



TECHNICAL SPECIFICATION



**Rotating electrical machines –
Part 27-5: Off-line measurement of partial discharge inception voltage on
winding insulation under repetitive impulse voltage**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.160.01

ISBN 978-2-8322-9648-6

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms, definitions, symbols and abbreviated terms.....	8
4 Repetitive impulse voltages for PD measurement	11
4.1 General.....	11
4.2 Waveform of single impulse voltage	12
4.2.1 Waveform at impulse generator terminal without test object.....	12
4.2.2 Typical distortions of impulse waveform at the terminals of test object.....	14
4.3 Train of single impulse voltage.....	17
4.4 Step-by-step voltage increase and decrease using trains of single impulse voltage.....	18
4.5 Impulse voltage distribution inside rotating machines.....	22
5 PD measurement methods with impulse voltage	23
5.1 General.....	23
5.2 Electrical PD measurements	23
5.2.1 General	23
5.2.2 Coupling capacitor with higher order analogue filter.....	23
5.2.3 HFCT with higher order analogue filter	24
5.2.4 Electromagnetic couplers.....	25
5.3 Threshold level of PD detection	26
5.4 Measuring system with impulse generator and computer.....	27
5.5 Calculation and interpretation of RPDIV and RPDEV	27
6 Impulse PD test procedure	28
6.1 Test object.....	28
6.1.1 Twisted-pair or equivalent.....	28
6.1.2 Motorette or formette	29
6.1.3 Complete winding and connection.....	29
6.2 Safety and environment during PD test.....	31
6.2.1 Grounding and floating of test objects during tests.....	31
6.2.2 Environment during test.....	31
6.3 Test procedure and reports	32
Annex A (informative) Typical PD measurements on a complete winding	33
Annex B (informative) Example of PD data analysis using phase angle.....	35
Annex C (informative) Example of connection of complete windings	37
C.1 General.....	37
C.2 Connections for three-terminal machines	37
C.3 Connections for four-terminal machines	40
Annex D (informative) Example of SBS voltage increase pattern of repetitive impulse	41
Bibliography.....	42
Figure 1 – Block representation of measurement circuit for RPDIV and RPDEV	11
Figure 2 – Simplified impulse generator (IG) circuit with a single switch S	12
Figure 3 – Output voltage at open terminal of IG with single switch.....	13

Figure 4 – Two impulses at open terminal of IG with single switch	13
Figure 5 – Simplified IG circuit with four-arm (switch) bridge circuit.....	13
Figure 6 – Output voltages at open terminal of four-arm bridge circuit.....	14
Figure 7 – Increase of rise time and decrease of peak voltage of triangular impulse	15
Figure 8 – Increase of rise time and decrease of peak voltage of rectangular impulse.....	15
Figure 9 – Overshoot of peak and following fast oscillation of triangular impulse	15
Figure 10 – Overshoot of peak and following fast oscillation of rectangular impulse	16
Figure 11 – Typical "ringing" observed during bipolar rectangular voltage test	16
Figure 12 – Slow oscillating decay of triangular impulse	17
Figure 13 – Slow oscillating decay of rectangular impulse.....	17
Figure 14 – Schematic representation of train parameters of positive unipolar impulses	18
Figure 15 – Schematic representation of train parameters of bipolar impulses	18
Figure 16 – SBS parameters of positive unipolar impulses	19
Figure 17 – SBS voltage pattern of positive unipolar impulses for RPDIV and RPDEV	19
Figure 18 – SBS voltage pattern of bipolarly distorted positive unipolar impulse	20
Figure 19 – SBS voltage increase of bipolar impulses	20
Figure 20 – Representative scheme of conditioning procedure before RPDIV measurement.....	21
Figure 21 – Schematic representation of phase/phase, phase/ground and turn/turn voltages of the winding of a rotating machine fed from a two-level converter [2]	23
Figure 22 – Coupling capacitor with higher order analogue filter	24
Figure 23 – Example of voltage impulse and PD pulse frequency spectra before (left) and after (right) filtering	24
Figure 24 – HFCT between supply and test object with higher order analogue filter	25
Figure 25 – HFCT between test object and earth with higher order analogue filter	25
Figure 26 – Circuit using an electromagnetic coupler (for example an antenna) to suppress impulses from the test supply.....	25
Figure 27 – Circuit using an electromagnetic UHF antenna	26
Figure 28 – Schematic representation of noise, disturbance and threshold values	26
Figure 29 – Example diagram of PD measurements with PC	27
Figure 30 – Example of RPDIV and RPDEV calculation using a 50 % PD probability against repetitive impulse voltage (Figure 12 of IEC TS 61934:2011, modified).....	28
Figure 31 – Representative scheme of voltage terminals for three-terminal machine and four-terminal machine	30
Figure A.1 – Block diagram of PD measurement system used in RRT	33
Figure A.2 – Impulse pattern used in RRT and PD inception	33
Figure B.1 – Example of PD phase angle pattern of sinusoidal voltage	35
Figure B.2 – Example of PD phase angle pattern of PWM voltage on the phase angle of a sinusoidal one.....	36
Figure B.3 – Example of PD phase angle pattern of PWM voltage on rectangular voltage angle (PRPD pattern)	36
Figure C.1 – Connection of six-terminal machines.....	37
Figure C.2 – Connection of three- or four-terminal machines (with N terminal).....	37
Figure C.3 – Three-terminal machine connection, Type A (Table 2)	38
Figure C.4 – Three-terminal machine connection, Type B (Table 2)	38
Figure C.5 – Three-terminal machine connection, Type C (Table 2).....	38

