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INTERNATIONAL STANDARD

colour inside

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

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

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ROTATING ELECTRICAL MACHINES –

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

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 IEC 60034-12:2016. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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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

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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 ~~may~~ can be necessary for particular applications.

NOTE 3 ~~It should be noted that~~ Values given in manufacturers' catalogues ~~may~~ 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.~~; at motor switch on there will be a one-half cycle asymmetrical instantaneous~~ The start of the motor leads to transient asymmetrical currents in the whole supply, so called inrush currents, the peak ~~current~~ value of which ~~may~~ 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*

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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 ~~may~~ 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.

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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

[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
P_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
U_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
S_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
I_l
~~steady state~~ 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

$P_{1,g}$ 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

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$P_{T,g}$ 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 ~~a higher~~ 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.

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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:

$$I_l = \frac{S_l}{P_N} \times \frac{P_N}{\sqrt{3} U_N} \qquad (1)$$

~~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.

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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.

~~NOTE~~ 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.

~~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.

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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.

~~NOTE~~ 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

$$\frac{dn}{dt} \le \frac{0,05}{2\pi J_M} T_l \quad (2)$$

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.

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12.3 Torque-speed curve and current-speed curve

12.3.1 General

Any one of the methods listed below may be used to obtain data for a speed-torque curve. The selection of the method will depend upon the size and the speed-torque characteristics of the machine and the testing facilities. In all three methods, sufficient test points should be recorded to ensure that reliable curves, including irregularities, can be drawn in the regions of interest from the test data. It is important that the frequency of the power supply be maintained constant throughout the test.

Method a) requires the maintenance of constant speed for each reading. Therefore, it cannot be used in regions where the torque of the machine increases with speed more rapidly than that of the loading device. From the results of the following tests, adjusted to the rated voltage and frequency, curves of torque and current should be plotted vs. speed.

It is understood that the temperature of the stator and the rotor winding will influence the measured torque-speed and current-speed curves (see Annex A).

12.3.2 Torque-speed and current-speed curves from direct measurement (method a)

In this method, a calibrated generator with known losses versus speed or a transducer or mechanical brake is coupled to the motor being tested. The motor is supplied preferably with rated frequency and rated voltage. The speed of the motor for each test point is controlled by varying the load on the generator or the brake.

In this test, readings of voltage, current, and speed of the motor as well as readings of

– either the torque directly measured by, e.g. a torque transducer, a dynamometer or a mechanical brake,
– or the power at the generator are taken at speeds between approximately 30 % of synchronous speed and the maximum speed obtainable. The total power output of the motor is the sum of the power at the generator terminals $P_{1,g}$ and the total losses of the generator $P_{T,g}$. The torque T at each speed n is calculated from

$$T = \left(P_{1,g} + P_{T,g}\right) / \left(2\pi n\right) \tag{3}$$

NOTE For determining losses and loss portions by measurement, see IEC 60034-2-1.

The speed should be constant or sufficiently low satisfying Formula (2) when the readings are taken, so that acceleration or deceleration power does not affect the results. Care should be taken not to overheat the motor. The accuracy of speed measurement is particularly important at low slip.

In case the voltage and/or the frequency differ from the rated values, the values of torque and current are corrected as described in 12.4.

12.3.3 Torque-speed and current-speed curves from acceleration (method b)

In this method, the motor is started with no load, and the values of voltage, current, and speed are recorded versus time. The torque is determined from the acceleration of the inertia J of the rotating parts. An accurate measurement of speed versus time is an essential requirement of this method. In addition, the accelerating time should be long enough so that electrical transient effects do not distort the readings of voltage, current, and speed. In order to achieve this, the accelerating time may be increased by using a lower applied voltage or by coupling a suitable inertia to the motor shaft. In case the accelerating time is too short, the measured torque will underestimate the motor's steady state torque-speed curve.

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If the motor's starting friction is high, or if more accurate data in the zero speed range are desired, the motor can be started rotating in the reverse direction prior to application of power for the acceleration.

The torque T at each speed is calculated from the time-derivative of speed according to

$$T = 2\pi J \frac{dn}{dt} \tag{4}$$

This requires a sufficiently exact knowledge of the moment of inertia. In case the voltage and/or the frequency differ from the rated values, the values of torque and current are corrected as described in 12.4.

12.3.4 Torque-speed and current-speed curves from measured input power (method c)

In this method, the torque is determined by subtracting the iron losses P_{Fe} and the I²R losses of the stator winding P_L in the machine from the motor's terminal power P_1. The difference divided by the synchronous angular velocity $2\pi f/p$ of the motor is the sum of friction and windage torque T_{fw} and motor torque, leading to

$$T = \frac{p}{2\pi f}(P_1 - P_{Fe} - P_L) - T_{fw} \tag{5}$$

NOTE For determining losses and loss portions by measurement, see IEC 60034-2-1.

The motor does not have to be unloaded. The values of voltage, current, power, and speed are recorded versus time.

In case the voltage and/or the frequency differ from the rated values, the values of torque and current are corrected as described in 12.4.

12.4 Correction of data for tests performed at reduced voltage and/or other than rated frequency

In case tests of a motor with a rated frequency of 60 Hz are done at a 50 Hz supply, the voltage shall be reduced to 50/60 times (i.e. 83,3 %) of the rated voltage in order to maintain the rated flux. If this is done, no further correction of the measured current and torque values is required.

In case tests of a motor with a rated frequency of 50 Hz are done at a 60 Hz supply, the supply voltage shall not be increased as this would exceed the rated voltage. Instead, this shall be considered as an (additional) reduction of the test voltage in the ratio of 50 Hz/60 Hz.

In addition, the change of frequency will lead to a different current displacement in the rotor cage and thus to a different locked-rotor impedance and a different rotor resistance, which will influence the locked-rotor current and torque. For larger power ratings, a method for correcting the measured current and torque values to rated frequency according to the experience of the manufacturer can be used.

Ignoring saturation, the current varies linearly with voltage and the torque varies with the square of voltage. However, saturation of leakage flux paths will lead, depending on the motor design, to voltage dependencies that are somewhat higher than this.

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In case tests are done at reduced voltage, a method for correcting the measured current and torque values to rated voltage according to the experience of the manufacturer shall be used. In case no such method is available, Annex B offers a possible and suitable method for a manufacturer to develop his own saturation factors correcting the measured values considering saturation.

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
$0,12 \leq P_N \leq 0,63$	1,9	1,3	2,0	2,0	1,4	2,0	1,7	1,2	1,7	1,5	1,1	1,6
$0,63 < P_N \leq 1,0$	1,8	1,2	2,0	1,9	1,3	2,0	1,7	1,2	1,8	1,5	1,1	1,7
$1,0 < P_N \leq 1,6$	1,8	1,2	2,0	1,9	1,3	2,0	1,6	1,1	1,9	1,4	1,0	1,8
$1,6 < P_N \leq 2,5$	1,7	1,1	2,0	1,8	1,2	2,0	1,6	1,1	1,9	1,4	1,0	1,8
$2,5 < P_N \leq 4,0$	1,6	1,1	2,0	1,7	1,2	2,0	1,5	1,1	1,9	1,3	1,0	1,8
$4,0 < P_N \leq 6,3$	1,5	1,0	2,0	1,6	1,1	2,0	1,5	1,1	1,9	1,3	1,0	1,8
$6,3 < P_N \leq 10$	1,5	1,0	2,0	1,6	1,1	2,0	1,5	1,1	1,8	1,3	1,0	1,7
$10 < P_N \leq 16$	1,4	1,0	2,0	1,5	1,1	2,0	1,4	1,0	1,8	1,2	0,9	1,7
$16 < P_N \leq 25$	1,3	0,9	1,9	1,4	1,0	1,9	1,4	1,0	1,8	1,2	0,9	1,7
$25 < P_N \leq 40$	1,2	0,9	1,9	1,3	1,0	1,9	1,3	1,0	1,8	1,2	0,9	1,7
$40 < P_N \leq 63$	1,1	0,8	1,8	1,2	0,9	1,8	1,2	0,9	1,7	1,1	0,8	1,7
$63 < P_N \leq 100$	1,0	0,7	1,8	1,1	0,8	1,8	1,1	0,8	1,7	1,0	0,7	1,6
$100 < P_N \leq 160$	0,9	0,7	1,7	1,0	0,8	1,7	1,0	0,8	1,7	0,9	0,7	1,6
$160 < P_N \leq 250$	0,8	0,6	1,7	0,9	0,7	1,7	0,9	0,7	1,6	0,9	0,7	1,6
$250 < P_N \leq 400$	0,75	0,6	1,6	0,75	0,6	1,6	0,75	0,6	1,6	0,75	0,6	1,6
$400 < P_N \leq 630$	0,65	0,5	1,6	0,65	0,5	1,6	0,65	0,5	1,6	0,65	0,5	1,6
$630 < P_N \leq 1\,600$	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.												

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

Range of rated output 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
$1,0 < P_N \leq 1,8$	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

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

Range of rated output 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

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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**[a] 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 80000-4:~~2006~~2019, 4.7.

~~NOTE 3~~ [a] 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 $J = 0{,}04P^{0{,}9}\ p^{2{,}5}$

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

where:

J is the external moment of inertia in kg m2;

P is the output in kW;

p is the number of pairs of poles.

