Basic Motor Technology

ABB Motors
Basic Motor Technology
for ABB Motors’ totally enclosed, fan cooled, three-phase squirrel cage motors.

This catalogue includes basic technical information about the electrical and mechanical design of standard motors. General specifications stated in the international standards for electrical machines are also included.

Information about the electrical and mechanical design of Ex-motors, open drip proof motors IP 23, slip-ring motors, brake motors, single-phase motors and other special motors can be found in respective product catalogues. The contact information for obtaining catalogues and brochures is on the back cover.

ABB Motors reserves the right to change the design, technical specification and dimensions, without prior notice.
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## Standards

### General

ABB motors are of the totally enclosed, three phase squirrel cage type complying with International IEC-standards, CENELEC, relevant VDE-regulations and DIN-standards. Motors are also available conforming to other national and international specifications.

All ABB Motors European production units are certified according to ISO 9001, an international quality standard. ABB Motors conform to the applicable EEC Directives.

<table>
<thead>
<tr>
<th>Title</th>
<th>IEC</th>
<th>DIN</th>
<th>VDE</th>
<th>CENELEC</th>
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</thead>
<tbody>
<tr>
<td>General specifications for electrical machines</td>
<td>IEC 34-1</td>
<td>DIN VDE 0530 pt. 1</td>
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<td>Insulating materials</td>
<td>IEC 85</td>
<td>DIN VDE 0530 pt. 1</td>
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<td>Designations of terminals and sense of rotation of electrical machines</td>
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<td>Built-in thermal protection</td>
<td>IEC 34-11</td>
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<td>Starting characteristics of three phase squirrel cage motors at 50 Hz up to 660 V</td>
<td>IEC 34-12</td>
<td>DIN VDE 0530 pt. 12</td>
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<td>Dimensions and output series for rotating electrical machines³</td>
<td>IEC 72-1</td>
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<td>Dimensions and correlation of output ratings, mounting arrangements IM B3</td>
<td>-</td>
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<tr>
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<td>DIN 42673 pt. 4</td>
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<tr>
<td>Dimensions and correlation of output ratings, mounting arrangements IM B5</td>
<td>-</td>
<td>DIN 42677 pt. 2</td>
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<td>Classification of degrees of protection provided by enclosures of rotating machines</td>
<td>IEC 34-5</td>
<td>DIN VDE 0530 pt. 5</td>
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<td>Symbols for types of construction and mounting arrangements of rotating electrical machines</td>
<td>IEC DIN 34 pt. 7</td>
<td>-</td>
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<tr>
<td>Mounting flanges for electrical machinery</td>
<td>-</td>
<td>DIN 42948</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>True running of the shaft ends, concentricity and true axial running of the mounting flanges of rotating electrical machines</td>
<td>-</td>
<td>DIN 42955</td>
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<td>-</td>
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<td>Cylindric shaft ends for electrical machines</td>
<td>IEC 72-1</td>
<td>DIN 748 pt. 3</td>
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<td>IEC DIN 34-6</td>
<td>-</td>
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<tr>
<td>Noise limits for rotating electrical machines</td>
<td>IEC 34-9</td>
<td>DIN VDE 0530 pt. 9</td>
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<td>Rules for electric equipment for hazardous areas</td>
<td>-</td>
<td>DIN -EN 50019 / DIN-en 50014/</td>
<td>VDE 0171 pt. 6</td>
<td>-</td>
</tr>
</tbody>
</table>

³ The fixing dimensions of ABB Motors product conform to international standards and tolerances with the exception of flange perpendicularity in machines with aluminium frames.
Degree of protection

The standard degree of enclosure protection for ABB totally enclosed motors, according to IEC 34-5, DIN 40050, is IP 55. Higher degrees of protection, e.g. IP 56, are available for some types on request.

Cooling

The totally enclosed fan cooled motors are frame surface cooled by means of an external fan; the method of cooling being IC 411 as defined in IEC 34-6.

Mounting arrangements

Mounting arrangements are according to IEC 34-7.

Examples of designations according to Code II*

<table>
<thead>
<tr>
<th>IM</th>
<th>1</th>
<th>00</th>
<th>1</th>
</tr>
</thead>
</table>

Designation for International Mounting

Type of construction, foot-mounted motor, with two bearing end shields

Mounting arrangement, horizontal mounting, with feet downwards, etc.

External shaft extension, one cylindrical shaft extension, etc.

IEC 34-7 specifies two ways of stating how a motor is mounted.

*Code I covers only motors with bearing end shields and one shaft extension.

*Code II is a general code.

The table on page 6 includes the designations for the most commonly encountered mounting arrangements, according to the two codes.

In addition to these designations, the designation IM..8. also occurs. This indicates that the motor shall operate in all mounting positions, according to IM ..0. to IM ..7.
| Code I: | IM B 3 | IM V 5 | IM V 6 | IM B 6 | IM B 7 | IM B 8 |
| Code II: | IM 1001 | IM 1011 | IM 1031 | IM 1051 | IM 1061 | IM 1071 |

**Foot-mounted motor:**

| Code I: | IM B 5 | IM V 1 | IM V 3 | *) | *) | *) |
| Code II: | IM 3001 | IM 3011 | IM 3031 | (IM 3051) | (IM 3061) | (IM 3071) |

**Flange-mounted motor. Large flange with clearance fixing holes:**

| Code I: | IM B 14 | IM V 18 | IM V 36 | *) | *) | *) |
| Code II: | IM 3601 | IM 3611 | IM 3631 | (IM 3651) | (IM 3661) | (IM 3671) |

**Flange-mounted motor. Small flange with tapped fixing holes:**

| Code II: | IM 2101 | IM 2111 | IM 2131 | IM 2151 | IM 2161 | IM 2171 |

**Modified versions**

| Code I: | IM B 34 | IM 2101 |
| Code II: | IM 2111 | IM 2131 | IM 2151 | IM 2161 | IM 2171 |

**Foot- and flange-mounted motor: with feet, large flange, clearance fixing holes:**

| Code I: | IM 1002 | IM 1012 | IM 1032 | IM 1052 | IM 1062 | IM 1072 |

**) Not stated in IEC 34-7.
D-end and N-end

According to IEC 34-7, the ends of a motor are defined as follows: D-end: the end that is normally the drive end of the motor. N-end: the end that is normally the non-drive end of the motor.

Direction of rotation

The cooling of the motors is independent of the direction of rotation, with the exception of some larger 2-pole motors.

If the mains supply is connected to the stator terminals, which are marked U, V and W, of a three phase motor and the phase sequence of the mains is L1, L2, L3, the motor will rotate clockwise, as viewed from the D-end. To reverse the direction of rotation, interchange any two of the three conductors connected to the starter switch or motor.

Dimensions and power standards

CENELEC harmonisation document, HD 231, lays down data for rated output and mounting, i.e. shaft height, fixing dimensions and shaft extension dimensions, for various degrees of protection and sizes. It covers totally enclosed squirrel cage motors at 50 Hz, in frame sizes 56 to 315 M.

