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Edition 1.0 2014-03

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

IEC 60034-30-1:2014-03(en-fr)

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CONTENTS

FOREWORD ... 3
INTRODUCTION ... 5
1 Scope ... 7
2 Normative references ... 8
3 Terms, definitions and symbols ... 9
3.1 Terms and definitions ... 9
3.2 Symbols ... 9
4 Fields of application ... 10
5 Efficiency ... 11
5.1 Determination ... 11
5.1.1 General ... 11
5.1.2 Rated voltages, rated frequencies and rated power ... 11
5.1.3 Auxiliary devices ... 12
5.2 Rating ... 12
5.3 Classification and marking ... 13
5.3.1 General ... 13
5.3.2 Efficiency classification ... 13
5.3.3 Motors below IE1 efficiency ... 13
5.3.4 Marking ... 13
5.4 Nominal limits for efficiency classes IE1, IE2, IE3 and IE4 ... 13
5.4.1 Nominal efficiency limits for IE1 ... 14
5.4.2 Nominal efficiency limits for IE2 ... 16
5.4.3 Nominal efficiency limits for IE3 ... 18
5.4.4 Nominal efficiency limits for IE4 ... 20
5.4.5 Interpolation of nominal efficiency limits of intermediate rated powers for 50 Hz mains supply frequency ... 21
5.4.6 Interpolation of nominal efficiency limits of intermediate rated powers for 60 Hz mains supply frequency ... 23
Annex A (informative) Nominal limits for efficiency class IE5 ... 24
Bibliography ... 25

Table 1 – Motor technologies and their energy-efficiency potential ... 10
Table 2 – IE-Efficiency classification ... 13
Table 3 – Nominal efficiency limits (%) for 50 Hz IE1 ... 14
Table 4 – Nominal efficiency limits (%) for 60 Hz IE1 ... 15
Table 5 – Nominal efficiency limits (%) for 50 Hz IE2 ... 16
Table 6 – Nominal efficiency limits (%) for 60 Hz IE2 ... 17
Table 7 – Nominal efficiency limits (%) for 50 Hz IE3 ... 18
Table 8 – Nominal efficiency limits (%) for 60 Hz IE3 ... 19
Table 9 – Nominal efficiency limits (%) for 50 Hz IE4 ... 20
Table 10 – Nominal efficiency limits (%) for 60 Hz IE4 ... 21
Table 11 – Interpolation coefficients for 0,12 kW up to 0,74 kW ... 22
Table 12 – Interpolation coefficients for 0,75 kW up to 200 kW ... 22

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ROTATING ELECTRICAL MACHINES –

Part 30-1: Efficiency classes of line operated AC motors (IE code)

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International Standard IEC 60034-30-1 has been prepared by IEC technical committee 2: Rotating machinery.

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

FDIS	Report on voting
2/1729/FDIS	2/1739/RVD

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

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INTRODUCTION

This IEC standard provides for the global harmonization of energy-efficiency classes of electric motors. It deals with all kinds of electric motors that are rated for line operation (including starting at reduced voltage). This includes all single- and three-phase low voltage induction motors, regardless of their rated voltage and frequency, as well as line-start permanent-magnet motors.

A second part of this standard series (IEC 60034-30-2) will be prepared for motors rated for variable voltage and frequency supply, such as synchronous motors. The second part will also provide for harmonic voltage losses in motors capable of line operation when fed by frequency converters.

IEC 60034-30-1 widens the product range covered in the first edition of IEC 60034-30 significantly. The power range has been expanded (starting at 0,12 kW and ending at 1 000 kW). All technical constructions of electric motors are covered as long as they are rated for on-line operation and not just three-phase, cage-induction motors as in the first edition.

The IE4 class is newly included in this standard. The informative definition of IE4, which was previously included in IEC/TS 60034-31:2010, is therefore outdated.

The new class IE5 is not yet defined in detail but is envisaged for potential products in a future edition of the standard.

For a given power and frame size it is generally easier to achieve a higher motor efficiency when the motor is designed for and operated directly on-line with a 60 Hz supply frequency rather than on 50 Hz as explained in Note 1.

NOTE 1 As the utilization and size of motors are related to torque rather than power the theoretical power of single-speed motors increases linearly with supply frequency (and hence with speed), i.e. by 20 % from 50 Hz to 60 Hz.

I^2R winding-losses are dominant especially in small and medium sized induction motors. They basically remain constant at 50 Hz and 60 Hz as long as the torque is kept constant. Although windage, friction and iron losses increase with frequency, they play a minor role especially in motors with a number of poles of four and higher. Therefore, at 60 Hz, the losses increase less than the 20 % power increase when compared to 50 Hz and consequently, the efficiency is improved.

