

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

**Rotating electrical machines –  
Part 18-41: Partial discharge free electrical insulation systems (Type I) used in  
rotating electrical machines fed from voltage converters – Qualification and  
quality control tests**

**Machines électriques tournantes –  
Partie 18-41: Systèmes d'isolation électrique sans décharge partielle (Type I)  
utilisés dans des machines électriques tournantes alimentées par des  
convertisseurs de tension – Essais de qualification et de contrôle qualité**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2014 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 Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://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 corrigenda or an amendment might have been published.

#### IEC Catalogue - [webstore.iec.ch/catalogue](http://webstore.iec.ch/catalogue)

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

#### IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

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](http://webstore.iec.ch/justpublished)

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

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing more than 30 000 terms and definitions in English and French, with equivalent terms in 14 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)

More than 55 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://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: [csc@iec.ch](mailto:csc@iec.ch).

---

### 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.

#### Catalogue IEC - [webstore.iec.ch/catalogue](http://webstore.iec.ch/catalogue)

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

#### Recherche de publications IEC - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

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](http://webstore.iec.ch/justpublished)

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

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient plus de 30 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 14 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

#### Glossaire IEC - [std.iec.ch/glossary](http://std.iec.ch/glossary)

Plus de 55 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

#### Service Clients - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: [csc@iec.ch](mailto:csc@iec.ch).



# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

---

**Rotating electrical machines –  
Part 18-41: Partial discharge free electrical insulation systems (Type I) used in  
rotating electrical machines fed from voltage converters – Qualification and  
quality control tests**

**Machines électriques tournantes –  
Partie 18-41: Systèmes d'isolation électrique sans décharge partielle (Type I)  
utilisés dans des machines électriques tournantes alimentées par des  
convertisseurs de tension – Essais de qualification et de contrôle qualité**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE  
CODE PRIX



---

ICS 29.160

ISBN 978-2-8322-1416-9

**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.....	5
INTRODUCTION.....	7
1 Scope.....	9
2 Normative references .....	9
3 Terms and definitions .....	10
4 Machine terminal voltages arising from converter operation.....	13
5 Electrical stresses in the insulation system of machine windings .....	17
5.1 General.....	17
5.2 Voltages stressing the phase/phase insulation .....	18
5.3 Voltages stressing the phase/ground insulation.....	18
5.4 Voltages stressing the turn and strand insulation .....	18
5.5 Mechanisms of insulation degradation .....	19
6 Types of machine insulation .....	20
7 Stress categories for Type I insulation systems used in converter fed machines .....	20
8 Design qualification and type tests for Type I insulation systems .....	22
8.1 General.....	22
8.2 Design qualification test.....	22
8.3 Type test.....	22
9 Test equipment.....	22
9.1 PD measurement at power frequency.....	22
9.2 PD measurement during voltage impulses.....	22
9.3 Voltage impulse generators.....	23
9.4 Sensitivity .....	23
9.5 PD tests.....	23
9.5.1 Power frequency voltage .....	23
9.5.2 Impulse excitation.....	23
10 Qualification of the design of Type I insulation systems .....	23
10.1 General.....	23
10.2 Approach .....	24
10.2.1 General .....	24
10.2.2 Twisted pair or equivalent arrangement .....	24
10.2.3 Motorette (random wound) or formette (form-wound) .....	24
10.2.4 Complete windings .....	24
10.3 Preparation of test objects .....	25
10.3.1 General .....	25
10.3.2 Turn/turn insulation samples.....	25
10.3.3 Motorette/formette test samples or complete windings .....	25
10.4 Design qualification tests .....	26
10.4.1 General .....	26
10.4.2 Pre-diagnostic tests.....	26
10.4.3 Diagnostic tests.....	26
10.4.4 Ageing cycle .....	26
10.4.5 PD tests .....	26
10.5 Pass criterion for the design qualification test .....	27
11 Type test procedure for Type I insulation systems .....	27
11.1 General.....	27

