Planning and Commissioning Guideline for NORD IE4 Motors with NORD Frequency Inverters

General Information

From their basic function, motors with efficiency class IE4 are **synchronous motors** and are suitable for operation with frequency inverters. Due to their high efficiency, they offer the advantage of energy saving, especially for continuous operation applications. However, from the point of view of efficiency, it is **always** necessary to consider the system as a whole.

- Frequency inverters have an efficiency of > 95 %. With process optimization, the use of frequency inverters can provide energy savings which greatly offsets the losses of the individual devices (e.g. speed control for pumps instead of the use of throttle valves).
- For the selection of the gear unit, in addition to the operating factor (f_B) the viability of the motor-gear unit combination is also important, especially for the combination with high efficiency motors (IE4). Higher operating factors result in higher operating reliability, but on the other hand may also cause considerably higher losses. There are also considerable differences in the efficiencies of the various gear unit types.

NORD IE4 Motors

At present, NORD supplies motors with efficiency class IE4 in the power range 1.1 kW – 5.5 kW (Sizes 80 – 100).

The motors are self-ventilated, and have stator housings which are identical to asynchronous motors and unrestricted attachment facilities for all options and gear unit combinations. The terminal box is identical to that for standard motors and the 6-pole terminal board can be connected as usual in a star or delta circuit using the appropriate bridges.

NORD IE4 motors are synchronous motors with permanent magnets in the rotor package. These are inserted into recesses (so-called IPSM: integrated permanent magnet synchronous motor) and therefore require less magnetic material (cost) in comparison with SPMSM (surface permanent magnets on the surface of the rotor, as in conventional servo motors).

A synchronous motor cannot be started or operated with the mains supply, but rather can only be operated with a frequency inverter (indicated by a safety label). All NORD frequency inverters can operate NORD IE4 motors.

In principle, NORD IE4 motors can be operated with inverters from other manufacturers. Several devices from our competitors have been successfully tested with our motors. 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 inverter and its function and settings.

Synchronous motors from other manufacturers can theoretically also be operated with NORD frequency inverters, however, this option must be investigated in advance. If necessary, a test motor must be measured at our headquarters (consultation is essential).

NORD IE4 motors are not servo motors. Due to the rise times and electrical time constants, the dynamic characteristics are comparable with those of IE1 or IE2 motors.

As synchronous motors, IE4 motors do not have any load-dependent slip. NORD motors are designed for 2 different nominal speeds:

1. 2100 rpm at 70 Hz, 400 V star or 230 V delta.
2. 3000 rpm with 100 Hz, 400 V. For this the motor is connected in a delta circuit and theoretically operated with 70 Hz x 1.71 = 121 Hz (comparable with the 87 Hz characteristic curve for 50 Hz motors). However, as 121 Hz operation generates a high level of noise (fan) and makes the assignment of gear units more difficult, the operating point for the type is specified as *100 Hz, 400 V delta*.

Both operating points are described in the catalogues and are stamped on the type plate or can be found in the motor selection tables of the NORD inverters.

In addition, the type plate provides information about the motor stator resistance R_S, the stator inductances L_d and L_q as well as the value of the induction voltage (U_{EMK}). This information is necessary in order to program the inverter.

Motor type code using the example of an 80T1/4

80 T 1 /4

/4	Number of poles	**/4** = 4-pole)
1	Package length	**1** … 9: **The coding depends on the length and the frame size**
T	Winding type	**T** = 2100 / 3000 rpm
80	Motor size (frame size)	**80**, 90, 100