<table>
<thead>
<tr>
<th>Motor size</th>
<th>Shaft extension diameter</th>
<th>Rated output</th>
<th>Flange number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 poles mm</td>
<td>4,6,8 poles mm</td>
<td>2 poles kW</td>
</tr>
<tr>
<td>56 63 71</td>
<td>9 11 14</td>
<td>9 11 14</td>
<td>0.09 or 0.12</td>
</tr>
<tr>
<td>80</td>
<td>19 24</td>
<td>19 24</td>
<td>0.75 or 1.1</td>
</tr>
<tr>
<td>90 S 90 L</td>
<td>24 24</td>
<td>22 22</td>
<td>1.5</td>
</tr>
<tr>
<td>100 L</td>
<td>28 28</td>
<td>3 4</td>
<td>2.2 or 3</td>
</tr>
<tr>
<td>112 M</td>
<td>28 28</td>
<td>3 4</td>
<td>1.5</td>
</tr>
<tr>
<td>132 S 132 M</td>
<td>38 38</td>
<td>5.5 or 7.5</td>
<td>5.5</td>
</tr>
<tr>
<td>160 M 160 L</td>
<td>42 42</td>
<td>11 or 15</td>
<td>11</td>
</tr>
<tr>
<td>180 M 180 L</td>
<td>48 48</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>200 L</td>
<td>55 55</td>
<td>30 or 37</td>
<td>30</td>
</tr>
<tr>
<td>225 S 225 M</td>
<td>55 60</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>250 M</td>
<td>60 65</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>315 S 315 M</td>
<td>65 80</td>
<td>110</td>
<td>110</td>
</tr>
</tbody>
</table>

ABB Motors
Insulation and insulation classes

According to IEC 85, insulating materials are divided into insulation classes. Each class has a designation corresponding to the temperature that is the upper limit of the range of application of the insulating material under normal operating conditions.

The winding insulation of a motor is determined on the basis of the temperature rise in the motor and the ambient temperature. The insulation is normally dimensioned for the hottest point in the motor at its normal rated output and at ambient temperature of 40 °C. Motors subjected to ambient temperatures above 40 °C will generally have to be derated.

In most cases, the standard rated outputs of motors from ABB Motors are based on the temperature rise for insulation class B. Where the temperature rise is according to class F, this is specified in the data tables.

However, all the motors are designed with class F insulation, which permits a higher temperature rise than class B. The motors, therefore, have a generous overload margin. If temperature rise to class F is allowed, the outputs given in the tables can generally be increased by about 12 %.

Temperature limits are according to standards. The extra thermal margin when using class F insulation with class B temperature rise makes the motors more reliable.

Terminal markings

IEC 34-8 lays down that the stator winding, its parts and the terminals of AC motors, must be designated with letters U, V and W. External neutral terminals are designated N. The letters used for the rotor winding are K, L, M and Q. End points and intermediate points of a winding are indicated by a digit after the letter, e.g. U1, U2 etc. Parts of the same winding are designated by a digit before the letter, e.g. 1U1, 2U1 etc. If there is no possibility of confusion, the digit before the letter, or both, may be omitted.

Connection of three phase, single speed motors

Δ-connection

Y-connection
Connection of two-speed motors

Two-speed motors are normally connected as shown below; direction of rotation as shown on page 7. Motors of normal design have six terminals and one earth terminal in the terminal box. Motors with two separate windings are normally Δ/Δ-connected. They can also be Y/Y, Y/Δ or Δ/Y connected. Motors with one winding, Dahlander-connection, are connected Δ/YY when they are designed for constant torque drives. For fan drive the connection is Y/YY.

A connection diagram is supplied with every motor.

1. Two separate windings Y/Y

2. Two separate windings Δ/Δ

3. Dahlander-connection Δ/YY  Constant torque drive

4. Dahlander-connection Y/YY  Fan drive
## Symbols and Units

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Units</th>
<th>Relationship within the new SI-system</th>
<th>Correlation between the old and new system of units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>P</td>
<td>W</td>
<td>1 W = 1 J/s = 1 Nm/s = 1 VA</td>
<td>1 ps = 735.5 W = 75 kpm/s = 1 hp = 746 W</td>
</tr>
<tr>
<td>Voltage</td>
<td>U</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>I</td>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance</td>
<td>R</td>
<td>Ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td>f</td>
<td>Hz</td>
<td>1 Hz = 1/s</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>n</td>
<td>r/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mass</td>
<td>m</td>
<td>g</td>
<td>1 kg = 1000 g</td>
<td>1 t = 1000 kg</td>
</tr>
<tr>
<td>Moment of inertia, (old flywheel effect WR^2)</td>
<td>J</td>
<td>kgm^2</td>
<td>J = 1/4 WR^2</td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>E</td>
<td>J</td>
<td>1 J = 1 Nm = 1 Ws</td>
<td></td>
</tr>
<tr>
<td>Force</td>
<td>F</td>
<td>N</td>
<td>1 N = 1 kgm/s^2</td>
<td>1 kp = 9.81 N = 10 N</td>
</tr>
<tr>
<td>Torque</td>
<td>T</td>
<td>Nm</td>
<td>1 Nm = 1 kgm^2/s^2</td>
<td>1 kpm = 9.81 Nm</td>
</tr>
<tr>
<td>Temperature</td>
<td>t</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference in temperature</td>
<td>ΔT</td>
<td>K</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conversion factors for table data:

- 1 kW = 1.34 hp
- 1 Nm = 0.102 kpm
- J = 1/4 GD^2 kgm^2

## Characteristics and Tolerances

The following tolerances apply to product catalogue table values, as stated in IEC 34-1 (in reference to guaranteed values).

### Power Factor

The power factor is determined by measuring the input power, voltage and current at the rated output. The table values are subject to a standard tolerance of

- \( -1/6 \ (1 - \cos \phi) \) Minimum 0.02 Maximum 0.07
Voltage and frequency

The table values for output, speed, efficiency, power factor, starting torque and starting current apply at the rated voltage and frequency. These values will be affected if the supply voltage or frequency deviate from the rated values.

The motors can operate continuously at the rated output, with a long-term voltage deviation of 5 % from the specified value or range of values, and at the rated frequency. The temperature rise may increase by 10 K. Voltage deviations of up to 10 % are permissible for short periods only.

Starting current

The standard tolerance on the table values for starting current is + 20 % of the current (no lower limit).

Speed, slip

The speed of motors applies at the rated output and operating temperature. The standard tolerance on the slip is ±20 % of the guaranteed slip. With regard to overspeed, the normal testing speed is 120 % of rated speed for 2 minutes.

The slip is defined by the formula:

\[
s = \frac{n_s - n}{n_s}
\]

s = slip
n_s = synchronous speed
n = operating speed

At part load the slip varies approximately in proportion to the output.

Efficiency

The efficiency at rated output, rated voltage and rated frequency is determined on the basis of bearing and friction losses, iron losses, resistance losses and stray losses (summation of losses).

