# IEC 60034-12

Edition 3.0 2016-11
REDLINE VERSION

# INTERNATIONAL STANDARD



colour inside

## Rotating electrical machines –
## Part 12: Starting performance of single-speed three-phase cage induction motors



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# ROTATING ELECTRICAL MACHINES –

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## FOREWORD



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**This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.**

International Standard IEC 60034-12 has been prepared by IEC technical committee 2: Rotating machinery.

This third edition cancels and replaces the second edition, published in 2002, and its amendment 1, published in 2007. It constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

| Clause or subclause | Change |
|---|---|
| 1 | Part of note 3 moved to the regular text |
| 3 | Definition of locked rotor current and of rated voltage added |
| 5 | New design letter E for extended efficiency motors, explanation of all design letters, and description of new designs NE, NEY, HE, and HEY |
| 6.2 and 9.2 | Limits for locked rotor apparent power for E(Ex)e motors replaced by a reference to IEC 60079-7 |
| | Formula added to calculate locked rotor current from apparent power |
| 7 and 10 | Definition of new limits for locked rotor apparent power for extended efficiency motors (new table 3) |
| Tables | Tables 1 and 4 to 7 extended down to $P_N$ = 120 W |
| | Name of type of protection updated according to IEC 60079-7 Ed. 5 |

The text of this standard is based on the following documents:

| CDV | Report on voting |
|---|---|
| 2/1789/CDV | 2/1821A/RVC |

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.



This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60034 series, published under the general title *Rotating electrical machines,* can be found on the IEC website.

NOTE A table of cross-references of all IEC TC 2 publications can be found in the IEC TC 2 dashboard on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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# ROTATING ELECTRICAL MACHINES –

# Part 12: Starting performance of single-speed three-phase cage induction motors

## 1 Scope

This part of IEC 60034 specifies the parameters for ~~four~~ eight designs of starting performance of single-speed three-phase 50 Hz or 60 Hz cage induction motors in accordance with IEC 60034-1 that:

– have a rated voltage up to 1 000 V;
– are intended for direct-on-line or star-delta starting;
– are rated on the basis of duty type S1;
– are constructed to any degree of protection and explosion protection.

This document also applies to dual voltage motors provided that the flux saturation level is the same for both voltages ~~and to motors having type of protection 'e' – increased safety' with temperature classes T1 to T3 complying with IEC 60079-0 and IEC 60079-7~~.



The values of torque, apparent power and current given in this document are limiting values (that is, minimum or maximum without tolerance).

NOTE 1 It is not expected that all manufacturers will produce machines for all ~~four~~ eight designs. The selection of any specific design in accordance with this document will be a matter of agreement between the manufacturer and the purchaser.

NOTE 2 Designs other than the ~~four~~ eight specified may be necessary for particular applications.

NOTE 3 It should be noted that values given in manufacturers' catalogues may include tolerances in accordance with IEC 60034-1.

NOTE 4 The values tabled for locked rotor apparent power are based on r.m.s. symmetrical steady state locked rotor currents; at motor switch on there will be a one-half cycle asymmetrical instantaneous peak current which may range from 1,8 to 2,8 times the steady state locked rotor value. The current peak and decay time are a function of the motor design and switching angle.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

~~IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*~~

IEC 60034-30-1, *Rotating electrical machines – Part 30-1: Efficiency classes of line-operated AC motors (IE-code)*

~~IEC 60079-0, *Electrical apparatus for explosive gas atmospheres – Part 0: General requirements*~~

IEC 60079-7:2015, ~~*Electrical apparatus for*~~ *Explosive* ~~*gas*~~ *atmospheres – Part 7: Equipment protection by increased safety "e"*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**rated torque**
$T_N$
torque the motor develops at its shaft end at rated output and speed

[SOURCE: IEC 60050-411:1996, 411-48-05]

**3.2**
**locked-rotor torque**
$T_l$
smallest measured torque the motor develops at its shaft end with the rotor locked, over all its angular positions, at rated voltage and frequency

[SOURCE: IEC 60050-411:1996, 411-48-06]



**3.3**
**pull-up torque**
$T_u$
smallest steady-state asynchronous torque which the motor develops between zero speed and the speed which corresponds to the breakdown torque, when the motor is supplied at the rated voltage and frequency

Note 1 to entry: This definition does not apply to those motors whose torque continually decreases with increase in speed.

