
<td>25</td>
<td>$\sim$ 25 (leave as set)</td>
</tr>
</tbody>
</table>

**Speed control**

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P300 (P)</td>
<td>Servo mode</td>
<td>0 (Off = VFC Open-Loop)</td>
<td>$\sim$ 0 (leave as set)</td>
</tr>
</tbody>
</table>

* $\ominus$ To "0" for iE4 synchronous motors from Getriebebau NORD

$\ominus$ To "0" for third party motors /synchronous motors from other manufacturers

**Refer to the information for IPMSM or SPMSM

If the synchronous motor is running under no-load conditions, the **Stator inductance** $L_d$ can also be optimised in "disabled" **Servo Modus P300**, i.e. **Function (0 = Off (VFC Open-Loop))** and with a

- Specified setpoint as high as possible (**the setpoint frequency** should be at least $< weak field range$)

After this, the parameter **No Load Current P209** is set to the value of the **Nominal current P203**.

The objective is to determine the optimum value for the **Stator inductance** $L_d$ or the parameter **Inductance PMSM P241 [-01]**.

**Inductance PMSM P241 [-01]**

The "correct" or optimum value for the **Stator inductance** $L_d$ has been found when the parameter **Actual current P719** under no-load conditions corresponds to the **No Load Current P209**.

Otherwise, the parameter for the **Inductance PMSM P241 [-01]** must be corrected until the value in the parameter **Actual current P719** approximately corresponds to the **No Load Current P209** or the **Nominal motor current P203**.
Inductance PMSM P241 [-02]

For the parameterisation of stator inductances attention must be paid to the version or type of the synchronous motor (PMSM):

- **IPMSM**
  
  For IPMSM drives, the value of the Stator inductance $L_q$ in the parameter Inductance PMSM P241 [-02] for the q-axis should not be changed.

- **SPMSM**
  
  For SPMSM drives, the two values for the Stator inductance $L_d$ and $L_q$ should always be equal, i.e. the parameter Inductance PMSM P241 [-02] for the q-axis must be parameterised to the identical value of Inductance PMSM P241 [-01] for the d-axis.
3.5 Incremental encoder (IG)

For the speed feedback, incremental encoders (IG) are usually used, which convert the rotary movement into electrical signals (TTL or HTL). Incremental encoders both with and without zero tracks can be used.

Three different encoder resolutions (1024, 2048 and 4096) are available as standard Getriebebau NORD encoders. As the default rotary encoder, a resolution of 4096 pulses (pulses/rotation) is pre-set at the factory in the frequency inverter. Technical data for the incremental encoder, e.g. the relevant connections can be obtained from catalogue M7000 Electric Motors.

**NOTICE**

Installation of rotary encoders

The incremental encoder must be mounted on the end of the motor shaft. Otherwise, inaccuracy of the speed and/or the position control may result.

3.5.1 Parameterisation of encoders (IG)

For connection of the incremental encoder to the control terminals of decentralised SK 2xxE frequency inverters, adjustment of the parameterisation of the digital inputs DIN2 and DIN3 is required via the parameters digit inputs P420 [-02] and [-03]. The connection of an IG with a zero track via DIN1 must be parameterised via the parameter Digital inputs P420 [-01], for further details see 3.5.2 "Encoder connection (IG)".

For control in CFC Closed-Loop mode (servo mode) it is essential that speed control with speed measurement is enabled via an incremental encoder (IG). In the "Control parameters" tab, the parameter Servo mode P300 with the function \{1 = On (CFC Closed-Loop)\} is available for this.

**Enabling of control parameters**

For decentralised SK 2xxE frequency inverters, the Control parameters P3xx tab is enabled with the parameter P003 Supervisor-Code \{3 = all parameters visible\}

For the control cabinet frequency inverters SK 53xE and SK 54xE the tab is enabled as the default in the factory settings.

The corresponding pulse number / resolution for the encoder system must be parameterised in the parameter Incremental encoder P301, taking the appropriate prefix (note the installation position) into account.
### 3 Basic Commissioning

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P300  (P)</td>
<td>Servo mode</td>
<td>0 (Off = VFC Open-Loop)</td>
<td>Refer to 3.5.5 &quot;Activating the speed control&quot;</td>
</tr>
<tr>
<td>P301</td>
<td>Incremental encoder</td>
<td>6*</td>
<td>6 → 5 (2048 pulses)</td>
</tr>
</tbody>
</table>

* 6 corresponds to 4096 pulses

**Incremental encoder (IG) with zero track**

For applications with an incremental encoder with a zero track, the offset between the zero pulse and the actual rotor position "0" must be set manually in the parameter **Encoder offset PMSM P334**.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Speed control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P334  (S)</td>
<td>Encoder offset PMSM [rev]</td>
<td>0.000</td>
<td>0 → 0.491*</td>
</tr>
<tr>
<td>P335 **</td>
<td>Sync. 0-pulse **</td>
<td>0</td>
<td>See 3.5.4 &quot;Incremental encoder (IG) with zero track&quot;</td>
</tr>
</tbody>
</table>

*For the value, see on the label in the motor terminal box

* Parameter P335 Sync. 0-pulse encoders are only available for SK 54xE

Details of the parameters **Encoder offset PMSM P334** and **Sync. 0-pulse P335** can be obtained from Section 9.1 "Manuals".

### 3.5.2 Encoder connection (IG)

Connection of the incremental encoder to the control terminals of the frequency inverter is different for the two frequency inverter series SK 2xxE and SK 5xxE and requires appropriately modified parameterisation. The connection of an incremental encoder with a zero track is also different for the two frequency inverters.

**SK 2xxE**

For decentralised SK 2xxE frequency inverters, connection of the incremental encoder (HTL) is made exclusively via the two **digital inputs DIN2** (Terminal 22) and **DIN3** (Terminal 23). In the "Control terminals" tab in parameter **Digital inputs P420 [-02] and [-03]** these must be switched to the function \(0 = \text{No function}\).

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONTROL TERMINALS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P420  [-01]</td>
<td>Digital inputs (DIN1)</td>
<td>1</td>
<td>1 → 43 (only for IG with zero track)</td>
</tr>
<tr>
<td>P420  [-02]</td>
<td>Digital inputs (DIN2)</td>
<td>2</td>
<td>2 → 0</td>
</tr>
<tr>
<td>P420  [-03]</td>
<td>Digital inputs (DIN3)</td>
<td>4</td>
<td>4 → 0</td>
</tr>
</tbody>
</table>
If the incremental encoder is connected and the Digital inputs DIN2 and DIN3 are not parameterised to the function \(0 = \text{No function}\) there will be a "clicking" noise when the drive unit is enabled!

Connection of incremental encoders with a zero track may only be made to Digital input 1 (DIN1). Only the signal + zero track is connected to Terminal 21 (DIN1).

In the parameter Digital inputs P420 [-01], by selecting the function \(43 = 0\)-track HTL encoder DI1, the starting behaviour of the synchronisation of the rotor position is specified.

**SK 520E to SK 535E**

Connection of the incremental encoder (TTL) for control cabinet frequency inverters of performance levels ≥ SK 520E is made via the terminal bar X6 (Terminals 51 … 54).

Connection of incremental encoders with a zero track is only made to the Universal encoder interface, terminal bar X14, terminals 63 (Signal CLK-) and 64 (Signal CLK+) in the case of SK 540E and SK 545E control cabinet frequency inverters.

<table>
<thead>
<tr>
<th>Information</th>
<th>Power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encoder systems with a suitable power supply (10 V to 30 V) should be planned and used. The technical data can be obtained from catalogue M7000 Electric Motors or from the data sheets 9.3.1 &quot;TIs – Incremental encoder (IG)&quot;.</td>
<td></td>
</tr>
</tbody>
</table>
3.5.3 Function test of rotary encoders (IG)

After completion of connection and basic commissioning the correct function of the incremental encoder (IG) should always be checked.

The prefix (+ or - pulse numbers) depends on the installation position of the incremental encoder on the motor shaft. For example, if the direction of rotation of the IG does not correspond to the direction of rotation of the frequency inverter (recommended specification: positive values = clockwise rotation) a negative pulse number must be set in the Incremental encoder P301.

Information

Checking the encoder speed

To check the correct selection of the Incremental encoder P301 the parameter Speed encoder P735 is available in the "Information Parameters" tab.

For the function test of the parameterised encoder function, the motor can be enabled e.g. with a setpoint of 10 Hz depending on the Nominal frequency P201, e.g. 50 Hz or 70 Hz in clockwise rotation. With this, for a 4-pole motor the parameter Speed encoder P735 should have a value of approx. 300 rpm.

However, the value for the Speed encoder P735 may vary according to the application, as the setting for the Maximum frequency P105 parameter and the selected setpoint source must also be taken into account.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFORMATION, read only</td>
<td>P735 Speed encoder</td>
<td></td>
<td>✔ approx. 300 rpm</td>
</tr>
</tbody>
</table>

3.5.4 Incremental encoder (IG) with zero track

With the SK 54xE, the zero track of an incremental encoder is only evaluated if no universal encoder is connected to the universal encoder interface, terminal bar X14. Refer to 3.5.2 "Encoder connection (IG)" for further details.

The zero track of an incremental encoder can be used to determine either the

- Zero rotor position of the synchronous motor or the PMSM

The parameter Regulation PMSM P330 must be set to either the function

- {0 = Voltage-controlled} or
- {1 = Test signal method}

if an incremental encoder is used..

For IE4 synchronous motors manufactured by Getriebebau NORD, the encoder offset between the d-axis of the rotor and the zero pulse is measured and documented with a "rpm" and "°" label in the terminal box.

For further details, refer to P334 Encoder offset PMSM 3.5.1 "Parameterisation of encoders (IG)".

or for the synchronisation of the

- Zero point (reference point) of the incremental encoder.

The following parameters are available for synchronisation of the zero pulse of the incremental encoder.
Sync. 0-pulse P335

Various functions can be selected for synchronisation:

- **Function (0 = Sync. off)**
  Synchronisation is disabled or switched off and corresponds to the factory setting.

- **Function (1 = Sync rotor pos. PMSM)**
  Synchronisation of the rotor position of a PMSM, i.e. a synchronous motor is enabled or switched on.

- **Function (2 = Sync. reference pos.)**
  Synchronisation of the reference point for positioning applications (POSICON) is enabled or switched on.

- **Function (3 = Sync. PMSM + pos.)**
  Both the synchronisation of the rotor position of a PMSM / synchronous motor as well as the reference point for positioning applications (POSICON) is enabled or switched on.

### 3.5.5 Activating the speed control

For activation of the speed feedback (CFC Closed-Loop mode), under the tab "Control parameters" the parameter **Servo mode P300** must be set to Function (1 = **On** (CFC Closed-Loop)).

---

**CAUTION Servo mode activation**

This setting should only be made after the check of the direction of rotation of the incremental encoder has been successfully completed.

Otherwise, unexpected movements (wrong direction of rotation) may result. This may cause both material damage as well as injuries to persons.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P300 (P)</td>
<td>Servo mode</td>
<td>0 (Off = VFC Open-Loop)</td>
<td>0 → 1 (On = CFC Closed-Loop)</td>
</tr>
</tbody>
</table>
3.6 Absolute encoder (AG)

Information & instructions

For the speed feedback a **combined absolute encoder (AG)** with a separate **incremental track (IG track)** which as a measurement sensor converts the rotary movement into electrical signals (TTL or HTL) can also be used. Both **CANopen absolute encoders**, as well as various **universal encoders** can be used.

Four different encoder types with 13 Bit single turn resolution (8192) as well as 12 Bit (4096) or 16 Bit (65536) multturn resolution are available as standard Getriebebau NORD encoders. A pulse number of 2048 (pulses/rotation) is used as the standard resolution of the incremental track and is pre-set at the factory in the frequency encoder. Technical data **CANopen absolute encoders**, e.g. the relevant connections can be obtained from catalogue [M7000 Electric Motors](#).

**NOTICE**

Installation of rotary encoders

It is **essential** that the **combination absolute encoder** (single and multturn with integral incremental track) is mounted on the **end of the motor shaft**.

Other types of absolute encoder (e.g. Type AG1 / Part no. 19551881 / Kübler Type 8.5888.0421.2102. S010.K014) must **not necessarily** be mounted on the end of the motor shaft.

In this case, the speed ratio in the frequency inverter must be parameterised with the aid of the Ratio P607 and the Reduction Ratio P608. Otherwise, **inaccuracy** of the **speed** (incremental track) and / or the **position control** may result.

**Instructions**

3.6.1 Parameterisation of CANopen encoders (absolute encoders)

For control in **CFC closed loop** mode (servo mode), for a **CANopen standard combined absolute encoder (AG)** with an additional **incremental track (IG)** it is essential that the speed control with speed measurement is enabled. In the "Control parameters" tab, the parameter **Servo mode P300** with the function {1 = On (CFC Closed-Loop)} is available for this.