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Table 5 – Minimum values of torques for design H

Range of rated output kW	Number of poles								
	4			6			8		
	T_l	T_u	T_b	T_l	T_u	T_b	T_l	T_u	T_b
$0{,}12 \leq P_N \leq 0{,}63$	3,0	2,1	2,1	2,55	1,8	1,9	2,25	1,65	1,9
$0{,}63 < P_N \leq 1{,}0$	2,85	1,95	2,0	2,55	1,8	1,9	2,25	1,65	1,9
$1{,}0 < P_N \leq 1{,}6$	2,85	1,95	2,0	2,4	1,65	1,9	2,1	1,5	1,9
$1{,}6 < P_N \leq 2{,}5$	2,7	1,8	2,0	2,4	1,65	1,9	2,1	1,5	1,9
$2{,}5 < P_N \leq 4{,}0$	2,55	1,8	2,0	2,25	1,65	1,9	2,0	1,5	1,9
$4{,}0 < P_N \leq 6{,}3$	2,4	1,65	2,0	2,25	1,65	1,9	2,0	1,5	1,9
$6{,}3 < P_N \leq 10$	2,4	1,65	2,0	2,25	1,65	1,9	2,0	1,5	1,9
$10 < P_N \leq 16$	2,25	1,65	2,0	2,1	1,5	1,9	2,0	1,4	1,9
$16 < P_N \leq 25$	2,1	1,5	1,9	2,1	1,5	1,9	2,0	1,4	1,9
$25 < P_N \leq 40$	2,0	1,5	1,9	2,0	1,5	1,9	2,0	1,4	1,9
$40 < P_N \leq 160$	2,0	1,4	1.,9	2,0	1,4	1,9	2,0	1,4	1,9

NOTE 1 The values given are per unit T_N

NOTE 2 The values of T_l are 1,5 times the corresponding values for design N, but are not less than 2,0.

NOTE 3 The values of T_u are 1,5 times the corresponding values for design N, but are not less than 1,4.

NOTE 4 The values of T_b are equal to the corresponding values for design N, but are not less than 1,9 and the values of T_u.

Table 6 – Minimum values of torques for design N motors with type of protection 'Ex eb – increased safety'

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
$0{,}12 \leq P_N \leq 0{,}63$	1,7	1,1	1,8	1,8	1,2	1,8	1,5	1,1	1,6	1,4	1,0	1,6
$0{,}63 < P_N \leq 1{,}0$	1,6	1,1	1,8	1,7	1,2	1,8	1,5	1,1	1,6	1,4	1,0	1,6
$1{,}0 < P_N \leq 1{,}6$	1,6	1,1	1,8	1,7	1,2	1,8	1,4	1,0	1,7	1,3	1,0	1,6
$1{,}6 < P_N \leq 2{,}5$	1,5	1,0	1,8	1,6	1,1	1,8	1,4	1,0	1,7	1,3	1,0	1,6
$2{,}5 < P_N \leq 4{,}0$	1,4	1,0	1,8	1,5	1,1	1,8	1,4	1,0	1,7	1,2	0,9	1,6
$4{,}0 < P_N \leq 6{,}3$	1,4	1,0	1,8	1,4	1,0	1,8	1,4	1,0	1,7	1,2	0,9	1,6
$6{,}3 < P_N \leq 10$	1,4	1,0	1,8	1,4	1,0	1,8	1,4	1,0	1,6	1,2	0,9	1,6
$10 < P_N \leq 16$	1,3	0,9	1,8	1,4	1,0	1,8	1,3	1,0	1,6	1,1	0,8	1,6
$16 < P_N \leq 25$	1,2	0,9	1,7	1,3	1,0	1,7	1,3	1,0	1,6	1,1	0,8	1,6
$25 < P_N \leq 40$	1,1	0,8	1,7	1,2	0,9	1,7	1,2	0,9	1,6	1,1	0,8	1,6
$40 < P_N \leq 63$	1,0	0,7	1,6	1,1	0,8	1,6	1,1	0,8	1,6	1,0	0,7	1,6
$63 < P_N \leq 100$	0,9	0,65	1,6	1,0	0,8	1,6	1,0	0,8	1,6	0,9	0,7	1,6
$100 < P_N \leq 160$	0,8	0,6	1,6	0,9	0,7	1,6	0,9	0,7	1,6	0,8	0,6	1,6
$160 < P_N \leq 250$	0,75	0,55	1,6	0,8	0,6	1,6	0,8	0,6	1,6	0,8	0,6	1,6
$250 < P_N \leq 400$	0,7	0,55	1,6	0,7	0,55	1,6	0,7	0,55	1,6	0,7	0,55	1,6
$400 < P_N \leq 630$	0,6	0,45	1,6	0,6	0,45	1,6	0,6	0,4	1,6	0,6	0,4	1,6

NOTE The values given are per unit T_N.

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Table 7 – External moment of inertia (*J*) for motors with type of protection 'Ex eb – increased safety'

Number of poles	2		4		6		8	
Frequency Hz	50	60	50	60	50	60	50	60
Rated output kW	**Moment of inertia**[a] kg m²							
0,12	0,006	0,005	0,037	0,027	0,101	0,076	0,207	0,155
0,25	0,012	0,009	0,066	0,050	0,183	0,137	0,375	0,281
0,4	0,017	0,013	0,097	0,073	0,267	0,200	0,548	0,411
0,63	0,025	0,019	0,140	0,105	0,386	0,289	0,792	0,594
1,0	0,036	0,027	0,204	0,153	0,561	0,421	1,15	0,864
1,6	0,053	0,040	0,298	0,223	0,821	0,616	1,69	1,26
2,5	0,076	0,057	0,428	0,321	1,18	0,884	2,42	1,81
4,0	0,110	0,083	0,626	0,469	1,72	1,29	3,54	2,66
6,3	0,160	0,120	0,904	0,678	2,49	1,87	5,12	3,84
10	0,232	0,174	1,31	0,986	3,62	2,72	7,44	5,58
16	0,340	0,255	1,92	1,44	5,30	3,98	10,9	8,16
25	0,488	0,366	2,76	2,07	7,61	5,71	15,6	11,7
40	0,714	0,536	4,04	3,03	11,1	8,35	22,9	17,1
63	1,03	0,774	5,84	4,38	16,1	12,1	33,0	24,8
100	1,50	1,13	8,49	6,37	23,4	17,5	48,0	36,0
160	2,20	1,65	12,4	9,32	34,2	25,7	70,3	52,7
250	3,15	2,36	17,8	13,4	49,1	36,9	101,0	75,7
400	4,61	3,46	26,1	19,6	71,9	53,9	148	111
630	6,66	5,00	37,7	28,3	104	77,9	213	160

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 80000-4:~~2006~~2019, 4.7.

~~NOTE 3~~ [a] 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 $J = 0{,}036 P^{0{,}81} p^{2{,}5}$

– for 60 Hz motors $J = 0{,}027 P^{0{,}81} p^{2{,}5}$

where:

J is the external moment of inertia in kg m²;

P is the output in kW;

p is the number of pairs of poles.

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Annex A
(informative)

Current and torque characteristics with locked rotor

The following statements describe the general time characteristics of current and torque during direct online starting of cage induction motors.

a) Locked-rotor current versus time, see Figure A.1

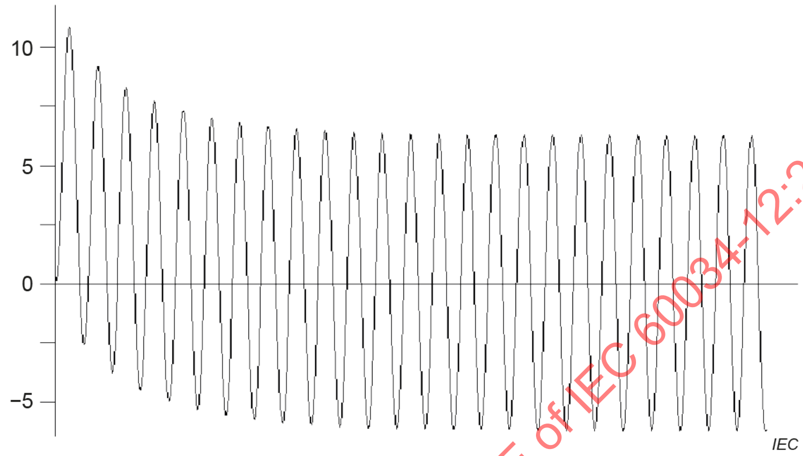

Figure A.1 – Locked-rotor current in multiples of rated current versus time

As the magnetic field energy cannot step-change but increase only with a finite time constant depending on the inductances and resistances of the stator and the rotor winding, a peak in the inrush current will be observed half a period (e.g,.10 ms in case of 50 Hz) after energizing the stator winding. The peak value differs from phase to phase depending on the phase angle of the phase voltage. The theoretical worst-case value of the peak inrush current is

$$\hat{I} = 2\sqrt{2}I_{\text{l}}$$

I_{l} being the steady-state value of the locked-rotor current. The smaller a motor is, the smaller are its time constants and the smaller the peak in the inrush current will be compared to this worst-case value.

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b) Locked-rotor torque versus time, see Figure A.2

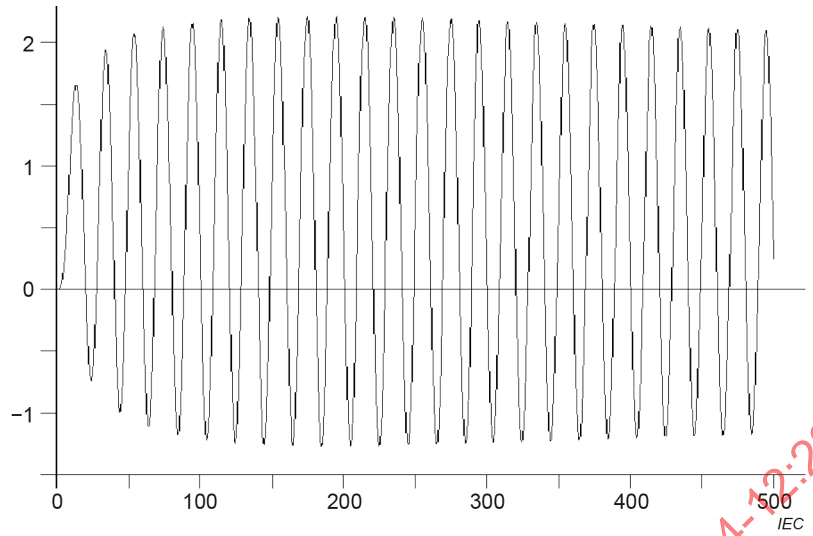

Figure A.2 – Locked-rotor torque in multiples of rated torque versus time

As torque requires both, current and flux, and as the magnetic field is zero before energizing the stator winding, the peak inrush current does not cause a torque peak. However, the DC component in the current leads to a torque oscillation of supply frequency that first increases with the flux in the machine building up and then decreases with the decreasing DC component of the current. After some 100 ms or some seconds, the torque oscillation will disappear and only the constant locked-rotor torque will remain.