The table values are subject to standard tolerance in accordance with IEC as follows, with the efficiency expressed per units:

- 15 % (1 - η) when P > 50 kW
- 10 % (1 - η) when P > 50 kW.

Torque

The maximum torque and the overload capacity, at rated voltage and rated frequency, is at least 160 % of the rated torque. The data tables state the maximum torque of each motor variant. If a higher maximum torque is required, a larger motor should be chosen.

If the mains voltage deviates from the rated voltage of the motor, the torque of the motor will vary, approximately in proportion to the square of the voltage. It is therefore vital that the cables supplying the motor are dimensioned generously, to ensure that there is no significant voltage drop during starting or when the motor is running.

\[
T = \frac{9550 \cdot P}{n} \text{Nm}
\]

T = torque, Nm
P = output power, kW
n = motor speed, r/min

The standard tolerance of the table values for starting torque is -15 to +25 %.

The standard tolerance on the table values for maximum torque is -10 %.
Typical motor current and torque curves

- $T_M$ - motor torque
- $T_{MD}$ - motor torque with direct-on-line starting
- $T_{MY}$ - motor torque with star-delta starting
- $T_L$ - load torque
- $T_{LO}$ - load breakaway torque
- $T_N$ - rated motor torque
- $T_s$ - breakaway torque or locked rotor torque
- $T_{min}$ - pull-up torque
- $T_{max}$ - breakdown torque or pull-out torque
- $T_{acc}$ - accelerating torque
- $I$ - current
- $I_N$ - rated current
- $I_{Δ}$ - current in Δ-connection
- $I_Y$ - current in Y-connection
- $n$ - speed
- $n_s$ - synchronous speed.
Electrical design

Starting of motors

Direct-On-Line starting (D.O.L.)

The simplest way to start a squirrel cage motor is to connect the mains supply to the motor, directly. In such cases, the only starting equipment needed will be a direct-on-line (D.O.L.) starter. The starting current is high with this method, so it has its limitations. This is, however, the preferred method, if there are no special reasons for avoiding it.

Y/Δ-starting

If it is necessary to restrict the starting current of a motor due to supply limitations, it is possible to employ star/delta starting, e.g. a motor wound 380 V Δ is started with the winding Y connected. By this method the starting current will be reduced to about 30% of the value for direct start and the starting torque will be reduced to about 25% of the D.O.L. value.

However, it must be determined whether the reduced motor torque is sufficient to accelerate the load over the whole speed range.

Starting time

The starting current of an induction motor is always very much higher than the rated current, and an excessively long starting period causes a harmful temperature rise in the motor. The high current also leads to electromechanical stresses. Catalogues usually state a longest starting time that is a function of motor size and speed. There is now a standardised requirement in IEC 34-12; instead of starting time, this specifies the permitted moment of inertia of the driven machine. For small motors the thermal stress is greatest in the stator winding, whilst for large motors it is greatest in the rotor winding.

If the torque curves for the motor and the load are known, the starting time can be calculated by integrating the equation:

\[ T - T_L = (J_M + J_L) \cdot \frac{d\omega}{dt} \]

where

- \( T \) = motor torque, Nm
- \( T_L \) = load torque, Nm
- \( J_M \) = moment of inertia of motor, kgm²
- \( J_L \) = moment of inertia of load, kgm²
- \( \omega \) = motor angular velocity

If only the starting torque and maximum torque of the motor and the nature of the load are known, the starting time can be approximately calculated with the equation:

\[ t_{st} = \left(\frac{K_1}{T_{acc}}\right) \cdot \frac{J_M + J_L}{T_L} \]

where

- \( t_{st} \) = starting time
- \( T_{acc} \) = acceleration torque as per diagrams, Nm
- \( K_1 \) = as per table below:

<table>
<thead>
<tr>
<th>Speed</th>
<th>Constant 2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>Frequency Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>n_M</td>
<td>3000</td>
<td>1500</td>
<td>1000</td>
<td>750</td>
<td>600</td>
<td>50</td>
</tr>
<tr>
<td>K_1</td>
<td>345</td>
<td>157</td>
<td>104</td>
<td>78</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>n_M</td>
<td>3600</td>
<td>1800</td>
<td>1200</td>
<td>900</td>
<td>720</td>
<td>60</td>
</tr>
<tr>
<td>K_1</td>
<td>415</td>
<td>188</td>
<td>125</td>
<td>94</td>
<td>75</td>
<td></td>
</tr>
</tbody>
</table>

This method of calculation may be used for direct-on-line starting and for motors up to about 250 kW. In other cases, more points on the motor torque curves are required, in any case up to the point of maximum torque.

If there is gearing between the motor and the driven machine, the load torque must be recalculated for the motor speed, by insertion in the following formula:

\[ T'_L = \frac{T_L \cdot n_L}{n_M} \]

where

- \( T'_L \) = recalculated load torque, Nm
- \( n_M \) = motor speed, r/min
- \( n_L \) = load speed, r/min

The moment of inertia must also be recalculated:

\[ J'_L = J_L \cdot \left(\frac{n_M}{n_L}\right)^2 \]

where \( J'_L \) = recalculated moment of inertia, kgm²
Example of starting performance with different load torques

4-pole motor, 160 kW, 1475 r/min

Torque of motor:
\[ T_N = 1040 \text{ Nm}, \]
\[ T_s = 1.7 \times 1040 = 1768 \text{ Nm}, \]
\[ T_{\text{max}} = 2.8 \times 1040 = 2912 \text{ Nm} \]

Moment of inertia of motor: \( J_M = 2.5 \text{ kgm}^2 \)

The load is geared down in a ratio of 1:2

Torque of load:
\[ T_L = 1600 \text{ Nm at } n_l = \frac{n_M}{2} \text{ r/min} \]
\[ T_{L}' = 1600 \times \frac{1}{2} = 800 \text{ Nm at } n_M \text{ r/min} \]

Example 1:

- Lift motion

\[ T_L = 1600 \text{ Nm} \quad T_{L}' = 800 \text{ Nm} \]

Constant during acceleration
\[ T_{\text{acc}} = 0.45 \times (T_s + T_{\text{max}}) - T_{L}' \]
\[ T_{\text{acc}} = 0.45 \times (1768 + 2912) - 800 = 1306 \text{ Nm} \]
\[ t_{\text{st}} = (J_M + J_{L}') \times \frac{K_1}{T_{\text{acc}}} \]
\[ t_{\text{st}} = 22.5 \times \frac{157}{1306} = 2.7 \text{ s} \]

Example 2:

- Piston pump

\[ T_L = 1600 \text{ Nm} \quad T_{L}' = 800 \text{ Nm} \]

Linear increase during acceleration
\[ T_{\text{acc}} = 0.45 \times (T_s + T_{\text{max}}) - \frac{1}{2} \times T_{L}' \]
\[ T_{\text{acc}} = 0.45 \times (1768 + 2912) - \frac{1}{2} \times 800 = 1706 \text{ Nm} \]
\[ t_{\text{st}} = (J_M + J_{L}') \times \frac{K_1}{T_{\text{acc}}} \]
\[ t_{\text{st}} = 22.5 \times \frac{157}{1706} = 2.1 \text{ s} \]

