

# TECHNICAL SPECIFICATION

# IEC TS 60034-25

Second edition  
2007-03

---

---

## Rotating electrical machines –

### Part 25:

### Guidance for the design and performance of a.c. motors specifically designed for converter supply

© IEC 2007 — Copyright - all rights reserved

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland  
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: [inmail@iec.ch](mailto:inmail@iec.ch) Web: [www.iec.ch](http://www.iec.ch)



Commission Electrotechnique Internationale  
International Electrotechnical Commission  
Международная Электротехническая Комиссия

PRICE CODE XB

*For price, see current catalogue*

## CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references .....	9
3 Terms and definitions .....	10
4 System characteristics.....	11
4.1 General.....	11
4.2 System information.....	11
4.3 Torque/speed considerations.....	12
4.4 Motor requirements .....	16
5 Losses and their effects (for induction motors fed from U-converters).....	18
5.1 General.....	18
5.2 Location of the additional losses due to <i>converter</i> supply and ways to reduce them .....	18
5.3 <i>Converter</i> features to reduce the motor losses .....	18
5.4 Use of filters to reduce additional motor losses due to <i>converter</i> supply .....	20
5.5 Temperature and life expectancy.....	20
5.6 Determination of motor efficiency .....	21
6 Noise, vibration and torsional oscillation.....	21
6.1 Noise .....	21
6.2 Vibration (excluding torsional oscillation).....	24
6.3 Torsional oscillation .....	25
7 Motor insulation electrical stresses.....	25
7.1 General.....	25
7.2 Causes.....	25
7.3 Winding electrical stress.....	27
7.4 Insulation stress limitation .....	29
7.5 Responsibilities .....	29
7.6 <i>Converter</i> characteristics.....	30
7.7 Methods of reduction of voltage stress .....	31
7.8 Motor choice .....	31
8 Bearing currents.....	32
8.1 Sources of bearing currents in <i>converter</i> -fed motors.....	32
8.2 Generation of high-frequency bearing currents .....	32
8.3 <i>Common mode</i> circuit.....	34
8.4 Stray capacitances .....	34
8.5 Consequences of excessive bearing currents .....	36
8.6 Preventing high-frequency bearing current damage.....	36
8.7 Additional considerations for motors fed by high voltage U-converters .....	38
8.8 Bearing current protection for motors fed by high-voltage current-source <i>converters</i> (I-converters) .....	39
9 Installation.....	39
9.1 Earthing, <i>bonding</i> and cabling .....	39
9.2 Reactors and filters .....	45
9.3 Integral motors (integrated motor and drive modules).....	46

10	Additional considerations for permanent magnet (PM) synchronous motors fed by U-converters.....	47
10.1	System characteristics .....	47
10.2	Losses and their effects .....	47
10.3	Noise, vibration and torsional oscillation.....	47
10.4	Motor insulation electrical stresses.....	47
10.5	Bearing currents.....	48
10.6	Particular aspects of permanent magnets.....	48
11	Additional considerations for cage induction motors fed by high voltage U-converters.....	48
11.1	General.....	48
11.2	System characteristics .....	48
11.3	Losses and their effects .....	50
11.4	Noise, vibration and torsional oscillation.....	50
11.5	Motor insulation electrical stresses.....	51
11.6	Bearing currents.....	53
12	Additional considerations for synchronous motors fed U-converters.....	53
12.1	System characteristics .....	53
12.2	Losses and their effects .....	53
12.3	Noise, vibration and torsional oscillation.....	53
12.4	Motor insulation electrical stresses.....	53
12.5	Bearing currents.....	53
13	Additional considerations for cage induction motors fed by block-type I-converters .....	54
13.1	System characteristics .....	54
13.2	Losses and their effects .....	55
13.3	Noise, vibration and torsional oscillation.....	55
13.4	Motor insulation electrical stresses.....	56
13.5	Bearing currents.....	56
13.6	Additional considerations for six-phase cage induction motors .....	56
14	Additional considerations for synchronous motors fed by LCI .....	56
14.1	System characteristics .....	56
14.2	Losses and their effects .....	58
14.3	Noise, vibration and torsional oscillation.....	58
14.4	Motor insulation electrical stresses.....	58
14.5	Bearing currents.....	58
15	Additional considerations for pulsed I-converters (PWM CSI) feeding induction motors.....	58
15.1	System characteristics .....	58
15.2	Losses and their effects .....	59
15.3	Noise, vibration and torsional oscillation.....	59
15.4	Motor insulation electrical stresses.....	59
15.5	Bearing currents.....	59
16	Other motor/converter systems.....	60
16.1	Drives supplied by cyclo-converters .....	60
16.2	Wound rotor induction (asynchronous) machines supplied by I-converters in the rotor circuit.....	61
16.3	Wound rotor induction (asynchronous) machines supplied by U-converters in the rotor circuit.....	61