c) Change of locked-rotor torque with rotor position, see Figure A.3

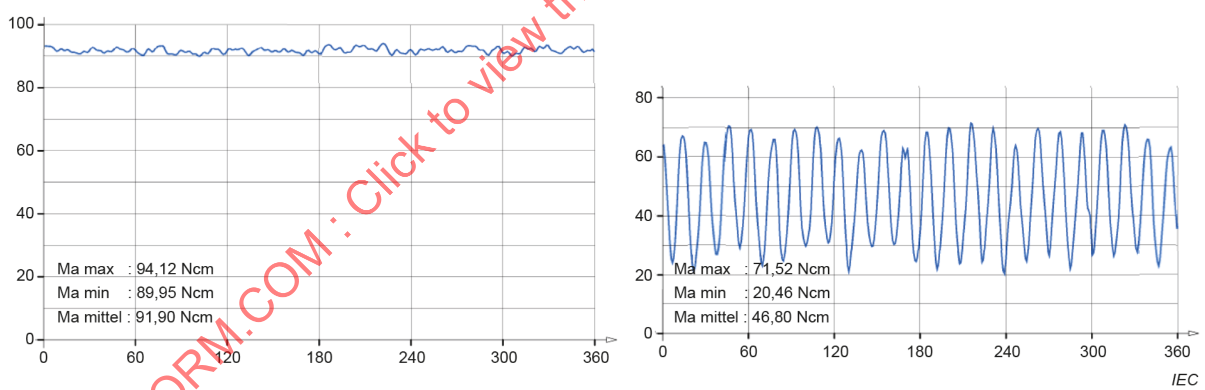

Figure A.3 – Locked-rotor torque in cNm versus rotor position in °;
left: preferable number of rotor slots, right: less preferable number of rotor slots

As mentioned in 12.1, the locked-rotor torque depends on the rotor position. The reason for this are interactions between spatial harmonics of the stator winding and of the rotor cage. How big this dependency is, depends on the chosen number of rotor slots for given numbers of pole-pairs and stator slots. The two measurement plots displaying the locked-rotor torque over rotor position for a full revolution of the rotor show that the effect may be negligible in case of a preferable number of rotor slots but may be significant in case of a less preferable choice. Worst case would be choosing the same slot numbers in stator and rotor.

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d) Influence of motor temperature on locked-rotor torque, see Figure A.4

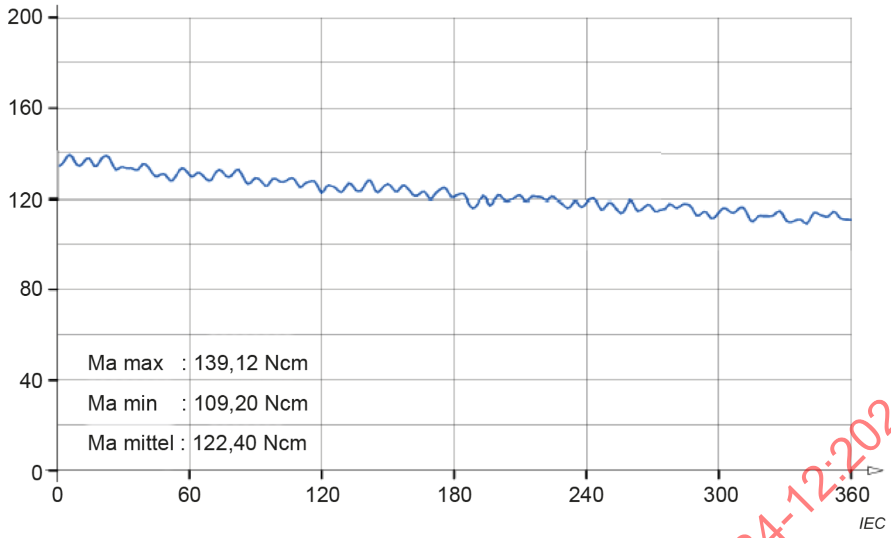

Figure A.4 – Locked-rotor torque in cNm versus rotor position in °

The high current during a locked-rotor test may cause a significant temperature rise in both, stator and rotor winding, and thus to increasing resistance. This will influence the current value and the locked-rotor torque. This effect is the more significant the smaller the motor is. The measurement plot above shows that, in case of a small motor, even measuring the locked-rotor torque over one rotor revolution might show a decreasing mean value of the locked-rotor torque due to this temperature effect.

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e) Additional considerations for star-delta starting, see Figure A.5

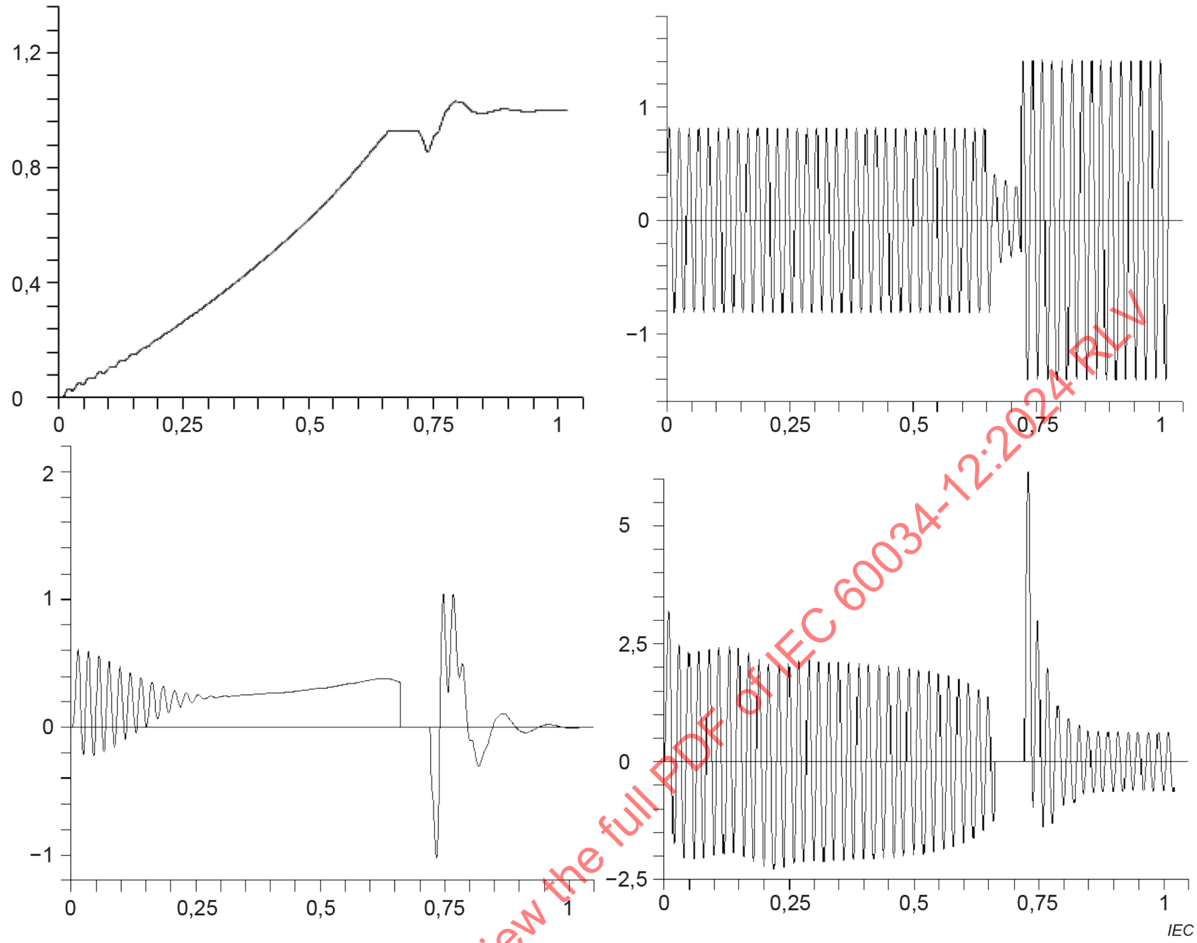

Figure A.5 – Time-courses (in s) of rotational speed (upper left), torque (lower left), phase voltage (upper right) and phase current (lower right) during a star-delta start-up

Starting a motor that is designed having a delta-connected stator winding at rated voltage with a star-connection of the winding, will reduce the locked-rotor current and the locked-rotor torque both by a factor of approximately 3. Also the peak inrush current described in item a) will be reduced by this factor. However, it should be considered that, when changing from star- to delta-connection during or after the start-up, current peaks and also a torque peak will occur that are usually higher than the peak inrush current and the peak torque that will occur at stand-still with delta-connected winding at rated voltage. The reason for this is that, in the time interval after opening the star-connection of the stator winding, but before reenergizing it in delta-connection, the motor still holds a residual flux, even though the stator current is zero. The residual flux is maintained by DC current flowing in the rotor cage during this time interval. When reenergizing the stator winding, the voltage induced in the stator winding by the residual flux (see upper right time-course) and the supply voltage are differing in magnitude and in phase which causes again an inrush phenomenon with peaks in current and torque that both can be higher than the initial peaks at start up. Attention should be paid to the correct layout of the wiring of the switches, particularly when reversing the rotation of the motor by swapping two phases.

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Annex B
(informative)

Correction method for test done on reduced voltage

A well-proven and more accurate method than correcting current proportional to the voltage and torque proportional to the square of the voltage requires determining the rate of change of current and torque with voltage by measuring locked-rotor current and locked-rotor torque for different values of voltage.

For a test voltage equal to or exceeding 90 % of the rated voltage, it is sufficient to correct the torque with the square of the voltage and the current proportional to the voltage.

For voltages below 90 % of the rated voltage or to increase accuracy, current and torque have to be corrected using saturation factors. The saturation factors are determined on the basis of the voltage-dependencies of locked-rotor torque and locked-rotor current T_l/T_N = f(U_{test}/U_N) and I_l/I_N = f(U_{test}/U_N) measured for at least three (preferably five) different voltages between 20 % and 50 % (preferably 60 %) of the rated voltage.