In practice, both 60 Hz and 50 Hz power designations of single-speed motors have to conform to standard power levels in accordance with IEC 60072-1 and local standards such as EN 50347. Therefore, an increased rating of motor power by 20 % is not always possible. However the general advantage of 60 Hz still applies when the motor design is optimized for the respective supply frequency rather than just re-rated.

The difference in efficiency between 50 Hz and 60 Hz varies with the number of poles and the size of the motor. In general, the 60 Hz efficiency of three-phase, cage-induction motors in the power range from 0,75 kW up to 375 kW is between 2,5 percentage points to less than 0,5 percentage points greater when compared to the 50 Hz efficiency. Only large 2-pole motors may experience a reduced efficiency at 60 Hz due to their high share of iron, windage and friction losses.

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

Users should select the efficiency class in accordance with a given application depending on the actual operating hours. It may not be energy efficient to select motors of a high efficiency class for intermittent or short time duty due to increased inertia and start-up losses.

NOTE 2 The application guide IEC/TS 60034-31:2010 gives further information on useful applications of high-efficient electric motors.

In order to achieve a significant market share it is essential for high-efficiency motors to meet national/regional standards for assigned powers in relation to mechanical dimensions (such as frame-size, flanges). There are a number of national/regional frame assignment standards (EN 50347, JIS C 4212, NBR 17094, NEMA MG13, SANS 1804 and others) but these are

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IEC standard. As this standard (IEC 60034-30-1) defines energy-efficiency classes independent of dimensional constraints it may not be possible in all markets to produce motors with higher efficiency classes and maintain the mechanical dimensions of the national/regional standards.

IE codes are not limited to motors but may 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.

Combinations of components (such as power drive systems) will need a combined efficiency rating. That rating should not be an IE code in order to avoid confusion. It will be defined in other IEC standards.

The efficiency levels in this standard for 50 Hz and 60 Hz are not always entirely consistent across all numbers of poles and over the whole power range.

NOTE 3 The efficiency levels for 60 Hz motors were assigned for compatibility with U.S. legal requirements.

NOTE 4 The efficiency levels for 50 Hz motors between 0,75 kW and 375 kW remain unchanged for compatibility with European legal requirements.

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ROTATING ELECTRICAL MACHINES –

Part 30-1: Efficiency classes of line operated AC motors (IE code)

1 Scope

This part of IEC 60034 specifies efficiency classes for single-speed electric motors that are rated according to IEC 60034-1 or IEC 60079-0, are rated for operation on a sinusoidal voltage supply and:

- 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 2, 4, 6 or 8 poles;
- are capable of continuous operation at their rated power with a temperature rise within the specified insulation temperature class;

  NOTE 1 Most motors covered by this standard 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.

- are marked with 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.

  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 standard.

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

- are marked with an 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.

This standard establishes a set of limit efficiency values based on frequency, number of poles and motor power. No distinction is made between motor technologies, supply voltage or motors with increased insulation designed specifically for converter operation even though these motor technologies may not all be capable of reaching the higher efficiency classes (see Table 1). This makes different motor technologies fully comparable with respect to their energy efficiency potential.

NOTE 6 Regulators should consider the above constraints when assigning national minimum energy-efficiency performance standards (MEPS) with respect to any particular type of motor.

The efficiency of power-drive systems is not covered by this standard. In particular, motor losses due to harmonic content of the supply voltage, losses in cables, filters and frequency-converters, are not covered.

Motors with flanges, feet and/or shafts with mechanical dimensions different from IEC 60072-1 are covered by this standard.

Geared motors are covered by this standard including those incorporating non-standard shafts and flanges.

Excluded are:

- Single-speed motors with 10 or more poles or multi-speed motors.

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- Motors with mechanical commutators (such as DC motors).
- Motors completely integrated into a machine (for example pump, fan and compressor) that cannot be practically tested separately from the machine even with provision of a temporary end-shield and drive-end bearing. This means the motor shall: 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. That is, for a motor to be excluded from this standard, the process of separation shall render the motor inoperative.

  (TEAO, IC418) Totally enclosed air-over machines, i.e. totally enclosed frame-surface cooled machines intended for exterior cooling by a ventilating means external to the machine, are covered by this standard. Efficiency testing of such motors may be performed with the fan removed and the cooling provided by an external blower with a similar airflow rate as the original fan.
- Motors with integrated frequency-converters (compact drives) when the motor cannot be tested separately from the converter. Energy efficiency classification of compact drives shall be based on the complete product (PDS : Power Drive System) and will be defined in a separate standard.

