

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Rotating electrical machines –
Part 2-3: Specific test methods for determining losses and efficiency of
converter-fed AC motors**

**Machines électriques tournantes –
Partie 2-3: Méthodes d'essai spécifiques pour la détermination des pertes et du
rendement des moteurs à courant alternatif alimentés par convertisseur**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, 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 either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications, symboles graphiques et le glossaire. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 500 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 25 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.



INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Rotating electrical machines –
Part 2-3: Specific test methods for determining losses and efficiency of
converter-fed AC motors**

**Machines électriques tournantes –
Partie 2-3: Méthodes d'essai spécifiques pour la détermination des pertes et du
rendement des moteurs à courant alternatif alimentés par convertisseur**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.160.01

ISBN 978-2-8322-8172-7

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	9
4 Symbols and abbreviated terms.....	10
5 Basic requirements.....	11
5.1 Instrumentation.....	11
5.1.1 General	11
5.1.2 Power analyser and transducers.....	11
5.1.3 Mechanical output of the motor.....	12
5.2 Converter set-up.....	12
5.2.1 General	12
5.2.2 Comparable converter set-up for rated voltages up to 1 kV.....	12
5.2.3 Converters with rated voltages above 1 kV	13
5.2.4 Testing with other converters.....	13
5.3 Ambient temperature during testing	13
5.4 State of the motor under test.....	13
6 Test method for the determination of the efficiency of converter-fed motors.....	14
6.1 Selection of determination method.....	14
6.2 Method 2-3-A – Direct measurement of input and output.....	14
6.2.1 Test set-up	14
6.2.2 Test procedure	14
6.2.3 Efficiency determination	15
6.2.4 Measurement at seven standardized operating points.....	15
6.3 Method 2-3-B – Summation of losses with determination of additional high frequency loss at converter supply at no-load operation.....	16
6.3.1 General	16
6.3.2 Test set-up	16
6.3.3 Test procedure	16
6.3.4 Efficiency determination	16
6.4 Method 2-3-C – Alternate Efficiency Determination Method (AEDM)	17
6.5 Method 2-3-D – Determination of efficiency by calculation	17
7 Interpolation of motor losses at any operating point.....	17
7.1 General.....	17
7.2 Definitions	18
7.3 Interpolation and extrapolation of relative losses at any operating point.....	18
7.4 Determination of interpolation coefficients.....	19
7.4.1 General	19
7.4.2 Analytical determination	20
7.4.3 Numerical determination.....	21
7.5 Alternate operating points to determine interpolation coefficients	21
7.6 Optional determination of interpolation error	23
Annex A (informative) Losses of AC motors	24
A.1 General.....	24
A.2 Stator and rotor winding I^2R losses P_{LSR} ($P_{LS} + P_{LR}$).....	24

A.3	Iron losses (P_{Lfe}).....	25
A.4	Additional load losses (P_{LL}).....	25
A.5	Friction and windage losses (P_{Lfw}).....	25
A.6	Additional high frequency losses (P_{LHL}).....	26
Annex B (informative) Exemplary determination of losses and efficiency at various load points.....		27
B.1	General.....	27
B.2	Determination of the interpolation coefficients.....	27
B.3	Calculation of losses and efficiency for certain operating points.....	28
Annex C (informative) Loss interpolation for different winding connections		30
Annex D (informative) Examples for additional load points for the numerical interpolation procedure		32
Bibliography.....		34
Figure 1 – Standardized operating points.....		20
Figure C.1 – Connection Y or D, ranges a and b		30
Figure C.2 – Connection Y ► D, ranges a and b.....		31
Figure C.3 – Connection Y ► YY, range a		31
Figure D.1 – Example for additional load points mainly in the over speed area		32
Figure D.2 – Example for additional load points in the overload and over speed area		33
Table 1 – Preferred test methods.....		14
Table 2 – Other test methods.....		14
Table 3 – Normative operating points.....		20
Table 4 – Non-normative alternate operating points		22
Table A.1 – Recommended split of windage and friction losses for IC 411 self-ventilated motors		26
Table B.1 – Name plate data.....		27
Table B.2 – Reference values		27
Table B.3 – Losses for the 7 operating points		28
Table B.4 – Interpolation coefficients		28
Table B.5 – User-defined operating points		29
Table B.6 – Calculated losses for the user-defined operating points		29