For an encoder system with incremental signals, the corresponding pulse number / resolution must be parameterised in the parameter **Incremental encoder P301**, taking the appropriate prefix (note the installation position) into account.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P300 (P) Servo mode</td>
<td></td>
<td>0 (Off = VFC Open-Loop)</td>
<td>0 → 1 (On = CFC Closed-Loop)</td>
</tr>
<tr>
<td>P301 Incremental encoder</td>
<td>6*</td>
<td></td>
<td>6 → 5 (2048 pulses)</td>
</tr>
</tbody>
</table>

* 6 corresponds to 4096 pulses

For the position detection of the position controller with a **standard combination encoder** with a **CANopen** interface (see Section 2.6 "Selection of absolute encoders"), several parameters must be set under the "Positioning" tab for position detection by the position controller.
### Positioning / Control Parameters

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P604</td>
<td>Encoder type</td>
<td>0</td>
<td>![Symbol] 0 → 1 (CANopen absolute)</td>
</tr>
<tr>
<td>P605 [-01]</td>
<td>Absolute encoder (Multi)</td>
<td>10</td>
<td>![Symbol] 10 → 12 (4096 pulses)</td>
</tr>
<tr>
<td>P605 [-02]</td>
<td>Absolute encoder (Single)</td>
<td>10</td>
<td>![Symbol] 10 → 13 (8192 pulses)</td>
</tr>
</tbody>
</table>

### 3.6.2 Parameterisation of the CANopen Interface

For the communication interface of a **CANopen standard combination absolute encoder** (see Section 2.6 "Selection of absolute encoders") further parameters must be set in the "Extra parameters" tab.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P514</td>
<td>CAN bus baud rate * [kBaud]</td>
<td>5 **</td>
<td>![Symbol] 5 (250 kBaud) ** (leave as set)</td>
</tr>
<tr>
<td>P515 [-01]</td>
<td>CAN bus address * Slave address</td>
<td>32_{dec}</td>
<td>![Symbol] 32 (leave as set)</td>
</tr>
<tr>
<td>P515 [-02]</td>
<td>CAN bus address * Broadcast slave addr.</td>
<td>32_{dec}</td>
<td>![Symbol] 32 (leave as set)</td>
</tr>
<tr>
<td>P515 [-03]</td>
<td>CAN bus address * Master address</td>
<td>32_{dec}</td>
<td>![Symbol] 32 (leave as set)</td>
</tr>
</tbody>
</table>

* System bus
** Depending on the frequency inverter, ≥ SK 530E factory setting = 4
*** Depending on the frequency inverter, ≥ SK 530E factory setting = 50

The default settings for the parameters **CAN Baud rate P514** as well as the **CAN address P515 Array [-01 ... -03]** vary between the SK 2xxE and the ≥ SK 530E control cabinet frequency inverters. These two parameters must be parameterised differently for application-specific requirements or deviations.

### Information

**CANopen parameterisation**

For connection of a standard combined absolute encoder to the particular frequency inverter, the **standard address setting** on the CAN open absolute encoder is pre-set at the factory to the value / address {33} or {51}.

For control cabinet frequency inverters ≥ SK 530E the standard Baud rate setting / function {4 = 125 kBaud} deviates from that of decentralised frequency inverters with {5 = 250 kBaud} and is pre-set at the factory for CANopen absolute encoders from Getriebebau NORD.
3.6.3 Connection of CANopen encoders (absolute encoder)

The connection and the necessary 24 V power supply of the CANopen absolute encoders is different for the frequency inverter series SK 2xxE and ≥ SK 5xxE.

SK 2xxE

Direct connection to the relevant bus option with system bus interface to the terminals:

<table>
<thead>
<tr>
<th>Terminal</th>
<th>Designation</th>
<th>Function</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>VO / 24 V</td>
<td>24 V supply</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>GND / 0 V</td>
<td>0 V supply</td>
<td></td>
</tr>
<tr>
<td>77</td>
<td>SYS H</td>
<td>System bus +</td>
<td>SYS H / (CAN High)</td>
</tr>
<tr>
<td>78</td>
<td>SYS L</td>
<td>System bus -</td>
<td>SYS L / (CAN Low)</td>
</tr>
<tr>
<td></td>
<td>Shield</td>
<td>Shield</td>
<td>via large-area earthing using the EMC cable connector</td>
</tr>
</tbody>
</table>

Table 6: SK 2xxE interface connection to the system bus

For detailed information regarding the connection of a CANopen absolute encoder to an SK 2xxE please refer to the supplementary manual BU 0210 and the manual BU 0200, see Section 9.1 "Manuals".

SK 53xE and SK 54xE

An optional RJ45 WAGO connection module (Part No. 278910300) is available for connection of the external power supply of the CANopen absolute encoder of SK 53xE and SK 54xE for frequency encoder applications.

Detailed information for the connection of a CANopen absolute encoder to a frequency inverter ≥ SK 530E and to the RJ45 WAGO connection manual can be obtained from the supplementary manual BU 0510 and the manuals BU 0500 or BU 0505, see Section 9.1 "Manuals".

Fig. 18: RJ45 WAGO connection module
3.6.4 Function test of CANopen encoders (absolute encoders)

After completion of connection and basic commissioning the correct function of the CANopen absolute encoder (AG) should always be checked.

Information

The **CANopen status** of the absolute encoder interface and the frequency inverter can be evaluated or checked with the parameter **CANopen status P748** under the tab "Information Parameters".

Further CANopen participants (nodes / addresses) may possibly be connected to the CANopen field bus, so that the assignment of double addresses or different Baud rates etc. may have been parameterised.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFORMATION, read only</td>
<td></td>
<td></td>
<td>Check display of CANopen status</td>
</tr>
</tbody>
</table>

The parameter **CANopen state P748** shows the status of the CANbus /CANopen in bit-coded form, i.e. therefore the state of CANopen MNT. For detailed information, please refer to the relevant manual for the frequency inverter, see \( 9.1 \) "Manuals".

Procedure

For both the function test of the CANopen encoder as well as for commissioning of the position control, it is recommended that a set procedure is followed.

**CAUTION**

Servo mode activation

Ensure that the Emergency Stop and safety circuits are functional! For lifting gear applications, prior to switching on for the first time measures must be taken to prevent the load from falling. In addition, for the load take-up, the parameters **Brake reaction time P107** and **Brake delay off P114** should be optimised after the optimisation of the speed controller.

Otherwise, unexpected movements (wrong direction of rotation) may result. This may cause both material damage as well as injuries to persons.

1. **Commission the axis without position control**

   After the input of all parameters the drive unit should first be commissioned without control of the position or speed.

   For this the speed control must be switched off in the parameter **Servo mode P300** with the function \( 0 = \text{Off (VFC Open-Loop)} \) and the parameter **Position control P600** and the function \( 0 = \text{Off} \).

2. **Commissioning the speed controller**

   This step may be omitted if no speed control is required or if an incremental encoder is used.

   Otherwise the **Servo mode P300** should be switched to \( 1 = \text{On (CFC Closed-Loop)} \)
3 Basic Commissioning

Information

Servo mode

If the motor only runs at a slow speed with a high current consumption after activation of the Servo mode P300 with the function \(1 = \text{On (CFC Closed-Loop)}\), there is usually an error in the wiring or the parameterisation of the incremental encoder connection. The most frequent cause is an incorrect assignment of the direction of rotation of the motor to the counting direction of the encoder.

The optimisation of the speed control is optimised after commissioning of the position control, as the behaviour of the position control circuit can be influenced by changes to the speed control parameters.

3 Commissioning the position controller

After setting parameter Encoder type P604 and Absolute encoder P605 it must be checked whether the actual position is correctly detected. The actual position is displayed in the parameter actual position P601.

The value must be stable and become larger if the motor is switched on with rotation to the right enabled. If the value does not change when the axis is moved, the parameterisation and the encoder connection must be checked. The same applies if the displayed value for the actual position jumps although the axis has not moved.

4 Specify and move to the setpoint position

After this a setpoint position in the vicinity of the actual position should be specified and moved to by enabling the drive unit.

Information

Testing the absolute encoder function

The encoder position of the absolute encoder can be checked with the parameter Actual position P601 using NORD CON. If the direction of action of the absolute encoder is not correct, i.e. after being enabled, the axis moves away from the setpoint position instead of towards it, this indicates an incorrect assignment between the direction of rotation of the motor and the direction of rotation of the encoder. In this case, there is the possibility of changing this by a negative input of the speed ratio value in the parameter Ratio P607.

Under the "Positioning Parameters" tab, using the parameter Encoder type P604, the corresponding encoder system is parameterised for detection of the actual position value.

The direction of effect of the absolute encoder, i.e. the prefix (+ or - pulse numbers) depends on the installation position of the incremental encoder on the motor shaft. For example, if the direction of rotation of the incremental encoder does not correspond to the direction of rotation of the frequency inverter (recommended specification: positive values = clockwise rotation) a negative pulse number must be set in the Incremental encoder P301.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>actual position [rev]</td>
<td>---</td>
<td>✂ Check display</td>
</tr>
<tr>
<td></td>
<td>Actual Ref. Pos. [rev]</td>
<td>---</td>
<td>✂ Check display</td>
</tr>
<tr>
<td></td>
<td>Curr. position diff. [rev]</td>
<td>---</td>
<td>✂ Check display</td>
</tr>
<tr>
<td>P604</td>
<td>Encoder type</td>
<td>0</td>
<td>✈ 0 ⇔ 1 (CANopen absolute)</td>
</tr>
<tr>
<td>P607 [-02]</td>
<td>Ratio (absolute encoder)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P608 [-02]</td>
<td>Reduction Ratio (absolute encoder)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

If the function test is complete and the detection of the actual position operates correctly, the position controller can be optimised according to the following procedure, see 6 "Position control".
3.7 Identification of the rotor position

Instructions

For the determination of the **start position of the rotor** a **determination procedure** is required, which depends on the encoder system which is used (IG or AG).

**NOTICE**

Incorrect positioning

For applications with **incremental encoder feedback**, determination of the start position of the rotor is **necessary each time that the mains are switched on**.

If this is not done, there is a danger of incorrect positioning or damage to the drive unit or the entire system.

Incremental encoders (IG) both with and without zero tracks can be used for the **identification of the rotor position**.

For this, the identification method is set in the "**Control parameters**" tab using the parameter **Control method PMSM P330** and on the basis of the required functionality.

Further parameters are available for **identification of the rotor position** and for setting specific parameter values for the encoder system:

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P212 (P) (S)</td>
<td>Slip compensation [%]</td>
<td>100</td>
<td>↗ (check if necessary)</td>
</tr>
<tr>
<td>P213 (P) (S)</td>
<td>Amplification ISD control [%]</td>
<td>100</td>
<td>↗ (check if necessary)</td>
</tr>
<tr>
<td><strong>Speed control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P300 (P)</td>
<td>Servo mode</td>
<td>0 (Off = VFC Open-Loop)</td>
<td>↗ 1 (On = CFC Closed-Loop)</td>
</tr>
<tr>
<td>P330 (S)</td>
<td>Regulation PMSM</td>
<td>1 (test signal method)</td>
<td>☝ 1 → ... (depending on the encoder system)</td>
</tr>
<tr>
<td>P334 (S)</td>
<td>Encoder offset PMSM [rev]</td>
<td>0.000</td>
<td>☝ 0.000 → ... (depending on the encoder system)</td>
</tr>
<tr>
<td>P335</td>
<td>Sync. 0-pulse</td>
<td>0</td>
<td>☝ 0 → ... (depending on the encoder system)</td>
</tr>
</tbody>
</table>

**Information**

**Applications with a brake**

Identification of the rotor position by means of the parameter **Control method PMSM P330** is only possible to a **limited extent** if a **brake** is used (e.g. release of the brake).

For determination of the start position of the rotor, only **enabling** of the **drive** is necessary for the identification method, i.e. the specified setpoint can be left as **0 Hz**.
3.7.1 Procedure for determining the start position of the rotor

Determination of the start position of the rotor is carried out with the parameter Control method PMSM P330. Depending on the encoder system which is used, four different functions are available for synchronous motors.

The function to be set for identification of the rotor position or the control method depends on the frequency inverter series and the performance level which is used.

For incremental encoders the Control method PMSM P330 must be set with either the function (0 = Voltage controlled) or (1 = Test signal method).

For absolute encoders either the function (2 = Value for universal encoder) or (3 = Value for CANopen encoder) must be set.

For detailed information regarding the particular encoders and their parameterisation, please refer to the relevant supplementary manual POSICON Positioning Control (see BU 0210 or BU 0510) see Handbücher).

Function (0 = Voltage controlled) (only for incremental encoders)

With the first start of the machine, a voltage indicator is memorised which ensures that the rotor of the machine is set to the rotor position "zero". This type of determination of the starting position of the rotor can only be used if there is no counter-torque from the machine (e.g. flywheel drive) at frequency "zero". If this condition is fulfilled, this method of determining the position of the rotor is very precise (<1° electrical).