  NOTE 7 A motor is not excluded when the motor and frequency-converter can be separated and the motor can be tested independently of the converter.
- 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.

  NOTE 8 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 or by energizing the brake coil from a separate power source).

  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.
- Submersible motors specifically designed to operate wholly immersed in a liquid.
- Smoke extraction motors with a temperature class above 400 °C.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

IEC 60034-2-1, *Rotating electrical machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles)*

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

IEC 60034-6, *Rotating electrical machines – Part 6: Methods of cooling (IC Code)*

IEC/TS 60034-25, *Rotating electrical machines – Part 25: Guidance for the design and performance of a.c. motors specifically designed for converter supply*

IEC 60038, *IEC standard voltages*

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IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

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.

3.1.1
single-speed motor
motor rated for 50 Hz and/or 60 Hz on-line operation

Note 1 to entry: Single-speed motors may be capable of frequency converter operation with variable speed.

3.1.2
multi-speed motor
motor rated for 50 Hz and/or 60 Hz on-line operation that has multiple windings or a switchable winding to provide two or more different number of poles with different synchronous speeds

3.1.3
variable speed motor
motor rated for a speed range and supplied by voltage of variable amplitude and frequency

3.1.4
brake motor
motor equipped with an electro-mechanical brake unit operating directly on the motor shaft without couplings

3.1.5
geared motor
motor equipped with an integral gearbox without couplings (i.e. the first gear wheel is fixed to the motor shaft)

3.1.6
pump motor
motor directly attached to a pump without couplings (i.e. the impeller is fixed to the motor shaft)

3.1.7
average efficiency
average efficiency value for a motor population of the same design and rating

3.1.8
nominal efficiency
efficiency value required to meet a certain efficiency class according to the efficiency tables in this standard

3.1.9
rated efficiency
efficiency value assigned by the manufacturer, equal to the nominal efficiency value or higher

3.2 Symbols

η_n is the nominal efficiency, %

η_N is the rated efficiency, %

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f_N is the rated frequency, Hz

n_N is the rated speed, min^{-1}

P_N is the rated power, kW

T_N is the rated torque, Nm

U_N is the rated voltage, V

4 Fields of application

Table 1 gives information on line-start and energy-efficiency potential of various commonly used motor technologies.

Not all motor technologies are able to reach all efficiency classes nor can motors for all efficiency classes or sizes be produced or operated in an economically feasible way. Therefore, regulators are asked to consider the following constraints when assigning minimum energy efficiency performance standards (MEPS).

Motors marked with “Yes” in Table 1 are considered to be state of present technology and are consequently suitable for consideration in mandatory requirements in legislation.

Table 1 – Motor technologies and their energy efficiency potential

Motor type		IE1	IE2	IE3	IE4	IE5
Three-phase cage-rotor induction motors (ASM)	Random wound windings (all enclosures, all ratings)	Yes	Yes	Yes	Difficult	No
	Form wound windings; IP2x (open motors)	Yes	Yes	Difficult	No	No
	Form wound windings; IP4x and above	Yes	Yes	Yes	Difficult	No
Three-phase wound-rotor induction motors		Yes	Yes	Yes	Difficult	No
Single-phase induction motors	Start capacitor	Difficult	No	No	No	No
	Run capacitor	Yes	Difficult	No	No	No
	Start/run capacitor	Yes	Difficult	No	No	No
	Split-phase	Difficult	No	No	No	No
Synchronous motors	Line-start permanent-magnet (LSPM [a])	Yes	Yes	Yes	Difficult	No

[a] Line-start permanent-magnet motors have limitations on their line-start capabilities with respect to torque and external inertia and may not be suitable for all types of applications.

NOTE 1 With regard to the IE levels, “Yes” means the efficiency class is achievable with present technology (although in some cases it may not be economical); “No” means the efficiency class is not generally achievable with present technology; “Difficult” means that the energy-efficiency level may be achieved with present technology for some but not all power ratings and the standardized frame-size may be exceeded. “Line-start” means the capability of the motor to start direct on-line (Design N of IEC 60034-12 for single-speed, three-phase cage induction motors) without the need for a frequency converter.

NOTE 2 It may be difficult to develop motors for efficiency classes IE3 and above within the local power / frame size standards (such as NBR 17094 or EN 50347).

NOTE 3 It is expected that motors for efficiency class IE5 will be covered in part 2 of this standard.

