IEC 60034-27-1

Edition 1.0 2017-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Rotating electrical machines –
Part 27-1: Off-line partial discharge measurements on the winding insulation

Machines électriques tournantes –
Partie 27-1: Mesurages à l’arrêt des décharges partielles effectués sur le système d'isolation des enroulements

IEC 60034-27-1:2017-12(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
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 corrigenda or an amendment might have been published.

IEC Catalogue - 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
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 It also gives information on projects, replaced and withdrawn publications.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 also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 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
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: 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
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
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 aussi une fois par mois par email.

Electropedia - www.electropedia.org
Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
65 000 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
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 60034-27-1

Edition 1.0 2017-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Rotating electrical machines – Part 27-1: Off-line partial discharge measurements on the winding insulation

Machines électriques tournantes – Partie 27-1: Mesurages à l'arrêt des décharges partielles effectués sur le système d'isolation des enroulements

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.160.01

ISBN 978-2-8322-5104-1

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

ROTATING ELECTRICAL MACHINES –

Part 27-1: Off-line partial discharge measurements on the winding insulation

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 60034-27-1 has been prepared by IEC technical committee 2: Rotating machinery.

This International Standard cancels and replaces IEC TS 60034-27 (2006). It constitutes a technical revision.

The main technical changes with regard to IEC TS 60034-27 (2006) are as follows:

- In 1st version the scope was not well defined, and open to a too wide range of measurement frequencies. That has been corrected.
- In 1st version pulse magnitude was defined in different ways. Now, 2 definitions are given, one for each method.
- In 1st version the types of PD were erroneous. Especially the definition of the most critical "slot discharges" has been improved.

- Adding one more common test arrangement to Clause 7.
- Adding Annex A.
- Adding Annex B.
- Adding Annex G.
- Moving part of the original text (valid for old fashioned instruments) to new Annex H.

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

FDIS	Report on voting
2/1877/FDIS	2/1887/RVD

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

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

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.

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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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

For many years, the measurement of partial discharges (PD) has been employed as a means of assessing the quality of new insulation systems and the condition of aged insulation systems. It is also considered as a means of detecting localized sources of PD in used electrical winding insulation arising from operational stresses in service. Compared with other dielectric tests (e.g. the measurement of dissipation factor or insulation resistance) the differentiating character of partial discharge measurements allows PD sources within the insulation system to be detected.

In connection with the servicing and overhaul of rotating machines, the measurement and analysis of partial discharges can also provide information on:

– presence of ageing effects and potential defects in the insulating system;
– ageing processes;
– further measures and intervals between overhauls.

Although the PD testing of rotating machines has gained widespread acceptance, it has emerged from several studies that not only are there different methods of measurement in existence but also the criteria and methods of analysing and finally assessing the measured data are often different and not comparable. Consequently, there is a need to give some guidance to those users who are considering the use of PD measurements to assess the condition of their insulation systems.

Partial discharge testing of stator windings can be divided into two broad groups:

a) off-line measurements, in which the stator winding is isolated from the power system and a separate power supply is employed to energize the winding;
b) on-line measurements, in which the rotating machine is operating normally and connected to the power system (IEC 60034-27-2).

Both of these approaches have advantages and disadvantages with respect to one another. While acknowledging the extensive world-wide use of on-line methods and their proven value to industry, this international standard is confined to off-line techniques. This approach is considered necessary to render this standard sufficiently concise to be of use by non-specialists in the field of PD testing.

Limitations:

When PD measurements are performed on stator windings, several external factors will inevitably affect the result. Consequently, PD measurements are only comparable under certain conditions.

In a factory or site environment, the PD measurement results will be influenced by noise, unless provisions have been made to reduce the influence of noise. Different hardware and software methods, affecting for example measurement frequency band or noise cancellation algorithms, are used in different equipment systems to separate relevant PD signals from noise. Recalculation of the measured PD signal to an equivalent charge is an additional step that will be dependent on the measurement and the calibration equipment that has been used for normalization, as well as the method used.

Measurement conditions including temperature and moisture as well as test object set-up will further affect the PD result. In case of a stator winding, the attenuation and dispersion of the PD pulse during propagation will be dependent on the actual winding design and the origin of the pulse.

Based on the above reasons, absolute PD magnitude limits for the windings of rotating machines, for example as acceptance criteria for production or operation are difficult to define.

In addition, the degree of deterioration, and hence the risk of insulation system failure, depends on the specific type of PD source and its location within the stator winding insulation, both of which can influence the test results significantly.

Users of PD measurement should be aware that, due to the principles of the method, not all insulation-related problems in stator windings can be detected by measuring partial discharges (for example insulation failure mechanisms, which are not accompanied by pulse signals due to conductive paths between different elements of the insulation). Pulse signals may further remain undetected in practice due to the impact of electrical noise and disturbance conditions, which limit the detection sensitivity.

For individual bars and coils, absolute limits for PD magnitude are also difficult to establish due to disparities between different test equipment and test setups. Therefore, no absolute limits are given in the current version of this document.