The function (0 = Voltage controlled) may only be used for horizontal or "torque-free" applications (without a brake). In principle, this method is unsuitable for lifting equipment applications, as there is always a counter-torque. In case of parameter changes or mains failure / mains switch-off the method is always restarted automatically. If the rotor position is changed while a voltage is applied to the frequency inverter, this is automatically taken into account on condition that the incremental encoder is connected.

Function (1 = Test signal method) (only for incremental encoders)

The function (1 = Test signal method) which is to be set for the detection of the rotor position / control method may only be used for synchronous motors with permanent magnets which are integrated in recesses, i.e. so-called IPMSM (Interior Permanent Magnet Synchronous Motors).

Detailed information about IE4 synchronous motors from Getriebebau NORD is contained in the Technical Information TI 80-0010; refer to Richtlinien for further details.

The starting position of the rotor is determined with a test signal. This method also functions at a standstill with the brake applied, however it requires a PMSM with sufficient anisotropy between the stator inductance Ld und Lq, see Statorinduktivität. This difference exists for IE4 synchronous motors from Getriebebau NORD (IPMSM). The higher this anisotropy (direction dependence) is, the greater the precision of the method. The voltage level of the test signal can be changed via the parameter Slip compensation P212.

The position of the rotor position controller is adjusted with the parameter Adjust ISD control P213. For motors which are suitable for use with the test signal method, a rotor position accuracy of 5°...10° electrical can be achieved (depending on the synchronous motor and the anisotropy).
In case of parameter changes or mains failure / mains switch-off the rotor position is always reetermined automatically.

**Information**

**Incremental encoders with zero track**

If there is an incremental encoder with a "zero track" on the motor shaft, the "zero track" can also be used to determine the starting position of the rotor. The zero pulse can be used with both decentralised SK 2xxE and SK 54xE frequency inverters for synchronisation of the rotor position.

Detailed information for the parameterisation and connection of an incremental encoder with a zero track can be found in Section <dg_ref_source_inline>Inkrementaldrehgeber</dg_ref_source_inline>.

**Function (2 = Value from universal encoder)** (Universal encoder only for ≥ SK 54xE)

With this method the starting position of the rotor is determined from the absolute position of a universal encoder (Hiperface, EnDat with Sin/Cos track, BISS with Sin/Cos track or SSI with Sin/Cos track). The universal encoder type is set in the parameter **Encoder type P604** (see Function (8 - 15)).

For this position information to be unique it must be known (or determined) how this rotor position relates to the absolute position of the universal encoder. This is performed via the offset parameter **Encoder offset PMSM P334**.

Synchronous motors from **Getriebebau NORD** are always supplied with a defined rotor start position or encoder offset. The value or the encoder offset are always documented in "°" and "rev" details on the synchronous motor by means of a label in the terminal box.

If this value is not known, the **offset value** can also be determined by setting the function {0 = Voltage controlled} or {1 = Test signal method} of the parameter **Control method PMSM P330**. For this the drive unit is started with the function setting {0 = Voltage controlled} or {1 = Test signal method}. After the first start, the determined offset value is stated in the parameter **Encoder offset P334**.

**Information**

**Encoder offset label**

This value in the parameter **Encoder offset P334** is volatile, and therefore is only saved in the RAM of the frequency encoder. In order to overwrite the value in the EEPROM, the value must be changed and then parameterised back to the value which was originally determined. After this, fine adjustment can be carried out with the synchronous motor running under no load.

For this, in **Servo mode P300** the drive is parameterised to the function {1 = On (CFC Closed-Loop)} and run with a speed which is as high as possible, but ≤ weak field range. From the starting point, the offset is gradually adjusted so that the value of the **Voltage component U_d** in parameter **Voltage d P723** is as close as possible to "0". A balance between the positive and negative direction of rotation should be sought. In general the value "0" cannot be achieved, as the synchronous motor has a load due to the fan wheel at high speeds. The universal encoder should be located on the motor shaft.
Function \((3 = \text{Value for CANopen encoder})\) (only for CANopen absolute encoders)

Identical function description as for function \((2 = \text{Value of universal encoder})\), see above, however for the determination of the rotor start position or the absolute position, a CANopen absolute encoder is used instead of a universal encoder. The type or function of the CANopen absolute encoder is set in the parameter Encoder type P604 (see Function \(\{1, 5 - 7\}\)).

For the determination of the start position of the rotor with incremental encoders, with the parameter Regulation PMSM P330 a measurement precision of approx. ± 3 to 10° (electrical) is achieved.

For CANopen standard combination absolute encoders from Getriebebau NORD determination of the start position of the rotor is normally unnecessary. The encoder adjustment is carried out at the factory and does not require further determination of the encoder offset. The encoder must be readjusted if it is not adjusted, or the adjustment has been changed due to impact or removal of the synchronous motor.
4 Current control

The current control is comprised of two different PI controllers:
- Torque current controller (P312, P313, P314)
- Field current controller (P315, P316, P317)

These are divided into parameters P312 / P315 for the P component and parameters P313 / P316 for an I component. In addition, two further "limit parameters" P314 or P317 complete the particular controller. These are used to limit the maximum voltage range (9.1 "Manuals").

The settings for the P component and the I component of the particular controller should always have the same setting, i.e. P312 = P315 and P313 = P316. The limit parameters P314 or P317 are not considered in further detail in this guide!

The following diagrams show several control curves / transient responses which occur after a sudden change of the setpoint for various PI controllers.

Diagram 1
Selected P component too small

Diagram 2
P component optimised and I component selected too small

Diagram 3
P and I component optimal

Diagram 4
P component optimised and I component selected too large

Fig. 19: Control value curves
The various control curves, where the setpoint is shown in RED and the actual value is shown in GREEN, describe the dynamic curve for the transient response, which is set via the individual control parameters (P and I component) of the controller.

It is recommended that the following optimisation steps are performed to systematically adjust a current controller.

**Overview of the optimisation procedure**

- Set the I component to a low value

- Increase the P component from the standard value in e.g. 50 % increments until no further rapid increase of the actual value (Flux current ~P721) can be achieved. A curve as shown in Diagram 2 results.

- This is followed by an increase of the I component in e.g. 20 % / ms increments until an overshoot of approx. 3 to 5 % is achieved. Diagram 3 shows the optimised curve, whereby in this diagram, the overshoot is slightly exaggerated for clarity.

Diagram 1 shows the curve if the P components is selected too small. In contrast Diagram 4 shows the curve for the actual value when the I component is set too large. In this case, the I component should be gradually reduced to set a curve as shown in Diagram 3.

The aim is to optimise the curve for the Flux current ~P721 with the "correct" settings of the P and I components.

The practical implementation for optimisation of a current controller is described in Section 4.4 "Optimisation procedure".
4.1 Further settings

Instructions

For optimisation of the current controller, it is essential that the following two parameters are set in advance.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MOTOR DATA/CHARACTERISTIC CURVE PARAMETERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P209 (P)</td>
<td>No load current [A]</td>
<td>8.3*</td>
<td>☬ 0 → e.g. 5.4 (Nominal motor current P203)**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>*) dependent on FI power or P200 / P220</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>** To &quot;0&quot; for IE4 synchronous motors from Getriebebau NORD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>To &quot;0&quot; for synchronous motors from other manufacturers</td>
</tr>
</tbody>
</table>

** Detailed information about the various functions, e.g. interface configuration, operation, oscilloscope settings, etc. can be found in the NORD CON Manual BU 0000, see 9.1 "Manuals".

4.2 NORD CON

Information & instructions

NORD CON should be used for programming, operation and optimisation of the controllers.
Optimisation of the controllers for NORD frequency inverters can be performed with this parameterisation and control software. The oscilloscope function provides e.g. the possibility to assess the particular optimisation steps on the basis of several scope recordings.
Further information about the latest version can be found under the following link: NORD CON
The functions Remote Control and Control as well as the Device Overview are available for control of the frequency inverter.

Fig. 20: NORD CON

For optimisation of the current controller of a synchronous motor, the Absolute mini. Freq. P505 must not be "0". It is recommended that the value is left at the factory setting. Furthermore, for optimisation it should be noted that after a change to the motor-specific parameter value (P2xx) the rotor position must always be redetermined (see Fehler! Verweisquelle konnte nicht gefunden werden. "Fehler! Verweisquelle konnte nicht gefunden werden.").

Enabling or performance of the measurement must only be carried out after redetermination of the rotor position.
Before starting the scope recording and enabling the drive unit, the setpoint must always be set to 0 % (0 Hz).
4.2.1 Remote control

The following setting must be made in the Remote Control screen to optimise the current controller before starting the scope recordings.

1. Leave the setpoint at 0 %, i.e. leave the setpoint frequency at 0 Hz

   Alternative display possibility

2. Press the Enable button

Fig. 21: Remote control of the current controller, setpoint and enabling

New display in NORD CON

Fig. 22: Remote control of the current controller, setpoint and enabling

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**Information**

Remote Control display

The display in the Remote Control screen may vary for different NORD CON settings and versions. E.g. the Remote Control screen is displayed differently for SK 5xxE frequency inverters.
4.2.2 Oscilloscope

The following settings should be made under the two tabs Recording or Channel Settings of the NORD CON Oscilloscope Function before starting the oscilloscope recordings. The settings and graphic displays in the illustrations may differ according to the frequency inverter types, versions and software status.

**Set Trigger to Enable**

**Set the scan rate to 0.25 ms**

→ Scan duration 50 ms

Note

The scan rate should be selected so that it corresponds to the scope recordings in the illustrations in Section 4 "Current control"!

![Oscilloscope settings](image)

Fig. 23: Oscilloscope settings for trigger and scan rate / scan duration

![Resolution settings](image)

Fig. 24: Resolution settings for the time axis, comment examples

Various types are available for selection of the measuring values which are to be recorded. Depending on the controller, the "unfiltered" (~P7xx / with approx. 250 µs) and the "filtered" (~P7xx / with approx. 50 ms) values should be set for the oscilloscope recordings.

![Measure value table](image)

Fig. 25: Legend / Meaning of measurement functions

### Oscilloscope recordings

**Information**

To obtain a better depiction of the measurement values, in this guideline the colours in the channel settings for the particular measurement values have been modified for the oscilloscope settings.

For the use of the application guide it would be generally advantageous if during the optimisations / oscilloscope recordings which are carried out (e.g. for the current, speed, position controllers, etc.) the identical settings are selected for the colour and resolution of the measurement values which are to be displayed.
**4 Current control**

<table>
<thead>
<tr>
<th>Active</th>
<th>Color</th>
<th>Measure value</th>
<th>Resolution/DIV</th>
<th>Offset</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Field setpoint from weak ctrl</td>
<td>1 A</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>(~P721) Flux current</td>
<td>1 A</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>(~P723) Voltage -d</td>
<td>20 V</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>(~P718/2) Setp. freq after freq. ramp</td>
<td>10 Hz</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 26: Oscilloscope channel settings for the three measurement values

Press the Start button

Fig. 27: Start the scope recording

---

**Information**

After pressing the start button, the initialisation phase of the oscilloscope recording begins. This is indicated with the indicator light. Because of this, enabling must only be carried out after completion of the initialisation phase for the oscilloscope recording.

Completion of the initialisation phase is indicated with a colour change.

---

Fig. 28: Initialisation phase of scope recording
4.3 Torque and field current controller

**Information & instructions**

For current controllers, in general both the P and the I component of the torque current control and the field current control should always be changed simultaneously for the particular optimisation step.

As the pre-setting for optimising the current controller, the P component (P313 / P316) for the 1st optimisation step should be set to 55 % and the I component (P313 / P316) should be set to 5 % / ms.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P312 (P)</td>
<td>Torque curr. Ctrl. P [%]</td>
<td>400</td>
<td>🎁 50 → vary</td>
</tr>
<tr>
<td>P313 (P)</td>
<td>Torque curr. ctrl. I [%/ms]</td>
<td>50</td>
<td>🎁 50 → 5</td>
</tr>
<tr>
<td>P314 (P)</td>
<td>Torq. curr. ctrl. limit [V]</td>
<td>400</td>
<td>🎁 400 (leave as set)</td>
</tr>
<tr>
<td>P315 (P)</td>
<td>Field curr. ctrl. P [%]</td>
<td>400</td>
<td>🎁 50 → vary</td>
</tr>
<tr>
<td>P316 (P)</td>
<td>Field curr. ctrl. I [%/ms]</td>
<td>50</td>
<td>🎁 50 → 5</td>
</tr>
<tr>
<td>P317 (P)</td>
<td>Field curr ctrl lim [V]</td>
<td>400</td>
<td>🎁 400 (leave as set)</td>
</tr>
</tbody>
</table>

The changes to the control parameters must be checked with the **NORD CON Oscilloscope Function** ([4.2.2 "Oscilloscope"]).