Example 3:

- Fan

\[ T_L = 1600 \text{ Nm} \quad T_{L}' = 800 \text{ Nm} \]

Square-law increase during acceleration
\[ T_{\text{acc}} = 0.45 \times (T_s + T_{\text{max}}) - \frac{1}{3} \times T_{L}' \]
\[ T_{\text{acc}} = 0.45 \times (1768 + 2912) - \frac{1}{3} \times 800 = 1839 \text{ Nm} \]
\[ t_{\text{st}} = (J_M + J_{L}') \times \frac{K_1}{T_{\text{acc}}} \]
\[ t_{\text{st}} = 22.5 \times \frac{157}{1839} = 1.9 \text{ s} \]

Example 4:

- Flywheel

\[ T_L = 0 \]
\[ T_{\text{acc}} = 0.45 \times (T_s + T_{\text{max}}) \]
\[ T_{\text{acc}} = 0.45 \times (1768 + 2912) = 2106 \text{ Nm} \]
\[ t_{\text{st}} = (J_M + J_{L}') \times \frac{K_1}{T_{\text{acc}}} \]
\[ t_{\text{st}} = 22.5 \times \frac{157}{2106} = 1.7 \text{ s} \]

Moment of inertia of load:
\[ J_L = 80 \text{ kgm}^2 \text{ at } n_l = \frac{n_M}{2} \text{ r/min} \]
\[ J_{L}' = 80 \times \left(\frac{1}{2}\right)^2 = 20 \text{ kgm}^2 \text{ at } n_M \text{ r/min} \]

Total moment of inertia:
\[ J_M + J_{L}' \text{ at } n_M \text{ r/min} \]
\[ 2.5 + 20 = 22.5 \text{ kgm}^2 \]

Moment of inertia of load:
\[ J_L = 80 \text{ kgm}^2 \text{ at } n_l = \frac{n_M}{2} \text{ r/min} \]
\[ J_{L}' = 80 \times \left(\frac{1}{2}\right)^2 = 20 \text{ kgm}^2 \text{ at } n_M \text{ r/min} \]

Total moment of inertia:
\[ J_M + J_{L}' \text{ at } n_M \text{ r/min} \]
\[ 2.5 + 20 = 22.5 \text{ kgm}^2 \]
Torque on voltage deviation

Almost without exception, the starting current decreases slightly more than proportionately to the voltage. Thus, at 90% of rated voltage the motor will draw slightly less than 90% of the starting current, say 87 to 89%. The starting torque is proportional to the square of the current. The torque delivered at 90% of rated voltage is therefore only 75 to 79% of the starting torque. Particular attention should be paid to these points if the electrical supply is weak and when starting techniques based on current reduction are being used. The maximum torque is roughly proportional to the square of the voltage.

Permitted starting time

In view of the temperature rise, the starting time must not exceed the time specified in the table.

The figures in the table are for starting from normal operating temperature. They can be doubled if starting from cold.

Maximum starting times in seconds, for occasional starting

<table>
<thead>
<tr>
<th>Motor size</th>
<th>Starting method</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>D.O.L.-starting</td>
<td>25</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>71</td>
<td>D.O.L.-starting</td>
<td>20</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>80</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>20</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>90</td>
<td>D.O.L.-starting</td>
<td>10</td>
<td>20</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>100</td>
<td>D.O.L.-starting</td>
<td>10</td>
<td>15</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>112</td>
<td>D.O.L.-starting</td>
<td>20</td>
<td>15</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>60</td>
<td>45</td>
<td>75</td>
<td>150</td>
</tr>
<tr>
<td>132</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>30</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>160</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>45</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>180</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>45</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>200</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>45</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>225</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>45</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>250</td>
<td>D.O.L.-starting</td>
<td>15</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>45</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>280</td>
<td>D.O.L.-starting</td>
<td>20</td>
<td>15</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>54</td>
<td>51</td>
<td>45</td>
</tr>
<tr>
<td>315</td>
<td>D.O.L.-starting</td>
<td>20</td>
<td>18</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>54</td>
<td>48</td>
<td>36</td>
</tr>
<tr>
<td>355</td>
<td>D.O.L.-starting</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>60</td>
<td>54</td>
<td>90</td>
</tr>
<tr>
<td>400</td>
<td>D.O.L.-starting</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Y/Δ-starting</td>
<td>45</td>
<td>60</td>
<td>54</td>
<td>90</td>
</tr>
</tbody>
</table>
Permitted frequency of starting and reversing

When a motor is subjected to frequent starting, it cannot be loaded at its rated output because of thermal starting losses in the windings. The permissible output power can be calculated on the basis of the number of starts per hour, the moment of inertia of the load and the speed of the load. The limit imposed by mechanical stresses may be below that imposed by thermal factors. The formula below may be used to calculate the permitted output at moderate frequency of starting, or for a high frequency of starting over limited periods.

Permitted output power \( P = P_N \sqrt{1 - \frac{m}{m_o}} \)

\[ P_N = \text{rated output of motor in continuous duty} \]

\[ m = \text{x} \times \frac{J_m + J'_L}{J_m} \]

\[ J'_L = \text{moment of inertia of load in kgm}^2, \text{recalculated for the motor shaft, i.e. multiplied by (load speed/motor speed)}^2. \]

\[ J_m = \text{moment of inertia of motor in kgm}^2 \]

\[ x = \text{number of starts per hour} \]

\[ J_m = \text{moment of inertia of motor in kgm}^2 \]

\[ m_o = \text{highest permitted number of starts per hour for motor at no load, as stated in the table below.} \]