Note 2 to entry: In addition to the steady-state asynchronous torques, harmonic synchronous torques, which are a function of rotor load angle, will be present at specific speeds. At such speeds, the accelerating torque may be negative for some rotor load angles. Experience and calculation show this to be an unstable operating condition and therefore harmonic synchronous torques do not prevent motor acceleration and are excluded from this definition.



**3.4**
**breakdown torque**
$T_b$
maximum steady-state asynchronous torque which the motor develops without an abrupt drop in speed, when the motor is supplied at the rated voltage and frequency

Note 1 to entry: This definition does not apply to those motors whose torque continually decreases with increase in speed.

**3.5**
**rated output**
$P_N$
value of the output included in the rating

**3.6**
**rated voltage**
$U_N$
value of the voltage included in the rating

**3.7**
**locked rotor apparent power**
$S_l$
apparent power input with the motor held at rest at rated voltage and frequency

**3.8**
**locked rotor current**
$I_l$
steady state current with the motor held at rest at rated voltage and frequency

## 4 Symbols

| Symbol | Quantity |
|---|---|
| $J$ | External moment of inertia |
| $p$ | Number of pole pairs |
| $P_N$ | Rated output |
| $S_l$ | Locked rotor apparent power |
| $T_N$ | Rated torque |
| $T_l$ | Locked rotor torque |
| $T_u$ | Pull-up torque |
| $T_b$ | Breakdown torque |



## 5 Designation

### 5.1 General

Motors designed according to this document are classified according to 5.2 to 5.7. The letters used to specify the different designs stand for:

N: normal starting torque

H: high starting torque

Y: star-delta starting

E: motors utilizing extended / higher locked rotor apparent power and current to achieve a higher efficiency class according to IEC 60034-30-1

### 5.2 Design N

Normal starting torque three-phase cage induction motors, intended for direct-on-line starting, having 2, 4, 6 or 8 poles, rated from ~~0,4~~ 0,12 kW to 1 600 kW.

### 5.3 Design NE

Normal starting torque three-phase cage induction motors having higher locked rotor apparent power than design N, intended for direct-on-line starting, having 2, 4, 6 or 8 poles, rated from 0,12 kW to 1 600 kW.

### 5.4 Designs NY and NEY

Motors similar to designs N or NE, respectively, but intended for star-delta starting. For these motors in star-connection, minimum values for $T_l$ and $T_u$ are 25 % of the values of design N or NE, respectively, see Table 1.

### 5.5 Design H

High starting torque three-phase cage induction motors with 4, 6 or 8 poles, intended for direct-online starting, rated from ~~0,4~~ 0,12 kW to 160 kW at a frequency of 60 Hz.

### 5.6 Design HE

High starting torque three-phase cage induction motors having higher locked rotor apparent power than design H, with 4, 6 or 8 poles, intended for direct-online starting, rated from 0,12 kW to 160 kW at a frequency of 60 Hz.

### 5.7 Designs HY and HEY

Motors similar to designs H or HE, respectively, but intended for star-delta starting. For these motors in star-connection, minimum values for $T_l$ and $T_u$ are 25 % of the values of design H or HE, respectively, see Table 5.

## 6 Design N requirements

### 6.1 Torque characteristics

The starting torque is represented by three characteristic features. These features shall be in accordance with the appropriate values given in Table 1 or Table 6. The values in Table 1 and Table 6 are minimum values at rated voltage. Higher values are allowed.

The motor torque at any speed between zero and that at which breakdown torque occurs shall be not less than 1,3 times the torque obtained from a curve varying as the square of the speed and being equal to rated torque at rated speed. However, for 2-pole motors with type of protection '~~e~~ Ex eb – increased safety' having a rated output greater than 100 kW, the motor torque at any speed between zero and that at which breakdown torque occurs shall not be less than 1,3 times the torque obtained from a curve varying as the square of the speed and being equal to 70 % rated torque at rated speed. For motors with type of protection '~~e~~ Ex eb', the three characteristic torques shall be in accordance with the appropriate values given in Table 6.

NOTE The factor 1,3 has been chosen with regard to an undervoltage of 10 % in relation to the rated voltage at the motor terminals during the acceleration period.

### 6.2 Locked rotor current and apparent power

The locked rotor apparent power shall be not greater than the appropriate value given in Table 2 ~~or table 6~~. The values given in Table 2 ~~and table 6~~ are independent of the number of poles and are maximum values at rated voltage. For motors with type of protection 'e', locked rotor apparent power shall be in accordance with the appropriate values ~~given in table 6~~ specified in IEC 60079-7.