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

Part 2-3: Specific test methods for determining losses and efficiency of converter-fed AC motors

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 itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60034-2-3 has been prepared by IEC technical committee 2: Rotating machinery. It is an International Standard.

This second edition cancels and replaces the first edition of IEC 60034-2-3 published in 2020. This edition constitutes a technical revision.

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

- a) Harmonization of requirements and procedures with IEC 60034-2-1.
- b) Extension of the interpolation procedure to the field weakening range.

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

Draft	Report on voting
2/2164/FDIS	2/2179/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 is English.

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

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The objective of this document is to define test methods for determining total losses including additional high frequency motor losses and efficiency of converter-fed motors. Additional high frequency losses appear in addition to the losses on nominally sinusoidal power supply as determined by the methods of IEC 60034-2-1. Results determined according to this document are intended to allow comparison of losses and efficiency of different motors if fed by converters.

Furthermore, the document gives seven standardized operating points to characterize the development of losses and efficiency across the whole torque/speed range. An interpolation procedure is provided to calculate losses and efficiency at any operating point (torque, speed).

In power-drive systems (PDS), the motor and the frequency converter are often manufactured by different suppliers. Motors of the same design are produced in large quantities. They may be operated from the grid or from frequency converters of many different types, supplied by many different manufacturers. The individual converter properties (switching frequency, DC link voltage level, etc.) will also influence the system efficiency. As it is impractical to determine motor losses for every combination of motor, frequency converter, connection cable, output filter and parameter settings, this document describes a limited number of approaches, depending on the voltage level and the rating of the motor under test.

The losses determined with the comparable converter as defined in this document are not intended to represent the losses in the final application. They provide, however, an objective basis for comparing different motor designs with respect to suitability for converter operation.

In general, if fed from a converter, motor losses are higher than during operation on a nominally sinusoidal system, even though the converter normally enables vast energy savings overall on system level, when the motor and the load application can be operated with variable speed. The additional high frequency losses depend on the harmonic spectrum of the impressed converter output quantity (either current or voltage) which is influenced by its circuitry and control method. For further information, see IEC TS 60034-25.

It is not the purpose of this document to define test procedures either for power drive systems or for frequency converters alone.

Comparable converter

Latest experience and theoretical analysis have shown that the additional high frequency motor losses generally do not increase much with torque for a specific speed. The methods in this document are mainly based on supplies from converters with pulse width modulation (PWM).

With respect to these types of converters and the growing need for verification of compliance with national energy efficiency regulations, this document defines a so-called comparable converter for testing of low voltage motors.

In principle, the comparable converter is a voltage source with a typical high frequency harmonic content supplying the motor under test. It is not applicable to medium voltage motors.

Limitations for the application of the comparable converter

The test method with the comparable converter described herein is a standardized method intended to give comparable efficiency figures for standardized test conditions. A motor ranking with respect to suitability for converter operation may be derived, but it is not equivalent to determining of the actual motor losses for operation with a specific converter which requires a test of the whole power drive system (PDS) with the specific converter used in the final application.

Deviations are also expected for motors driven by multi-level voltage source or current source converters where the additional high frequency motor losses differ much more depending on speed and load than for two-level voltage source converters. Hence the determination of losses and efficiency should use procedures where the motor is operated together with the same converter with which it is driven in service.

Another option is the determination of the additional high frequency motor losses by calculation. If this is requested, then the pulse pattern of the converter is required. Such procedures are not part of this document.