### Highest permitted number of starts/hour at no load

<table>
<thead>
<tr>
<th>Motor size</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>63B</td>
<td>11200</td>
<td>8700</td>
<td>–</td>
<td>17500</td>
</tr>
<tr>
<td>71</td>
<td>–</td>
<td>–</td>
<td>16800</td>
<td>–</td>
</tr>
<tr>
<td>71A</td>
<td>9100</td>
<td>8400</td>
<td>16800</td>
<td>15700</td>
</tr>
<tr>
<td>71B</td>
<td>7300</td>
<td>8000</td>
<td>16800</td>
<td>15700</td>
</tr>
<tr>
<td>80A</td>
<td>5900</td>
<td>8000</td>
<td>16800</td>
<td>11500</td>
</tr>
<tr>
<td>80B</td>
<td>4900</td>
<td>8000</td>
<td>16800</td>
<td>11500</td>
</tr>
<tr>
<td>90S</td>
<td>4200</td>
<td>7700</td>
<td>15000</td>
<td>11500</td>
</tr>
<tr>
<td>90L</td>
<td>3500</td>
<td>7000</td>
<td>12200</td>
<td>11500</td>
</tr>
<tr>
<td>100 L</td>
<td>2800</td>
<td>–</td>
<td>8400</td>
<td>–</td>
</tr>
<tr>
<td>100 LA</td>
<td>–</td>
<td>5200</td>
<td>–</td>
<td>11500</td>
</tr>
<tr>
<td>100 LB</td>
<td>–</td>
<td>4500</td>
<td>–</td>
<td>9400</td>
</tr>
<tr>
<td>112 M</td>
<td>1700</td>
<td>6000</td>
<td>9900</td>
<td>16000</td>
</tr>
<tr>
<td>132S (S, M)</td>
<td>1700</td>
<td>2900</td>
<td>4500</td>
<td>6600</td>
</tr>
<tr>
<td>160 MA</td>
<td>650</td>
<td>–</td>
<td>–</td>
<td>5000</td>
</tr>
<tr>
<td>160 M</td>
<td>650</td>
<td>1500</td>
<td>2750</td>
<td>5000</td>
</tr>
<tr>
<td>160 L</td>
<td>575</td>
<td>1500</td>
<td>2750</td>
<td>4900</td>
</tr>
<tr>
<td>180 M</td>
<td>400</td>
<td>1100</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>180 L</td>
<td>–</td>
<td>1100</td>
<td>1950</td>
<td>3500</td>
</tr>
<tr>
<td>200 LA</td>
<td>385</td>
<td>–</td>
<td>1900</td>
<td>–</td>
</tr>
<tr>
<td>200 L</td>
<td>385</td>
<td>1000</td>
<td>1800</td>
<td>3400</td>
</tr>
<tr>
<td>225 S</td>
<td>–</td>
<td>900</td>
<td>–</td>
<td>2350</td>
</tr>
<tr>
<td>225 M</td>
<td>300</td>
<td>900</td>
<td>1250</td>
<td>2350</td>
</tr>
<tr>
<td>250 M</td>
<td>300</td>
<td>900</td>
<td>1250</td>
<td>2350</td>
</tr>
<tr>
<td>280</td>
<td>125</td>
<td>375</td>
<td>500</td>
<td>750</td>
</tr>
<tr>
<td>315</td>
<td>75</td>
<td>250</td>
<td>375</td>
<td>500</td>
</tr>
<tr>
<td>355</td>
<td>50</td>
<td>175</td>
<td>250</td>
<td>350</td>
</tr>
<tr>
<td>400</td>
<td>50</td>
<td>175</td>
<td>250</td>
<td>350</td>
</tr>
</tbody>
</table>

Highest permitted number of reversings/hour at no load \( m_r = 0.25 \times m_o \).
Soft starters

The main circuit of the ABB soft starter is controlled by semiconductors instead of mechanical contacts. Each phase is provided with two antiparallel connected thyristors which allows current to be switched at any point within both positive and negative half cycles.

The lead time is controlled by the firing angle of the thyristor which, in turn, is controlled by the built-in printed circuit board.

The soft starter provides a smooth start at the same time as the starting current is limited. The magnitude of the starting current is directly dependent on the static torque requirement during a start and on the load’s mass which is to be accelerated. In many cases, the soft starter saves energy by automatically adapting the motor voltage continually to the actual requirement. This is particularly noticeable when the motor runs with a light load.

### Permitted output in high ambient temperatures or at high altitudes

Motors of basic design are intended for operation in a maximum ambient temperature of 40°C and at a maximum altitude of 1000 meters above sea level. If a motor is to be operated in higher ambient temperatures or at higher altitudes, it should normally be derated according to the following table. Note that when the output power of a standard motor is derated, the relative values in catalogues, such as $I_s/I_n$, will change.

<table>
<thead>
<tr>
<th>Ambient temperature, °C</th>
<th>30</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60*</th>
<th>70*</th>
<th>80*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permitted output, % of rated output</td>
<td>107</td>
<td>100</td>
<td>96.5</td>
<td>93</td>
<td>90</td>
<td>86.5</td>
<td>79</td>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Height above sea level, m</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>2500</th>
<th>3000</th>
<th>3500</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permitted output, % of rated output</td>
<td>100</td>
<td>96</td>
<td>92</td>
<td>88</td>
<td>84</td>
<td>80</td>
<td>76</td>
</tr>
</tbody>
</table>

*Changes in type of lubricant and lubrication interval required
Motors for 60 Hz operation

Motors wound for a certain voltage at 50 Hz can be operated at 60 Hz, without modification, subject to the following changes in their data.

<table>
<thead>
<tr>
<th>Motor wound for 50 Hz and</th>
<th>Connected to 60 Hz and</th>
<th>Data at 60 Hz in percentage of values at 50 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output</td>
<td>r/min</td>
</tr>
<tr>
<td>220 V</td>
<td>220 V</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>255 V</td>
<td>115</td>
</tr>
<tr>
<td>380 V</td>
<td>380 V</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>415 V</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>440 V</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>460 V</td>
<td>120</td>
</tr>
<tr>
<td>400 V</td>
<td>380 V</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>400 V</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>415 V</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>440 V</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>460 V</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>480 V</td>
<td>120</td>
</tr>
<tr>
<td>415 V</td>
<td>415 V</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>460 V</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>480 V</td>
<td>115</td>
</tr>
<tr>
<td>500 V</td>
<td>500 V</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>550 V</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>575 V</td>
<td>115</td>
</tr>
<tr>
<td></td>
<td>600 V</td>
<td>120</td>
</tr>
</tbody>
</table>

Efficiency, power factor and temperature rise will be approximately the same as at 50 Hz.

1) \( I_N \) = rated current

\( I_s/I_N \) = starting current/rated current

\( T_N \) = rated torque

\( T_{max}/T_N \) = maximum torque/rated torque

\( T_s/T_N \) = starting torque/rated torque
Duty types

The duty types are indicated by the symbols S1...S9 according to IEC 34-1 and VDE 0530 Part 1. The outputs given in the tables are based on continuous running duty, S1, with rated output.

In the absence of any indication of the rated duty type, continuous running duty is assumed when considering motor operation.

S1
Continuous running duty

Operation at constant load of sufficient duration for thermal equilibrium to be reached.
Designation: S1

S2
Short-time duty

Operation at constant load during a given time, less than that required to reach thermal equilibrium, followed by a rest and de-energized period of sufficient duration to allow motor temperature to return to the ambient or cooling temperature. The values 10, 30, 60 and 90 minutes are recommended for the rated duration of the duty cycle.

Designation e.g. S2 60 min.

S3
Intermittent duty

A sequence of identical duty cycles, each including a period of operation at constant load and a rest and de-energized period. The duty cycle is too short for thermal equilibrium to be reached. The starting current does not significantly affect the temperature rise. Recommended values for the cyclic duration factor are 15, 25, 40 and 60 %. The duration of one duty cycle is 10 min.

Designation e.g. S3 25 %.