The saturation factors for current k_{sI} and for torque k_{sT} are obtained via a potential regression of the measured voltage-dependencies, i.e. by calculating the coefficients a_I, b_I, a_T and b_T giving the best fit between the measured values and the functions

$$k_{sI} = a_I \left(\frac{U_{test}}{U_N} \right)^{b_I} \quad \text{(B.1)}$$

$$k_{sT} = a_T \left(\frac{U_{test}}{U_N} \right)^{b_T} \quad \text{(B.2)}$$

Depending on the motor design, $b_I \geq 1$ and $b_T \geq 2$ hold. As plausibility criterion $b_T \approx 2b_I$ should be met.

The coefficient $a_I I_N$ is the locked-rotor current at rated voltage and $a_T T_N$ is the locked-rotor torque at rated voltage.

If at least 50 % of the rated voltage is reached in the test, the coefficients of the extrapolation functions determined for stand-still can also be used for the voltage correction of the complete torque-speed and current-speed curves.

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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

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ROTATING ELECTRICAL MACHINES –

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

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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.

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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.

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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 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)*

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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.

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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

[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
P_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
U_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
S_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
I_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
$P_{1,g}$	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

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$P_{T,g}$ 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.

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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:

$$I_{\mathrm{l}} = \frac{S_{\mathrm{l}}}{P_{\mathrm{N}}} \times \frac{P_{\mathrm{N}}}{\sqrt{3}U_{\mathrm{N}}} \qquad (1)$$

The advantage of specifying $S_{\mathrm{l}}/P_{\mathrm{N}}$ instead of $I_{\mathrm{l}}/I_{\mathrm{N}}$ 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.

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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.

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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.

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12.3 Torque-speed curve and current-speed curve

12.3.1 General

Any one of the methods listed below may be used to obtain data for a speed-torque curve. The selection of the method will depend upon the size and the speed-torque characteristics of the machine and the testing facilities. In all three methods, sufficient test points should be recorded to ensure that reliable curves, including irregularities, can be drawn in the regions of interest from the test data. It is important that the frequency of the power supply be maintained constant throughout the test.

Method a) requires the maintenance of constant speed for each reading. Therefore, it cannot be used in regions where the torque of the machine increases with speed more rapidly than that of the loading device. From the results of the following tests, adjusted to the rated voltage and frequency, curves of torque and current should be plotted vs. speed.

It is understood that the temperature of the stator and the rotor winding will influence the measured torque-speed and current-speed curves (see Annex A).

12.3.2 Torque-speed and current-speed curves from direct measurement (method a)

In this method, a calibrated generator with known losses versus speed or a transducer or mechanical brake is coupled to the motor being tested. The motor is supplied preferably with rated frequency and rated voltage. The speed of the motor for each test point is controlled by varying the load on the generator or the brake.

In this test, readings of voltage, current, and speed of the motor as well as readings of

– either the torque directly measured by, e.g. a torque transducer, a dynamometer or a mechanical brake,
– or the power at the generator are taken at speeds between approximately 30 % of synchronous speed and the maximum speed obtainable. The total power output of the motor is the sum of the power at the generator terminals $P_{1,g}$ and the total losses of the generator $P_{T,g}$. The torque T at each speed n is calculated from

$$T = \left(P_{1,g} + P_{T,g}\right) / \left(2\pi n\right) \tag{3}$$

NOTE For determining losses and loss portions by measurement, see IEC 60034-2-1.

The speed should be constant or sufficiently low satisfying Formula (2) when the readings are taken, so that acceleration or deceleration power does not affect the results. Care should be taken not to overheat the motor. The accuracy of speed measurement is particularly important at low slip.

In case the voltage and/or the frequency differ from the rated values, the values of torque and current are corrected as described in 12.4.

12.3.3 Torque-speed and current-speed curves from acceleration (method b)

In this method, the motor is started with no load, and the values of voltage, current, and speed are recorded versus time. The torque is determined from the acceleration of the inertia J of the rotating parts. An accurate measurement of speed versus time is an essential requirement of this method. In addition, the accelerating time should be long enough so that electrical transient effects do not distort the readings of voltage, current, and speed. In order to achieve this, the accelerating time may be increased by using a lower applied voltage or by coupling a suitable inertia to the motor shaft. In case the accelerating time is too short, the measured torque will underestimate the motor's steady state torque-speed curve.

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If the motor's starting friction is high, or if more accurate data in the zero speed range are desired, the motor can be started rotating in the reverse direction prior to application of power for the acceleration.

The torque T at each speed is calculated from the time-derivative of speed according to

$$T = 2\pi J \frac{\mathrm{d}n}{\mathrm{d}t} \tag{4}$$

This requires a sufficiently exact knowledge of the moment of inertia. In case the voltage and/or the frequency differ from the rated values, the values of torque and current are corrected as described in 12.4.

12.3.4 Torque-speed and current-speed curves from measured input power (method c)

In this method, the torque is determined by subtracting the iron losses P_{Fe} and the $\mathrm{I}^2\mathrm{R}$ losses of the stator winding P_{L} in the machine from the motor's terminal power P_1. The difference divided by the synchronous angular velocity $2\pi f/p$ of the motor is the sum of friction and windage torque T_{fw} and motor torque, leading to

$$T = \frac{p}{2\pi f}\left(P_1 - P_{\mathrm{Fe}} - P_{\mathrm{L}}\right) - T_{\mathrm{fw}} \tag{5}$$

NOTE For determining losses and loss portions by measurement, see IEC 60034-2-1.

The motor does not have to be unloaded. The values of voltage, current, power, and speed are recorded versus time.

In case the voltage and/or the frequency differ from the rated values, the values of torque and current are corrected as described in 12.4.

12.4 Correction of data for tests performed at reduced voltage and/or other than rated frequency

In case tests of a motor with a rated frequency of 60 Hz are done at a 50 Hz supply, the voltage shall be reduced to 50/60 times (i.e. 83,3 %) of the rated voltage in order to maintain the rated flux. If this is done, no further correction of the measured current and torque values is required.

In case tests of a motor with a rated frequency of 50 Hz are done at a 60 Hz supply, the supply voltage shall not be increased as this would exceed the rated voltage. Instead, this shall be considered as an (additional) reduction of the test voltage in the ratio of 50 Hz/60 Hz.

In addition, the change of frequency will lead to a different current displacement in the rotor cage and thus to a different locked-rotor impedance and a different rotor resistance, which will influence the locked-rotor current and torque. For larger power ratings, a method for correcting the measured current and torque values to rated frequency according to the experience of the manufacturer can be used.

Ignoring saturation, the current varies linearly with voltage and the torque varies with the square of voltage. However, saturation of leakage flux paths will lead, depending on the motor design, to voltage dependencies that are somewhat higher than this.

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In case tests are done at reduced voltage, a method for correcting the measured current and torque values to rated voltage according to the experience of the manufacturer shall be used. In case no such method is available, Annex B offers a possible and suitable method for a manufacturer to develop his own saturation factors correcting the measured values considering saturation.

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
$0,12 \le P_N \le 0,63$	1,9	1,3	2,0	2,0	1,4	2,0	1,7	1,2	1,7	1,5	1,1	1,6
$0,63 < P_N \le 1,0$	1,8	1,2	2,0	1,9	1,3	2,0	1,7	1,2	1,8	1,5	1,1	1,7
$1,0 < P_N \le 1,6$	1,8	1,2	2,0	1,9	1,3	2,0	1,6	1,1	1,9	1,4	1,0	1,8
$1,6 < P_N \le 2,5$	1,7	1,1	2,0	1,8	1,2	2,0	1,6	1,1	1,9	1,4	1,0	1,8
$2,5 < P_N \le 4,0$	1,6	1,1	2,0	1,7	1,2	2,0	1,5	1,1	1,9	1,3	1,0	1,8
$4,0 < P_N \le 6,3$	1,5	1,0	2,0	1,6	1,1	2,0	1,5	1,1	1,9	1,3	1,0	1,8
$6,3 < P_N \le 10$	1,5	1,0	2,0	1,6	1,1	2,0	1,5	1,1	1,8	1,3	1,0	1,7
$10 < P_N \le 16$	1,4	1,0	2,0	1,5	1,1	2,0	1,4	1,0	1,8	1,2	0,9	1,7
$16 < P_N \le 25$	1,3	0,9	1,9	1,4	1,0	1,9	1,4	1,0	1,8	1,2	0,9	1,7
$25 < P_N \le 40$	1,2	0,9	1,9	1,3	1,0	1,9	1,3	1,0	1,8	1,2	0,9	1,7
$40 < P_N \le 63$	1,1	0,8	1,8	1,2	0,9	1,8	1,2	0,9	1,7	1,1	0,8	1,7
$63 < P_N \le 100$	1,0	0,7	1,8	1,1	0,8	1,8	1,1	0,8	1,7	1,0	0,7	1,6
$100 < P_N \le 160$	0,9	0,7	1,7	1,0	0,8	1,7	1,0	0,8	1,7	0,9	0,7	1,6
$160 < P_N \le 250$	0,8	0,6	1,7	0,9	0,7	1,7	0,9	0,7	1,6	0,9	0,7	1,6
$250 < P_N \le 400$	0,75	0,6	1,6	0,75	0,6	1,6	0,75	0,6	1,6	0,75	0,6	1,6
$400 < P_N \le 630$	0,65	0,5	1,6	0,65	0,5	1,6	0,65	0,5	1,6	0,65	0,5	1,6
$630 < P_N \le 1\,600$	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.												

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

Range of rated output 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
$1,0 < P_N \leq 1,8$	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

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

Range of rated output 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

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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**[a] 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 80000-4:2019, 4.7.

[a] 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 $J = 0{,}04P^{0{,}9}\ p^{2{,}5}$

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

where:

J is the external moment of inertia in kg m2;

P is the output in kW;

p is the number of pairs of poles.

