# IEC 60034-30-3

Edition 1.0 2024-02

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

colour inside

## Rotating electrical machines –
## Part 30-3: Efficiency classes of high voltage AC motors (IE-code)

## Machines électriques tournantes –
## Partie 30-3: Classes de rendement des moteurs à courant alternatif à haute tension (code IE)

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CONTENTS

FOREWORD ..... 3
INTRODUCTION ..... 5
1 Scope ..... 6
2 Normative references ..... 9
3 Terms, definitions and symbols ..... 9
3.1 Terms and definitions ..... 9
3.2 Symbols ..... 10
4 Efficiency classification ..... 10
4.1 Determination ..... 10
4.1.1 General ..... 10
4.1.2 Auxiliary devices ..... 10
4.2 Efficiency rating – General procedure ..... 11
5 Required documentation ..... 18
Annex A (informative) Standardized nameplate efficiency values ..... 19
Annex B (informative) Proposal for technology factor for starting conditions for high voltage cage induction motors outside the scope of this document ..... 20
Annex C (informative) Example for determining the nominal efficiency ..... 21
Bibliography ..... 22

Figure 1 – Envelope of the load torque during starting: Load torque during starting in % of rated torque over speed in % of rated speed ..... 7

Table 1 – Maximum external moment of inertia ..... 8
Table 2 – Reference efficiency values $\eta_r$ for $2p$ = 2, $f_N$ = 50 Hz ..... 11
Table 3 – Reference efficiency values $\eta_r$ for $2p$ = 4, $f_N$ = 50 Hz ..... 12
Table 4 – Reference efficiency values $\eta_r$ for $2p$ = 6, $f_N$ = 50 Hz ..... 13
Table 5 – Reference efficiency values $\eta_r$ for $2p$ = 2, $f_N$ = 60 Hz ..... 14
Table 6 – Reference efficiency values $\eta_r$ for $2p$ = 4, $f_N$ = 60 Hz ..... 15
Table 7 – Reference efficiency values $\eta_r$ for $2p$ = 6, $f_N$ = 60 Hz ..... 16
Table 8 – Technology factor $c_u$ for rated voltage $U_N$ ..... 17
Table 9 – Technology factor $c_c$ for method of cooling (IC class) ..... 17
Table 10 – Technology factor $c_s$ for starting conditions for motors within the scope of this document ..... 17
Table A.1 – Standardized nameplate efficiency levels ..... 19
Table B.1 – Technology factor $c_s$ for starting conditions for high voltage cage induction motors outside the scope of this document ..... 20

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# ROTATING ELECTRICAL MACHINES –

## Part 30-3: Efficiency classes of high voltage AC motors (IE-code)

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

| Draft | Report on voting |
|---|---|
| 2/2131/CDV | 2/2160/RVC |

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

The language used for the development of this International Standard is English.

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This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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# INTRODUCTION

This document provides the global harmonization of energy-efficiency classes of three-phase cage induction motors with rated voltage above 1 000 V that are rated for direct online starting and fixed-speed operation at a 50 Hz or 60 Hz supply with sinusoidal voltage.

For these motors, the demands of the power supply and of the driven equipment in many cases govern the design of the electrical machine. Due to the large size and power of high-voltage (HV) motors, these demands are more complex than for low-voltage motors and often limit the design. Vice versa, the properties of the electrical machine itself influence the grid considerably in many cases.

In order to ensure an easy applicability of this document, the scope is limited to the most relevant applications, i.e. motors for driving the vast majority of pumps, fans, or compressors, which cover approximately 80 % to 90 % of all applications. Motors for special applications, e.g. for accelerating very high load inertia, for very low supply voltage during starting, for very low locked-rotor current or for accelerating against high load torque, are therefore out of the scope of this document.

Despite this, the motor technology, namely

- rated voltage,
- method of cooling,
- locked-rotor current,

have a significant influence on the achievable motor efficiency as well as the rated frequency, the rated power and the number of poles, and are considered when specifying the efficiency class.

NOTE When specifying or designing a power drive system, low voltage motors will mostly have a higher efficiency than high voltage motors with the same rated power. However, considering the losses of the complete system, i.e. including cabling and transformer losses, high voltage solution might be advantageous.