Cyclic duration factor = \( \frac{N}{N+R} \times 100\% \)

P = output power
D = acceleration
N = operation under rated condition
F = electrical braking
V = operation of no load
R = at rest and de-energized
\( P_N \) = full load
S4
Intermittent duty with starting

A sequence of identical duty cycles, each cycle including a significant period of starting, a period of operation at constant load and a rest and de-energized period. The cycle time is too short for thermal equilibrium to be reached.

In this duty type the motor is brought to rest by the load or by mechanical braking which does not thermally load the motor.

The following parameters are required to fully define the duty type: the cyclic duration factor, the number of duty cycles per hour (c/h), the moment of inertia of the load \( J_{\text{LOAD}} \) and the moment of inertia of the motor \( J_{\text{M}} \).

Designation e.g. S4 25 % 120 c/h \( J_{\text{L}} = 0.2 \text{ kgm}^2 \)
\( J_{\text{M}} = 0.1 \text{ kgm}^2 \)

\[
\text{Cyclic duration factor} = \frac{D+N}{D+N+R} \times 100\%
\]

S5
Intermittent duty with starting and electrical braking

A sequence of identical duty cycles, each cycle consisting of a significant starting period, a period of operation at constant load, a period of rapid electric braking and a rest and de-energized period.

The duty cycles are too short for thermal equilibrium to be reached.

The following parameters are required to fully define the duty type: the cyclic duration factor, the number of duty cycles per hour (c/h), the moment of inertia of the load \( J_{\text{L}} \), and the moment of inertia of the motor \( J_{\text{M}} \).

Designation e.g. S5 40 % 120 c/h \( J_{\text{L}} = 2.6 \text{ kgm}^2 \)
\( J_{\text{M}} = 1.3 \text{ kgm}^2 \)

\[
\text{Cyclic duration factor} = \frac{D+N+F}{D+N+F+R} \times 100\%
\]

S6
Continuous-operation periodic duty

A sequence of identical duty cycles, each cycle consisting of a period at constant load and a period of operation at no-load. The duty cycles are too short for thermal equilibrium to be reached.

Recommended values for the cyclic duration factor are 15, 25, 40 and 60 %. The duration of the duty cycle is 10 min.

Designation e.g. S6 40 %.

\[
\text{Cyclic duration factor} = \frac{N}{N+V} \times 100\%
\]
S7
Continuous-operation periodic duty with electrical braking

A sequence of identical duty cycles, each cycle consisting of a period of starting, a period of operation at constant load and a period of braking. The braking method is electrical braking e.g. counter-current braking. The duty cycles are too short for thermal equilibrium to be reached. The following parameters are required to fully define the duty type: the number of duty cycles per hour c/h, the moment of inertia of the load \( J_L \), and the moment of inertia of the motor \( J_M \). Designation e.g. S7 500 c/h \( J_L = 0.08 \) kgm\(^2\) \( J_M = 0.08 \) kgm\(^2\) 

S8
Continuous-operation periodic duty with related load speed changes

A sequence of identical duty cycles, each cycle consisting of a starting period, a period of operation at constant load corresponding to a predetermined speed, followed by one or more periods of operation at other constant loads corresponding to different speeds. There is no rest and de-energized period. The duty cycles are too short for thermal equilibrium to be reached. This duty type is used for example by pole changing motors.

The following parameters are required to fully define the duty type: the number of duty cycles per hour c/h, the moment of inertia of the load \( J_L \), and the moment of inertia of the motor \( J_M \). Designation e.g. S8 30 c/h \( J_L = 63.8 \) kgm\(^2\) \( J_M = 2.2 \) kgm\(^2\) 

\[
\text{Cyclic duration factor } 1 = \frac{D+N_1}{D+N_1+F_1+N_2+N_3} \times 100\%
\]

\[
\text{Cyclic duration factor } 2 = \frac{F_1+N_2}{D+N_1+F_1+N_2+F_2+N_3} \times 100\%
\]

\[
\text{Cyclic duration factor } 3 = \frac{F_2+N_3}{D+N_1+F_1+N_2+F_2+N_3} \times 100\%
\]

S9
Duty with non-periodic load and speed variations

A duty in which, generally, load and speed are varying non-periodically within the permissible operating range. This duty includes frequently applied overloads that may greatly exceed the full loads. For this duty type, suitable full load values should be taken as the basis of the overload concept.
## Efficiency and power factor

The efficiency and power factor $\cos \varphi$ values for the rated output are listed in the technical data tables in the product catalogue.

The following values are typical values. Guaranteed values are available on request.

### 2 - 4 poles

<table>
<thead>
<tr>
<th>Efficiency $\eta$ (%)</th>
<th>1.25</th>
<th>1.00</th>
<th>0.75</th>
<th>0.50</th>
<th>0.25</th>
</tr>
</thead>
<tbody>
<tr>
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### 6 - 12 poles

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### Typical power factor $\cos\varphi$ at start

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</table>

### Inspection and testing

All motors supplied are inspected and tested.

IEC Publ. 34-1 and 34-2 describe various types of inspection and testing of motors. The motors are inspected during testing, to ensure that they are free from defects and that they have the desired characteristics.

**Routine testing**

This inspection is carried out on every motor. It involves checking that the motor possesses the necessary electrical strength and that its electrical and mechanical performance is satisfactory.

**Type inspection**

Type inspection is performed for one or more motors, to demonstrate that the characteristics and functions of the design are in accordance with the specifications of the manufacturer. Type inspection covers the inspection and testing of:
- electrical and mechanical operation
- electrical and mechanical strength
- temperature rise and efficiency
- overload capacity
- other special characteristics of the motor
- type test reports can be issued to customers to provide typical performance values for purchased motors.

**Random inspection**

Subject to agreement at the time of ordering, the purchaser may select a certain number of motors from a specific order, for more detailed inspection and testing, similar in content to type inspection. The remaining motors undergo routine testing.

**Inspection for special motor versions**

Motors to be used on board merchant vessels or in potentially explosive areas must undergo additional inspection and testing as laid down in the requirements of the relevant classification society or in applicable national or international standards.

**Test reports**

Subject to agreement at the time of ordering, the purchaser receives a copy of the inspection and testing report.
Frequency converter drives

When using a squirrel cage motor with a frequency converter the following points must be taken into account, in addition to the general selection criteria:

1. Always check
   - Motor and converter loadability for the actual application
   - Insulation level of the motor
   - Earthing and grounding arrangements of the motor, driven machinery and possible tachometer.

2. At high speeds special attention should be paid to:
   - Bearing construction
   - Lubrication
   - Fan noise
   - Balancing
   - Critical speeds
   - Shaft seals
   - Maximum torque of the motor.

3. At low speeds the following should be noted:
   - Bearing lubrication
   - Motor cooling
   - Electromagnetic noise.

Guidelines for motor selection

The voltage (or current) fed by the converter is not purely sinusoidal, which, as a result, may increase the losses, vibration, and noise of the motors. Different converters with varying modulation and switching frequencies give deviating performances for the same motor. The curves shown in Figures 1, 2 and 3 can be used as a guideline for selecting the motor.

