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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)

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

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IEC 60034-30-1 has been prepared by IEC Technical Committee 2: Rotating machinery. It is an International Standard.

This second edition of IEC 60034-30-1 cancels and replaces the first edition of IEC 60034-30-1 published in 2014. This edition constitutes a technical revision.

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

a) Table 1 in Clause 4 revised and IE5 efficiency introduced.
b) New efficiency tables (Table 11 and Table 12) added for IE5 nominal efficiency limits.
c) Table 13 for interpolation coefficients revised based on IE5 limits and the coefficients limited from 0,12 kW to 0,75 kW 0,12 kW to 0,55 kW. A linear interpolation shall be applied to obtain minimum efficiency between 0,55 kW and 0,75 kW.

d) Annex A revised and added Figure A.1 showing nominal, rated, minimum efficiency and tolerance.

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

Draft	Report on voting
2/2235/FDIS	2/2279/RVD

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 are English and French.

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.

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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

INTRODUCTION

This first part of the IEC 60034-30 series, IEC 60034-30-1, 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 either 50 Hz or 60 Hz, or both single- and three-phase low voltage induction motors, regardless of their rated voltage, as well as line-start synchronous motors.

The second part of this standard series (IEC 60034-30-2) is prepared for motors rated for variable voltage and frequency supply.

This second edition of IEC 60034-30-1 introduces a new efficiency class, IE5. It is important to note that International Energy efficiency (IE) class definition is generally independent of the output power – frame size assignment. As standardized dimensions and outputs in the IEC 60072 series are based on today's technology (up to IE4), it can be challenging to implement highest IE classes according to existing frame sizes.

It is possible that motors, especially those with lower output power ratings, are designed and manufactured in one frame size bigger than frame size assigned in IEC 60072-1 to reach IE4 and IE5 efficiency levels.

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 usually conform to standard power levels in accordance with IEC 60072-1. 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 can 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 dimension motors to be suitable for the intended applications based on the load profile, operating hours in order to maximize energy savings considering most energy efficient solutions in addition that all other requirements set by the application are covered. It is possible that selecting motors of a high efficiency class for intermittent or short time duty due to increased inertia and start-up losses is not energy efficient.

NOTE 2 The application guide IEC TS 60034-31 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 or regional standards for assigned powers in relation to mechanical dimensions (such as frame-size, flanges). IEC 60072-1 defines the relationship between mechanical dimensions and rated output as well. There are several national or regional frame assignment standards (JIS C 4212, NBR 17094, NEMA MG13, SANS 1804 and others). As this document (IEC 60034-30-1) defines energy efficiency classes independent of dimensional constraints, it is possible that producing motors with higher efficiency classes, whilst maintaining the mechanical dimensions of national or regional standards, will not be feasible in all markets.

To meet the demands of higher energy efficiency classes, the designs of components and equipment and the selection of efficient materials should not be overlooked. There can be a need to use more materials such as electrical steel, copper and aluminium to enable the design of high efficiency motors. Consequently, the develop IE5 class motors using the same frames sizes as IE4 class motors is not always possible. The higher efficiency class motors are likely to be heavier. This will drive the need to re-design the application of the high efficiency motor.

IE codes are not limited only to motors and are used to classify other components such as frequency converters (IEC 61800-9-2). The same standard defines also IES classes to combinations of components (such as power drive systems).

However, it is anticipated that other components are rated with a comparable system: IE1 meaning low efficiency up to IE5 meaning the highest efficiency.

The efficiency levels in this document 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. and North American legal requirements.

1 Scope

This part of IEC 60034 specifies efficiency classes for single-speed electric motors that are rated in accordance with IEC 60034-1 or IEC 60079-0 and are rated for operation on a sinusoidal either 50 Hz or 60 Hz, or both voltage supply.

The motors within this document:

– have a rated power P_N from 0,12 kW to 1 000 kW;

– have a rated voltage U_N from 50 V up to and including 1 000 V;

– 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 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 by this document.

– are marked with any ambient temperature within the range of –30 °C to +60 °C;

NOTE 2 The rated efficiency and efficiency classes are based on 25 °C ambient temperature in accordance with IEC 60034-2-1.

NOTE 3 Motors exclusively rated for temperatures outside the range –30 °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 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 document establishes a set of nominal efficiency values based on supply frequency, number of poles and motor output power. No distinction is made between motor technologies, supply voltage or motors with increased insulation designed specifically for converter operation even though not all motor technologies are capable of reaching the higher efficiency classes (see Table 1). This makes different motor technologies fully comparable with respect to their energy efficiency potential.

