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# Planning and Commissioning Guideline for NORD IE4 Synchronous 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 synchronous 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 Synchronous 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 synchronous motors are equipped 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 synchronous motors.

In principle, NORD synchronous 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 PMSM 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.

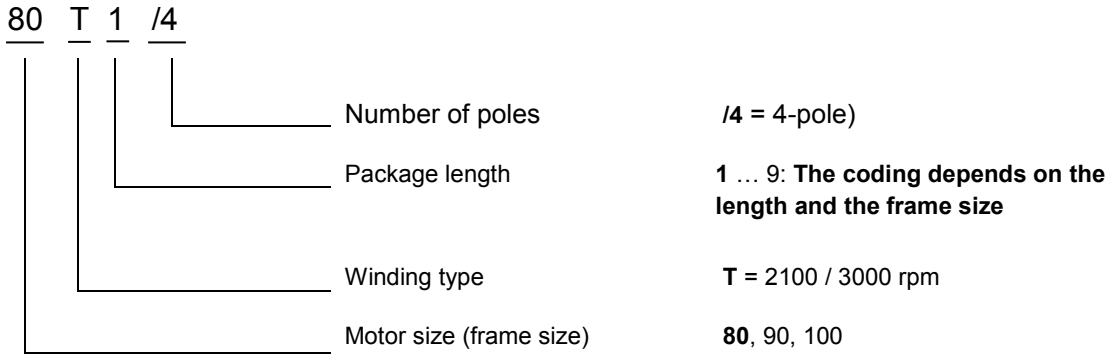
As synchronous motors, they do not have any load-dependent slip. NORD motors are designed for 2 different nominal speeds:

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**



**Motor - inverter assignment**

The following assignment of the motors to the particular frequency inverters applies for operation up to the nominal speed. Higher speeds and overloads require corresponding application planning.

| Size | $M_N$ [Nm] | $P_N$ [kW] | $n_N$ [rpm] | I [A] | η | J [kgm²] | m [kg] | $M_{max}$ [Nm] | $K_T$ [Nm/A] | $K_E$ [mV/rpm] | FI assignment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 80T1/4 | 5.0 | 1.1 | 2100 | 2.07 | 90.5 | 0.0011 | 8.0 | 14.4 | 2.5 | 154 | -111-123-<br>-111-323-<br>-111-340- |
| 80T1/4 HM | 3.41 | 0.75 | 2100 | 1.46 | 90.5 | 0.0011 | 7.8 | 14.4 | 2.3 | 154 | -111-123-<br>-111-323-<br>-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-<br>-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-<br>-221-340- |
| 90T3/4 HM | 5.0 | 1.1 | 2100 | 2.08 | 92.7 | 0.0024 | 11.6 | 28.3 | 2.4 | 156 | -151-323-<br>-151-340- |
| 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 | -301-323-<br>-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 | -401-323-<br>-401-340- |
| 100T5/4 HM | 10.0 | 2.2 | 2100 | 4.16 | 91.0 | 0.0060 | 20.2 | 53.5 | 2.4 | 165 | -301-323-<br>-301-340- |
| 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:

For IE4 smooth motors (HM) assignment of the inverter is carried out as for separate inverters (e.g. NORDAC *PRO* in control cabinet) for encoder feedback.

Overloads or dynamic applications may require assignment 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 provide up to 3x the nominal torque (when starting and in the limited speed range).

Continuous overload with a factor 1.4 is possible above 10 Hz (however this does not apply for IE4 smooth motors (HM)).

### Operating modes

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

- No mains operation:

  NORD synchronous motors can only be operated with inverters.

- Weak field range:

  NORD synchronous 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.