NOTE 4 The energy efficiency potential of motor technologies regarding IE5 classification will be revised after the IE5 classification has been defined.

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Motors covered by this standard may be used in variable-speed drive applications (see IEC/TS 60034-25). In such applications the actual efficiency of the motor is lower than the rated efficiency due to increased losses from the harmonic-voltage content of the power supply. For efficiency testing see IEC/TS 60034-2-3.

The energy efficiency classification of motors in this standard is related to the losses at sinusoidal power supply only.

The following motors may not be able to reach the higher efficiency classes specifications (IE3 and above):

- Motors with cooling methods other than IC0Ax, IC1Ax, IC2Ax, IC3Ax or IC4Ax (see IEC 60034-6);
- Motors built for a restricted space (high-output design, i.e. smaller frame sizes than usual in national standards);
- Motors specifically built for operation in explosive environments according to IEC 60079-0 (due to safety requirements and possible design constraints of explosion proof motors such as increased air-gap, reduced starting current, enhanced sealing);
- Motors for special requirements of the driven machine beyond the requirements of the IEC 60034 series of standards (such as motors for heavy starting duty, special torque stiffness and/or breakdown torque characteristics, large number of start/stop cycles, very low rotor inertia);
- Motors for special characteristics of the grid supply beyond the requirements of the IEC 60034 series of standards (such as motors with limited starting current, increased tolerances of voltage and/or frequency);
- Motors with liquid cooling on account of their higher power density compared with air cooled motors of the same frame size;
- Smoke extraction motors with a temperature class higher than 300 °C.

5 Efficiency

5.1 Determination

5.1.1 General

This standard deals with single-speed motors operated on-line. Motors operated by frequency-converters may have higher losses as compared to on-line (sinusoidal) power supply due to the harmonic voltage content (for details see IEC/TS 60034-25). They are covered in part two of this standard series.

In order to make efficiency class ratings comparable between different motor technologies, all tests according to this standard shall be performed on sinusoidal voltage.

Efficiency and losses shall be tested in accordance with the preferred method of the individual motor type as given in IEC 60034-2-1.

5.1.2 Rated voltages, rated frequencies and rated power

The rated efficiency shall be determined at rated power P_N, rated voltage U_N and rated frequency f_N.

Motors rated for an extended voltage tolerance (for example 400 V ± 10 % according to IEC 60038) shall be assigned a single rated efficiency, i.e. the extended tolerance shall be disregarded.

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Motors with rated voltage/frequency combinations of the same magnetic flux and power, for example 230 V/400 V (delta/star) or 230 V/460 V (double-star/star), shall have only one rated efficiency and efficiency class (IE code).

Motors with more than one rated voltage/frequency/power combination should be assigned a rated efficiency and a rated efficiency-class (IE code) for each rated voltage/frequency/power combination.

However, as a minimum the lowest efficiency value and the associated IE code (of all rated voltage/frequency/power combinations) shall always be printed on the rating plate.

All efficiency values and IE codes shall be available in the product documentation (catalogue or operating instructions).

NOTE For example in Japan the rating combination “200 V/50 Hz – 200 V/60 Hz – 220 V/60 Hz” is commonly used for single-speed motors and in Europe the rating combination “380 V/50 Hz – 400 V/50 Hz – 415 V/50 Hz – 460 V/60 Hz” is sometimes used. For these examples there will be three or four efficiency ratings and there may be several different IE codes.

5.1.3 Auxiliary devices

Some electric motors covered by this standard 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. Tests for efficiency of such modified standard motors shall be performed on basic motors with original cooling without auxiliary devices installed.

The losses of a separately driven fan are 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.

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

Some types of motors (such as geared motors, pump motors and others) are equipped with shaft seals to prevent ingress of oil or water into the motor. External seals shall be removed for efficiency testing. This applies only to seals that are accessible from the outside without dismantling of the motor (dismantling of the fan-cover and the fan is accepted).

Electro-mechanical brakes shall be removed during testing of motor efficiency. When the motor construction prohibits a 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.

5.2 Rating

The efficiency declared by the manufacturer on the rating plate (rated efficiency) shall be greater or equal to the nominal efficiency as defined in this standard (according to the efficiency class (IE code) on the rating plate).

The full-load efficiency of any motor, when tested at rated voltage and rated frequency shall not be less than the rated-/classification efficiency minus the tolerance of the total losses in accordance with IEC 60034-1.

It is recommended to report efficiencies at 50 %, 75 % and full load in the product documentation. For the purpose of this standard only the efficiency at rated power applies.