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Table 5 – Minimum values of torques for design H

Range of rated output kW	Number of poles								
	4			6			8		
	T_l	T_u	T_b	T_l	T_u	T_b	T_l	T_u	T_b
0,12 ≤ P_N ≤ 0,63	3,0	2,1	2,1	2,55	1,8	1,9	2,25	1,65	1,9
0,63 < P_N ≤ 1,0	2,85	1,95	2,0	2,55	1,8	1,9	2,25	1,65	1,9
1,0 < P_N ≤ 1,6	2,85	1,95	2,0	2,4	1,65	1,9	2,1	1,5	1,9
1,6 < P_N ≤ 2,5	2,7	1,8	2,0	2,4	1,65	1,9	2,1	1,5	1,9
2,5 < P_N ≤ 4,0	2,55	1,8	2,0	2,25	1,65	1,9	2,0	1,5	1,9
4,0 < P_N ≤ 6,3	2,4	1,65	2,0	2,25	1,65	1,9	2,0	1,5	1,9
6,3 < P_N ≤ 10	2,4	1,65	2,0	2,25	1,65	1,9	2,0	1,5	1,9
10 < P_N ≤ 16	2,25	1,65	2,0	2,1	1,5	1,9	2,0	1,4	1,9
16 < P_N ≤ 25	2,1	1,5	1,9	2,1	1,5	1,9	2,0	1,4	1,9
25 < P_N ≤ 40	2,0	1,5	1,9	2,0	1,5	1,9	2,0	1,4	1,9
40 < P_N ≤ 160	2,0	1,4	1.,9	2,0	1,4	1,9	2,0	1,4	1,9

NOTE 1 The values given are per unit T_N

NOTE 2 The values of T_l are 1,5 times the corresponding values for design N, but are not less than 2,0.

NOTE 3 The values of T_u are 1,5 times the corresponding values for design N, but are not less than 1,4.

NOTE 4 The values of T_b are equal to the corresponding values for design N, but are not less than 1,9 and the values of T_u.

Table 6 – Minimum values of torques for design N motors with type of protection 'Ex eb – increased safety'

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
0,12 ≤ P_N ≤ 0,63	1,7	1,1	1,8	1,8	1,2	1,8	1,5	1,1	1,6	1,4	1,0	1,6
0,63 < P_N ≤ 1,0	1,6	1,1	1,8	1,7	1,2	1,8	1,5	1,1	1,6	1,4	1,0	1,6
1,0 < P_N ≤ 1,6	1,6	1,1	1,8	1,7	1,2	1,8	1,4	1,0	1,7	1,3	1,0	1,6
1,6 < P_N ≤ 2,5	1,5	1,0	1,8	1,6	1,1	1,8	1,4	1,0	1,7	1,3	1,0	1,6
2,5 < P_N ≤ 4,0	1,4	1,0	1,8	1,5	1,1	1,8	1,4	1,0	1,7	1,2	0,9	1,6
4,0 < P_N ≤ 6,3	1,4	1,0	1,8	1,4	1,0	1,8	1,4	1,0	1,7	1,2	0,9	1,6
6,3 < P_N ≤ 10	1,4	1,0	1,8	1,4	1,0	1,8	1,4	1,0	1,6	1,2	0,9	1,6
10 < P_N ≤ 16	1,3	0,9	1,8	1,4	1,0	1,8	1,3	1,0	1,6	1,1	0,8	1,6
16 < P_N ≤ 25	1,2	0,9	1,7	1,3	1,0	1,7	1,3	1,0	1,6	1,1	0,8	1,6
25 < P_N ≤ 40	1,1	0,8	1,7	1,2	0,9	1,7	1,2	0,9	1,6	1,1	0,8	1,6
40 < P_N ≤ 63	1,0	0,7	1,6	1,1	0,8	1,6	1,1	0,8	1,6	1,0	0,7	1,6
63 < P_N ≤ 100	0,9	0,65	1,6	1,0	0,8	1,6	1,0	0,8	1,6	0,9	0,7	1,6
100 < P_N ≤ 160	0,8	0,6	1,6	0,9	0,7	1,6	0,9	0,7	1,6	0,8	0,6	1,6
160 < P_N ≤ 250	0,75	0,55	1,6	0,8	0,6	1,6	0,8	0,6	1,6	0,8	0,6	1,6
250 < P_N ≤ 400	0,7	0,55	1,6	0,7	0,55	1,6	0,7	0,55	1,6	0,7	0,55	1,6
400 < P_N ≤ 630	0,6	0,45	1,6	0,6	0,45	1,6	0,6	0,4	1,6	0,6	0,4	1,6

NOTE The values given are per unit T_N.

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Table 7 – External moment of inertia (J) for motors with type of protection 'Ex eb – increased safety'

Number of poles	2		4		6		8	
Frequency Hz	50	60	50	60	50	60	50	60
Rated output kW	**Moment of inertia**[a] kg m^2							
0,12	0,006	0,005	0,037	0,027	0,101	0,076	0,207	0,155
0,25	0,012	0,009	0,066	0,050	0,183	0,137	0,375	0,281
0,4	0,017	0,013	0,097	0,073	0,267	0,200	0,548	0,411
0,63	0,025	0,019	0,140	0,105	0,386	0,289	0,792	0,594
1,0	0,036	0,027	0,204	0,153	0,561	0,421	1,15	0,864
1,6	0,053	0,040	0,298	0,223	0,821	0,616	1,69	1,26
2,5	0,076	0,057	0,428	0,321	1,18	0,884	2,42	1,81
4,0	0,110	0,083	0,626	0,469	1,72	1,29	3,54	2,66
6,3	0,160	0,120	0,904	0,678	2,49	1,87	5,12	3,84
10	0,232	0,174	1,31	0,986	3,62	2,72	7,44	5,58
16	0,340	0,255	1,92	1,44	5,30	3,98	10,9	8,16
25	0,488	0,366	2,76	2,07	7,61	5,71	15,6	11,7
40	0,714	0,536	4,04	3,03	11,1	8,35	22,9	17,1
63	1,03	0,774	5,84	4,38	16,1	12,1	33,0	24,8
100	1,50	1,13	8,49	6,37	23,4	17,5	48,0	36,0
160	2,20	1,65	12,4	9,32	34,2	25,7	70,3	52,7
250	3,15	2,36	17,8	13,4	49,1	36,9	101,0	75,7
400	4,61	3,46	26,1	19,6	71,9	53,9	148	111
630	6,66	5,00	37,7	28,3	104	77,9	213	160

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 80000-4:2019, 4.7.

[a] 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 $J = 0{,}036P^{0{,}81}p^{2{,}5}$

– for 60 Hz motors $J = 0{,}027P^{0{,}81}p^{2{,}5}$

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.

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Annex A
(informative)

Current and torque characteristics with locked rotor

The following statements describe the general time characteristics of current and torque during direct online starting of cage induction motors.

a) Locked-rotor current versus time, see Figure A.1

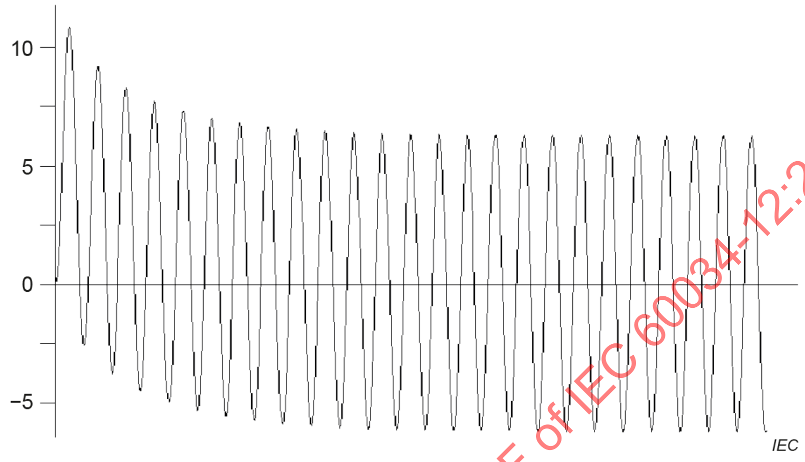

Figure A.1 – Locked-rotor current in multiples of rated current versus time

As the magnetic field energy cannot step-change but increase only with a finite time constant depending on the inductances and resistances of the stator and the rotor winding, a peak in the inrush current will be observed half a period (e.g,.10 ms in case of 50 Hz) after energizing the stator winding. The peak value differs from phase to phase depending on the phase angle of the phase voltage. The theoretical worst-case value of the peak inrush current is

$$\hat{I} = 2\sqrt{2} I_l$$

I_l being the steady-state value of the locked-rotor current. The smaller a motor is, the smaller are its time constants and the smaller the peak in the inrush current will be compared to this worst-case value.

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b) Locked-rotor torque versus time, see Figure A.2

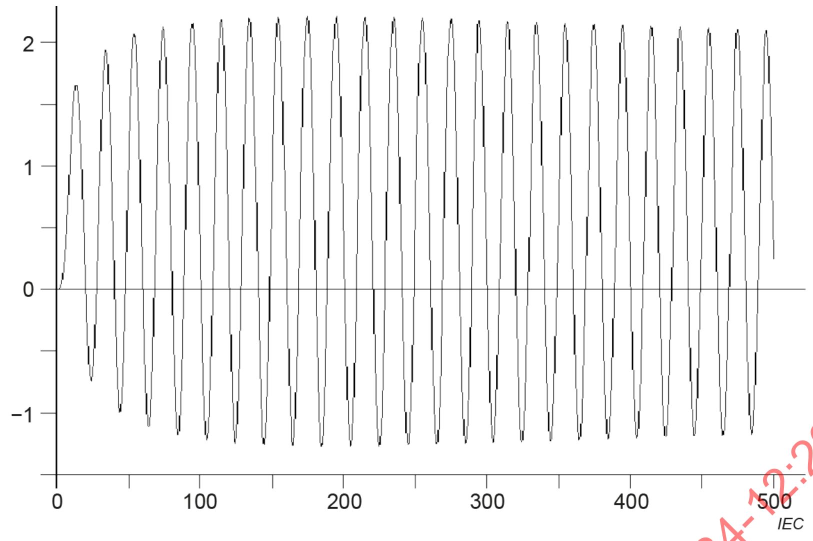

Figure A.2 – Locked-rotor torque in multiples of rated torque versus time

As torque requires both, current and flux, and as the magnetic field is zero before energizing the stator winding, the peak inrush current does not cause a torque peak. However, the DC component in the current leads to a torque oscillation of supply frequency that first increases with the flux in the machine building up and then decreases with the decreasing DC component of the current. After some 100 ms or some seconds, the torque oscillation will disappear and only the constant locked-rotor torque will remain.