The locked rotor current is calculated from the locked rotor apparent power according to:

$$I_l = \frac{S_l}{P_N} \times \frac{P_N}{\sqrt{3}U_N}$$

NOTE The advantage of specifying $S_l/P_N$ instead of $I_l/I_N$ is that the locked rotor current can be calculated from rated power and rated voltage only, not requiring to know the rated current which depends on quantities such as power factor and efficiency that are usually not known in early stages of a project.

### 6.3 Starting requirements

Motors shall be capable of withstanding two starts in succession (coasting to rest between starts) from cold conditions and one start from hot after running at rated conditions. The retarding torque due to the driven load will be in each case proportional to the square of the speed and equal to the rated torque at rated speed with the external moment of inertia given in Table 4 or Table 7.

In each case, a further start is permissible only if the motor temperature before starting does not exceed the steady temperature at rated load. However, for 2-pole motors with type of protection '~~e~~ Ex eb – increased safety' having a rated output greater than 100 kW, the retarding torque due to the driven load is proportional to the square of the speed and equal to 70 % rated torque at rated speed, with the external moment of inertia given in Table 7. After this starting, load with rated torque is possible.

NOTE It should be recognized that the number of starts should be minimized since these affect the life of the motor.

## 7 Design ~~NY~~ NE starting requirements

The starting requirements are as for design N, except that the limits for locked rotor apparent power in Table 3 apply, as increasing efficiency values require physically increasing values for locked rotor apparent power.

## 8 Designs NY and NEY starting requirements

The starting requirements are as for designs N or NE, respectively. In addition, however, a reduced retarding torque is necessary as the starting torque in 'star connection' may be insufficient to accelerate some loads to an acceptable speed.

NOTE It should be recognized that the number of starts should be minimized since these affect the life of the motor.



## 9 Design H requirements

### 9.1 Starting torque

The starting torque is represented by three characteristic features. These features shall be in accordance with the appropriate values given in Table 5. These values are minimum values at rated voltage. Higher values are allowed.

### 9.2 Locked rotor current and apparent power

The locked rotor apparent power shall be not greater than the appropriate value given in Table 2. The values in Table 2 are independent of the number of poles and are maximum values at rated voltage.

The locked rotor current is calculated from the locked rotor apparent power according to the formula given in 6.2.

### 9.3 Starting requirements

Motors shall be capable of withstanding two starts in succession (coasting to rest between starts) from cold conditions, and one start from hot after running at rated conditions. The retarding torque due to the driven load is assumed to be constant and equal to rated torque, independent of speed, with an external moment of inertia of 50 % of the values given in Table 4.

In each case, a further start is permissible only if the motor temperature before starting does not exceed the steady temperature at rated load.

NOTE It should be recognized that the number of starts should be minimized since these affect the life of the motor.

## 10 Design ~~HY~~ HE starting requirements

The starting requirements are as for design H, except that the limits for locked rotor apparent power in Table 3 apply, as increasing efficiency values require physically increasing values for locked rotor apparent power.

## 11 Designs HY and HEY starting requirements

The starting requirements are as for design H or HE, respectively. In addition, however, a reduced retarding torque is necessary as the starting torque in 'star connection' may be insufficient to accelerate some loads to an acceptable speed.

NOTE It should be recognized that the number of starts should be minimized since these affect the life of the motor.