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# ROTATING ELECTRICAL MACHINES –

## Part 30-3: Efficiency classes of high voltage AC motors (IE-code)

## 1 Scope

This part of IEC 60034 specifies efficiency classes for fixed-speed three-phase high-voltage cage induction motors in accordance with IEC 60034-1 that

- have a rated voltage exceeding 1 000 V, but not exceeding 11 kV;
- have a rated power from 200 kW to 2 000 kW;

  NOTE 1 Motors with rated power above 2 000 kW are produced in such small numbers and are designed and produced with a focus on achieving an optimum efficiency anyway, even though fulfilling increasingly special requirements that assigning efficiency classes would be an additional effort without the result of any countable energy saving.

- have two, four or six poles;
- are rated for single-speed line-operation;
- are intended for direct-on-line starting at rated or at reduced voltage and rated frequency;
- are constructed to any degree of protection;
- are designed for cooling methods IC411, IC511, IC611, IC01 or IC81W;
- are capable of continuous operation at their rated operating point (torque/power, speed) with a temperature rise within the specified insulation temperature class;

  NOTE 2 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.

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

  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.

- are rated for an operating altitude up to 2 000 m above sea level;

  NOTE 4 The rated efficiency and the efficiency class are based on a rating for altitudes up to 1 000 m above sea level.

- have a locked-rotor current $I_l$ at stand-still and supply with rated voltage and frequency before application of any IEC or agreed tolerance in the range $I_l$ / $I_N$ ≥ 4,5;
- are designed for a customer load torque during starting not exceeding an envelope with a minimum of 25 % of the rated torque at low speed and a square shape $T \sim n^2$ up to a maximum load torque at full speed of 60 % of the rated torque in case of 2 pole motors or 100 % of the rated torque in case of 4 pole or 6 pole motors, respectively, (see Figure 1), After starting is completed, the load torque of 2 pole motors is increased to 100 % of the rated torque;
- have to accelerate an external moment of inertia as defined by the customer requirements not exceeding the values given in Table 1 considering all start up conditions defined in this document for not more than three consecutive starts from cold condition or two starts from hot condition, respectively;
- are designed for a minimum locked-rotor steady state supply voltage of at least 80 % of the rated voltage during starting.

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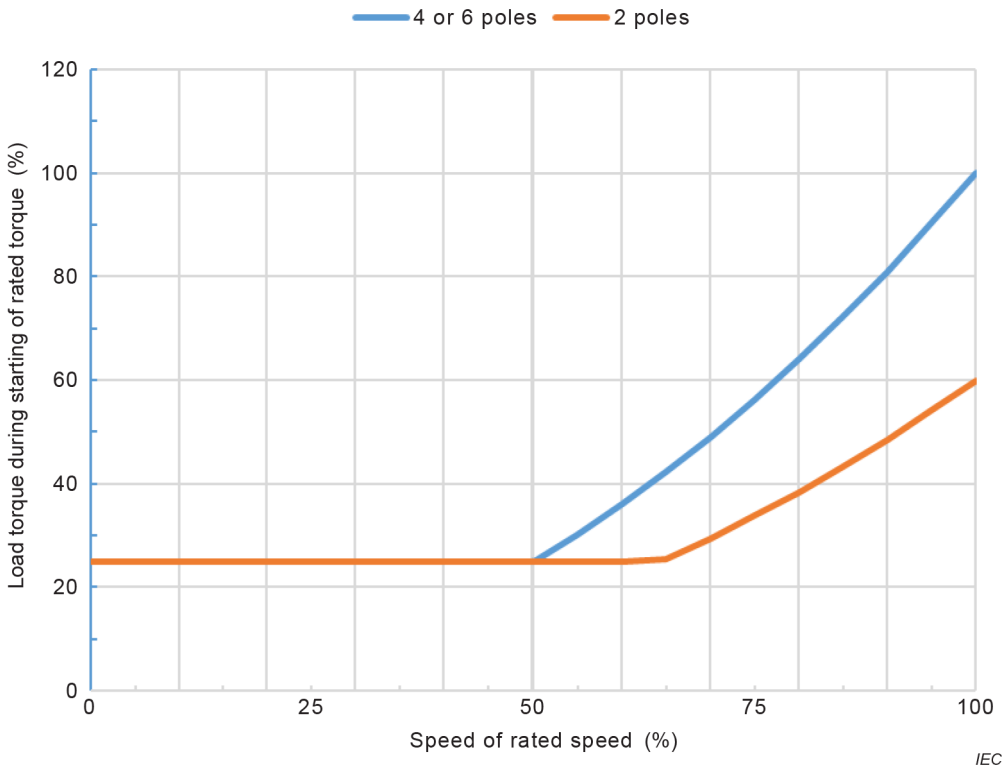


