IEC TS 60034-30-2

Edition 1.0 2016-12

TECHNICAL SPECIFICATION

Rotating electrical machines –
Part 30-2: Efficiency classes of variable speed AC motors (IE-code)

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Part 30-2: Efficiency classes of variable speed AC motors (IE-code)

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 60034-30-2, which is a technical specification, has been prepared by IEC technical committee 2: Rotating machinery.

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

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
2/1833/DTS	2/1850A/RVC

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

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

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

NOTE A table of cross-references of all IEC TC 2 publications can be found on the IEC TC 2 dashboard 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This technical specification provides for the global harmonization of energy-efficiency classes of variable speed electric motors. It deals with all types of AC low-voltage electric motors that are rated for variable speed operation in their constant magnetic-flux speed-range (base speed-range). An electronic frequency converter provides variable voltage and variable frequency.

NOTE For the time being, IEC TS 60034-2-3, which is the testing basis of this document, is limited to induction motors. However, the relevant input-output procedure 3-C is already applicable to all kinds of variable speed AC motors. Future editions of IEC TS 60034-2-3 will have an expanded scope and include testing procedures for synchronous machines.

This technical specification regards energy efficiency classification of AC motors rated for variable voltage and frequency, namely induction motors and synchronous motors not covered in IEC 60034-30-1. It is harmonized with the future standard IEC 61800-9-2 where IE-classifications of frequency converters (complete drive modules = CDM) and IES-classifications of power drive systems (PDS) are defined.

An efficient motor alone does not necessarily result in an efficient PDS. Users should select the efficiency class in accordance with a given application depending on the actual load / speed operating points and related operating time.

It may not be energy efficient to select very high efficiency S1 motors for intermittent or short time duty or part load applications. The use of the Extended Product Approach (EPA) as described in the future standard series IEC 61800-9 will help applicative sectors for specification of energy efficiency performance of power driven equipment and parts.

It is not expected that all manufacturers will produce motors for all efficiency classes nor all ratings of a given class.

IE-codes are not limited to motors, but may in future be used to classify other components such as frequency converters and gearboxes. However, it is anticipated that other components are rated with a comparable system: IE1 meaning low efficiency up to IE5 meaning the highest efficiency.

ROTATING ELECTRICAL MACHINES –

Part 30-2: Efficiency classes of variable speed AC motors (IE-code)

1 Scope

This part of IEC 60034, which is a technical specification, specifies efficiency classes for variable speed rotating electric machines not covered in IEC 60034-30-1.

The document only applies to machines that:

- have a rated power P_N from 0,12 kW to 1 000 kW;
- have a rated voltage U_N above 50 V up to 1 kV;
- have a rated speed n_N from 600 1/min up to 6 000 1/min regardless of the number of magnetic poles;
- are designed for cooling methods IC4A1A0 (IC410), IC4A1A1 (IC411), IC4A1A6 (IC416), or IC4A1A8 (IC418) according to IEC 60034-6;
- are capable of continuous operation at their rated operating point (torque/power, speed) with a temperature rise within the specified insulation temperature class;

NOTE 1 Most motors covered by this document are rated for duty type S1 (continuous duty). However, some motors that are rated for other duty cycles are still capable of continuous operation at their rated power and these motors are also covered. Motors rated between S3 and S10 with a cycle time of 80 % or more may be included.

- are rated for any ambient temperature within the range of – 20 °C to + 60 °C;

NOTE 2 The rated efficiency and efficiency classes are based on 25 °C ambient temperature according to IEC 60034-2-1 and IEC TS 60034-2-3.

NOTE 3 Motors rated for temperatures outside the range – 20 °C and + 60 °C are considered to be of special construction and are consequently excluded from this document.

NOTE 4 Smoke extraction motors with a temperature class of up to and including 400 °C are covered by this document.

- are rated for an operating altitude up to 4 000 m above sea level.

NOTE 5 The rated efficiency and efficiency class are based on a rating for altitudes up to 1 000 m above sea level.

The classification only covers machines designed for operation with sinusoidal fundamental current that are not designed to be operated direct on-line (grid), for example permanent magnet synchronous machines with and without additional reluctance torque, sinusoidal reluctance synchronous machines and synchronous machines with DC field windings. This also includes induction machines that are designed exclusively for variable speed operation.