c) Change of locked-rotor torque with rotor position, see Figure A.3

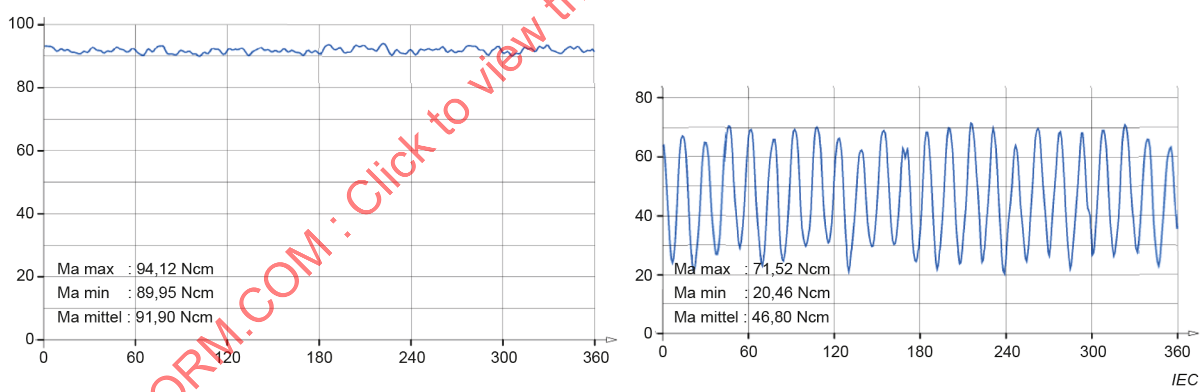

Figure A.3 – Locked-rotor torque in cNm versus rotor position in °;
left: preferable number of rotor slots, right: less preferable number of rotor slots

As mentioned in 12.1, the locked-rotor torque depends on the rotor position. The reason for this are interactions between spatial harmonics of the stator winding and of the rotor cage. How big this dependency is, depends on the chosen number of rotor slots for given numbers of pole-pairs and stator slots. The two measurement plots displaying the locked-rotor torque over rotor position for a full revolution of the rotor show that the effect may be negligible in case of a preferable number of rotor slots but may be significant in case of a less preferable choice. Worst case would be choosing the same slot numbers in stator and rotor.

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d) Influence of motor temperature on locked-rotor torque, see Figure A.4

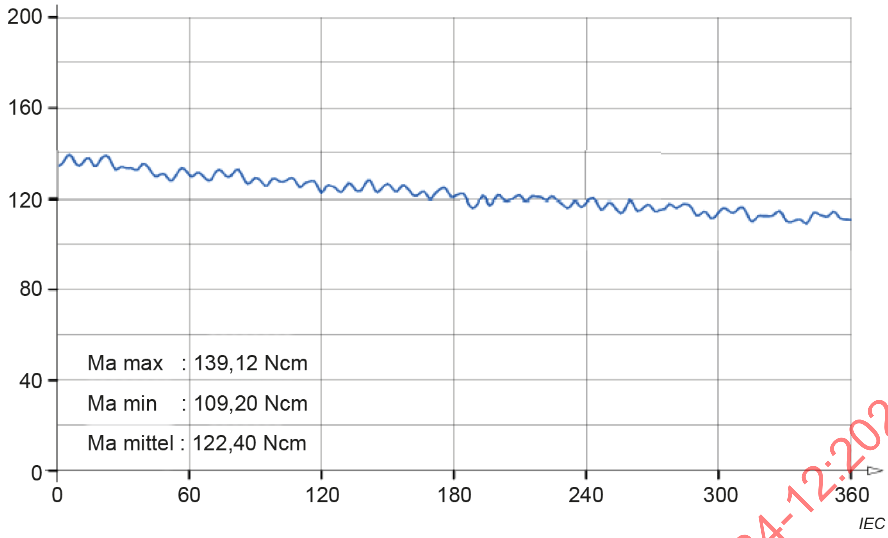

Figure A.4 – Locked-rotor torque in cNm versus rotor position in °

The high current during a locked-rotor test may cause a significant temperature rise in both, stator and rotor winding, and thus to increasing resistance. This will influence the current value and the locked-rotor torque. This effect is the more significant the smaller the motor is. The measurement plot above shows that, in case of a small motor, even measuring the locked-rotor torque over one rotor revolution might show a decreasing mean value of the locked-rotor torque due to this temperature effect.

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e) Additional considerations for star-delta starting, see Figure A.5

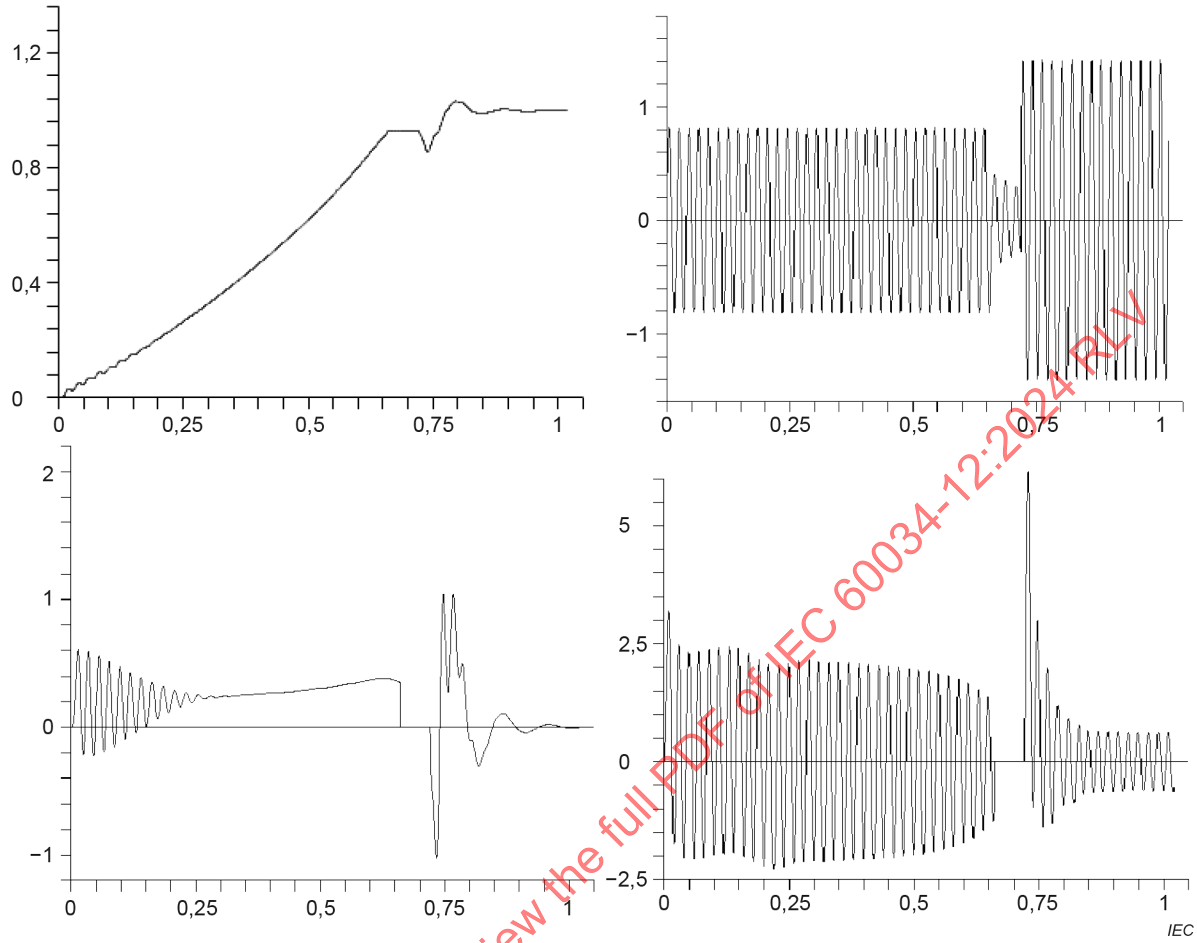

Figure A.5 – Time-courses (in s) of rotational speed (upper left), torque (lower left), phase voltage (upper right) and phase current (lower right) during a star-delta start-up

Starting a motor that is designed having a delta-connected stator winding at rated voltage with a star-connection of the winding, will reduce the locked-rotor current and the locked-rotor torque both by a factor of approximately 3. Also the peak inrush current described in item a) will be reduced by this factor. However, it should be considered that, when changing from star- to delta-connection during or after the start-up, current peaks and also a torque peak will occur that are usually higher than the peak inrush current and the peak torque that will occur at stand-still with delta-connected winding at rated voltage. The reason for this is that, in the time interval after opening the star-connection of the stator winding, but before reenergizing it in delta-connection, the motor still holds a residual flux, even though the stator current is zero. The residual flux is maintained by DC current flowing in the rotor cage during this time interval. When reenergizing the stator winding, the voltage induced in the stator winding by the residual flux (see upper right time-course) and the supply voltage are differing in magnitude and in phase which causes again an inrush phenomenon with peaks in current and torque that both can be higher than the initial peaks at start up. Attention should be paid to the correct layout of the wiring of the switches, particularly when reversing the rotation of the motor by swapping two phases.

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Annex B
(informative)

Correction method for test done on reduced voltage

A well-proven and more accurate method than correcting current proportional to the voltage and torque proportional to the square of the voltage requires determining the rate of change of current and torque with voltage by measuring locked-rotor current and locked-rotor torque for different values of voltage.

For a test voltage equal to or exceeding 90 % of the rated voltage, it is sufficient to correct the torque with the square of the voltage and the current proportional to the voltage.

For voltages below 90 % of the rated voltage or to increase accuracy, current and torque have to be corrected using saturation factors. The saturation factors are determined on the basis of the voltage-dependencies of locked-rotor torque and locked-rotor current $T_l/T_N = f(U_{test}/U_N)$ and $I_l/I_N = f(U_{test}/U_N)$ measured for at least three (preferably five) different voltages between 20 % and 50 % (preferably 60 %) of the rated voltage.