**Figure 1 – Envelope of the load torque during starting:**
**Load torque during starting in % of rated torque over speed in % of rated speed**

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**Table 1 – Maximum external moment of inertia**

| **Number of poles** | **2** | | **4** | | **6** | |
|---|---|---|---|---|---|---|
| **Frequency** Hz | **50** | **60** | **50** | **60** | **50** | **60** |
| **Rated output** kW | **Moment of inertia *J*** kg m$^2$ | | | | | |
| 200 | 25 | 15 | 115 | 75 | 310 | 200 |
| 220 | 25 | 15 | 120 | 80 | 330 | 210 |
| 250 | 25 | 15 | 130 | 85 | 360 | 230 |
| 280 | 30 | 20 | 140 | 90 | 400 | 250 |
| 315 | 30 | 20 | 150 | 100 | 440 | 270 |
| 355 | 35 | 20 | 170 | 110 | 480 | 300 |
| 400 | 35 | 25 | 190 | 120 | 530 | 330 |
| 450 | 40 | 25 | 210 | 130 | 580 | 360 |
| 500 | 45 | 30 | 230 | 140 | 640 | 400 |
| 560 | 50 | 30 | 250 | 150 | 700 | 440 |
| 630 | 55 | 35 | 280 | 170 | 780 | 490 |
| 710 | 60 | 35 | 310 | 190 | 870 | 550 |
| 800 | 65 | 40 | 340 | 210 | 970 | 610 |
| 900 | 70 | 45 | 380 | 230 | 1 100 | 680 |
| 1 000 | 80 | 50 | 420 | 260 | 1 200 | 750 |
| 1 120 | 90 | 55 | 460 | 290 | 1 300 | 830 |
| 1 250 | 100 | 60 | 510 | 320 | 1 450 | 920 |
| 1 400 | 110 | 65 | 570 | 360 | 1 650 | 1 000 |
| 1 600 | 120 | 70 | 640 | 400 | 1 850 | 1 150 |
| 1 800 | 130 | 80 | 720 | 440 | 2 050 | 1 300 |
| 2 000 | 150 | 90 | 800 | 490 | 2 300 | 1 450 |

NOTE 1 The values of the moment of inertia given are in terms of $mr^2$ where $m$ is the mass and $r$ is the mean radius of gyration.

NOTE 2 Moment of inertia is defined in ISO 3: 1973, 3.7.

NOTE 3 If necessary, linear interpolation is permitted between two adjacent values.

Excluded are:

- Motors with mechanical commutators or slip-rings;
- Motors with 8 or more poles;
- Multi-speed motors;
- Motors with customer starting torque requirements exceeding the load torque envelope above, and motors exceeding the maximum external inertia defined in Table 1;
- Motors designed specifically for operation fed by a power electronic frequency converter with a temperature rise within the specified insulation thermal class or thermal class;
- Motors completely integrated with the driven machine (for example pumps, fans and compressors). This means that the motor cannot be designed in such a way as to enable the motor to be separated from the driven unit, i.e. it is not possible to operate the separated motor without the driven unit;
- Submersible motors specifically designed to operate wholly immersed in a liquid;

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- Smoke extraction motors;
- Motors dedicated to operate in explosive atmospheres;
- Motors for operation in nuclear plants, especially nuclear power plants.

## 2 Normative references

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

IEC 60034-1:2022, *Rotating electrical machines – Part 1: Rating and performance*

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

IEC 60050-411:1996, *International Electrotechnical Vocabulary (IEV) – Part 411: Rotating machinery*
IEC 60050-411:1996/AMD1:2007
IEC 60050-411:1996/AMD2:2021

## 3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions in IEC 60050-411, IEC 60034-1, and the following apply.

NOTE 1 For definitions concerning cooling and coolants, other than those in 3.17 to 3.22, see IEC 60034-6.

NOTE 2 For the purposes of this document, the term ‘agreement’ means ‘agreement between the manufacturer and purchaser’.