Switched reluctance synchronous machines are not covered.

The procedures to determine losses at any speed and load point are given in IEC TS 60034-2-3. They apply to all converter operated motors.

No distinction is made between motor technologies, supply voltage or motors with increased insulation even though these motor technologies may not all be capable of reaching the higher efficiency classes. This makes different motor technologies fully comparable with respect to their energy efficiency potential.

The efficiency of power-drive systems (i.e. the combined losses of motor and power supply) and the losses of the driven load are not covered by this document, see IEC 61800-9-2.

Covered in this document are also:

- Motors with flanges, feet and/or shafts with mechanical dimensions different from IEC 60072-1.
- Geared motors including those incorporating non-standard shafts and flanges. However, the testing of efficiency is to be performed on the motor part of a geared motor only.
- Motors specifically built for operation in explosive environments according to IEC 60079-0. Such motors may not be able to reach the higher efficiency classes (due to safety requirements and possible design constraints of explosion proof motors such as increased air-gap, reduced starting current, enhanced sealing).

Excluded from this document are:

- Motors with mechanical commutators;
- Motors completely integrated with the driven machine (for example pumps, fans and compressors) that cannot be practically tested separately from the machine even with provision of a temporary end-shield and drive-end bearing. This means that motors included in this document must:
  a) share common components (apart from connectors such as bolts) with the driven unit (for example, a shaft or housing), and
  b) not be designed in such a way as to enable the motor to be separated from the driven unit as an entire motor that can operate independently of the driven unit, When the process of separation renders the motor inoperative, it is excluded from this document.

NOTE 6 Some motors used in horizontal, inclined and vertical transport of goods and people are specifically designed for this purpose. They are often integrated into a machine and are not brought to the market as individual products. These motors are excluded.

- Brake motors when the brake is an integral part of the inner motor construction and can neither be removed nor supplied by a separate power source during the testing of motor efficiency.

  Brake motors with a brake coil that is integrated into the flange of the motor are covered as long as it is possible to test motor efficiency without the losses of the brake (for example by dismantling the brake, removing the brake or by energizing the brake coil from a separate power source).
- Submersible motors specifically designed to operate wholly immersed in a liquid;
- Smoke extraction motors with a temperature class above 400 °C;
- Motors that are just soft-started with a frequency-converter and then operated on sinusoidal mains supply are rated according to IEC 60034-30-1;
- Motors that are designed for servo applications, i.e. applications where frequent overload or field-weakening operations or frequent speed or torque changes occur or no thermal steady state operation is reached.

NOTE 7 This document covers industrial motors which mostly run continuously at or near rated load, and whose speed is not changing often or rapidly. Such motors include those which drive compressors and conveyor belts, for example.

In order to achieve high efficiency at full load, magnetic flux densities within those motors are normally modest, often resulting in larger sizes and higher inertia rotors compared with standard efficiency machines.

On the other hand, motors for servo-drive applications, such as robot drives, machine tools and pick-and-place machines which experience frequent and rapid load and speed changes, often have low rotor inertia in order to achieve the required dynamic performance. Energy consumption in that case is mainly determined by the energy required for acceleration. Low inertia rotors tend to have higher losses in continuous operation, however.

Motors for servo-drives are therefore not covered by this IE-classification.

Motors are often regarded as servo motors when typically one of the following criteria is met:

Maximum speed criterion: $n_{\max} > a_0 \cdot e^{-a_1 \cdot P_N + a_2} + a_3$; with a_0 = 6 000 1/min; a_1 = 0,02 1/kW; a_2 = –0,4; a_3 = 3 200 1/min.

Angular acceleration capability criterion: $acc_{\mathrm{coeff}} = \frac{T_{\max}}{J} > b_0 \cdot e^{-b_1 \cdot P_N + b_2} + b_3$; with b_0 = 18000 1/s^2; b_1 = 1,3 1/kW; b_2 = –1; b_3 = 5 800 1/s^2.

Motors excluded from this document may be evaluated as a power drive system (PDS) according to IEC 61800-9-2. In this case, the PDS which is composed of the motor and the frequency converter (CDM) is evaluated as IES0, IES1 or IES2.