The saturation factors for current k_{sI} and for torque k_{sT} are obtained via a potential regression of the measured voltage-dependencies, i.e. by calculating the coefficients a_I, b_I, a_T and b_T giving the best fit between the measured values and the functions

$$k_{sI} = a_I \left(\frac{U_{test}}{U_N} \right)^{b_I} \tag{B.1}$$

$$k_{sT} = a_T \left(\frac{U_{test}}{U_N} \right)^{b_T} \tag{B.2}$$

Depending on the motor design, $b_I \geq 1$ and $b_T \geq 2$ hold. As plausibility criterion $b_T \approx 2b_I$ should be met.

The coefficient $a_I I_N$ is the locked-rotor current at rated voltage and $a_T T_N$ is the locked-rotor torque at rated voltage.

If at least 50 % of the rated voltage is reached in the test, the coefficients of the extrapolation functions determined for stand-still can also be used for the voltage correction of the complete torque-speed and current-speed curves.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MACHINES ÉLECTRIQUES TOURNANTES –

Partie 12: Caractéristiques de démarrage des moteurs triphasés à induction à cage à une seule vitesse

AVANT-PROPOS

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Cette quatrième édition annule et remplace la troisième édition parue en 2016. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

Article ou paragraphe	Modification
Tableau 6	Aligné sur les exigences du CE 31, GT 27, concernant les moteurs antidéflagrants
12	Nouvel article relatif aux méthodes de mesure du courant et du couple à rotor bloqué
Annexe A	Nouvelle annexe informative relative aux caractéristiques générales de courant et de couple à rotor bloqué
Annexe B	Nouvelle annexe informative relative à la correction de la tension et de la fréquence

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
2/2132/CDV	2/2150A/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

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MACHINES ÉLECTRIQUES TOURNANTES –

Partie 12: Caractéristiques de démarrage des moteurs triphasés à induction à cage à une seule vitesse

1 Domaine d'application

La présente partie de l'IEC 60034 spécifie les paramètres de huit conceptions de caractéristiques de démarrage de moteurs triphasés à induction à cage à une seule vitesse fonctionnant à 50 Hz ou 60 Hz conformes à l'IEC 60034-1, qui:

– ont des tensions assignées jusqu'à 1 000 V;
– sont prévus pour démarrage direct ou étoile-triangle;
– sont dimensionnés pour le service type S1;
– peuvent avoir n'importe quel degré de protection tel qu'il est défini dans l'IEC 60034-5 et incluant les protections contre les explosions.

Ce document s'applique également aux moteurs bitension à condition que le niveau de saturation du flux soit le même aux deux tensions.

Les valeurs de couple, de puissance apparente et de courant données dans le présent document sont des valeurs limites (c'est-à-dire minimales ou maximales sans tolérance).

NOTE 1 Les constructeurs ne sont pas tenus de fabriquer des machines correspondant à ces huit conceptions. Le choix d'une conception spécifique répondant au présent document fera l'objet d'un accord entre le constructeur et son client.

NOTE 2 Des conceptions autres que les huit spécifiées peuvent s'avérer nécessaires pour des applications particulières.

NOTE 3 Les valeurs données dans les catalogues des constructeurs peuvent inclure des tolérances conformes à l'IEC 60034-1.

NOTE 4 Les valeurs calculées pour la puissance apparente à rotor bloqué sont fondées sur les courants à rotor bloqué en régime établi symétriques en valeur efficace. Le démarrage du moteur entraîne des pics de courants asymétriques transitoires dans toute l'alimentation, appelés courants d'appel, dont la valeur peut fluctuer entre 1,8 et 2,8 fois la valeur à rotor bloqué en régime établi. La crête de courant et le temps de descente dépendent de la conception du moteur et de l'angle de commutation. Des effets semblables peuvent se produire lors du passage du fonctionnement en étoile au fonctionnement en triangle. Une description plus détaillée est fournie à l'Annexe A.

Les méthodes d'essai décrites à l'Article 12 peuvent également être appliquées aux moteurs à induction à cage qui n'entrent pas dans le domaine d'application du présent document. Toutefois, des précautions particulières doivent être prises dans de tels cas afin d'empêcher la surchauffe du stator ou de l'enroulement du rotor, selon la méthode concrète et les paramètres choisis.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60034-1:2022, *Machines électriques tournantes – Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement*

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IEC 60034-5:2020, *Machines électriques tournantes – Partie 5: Degrés de protection procurés par la conception intégrale de machines électriques tournantes (code IP) – Classification*

IEC 60034-30-1:2014, *Machines électriques tournantes – Partie 30-1: Classes de rendement pour les moteurs à courant alternatif alimentés par le réseau (code IE)*

IEC 60079-7:2015, *Atmosphères explosives – Partie 7: Protection du matériel par sécurité augmentée "e"*
IEC 60079-7:2015/AMD1:2017

ISO 80000-4:2019, *Grandeurs et unités – Partie 4: Mécanique*

3 Termes et definitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse https://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse https://www.iso.org/obp

3.1
couple assigné
T_N
couple que développe le moteur sur son bout d'arbre d'entraînement aux puissance et vitesse assignées

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

3.2
couple à rotor bloqué
T_l
couple mesuré le plus faible que développe le moteur sur son bout d'arbre d'entraînement, quand son rotor est maintenu bloqué, quelle que soit sa position angulaire et qu'il est alimenté à tension et fréquence assignées

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

3.3
couple minimal pendant le démarrage
T_u
valeur la plus faible du couple asynchrone en régime établi que le moteur développe entre la vitesse nulle et la vitesse qui correspond au couple de décrochage lorsque le moteur est alimenté à la tension et à la fréquence assignées

[SOURCE: IEC 60050-411:1996, 411-48-42, modifié – Les notes 1 et 2 à l'article ont été modifiées.]

Note 1 à l'article: Cette définition ne s'applique pas aux moteurs dont le couple diminue de manière continue quand la vitesse augmente.

Note 2 à l'article: En plus des couples asynchrones en régime établi, les couples synchrones harmoniques, qui dépendent de l'angle de charge du rotor, seront présents à certaines vitesses. À de telles vitesses, le couple d'accélération peut être négatif pour certains angles de charge de rotor. L'expérience et les calculs montrent qu'il s'agit d'une condition de fonctionnement instable. C'est pourquoi les couples synchrones harmoniques n'empêchent pas l'accélération du moteur et sont exclus de la présente définition.

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3.4
couple de décrochage
T_b
valeur maximale du couple asynchrone en régime établi développé par le moteur sans chute brutale de la vitesse lorsque le moteur est alimenté à la tension et à la fréquence assignées

[SOURCE: IEC 60050-411:1996, 411-48-43, modifié – Les notes 1 et 2 à l'article ont été modifiées.]

Note 1 à l'article: Cette définition ne s'applique pas aux moteurs dont le couple diminue de manière continue quand la vitesse augmente.

3.5
puissance de sortie assignée
P_N
valeur de la puissance de sortie incluse dans les caractéristiques assignées

Note 1 à l'article: Les termes valeur assignée et caractéristiques assignées sont définis dans l'IEC 60034-1:2022, 3.1 et 3.2 (voir aussi l'IEC 60050-411:1996, 411-51-23 et 411-51-24).

3.6
tension assignée
U_N
valeur de la tension incluse dans la fréquence assignée

Note 1 à l'article: Les termes valeur assignée et caractéristiques assignées sont définis dans l'IEC 60034-1:2022, 3.1 et 3.2 (voir aussi l'IEC 60050-411:1996, 411-51-23 et 411-51-24).

3.7
puissance apparente rotor bloqué
S_l
puissance apparente d'entrée, avec le moteur maintenu à l'arrêt à la tension et à la fréquence assignées après que les courants d'appel sont descendus à un système de courant symétrique

[SOURCE: IEC 60050-411:1996, 411-48-49, modifié – ajout de "après que les courants d'appel sont descendus à un système de courant symétrique".]

3.8
courant à rotor bloqué
I_l
courant avec le moteur maintenu à l'arrêt à la tension et à la fréquence assignées après que les courants d'appel sont descendus à un système de courant symétrique

4 Symboles

I_l	Courant à rotor bloqué
J	Moment d'inertie extérieur
J_M	Moment d'inertie du moteur soumis à l'essai
n	Vitesse de rotation
p	Nombre de paires de pôles
P_1	Puissance aux bornes du moteur pendant la méthode d'essai c) en 12.3.4
$P_{1,g}$	Puissance aux bornes du générateur pendant la méthode d'essai a) en 12.3.2
P_{fe}	Pertes fer du moteur pendant la méthode d'essai c) en 12.3.4
P_L	Pertes I^2R du moteur pendant la méthode d'essai c) en 12.3.4

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$P_{T,g}$ Pertes totales du générateur pendant la méthode d'essai a) en 12.3.2

P_N Puissance de sortie assignée

S_l Puissance apparente rotor bloqué

T_N Couple assigné

T_l Couple à rotor bloqué

T_u Couple minimal pendant le démarrage

T_b Couple de décrochage

T_{fw} Couple de frottement et de pertes par ventilation du moteur pendant la méthode d'essai c) en 12.3.4

U_N Tension assignée

5 Désignation

5.1 Généralités

Les moteurs conçus selon le présent document sont classés conformément aux paragraphes 5.2 à 5.7. Les lettres utilisées pour spécifier les différentes conceptions sont:

N: couple de démarrage normal.

H: couple de démarrage élevé.

Y: démarrage étoile-triangle.

E: moteurs utilisant des valeurs étendues / supérieures de la puissance apparente et du courant à rotor bloqué pour obtenir des classes de rendement IE3 ou plus conformément à l'IEC 60034-30-1.

5.2 Moteurs de conception N

Moteurs triphasés à induction à cage à couple de démarrage normal prévus pour démarrage direct à 2, 4, 6 ou 8 pôles, avec des puissances assignées comprises entre 0,12 kW et 1 600 kW.

5.3 Moteurs de conception NE

Moteurs triphasés à induction à cage à couple de démarrage normal ayant une puissance apparente à rotor bloqué supérieure à celle des moteurs de conception N, prévus pour démarrage direct à 2, 4, 6 ou 8 pôles, avec des puissances assignées comprises entre 0,12 kW et 1 600 kW.

