IEC 60034-30

Edition 1.0 2008-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Rotating electrical machines –
Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code)**

**Machines électriques tournantes –
Partie 30: Classes de rendement pour les moteurs à induction triphasés à cage, mono vitesse (Code IE)**

IEC 60034-30:2008

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CONTENTS

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Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code)

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

FDIS	Report on voting
2/1518/FDIS	2/1521/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.

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

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

A table of cross-references of all IEC technical committee 2 publications can be found in the IEC technical committee 2 dashboard on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

INTRODUCTION

This International Standard provides for the global harmonization of energy-efficiency classes for electric motors.

Electric motor applications in industry consume between 30 % and 40 % of the generated electrical energy worldwide. Improving efficiency of the complete drive system (i.e. motor and adjustable-speed drives) including the application (or process) is therefore a major concern in energy-efficiency efforts. The total energy saving potential of an optimized system is assumed to be around 30 % to 60 %.

According to the findings of the IEA 7 July 2006 Motor Workshop, electric motors with improved efficiency in combination with frequency converters can save about 7 % of the total worldwide electrical energy. Roughly one quarter to one third of these savings come from the improved efficiency of the motor. The remaining part results from system improvements.

Many different energy efficiency standards for cage induction motors are already in use (NEMA, EPACT, CSA, CEMEP, COPANT, AS/NZS, JIS, GB and others) with new classes currently being developed. It becomes increasingly difficult for manufacturers to design motors for a global market and for customers to understand differences and similarities of standards in different countries.

Motors from 0,75 kW up to 375 kW make up the vast majority of installed motor population and are covered by this standard as shown in Figure 1.

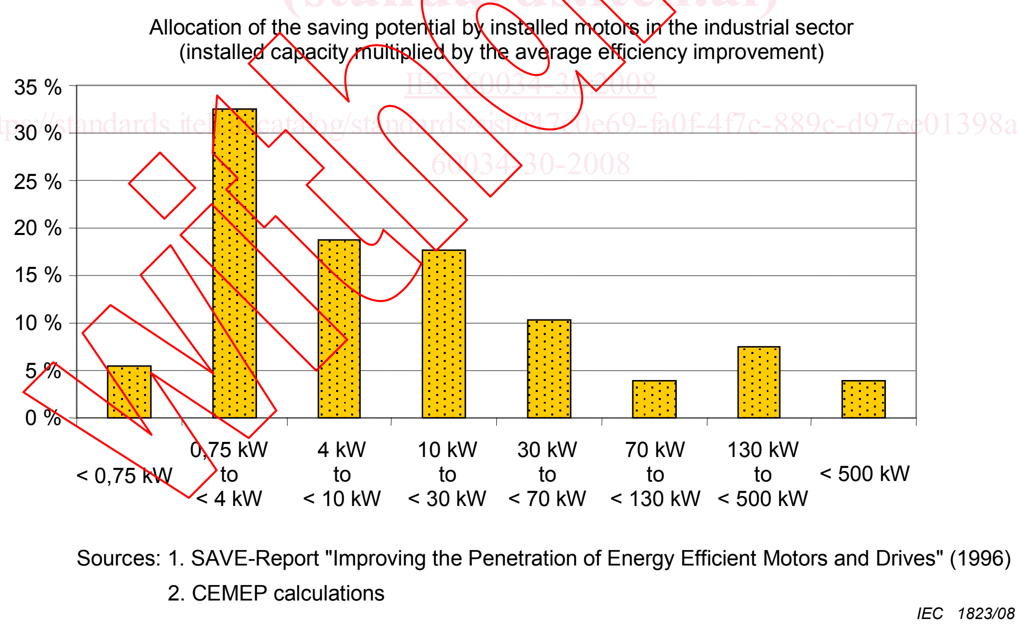

Figure 1 – Allocation of the saving potential by installed motors in the industrial sector

In some countries smaller motors are included in energy efficiency regulations. Most of these motors are not three-phase, cage-induction machines. Also they typically do not run continuously so their energy saving potential is rather limited.

In some countries 8-pole motors are included in energy efficiency regulations. However, their market share is already very low (1 % or less). Due to increasing acceptance of variable-speed drives and the low cost associated with 4- and 6-pole standard motors it is expected that 8-pole motors will even further disappear from the general market in the future. Therefore, this standard does not include provisions for 8-pole motors.

For a given output power and frame size it is generally easier to reach a high motor efficiency when the motor is designed for and operated at 60 Hz mains supply frequency rather than at 50 Hz.