2 Normative references

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

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

IEC TS 60034-2-3, *Rotating electrical machines – Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC motors*[1]

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

IEC 61800-9-2, *Adjustable speed electrical power drive systems – Ecodesign for power drive systems, motor starters, power electronics and their driven applications – Part 2: Energy efficiency indicators for power drive systems and motor starters*[2]

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60034-1 and the following apply.

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

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

3.1.1
variable speed motor
motor rated for a speed-range or a specific single speed and supplied by voltage of variable amplitude and frequency

3.1.2
brake motor
motor equipped with an electro-mechanical brake unit installed directly on the motor shaft without couplings

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1 This document already refers to the future edition of IEC TS 60034-2-3, which will contain procedures for testing of synchronous machines on frequency converters and for interpolation of losses and efficiency over the whole torque-speed operating range. A first committee draft (CD) should be available before the publication of this document.

2 Under preparation. Stage at the time of publication: IEC/RFDIS 61800-9-2:2016.

3.1.3
geared motor
motor equipped with an integral gearbox without couplings (i.e. the first gear wheel is fixed to the motor shaft)

3.1.4
nominal efficiency
efficiency value required to meet a certain efficiency class

Note 1 to entry: Nominal efficiency is calculated from the reference values given in the efficiency tables or the interpolation formula reduced by the additional harmonic losses (see r_{HL} factor).

3.1.5
rated efficiency
efficiency value assigned by the manufacturer to the motor when operating on a converter at rated speed and rated power

3.1.6
reference value
reference value of efficiency given in Tables 2 to 6 and in 4.10

3.1.7
rated speed
maximum operating speed of the constant magnetic-flux speed-range (base speed-range) designated by the manufacturer

3.1.8
maximum speed
maximum operating speed designated by the manufacturer

3.1.9
rated power
maximum continuous output power at rated speed designated by the manufacturer

3.1.10
rated torque
maximum continuous output torque at rated speed designated by the manufacturer

3.1.11
constant magnetic-flux speed-range
base speed-range
speed-range between standstill and rated speed in which the motor can be operated with a magnetic flux similar to rated operation (base speed-range). In this speed-range, the motor is capable of delivering rated output torque

3.1.12
field-weakening speed-range
speed-range above rated speed up to a maximum speed in which the motor is operated with reduced magnetic-flux (field-weakening speed-range). In this speed-range, the motor is capable of delivering rated output power

3.1.13
additional harmonic losses
additional harmonic losses are produced in the motor by the non-sinusoidal voltage and current waveforms generated by the converter and are in addition to the fundamental losses of iron, rotor-winding, stator-winding and additional-load loss

3.1.14
fundamental losses
losses of a motor running with rated voltage at fundamental frequency (usually 50 Hz or 60 Hz), without additional losses caused by voltage and current harmonics

3.2 Symbols

acc_{coeff} is the ratio of the maximum torque over rotor inertia, $1/s^2$
f is the frequency at any operating point, Hz
f_N is the rated frequency, Hz
I_N is the rated current, A
J is the rotor inertia, kgm^2
n is the speed at any operating point, min^{-1}
n_{max} is the maximum speed, min^{-1}
n_N is the rated speed, min^{-1}
n_{90} is 90 % of the rated speed, min^{-1}
η_n is the nominal efficiency, %
η_N is the rated efficiency, %
η_{90} is the efficiency determined at 90 % speed and full-load, %
η_{ref} is the reference efficiency according to Tables 2 to 6 and 4.10, %
P_N is the rated output power, kW
P_{90} is the output power at 90 % speed and rated torque, kW
r_{HL} is the additional harmonic loss factor, %
T_N is the rated torque, Nm
T_{max} is the maximum torque, Nm
T_{100} is the full-load torque determined from rated speed and rated power, Nm
U_N is the rated voltage, V

4 Efficiency classification

4.1 Determination

4.1.1 General

This clause deals with AC motors that are exclusively rated for variable frequency and voltage operation.