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

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

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

Totally enclosed air-over machines (TEAO, IC418), i.e. totally enclosed frame-surface cooled machines intended for exterior cooling by a ventilating means external to the machine, are covered by this document. Efficiency testing of such motors can be performed with the fan removed and the cooling provided by an external blower with a similar airflow rate as the original fan.

This document does not apply to the following:

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

– 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: a) shares common components (apart from connectors such as bolts) with the driven unit (for example, a shaft or housing) and b) is not 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 document, the process of separation shall render the motor inoperative.
– Motors with integrated frequency converters (compact drives) when the motor cannot be tested separately from the converter. Energy efficiency classification of compact drives is based on the complete product (PDS, ie. Power Drive System) and is defined in IEC 61800-9-2.

NOTE 6 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 7 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 can be done on a motor without the brake. The determined efficiency may then be used as the rating for a motor with or without the brake.

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

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

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

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 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

3.1.1
single-speed motor
motor rated either 50 Hz or 60 Hz, or both for direct-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 either 50 Hz or 60 Hz, or both for direct-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
brake motor
motor equipped with an electro-mechanical brake unit operating directly on the motor shaft without couplings

3.1.4
geared motor
motor equipped with an integral gearbox without couplings (i.e. the first gear wheel is fixed to the motor shaft)

3.1.5
nominal efficiency
minimum rated efficiency value required to meet a certain efficiency class according to the efficiency tables in this document

3.1.6
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, %

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 energy efficiency potential of various commonly used technologies for motors in direct-on-line start and operation.

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-the-art based on present technology and availability of materials for industrial products and can be subject to regulatory requirements.

Table 1 – Common 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	Yes Difficult	Very Difficult[a]
	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 and run capacitor	Yes	Difficult	No	No	No
	Split-phase	Difficult	No	No	No	No
Synchronous motors	Line-start synchronous[b]	Yes	Yes	Yes	Difficult	Very Difficult

[a] It is possible that the design and frame size can be different for IE5 motors, especially for smaller size of motors, in comparison with existing designs with lower efficiency (IE2, IE3 and IE4) levels.

[b] Line-start synchronous motors have limitations on their line-start capabilities with respect to torque and external inertia and are not 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 is not economical); "No" means the efficiency class is not generally achievable with present technology; "Difficult" means that the energy efficiency level can be achieved with present technology for some but not all power ratings and the standardized frame size can 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 can be difficult to develop motors for efficiency classes IE4 and above within the local power/frame size standards (such as NBR 17094-1).

Motors covered by this document may be used in variable-speed drive applications. 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.

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

It is possible that the following motors are not able to reach the highest efficiency classes specifications (IE3 and above):

– motors with cooling methods other than IC0Ax, IC1Ax, IC2Ax, IC3Ax or IC4Ax according to 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 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 (such as motors with limited starting current, increased tolerances of either the voltage or frequency, or both of them);
– 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 document deals with single-speed motors operated on-line.

To make efficiency class ratings comparable between different motor technologies according to this document, all tests 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 and corrected to the ambient temperature of 25 °C.

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.

Motors rated for an extended voltage range (for example 380 V – 440 V) shall fulfil the assigned rated efficiency in the whole voltage range. 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 or double-delta/delta), shall have only one rated efficiency and efficiency class (IE code) per voltage/frequency combination of same flux and power.

Motors with more than one rated voltage/frequency/power combination shall 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) for both 50 Hz and 60 Hz ratings 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 can be several different IE codes.

5.1.3 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, if 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.

Most motors 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 document 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 efficiency minus the tolerance of the total losses in accordance with IEC 60034-1.

It is recommended to report efficiencies at 50 %, 75 % and 100 % power in the product documentation. For this document only the efficiency at rated power applies.

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 document are nominal.

See Figure A.1 in Annex A for the clarification of tolerances and rated (declared), nominal and minimum allowed (guaranteed) efficiency.

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	Motors with a rated full-load efficiency equal to or exceeding the limits listed in 5.4.5.

5.3.3 Motors below IE1 efficiency

Some motors have rated efficiencies below the limits given in Table 3 and Table 4. No efficiency marking of such motors below IE1 efficiencies are 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 %".