11.2	Power frequency PD tests.....	27
11.3	Impulse PD tests.....	28
12	Routine tests .....	28
13	Analysis, reporting and classification .....	28
Annex A (informative) Derivation of possible terminal voltages in service for a converter-fed machine .....		29
A.1	Calculation of d.c. bus voltage .....	29
A.2	Calculation of maximum peak voltages for a 2-level converter .....	30
Annex B (normative) Derivation of test voltages for Type I insulation systems .....		32
B.1	Stress categories .....	32
B.2	Requirements for the applied impulse voltage .....	32
B.3	Enhancement factors for PD tests .....	33
B.4	Voltage for design qualification and type tests .....	34
B.5	Examples of maximum peak/peak operating voltages.....	37
B.6	Calculation of test voltages .....	37
Annex C (normative) Derivation of allowable voltages in service.....		39
C.1	Impulse voltage insulation class (IVIC) of the machine.....	39
C.2	Impulse voltage insulation class assigned in special designs .....	39
Bibliography.....		41
Figure 1 – Voltage impulse waveshape parameters .....		13
Figure 2 – Five step phase to phase voltage at the terminals of a machine fed by a 3-level converter .....		15
Figure 3 – Jump voltage ( $U_j$ ) at the machine terminals associated with a converter drive .....		15
Figure 4 – Voltage enhancement at the terminals of a motor due to reflection as a function of cable length for various impulse rise times .....		17
Figure 5 – Example of a random wound design.....		18
Figure 6 – Example of a form-wound design .....		18
Figure 7 – Worst case voltage stressing the turn/turn insulation in a variety of random wound stators as a function of the rise time of the impulse .....		19
Figure A.1 – Circuit diagram for a converter/machine system.....		29
Figure B.1 – Forbidden zone (shaded) for impulse tests .....		33
Figure B.2 – Examples of test waveforms .....		33
Figure B.3 – Comparison of phase/phase, phase/ground, and turn/turn voltages for a 2-level converter.....		35
Figure B.4 – Impulse test voltage waveforms and the levels for applying the same peak/peak voltage of $2aU_j$ on the turn/turn insulation (schematic representation).....		36
Figure B.5 – Test voltages for phase/ground and turn/turn impulse tests using a unipolar impulse .....		38
Table 1 – Common ranges of characteristics of the terminal voltages of converter fed machines .....		14
Table 2 – Definition of symbols .....		14
Table 3 – Influence of features of the machine terminal voltage on components of Type I insulation systems .....		21
Table 4 – Stress categories for Type I insulation systems based on a 2-level converter.....		21
Table 5 – Allowable voltage waveforms for testing system components .....		25

Table A.1 – Examples of maximum peak voltages .....	31
Table B.1 – Summary of stress categories .....	32
Table B.2 – Summary of enhancement factors to be applied to the operating voltages.....	34
Table B.3 – Maximum peak/peak operating voltages related to $U_{dc}$ for a 2-level converter according to the stress categories of Table 4 .....	36
Table B.4 – Examples of maximum peak/peak operating voltage for a 500 V r.m.s. rated winding fed from a 2-level converter, according to the stress categories of Table 4.....	37
Table B.5 – Examples of maximum peak/peak test voltage for a 500 V rated winding fed from a 2-level converter, according to the stress categories of Table 4 and with EF 1,25 .....	37
Table B.6 – Turn/turn PD test levels for special windings and twisted pairs.....	38
Table C.1 – Maximum allowable operating voltage at the machine terminals in units of $U_N$ ...	39

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ROTATING ELECTRICAL MACHINES –

**Part 18-41: Partial discharge free electrical insulation systems (Type I)  
used in rotating electrical machines fed from voltage converters –  
Qualification and quality control tests**

## 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) 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.

International Standard IEC 60034-18-41 has been prepared by IEC technical committee 2: Rotating machinery.

IEC 60034-18-41 cancels and replaces IEC/TS 60034-18-41 (2006).

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

FDIS	Report on voting
2/1728/FDIS	2/1738/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.

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

The committee has decided that the contents of this publication will remain unchanged until the stability 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

The approval of electrical insulation systems for use in rotating electrical machines driven from voltage converters is set out in two IEC documents. They divide the systems into those which are not expected to experience partial discharge activity within specified conditions in their service lives (Type I) and those which are expected to withstand partial discharge activity in any part of the insulation system throughout their service lives (Type II). For both Type I and Type II insulation systems, the drive system integrator (the person responsible for co-ordinating the electrical performance of the entire drive system) shall inform the machine manufacturer what voltage will appear at the machine terminals in service. The machine manufacturer will then decide upon the severity of the tests appropriate for qualifying the insulation system. The severity is based on the impulse rise time, the peak to peak voltage and, in the case of Type II systems, the impulse repetition rate. After installation of the converter/machine system, it is recommended that the drive system integrator measures the phase/phase and phase/ground voltages between the machine terminals and ground to check for compliance.