Motors that fall under both IEC 60034-30-1 and IEC 60034-30-2 standards (that are AC motors, which are rated for both on-line (grid) operation and variable speed operation (dual rated motors), for example most induction-motors or line-start permanent-magnet motors), shall bear the IE efficiency class according to the procedures laid out in IEC 60034-30-1 only.

The manufacturer shall use a comparable frequency converter for testing of the motor according to IEC TS 60034-2-3.

4.1.2 Auxiliary devices

Some electric motors covered by this document may be equipped with auxiliary devices such as shaft seals, external fans, mechanical brakes, back-stops and unidirectional bearings, speed sensors, tacho-generators in various combinations.

However, as long as these auxiliary devices are not an integral part of the basic motor design, the determination of efficiency in all possible combinations is not practical. It is recommended that tests for efficiency of such modified standard motors are performed on basic motors with original cooling without auxiliary devices installed.

The power consumption of a separately driven fan is to be included in the efficiency determination procedure when the external fan is an integral part of the basic motor construction. When the external fan is just an optional add-on to a mass-produced motor, which normally carries a shaft-mounted fan, the losses of the basic motor (with the shaft-mounted fan) can be used to determine efficiency.

All vertical motors may be tested horizontally. Angular-contact bearings (thrust bearings) for vertical mounted motors may be replaced by standard bearings during efficiency testing.

Roller bearings may be replaced by standard bearings during efficiency testing.

For all motors where contact seals are accessible from the outside without dismantling of the motor (dismantling of the fan-cover and the fan is accepted), external contact seals should be removed for efficiency testing.

Electro-mechanical brakes shall be removed during testing of motor efficiency. When the motor construction prohibits the removal of the brake, the brake-coil shall be energized from a separate power source and the energy consumption of the brake-coil shall be disregarded in the calculation of motor efficiency.

When the manufacturer offers a motor of the same design with and without a brake the test of motor efficiency may be done on a motor without the brake. The determined efficiency may then be used as the rating of both motor and brake motor.

NOTE When removing auxiliary devices for efficiency testing by third party labs the motor or auxiliaries may be permanently damaged.

4.2 Efficiency rating

The efficiency η_{90} of a motor shall be determined from the losses obtained according to IEC TS 60034-2-3 at 90 % of rated speed n_{90} and at rated torque T_N or at full-load torque T_{100} in relation to the output power at that operating point P_{90}:

$$P_{90} = 0{,}9 \cdot P_N \text{ and } n_{90} = 0{,}9 \cdot n_N$$

When a rated torque T_N is not provided by the manufacturer, the full-load torque T_{100} shall be determined from the rated speed and rated output power by applying the following formula:

$$T_{100} = \frac{P_N}{2\pi \cdot n_N}$$

with P_N in [W], n_N in [1/s], T_{100} in [Nm].

Thermal equilibrium of the motor shall be maintained at the beginning of the tests.

NOTE 1 Rated speed is usually the highest speed in the base speed-range.

NOTE 2 The requirement to test at 90 % of rated speed will ensure that the motor is operated at full magnetic flux (full voltage) regardless of the voltage drop in the internal electronic switches of the frequency converter. This procedure is harmonized with the requirements of frequency converter (CDM) testing included in IEC 61800-9-2.

NOTE 3 There is usually a slight drop of the motor efficiency when determined at 90 % rated speed and 90 % rated power compared to the efficiency determined at rated speed and rated power. This is covered by the

reduction of the nominal efficiency limits required for the IE classification according to this document when compared to the nominal efficiency limits given in IEC 60034-30-1.

The determined efficiency η_{90} shall be greater than or equal to the nominal efficiency η_{n} of the designated efficiency class (IE-code).

The nominal efficiency η_{n} of the IE1 - IE5 classes according to this document shall be calculated from the respective reference value η_{ref} given in Tables 2 to 6 or determined according to the interpolation given in 4.10, reduced by an allowance due to additional harmonic losses and efficiency determination at partial speed (90 %) by applying the following formula:

$$\eta_{n} = \frac{1}{1+(1+r_{HL})\cdot\left(\dfrac{1}{\eta_{ref}}-1\right)}$$

The additional harmonic loss factor r_{HL} is:

r_{HL} = 0,15 (15 %) for motors with a rated output power up to and including 90 kW;

r_{HL} = 0,25 (25 %) for motors with a rated output power above 90 kW.