ROTATING ELECTRICAL MACHINES –

Part 27-1: Off-line partial discharge measurements on the winding insulation

1 Scope

This part of IEC 60034 provides a common basis for:

– measuring techniques and instruments;
– the arrangement of test circuits;
– normalization and testing procedures;
– noise reduction;
– the documentation of test results;
– the interpretation of test results,

with respect to partial discharge off-line measurements on the winding insulation of rotating electrical machines.

The measurement methods described in this document are applicable to stator windings of machines with or without conductive slot coating and to the stator windings of machines made with form wound or random wound windings. In special cases like high voltage rotor field windings, this document is applicable as well. The measurement methods are applicable when testing with alternating sinusoidal voltages from 0,1 Hz up to 400 Hz.

Interpretation guidelines are given in this document and are applicable only if all the following requirements are fulfilled:

– Measurements performed with power frequency of 50 Hz or 60 Hz, or when testing with power supply within a frequency range of 45 Hz to 65 Hz.
– Form wound windings and winding components such as bars and coils.
– Winding with conductive slot coating. This is usually valid for machines with voltage rating of 6 kV and higher.

For machines with random wound windings, form-wound windings without conductive slot coating, and testing at frequencies differing from power frequencies, the interpretation guidelines are not applicable. The testing procedures for off-line PD-measurements of this document can be used for assessing the uniform quality of manufacturing or/and the trending of these kind of windings as well as converter driven machine windings.

NOTE Testing of low voltage machines with so called Type I insulation systems is defined in reference [10][1]. Testing procedures for qualification of converter driven high voltage machines with so called Type II insulation systems are dealt with in IEC 60034-18-42 (in addition to the optional electric tests described therein).

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.

1 Numbers in square brackets refer to the Bibliography.

IEC 60034-18-32, *Rotating electrical machines – Part 18-32: Functional evaluation of insulation systems – Test procedures for form-wound windings – Evaluation by electrical endurance*

IEC 60034-18-42, *Rotating electrical machines – Part 18-42: Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters – Qualification tests*

IEC TS 60034-27-2, *Rotating electrical machines – Part 27-2: On-line partial discharge measurements on the stator winding insulation of rotating electrical machines*

IEC 60034-27-4, *Rotating electrical machines – Part 27-4: Measurement of insulation resistance and polarization index of winding insulation of rotating electrical machines*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*
IEC 60270:2000/AMD1:2015

3 Terms and definitions

For the purposes of this document, the general terms and definitions for partial discharge measurements given in IEC 60270 apply, together with the following.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
partial discharge
PD
localized electrical discharge that only partially bridges the insulation between conductors and which can or cannot occur adjacent to a conductor

3.2
off-line measurement
measurement taken with the rotating machine at standstill and disconnected from the power system

Note 1 to entry: The necessary test voltage is applied to the winding from a separate voltage source.

3.3
on-line measurement
measurement taken with the rotating machine in operation and connected to the power system

3.4
stress control coating
paint or tape on the surface of the groundwall insulation outside the slot section whose purpose is to smoothen the potential differences on the surface of high voltage stator bars and coils

Note 1 to entry: The stress control coating reduces the electric field stress along the winding overhang to below a critical value that would initiate PD on the surface. The stress control coating overlaps the conductive slot portion coating to provide electrical contact between them.

3.5
conductive slot coating
conductive paint or tape layer in intimate contact with the groundwall insulation in the slot portion of the coil or bar side, often called ‘semiconductive’ coating

Note 1 to entry: This coating provides electrical contact to the stator core.

3.6
slot discharges
discharges that occur between the outer insulation surface of the slot portion of a coil or bar and the grounded core laminations

3.7
internal discharges
discharges that occur within the groundwall insulation

3.8
surface discharges
discharges that occur on the surface of the insulation or on the surface of winding components in the winding overhang or the active part of the machine winding

3.9
pulse magnitude distribution
number of pulses within a series of equally spaced windows of pulse magnitude during a predefined measuring time

3.10
pulse phase distribution
number of pulses within a series of equally spaced windows of phase during a predefined measuring time

3.11
partial discharge pattern
number of pulses for a matrix of PD magnitude vs. AC cycle phase position for visualization of the PD behaviour during a predefined measuring time

Note 1 to entry: Another type of representation may be used for the interpretation and source separation, such as frequency vs. time.

3.12
coupling device
usually an active or passive four-terminal network that converts the input currents to output voltage signals

Note 1 to entry: These signals are transmitted to the measuring instrument by a transmission system. The frequency response of the coupling device is normally chosen at least so as to efficiently prevent the test voltage frequency and its harmonics from reaching the measuring instrument.

3.13
PD coupling unit
high voltage coupling capacitor of low inductance design and a low voltage coupling device in series

3.14
largest repeatedly occurring PD magnitude
Q_m
largest magnitude associated with a PD pulse repetition rate of 10 pulses per second (pps), which can be directly inferred from a pulse magnitude distribution

Note 1 to entry: Other repetition rates may be used for defining the Q_m, for example 50 or 60 pulses per second. If other rates are used, this needs to be indicated, for example as Q_{m50} or Q_{m60}.