The guidelines present the maximum continuous load torque for a TEFC motor as function of frequency giving the same temperature rise as rated sine voltage and frequency with rated full load (normally B-class temperature rise). Please note that the frequency converter application in critical conditions may require a special rotor design in frame sizes 355 and 400.

Insulation level

If the rated supply voltage is 500 V or less and you are using an ACS 200 or ACS 500 or any other converter with IGBT-power components, no special check of the motor insulation level is necessary. But if any other converter type, with GTO- or GTR-power components supply, is used at 500 V or 575 V, check the cable length between the converter and motor and use the insulation level guideline (available on request) to obtain the correct motor insulation. For voltages between 660 - 690 V we recommend a reinforced motor insulation because of the high voltage peaks.

Figure 1.

MOTOR LOADABILITY WITH SAMI STAR
Figure 2.

MOTOR LOADABILITY WITH ACD 501 and ACS 200

Note: Field weakening point $F_{FWD} = 50 \text{ Hz}$
Fundamental voltage at $F_{FWD} = 100\% U_N$
Switching frequency $F_{SW} > 5 \text{ kHz}$
If $F_{SW} < 5 \text{ kHz}$ use ACS 502...504 curve

![Graph showing motor loadability with ACD 501 and ACS 200.]

Figure 3.

MOTOR LOADABILITY WITH ACS 502...504

Note: Field weakening point $F_{FWD} = 50 \text{ Hz}$
Fundamental voltage at $F_{FWD} = 100\% U_N$
Switching frequency $F_{SW} = 3 \text{ kHz (max)}$

![Graph showing motor loadability with ACS 502...504.]

ABB Motors
Earthing arrangements

Correct earthing of the motor, driven equipment and tachometer is very important to avoid bearing currents and bearing damages. We recommend that an earthing lead (as a matter of fact an equalising lead) is always used between the motor frame and the driven machinery frame. This lead equalises the potential of both machines, thus preventing any currents from going through the bearings of both machines.

Note that with high switching frequency there is a high capacitive connection between the motor winding and the stator core. No additional earthing current paths with the tachometer lead should be made.

Separate cooling

A separate cooling system may be necessary at low speeds (see dotted line in the guideline curves).

Noise

A separate cooling fan may also help in electromagnetic noise problems by "damping" the pure tones which one can hear in different modulation points. The electromagnetic noise is very much dependent on the converter type (modulation, switching frequency etc) and on the construction and pole number of the motor.

High speed operation

In a frequency converter drive the actual speed of the motor may deviate considerably from its rated speed (rating plate speed). For higher speeds, ensure that the highest permissible speed of the motor type – or the critical speed of the entire equipment – is not exceeded. The permissible maximum speeds for standard motors (the basic motor) according to frame sizes are as follows:

<table>
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<tr>
<th>Frame Size</th>
<th>Maximum Speed</th>
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<tr>
<td>63 - 100</td>
<td>6000 r/min</td>
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<td>112 - 200</td>
<td>4500 - -</td>
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<td>225 - 280</td>
<td>3600 - -</td>
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<td>315</td>
<td>3600 - -</td>
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<tr>
<td>315 others</td>
<td>3000 - -</td>
</tr>
<tr>
<td>355, 400</td>
<td>3600 - -</td>
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<tr>
<td>355, 400 others</td>
<td>2500 - -</td>
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</table>

At high speeds bearing lubrication, ventilation noise suppression and rubbing shaft seals will require special attention. High speed grease, separate cooling fan and labyrinth shaft seals may be necessary in difficult cases. Note that special high speed motors are available which can cover much higher speed ranges than above.

Low speed operation

At very low speeds the lack of cooling of a standard motor and the change in the distribution of the losses, affect the motor temperature balance increasing the temperature of bearings. The effectiveness of the motor lubrication should be checked by measuring the surface temperature of bearing endshield during normal operating conditions. If the measured value is +80°C or higher depending on the type of grease, the relubrication intervals specified in our maintenance instructions must be shortened; i.e. the relubrication interval should be halved for every 15°C increase in bearing temperature. If this is not possible we recommend the use of lubricants for high operating temperature and with very low speeds the use of EP-grease alternatives.

Dimensioning the drive

1. General selection criteria:
   - Supply network voltage
   - Load torque type (constant, pump, decreasing)
   - Speed range
   - Special need for high starting torque
   - Special needs for environment etc.

2. Select a motor so that
   - The actual load torque is totally below the guideline (Note you must know what kind of converter you are going to use!) If the operation is not continuous in all speed range duty points, the load torque curve may exceed the guideline but this case requires special dimensioning.
   - The maximum torque of the motor is at least 40% higher than the load torque at any frequency.
   - The maximum permissible speed of the motor is not exceeded.

3. Select the right converter
   - according to the motor nominal power Pn. Check also that the rated current of the converter is equal or greater than that of the selected motor. Check that the torque ratio of the motor is \( T_{max}/T_n \leq 2.9 \). If not, you need additional information for selection of the converter, or take the next, higher rated converter
   - Check that high starting torque requirements can be realized.

Check if a separate cooling system reduces the motor size and consequently the converter size.

Computer disks containing information about the dimensioning of frequency converters are available from ABB Industry.
Mechanical design

Protection against corrosion

Special attention has been paid to the finish of ABB’s motors. Screws, steel-, aluminium alloy as well as cast iron parts are treated by a method appropriate to each material, thus giving reliable anti-corrosion protection under the most severe environmental conditions. The colour of the paint is blue, Munsel colour code: 8B 4.5/3.25. It is also designated NCS 4822B05G. The standard paint finish is moisture and tropic proof in accordance with DIN 50016. It is suitable for outdoor installations, including chemical works. Specific details of paint types are given in the respective product catalogues.

Drain holes

Totally-enclosed motors that will be operated in very humid or wet environments, and especially under intermittent duty, should be provided with drain holes. The appropriate IM designation, such as IM 3031, is specified, on the basis of the method of motor mounting.

In the basic design, sizes 63 to 100 (in aluminium) and 71 to 132 (in cast iron) are supplied without drain holes, although this can be provided as needed. If holes are drilled, the degree of protection will change to IP 54. If the motors are provided with special felt plugs, the IP 55 will be retained. Larger sizes are provided with closable plastic plugs in the drain holes. The plugs will be open, on delivery. When mounting the motors, ensure that the drain holes face downwards. In the case of vertical mounting, the upper plug must be hammered home completely. In very dusty environments, both plugs should be hammered home.

Stator winding

Motor stators are wound with enamel wire and the winding is then impregnated with polyester or epoxy resin. The winding satisfies insulation class F and is mechanically strong, moisture and tropic proof.

Rotor winding

The rotor cages are normally cast aluminium. In some larger cast iron motor sizes, copper bars are used for special applications, such as frequency converter drives.

Terminal box

The standard terminal box is located on top of the motor; the degree of protection is IP 55. Higher protection is available on request. In some types of motors, the terminal box can also be on either of the sides.

The terminal box is either rotatable or at least allows cable entry from either side which gives a choice of connection possibilities.