η_{n} and η_{ref} shall be given as numbers in the range of (0...1). The result shall be mathematically rounded to three decimal places or one decimal place when the efficiency is expressed as a percentage value.

NOTE 4 The change of the value of r_{HL} at 90 kW reflects the change of the switching frequency of the comparable converter as defined in IEC TS 60034-2-3.

4.3 Tolerances

Variations in materials, manufacturing processes and in testing result in motor-to-motor efficiency variations for a given motor design; the efficiency for a large population of motors of a single design is not a unique value but rather a band of efficiency. Therefore, the efficiency η_{90} of the population is to be evaluated from the determined efficiencies. The efficiency η_{90} of any motor shall not be less than the nominal efficiency η_{n} minus the tolerance in accordance with IEC 60034-1.

4.4 Classification

The designation of the energy-efficiency class consists of the letters “IE” (short for “International Energy-efficiency class”), directly followed by a numeral representing the classification according to Table 1.

Table 1 – IE-efficiency classification

Designation	Definition
IE1	Motors with an efficiency equal to or exceeding the reference values given in Table 2 diminished by the r_{HL} factor according to the procedure given in 4.2.
IE2	Motors with an efficiency equal to or exceeding the reference values given in Table 3 diminished by the r_{HL} factor according to the procedure given in 4.2.
IE3	Motors with an efficiency equal to or exceeding the reference values given in Table 4 diminished by the r_{HL} factor according to the procedure given in 4.2.
IE4	Motors with an efficiency equal to or exceeding the reference values given in Table 5 diminished by the r_{HL} factor according to the procedure given in 4.2.
IE5	Motors with an efficiency equal to or exceeding the reference values given in Table 6 diminished by the r_{HL} factor according to the procedure given in 4.2.

NOTE 1 Efficiency classes above IE5 are not planned.

NOTE 2 Table 1 is applicable to motors rated to any fundamental frequency.

To determine reference efficiency values with rated powers not given in Tables 2 to 6 within the range of 0,12 kW up to 200 kW, the interpolation formula and coefficients of 4.10 of this document can be applied.

4.5 Nominal limits for efficiency class IE1

Table 2 – Reference values (%) for the calculation of IE1 nominal efficiency limits

Rated output power P_N [kW] at rated speed and full-load torque	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
0,12	31,0	38,3	50,0	45,0
0,18	38,0	45,5	57,0	52,8
0,20	39,7	47,6	58,5	54,6
0,25	43,4	52,1	61,5	58,2
0,37	49,7	59,7	66,0	63,9
0,40	50,9	61,1	66,8	64,9
0,55	56,1	65,8	70,0	69,0
0,75	61,2	70,0	72,1	72,1
1,1	66,5	72,9	75,0	75,0
1,5	70,2	75,2	77,2	77,2
2,2	74,2	77,7	79,7	79,7
3	77,0	79,7	81,5	81,5
4	79,2	81,4	83,1	83,1
5,5	81,4	83,1	84,7	84,7
7,5	83,1	84,7	86,0	86,0
11	85,0	86,4	87,6	87,6
15	86,2	87,7	88,7	88,7
18,5	86,9	88,6	89,3	89,3
22	87,4	89,2	89,9	89,9
30	88,3	90,2	90,7	90,7
37	88,8	90,8	91,2	91,2
45	89,2	91,4	91,7	91,7
55	89,7	91,9	92,1	92,1
75	90,3	92,6	92,7	92,7
90	90,7	92,9	93,0	93,0
110	91,1	93,3	93,3	93,3
132	91,5	93,5	93,5	93,5
160	91,9	93,8	93,8	93,8
200	92,5	94,0	94,0	94,0
250	92,5	94,0	94,0	94,0
315	92,5	94,0	94,0	94,0
355	92,5	94,0	94,0	94,0
400	92,5	94,0	94,0	94,0
450	92,5	94,0	94,0	94,0
500 up to 1 000	92,5	94,0	94,0	94,0

NOTE The tabled values are identical to the nominal values given for IE1 classification in IEC 60034-30-1.