NOTE 1 As the utilization and size of motors are related to torque rather than power the theoretical output power increases linearly 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 for 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 in these motors. Therefore, at 60 Hz, the losses increase less than the 20 % output-power increase compared to 50 Hz and the efficiency improves.

In practice, both 60 Hz and 50 Hz output power designations should conform to standard power levels in accordance with IEC 60072-1 and local standards like EN 50347. Therefore, an increased rating of motor power by 20 % is not always possible. However, the general advantage of 60 Hz still applies if 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 output power range from 0,75 kW up to 375 kW is between 2,5 % to less than 0,5 % 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.

In this standard, the nominal 50 Hz limits of Standard (IE1) and High Efficiency (IE2) are based on the CEMEP-EU EFF2 and EFF1 limits respectively. However, they have been adjusted to take the different test procedures into account (CEMEP: Additional load losses P_{LL} flat 0,5 % of input power; in this standard P_{LL} is determined from test).

The nominal 50 Hz limits for Premium Efficiency (IE3) are set with the losses about 15 % to 20 % lower compared to the limits for High Efficiency (IE2).

The nominal 60 Hz limits for Standard Efficiency (IE1) are identical to Brazilian regulations. The nominal 60 Hz limits for High Efficiency (IE2) and for Premium Efficiency (IE3) are identical to US American EPAct regulations.

A new Super-Premium class (IE4) is envisaged for future editions of this standard.

It is not expected that all manufacturers will produce motors for all efficiency classes or all ratings for a given class.

Users should select the efficiency class in accordance with the application depending on the actual operating hours. It may not be energy efficient to select High- or Premium-Efficiency motors for intermittent or short-time duty.

NOTE 2 An application guide with more details is planned to be released as an IEC publication soon.

In order to achieve a significant market share it is essential for high-efficiency motors to meet national/regional standards for assigned output powers in relation to mechanical dimensions (frame-size, flanges, etc.). There are a number of national/regional frame assignment standards (EN 50347, JISC 4212, NBR 7094, NEMA MG1, SANS 1804 and others) but there is no IEC standard. As this standard (IEC 60034-30) 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.

Regulators should consider the above constraints as well as the field of applications as detailed in Clause 4 when assigning minimum energy-efficiency performance standards (MEPS).

ROTATING ELECTRICAL MACHINES –

Part 30: Efficiency classes of single-speed, three-phase, cage-induction motors (IE-code)

1 Scope

This part of IEC 60034 specifies efficiency classes for single-speed, three-phase, 50 Hz and 60 Hz, cage-induction motors that:

- have a rated voltage U_N up to 1 000 V;

  NOTE The standard also applies to motors rated for two or more voltages and/or frequencies.
- have a rated output P_N between 0,75 kW and 375 kW;
- have either 2, 4 or 6 poles;
- are rated on the basis of either duty type S1 (continuous duty) or S3 (intermittent periodic duty) with a rated cyclic duration factor of 80 % or higher;
- are capable of operating direct on-line;
- are rated for operating conditions in accordance with IEC 60034-1, Clause 6.

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

Geared motors and brake motors are covered by this standard although special shafts and flanges may be used in such motors.

Excluded are:

- Motors made solely for converter operation in accordance with IEC 60034-25.
- Motors completely integrated into a machine (for example pump, fan and compressor) that cannot be tested separately from the machine.

2 Normative references

The following referenced documents are indispensable for the application 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)*

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

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

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

3.1.2
geared motor
a motor directly attached to a gearbox without couplings (i.e. the first gear wheel is fixed to the motor shaft)

3.1.3
pump motor
a motor directly attached to a pump without couplings (i.e. the impeller is fixed to the motor shaft)

3.1.4
average efficiency
the average efficiency value for a motor population of the same design and rating

3.1.5
nominal efficiency
the efficiency value required to meet a certain efficiency class according to the efficiency tables in this standard

3.1.6
rated efficiency
the 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 output power, kW

T_N is the rated output torque, Nm

U_N is the rated voltage, V

4 Fields of application (informative)

Motors covered by this standard may be used in variable-speed drive applications (see IEC 60034-17). In such applications the rated efficiency of the motor should not be assumed to apply due to increased losses from the harmonic-voltage content of the power supply.

Motors with cooling methods other than IC0Ax, IC1Ax, IC2Ax, IC3Ax or IC4Ax (see IEC 60034-6) may not be able to achieve the higher efficiency classes specification.

In some countries, motors are built for a restricted space (high-output design, i.e. smaller frame sizes than usual in national standards). These motors are covered by this standard. However, as a result of the small frame-size they may not be able to achieve the higher efficiency classes specification.

