IEC 60034-12

Edition 4.0 2024-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Machines électriques tournantes –
Partie 12: Caractéristiques de démarrage des moteurs triphasés à induction à cage à une seule vitesse

IEC 60034-12:2024-05(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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ROTATING ELECTRICAL MACHINES –

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

FOREWORD

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

This fourth edition cancels and replaces the third edition published in 2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

Clause or subclause	**Change**
Table 6	Aligned with the requirements for explosion protected motors from TC31 WG27
12	New clause on methods for measuring locked-rotor current and torque
Annex A	New informative annex on the general current and torque characteristics with locked rotor
Annex B	New informative annex on correction of voltage and frequency

The text of this International Standard is based on the following documents:

Draft	Report on voting
2/2132/CDV	2/2150A/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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.

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

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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 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 as defined in IEC 60034-5 and explosion protection.

This document also applies to dual voltage motors provided that the flux saturation level is the same for both voltages.

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 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 eight specified can be necessary for particular applications.

NOTE 3 Values given in manufacturers' catalogues can include tolerances in accordance with IEC 60034-1.

NOTE 4 The values tabled for locked rotor apparent power are based on RMS symmetrical steady state locked rotor currents. The start of the motor leads to transient asymmetrical currents in the whole supply, so called inrush currents, the peak value of which can 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. Similar effects can occur during the switchover from star to delta operation. A more detailed description is provided in Annex A.

The application of the test methods described in Clause 12 can be applied to cage induction motors outside the scope of this document. However, special care shall be taken in such cases to prevent overheating of the stator or the rotor winding depending on the concrete method and parameters chosen.

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 60034-1:2022, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-5:2020, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*

IEC 60034-30-1:2014, *Rotating electrical machines – Part 30-1: Efficiency classes of line-operated AC motors (IE-code)*

IEC 60079-7:2015, *Explosive atmospheres – Part 7: Equipment protection by increased safety "e"*
IEC 60079-7:2015/AMD1:2017

ISO 80000-4:2019, *Quantities and units – Part 4: Mechanics*

3 Terms and definitions

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

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

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://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

[SOURCE: IEC 60050-411:1996, 411-48-42, modified – The notes 1 and 2 to entry have been modified.]

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 can 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
$\boldsymbol{T}_{\mathbf{b}}$
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

[SOURCE: IEC 60050-411:1996, 411-48-43, modified – The notes 1 and 2 to entry have been modified.]

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

3.5
rated output
$\boldsymbol{P}_{\mathbf{N}}$
value of the output power included in the rating

Note 1 to entry: The terms rated value and rating are defined in IEC 60034-1:2022, 3.1 and 3.2 (see also IEC 60050-411:1996, 411-51-23 and 411-51-24).

3.6
rated voltage
$\boldsymbol{U}_{\mathbf{N}}$
value of the voltage included in the rating

Note 1 to entry: The terms rated value and rating are defined in IEC 60034-1:2022, 3.1 and 3.2 (see also IEC 60050-411:1996, 411-51-23 and 411-51-24).

3.7
locked rotor apparent power
$\boldsymbol{S}_{\mathbf{l}}$
apparent power input with the motor held at rest at rated voltage and frequency after the inrush currents have decayed to a symmetrical system of current

[SOURCE: IEC 60050-411:1996, 411-48-49, modified – "after the inrush currents have decayed to a symmetrical system of current" has been added.]

3.8
locked rotor current
$\boldsymbol{I}_{\mathbf{l}}$
current with the motor held at rest at rated voltage and frequency after the inrush currents have decayed to a symmetrical system of current

4 Symbols

I_{l}	Locked rotor current
J	External moment of inertia
J_{M}	Moment of inertia of motor under test
n	Rotational speed
p	Number of pole pairs
P_1	Power at the motor terminals during test method c) in 12.3.4
$P_{1,\text{g}}$	Power at the generator terminals during test method a) in 12.3.2
P_{fe}	Motor iron losses during test method c) in 12.3.4
P_{L}	Motor I^2R losses during test method c) in 12.3.4

$P_{\mathrm{T,g}}$ Total losses of the generator during test method a) in 12.3.2

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

T_{fw} Motor friction and windage torque during test method c) in 12.3.4

U_{N} Rated voltage

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 efficiency classes of IE3 or higher 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 0,12 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 0,12 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 '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 '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. The values given in Table 2 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 specified in IEC 60079-7.

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

$$I_l = \frac{S_l}{P_N} \times \frac{P_N}{\sqrt{3} U_N} \tag{1}$$

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 '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.

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

7 Design 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.

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.

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

10 Design 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.

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

12 Determination of current and torque from measurement

12.1 Locked-rotor current and locked-rotor torque

When possible, the locked-rotor current shall be measured at rated voltage and frequency as the current is not directly proportional to the voltage because of changes in reactance caused by saturation of the leakage paths. In case this isn't possible, see 12.4.

The locked-rotor torque may be measured with, e.g. a scale or force transducer with a brake or beam, or it may be measured directly using an in-line torque transducer, or it may be determined from the electrical input power using Formula (5). Depending on the chosen number of rotor slots, the locked-rotor torque of cage induction motors is subject to variations depending on the angular position of the rotor with respect to the stator. In case a preferable number of rotor slots is chosen according to the manufacturer's experience, it is usual practice to lock the rotor of a cage induction motor in any convenient position or to measure current and torque values with the rotor being stalled at very low speed, i.e. with a speed below 2 % of the rated speed.

12.2 Breakdown torque

The breakdown torque can be measured by loading the motor, starting at no-load condition, with an increasing load torque. The load torque that is reached when the motor starts quickly loosing speed, is the breakdown torque.

Alternatively, the values of pull-up and breakdown torque can be measured during acceleration from reverse speed to no-load speed (see method c) below), provided the load machine inertia or load torque is sufficiently large. Sufficiently large means in case of power ratings up to 100 kW that the change of rotational speed during test satisfies, depending on the motor's moment of inertia J_{M} and the motor's locked-rotor torque T_{l}, the relation

$$\frac{\mathrm{d}n}{\mathrm{d}t} \leq \frac{0{,}05}{2\pi J_M} T_{\mathrm{l}} \ . \qquad (2)$$

Otherwise, the breakdown torque will be underestimated. For power ratings above 100 kW, different relations of the moment of inertia and the locked-rotor torque may be suitable according to the experience to the manufacturer.

In case the complete torque-speed curve is measured using one of the methods below, no separate measurement of the breakdown torque is required.