4.6 Nominal limits for efficiency class IE2

Table 3 – Reference values (%) for the calculation of IE2 nominal efficiency limits

Rated output power P_N [kW] at rated speed and full-load torque	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
0,12	39,8	50,6	59,1	53,6
0,18	45,9	56,6	64,7	60,4
0,20	47,4	58,2	65,9	61,9
0,25	50,6	61,6	68,5	64,8
0,37	56,1	67,6	72,7	69,5
0,40	57,2	68,8	73,5	70,4
0,55	61,7	73,1	77,1	74,1
0,75	66,2	75,9	79,6	77,4
1,1	70,8	78,1	81,4	79,6
1,5	74,1	79,8	82,8	81,3
2,2	77,6	81,8	84,3	83,2
3	80,0	83,3	85,5	84,6
4	81,9	84,6	86,6	85,8
5,5	83,8	86,0	87,7	87,0
7,5	85,3	87,2	88,7	88,1
11	86,9	88,7	89,8	89,4
15	88,0	89,7	90,6	90,3
18,5	88,6	90,4	91,2	90,9
22	89,1	90,9	91,6	91,3
30	89,8	91,7	92,3	92,0
37	90,3	92,2	92,7	92,5
45	90,7	92,7	93,1	92,9
55	91,0	93,1	93,5	93,2
75	91,6	93,7	94,0	93,8
90	91,9	94,0	94,2	94,1
110	92,3	94,3	94,5	94,3
132	92,6	94,6	94,7	94,6
160	93,0	94,8	94,9	94,8
200 up to 1 000	93,5	95,0	95,1	95,0

NOTE The tabled values are identical to the nominal values given for IE2 classification in IEC 60034-30-1.

4.7 Nominal limits for efficiency class IE3

Table 4 – Reference values (%) for the calculation of IE3 nominal efficiency limits

Rated output power P_N [kW] at rated speed and full-load torque	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
0,12	50,7	57,7	64,8	60,8
0,18	58,7	63,9	69,9	65,9
0,20	60,6	65,4	71,1	67,2
0,25	64,1	68,6	73,5	69,7
0,37	69,3	73,5	77,3	73,8
0,40	70,1	74,4	78,0	74,6
0,55	73,0	77,2	80,8	77,8
0,75	75,0	78,9	82,5	80,7
1,1	77,7	81,0	84,1	82,7
1,5	79,7	82,5	85,3	84,2
2,2	81,9	84,3	86,7	85,9
3	83,5	85,6	87,7	87,1
4	84,8	86,8	88,6	88,1
5,5	86,2	88,0	89,6	89,2
7,5	87,3	89,1	90,4	90,1
11	88,6	90,3	91,4	91,2
15	89,6	91,2	92,1	91,9
18,5	90,1	91,7	92,6	92,4
22	90,6	92,2	93,0	92,7
30	91,3	92,9	93,6	93,3
37	91,8	93,3	93,9	93,7
45	92,2	93,7	94,2	94,0
55	92,5	94,1	94,6	94,3
75	93,1	94,6	95,0	94,7
90	93,4	94,9	95,2	95,0
110	93,7	95,1	95,4	95,2
132	94,0	95,4	95,6	95,4
160	94,3	95,6	95,8	95,6
200 up to 1 000	94,6	95,8	96,0	95,8

NOTE The tabled values are identical to the nominal values given for IE3 classification in IEC 60034-30-1.

4.8 Nominal limits for efficiency class IE4

Table 5 – Reference values (%) for the calculation of IE4 nominal efficiency limits