Before optimisation of the current controller it is **essential** that the parameter **No Load Current P209** described in Section [4.1 "Further settings"] is adjusted.

The next optimisation steps and the corresponding scope recordings should be carried out as follows:

**Information**

Oscilloscope recording

If a range is reached in which the changes in the curve cannot be viewed directly, it is advisable to save the oscilloscope recordings. With the facility for displaying several recordings simultaneously a direct comparison with the previous settings is possible.
4.3.1 Current control P components

Starting from the standard value [50 %], increase the parameter for the P component of the Torque current controller P P312 and the Field current controller P P315 in 50 % increments until a rapid increase of the actual value, i.e. of the Flux current ~P721 no longer occurs.

The curve is as illustrated in Diagram 2 (see 4 "Current control").

With this setting, the Voltage component \( U_{sd} \sim P723 \) or the parameter Voltage -d P723 must not exceed the maximum value of 20 % of the nominal voltage P204, i.e. for 385 V this corresponds to \( U_N = 77 \) V.

### Information

#### Standard values of P components

For some motor sizes it may be the case that with the standard setting for the P components of the current controller (P312 and P315) the maximum permissible value for the Voltage component \( U_{sd} \sim P723 \) is already exceeded.

In this case a starting value < 50 % (standard value) must be selected for the P components.

4.3.2 Current control I components

Increase the parameter for the I component of the Torque current control I P313 and the Field current control I P316 from the set starting value [5 % / ms] in 5 % increments until a slight overshoot of approx. 3 % to 5 % of the actual value, i.e. of the Flux current ~P721 occurs.

The curve is as illustrated in Diagram 3 (see 4 "Current control").

The Voltage component \( U_{sd} \sim P723 \) or the parameter Voltage -d P723 must not exceed the maximum value of 25 % of the Nominal voltage P204, i.e. for 385 V this corresponds to \( U_N = 96 \) V.

### Information

#### Voltage component \( U_{sd} \)

Depending on the motor data a more rapid or slower reduction of the Voltage component \( U_{sd} \sim P723 \) may occur after reaching the maximum value (≈ 25 % of the nominal voltage P204).
4.3.3 Criteria

The following criteria should be noted for optimisation of the field weakening control:

The aim is to optimise the curve for the Flux current $\sim P721$ with the "correct" settings of the P and I components.

- Keep the rise time of the Flux current $\sim P721$ to a minimum
- Aim for a maximum overshoot of 3 – 5 % of the Magnetisation current $\sim P721$
- Only allow an amplitude of the Voltage component $U_{ad} \sim P723$ which does not exceed 20 % or 25 % of the Nominal voltage $P204$

Information

Optimisation steps

The step widths stated for control optimisation may differ depending on the application. Furthermore, the step widths can be selected even finer for the final optimisation steps.
4.4 Optimisation procedure

Information

It is possible that an oscillation may occur at the start of the curve. This oscillation occurs with frequency inverters with an integrated "automatic short circuit detection". This has no effect on the optimisation of the current controller.

Fig. 29: Short circuit measurement of SK 200E frequency inverter

The following illustrations show the optimisation process for the current controller using the example of a 3.0 kW synchronous motor with efficiency class IE4 on the basis of individual scope recordings.
Drive Optimisation – Guideline for PMSM - CFC Closed-Loop

Legend

Field setpoint vs. Weak field

Flux current \( \sim P21 \)

Voltage component \( \sim P23 \)

<table>
<thead>
<tr>
<th>Step</th>
<th>1. &quot;P&quot; scope recording</th>
<th>2. &quot;P&quot; scope recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter settings</td>
<td>P312 / P315 = 50 %</td>
<td>P312 / P315 = 100 %</td>
</tr>
<tr>
<td></td>
<td>P313 / P316 = 5 % / ms</td>
<td>P313 / P316 = 5 % / ms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter settings</td>
<td>P312 / P315 = 150 %</td>
<td>P312 / P315 = 200 %</td>
</tr>
<tr>
<td></td>
<td>P313 / P316 = 5 % / ms</td>
<td>P313 / P316 = 5 % / ms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>5. &quot;P&quot; scope recording</th>
<th>8. &quot;P&quot; scope recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter settings</td>
<td>P312 / P315 = 250 %</td>
<td>P312 / P315 = 400 %</td>
</tr>
<tr>
<td></td>
<td>P313 / P316 = 5 % / ms</td>
<td>P313 / P316 = 5 % / ms</td>
</tr>
</tbody>
</table>

Fig. 30: Curve for the P component of the current control
4 Current control

<table>
<thead>
<tr>
<th>Step</th>
<th>Parameter settings</th>
<th>Flux current</th>
<th>Voltage component</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>&quot;I&quot; scope recording</td>
<td>P312 / P315 = 200 %</td>
<td>P312 / P315 = 200 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P313 / P316 = 5 % / ms</td>
<td>P313 / P316 = 10 % / ms</td>
</tr>
<tr>
<td>2.</td>
<td>&quot;I&quot; scope recording</td>
<td>P312 / P315 = 200 %</td>
<td>P312 / P315 = 200 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P313 / P316 = 10 % / ms</td>
<td>P313 / P316 = 3 % / ms</td>
</tr>
</tbody>
</table>

Fig. 31: Curve for the I component of the current controller

4.5 Setting the no load current

After completion of optimisation of the current controller, the following parameter must be reset accordingly.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P209 (P)</td>
<td>No load current [A]</td>
<td>8.3*</td>
<td>e.g. 5.4 → 0</td>
</tr>
</tbody>
</table>

*) dependent on FL power or P200 / P220
5 Speed control

The speed controller is a PI controller and comprises the two following parameters.

- Speed controller (P310, P311)

The parameter Speed Ctrl P P310 influences the P component of the controller. For the I component the parameter Speed Ctrl I P311 is available.

It is recommended that the following optimisation steps are performed to systematically adjust the speed controller for constant loads.

Overview of optimisation procedure

- Set the I component to a low value

- Set the P component to a low value and e.g. increase in 50 % increments until the Torque current ~P720 has a curve which is as rectangular as possible.
  The Speed encoder ~P735 should have a linearly increasing curve.

- This is followed by the increase of the I component in e.g. 5 % / ms increments, in order to further optimise the rectangular curve of the Torque current ~P720. This optimisation causes a slight overshoot of the speed.

The aim is to optimise the curve for the Torque current ~P720 with the "correct" settings of the P and I components.

The practical implementation for optimisation of a speed controller is described in Section 5.4 "Optimisation procedure".
5.1 Further settings

Instructions

For optimisation of the speed controller, the ramp time must be set under the "Basic Parameters" tab in the parameter Acceleration time P102. In addition the Jog frequency P113 and the Absolute mini. freq. P505 must be parameterised as necessary.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BASIC PARAMETERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P102 (P)</td>
<td>Acceleration time [s]</td>
<td>2.0</td>
<td>2.0 → 0.3 *</td>
</tr>
<tr>
<td>P113 (P)</td>
<td>Jog frequency [Hz]</td>
<td>0.0</td>
<td>0.0 → 50</td>
</tr>
<tr>
<td></td>
<td>EXTRA PARAMETERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P505 (P)</td>
<td>Absolute mini. freq. [Hz]</td>
<td>2.0</td>
<td>2.0 → 0.0</td>
</tr>
</tbody>
</table>

* Notice: this is set without load in the example

Information

Brake applications

For applications with a brake, the parameter Brake reaction time P107 as well as the Brake delay off P114 must be parameterised for the optimisation of the controller.

Otherwise a fault message will occur, as the drive goes into fault status due to the applied brake.

Information

Setpoint / Weak field range

Optimisation of the speed controller must be performed below the weak field range!

Because of this, the setpoint specification must be matched to the design range (70 Hz / 100 Hz – curves). For a standard design according to the 70 Hz characteristic curve the setpoint (frequency) should be approx. 70 % approx. 50 Hz.

For applications with an operating point (100 Hz – Characteristic curve) a setpoint (frequency) in the range of approx. 70 % (i.e. approx. 70 Hz) must be specified.

The weak field range for this application depends on the load and therefore starts above the Nominal frequency P201, i.e. in this case > 70 Hz.

The setting for the Acceleration time P102 must be selected so that if possible, the Torque current ~P720 achieves 50 % - 100 % of the nominal current P203 (see type plate / nominal motor current) with the optimisation.

Setting of the Torque current ~P720 (I_{eq}) sollte mit Hilfe der NORD CON Oszilloskop Funktion vorgenommen werden.

Before starting the scope recording and enabling the drive unit, the setpoint must be set to a value of approx. 70 % of the Nominal frequency P201 (70 Hz), i.e. in this example (frequency inverter 4.0 kW / motor combination 3.0 kW) a setpoint frequency of approx. 50 Hz must be specified.
5.2 NORD CON

Further information about the settings can be obtained from Section 4.2 "NORD CON" and the following.

5.2.1 Remote control

The following setting must be made in the Remote Control screen to optimise the speed controller before starting the scope recordings.

1. Set the setpoint to 70 %, i.e. set the setpoint frequency to approx. 50 Hz
2. Use the + value or the - value button
3. Press the OK button to save the frequency as the jog frequency in P113
4. Press the Enable button

Steps 1, 2, and 3 are not required if a jog frequency has been parameterised.

Fig. 32: Remote control of the speed controller, setpoint and enabling
5.2.2 Oscilloscope

The following settings should be made under the two tabs Recording or Channel Settings of the NORD CON Oscilloscope Function before starting the oscilloscope recordings. The settings and graphic displays in the illustrations may differ according to the frequency inverter types, versions and software status.

1. Set Trigger to Enable

2. Set the scan rate to 5 ms
   - Scan duration 1 s
   - Scan rate depending on the run up time which is set

Note
The scan rate should be selected so that it corresponds to the scope recordings in the illustrations in Section 5.4 "Optimisation procedure!"

Fig. 33: Oscilloscope settings for trigger and scan rate / scan duration

Fig. 34: Resolution settings for the time axis, comment examples

Fig. 35: Oscilloscope channel settings for the four measurement values

3. Press the Start button

Note
Note the initialisation phase, see the illustrations in Section 4.2.2 "Oscilloscope"

Fig. 36: Start the scope recording
5.3 Speed controller

For the speed controller, the \textbf{P} and \textbf{I} component must be changed for the relevant optimisation steps. As the initial for optimisation of the speed controller, for the \textbf{1st optimisation step} the \textbf{P component} (P310) should be set to \textbf{50 \%} and the \textbf{I component} (P311) should be set to \textbf{5 \% \/ ms}.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P310 (P)</td>
<td>Speed Ctrl P [%]</td>
<td>100</td>
<td>( \swarrow 100 \rightarrow 50 )</td>
</tr>
<tr>
<td>P311 (P)</td>
<td>Speed Ctrl I [%/ms]</td>
<td>20</td>
<td>( \swarrow 20 \rightarrow 5 )</td>
</tr>
</tbody>
</table>

The changes to the control parameters must be checked with the \textbf{NORD CON Oscilloscope Function} (see \( \swarrow 4.2 \) "NORD CON").

In the following illustration, the curve for an \textbf{optimally} adjusted speed controller for a 3.0 kW synchronous motor with efficiency class IE4 is shown as the target.

![Example of an optimised speed controller curve](image)

\textbf{Fig. 37: Example of an optimised speed controller curve}

The left-hand detailed illustration shows the almost \textbf{rectangular curve} for the \textbf{Torque current ~P720}, while the acceleration ramp in the right-hand illustration shows a linear increase of the \textbf{Speed encoder ~P735}.

As well as this, in the previous left-hand illustration a slight overshoot can be seen when the setpoint, i.e. the \textbf{Setp. freq after freq. ramp ~P718/2} is reached.

This setting ensures that the motor is fully magnetised when the acceleration ramp is applied.
The display of the required rectangular form of the **Torque current ~P720** curve during the acceleration ramp may differ, as the curve results from the requirements specific to the application.

The following illustration shows the form of the curve of the **P component** of the speed encoder is set **too high**. The value of the **Speed control P P310** which is too high results in oscillation of the **Torque current ~P720**.

Fig. 38: Example with an excessive P component of the speed controller

The next optimisation steps and scope recordings should be carried out as follows:

### Information

**Oscilloscope recording**

If a range is reached in which the changes in the curve cannot be viewed directly, it is advisable to save the oscilloscope recordings. With the facility for displaying several recordings simultaneously a direct comparison with the previous settings is possible.
5.3.1 Speed control P component

Increase the parameter for the P component in 50% increments until the curve for the Torque current ~P720 is as rectangular as possible. The Speed encoder ~P735 should have a linearly increasing curve.

The curve is as illustrated in the second illustration (see 5.3 "Speed controller").

The upper adjustment limit of the Speed Ctrl P P310 is reached, when a further increase of the P component does not result in a better shape of the curve in the sense of a rectangular shape. A setting of the P component which is too high can cause oscillations of the Torque current ~P720 as well as in the Speed encoder ~P735.