Motor-inverter assignment

Size	M_N [Nm]	P_N [kW]	n_N [rpm]	I [A]	η	J [kgm²]	m [kg]	M_{max} [Nm]	K_T [Nm/A]	k_F [mV/rpm]	FI assignment
80T1/4	5.0	1.1	2100	2.03	90.5	0.0011	8.0	14.4	2.5	154	-111-123- -111-323- -111-340-
80T1/4 Δ	4.8	1.5	3000	3.44	90.4	0.0011	8.0	14.4	1.4	89	-151-340-
90T1/4	6.8	1.5	2100	2.82	89.9	0.0019	10.0	21.0	2.4	156	-151-323- -151-340-
90T1/4 Δ	7.0	2.2	3000	5.09	89.6	0.0019	10.0	21.0	1.4	90	-221-340-
90T3/4	10	2.2	2100	4.13	90.5	0.0024	12.0	29.0	2.4	158	-221-323- -221-340-
90T3/4 Δ	9.5	3.0	3000	6.84	92.3	0.0024	12.0	29.0	1.4	91	-301-340-
100T2/4	13.6	3.0	2100	5.4	91.4	0.0046	18.0	42.0	2.6	161	-301-340- -301-340-
100T2/4 Δ	12.7	4.0	3000	8.9	92.1	0.0046	18.0	42.0	1.5	93	-401-340-
100T5/4	18.2	4.0	2100	7.1	92.1	0.0060	21.0	57.0	2.6	165	-401-340- -401-340-
100T5/4 Δ	17.5	5.5	3000	11.9	92.2	0.0060	21.0	57.0	1.5	95	-551-340-

Information

Motor power vs. Inverter power

The assignment of the inverter → motor is primarily made according to power.

Due to the characteristic curves, in some cases a NORD inverter with a higher power must be assigned to the motor.

Overloads or dynamic start-stop applications may require the use of an inverter with a higher power. For a 1:1 assignment of the motor to the inverter, up to 2x the nominal torque is possible. In theory, the motor itself can produce up to 3 times the nominal torque (when starting and in the limited speed range); a continuous overload of a factor 1.4 is possible (above 10 Hz).

Operating modes

The operation of synchronous motors has the following relevant differences in comparison with asynchronous motors:

- No mains operation:

  NORD IE4 motors can only be operated with inverters.

- Weak field range:

  NORD IE4 motors cannot, or can only be operated to a very limited extent in the weak field range. By their rotation, the permanent magnets in the rotor induce a voltage in the stator, which opposes the terminal voltage. The induced voltage is proportional to the speed of the motor and reduces the effective terminal voltage. This reduces the available torque. In addition, there is a danger that falling loads in lifting gear may damage the inverter due to the voltages induced by the high speed of the motor.

- Inverter functions:

  Certain inverter functions, e.g. DC braking are not available.

IE4 motors can be operated with various types of control by the inverter.

VFC open-loop mode	CFC open-loop mode	CFC closed-loop mode
• Applications with linear or quadratic load characteristic curves • Ramp times ≥ 1 s (0.5 s) • Maximum torque 50…150 % M_N according to speed • Torque rise time ≥ 250 ms	• Applications with constant, linear or quadratic load torques • Ramp times ≥ 0.25 s • Maximum torque 100…200 % M_N according to speed • Torque rise times ≥ 150ms (from approx. n = 10 % n_n)	• All types of application, including lifting equipment • Ramp times ≥ 0.05 s (0 s) • Maximum torque up to 300 % M_N independent of speed • Torque rise times ≥ 100 ms
Fields of application		
• Pumps without starting torque • Compressors, fans • Certain mixers	• Material handling with starting torque • Pumps and fans with moderate starting torque	• Lifting gear • Handling machines • Dynamic material handling
Special features		
The precise motor data must be known!	Operation with the SK 180E is not possible due to the restricted current measurement. The precise motor data must be known!	CFC closed-loop mode requires the use of encoders and therefore an inverter which has the facility to evaluate encoders. Low sensitivity to RS, L and U_{EMK}.errors. The rotor position must be known (absolute encoder) or must be determined (see description).

The details above are based on application experience by NORD.