Figure C.6 – Three-terminal machine connection, Type D (Table 2)	39
Figure C.7 – Three-terminal machine connection, Type E (Table 2)	39
Figure C.8 – Three-terminal machine connection, Type F (Table 2)	39
Figure C.9 – Four-terminal machine with earthed N terminal – Connection types (Table 3).....	40
Figure D.1 – SBS voltage increase of alternating train of unipolar impulses	41
Table 1 – Typical ranges of impulse voltage parameters at terminal of test object to be reported	21
Table 2 – Connection of complete winding of three-terminal machine	30
Table 3 – Connection of complete winding of four-terminal machine	31
Table A.1 – Parameters used in RRT	33

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

Part 27-5: Off-line measurement of partial discharge inception voltage on winding insulation under repetitive impulse voltage

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.

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 TS 60034-27-5, which is a Technical Specification, has been prepared by IEC technical committee 2: Rotating machinery.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
2/1955/DTS	2/1962A/RVDTS

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 document 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 on 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

The recent development of power electronics technology has led to various power drive systems (PDS) of variable-speed rotating electrical machines. The new influences of PDS on rotating machines are introduced in IEC TS 60034-25 [1]¹. This document points out that electrical insulation of machine winding is exposed to numerous voltage impulses due to the repetitive fast switching of power devices in PDS. The severity of the impulses depends on ratings of converter and machines, converter topology, length of cable between machine and converter, filtering equipment and so on.

IEC 60034-18-41 [2], published in 2014, is the first International Standard which describes design qualification and type tests for Type I (partial discharge free) insulation systems used in converter-fed rotating electrical machines. In this document, both tests require partial discharge (PD) tests with power frequency voltage or impulse excitation. As for PD measurements with impulse excitation, IEC 60034-18-41 cites IEC TS 61934, which provides a technical explanation and several PD measuring methods, in general. For practical test guidance specific to winding insulation of rotating machines, this document was prepared as an off-line measurement of PD inception and extinction voltages during repetitive impulse condition, RPDIV and RPDEV.

¹ Numbers in square brackets refer to the Bibliography

ROTATING ELECTRICAL MACHINES –

Part 27-5: Off-line measurement of partial discharge inception voltage on winding insulation under repetitive impulse voltage

1 Scope

This document provides an off-line measurement method of the partial discharge inception and extinction voltage on winding insulation under repetitive impulse voltage. This document is relevant to rotating machines supplied by a voltage source converter.

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 60034-27-1, *Rotating electrical machines – Part 27-1: Off-line partial discharge measurements on the winding insulation*

IEC TS 61934:2011, *Electrical insulating materials and systems – Electrical measurement of partial discharges (PD) under short rise time and repetitive voltage impulses*

IEC TS 62478, *High voltage test techniques – Measurement of partial discharges by electromagnetic and acoustic methods*