Once the P component has been determined, in operation, the controller must be slowly run down from the setpoint frequency (e.g. 50 Hz) to 0 - 3 Hz. It must be checked that during the brake ramp the torque current ~P720 remains free from oscillations.

Among other things, this is used to test whether the P component is set correctly for all speeds.

If the P component is set too high for a selected speed (setpoint specification), this is apparent from oscillations in the Torque current ~P720 and an associated production of noise "scratching noise" during operation or during the movement profile.

5.3.2 Speed controller I component

Beginning from the set starting value [5 % / ms] increase the I component in small increments (e.g. 5 %) until an approximately rectangular curve results for the act. torque current ~P720.

Information

I component increment

If the application has a high inertial mass (relative to the inertia of the motor), the increment should not exceed > 5 % / ms.

If the ratio J_\text{act}\ / \ J_\text{Motor} is small, the increase of the I- component can be performed in larger increments.

The selected increment for the increase of the I component should be in the range from 5 to 20.

As a result of the increase of the I component there is a slight overshoot of the Speed encoder ~P735. If the I component is set too high the rectangular form of the Torque current ~P720 will be distorted upward to the left.

The curve is according to that in the scope recording for Step 6: "I" scope recording 5.4 "Optimisation procedure".

Once the I component has been determined, in operation, the controller must be slowly run down from the setpoint frequency (e.g. 50 Hz) to 0 - 3 Hz. It must be checked that during the brake ramp the Torque current ~P720 remains free from oscillations.

Among other things, this is used to test whether the I component is set correctly for all speeds.

If the I component is set too high for a selected speed (setpoint specification), this is apparent from oscillations in the act. torque current ~P720 and an associated production of noise "scratching noise" during operation or during the movement profile.
5.3.3 Criteria

The following criteria should be noted for optimisation of the field speed controller:

The aim is to optimise the curve for the Torque current \( \sim P720 \) taking the criteria into account, with the "correct" settings of the P and I components.

- The curve for the Speed encoder \( \sim P735 \) should be linear and free from oscillations
- No, or slight oscillation (approx. 3 – 5 %) when the setpoint of the Speed encoder \( \sim P735 \) is reached during optimisation of the I component
- Rectangular form of the Torque current \( \sim P720 \) in the acceleration phase
- No oscillations in the curve for the Torque current \( \sim P720 \) after completion of the acceleration phase
- No "scratching noises" when the drive unit is in operation

During operation there may be a "scratching noise", which is primarily apparent in applications with drive units \( \geq 3 \) kW. If noises are produced, the P or also the I component should be reduced.

### Information

Optimisation steps

The step widths stated for control optimisation may differ depending on the application. Furthermore, the step widths can be selected even finer for the final optimisation steps.

5.4 Optimisation procedure

The following illustrations show the optimisation process for the speed control using the example of a 3.0 kW synchronous motor with efficiency class IE4 on the basis of individual oscilloscope recordings.
<table>
<thead>
<tr>
<th>Legend</th>
<th>Set. freq after freq. ramp</th>
<th>~P718[02]</th>
<th>Speed encoder</th>
<th>~P735</th>
<th>Torque current</th>
<th>~P720</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>&quot;P&quot; scope recording</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter settings</td>
<td></td>
<td>P310 = 50 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P311 = 5 % / ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td>&quot;P&quot; scope recording</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parameter settings</td>
<td></td>
<td>P310 = 100 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P311 = 5 % / ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend**
- Set. freq after freq. ramp
- ~P718[02]
- Speed encoder
- ~P735
- Torque current
- ~P720

**Step 3**
- "P" scope recording
- P310 = 150 %
- P311 = 5 % / ms

**Step 4**
- "P" scope recording
- P310 = 200 %
- P311 = 5 % / ms

**Step 8**
- "P" scope recording
- P310 = 400 %
- P311 = 5 % / ms

**Step 12**
- "P" scope recording
- P310 = 600 %
- P311 = 5 % / ms

**Fig. 39:** Curve for the P component of the speed control

- **P component too high**
- **P component far too high**
5 Speed control

Legend

- Set. freq after freq. ramp ~P718[02]
- Speed encoder ~P735
- Torque current ~P720

<table>
<thead>
<tr>
<th>Step</th>
<th>1. &quot;I&quot; scope recording</th>
<th>2. &quot;I&quot; scope recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter settings</td>
<td>P310 = 200 %</td>
<td>P310 = 200 %</td>
</tr>
<tr>
<td></td>
<td>P311 = 5 % / ms</td>
<td>P311 = 10 % / ms</td>
</tr>
</tbody>
</table>

Fig. 40: Curve for the I component of the speed control
6 Position control

The position control can be used in combination with an encoder to provide a high precision positioning drive. Usually, various encoder systems e.g. incremental encoders or absolute encoders are used to provide speed feedback. These are used as measurement transducers, which convert the rotary movements and positioning data (position) into electrical signals.

The choice of the encoder system depends on the requirements of the application. This includes the following characteristics, such as:

- Encoder type: Absolute or incremental encoder
- Encoder type (TTL, HTL, combination, single-, multiturn) / resolution
- Application type (angle measurement, linear travel measurement)
- Connection method, interface drivers, filed bus system, with cable or plug-in
- Construction and mounting type (flange, shaft, hollow shaft, torque support, etc.)
- Electronic features (power supply, output drivers, etc.)
- Ambient conditions (protection type, temperature, ATEX, etc.)

Information

Encoder selection

HTL incremental encoders (IG) as well as CANopen absolute encoders (AG) can be used for decentralised SK 2xxE frequency encoders. TTL incremental encoders and CANopen absolute encoders can be used for control cabinet frequency inverters ≥ SK 530E.

In addition, for performance level SK 540E, SIN/COS encoders and other absolute encoder types such as Hiperface, Endat, SSI and BISS encoders can be connected to its universal encoder interface.

For detailed information regarding the particular encoder types, please refer to the relevant supplementary manual POSICON Positioning Control, see BU 0210 or BU 0510 9.1 "Manuals".

The following features and integrated frequency inverter functions are available for positioning control:

- Programmable position memory
  - For SK 2x5E there are 63 absolute positions
  - For SK 53xE there are 63 absolute positions
  - For SK 54xE there are 252 absolute positions
- Positions are also maintained with "severe" load fluctuations
- Time-optimised and safe travel up to the target position by means of path calculation function
- In addition to travelling to absolute positions, up to 4 step lengths (so-called position increments) can be stored in the frequency inverter.
- Positions can also be saved in a control unit and specified via an appropriate field bus interface (e.g. CANopen)
- The positions can be transferred to the frequency inverter via a field bus interface
### NOTICE

**Power supply**

Only encoder types with a 10 - 30 V supply may be used for frequency inverter applications.

---

For the **POSICON** positioning function, additional parameters (P6xx) which are required for the position control are available under the **Positioning** tab as a separate menu group.

---

### Information

#### Enabling POSICON

For decentralised SK 2xxE frequency inverters the **Positioning** tab is enabled with the parameter **Supervisor-Code P003** \(3 = \text{All parameters visible}\).

For **SK 530E control cabinet frequency inverters** the **Positioning** tab P6xx is enabled as the default in the factory settings.

---

### Application information

- The positioning function / configuration and control of the frequency inverter as well as the specification of the position setpoint can be made via the
  - Digital inputs
  - Bus IO In Bits
  - USS protocol or a field bus system (e.g. PROFIBUS DP, CANopen etc.)
- Position detection can be performed with incremental or absolute encoders
- Switch-over from **speed control** and **position control** (positioning) using **parameter switch-over**
- **Synchronisation functionality** between master and slave drives (one or more) using the integrated system bus interface
- **Endless axis function** (Modulo axes) for turntables and similar applications (this controls an endless axis) with **optimised path**. The drive unit turns clockwise or anticlockwise according to the required position.

For example, the frequency inverter is controlled using a specified position described by positions which are saved in the frequency inverter. In this example, the specification of the position and enabling of the drive unit is implemented via the BUS IO In bits. An incremental encoder (IG) or a standard CANopen combination absolute encoder as well as other types of rotary encoder (only ≥ SK 540E) can be used for the encoder system.

It is recommended that the following **optimisation steps** are performed to systematically adjust a position controller:

---

### Information

#### Application notes for brake resistor

An external brake resistor was used for the optimisation of the position control described in this guide, see § 2.1 "System components". The selection of an internal or external brake resistor for the SK 2xxE results from the **application requirements**.
Overview of optimisation procedure

- Select the encoder system and parameterise it accordingly
- Connect the encoder system and test the function
- Select and parameterise the interface for the setpoint or position specification
- Set the acceleration and braking ramps, i.e. Acceleration time P102 and Deceleration time P103
- Selection / Specification of the setpoint or target position
- Set the P component to a small value and e.g. increase this in 10% increments until the speed curve is as linear as possible for the Speed encoder =P735. In this case, a limit due to the brake ramp / Deceleration time (P103) should be apparent and effective.
- If the P component is set too high, this is apparent from oscillations of the Speed encoder =P735 in the actual position when braking. In addition there is an overshoot of the Torque current ~P720 in this range. In this case, the P component must be reduced again.

Fig. 41: Position control movement profile

For detailed information regarding the movement profile or the parameters which have to be set, please refer to the relevant supplementary manual POSICON Positioning Control (BU 0210 or BU 0510 see 9.1 "Manuals"). In addition, the relevant parameters are described in Sections 6.4 "Position controller" and 6.4.3 "Positioning".

The aim is to obtain the optimum curve of the movement profile with the "correct" setting of the P component. The Speed encoder ~P735 should follow the braking ramp and should not pass over the setpoint position.

The practical implementation for optimisation of a position controller is described in Section 6.5 "Optimisation procedure".
6 Position control

6.1 Further settings

Instructions

For optimisation of the position controller, the following two parameters must be set in advance. Some of the setting are listed here in order to illustrate the control, position specification and position selection with BUS IO In Bits or the USS interface. However, this may differ according to the application.

Information

The ramp times for the Acceleration time P102, the Deceleration time P103 and the setpoint specification (required speed) result from the requirements of the application. For use of the slow movement function at the end of a positioning procedure, the minimum frequency P104 must be taken into account. This is used during slow movement.

The ramp time must be set under the "Basic Parameters" tab in the parameter Acceleration time P102 and Deceleration time P103.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P102 (P)</td>
<td>Acceleration time [s]</td>
<td>2.0</td>
<td>2.0 → 0.3 *</td>
</tr>
<tr>
<td>P103 (P)</td>
<td>Deceleration time [s]</td>
<td>2.0</td>
<td>2.0 → 0.3 *</td>
</tr>
<tr>
<td>P104 (P)</td>
<td>Minimum frequency [Hz]</td>
<td>0.0</td>
<td>0.0 → ... **</td>
</tr>
</tbody>
</table>

CONTROL TERMINALS

| P480 [-11] | Funct. Bus I/O In Bits Bit 8 Bus control word | 0 | 0 → 55 (Bit 0 position (increment) array) |

ADDITIONAL PARAMETERS

<table>
<thead>
<tr>
<th>P509</th>
<th>Source Control Word</th>
<th>0</th>
<th>0 → 2 (USS) ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>P510 [-01]</td>
<td>Source Setpoints Source main setvalue</td>
<td>0 (Auto)</td>
<td>0 (leave as set) ***</td>
</tr>
<tr>
<td>P510 [-02]</td>
<td>Source Setpoints Source 2nd setpoint</td>
<td>0 (Auto)</td>
<td>0 (leave as set) ***</td>
</tr>
</tbody>
</table>

* To be set according to the specific application (Notice: in this example without load)

** To be set according to the specific application (Note: only relevant for slow running / Pos. Window P612)

*** Leave P510 Source main setvalue at the factory setting (0 = Auto)

Information

Setpoint and position specification

The setpoint specification and the setting of the Position control P600 should correspond to the design range (70 Hz / 100 Hz characteristic curves).

For optimisation of the position control, the setpoint should be selected according to the application requirements!

For the SK 200E frequency inverter / motor combination (4,0 kW) and the supply voltage of 400 V (50 Hz) described in this guide, the function {2 = Lin. ramp (setpoint frequency)} is set and a specified setpoint of e.g. 65 % is selected.
Optimisation of the position control should be made with the aid of the NORD CON oscilloscope function.

Before starting the scope recording and enabling the drive unit, the setpoint is set to 65 % i.e. in this example (frequency inverter 4.0 kW / motor combination 3.0 kW) a setpoint frequency of 45 Hz is specified.

It should be noted that the setpoint position “0” is used as the first specified position. From this, it follows that as the second setpoint position “10”, in parameter position P613, only the array [-01] is to be parameterised!

6.2 NORD CON

Further information about the settings can be obtained from Section 4.2 “NORD CON” and the following.

6.2.1 Control

The following setting must be made in the Control screen to optimise the position controller before starting the scope recordings.