Commissioning

1. Check the selection of the inverter with regard to the motor.
2. Check the selection of the inverter with regard to operating mode/encoders.
3. Check the motor circuit with regard to the characteristic curve and (inverter) mains voltage.
4. Inverter and motor connection as known.
5. Observe the safety information according to the operating instructions and work instruction.
6. Connect the mains supply.
7. Parameterisation of the inverter can be carried out with
   - SimpleBox,
   - ParameterBox (Firmware version V4.6R1 or higher, or in ControlBox mode)
   - NORD CON (Version 2.5 or higher or ControlBox Mode)
8. In P200 the relevant IE4 motor can be selected from the list. This ensures that the motor data are set correctly *A stator resistance measurement P220 = 1 is recommended.*
9. PMSM only:
   a. Select the control method (P330)
   b. Make the settings for the starting behaviour (P331 … P333)
   c. Make the settings for the 0 pulse of the encoder P334 … P335)
   d. Activation of slip error monitoring (P327 ≠ 0)

   VFC open loop mode (pumps, fans), P300 = 0

   a. See ISD control with ASM, however with lower dynamic characteristics
   b. From starting, up to the frequency according to P247 (switch-over frequency vfc) a current is applied, which reduces linearly as the frequency increases up to P245 in order to force the rotor to follow. The normal setting is 25 % of the nominal frequency. The amount of current can be influenced via P210 (stat. boost) (-> low starting torques = P210 < 100 %).
   c. No control parameters need to be set, however, the precise motor data, in particular RS, L and U_{EMK} are required.
   d. For stable operation, suitable damping of oscillations is necessary (P245), which quickly increases or reduces the frequency for dynamic load changes.

   CFC open-loop mode, P300 = 2
   (Material handling and pumps with starting torque, moderate dynamics)

   a. From 0 – 10 % of the synchronous speed, operation is in vfc mode (switch-over point P331, hysteresis P332, by the application of current, the rotor is forced to follow). The applied current is constant up to the frequency P331 and not linearly reducing as for vfc. In the hysteresis range, the current falls to the value in P208 (usually 0).
   b. Although this is an open loop mode, the current and speed controllers must be set.

   CFC closed-loop mode, P300 = 1
   (lifting equipment, dynamic movements)

   Operation is comparable with that of an asynchronous motor with encoder feedback → *"Servo mode"*

   a. Setting of the current and speed controller is necessary.

Possible encoder systems

- Incremental encoder without zero track:

  A method of determining the initial position of the rotor is necessary, (see below); electrically the measurement precision only achieves approx. +/- 3 - 10, so that there is a somewhat limited performance (unfavourable current-torque ratio).

- Incremental encoder with zero track (Nordac Flex, Nordac Link)):

  Connection of zero pulse to DIN1 (Flex, Link)
  For P420 [1] setting:42/43 see BU
  A method of determining the initial position of the rotor is necessary in order to control operation until the first zero point is passed (see below);
  The zero pulse corrects the error tolerance of the zero point determination process.
  For the factory setting of the zero track, the torque arm must be fitted on the motor side (B bearing cover or star plate), encoder offset P334 = 0.
  If the encoder is not synchronised, or has come out of adjustment due to an impact or removal of the motor, the zero track of the encoder must be synchronised to the rotor position (see Determination of Offset).
  Incremental encoders with the torque arm on the fan cover CANNOT be adjusted at the factory.

- Absolute/incremental combination encoders

  do not require determination of the initial position (due to the absolute signal), the synchronisation of the gear unit is adjusted by NORD prior to delivery of the geared motor and does not require determination of the offset. If the encoder is not synchronised, or has come out of adjustment due to an impact or removal of the motor, the zero track of the encoder must be synchronised to the rotor position (see Determination of Offset).
  It is essential to enable slip error monitoring (P327/P328).

Determination of the initial rotor position

(for incremental encoders, this is required each time that the mains supply is switched on or after zero pulse evaluation)

a. By the test signal method (P330 = 1): Determination of the rotor position by test measurement (duration approx. 1 second).
b. By the resting method (P330 =0, voltage control); the voltage forces the rotor into the zero position and therefore aligns the motor. This method is only possible for horizontal application or for torque-free drive units without motor braking. (NB: The shaft rotates)

Offset determination

(for incremental encoders with zero track or absolute measurement systems)

The following procedure is suitable for the synchronisation of the zero position of the encoder system with the zero position of the rotor:

a. Set the torque limit to approx. 100%.
b. Slowly rotate the drive unit and check the value U_d.
c. Adjust the value of P33 until a minimum voltage is achieved. A minimum must be found, which is the same for both directions of rotation of the motor.