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Variations in materials, manufacturing processes and testing result in motor-to-motor efficiency variations for a given motor design; the full-load efficiency for a large population of motors of a single design is not a unique value but rather a band of efficiency. Therefore, the energy efficiency limits given in this standard are nominal.

5.3 Classification and marking

5.3.1 General

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 2.

5.3.2 Efficiency classification

Table 2 – IE efficiency classification

Designation	Definition
IE1	Motors with a rated full-load efficiency equal to or exceeding the limits listed in 5.4.1.
IE2	Motors with a rated full-load efficiency equal to or exceeding the limits listed in 5.4.2.
IE3	Motors with a rated full-load efficiency equal to or exceeding the limits listed in 5.4.3
IE4	Motors with a rated full-load efficiency equal to or exceeding the limits listed in 5.4.4.
IE5	Envisaged for a future edition of this standard. See Annex A.

5.3.3 Motors below IE1 efficiency

Some motors have rated efficiencies below the limits given in Tables 3 and 4. No marking of these motors shall be required.

5.3.4 Marking

The rated efficiency and the IE code shall be durably marked on the rating plate, for example “IE2 – 84,0 %”.

5.4 Nominal limits for efficiency classes IE1, IE2, IE3 and IE4

NOTE Shaded areas in the tables indicate changes compared to the previous edition of this standard.

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5.4.1 Nominal efficiency limits for IE1

Table 3 – Nominal efficiency limits (%) for 50 Hz IE1

P_N kW	Number of poles/synchronous speed min^{-1}			
	2/3000	4/1500	6/1000	8/750
0,12	45,0	50,0	38,3	31,0
0,18	52,8	57,0	45,5	38,0
0,20	54,6	58,5	47,6	39,7
0,25	58,2	61,5	52,1	43,4
0,37	63,9	66,0	59,7	49,7
0,40	64,9	66,8	61,1	50,9
0,55	69,0	70,0	65,8	56,1
0,75	72,1	72,1	70,0	61,2
1,1	75,0	75,0	72,9	66,5
1,5	77,2	77,2	75,2	70,2
2,2	79,7	79,7	77,7	74,2
3	81,5	81,5	79,7	77,0
4	83,1	83,1	81,4	79,2
5,5	84,7	84,7	83,1	81,4
7,5	86,0	86,0	84,7	83,1
11	87,6	87,6	86,4	85,0
15	88,7	88,7	87,7	86,2
18,5	89,3	89,3	88,6	86,9
22	89,9	89,9	89,2	87,4
30	90,7	90,7	90,2	88,3
37	91,2	91,2	90,8	88,8
45	91,7	91,7	91,4	89,2
55	92,1	92,1	91,9	89,7
75	92,7	92,7	92,6	90,3
90	93,0	93,0	92,9	90,7
110	93,3	93,3	93,3	91,1
132	93,5	93,5	93,5	91,5
160	93,8	93,8	93,8	91,9
200	94,0	94,0	94,0	92,5
250	94,0	94,0	94,0	92,5
315	94,0	94,0	94,0	92,5
355	94,0	94,0	94,0	92,5
400	94,0	94,0	94,0	92,5
450	94,0	94,0	94,0	92,5
500 up to 1 000	94,0	94,0	94,0	92,5

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Table 4 – Nominal efficiency limits (%) for 60 Hz IE1

P_N kW	Number of poles/synchronous speed min^{-1}			
	2/3600	**4/1800**	**6/1200**	**8/900**
0,12	57,5	62,0	48,0	36,0
0,18	62,0	66,0	52,5	40,0
0,25	64,0	68,0	57,5	50,5
0,37	70,0	70,0	62,0	57,5
0,55	72,0	74,0	66,0	59,5
0,75	74,0	77,0	72,0	64,0
1,1	78,5	79,0	75,0	73,5
1,5	81,0	81,5	77,0	77,0
2,2	81,5	83,0	78,5	78,0
3,7	84,5	85,0	83,5	80,0
5,5	86,0	87,0	85,0	84,0
7,5	87,5	87,5	86,0	85,0
11	87,5	88,5	89,0	87,5
15	88,5	89,5	89,5	88,5
18,5	89,5	90,5	90,2	88,5
22	89,5	91,0	91,0	90,2
30	90,2	91,7	91,7	90,2
37	91,5	92,4	91,7	91,0
45	91,7	93,0	91,7	91,0
55	92,4	93,0	92,1	91,5
75	93,0	93,2	93,0	92,0
90	93,0	93,2	93,0	92,5
110	93,0	93,5	94,1	92,5
150 up to 1 000	94,1	94,5	94,1	92,5

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