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 Terms and definitions

**3.1.1**
**reference efficiency**
efficiency value required to meet a certain efficiency class according to the efficiency tables in this document before technology factors for voltage, cooling or starting conditions are applied

**3.1.2**
**nominal efficiency**
efficiency value that a motor’s assigned rated efficiency must meet or exceed at rated operation for a certain efficiency class, considering starting requirements and motor technology

**3.1.3**
**rated efficiency**
efficiency value assigned by the manufacturer to the motor for operation at rated conditions before the application of any IEC or agreed tolerance

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**3.1.4**
**average motor torque**
mean value of the steady-state torque at the motor shaft between stand-still and no-load operation when supplied with rated voltage and frequency

**3.1.5**
**load torque**
speed-dependent torque requirement of the driven equipment at the motor shaft during start-up of the motor between stand-still and full speed

### 3.2 Symbols

$I_l$ is the locked-rotor current at rated voltage before application of any IEC or agreed tolerance

$I_N$ is the rated current

$T_{av}$ is the average motor torque as defined in 3.1.4

$T_N$ is the rated torque

$P_N$ is the rated power

$2p$ is the number of poles

$U_N$ is the rated voltage

$\eta_n$ is the nominal efficiency

$\eta_r$ is the reference efficiency

$\eta_N$ is the rated efficiency

## 4 Efficiency classification

### 4.1 Determination

#### 4.1.1 General

For assigning an efficiency class, efficiency and losses of AC motors within the scope shall be tested according to IEC 60034-2-1 using method 2-1-1B or method 2-1-1C from this document.

#### 4.1.2 Auxiliary devices

Some electric motors covered by this document may be equipped with auxiliary devices such as shaft seals, 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.

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

Some types of motors (like pump motors and others) are equipped with shaft seals to prevent ingress of oil or water into the motor. External seals may 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).

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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.

### 4.2 Efficiency rating – General procedure

A motor's rated efficiency $\eta_N$ is determined from the losses at rated operation obtained by measurement according to IEC 60034-2-1.

The reference efficiency $\eta_r$ (i.e. not considering starting conditions and motor technology) for a certain IE class depends on the rated power $P_N$, the number of poles $2p$ and the rated frequency $f_N$. It is given in Table 2 to Table 7.

IE4 levels of efficiency are added for future consideration and might be unachievable for some power ratings.

**Table 2 – Reference efficiency values $\eta_r$ for $2p$ = 2, $f_N$ = 50 Hz**

| IE-class<br>$2p$ = 2<br>$P_N$ in kW | IE1 | IE2 | IE3 | IE4 |
|---|---|---|---|---|
| 200 | 90,65 % | 91,79 % | 92,79 % | 93,67 % |
| 220 | 90,91 % | 92,03 % | 93,00 % | 93,86 % |
| 250 | 91,18 % | 92,27 % | 93,22 % | 94,06 % |
| 280 | 91,46 % | 92,52 % | 93,44 % | 94,26 % |
| 315 | 91,79 % | 92,81 % | 93,70 % | 94,49 % |
| 355 | 92,12 % | 93,11 % | 93,97 % | 94,73 % |
| 400 | 92,39 % | 93,36 % | 94,20 % | 94,93 % |
| 450 | 92,67 % | 93,60 % | 94,42 % | 95,13 % |
| 500 | 92,94 % | 93,85 % | 94,64 % | 95,32 % |
| 560 | 93,22 % | 94,09 % | 94,86 % | 95,52 % |
| 630 | 93,49 % | 94,34 % | 95,08 % | 95,72 % |
| 710 | 93,71 % | 94,53 % | 95,25 % | 95,88 % |
| 800 | 93,92 % | 94,73 % | 95,43 % | 96,04 % |
| 900 | 94,08 % | 94,87 % | 95,56 % | 96,16 % |
| 1 000 | 94,23 % | 95,00 % | 95,68 % | 96,26 % |
| 1 120 | 94,41 % | 95,17 % | 95,83 % | 96,40 % |
| 1 250 | 94,59 % | 95,33 % | 95,97 % | 96,53 % |
| 1 400 | 94,76 % | 95,48 % | 96,11 % | 96,65 % |
| 1 600 | 94,95 % | 95,64 % | 96,25 % | 96,78 % |
| 1 800 | 95,08 % | 95,77 % | 96,36 % | 96,88 % |
| 2 000 | 95,22 % | 95,89 % | 96,47 % | 96,98 % |