By pressing the button in the “Standard” view, the control screen changes to the “Detail” view.

Fig. 42: Standard control view

Fig. 43: Control of the speed controller, setpoint and enabling
6 Position control

1. Set the setpoint to e.g. 65 %, i.e. the setpoint frequency to 45.5 Hz, using the Value + or Value – button or enter 65 % directly.

2. In the control word, enter the value 047F for Position 0 or press the Start button or enter the value 057F for Position 1.

Alternatively, a further "Detailed Control" view can be opened and used to enter the individual control bits directly.

3. Set Bit 3 ✓ = Enable operation

4. Set Bit 8 ✓ = Specify Position 1 and then set Bit 3 ✓ = Enable operation

Fig. 44: Control of position control, control bits left setpoint position 0, right setpoint position 1
6.2.2 Oscilloscope

The following settings should be made under the two tabs Recording or Channel Settings of the NORD CON Oscilloscope Function before starting the oscilloscope recordings. The settings and graphic displays in the illustrations may differ according to the frequency inverter types, versions and software status.

1. Set Trigger to Enable

2. Set the scan rate to 10 ms
   → Scan duration 2 s
   → Scan rate depending on the run up time which is set

Note
The scan rate should be selected so that it corresponds to the scope recordings in the illustrations in Section 6.5 "Optimisation procedure"!

Fig. 45: Oscilloscope settings for trigger and scan rate / scan duration

Fig. 46: Resolution settings for the time axis, comment examples

Fig. 47: Oscilloscope channel settings for the four measurement values

3. Press the Start button

Note
Note the initialisation phase, see the illustrations in Section 4.2.2 "Oscilloscope"

Fig. 48: Start the scope recording
6.2.3 Device overview

The course of positioning can be observed with the following settings of the three display possibilities in the NORD CON Device Overview function.

Setpoint position 1 reached

Setpoint position 0 is being approached

Fig. 49: Position control device overview, display settings

1. Set Display 1 to actual position,
3. Set Display 3 to Curr. position diff.

Fig. 50: Overview of position control devices, display selection
6.3 Function test of rotary encoders (IG)

Information & instructions

For incremental and absolute encoders, e.g. a CANopen standard combined absolute encoder (AG) with integrated incremental signal track (IG) the function or the detection of the direction of rotation should be checked.

Further information for the function test of the incremental encoder on the relevant frequency encoder is provided in Section 3.5.3 "Function test of rotary encoders (IG)".

In addition, it is advisable to maintain a certain sequence for the commissioning of the CANopen encoder or the function test of the position control. Refer to 3.6.4 "Function test of CANopen encoders (absolute encoders)" for further details.

6.4 Position controller

Information & instructions

For the position controller, the P component must be changed for the relevant optimisation steps.

The 1st optimisation step step for optimising the position controller can be started with the standard setting for the P component (P611).

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, …, P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POSITIONING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P611</td>
<td>P Pos. Control [%]</td>
<td>5</td>
<td>5 (leave at standard)</td>
</tr>
</tbody>
</table>

The changes to the positioning parameters must be checked with the NORD CON Oscilloscope Function (see 4.2 "NORD CON").

In addition, depending on the application, further positioning parameters, e.g. position, ramp criteria, travel measurement system, etc. must also be set.

NOTICE

Position control

In case of a different setting of the position control P600 from the function {0 = Off}, it is essential that under the "Basic Parameters" tab, the factory setting {0 = Voltage disable} is parameterised in the parameters Ramp smoothing P106 and that in the Disconnection mode P108, the function {1 = Ramp down} is parameterised.

This should always be taken into account before setting or parameterising the position control. For positioning, four different variants (functions) are available for the Position Control P600.

For position detection by the position control with a standard combination absolute encoder with a CANopen interface (see Section 2.6 "Selection of absolute encoders"), several parameters must be set under the "Positioning" tab for position detection by the position controller.
6 Position control

6.4.1 Parameterisation of the travel measurement system

For the selection of the travel measurement system or position detection with encoder feedback (CFC Closed-Loop mode), several parameters must be set in the "Positioning" tab according to the encoder system which is used.

For detailed information, please refer to the relevant manual for the frequency inverter, see 9.1 "Manuals" or 3.6.1 "Parameterisation of CANopen encoders (absolute encoders)".

6.4.2 Activating the position control

For activation of the position control or position detection with encoder feedback (CFC Closed-Loop mode) in the "Positioning" tab, the parameter Position control P600 must be set to the function (2 = lin. Ramp (setfreq.)).

CAUTION Enabling of position control

This setting should only be made after the check of the direction of rotation of the encoder has been successfully completed.

Otherwise, unexpected movements (wrong direction of rotation) may result. This may cause both material damage as well as injuries to persons.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POSITIONING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P600 (P) Position Control</td>
<td>0 (Off)</td>
<td>0 → 2 (lin. Ramp (max.freq.)) *</td>
<td></td>
</tr>
</tbody>
</table>

* To be set according to the specific application. Note refer to the information for position control 6.4 "Position controller"

6.4.3 Positioning

For positioning or position control, further parameters are available under the "Positioning" tab, which must be set by the user according to the specific application.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ... , P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POSITIONING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P600 (P) Position Control</td>
<td>0 (Off)</td>
<td>0 → 2 (lin. Ramp (max.freq.)) *</td>
<td></td>
</tr>
</tbody>
</table>

* To be set according to the specific application. Note refer to the information for position control 6.4 "Position controller"
### Drive Optimisation – Guideline for PMSM - CFC Closed-Loop

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P607 [-03]</td>
<td>Ratio (Multiplic set/actual)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P608 [-01]</td>
<td>Reduction (Incremental Enc)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P608 [-02]</td>
<td>Reduction (Absolute encoder)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P608 [-03]</td>
<td>Reduction (Multiplic set/actual)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P609 [-01]</td>
<td>Offset Position (Incr.) [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P609 [-02]</td>
<td>Offset Position (Abs.) [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P610</td>
<td>Setpoint Mode</td>
<td>0</td>
<td>0 (Position Array)</td>
</tr>
<tr>
<td>P611</td>
<td>P Pos. Control [%]</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>P612</td>
<td>Pos. Window [rev]</td>
<td>0</td>
<td>*</td>
</tr>
<tr>
<td>P613 [-01]</td>
<td>Position 1 [rev]</td>
<td>0</td>
<td>💚 0 → 10 **</td>
</tr>
<tr>
<td>P613 [-02]</td>
<td>Position 2 [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P613 [-03] to [-62]</td>
<td>Position 3 to 62 [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P613 [-63]</td>
<td>Position 63 [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P625</td>
<td>Hysteresis relais [rev]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P626</td>
<td>Relais Position [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P630</td>
<td>Position slip error [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P631</td>
<td>Abs/Inc slip error [rev]</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>P640</td>
<td>unit of pos. Value</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

* To be set according to the specific application, also known as slow movement.

Notice: This should be used for large moments of inertia and "backlash" in the gear unit.

** To be set according to the specific application. Note 💚 refer to the information for position control 6.4 "Position controller"

In the following illustration, the curve for an **optimally** adjusted position controller for a 4 kW IE2 motor is shown as the target.

![Graph showing optimised position controller curve](image)

**Fig. 51: Example of an optimised position controller curve**

An almost **oscillation-free curve** for the **Torque current ~P720** can be seen when the setpoint position is reached, as well as a linear form of the **Speed encoder ~P735** without rounding of the ramp when braking.
The following illustrations show the shape of the curve if the **P component** of the position control is set "too high" and "too low". Setting the value of the **Position Control P611** too low causes **ramp rounding** of the **Speed encoder ~P735** when the setpoint position is reached. A value which is set too high causes an **overshoot** of the **Speed encoder ~P735** and a visible **oscillation** of the **Torque current ~P720** when the setpoint position is reached.

![Graph showing curve progression](image)

**Fig. 52: Example with P component of the position control too small (left) and too high (right)**

The next optimisation steps and scope recordings should be carried out as follows:

<table>
<thead>
<tr>
<th>Information</th>
<th>Oscilloscope recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>If a range is reached in which the changes in the curve cannot be viewed directly, it is advisable to save the oscilloscope recordings. With the facility for <strong>displaying several recordings simultaneously</strong> a <strong>direct comparison</strong> with the previous settings is possible.</td>
<td></td>
</tr>
</tbody>
</table>
6.4.4 Position control P component

Increase the parameter for the P component in 10 % increments until the Speed encoder \( \sim P735 \) has a curve which linear as possible and which follows the braking ramp. In addition, ramp rounding for the brake process of the Speed encoder \( \sim P735 \) should no longer be visible.

The correct setting of the P component of the position controller depends on the dynamic characteristics of the system as a whole. Rule of thumb: the greater the masses and the smaller the friction if the system, the greater is the tendency of the system to oscillate and the smaller is the maximum possible P amplification.

The curve is as illustrated in the first illustration (see \( \Box \) 6.4 "Position controller").

The upper adjustment limit of the P Pos. Control 611 is reached, when a further increase of the P component does not result in a better shape of the curve. If the P component is set too high, this causes an overshoot of the Speed encoder \( \sim P735 \) when the setpoint position is reached.

To determine the critical value, the P component is increased until the drive unit oscillates about the position (leave the position and then approach it again).

Recommended guide value: Then set the P component from 0.5 to 0.7 times this value.

For POSICON applications with a subordinate speed control (Servo Mode P300 {1 = ON (CFC closed-loop)) use of a setting which deviates from the standard setting of the speed control is usually to be recommended for applications with large masses.

For the P component of the speed control a value of 100 to 150% should be set in the parameter Speed Ctrl P P310. As the I component in the parameter Speed Ctrl I P311, a value of between 3 % / ms and 5 % / ms has proved to be effective.

6.4.5 Criteria

The following criteria should be noted for optimisation of the field position controller:

- The aim is to optimise the curve for the Torque current \( \sim P720 \) taking the criteria into account, with the "correct" setting of the P component.

  - The curve for the Speed encoder \( \sim P735 \) should be linear and follow the braking ramp
  - No overshoot of the Speed encoder \( \sim P735 \) when the setpoint position is reached
  - No ramp rounding of the Speed encoder \( \sim P735 \) during braking or in the braking ramp
  - No oscillation of the Torque current \( \sim P720 \) should be evident when the setpoint position is reached

Information

Optimisation steps

The step widths stated for control optimisation may differ depending on the application. Furthermore, the step widths can be selected even finer for the final optimisation steps.
6.5 Optimisation procedure

The following illustrations show the optimisation process for the position control using the example of a 3.0 kW synchronous motor with efficiency class IE4 on the basis of individual scope recordings.

<table>
<thead>
<tr>
<th>Legend</th>
<th>Actual position 32bit Low =P601</th>
<th>Speed encoder ≈P735</th>
</tr>
</thead>
<tbody>
<tr>
<td>Act. ref. pos. 32bit Low =P602</td>
<td>Torque current ≈P720</td>
<td></td>
</tr>
</tbody>
</table>

**Instructions**

Step 1. "P" scope recording
Parameter settings: P611 = 5%

Step 2. "P" scope recording
Parameter settings: P611 = 15%

Step 3. "P" scope recording
Parameter settings: P611 = 25%

Step 4. "P" scope recording
Parameter settings: P611 = 35%

Step 5. "P" scope recording
Parameter settings: P611 = 45%

Step 9. "P" scope recording
Parameter settings: P611 = 85%

Fig. 53: Curve for the P component of the position control
7  Reluctance torque

Step 7

Information

For applications in which an even and sufficiently high load is moved, i.e. a load > 0.5 MN, by setting the parameter Servo mode P300 to the function \{1 = CFC Closed-Loop\}, the approximate reluctance angle, see parameter Reluctance angle IPMSM P243, can be determined.

Experimental determination must always be carried out below the weak field range and should only be carried out for IPMSM drives. With gradual adjustment of the parameter Reluctance angle IPMSM P243 the corresponding current change must be observed in the parameter Actual current P719 and must be adjusted until the current reaches the minimum value.

Note

Determination or optimisation of the reluctance torque must not be carried out in the weak field range.

The smaller the reluctance angle, the smaller the reluctance component of the synchronous motor with embedded magnets, i.e. for so-called IPMSM drives.

For further information regarding the reluctance torque or angle, please refer to Section 3.3.2 "NORD – Motor type plates / Data sheet"

The determination should then be carried out according to the following procedure after optimisation of the controller has been carried out (see Section 4, 5 und 6).

Overview of optimisation procedure

- Set the Reluctance angle IPMSM P243 to an initial value of 0° and increase this in increments of 1° or 2°, until the Actual current P719 reaches a minimum under constant operating and load conditions.

- Optimum adjustment of the Reluctance angle IPMSM P243 has been achieved if no improvement of the shape of the curve can be obtained by increasing the value. A curve as shown in Figure 1 or Figure 27.3 "Reluctance angle".

- For the optimisation, care must be taken that the setpoint which is selected corresponds to the design point or the load conditions!