**Table 1 – Minimum values of torques for design N**

| Range of rated output kW | Number of poles | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | | | 4 | | | 6 | | | 8 | | |
| | $T_l$ | $T_u$ | $T_b$ | $T_l$ | $T_u$ | $T_b$ | $T_l$ | $T_u$ | $T_b$ | $T_l$ | $T_u$ | $T_b$ |
| ~~0,4~~ 0,12 ≤ $P_N$ ≤ 0,63 | 1,9 | 1,3 | 2,0 | 2,0 | 1,4 | 2,0 | 1,7 | 1,2 | 1,7 | 1,5 | 1,1 | 1,6 |
| 0,63 < $P_N$ ≤ 1,0 | 1,8 | 1,2 | 2,0 | 1,9 | 1,3 | 2,0 | 1,7 | 1,2 | 1,8 | 1,5 | 1,1 | 1,7 |
| 1,0 < $P_N$ ≤ 1,6 | 1,8 | 1,2 | 2,0 | 1,9 | 1,3 | 2,0 | 1,6 | 1,1 | 1,9 | 1,4 | 1,0 | 1,8 |
| 1,6 < $P_N$ ≤ 2,5 | 1,7 | 1,1 | 2,0 | 1,8 | 1,2 | 2,0 | 1,6 | 1,1 | 1,9 | 1,4 | 1,0 | 1,8 |
| 2,5 < $P_N$ ≤ 4,0 | 1,6 | 1,1 | 2,0 | 1,7 | 1,2 | 2,0 | 1,5 | 1,1 | 1,9 | 1,3 | 1,0 | 1,8 |
| 4,0 < $P_N$ ≤ 6,3 | 1,5 | 1,0 | 2,0 | 1,6 | 1,1 | 2,0 | 1,5 | 1,1 | 1,9 | 1,3 | 1,0 | 1,8 |
| 6,3 < $P_N$ ≤ 10 | 1,5 | 1,0 | 2,0 | 1,6 | 1,1 | 2,0 | 1,5 | 1,1 | 1,8 | 1,3 | 1,0 | 1,7 |
| 10 < $P_N$ ≤ 16 | 1,4 | 1,0 | 2,0 | 1,5 | 1,1 | 2,0 | 1,4 | 1,0 | 1,8 | 1,2 | 0,9 | 1,7 |
| 16 < $P_N$ ≤ 25 | 1,3 | 0,9 | 1,9 | 1,4 | 1,0 | 1,9 | 1,4 | 1,0 | 1,8 | 1,2 | 0,9 | 1,7 |
| 25 < $P_N$ ≤ 40 | 1,2 | 0,9 | 1,9 | 1,3 | 1,0 | 1,9 | 1,3 | 1,0 | 1,8 | 1,2 | 0,9 | 1,7 |
| 40 < $P_N$ ≤ 63 | 1,1 | 0,8 | 1,8 | 1,2 | 0,9 | 1,8 | 1,2 | 0,9 | 1,7 | 1,1 | 0,8 | 1,7 |
| 63 < $P_N$ ≤ 100 | 1,0 | 0,7 | 1,8 | 1,1 | 0,8 | 1,8 | 1,1 | 0,8 | 1,7 | 1,0 | 0,7 | 1,6 |
| 100 < $P_N$ ≤ 160 | 0,9 | 0,7 | 1,7 | 1,0 | 0,8 | 1,7 | 1,0 | 0,8 | 1,7 | 0,9 | 0,7 | 1,6 |
| 160 < $P_N$ ≤ 250 | 0,8 | 0,6 | 1,7 | 0,9 | 0,7 | 1,7 | 0,9 | 0,7 | 1,6 | 0,9 | 0,7 | 1,6 |
| 250 < $P_N$ ≤ 400 | 0,75 | 0,6 | 1,6 | 0,75 | 0,6 | 1,6 | 0,75 | 0,6 | 1,6 | 0,75 | 0,6 | 1,6 |
| 400 < $P_N$ ≤ 630 | 0,65 | 0,5 | 1,6 | 0,65 | 0,5 | 1,6 | 0,65 | 0,5 | 1,6 | 0,65 | 0,5 | 1,6 |
| 630 < $P_N$ ≤ 1 600 | 0,5 | 0,3 | 1,6 | 0,5 | 0,3 | 1,6 | 0,5 | 0,3 | 1,6 | 0,5 | 0,3 | 1,6 |
| NOTE The values given are per unit $T_N$. | | | | | | | | | | | | |

**Table 2 – Maximum values of locked rotor apparent power for designs N and H**

| Range of rated output<br>kW | $S_l/P_N$ |
|---|---|
| $P_N \leq 0,4$ | 22 |
| ~~$0,4 \leq P_N \leq 6,3$~~ | ~~13~~ |
| $0,4 < P_N \leq 0,63$ | 19 |
| $0,63 < P_N \leq 1,0$ | 17 |
| $1,0 < P_N \leq 1,8$ | 15 |
| $1,8 < P_N \leq 4,0$ | 14 |
| $4,0 < P_N \leq 6,3$ | 13 |
| $6,3 < P_N \leq 25$ | 12 |
| $25 < P_N \leq 63$ | 11 |
| $63 < P_N \leq 630$ | 10 |
| $630 < P_N \leq 1\ 600$ | 9 |
| ~~NOTE $S_l$ is expressed as a per unit value of PN (kVA/kW).~~ | |