Various types of control are supported by operation on the inverter.

| VFC open-loop mode | CFC open-loop mode | CFC closed-loop mode |
|---|---|---|
| • Applications with linear or quadratic load characteristic curves<br>• low dynamics<br>• Maximum torque 50…150 % $M_N$ according to speed<br>• Torque rise time ≥ 250 ms | • Applications with constant, linear or quadratic load torques<br>• medium dynamics<br>• Maximum torque 100…200 % $M_N$ according to speed<br>• Torque rise times ≥ 150ms<br>(from approx. n = 10 % $n_n$) | • All types of application, including lifting equipment<br>• high dynamics<br>• Maximum torque up to 300 % $M_N$ independent of speed<br>• Torque rise times ≥ 100 ms |
| **Fields of application** | | |
| • Pumps without starting torque<br>• Compressors, fans<br>• Certain mixers | • Material handling with starting torque<br>• Pumps and fans with moderate starting torque | • Lifting gear<br>• Handling machines<br>• 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.<br>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.<br>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 NORD synchronous 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. Select the control method (P330):

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

   - From starting, up to the frequency according to P247 (switch-over frequency vfc PMSM) a current is applied, which reduces linearly as the frequency increases in order to force the rotor to follow (the usual setting is 25 % of the nominal frequency). The amount of current can be influenced via P210 (static boost) (→ low starting torques = P210 < 100 %).
   - No control parameters need to be set, however the precise motor data, in particular RS, L and $U_{EMK}$ are required.
   - For stable operation, suitable damping of oscillations is necessary (P245), which quickly increases or reduces the frequency for dynamic load changes.
   - When starting, the motor may briefly rotate in the opposite direction.

   ***CFC open-loop mode, P300 = 2***
   (moderate dynamics)

   - From 0 – 10 % of the synchronous speed operation is in CFC open-loop mode. In the hysteresis range, the current falls to the value in P209 (usually 0), after which the speed is determined from the current and the operating characteristics are improved by means of speed control.
   - Control parameters can be set, however the precise motor data, in particular RS, L and $U_{EMK}$ are required.

   ***CFC closed-loop mode, P300 = 1***
   (high dynamics)

   - Slip error monitoring required P337 + P338
   - 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).
  - It is essential that slip error monitoring is enabled (P327/P328).

  - Due to the incremental measuring method, it is advisable to reference the drive at frequent intervals. This can be performed by resetting the voltage. After a slip error message, this occurs automatically.

- Incremental encoder with zero track (NORDAC *FLEX*, NORDAC *LINK*)
  - Connection of the zero track to digital input 1.
  - Setting of P420[-01] = 42/ 43 (refer to relevant manual).
  - 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.
  - If the incremental encoder is not synchronised, or has come out of adjustment due to an impact or removal of the motor, the zero track of the incremental encoder must be synchronised to the rotor position. For this, an offset is set in P334.
  - Incremental encoders with the torque arm on the fan cover **cannot** be adjusted at the factory.
  - It is essential that slip error monitoring is enabled (P327/P328).
  - Due to the incremental measuring method, it is advisable to reference the drive at frequent intervals. If P420[-01] = 43 is used, this can be performed by resetting the voltage, with P420[-01] = 42 it is sufficient to remove the enabling. After a slip error message, this occurs automatically.

- Absolute/incremental combination encoders
  - Absolute/incremental encoders do not require determination of the starting position (due to the absolute signal). The encoder is adjusted by NORD prior to delivery of the geared motor and does not require determination of the offset.
  - If the incremental encoder is not synchronised, or has come out of adjustment due to an impact or removal of the motor, the zero position of the encoder must be adjusted.
  - It is essential that slip error monitoring is enabled (P327/P328).

**Determination of the initial rotor position**

With incremental encoders, determination of the zero rotor position is necessary each time that the mains voltage is switched on or after certain inverter errors.

a. By the test signal method (P330 = 1)

   Determination of the rotor position by test measurement (duration approx. 1 second). With P212, the current which is used for measurement can be amplified, in order to achieve better results under unfavourable conditions.

b. By the resting method (P330 =0, voltage controlled). The voltage forces the rotor into the zero position and therefore aligns the motor. This method is only possible for horizontal application e.g. for torque-free drive units without motor braking (NB: The shaft turns with this method).

The information in the relevant manuals must be observed.

Reference to document AG 0101 is recommended for setting and optimising the controller.