Rated output power P_N [kW] at rated speed and full-load torque	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
0,12	62,3	64,9	69,8	66,5
0,18	67,2	70,1	74,7	70,8
0,20	68,4	71,4	75,8	71,9
0,25	70,8	74,1	77,9	74,3
0,37	74,3	78,0	81,1	78,1
0,40	74,9	78,7	81,7	78,9
0,55	77,0	80,9	83,9	81,5
0,75	78,4	82,7	85,7	83,5
1,1	80,8	84,5	87,2	85,2
1,5	82,6	85,9	88,2	86,5
2,2	84,5	87,4	89,5	88,0
3	85,9	88,6	90,4	89,1
4	87,1	89,5	91,1	90,0
5,5	88,3	90,5	91,9	90,9
7,5	89,3	91,3	92,6	91,7
11	90,4	92,3	93,3	92,6
15	91,2	92,9	93,9	93,3
18,5	91,7	93,4	94,2	93,7
22	92,1	93,7	94,5	94,0
30	92,7	94,2	94,9	94,5
37	93,1	94,5	95,2	94,8
45	93,4	94,8	95,4	95,0
55	93,7	95,1	95,7	95,3
75	94,2	95,4	96,0	95,6
90	94,4	95,6	96,1	95,8
110	94,7	95,8	96,3	96,0
132	94,9	96,0	96,4	96,2
160	95,1	96,2	96,6	96,3
200	95,4	96,3	96,7	96,5
250	95,4	96,5	96,7	96,5
315 up to 1 000	95,4	96,6	96,7	96,5

NOTE The tabled values are identical to the nominal values given for IE4 classification in IEC 60034-30-1.

4.9 Nominal limits for efficiency class IE5

Table 6 – Reference values (%) for the calculation of IE5 nominal efficiency limits

Rated output power P_N [kW] at rated speed and full-load torque	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
0,12	67,4	69,8	74,3	71,4
0,18	71,9	74,6	78,7	75,2
0,20	73,0	75,7	79,6	76,2
0,25	75,2	78,1	81,5	78,3
0,37	78,4	81,6	84,3	81,7
0,40	78,9	82,2	84,8	82,3
0,55	80,6	84,2	86,7	84,6
0,75	82,0	85,7	88,2	86,3
1,1	84,0	87,2	89,5	87,8
1,5	85,5	88,4	90,4	88,9
2,2	87,2	89,7	91,4	90,2
3	88,4	90,6	92,1	91,1
4	89,4	91,4	92,8	91,8
5,5	90,4	92,2	93,4	92,6
7,5	91,3	92,9	94,0	93,3
11	92,2	93,7	94,6	94,0
15	92,9	94,3	95,1	94,5
18,5	93,3	94,6	95,3	94,9
22	93,6	94,9	95,5	95,1
30	94,1	95,3	95,9	95,5
37	94,4	95,6	96,1	95,8
45	94,7	95,8	96,3	96,0
55	94,9	96,0	96,5	96,2
75	95,3	96,3	96,7	96,5
90	95,5	96,5	96,9	96,6
110	95,7	96,6	97,0	96,8
132	95,9	96,8	97,1	96,9
160	96,1	96,9	97,2	97,0
200 up to 1 000	96,3	97,0	97,4	97,2

4.10 Interpolation of reference values at intermediate powers

To determine reference values for variable speed motors with rated powers not given in Tables 2, 3, 4, 5 and 6 within the range of 0,12 kW up to 200 kW the following formula shall be applied:

$$\eta_{\mathrm{ref}} = A \cdot [\log_{10}\{P_{\mathrm{N}}\}]^3 + B \cdot [\log_{10}\{P_{\mathrm{N}}\}]^2 + C \cdot [\log_{10}\{P_{\mathrm{N}}\}] + D$$

Where A, B, C, D are interpolation coefficients (see Table 7 and Table 8); P_{N} is given in [kW].

NOTE The formula and interpolation coefficients were mathematically derived to create a best fitting curve for the desired reference values. They do not have a physical meaning.

The resulting reference value (%) shall be rounded to the nearest tenth, i.e. xx,x %.

Table 7 – Interpolation coefficients for rated powers 0,12 kW up to 0,64 kW

IE-Code	Coefficients	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
IE1	A	5,9466	–45,9652	16,7271	11,924
	B	7,9458	–87,1474	12,7136	6,3699
	C	40,441	–8,2383	25,947	30,0509
	D	66,146	68,7303	76,174	76,6136
IE2	A	6,4855	–15,9218	17,2751	22,4864
	B	9,4748	–30,258	23,978	27,7603
	C	36,852	16,6861	35,5822	37,8091
	D	70,762	79,1838	84,9935	82,458
IE3	A	-0,5896	–17,361	7,6356	6,8532
	B	-25,526	–44,538	4,8236	6,2006
	C	4,2884	–3,0554	21,0903	25,1317
	D	75,831	79,1318	86,0998	84,0392
IE4	A	-4,9735	–13,0355	8,432	–8,8538
	B	-21,453	–36,9497	2,6888	–20,3352
	C	2,6653	–4,3621	14,6236	8,9002
	D	79,055	82,0009	87,6153	85,0641
IE5	A	-9,5776	–6,1120	11,0118	–7,0239
	B	-30,1627	–23,1331	8,3635	–16,9944
	C	-4,5962	1,6331	16,0368	8,1621
	D	81,2564	86,0990	90,5323	87,7915