3.15
weighted occurring PD magnitude
Q_{iec}
weighted magnitude recorded by a measuring system which has the pulse train response in accordance with IEC 60270

Note 1 to entry: In this document, the symbol Q will be used as a placeholder for both definitions of charge, Q_m and Q_{iec}.

3.16
noise
signals that clearly are not pulses and are not generated by the stator winding

3.17
disturbance
pulsed signals that clearly are not partial discharges but may have PD like characteristics

4 Nature of PD in rotating machines

4.1 Basics of PD

Generally, partial discharges (PD) can develop at locations where the dielectric properties of insulating materials are inhomogeneous. At such locations, the local electrical field strength may be enhanced. Due to local electrical over-stressing this may lead to a local, partial breakdown. This partial breakdown does not result in a breakdown of the insulation. PD in general requires a gas volume to develop, for example in gas filled voids embedded in the insulation, adjacent to conductors or at insulation interfaces.

A partial discharge can occur when the local electrical field strength at an inhomogeneity exceeds its breakdown strength. This process may result in several PD pulses during one cycle of the applied voltage. In rotating machines with micaceaous insulation the occurrence of numerous imperfections like small voids at new insulation and delaminations at aged windings is unavoidable. Therefore, a superposition of PD sources of different intensity will always be measured.

The amount of charge transferred in the discharge is closely related to the specific properties of the inhomogeneity such as the dimensions and the specific dielectric properties of the materials involved, for example surface properties, kind of gas, gas pressure, etc.

Stator winding insulation systems, including type II machines as defined in IEC 60034-18-42 are expected to experience PD activity in service. The insulation systems are inherently resistant to partial discharges due to their inorganic mica components. However, significant PD in these machines is usually a symptom of insulation deficiencies, such as a manufacturing problem or in-service deterioration, rather than a direct cause of failure. Nevertheless, depending on PD source and magnitude of the specific conditions at this point, it may turn into a significant ageing factor of a local insulation ageing process. The time to failure may not correlate with PD levels, but depends significantly on many factors for example but not limited to operating temperature, wedging conditions, degree of contamination, etc.

The measurement and the analysis of the specific PD behaviour can be used for quality control of new windings and winding components and for early detection of insulation deficiencies caused by thermal, electrical, ambient and mechanical ageing factors in service, which might result in an insulation failure.

4.2 Types of PD in rotating machines

4.2.1 General

Partial discharges shall be generally expected in insulation systems of HV rotating machines, but their magnitudes, amount and positions depend on the design, materials, manufacturing processes, quality as well as on environmental and ageing conditions. For a given machine design, the nature of the materials used, manufacturing methods, operating conditions, etc., can profoundly affect the quantity, location, characteristics, evolution and the significance of PD. For a given machine, the various PD sources may be identified and distinguished in many cases by their characteristic PD behaviour. Additional diagnostic tests and visual inspections, if applicable, may verify the PD source.

4.2.2 Internal discharges

4.2.2.1 Internal voids

Although manufacturing processes are designed to minimize internal voids, inevitably there is some void content in a resin impregnated mica tape insulation system that is normally used in high voltage rotating machines. As PD are normal for high voltage rotating electrical machines the mica in the insulation is intended to provide an acceptable life under the specified ageing conditions. See also IEC 60034-18-32 for detailed information.

4.2.2.2 Internal delamination

Internal delamination within the main insulation can be caused by improper resin impregnation or curing of the insulation system during manufacturing or by mechanical or thermal over-stressing during operation. Delamination can also develop due to ageing of insulation. Delamination due to ageing is normally a long-term process. Therefore, delamination in old insulation is a clear sign of insulation ageing. Large voids may develop over a large area resulting in discharges of relatively high energy, which may significantly deteriorate the insulation. In particular, delamination will reduce the thermal conductivity of the insulation, which might lead to accelerated ageing. Thus, delamination needs careful consideration when PD activity is being assessed.

4.2.2.3 Debonding between insulated conductor and groundwall insulation

Debonding PD between conductors and insulation material are generated within air or gas filled elongated pockets (in longitudinal direction) that are embedded between the main insulation and the conductor stack.

They may result from overheating or from extreme mechanical forces that both lead to separation of large areas between these layers.

4.2.3 Slot discharges

Slot discharges in high voltage rotating machines could develop when the conductive slot portion coating is compromised. This could happen due to high local electrical field enhancement at coating material impurities or because of bar/coil movement in the normal slot part or at the stepped slot exit area, for example by a loss of wedging pressure due to settlement, erosion or abrasion of the materials, chemical attack or manufacturing deficiencies. When coils/bars are loose, the electromagnetic forces will cause the loose bar/coil to vibrate in the slot, leading to abrasion of the slot conductive coating and insulation. Where a local damage of the conductive slot coating is already present, there is a starting point for partial discharges with high pulse magnitude acting between grounded metal electrode (slot iron) and main insulation surface. These discharges will be primarily generated