**Table 3 – Maximum values of locked rotor apparent power for designs NE and HE**

| Range of rated output<br>kW | $S_l/P_N$ |
|---|---|
| $P_N \leq 0,4$ | 22 |
| $0,4 < P_N \leq 0,63$ | 19 |
| $0,63 < P_N \leq 1,0$ | 17 |
| $1,0 < P_N \leq 6,3$ | 15 |
| $6,3 < P_N \leq 25$ | 14 |
| $25 < P_N \leq 63$ | 13 |
| $63 < P_N \leq 630$ | 12 |
| $630 < P_N \leq 1\ 600$ | 11 |

**Table 4 – External moment of inertia ($J$)**

| Number of poles | 2 | | 4 | | 6 | | 8 | |
|---|---|---|---|---|---|---|---|---|
| Frequency Hz | 50 | 60 | 50 | 60 | 50 | 60 | 50 | 60 |
| Rated output kW | Moment of inertia kg m$^2$ | | | | | | | |
| 0,12 | 0,006 | 0,004 | 0,034 | 0,025 | 0,092 | 0,069 | 0,190 | 0,142 |
| 0,25 | 0,011 | 0,009 | 0,065 | 0,049 | 0,179 | 0,134 | 0,368 | 0,276 |
| 0,4 | 0,018 | 0,014 | 0,099 | 0,074 | 0,273 | 0,205 | 0,561 | 0,421 |
| 0,63 | 0,026 | 0,020 | 0,149 | 0,112 | 0,411 | 0,308 | 0,845 | 0,634 |
| 1,0 | 0,040 | 0,030 | 0,226 | 0,170 | 0,624 | 0,468 | 1,28 | 0,960 |
| 1,6 | 0,061 | 0,046 | 0,345 | 0,259 | 0,952 | 0,714 | 1,95 | 1,46 |
| 2,5 | 0,091 | 0,068 | 0,516 | 0,387 | 1,42 | 1,07 | 2,92 | 2,19 |
| 4,0 | 0,139 | 0,104 | 0,788 | 0,591 | 2,17 | 1,63 | 4,46 | 3,34 |
| 6,3 | 0,210 | 0,158 | 1,19 | 0,889 | 3,27 | 2,45 | 6,71 | 5,03 |
| 10 | 0,318 | 0,239 | 1,80 | 1,35 | 4,95 | 3,71 | 10,2 | 7,63 |
| 16 | 0,485 | 0,364 | 2,74 | 2,06 | 7,56 | 5,67 | 15,5 | 11,6 |
| 25 | 0,725 | 0,544 | 4,10 | 3,07 | 11,3 | 8,47 | 23,2 | 17,4 |
| 40 | 1,11 | 0,830 | 6,26 | 4,69 | 17,2 | 12,9 | 35,4 | 26,6 |
| 63 | 1,67 | 1,25 | 9,42 | 7,06 | 26,0 | 19,5 | 53,3 | 40,0 |
| 100 | 2,52 | 1,89 | 14,3 | 10,7 | 39,3 | 29,5 | 80,8 | 60,6 |
| 160 | 3,85 | 2,89 | 21,8 | 16,3 | 60,1 | 45,1 | 123 | 92,5 |
| 250 | 5,76 | 4,32 | 32,6 | 24,4 | 89,7 | 67,3 | 184 | 138 |
| 400 | 8,79 | 6,59 | 49,7 | 37,3 | 137 | 103 | 281 | 211 |
| 630 | 13,2 | 9,90 | 74,8 | 56,1 | 206 | 155 | 423 | 317 |
| 1 600 | 30,6 | 23 | 173 | 130 | 477 | 358 | 979 | 734 |

NOTE 1 The values of the moment of inertia given are in terms of $mr^2$ where $m$ is the mass and $r$ is the mean radius of gyration.

NOTE 2 Moment of inertia is defined in ISO ~~31/3 1992, Number 3-7~~ 80000-4:2006, Number 4-7.

NOTE 3 For intermediate and higher values, external moments of inertia shall be calculated according to the following formula from which the values in the table have been calculated:

– for 50 Hz motors $J$ = 0,04$P^{0,9}p^{2,5}$

– for 60 Hz motors $J$ = 0,03$P^{0,9}p^{2,5}$

where: $J$ is the external moment of inertia in kg m$^2$;

$P$ is the output in kW;

$p$ is the number of pairs of poles.