Table 8 – Interpolation coefficients for rated powers 0,65 kW up to 200 kW

IE-Code	Coefficients	Rated speed within 600 to 900 /min	Rated speed within 901 to 1 200 /min	Rated speed within 1 201 to 1 800 /min	Rated speed within 1 801 to 6 000 /min
IE1	A	2,4433	0,0786	0,5234	0,5234
	B	–13,8	–3,5838	–5,0499	–5,0499
	C	30,656	17,2918	17,4180	17,4180
	D	65,238	72,2383	74,3171	74,3171
IE2	A	2,1311	0,0148	0,0278	0,2972
	B	–12,029	–2,4978	–1,9247	–3,3454
	C	26,719	13,2470	10,4395	13,0651
	D	69,735	77,5603	80,9761	79,077
IE3	A	0,7189	0,1252	0,0773	0,3569
	B	-5,1678	–2,613	–1,8951	–3,3076
	C	15,705	11,9963	9,2984	11,6108
	D	77,074	80,4769	83,7025	82,2503
IE4	A	0,6556	0,3598	0,2412	0,34
	B	-4,7229	–3,2107	–2,3608	–3,0479
	C	13,977	10,7933	8,446	10,293
	D	80,247	84,107	86,8321	84,8208
IE5	A	0,6183	0,3394	0,2459	0,3106
	B	–4,2672	–2,8578	–2,136	–2,6854
	C	12,0866	9,2088	7,1743	8,7516
	D	83,5379	86,8489	89,1712	87,4633

5 Required documentation

5.1 Information on the rating plate

The IE-code of the efficiency class shall be durably marked on the rating plate, for example "IE2". No marking of the efficiency value on the rating plate is required.

Some motors have rated efficiencies below IE1. No marking of these motors shall be required.

Minimum parameters to setup the converter should be provided on the rating plate or in the documentation.

5.2 Information in the documentation

The following information is required:

- The comparable frequency converter setup (converter type, supply voltage, etc.) that was used for testing losses and efficiency to allow a comparable re-testing (see IEC TS 60034-2-3).
- Motor losses at the seven standardized operating points according to IEC TS 60034-2-3.

The following information is optional:

- The seven parameters c_{L1} ... c_{L7} for the interpolation formula given in IEC TS 60034-2-3.
- Motor losses in more than the seven standardized operating points according to IEC TS 60034-2-3.

Bibliography

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

IEC 60034-12, *Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors*

IEC TS 60034-25, *Rotating electrical machines – Part 25: AC electrical machines used in power drive systems – Application guide*

IEC TS 60034-31, *Rotating electrical machines – Part 31: Selection of energy-efficient motors including variable speed applications – Application guide*

IEC 60072-1, *Dimensions and output series for rotating electrical machines – Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080*

ISO 3, *Preferred numbers – Series of preferred numbers*

ISO 25745-2: *Energy performance of lifts, escalators and moving walks – Part 2: Energy calculation and classification for lifts (elevators)*

EN 12101-3, *Smoke and heat control systems – Part 3: Specification for powered smoke and heat exhaust ventilators*

EN 50347, *General purpose three-phase induction motors having standard dimensions and outputs – Frame numbers 56 to 315 and flange numbers 65 to 740*

JIS C 4212 (Japanese Industrial Standard), *Low-voltage three-phase squirrel-cage high-efficiency induction motors*

NBR 17094-1, *Rotating electrical machines – Induction motors – Specification*

NEMA MG1, *Motors and Generators*

SANS 1804-1 (South African Standard), *Induction motors – Part 1: IEC requirements*

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