### **IEC 60034-18-41**

The Type I systems are dealt with in this standard. They are generally used in rotating machines rated at 700 V r.m.s. or less and tend to have random wound windings. The procedures described here are directed at:

- Qualification of the insulation system.
- Type and routine testing of the complete windings of service machines.

Before undertaking any testing, the machine manufacturer shall decide upon the level of severity that the system will be required to withstand. The severity is based on how large the voltage overshoot and how short the impulse rise time will be at the machine terminals. The machine designer then makes a choice from a table in which the range of expected overshoot voltage is divided into bands. Testing is performed at the extreme value of each band. A default value of 0,3  $\mu$ s is attributed to the impulse rise time. Other values of impulse rise time or voltage overshoot are dealt with as special cases.

In qualification testing, the insulation system is used to construct various representative test objects. These are subjected to the range of tests described in IEC 60034-18-21 or IEC 60034-18-31 with the addition of a high frequency voltage test and a partial discharge test. For the latter, it may be necessary to use impulse test equipment, as described in IEC/TS 61934. If the test object is partial discharge free under the specified test conditions at the end of the sequence of testing, the insulation system is qualified for the severity band that has been selected.

Type and optional routine tests are performed on complete windings to demonstrate that they are partial discharge free under sinewave or impulse voltage conditions (as appropriate) for the band of severity that the manufacturer has chosen. An impulse voltage insulation class is then assigned to the machine. A mechanism is described for dealing with special cases.

### **IEC/TS 60034-18-42**

The tests for qualification and acceptance of electrical insulation systems chosen for Type II rotating electrical machines are described in this technical specification. These insulation systems are generally used in rotating machines and tend to have form-wound coils, mostly rated above 700 V r.m.s. The qualification procedure is completely different from that used for Type I insulation systems and involves destructive ageing of insulated test objects under accelerated conditions. The rotating machine manufacturer requires a life curve for the insulation system that can be interpreted to provide an estimate of life under the service conditions with converter drive. Great importance is attached to the qualification of any stress grading system that is used and testing here should be performed under repetitive impulse conditions. If the insulation system can be shown to provide an acceptable life under the

appropriate ageing conditions, it is qualified for use. Acceptance testing is performed on coils made using this insulation system when subjected to a voltage endurance test.

## ROTATING ELECTRICAL MACHINES –

### **Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests**

#### **1 Scope**

This part of IEC 60034 defines criteria for assessing the insulation system of stator/rotor windings which are subjected to voltage-source pulse-width-modulation (PWM) drives. It applies to stator/rotor windings of single or polyphase AC machines with insulation systems for converter operation.

It describes qualification tests and quality control (type and routine) tests on representative samples or on completed machines which verify fitness for operation with voltage source converters.

This standard does not apply to:

- rotating machines which are only started by converters;
- rotating electrical machines with rated voltage  $\leq 300$  V r.m.s.;
- rotor windings of rotating electrical machines operating at  $\leq 200$  V (peak).

#### **2 Normative references**

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-18-1:2010, *Rotating electrical machines – Part 18-1: Functional evaluation of insulation systems – General guidelines*

IEC 60034-18-21, *Rotating electrical machines – Part 18-21: Functional evaluation of insulation systems – Test procedures for wire-wound windings – Thermal evaluation and classification*

IEC 60034-18-31, *Rotating electrical machines – Part 18-31: Functional evaluation of insulation systems – Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in rotating machines*

IEC/TS 60034-18-42, *Rotating electrical machines – Part 18-42: Qualification and acceptance tests for partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters*<sup>1</sup>

IEC/TS 60034-25:2007, *Rotating electrical machines – Part 25: Guidance for the design and performance of a.c. motors specifically designed for converter supply*

---

<sup>1</sup> This TS is in the process of being transformed into an IS.