Annex A (normative) <i>Converter</i> characteristics .....	63
Annex B (informative) <i>Converter</i> output spectra .....	67
Annex C (informative) Noise increments due to <i>converter</i> supply .....	70
Bibliography.....	71
Figure 1 – Torque/speed capability .....	13
Figure 2 – <i>Converter</i> output current .....	13
Figure 3 – <i>Converter</i> output voltage/frequency characteristics .....	15
Figure 4 – Example of measured losses $P_L$ as a function of frequency $f$ and supply type.....	19
Figure 5 – Additional losses $\Delta P_L$ of a motor (same motor as Figure 4) due to <i>converter</i> supply, as a function of pulse frequency $f_p$ , at 50 Hz rotational frequency .....	20
Figure 6 – Fan noise as a function of fan speed.....	22
Figure 7 – Vibration modes .....	23
Figure 8 – Typical surges at the terminals of a motor fed from a PWM <i>converter</i> .....	26
Figure 9 – Typical voltage surges on one phase at the <i>converter</i> and at the motor terminals (2 ms/division).....	26
Figure 10 – Individual short rise time surge from Figure 9 (1 $\mu$ s/division).....	27
Figure 11 – Definition of the <i>peak rise time</i> $t_r$ of the voltage at the motor terminals .....	28
Figure 12 – First turn voltage as a function of the <i>peak rise time</i> .....	28
Figure 13 – Discharge pulse occurring as a result of <i>converter</i> generated voltage surge at motor terminals (100 ns/division) .....	29
Figure 14 – Limiting curves of impulse voltage $U_{pk}$ , measured between two motor phase terminals, as a function of the <i>peak rise time</i> $t_r$ .....	30
Figure 15 – Possible bearing currents.....	33
Figure 16 – Motor capacitances .....	35
Figure 17 – Bearing pitting due to electrical discharge (pit diameter 30 $\mu$ m to 50 $\mu$ m).....	36
Figure 18 – Fluting due to excessive bearing current .....	36
Figure 19 – <i>Bonding</i> strap from motor terminal box to motor frame .....	41
Figure 20 – Examples of shielded motor cables and connections .....	42
Figure 21 – Parallel symmetrical cabling of high-power <i>converter</i> and motor.....	43
Figure 22 – <i>Converter</i> connections with 360° HF cable glands showing the Faraday cage .....	43
Figure 23 – Motor end termination with 360° connection .....	44
Figure 24 – Cable shield connection .....	44
Figure 25 – Characteristics of preventative measures .....	46
Figure 26 – Schematic of typical three-level <i>converter</i> .....	49
Figure 27 – Output voltage and current from typical three-level <i>converter</i> .....	49
Figure 28 – Typical first turn voltage $\Delta U$ (as a percentage of the line-to-ground voltage) as a function of $du/dt$ .....	51
Figure 29 – Medium-voltage and high-voltage form-wound coil insulating and voltage stress control materials.....	52
Figure 30 – Schematic of block-type I- <i>converter</i> .....	54
Figure 31 – Current and voltage waveforms of block-type I- <i>converter</i> .....	54

Figure 32 – Schematic and voltage and current waveforms for a synchronous motor supplied from an <i>I-converter</i> .....	57
Figure 33 – Schematic of pulsed <i>I-converter</i> .....	58
Figure 34 – Voltages and currents of pulsed <i>I-converter</i> .....	59
Figure 35 – Schematic of <i>cyclo-converter</i> .....	60
Figure 36 – Voltage and current waveforms of a <i>cyclo-converter</i> .....	60
Figure A.1 – Effects of switching frequency on motor and <i>converter</i> losses.....	65
Figure A.2 – Effects of switching frequency on acoustic noise.....	66
Figure A.3 – Effects of switching frequency on torque ripple .....	66
Figure B.1 – Typical frequency spectra of <i>converter</i> output voltage.....	67
Figure B.2 – Typical frequency spectra of <i>converter</i> output voltage.....	67
Figure B.3 – Typical spectra of <i>converter</i> output voltage .....	68
Figure B.4 – Typical time characteristics of motor current .....	68
Figure B.5 – Typical time characteristics of motor current .....	69
Table 1 – Alphabetical list of terms .....	10
Table 2 – Significant factors affecting torque/speed capability .....	14
Table 3 – Motor design considerations .....	16
Table 4 – Motor parameters .....	17
Table 5 – Effectiveness of bearing current countermeasures .....	37
Table C.1 – Noise increments .....	70