The objective is to achieve the minimum Actual current P719 under nominal load conditions by the "correct" setting of the reluctance angle.

The practical implementation for optimisation of the slip compensation is described in Section 7.4 "Optimisation procedure".
7.1 Further settings

For the determination or optimisation of the reluctance torque, all parameters of the

- Particular controller optimisation (see previous section) must be optimised
- All of the corresponding parameters for the application-specific requirements

must be optimised in advance.

### Information

All parameters which are to be set in advance, as well as the setpoint specification (required speed) result from the application requirements. When setting the Acceleration time P102, care must be taken that the frequency inverter does not enter the current limit (Warning C004 = Overcurrent measured).

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P113 (P)</td>
<td>Jog frequency [Hz]</td>
<td>0.0</td>
<td>☑ 0.0 → 65.0</td>
</tr>
<tr>
<td>Speed control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P300 (P)</td>
<td>Servo mode</td>
<td>0 (Off = VFC Open-Loop)</td>
<td>☑ 1 (On = CFC Closed-Loop)</td>
</tr>
</tbody>
</table>

Setting or optimisation of the reluctance angle should be carried out using observation of the Actual current (P719) e.g. with the aid of the NORD CON oscilloscope function.

Before starting the scope recording and enabling the drive unit, the setpoint must be set to a value which corresponds to the requirements of the application or the designed operating point. I.e. in this example (frequency inverter 4.0 kW / motor combination 3.0 kW) a setpoint frequency of e.g. 65 HZ must be specified.
7.2  NORD CON

Information & instructions

Further information about the settings can be obtained from Section 4.2 "NORD CON" and the following.

7.2.1 Remote control

The following setting must be made in the Remote Control screen to optimise the reluctance torque before starting the scope recordings.

1. Set the setpoint to e.g. 92%, i.e. set the setpoint frequency to approx. 65 Hz
2. Use the + value or the - value button
3. Press the OK button to save the frequency as the jog frequency in P113
4. Press the Enable button

Steps 1, 2, and 3 are not required if a jog frequency has been parameterised.

Fig. 54: Remote control of the reluctance torque setpoint and enabling

7.2.2 Device overview

Optimisation can be carried out with the following settings of the three display possibilities in the NORD CON Device Overview function.

1. Set Display 1 to Current frequency
2. Set Display 2 to act. torque current
3. Set Display 3 to actual current

Fig. 55: Reluctance torque device overview, display settings
Fig. 56: Slip compensation device overview, display options

7 Reluctance torque
7.3 Reluctance angle

To determine the reluctance torque, the reluctance angle must be changed for the various optimisation steps.

As the initial for optimisation of the reluctance torque for the 1st optimisation step the reluctance angle should be set to 0 ° in the parameter Reluctance angle IPMSM P243.

<table>
<thead>
<tr>
<th>Parameter No. [-Array]</th>
<th>Name [Unit]</th>
<th>Factory setting</th>
<th>Setting related to parameter set (P1, ..., P4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P243 (P)</td>
<td>Reluctance angle IPMSM [°]</td>
<td>10</td>
<td>☑ 0 → optimal</td>
</tr>
</tbody>
</table>

With constant load, the Reluctance angle IPMSM P243 must be optimised until the Actual current P719 is at a minimum.

A value for the reluctance angle which is not optimally set causes an increased current consumption of the drive unit under the same load conditions. Optimisation should always be carried out under nominal load operation and at the designed operating conditions (operating mode, operating temperature, load conditions etc.).

The following diagram / illustration shows the optimum setting for the Reluctance angle IPMSM P243:

![Diagram](image)

Fig. 57: Diagram for optimum current / reluctance angle IPMSM

The changes to the reluctance angle must be checked with the NORD CON Oscilloscope Function (‗4.2 "NORD CON").
In the following illustration, the curve for an **optimally** adjusted reluctance angle for a 3.0 kW IPMSM synchronous motor (third party motor) is shown as the target.

![Graph showing optimised reluctance angle](image)

**Fig. 58**: Example of an optimised reluctance angle

The **optimum curve** for the *Torque current =P720* at the operating point under nominal load conditions is illustrated.

The following illustrations show the shape of the curve if the **reluctance angle** is set "**too high**" and "**too low**". The value for the **Reluctance angle IPMSM P243** which is set too high or too low causes an increased *Torque current =P720* or an increase in the current consumption of the motor.

![Graph showing reluctance angle set too high and too low](image)

**Fig. 59**: Example with the reluctance angle set too high (right) and too low (left)

The next optimisation steps and scope recordings should be carried out as follows:

<table>
<thead>
<tr>
<th>Information</th>
<th>Oscilloscope recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>If a range is reached in which the changes in the curve cannot be viewed directly, it is advisable to save the oscilloscope recordings. With the facility for <strong>displaying several recordings simultaneously</strong> a direct <strong>comparison</strong> with the previous settings is possible.</td>
<td></td>
</tr>
</tbody>
</table>
7.3.1 Reluctance angle value

Increase or reduce the parameter for the Reluctance angle IPMSM P243 in e.g. 1° or 2° increments until the Actual current P719 reaches the lowest possible minimum e.g. during the acceleration ramp for movement applications.

The curve is as illustrated in the first Illustration (7 “Reluctance torque”).

The optimum setting of the Reluctance angle IPMSM P243 has been achieved, when a further increase or decrease of the value does not result in a better shape of the curve (in the sense of the minimum current). A value which is set “too low” or “too high” always causes an increase of the Torque current =P720.

7.3.2 Criteria

The following criteria should be noted for optimisation of the reluctance angle:

The objective is to achieve a minimum Torque current = P720 with the "correct" setting of the reluctance angle.

- For movement applications, the curve for the Torque current = P720 during the acceleration ramp under nominal load should reach a minimum.

Information

Optimisation steps

The increments stated for the optimisation of the reluctance torque may differ depending on the application. In addition, the increments can be selected even finer for the final optimisation steps.
7.4 Optimisation procedure

The following illustrations show the optimisation process of the reluctance angle IPMSM using the example of a 3.0 kW synchronous motor (third party motor) on the basis of individual scope recordings.
Legend

<table>
<thead>
<tr>
<th>Setpoint</th>
<th>Speed encoder</th>
</tr>
</thead>
<tbody>
<tr>
<td>~P718[02]</td>
<td>=P735</td>
</tr>
<tr>
<td>Torque current</td>
<td>Actual current</td>
</tr>
<tr>
<td>=P720</td>
<td>=P719</td>
</tr>
</tbody>
</table>

### Step 1
1. Scope recording
Parameter settings:
- \( P243 = 1^\circ \)

### Step 2
2. Scope recording
Parameter settings:
- \( P243 = 2^\circ \)

### Step 3
3. Scope recording
Parameter settings:
- \( P243 = 3^\circ \)

### Step 8
8. Scope recording
Parameter settings:
- \( P243 = 8^\circ \)

### Step 9
9. Scope recording
Parameter settings:
- \( P243 = 9^\circ \)

### Step 12
12. Scope recording
Parameter settings:
- \( P212 = 12^\circ \)

---

Fig. 60: Graph of reluctance angle IPMSM
8 Parameter lists

8.1 Basic Commissioning

![Parameter List](image.png)

Fig. 61: Parameter list for basic commissioning
### 8.2 Current control

**Parameter List**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>Select of disp. value</td>
<td>Setpoint frequency [2]</td>
<td></td>
<td></td>
<td></td>
<td>Hz</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
<td>Supervisor-Code</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>Maximum frequency</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>Hz</td>
</tr>
<tr>
<td>0</td>
<td>201</td>
<td>Nominal frequency</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>Hz</td>
</tr>
<tr>
<td>0</td>
<td>202</td>
<td>Nominal speed</td>
<td>2100</td>
<td>1445</td>
<td>1445</td>
<td>1445</td>
<td>rpm</td>
</tr>
<tr>
<td>0</td>
<td>203</td>
<td>Nominal current</td>
<td>6.4</td>
<td>8.3</td>
<td>8.3</td>
<td>8.3</td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>204</td>
<td>Nominal voltage</td>
<td>380</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>V</td>
</tr>
<tr>
<td>0</td>
<td>205</td>
<td>Nominal power</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>kW</td>
</tr>
<tr>
<td>0</td>
<td>206</td>
<td>Cosphi</td>
<td>0.92</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>207</td>
<td>Stator Delta con.</td>
<td>0.01</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>208</td>
<td>Stator resistance</td>
<td>1.44</td>
<td>3.44</td>
<td>3.44</td>
<td>3.44</td>
<td>Ohm</td>
</tr>
<tr>
<td>0</td>
<td>209</td>
<td>No Load Current</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>240</td>
<td>EMF voltage PMSM</td>
<td>341</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>0</td>
<td>241</td>
<td>Inductivity PMSM[1]</td>
<td>22.5</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>mH</td>
</tr>
<tr>
<td>0</td>
<td>241</td>
<td>Inductivity PMSM[2]</td>
<td>15.3</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>mH</td>
</tr>
<tr>
<td>0</td>
<td>244</td>
<td>Reluct. angle IPMSM</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>244</td>
<td>Peak current PMSM</td>
<td>14</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>A</td>
</tr>
<tr>
<td>0</td>
<td>246</td>
<td>Mass Inertia PMSM</td>
<td>16.9</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>kg*cm²</td>
</tr>
</tbody>
</table>

**Speed control**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>301</td>
<td>Incremental encoder</td>
<td>2048</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>312</td>
<td>Torque curr. ctrl. P</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>312</td>
<td>Torque curr. ctrl. I</td>
<td>5</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>315</td>
<td>Field curr. ctrl. P</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>315</td>
<td>Field curr. ctrl. I</td>
<td>5</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>330</td>
<td>Regulation PMSM</td>
<td>Value CANopen enc. [3]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>334</td>
<td>Encoder offset PMSM</td>
<td>0.491</td>
<td></td>
<td></td>
<td></td>
<td>rev</td>
</tr>
</tbody>
</table>

**Control clamps**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>420</td>
<td>digit input[2]</td>
<td>No function [3]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>420</td>
<td>digit input[3]</td>
<td>No function [3]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Extra functions**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>501</td>
<td>Inverter name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Fig. 62: Parameter list for optimised current control page 1
### Parameter List

**Device Name:** Offline parameterize  
**Device Type:** 2xIE 4,0kW/400V  
**Database:** optimized torque / field controller NORD IE4 10CT2-4  
**Filter:** Release: Off, No standard value: On, Info parameter: No, Supervisor: Yes

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>504</td>
<td>0</td>
<td>Encoder Type</td>
<td>CANopen ID 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>505</td>
<td>0</td>
<td>Absolute encoder 1</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>Bit</td>
</tr>
<tr>
<td>505</td>
<td>1</td>
<td>Absolute encoder 2</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td>Bit</td>
</tr>
</tbody>
</table>

**Parameter Number:** 32

**Legend**

- Parameter does not depend on the parameter set  
- [ ] The value is invalid

---

*Fig. 63: Parameter list for optimised current control page 2*
### 8.3 Speed control