5.4 Moteurs de conception NY et NEY

Moteurs analogues à ceux de conception N ou NE respectivement, mais qui sont prévus pour démarrage étoile-triangle. Pour ces moteurs en couplage étoile, les valeurs minimales de T_l et T_u sont égales à 25 % des valeurs indiquées pour la conception N ou NE, respectivement (voir Tableau 1).

5.5 Moteurs de conception H

Moteurs triphasés à induction à cage à couple de démarrage élevé à 4, 6 ou 8 pôles, prévus pour démarrage direct, avec des puissances assignées comprises entre 0,12 kW et 160 kW à une fréquence de 60 Hz.

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5.6 Moteurs de conception HE

Moteurs triphasés à induction à cage à couple de démarrage élevé ayant une puissance apparente à rotor bloqué supérieure à celle des moteurs de conception H, avec 4, 6 ou 8 pôles, prévus pour démarrage direct, avec des puissances assignées comprises entre 0,12 kW et 160 kW à une fréquence de 60 Hz.

5.7 Moteurs de conception HY et HEY

Moteurs analogues à ceux de conception H ou HE respectivement, mais qui sont prévus pour démarrage étoile-triangle. Pour ces moteurs en couplage étoile, les valeurs minimales de T_l et T_u sont égales à 25 % des valeurs indiquées pour la conception H ou HE, respectivement (voir Tableau 5).

6 Exigences pour les moteurs de conception N

6.1 Caractéristiques de couple

Le couple de démarrage est représenté par trois caractéristiques. Ces caractéristiques doivent être conformes aux valeurs appropriées données dans le Tableau 1 ou le Tableau 6. Les valeurs données dans le Tableau 1 et le Tableau 6 sont des valeurs minimales à la tension assignée. Des valeurs plus élevées sont autorisées.

Le couple du moteur à n'importe quelle vitesse entre la vitesse nulle et celle pour laquelle le couple de décrochage se produit ne doit pas être inférieur à 1,3 fois le couple obtenu à partir d'une courbe variant avec le carré de la vitesse et étant égale au couple assigné à la vitesse assignée. Cependant, pour les moteurs à 2 pôles à type de protection "Ex eb – sécurité augmentée" ayant une puissance de sortie assignée supérieure à 100 kW, le couple du moteur à n'importe quelle vitesse entre la vitesse nulle et celle pour laquelle le couple de décrochage se produit ne doit pas être inférieur à 1,3 fois le couple obtenu à partir d'une courbe variant avec le carré de la vitesse et étant égale à 70 % du couple assigné à la vitesse assignée. Pour les moteurs à type de protection 'Ex eb', les trois couples caractéristiques doivent être conformes aux valeurs appropriées données dans le Tableau 6.

NOTE Le facteur 1,3 a été choisi pour tenir compte d'une chute de tension de 10 % de la tension assignée aux bornes du moteur pendant la période d'accélération.

6.2 Courant et puissance apparente à rotor bloqué

La puissance apparente à rotor bloqué ne doit pas être supérieure à la valeur appropriée donnée dans le Tableau 2. Les valeurs données dans le Tableau 2 sont indépendantes du nombre de pôles et sont des valeurs maximales à la tension assignée. Pour les moteurs à type de protection "e", la puissance apparente à rotor bloqué doit être conforme aux valeurs appropriées spécifiées dans l'IEC 60079-7.

Le courant à rotor bloqué est calculé à partir de la puissance apparente à rotor bloqué conformément à:

$$I_l = \frac{S_l}{P_N} \times \frac{P_N}{\sqrt{3} U_N} \quad (1)$$

L'avantage de la spécification de S_l/P_N au lieu de I_l/I_N est que le courant à rotor bloqué peut être calculé à partir de la puissance assignée et de la tension assignée seulement, ce qui n'exige pas de connaître le courant assigné, qui dépend de grandeurs comme le facteur de puissance et le rendement, qui ne sont pas habituellement connues aux stades précoces d'un projet.

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6.3 Exigences de démarrage

Les moteurs doivent être capables d'assurer deux démarrages successifs (avec retour à l'arrêt entre les démarrages) à partir de l'état froid et un démarrage à partir de l'état chaud après avoir fonctionné au régime assigné. Le couple résistant dû à la charge entraînée sera dans chaque cas proportionnel au carré de la vitesse et égal au couple assigné à la vitesse assignée avec les moments d'inertie extérieurs donnés dans le Tableau 4 ou le Tableau 7.

Dans chaque cas, un démarrage supplémentaire n'est permis que si la température du moteur avant le démarrage ne dépasse pas la température d'équilibre à la charge assignée. Cependant, pour les moteurs à 2 pôles à type de protection "Ex eb – sécurité augmentée" ayant une puissance de sortie assignée supérieure à 100 kW, le couple résistant dû à la charge entraînée est proportionnel au carré de la vitesse et égal à 70 % du couple assigné à la vitesse assignée, avec les moments d'inertie extérieurs donnés dans le Tableau 7. Après ce démarrage, la charge avec couple assigné est possible.

Il convient d'admettre que le nombre de démarrages soit réduit le plus possible puisque ceux-ci affectent la durée de vie du moteur.

7 Exigences de démarrage pour les moteurs de conception NE

Les exigences de démarrage sont les mêmes que pour les moteurs de conception N, excepté que les limites pour la puissance apparente à rotor bloqué dans le Tableau 3 s'appliquent, car les valeurs croissantes du rendement exigent des valeurs physiquement croissantes pour la puissance apparente à rotor bloqué.

8 Exigences de démarrage pour les moteurs de conception NY et NEY

Les exigences de démarrage sont les mêmes que pour les moteurs de conception N ou NE, respectivement. Cependant, un couple résistant réduit est nécessaire, car le couple de démarrage en 'couplage étoile' peut être insuffisant pour accélérer certaines charges à une vitesse acceptable.

Il convient d'admettre que le nombre de démarrages soit réduit le plus possible puisque ceux-ci affectent la durée de vie du moteur.

9 Exigences pour les moteurs de conception H

9.1 Couple de démarrage

Le couple de démarrage est représenté par trois caractéristiques. Ces caractéristiques doivent être conformes aux valeurs appropriées données dans le Tableau 5. Ces valeurs sont des valeurs minimales à la tension assignée. Des valeurs plus élevées sont autorisées.

9.2 Courant et puissance apparente à rotor bloqué

La puissance apparente à rotor bloqué ne doit pas être supérieure à la valeur appropriée donnée dans le Tableau 2. Les valeurs données dans le Tableau 2 sont indépendantes du nombre de pôles et sont des valeurs maximales à la tension assignée.

Le courant à rotor bloqué est calculé à partir de la puissance apparente à rotor bloqué conformément à la formule donnée en 6.2.

9.3 Exigences de démarrage

Les moteurs doivent être capables d'assurer deux démarrages successifs (avec retour à l'arrêt entre les démarrages) à partir de l'état froid et un démarrage à partir de l'état chaud après avoir

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fonctionné au régime assigné. Le couple résistant dû à la charge entraînée est supposé constant et égal au couple assigné quelle que soit la vitesse, avec des moments d'inertie extérieurs de 50 % des valeurs données dans le Tableau 4.

Dans chaque cas, un démarrage supplémentaire n'est permis que si la température du moteur avant le démarrage ne dépasse pas la température d'équilibre à la charge assignée.

Il convient d'admettre que le nombre de démarrages soit réduit le plus possible puisque ceux-ci affectent la durée de vie du moteur.

10 Exigences de démarrage pour les moteurs de conception HE

Les exigences de démarrage sont les mêmes que pour les moteurs de conception H, excepté que les limites pour la puissance apparente à rotor bloqué dans le Tableau 3 s'appliquent, car les valeurs croissantes du rendement exigent des valeurs physiquement croissantes pour la puissance apparente à rotor bloqué.

11 Exigences de démarrage pour les moteurs de conception HY et HEY

Les exigences de démarrage sont les mêmes que pour les moteurs de conception H ou HE, respectivement. Cependant, un couple résistant réduit est nécessaire, car le couple de démarrage en 'couplage étoile' peut être insuffisant pour accélérer certaines charges à une vitesse acceptable.

Il convient d'admettre que le nombre de démarrages soit réduit le plus possible puisque ceux-ci affectent la durée de vie du moteur.

12 Détermination du courant et du couple par mesurage

12.1 Courant à rotor bloqué et couple à rotor bloqué

Dans la mesure du possible, le courant à rotor bloqué doit être mesuré à la tension et à la fréquence assignées, étant donné que le courant n'est pas directement proportionnel à la tension en raison de variations de réactance dues à la saturation des lignes de fuite. Si cela est impossible, voir 12.4.

Le couple à rotor bloqué peut par exemple être mesuré avec une graduation ou un capteur de force en utilisant un frein ou un bras de charge. Il peut aussi être directement mesuré à l'aide d'un capteur de couple en ligne ou être déterminé à partir de la puissance électrique absorbée en utilisant la Formule (5). En fonction du nombre choisi d'encoches rotoriques, le couple à rotor bloqué des moteurs à induction à cage est soumis à des variations qui dépendent de la position angulaire du rotor par rapport au stator. Si un nombre préférable d'encoches rotoriques est choisi suivant l'expérience du constructeur, il est d'usage de bloquer le rotor d'un moteur à induction à cage dans n'importe quelle position pratique ou de mesurer les valeurs de courant et de couple avec le rotor tournant à très faible vitesse, c'est-à-dire à une vitesse inférieure à 2 % de la vitesse assignée.

12.2 Couple de décrochage

Le couple de décrochage peut être mesuré en chargeant le moteur, qui démarre sans charge, avec un couple de charge qui augmente. Le couple de charge atteint lorsque le moteur commence à perdre rapidement de la vitesse est le couple de décrochage.

En variante, les valeurs de couple minimal pendant le démarrage et de couple de décrochage peuvent être mesurées pendant l'accélération, lors du passage de la vitesse en marche arrière à la vitesse sans charge (voir méthode c), ci-dessous), à condition que l'inertie de la machine sous charge ou le couple de charge soit suffisamment élevé. "Suffisamment élevé" signifie que,

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