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ROTATING ELECTRICAL MACHINES –

**Part 25: Guidance for the design and performance of a.c. motors  
specifically designed for converter supply**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

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

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

IEC 60034-25, which is a technical specification, has been prepared by IEC technical committee 2: Rotating machinery.

This second edition cancels and replaces the first edition published in 2004.

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

- a) replacement of the original introduction by a shorter introduction;
- b) extension of the scope to include all converter-fed motors, not just LV-induction motors;
- c) minor changes throughout Clauses 4 to 9;
- d) addition of subclauses 4.3.4, 4.3.5, 5.4, 6.2.1, 8.6.3, 8.7 and 8.8, and Figure 7;
- e) inclusion of subclauses 4.4 and 4.5 in Annex A;
- f) expansion of original Annex A which becomes Annex B;
- g) re-drafting of Clause 5;
- h) upgrading of 6.1.4 to 6.3;
- i) removal of noise limits from normative text;
- j) addition of reference to IEC 60034-9;
- k) addition of Annex C.

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

Enquiry draft	Report on voting
2/1406/DTS	2/1420A/RVC

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

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

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

## INTRODUCTION

The performance characteristics and operating data for *converter*-fed motors are influenced by the complete drive system, comprising supply system, *converter*, cabling, motor, mechanical shafting and control equipment. Each of these components exists in numerous technical variants. Any values quoted in this technical specification are thus indicative only.

In view of the complex technical interrelations within the system and the variety of operating conditions, it is beyond the scope and object of this technical specification to specify numerical or limiting values for all the quantities which are of importance for the design of the drive system.

To an increasing extent, it is practice that drive systems consist of components produced by different manufacturers. The object of this technical specification is to explain, as far as possible, the influence of these components on the design of the motor and its performance characteristics.

This technical specification deals with a.c. motors which are specifically designed for *converter* supply. *Converter*-fed motors within the scope of IEC 60034-12, which are designed originally for mains supply, are covered by IEC 60034-17.

Clauses 5 to 9 of this technical specification consider mainly the requirements for low voltage induction motors fed from voltage-source *converters* (*U-converters*). Clauses 10 to 16 provide additional information for other configurations.



## ROTATING ELECTRICAL MACHINES –

### Part 25: Guidance for the design and performance of a.c. motors specifically designed for converter supply

#### 1 Scope

This part of IEC 60034 describes the design features and performance characteristics of a.c. motors specifically designed for use on *converter* supplies. It also specifies the interface parameters and interactions between the motor and the *converter* including installation guidance as part of a *power drive system*.

The general requirements of relevant parts of the IEC 60034 series of standards also apply to motors within the scope of this technical specification.

NOTE 1 For motors operating in potentially explosive atmospheres, additional requirements as described in the IEC 60079 series apply.

NOTE 2 This technical specification is not primarily concerned with safety. However, some of its recommendations may have implications for safety, which should be considered as necessary.

NOTE 3 Where a *converter* manufacturer provides specific installation recommendations, they should take precedence over the recommendations of this technical specification.

#### 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, *Rotating electrical machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles)*

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

IEC 60034-9, *Rotating electrical machines – Part 9: Noise limits*

IEC 60034-14, *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity*

IEC 60034-17:2006, *Rotating electrical machines – Part 17: Cage induction motors when fed from converters – Application guide*

IEC 61000-5-1, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 1: General considerations – Basic EMC publication*

IEC 61000-5-2, *Electromagnetic compatibility (EMC) – Part 5: Installation and mitigation guidelines – Section 2: Earthing and cabling*

IEC 61800-2, *Adjustable speed electrical power drive systems – Part 2: General requirements – Rating specifications for low voltage adjustable frequency a.c. power drive systems*

IEC 61800-3, *Adjustable speed electrical power drive systems – Part 3: EMC product standard including specific test methods*

IEC 61800-5-1, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*

IEC 61800-5-2, *Adjustable speed electrical power drive systems – Part 5-2: Safety requirements – Functional*<sup>1</sup>

---

<sup>1</sup> To be published.