**Parameter List**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Operating displays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Select of disp.value</td>
<td>Set point frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Supervisor-Code</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>0</td>
<td>Acceleration time</td>
<td>0.3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>s</td>
</tr>
<tr>
<td>105</td>
<td>0</td>
<td>Maximum frequency</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>Hz</td>
</tr>
<tr>
<td>113</td>
<td>0</td>
<td>Jog frequency</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>Hz</td>
</tr>
<tr>
<td>201</td>
<td>0</td>
<td>Nominal frequency</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>Hz</td>
</tr>
<tr>
<td>202</td>
<td>0</td>
<td>Nominal speed</td>
<td>2100</td>
<td>1445</td>
<td>1445</td>
<td>1445</td>
<td>rpm</td>
</tr>
<tr>
<td>203</td>
<td>0</td>
<td>Nominal current</td>
<td>5.4</td>
<td>8.3</td>
<td>8.3</td>
<td>8.3</td>
<td>A</td>
</tr>
<tr>
<td>204</td>
<td>0</td>
<td>Nominal voltage</td>
<td>206</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>V</td>
</tr>
<tr>
<td>205</td>
<td>0</td>
<td>Nominal power</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>kW</td>
</tr>
<tr>
<td>206</td>
<td>0</td>
<td>Cos phi</td>
<td>0.92</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>207</td>
<td>0</td>
<td>Stator Delta.</td>
<td></td>
<td>Stator {[1]}</td>
<td>Delta {[1]}</td>
<td>Delta {[1]}</td>
<td></td>
</tr>
<tr>
<td>208</td>
<td>0</td>
<td>Stator resistance</td>
<td>1.44</td>
<td>3.44</td>
<td>3.44</td>
<td>3.44</td>
<td>Ohm</td>
</tr>
<tr>
<td>209</td>
<td>0</td>
<td>No Load Current</td>
<td>0</td>
<td>4.4</td>
<td>4.4</td>
<td>4.4</td>
<td>Ohm</td>
</tr>
<tr>
<td>240</td>
<td>0</td>
<td>EMF voltage PMSM</td>
<td>341</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>A</td>
</tr>
<tr>
<td>241</td>
<td>0</td>
<td>Inductivity PMSM[1]</td>
<td>22.8</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>mH</td>
</tr>
<tr>
<td>242</td>
<td>1</td>
<td>Inductivity PMSM[2]</td>
<td>45.9</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>mH</td>
</tr>
<tr>
<td>243</td>
<td>0</td>
<td>Reluct. angle PMSM</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>244</td>
<td>0</td>
<td>Peak current PMSM</td>
<td>14</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>A</td>
</tr>
<tr>
<td>245</td>
<td>0</td>
<td>Mass Inertia PMSM</td>
<td>46.8</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>kg*m²</td>
</tr>
<tr>
<td>300</td>
<td>0</td>
<td>Servo Mode</td>
<td>On (CFC closed loop) {[1]}</td>
<td>Off (VFC open loop) {[3]}</td>
<td>Off (VFC open loop) {[3]}</td>
<td>Off (VFC open loop) {[3]}</td>
<td></td>
</tr>
<tr>
<td>301</td>
<td>0</td>
<td>Incremental encoder</td>
<td>20kHz {[1]}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>310</td>
<td>0</td>
<td>Speed Ctrl P</td>
<td>200</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>%</td>
</tr>
<tr>
<td>312</td>
<td>0</td>
<td>Torque curr. ctrl. P</td>
<td>200</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>%</td>
</tr>
<tr>
<td>313</td>
<td>0</td>
<td>Torque curr. ctrl. I</td>
<td>5</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>%/ms</td>
</tr>
<tr>
<td>315</td>
<td>0</td>
<td>Field curr. ctrl. P</td>
<td>200</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>%</td>
</tr>
<tr>
<td>316</td>
<td>0</td>
<td>Field curr. ctrl. I</td>
<td>5</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>%/ms</td>
</tr>
<tr>
<td>330</td>
<td>0</td>
<td>Regulation PMSM</td>
<td>Value CAM value enc. {[3]}</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>334</td>
<td>0</td>
<td>Encoder offset PMSM</td>
<td>0.491</td>
<td></td>
<td></td>
<td></td>
<td>rev</td>
</tr>
<tr>
<td>421</td>
<td>0</td>
<td>digit inputs[2]</td>
<td>No function {[0]}</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>422</td>
<td>0</td>
<td>digit inputs[3]</td>
<td>No function {[0]}</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>501</td>
<td>0</td>
<td>Inverter name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 64: Parameter list for optimised speed control page 1
### Parameter List

**Device Name:** Offline parameterize  
**Device Type:** 20xLE 4.0kW/400V  
**Database:** Optimized speed controller NORD IE4-10072-L

**Filter:** Release: Off, No standard value: On, Info parameter: No, Supervisor: Yes

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>905</td>
<td>0</td>
<td>Absolute min. freq.</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Hz</td>
</tr>
</tbody>
</table>

**Positioning**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>904</td>
<td>0</td>
<td>Encoder type</td>
<td>CANopen abs. [1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>905</td>
<td>0</td>
<td>Absolute encoder(1)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>905</td>
<td>1</td>
<td>Absolute encoder(2)</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend**

- Parameter does not depend on the parameter set
- The value is invalid

---

**Fig. 65: Parameter list for optimised speed control page 2**
8.4 Position control

![Parameter List](image_url)

**Fig. 66: Parameter list for optimised position control page 1**
### Parameter List

**Device Name:** Offline parameterize  
**Device Type:** 20kE 1,00kW/400V  
**Database:** Optimized position controller NORD IE4 100T2-4  
**Filter:** Release: Off, No standard value: On, Info parameter: No, Supervisor: Yes

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>460</td>
<td>19</td>
<td>Func. Basic In Bit(11)</td>
<td>50.0 Prop. Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>501</td>
<td>0</td>
<td>Inverter name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>0</td>
<td>Source control word</td>
<td>UDC [2]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Positioning**

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0</td>
<td>Position Control</td>
<td>In: ramp (off/on) [2]</td>
<td>Off [0]</td>
<td>Off [0]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>004</td>
<td>0</td>
<td>Encoder type</td>
<td>CA open abs. [1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>005</td>
<td>0</td>
<td>Absolute encoder(1)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>005</td>
<td>1</td>
<td>Absolute encoder(2)</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>011</td>
<td>0</td>
<td>P Pos Control</td>
<td>96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>012</td>
<td>0</td>
<td>position(1)</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parameter Number: 41

---

Legend

- Parameter does not depend on the parameter set
- The value is invalid

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---

Fig. 67: Parameter list for optimised position control page 2
8.5 Reluctance torque

![Parameter List](image)

**Fig. 68: Parameter list for optimised reluctance angle page 1**
### Parameter List

<table>
<thead>
<tr>
<th>Nr</th>
<th>Index</th>
<th>Parameter Name</th>
<th>Parameter Set 1</th>
<th>Parameter Set 2</th>
<th>Parameter Set 3</th>
<th>Parameter Set 4</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Extra functions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>501</td>
<td>0</td>
<td>Inverter name</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source control word</td>
<td>USG [2]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>600</td>
<td>0</td>
<td>Position Control</td>
<td>Lin.Rampe(Sollfrequenz) [2]</td>
<td>Aus [0]</td>
<td>Aus [0]</td>
<td>Aus [0]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Encoder type</td>
<td>CANopen absolut [1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>605</td>
<td>0</td>
<td>Absolute encoder(1)</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>Bit</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Absolute encoder(2)</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td>Bit</td>
</tr>
<tr>
<td>611</td>
<td>0</td>
<td>P Pos. Control</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>913</td>
<td>0</td>
<td>Position[i]</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>rev</td>
</tr>
</tbody>
</table>

**Legend**

- Parameter does not depend on the parameter set
- The value is invalid

---

Fig. 69: Parameter list for optimised reluctance angle page 2
9 Further documentation

Information

In case of queries and for further information regarding this document, please contact Electronics Support at Getriebebau NORD GmbH & Co. KG.

On request, further information which is required, e.g. technical data sheets which are not available under www.nord.com - Documentation can be made available to users after technical consultation.

9.1 Manuals

<table>
<thead>
<tr>
<th>Document</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>BU 0000</td>
<td>NORD CON Software Manual (the Help function of the software should preferably be used)</td>
</tr>
<tr>
<td>BU 0200</td>
<td>SK 200E – Manual</td>
</tr>
<tr>
<td>BU 0210</td>
<td>POSICON for SK 200E - Manual</td>
</tr>
<tr>
<td>BU 0500</td>
<td>SK 5xxE – Manual (SK 500E ... SK 535E)</td>
</tr>
<tr>
<td>BU 0505</td>
<td>SK 54xE – Manual (SK 540E ... SK 545E)</td>
</tr>
<tr>
<td>BU 0510</td>
<td>POSICON for SK 500E – Position Control Manual ≥ SK 530E</td>
</tr>
</tbody>
</table>

Table 7: Manuals

9.2 Technical Information / Data Sheets

9.3 TIs - Guidelines

<table>
<thead>
<tr>
<th>Document</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tl 80_0010</td>
<td>Planning and Commissioning Guide for IE4 motors operated with frequency inverters</td>
</tr>
</tbody>
</table>

Table 8: TIs - Guidelines

9.3.1 TIs – Incremental encoder (IG)

<table>
<thead>
<tr>
<th>Document</th>
<th>Name</th>
<th>Supplier / Type</th>
<th>Part No.</th>
<th>Data sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enquiries to Service</td>
<td>Incremental encoder IG4 4096, TTL, 5 V, 1.5 m</td>
<td>Fritz Kübler GmbH 8.5820.0H10.xxxx.5093.xxxx</td>
<td>19551020</td>
<td>A0838_3_8.5820.0H1 0.0000.5093.0000.png</td>
</tr>
<tr>
<td>Enquiries to Service</td>
<td>Incremental encoder IG4 4096, TTL, 10 - 30 V, 1.5 m</td>
<td>Fritz Kübler GmbH 8.5820.0H30.xxxx.5093.xxxx</td>
<td>19551021</td>
<td>A1495_1_8.5820.0H3 0.0000.5093.0000.png</td>
</tr>
<tr>
<td>Enquiries to Service</td>
<td>Incremental encoder IG4 4096, HTL, 10 - 30 V, 1.5 m</td>
<td>Fritz Kübler GmbH 8.5820.0H40.xxxx.5093.xxxx</td>
<td>19551022</td>
<td>A1451_0_8.5820.0H4 0.0000.5093.0000.png</td>
</tr>
</tbody>
</table>

Table 9: TIs – Incremental encoder (IG)
### TIs - CANopen absolute encoder (AG)

<table>
<thead>
<tr>
<th>Document</th>
<th>Name</th>
<th>Supplier / Type</th>
<th>Part No.</th>
<th>Data sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>Absolute encoder with incremental track AG6 CANopen, Single / Multiturn 8192-65K/2048 HTL</td>
<td>Baumer IVO GmbH &amp; Co. KG GXMMS.Z18</td>
<td>19556994</td>
<td>AZ4654-1.PDF</td>
</tr>
<tr>
<td>Service</td>
<td>Absolute encoder with incremental track AG3 CANopen, Single / Multiturn 8192-65K/2048 TTL</td>
<td>Baumer IVO GmbH &amp; Co. KG GXMMS.Z10</td>
<td>19556995</td>
<td>AZ3903-1.PDF</td>
</tr>
</tbody>
</table>

Table 10: TIs - CANopen absolute encoder (AG)

### TIs - Options / Accessory components

<table>
<thead>
<tr>
<th>Document</th>
<th>Name</th>
<th>Supplier / Type</th>
<th>Part No.</th>
<th>Data sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>RJ 45 WAGO connection module</td>
<td>WAGO Kontakttechnik GmbH RJ45 connection 24 V + CANopen</td>
<td>278910300</td>
<td>in preparation</td>
</tr>
</tbody>
</table>

Table 11: Options and accessory components
# 10 Appendix

## 10.1 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AG</td>
<td>Absolute encoder</td>
</tr>
<tr>
<td>ASM</td>
<td>Asynchronous machine / motors</td>
</tr>
<tr>
<td>BG</td>
<td>Size</td>
</tr>
<tr>
<td>CAN</td>
<td>Controller Area Network</td>
</tr>
<tr>
<td>CANopen</td>
<td>International standardised protocol</td>
</tr>
<tr>
<td>CFC</td>
<td>Current Flux Control</td>
</tr>
<tr>
<td>DIN</td>
<td>Digital input</td>
</tr>
<tr>
<td>ENC</td>
<td>Special encoder extension</td>
</tr>
<tr>
<td>SCD</td>
<td>Schematic circuit diagram</td>
</tr>
<tr>
<td>FI</td>
<td>Frequency inverter</td>
</tr>
<tr>
<td>HTL</td>
<td>High Transistor Logic</td>
</tr>
<tr>
<td>IE1</td>
<td>Efficiency class of standard motors</td>
</tr>
<tr>
<td>IE2</td>
<td>Efficiency class of motors with higher efficiency</td>
</tr>
<tr>
<td>IE4</td>
<td>Efficiency class of motors with even higher efficiency, e.g. synchronous motors</td>
</tr>
<tr>
<td>IG</td>
<td>Incremental encoder</td>
</tr>
<tr>
<td>IO</td>
<td>Input / Output</td>
</tr>
<tr>
<td>IPMSM</td>
<td>Interior Permanent Magnet Synchronous Motor</td>
</tr>
<tr>
<td>P</td>
<td>Parameter</td>
</tr>
<tr>
<td>PI controller</td>
<td>Proportional-integral controller</td>
</tr>
<tr>
<td>POSICON</td>
<td>Positioning control</td>
</tr>
<tr>
<td>SK</td>
<td>Schlicht &amp; Küchenmeister</td>
</tr>
<tr>
<td>SPMSM</td>
<td>Surface Permanent Magnet Synchronous Motor</td>
</tr>
<tr>
<td>SSI</td>
<td>Synchronous Serial Interface</td>
</tr>
<tr>
<td>TI</td>
<td>Technical Information / Data Sheet (Data sheet for NORD accessories)</td>
</tr>
<tr>
<td>TTL</td>
<td>Transistor-Transistor Logic</td>
</tr>
<tr>
<td>VFC</td>
<td>Voltage Flux Control</td>
</tr>
</tbody>
</table>
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Headquarters and Technology Center
in Bargteheide close to Hamburg, Germany

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**Headquarters:**
Getriebebau NORD GmbH & Co. KG
Getriebebau-Nord-Straße 1
22941 Bargteheide, Germany
Fon +49 (0) 4532 / 289-0
Fax +49 (0) 4532 / 289-2253
info@nord.com, www.nord.com

Member of the NORD DRIVESYSTEMS Group