Motors specifically built for operation in explosive environments according to IEC 60079-0 are covered by this standard. However, as a result of safety requirements and certain design constraints of explosion proof motors (like increased air-gap, reduced starting current, enhanced sealing and others) some may not be able to achieve higher efficiency classifications.

NOTE 1 Due to the required certification processes additional time and cost may be necessary to achieve the higher efficiency ratings for some of these motors.

Motors specifically designed

- for special requirements of the driven machine (e.g. heavy starting duty, special torque stiffness and/or breakdown torque characteristics, large number of start/stop cycles, very low rotor inertia);
- for special characteristics of the grid supply (e.g. limited starting current, high tolerances of voltage and/or frequency);
- for special ambient conditions (e.g. very high or low ambient temperature; smoke extraction motors, high altitudes of installation),

may not be able to achieve higher efficiency classifications.

NOTE 2 Regulators should consider the above constraints when assigning national minimum energy efficiency performance standards (MEPS).

5 Efficiency

5.1 Determination

5.1.1 General

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

Efficiency and losses shall be determined in accordance with IEC 60034-2-1.

For IE1 (standard efficiency) and motors below standard efficiency, test methods associated with low and medium uncertainty are acceptable. The selected test method shall be stated in the documentation of the motor.

For all higher energy efficiency levels only methods associated with low uncertainty shall be acceptable.

5.1.2 Rated voltages, rated frequencies and rated output

Motors rated for an extended voltage tolerance (for example 400 V ±10 %) shall be assigned a single rated efficiency and rated efficiency-class (IE-code), i.e. the extended tolerance shall be disregarded.

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

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

All efficiency values and associated 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 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.

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

5.1.3 Auxiliary devices

Some electric motors covered by this standard may be equipped with auxiliary devices like shaft seals, external fans, mechanical brakes, back-stops, speed sensors, tacho-generators, etc. in various combinations.

However, as long as these auxiliary devices are not an integral part of the motor construction, 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 without auxiliary devices installed.

Geared motors and pump motors are often standard motors equipped with shaft seals to prevent ingress of oil or water into the motor. The seals are therefore considered a feature of the gearbox or pump and consequently the efficiency of these motors shall be determined without the seals installed.

5.2 Rating

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

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 individual motor, when tested at rated voltage and frequency, shall not be less than the rated efficiency minus the tolerance on efficiency in accordance with IEC 60034-1.

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

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 1.

5.3.2 Efficiency classification

Table 1 – IE-Efficiency classification

Characteristic numeral	Brief description	Definition
1	Standard	Motors with a rated efficiency at full-load (rated output) equal to or exceeding the limits listed in 5.4.2.
2	High	Motors with a rated efficiency at full-load (rated output) equal to or exceeding the limits listed in 5.4.3.
3	Premium	Motors with a rated efficiency at full-load (rated output) equal to or exceeding the limits listed in 5.4.4.
4	Super-Premium	Under consideration*.
* The levels of the IE4 efficiency class are envisaged to be incorporated into the next edition of this standard. It is the goal to reduce the losses of IE4 by some 15 % relative to IE3. It is expected that technologies other than cage-induction motors will be required to meet IE4 levels. The scope of this standard will be amended accordingly.		

5.3.3 Motors below standard efficiency

Some motors have rated efficiencies below the limits given in Tables 3 and 4. No marking of an IE-code for these motors is 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 efficiency limits

5.4.1 Interpolation

5.4.1.1 50 Hz mains supply frequency

For general use the following formula may be applied:

$$\eta_N = A \cdot \left[\log_{10}\left(\frac{P_N}{1\,\text{kW}}\right)\right]^3 + B \cdot \left[\log_{10}\left(\frac{P_N}{1\,\text{kW}}\right)\right]^2 + C \cdot \log_{10}\left(\frac{P_N}{1\,\text{kW}}\right) + D$$

where A, B, C, D are interpolation coefficients (see Table 2); P_N is given in kW.

NOTE 1 The formula and interpolation coefficients were mathematically derived to create a best fitting curve for the desired nominal efficiency limits. They do not have a physical meaning.

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

Normative, 50 Hz, nominal limits are given in Tables 3, 5 and 7. Normative, 50 Hz, nominal limits for rated output power values not defined in the tables within the output power range of 0,75 kW up to 200 kW shall be computed by applying the preceding formula.

NOTE 2 When efficiency classification of motors below 0,75 kW is requested by customers the interpolation function and coefficients may be used to compute informative values.