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**Table 3 – Reference efficiency values $\eta_r$ for $2p$ = 4, $f_N$ = 50 Hz**

| IE-class / $2p$ = 4 / $P_N$ in kW | IE1 | IE2 | IE3 | IE4 |
|---|---|---|---|---|
| 200 | 90,88 % | 92,00 % | 92,97 % | 93,83 % |
| 220 | 91,14 % | 92,23 % | 93,18 % | 94,02 % |
| 250 | 91,41 % | 92,47 % | 93,39 % | 94,21 % |
| 280 | 91,68 % | 92,71 % | 93,61 % | 94,40 % |
| 315 | 92,00 % | 93,00 % | 93,87 % | 94,63 % |
| 355 | 92,32 % | 93,29 % | 94,13 % | 94,87 % |
| 400 | 92,59 % | 93,53 % | 94,35 % | 95,06 % |
| 450 | 92,86 % | 93,77 % | 94,57 % | 95,26 % |
| 500 | 93,13 % | 94,01 % | 94,77 % | 95,44 % |
| 560 | 93,40 % | 94,25 % | 94,99 % | 95,64 % |
| 630 | 93,67 % | 94,49 % | 95,21 % | 95,84 % |
| 710 | 93,88 % | 94,68 % | 95,38 % | 95,99 % |
| 800 | 94,09 % | 94,87 % | 95,55 % | 96,15 % |
| 900 | 94,24 % | 95,01 % | 95,68 % | 96,26 % |
| 1 000 | 94,39 % | 95,14 % | 95,80 % | 96,37 % |
| 1 120 | 94,57 % | 95,31 % | 95,95 % | 96,51 % |
| 1 250 | 94,74 % | 95,46 % | 96,08 % | 96,63 % |
| 1 400 | 94,91 % | 95,61 % | 96,22 % | 96,75 % |
| 1 600 | 95,09 % | 95,77 % | 96,36 % | 96,88 % |
| 1 800 | 95,22 % | 95,89 % | 96,47 % | 96,98 % |
| 2 000 | 95,36 % | 96,01 % | 96,58 % | 97,07 % |

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**Table 4 – Reference efficiency values $\eta_r$ for $2p$ = 6, $f_N$ = 50 Hz**

| IE-class<br>$2p$ = 6<br>$P_N$ in kW | IE1 | IE2 | IE3 | IE4 |
|---|---|---|---|---|
| 200 | 90,57 % | 91,72 % | 92,73 % | 93,62 % |
| 220 | 90,83 % | 91,96 % | 92,94 % | 93,81 % |
| 250 | 91,11 % | 92,21 % | 93,16 % | 94,01 % |
| 280 | 91,38 % | 92,45 % | 93,38 % | 94,21 % |
| 315 | 91,72 % | 92,75 % | 93,65 % | 94,45 % |
| 355 | 92,05 % | 93,05 % | 93,92 % | 94,68 % |
| 400 | 92,33 % | 93,30 % | 94,15 % | 94,88 % |
| 450 | 92,60 % | 93,54 % | 94,37 % | 95,09 % |
| 500 | 92,88 % | 93,79 % | 94,59 % | 95,28 % |
| 560 | 93,16 % | 94,04 % | 94,81 % | 95,48 % |
| 630 | 93,43 % | 94,29 % | 95,03 % | 95,68 % |
| 710 | 93,65 % | 94,48 % | 95,21 % | 95,84 % |
| 800 | 93,87 % | 94,68 % | 95,38 % | 96,00 % |
| 900 | 94,03 % | 94,82 % | 95,51 % | 96,12 % |
| 1 000 | 94,17 % | 94,95 % | 95,63 % | 96,23 % |
| 1 120 | 94,36 % | 95,13 % | 95,79 % | 96,37 % |
| 1 250 | 94,54 % | 95,28 % | 95,93 % | 96,49 % |
| 1 400 | 94,70 % | 95,44 % | 96,07 % | 96,62 % |
| 1 600 | 94,90 % | 95,60 % | 96,22 % | 96,75 % |
| 1 800 | 95,04 % | 95,73 % | 96,33 % | 96,85 % |
| 2 000 | 95,18 % | 95,85 % | 96,44 % | 96,95 % |

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