Standard terminal boxes are suitable for Cu-cables. For Al-cable connection, please see the product catalogues.
**Bearings**

The motors are normally fitted with single-row deep groove ball bearings. The complete bearing designation is stated on the rating plate of most of the motor types.

If the bearing in the D-end of the motor is replaced with a roller bearing NU- or NJ-, higher radial forces can be handled. Roller bearings are especially suitable for belt drive applications.

When there are high axial forces, angular-contact ball bearings should be used. This version is available on request. When a motor with angular-contact ball bearings is ordered, the method of mounting and direction and magnitude of the axial force must be specified.

For specific details about bearings, please see the respective product catalogues.

**Transport locking**

Motors that have roller bearings or angular-contact ball bearings are fitted with a transport lock before despatch to prevent damage to the bearings during transport. In case of transport locked bearing, the motor is provided with a warning sign.

Locking may also be fitted in other cases where transport conditions are suspected of being injurious.

**Lubrication**

Smaller motors generally have bearings lubricated for life. Larger motor sizes usually have grease valves for lubrication in service.

The lubrication intervals and grease quantity are stated in the maintenance instruction which comes with the motor.

For details of lubrication requirements, please see the respective product catalogues.

**Bearing life**

The normal life L10 of a bearing is defined, according to ISO, as the number of operating hours achieved or exceeded by 90 % of identical bearings in a large test series under certain specified conditions. 50 % of the bearings achieve at least five times this figure. Please see the product catalogues.

**Permissible bearing and shaft loads**

The maximum permissible radial or axial forces on the shaft end for which a definite bearing rating life is obtained are shown in specific product catalogues. The strength of the shaft is also considered in the calculated values.

**Balancing**

The rotor is dynamically balanced with a full-sized key in the shaft extension. For vibration, the standard motors satisfy IEC 34-14 and ISO 2373 grade N. Grade R and S to ISO 2373 are also available on request.

The vibration is expressed in mm/s, rms, and shall be measured under no load with the motor on elastic mountings. The requirements apply over the measuring range 10 to 1000 Hz.

On the delivery the motors will be marked with the method of balancing.

H = half key, F = full key.
Noise levels

ABB's motors have a low noise level. Average test values are presented in respective product catalogues. Guaranteed noise data can be supplied on request.

Sound pressure and sound power

Sound is pressure waves and it is pressure that we measure. The pressure can then be converted into power radiated from the sound source.

Sound pressure is measured on a logarithmic scale, referred to the lowest pressure which can normally be detected by the human ear.

\[
\text{Sound pressure level} \, LP = 10 \log \left( \frac{p}{p_0} \right)^2 \, \text{dB}
\]

where \( p_0 = 2 \times 10^{-5} \text{Pa} \).

Information on sound pressure level is meaningful only if the distance from the sound source is stated. For example 80 dB (A) at a distance of one meter from a point sound source corresponds to 70 dB (A) at 3 meters.

The sound pressure level is not an absolute measure of the acoustic properties of a sound source, since the acoustics of the room affect the propagation of the sound. It is therefore generally simpler to state the sound power level of a given source instead of the sound pressure level. However, since there is no way of measuring the sound power level, it is calculated on the basis of a sound pressure level measured under known acoustical conditions.

Addition of sound sources

Noise levels are expressed in decibels as logarithmic values which complicates the calculation of the cumulative effect of several sources. In order to add or subtract logarithmic values, they must first be converted to absolute values. A simpler method of adding or subtracting sound sources is to use the diagram beside. When adding two similar sound sources, the total sound level will increase by 3 dB, for 4 similar sources, by 6 dB, etc.

Perception of differences in sound level

A difference in sound level of 1 dB is barely detectable, whereas a difference of 10 dB is perceived as a doubling, or halving, of the sound level.

When the difference between the two sound pressure levels exceeds 10 dB, the lower level contributes so little to the total sound pressure level that it may be disregarded.
### ABB Motors product range

<table>
<thead>
<tr>
<th>Motor type/application</th>
<th>IEC frame sizes</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-phase, IP 55</td>
<td>63 - 400</td>
<td>0.18 - 710 kW</td>
</tr>
<tr>
<td>Single-phase motors</td>
<td>63 - 100</td>
<td>0.15 - 2.2 kW</td>
</tr>
<tr>
<td>Marine motors</td>
<td>63 - 400</td>
<td>0.18 - 710 kW</td>
</tr>
<tr>
<td>EE-ex-motors</td>
<td>63 - 400</td>
<td>0.18 - 390 kW</td>
</tr>
<tr>
<td>Exn-motors</td>
<td>63 - 400</td>
<td>0.18 - 710 kW</td>
</tr>
<tr>
<td>EE-exd, EE-Exde-motors</td>
<td>80 - 400</td>
<td>0.55 - 710 kW</td>
</tr>
<tr>
<td>Slip-ring motors</td>
<td>250 - 355</td>
<td>45 - 280 kW</td>
</tr>
<tr>
<td>Brake motors</td>
<td>71 - 180</td>
<td>0.18 - 22 kW</td>
</tr>
<tr>
<td>IP 23 open motors</td>
<td>250 - 355</td>
<td>75 - 600 kW</td>
</tr>
</tbody>
</table>

### Basic alternatives
- aluminium, steel and cast iron frames available
- LV motors up to 1000 V
- standard versions of all types kept in stock
- our supplies can also include bigger LV and HV motors

### Special types/applications
- special variable speed AC drives
- high speed (over 3000 r/min)
- traction and wind mill
- roller table and mining
- water cooled
- vertical hollow shaft
- fire venting
- stator/rotor units
The Leader in Motors

ABB Group is the world’s leading electrical engineering company supplying expertise and products for electric power generation, transmission, and distribution as well as industrial and rail transportation markets. ABB supplies a full range of industrial electric motors, both AC and DC, LV and HV meeting the needs of most applications, with virtually any power rating.

Within the Group, ABB Motors is the world’s leading manufacturer of low-voltage induction motors, having over 100 years experience and a presence in more than 140 countries. ABB Motors’ broad understanding of customer applications enables it to work closely to solve individual problems or to supply custom-designed motors for any project - no matter how demanding.

For customers, this all represents a solid value and commitment revealed in the dependable quality of ABB Motors’ products and in its unrivalled customer service and back up. The hallmarks of its products are efficiency, robustness and reliability, combined to represent the best value available. Customers the world over rely on ABB Motors as the most solid and reliable supplier of electric motors. But above all, ABB Motors values its customers.

The best value is also enhanced by ABB Motors’ worldwide customer service network guaranteeing fast delivery, rapid response and local back-up, as well as by worldwide ABB Service network supporting the after sales service.

ABB Motors’ manufacturing facilities are located in Denmark, Finland, Germany, Spain, Sweden, India and Mexico. The comprehensive motor stocks at each of these sites are reinforced by large and versatile stocks at Central Stock Europe in Sümmern, Germany, Central Stock Asia in Singapore, and by numerous distribution stocks.
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