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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

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This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER: IEC 60034-18-41 ED2	
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IEC TC 2 : ROTATING MACHINERY	
SECRETARIAT: United Kingdom	SECRETARY: Mr Charles Whitlock
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☐ SAFETY	

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TITLE:

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

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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**

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This Consolidated version of IEC 60034-18-41 bears the edition number 1.1. It consists of the first edition (2014-03) [documents 2/1728/FDIS and 2/1738/RVD], its amendment 1 (2019-06) [documents 2/1949/FDIS and 2/1957/RVD] and its corrigendum (2020-12). The technical content is identical to the base edition and its amendment.

This Final version does not show where the technical content is modified by amendment 1. A separate Redline version with all changes highlighted is available in this publication.

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

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 the base publication and its amendment 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) is responsible to specify the Impulse Voltage Insulation Class (IVIC, defined in this standard) necessary to ensure the machine reliability.

For custom-made machines, based on the IVIC provided by the drive system integrator, the machine manufacturer will then decide upon the severity of the tests appropriate for qualifying the insulation system. For off-the-shelf machines, the drive integrator will select the machine with appropriate withstand levels. 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-to-phase and phase-to-ground voltages between the machine terminals and ground to check for compliance.

It should be borne in mind that acting only on the insulation does not provide the best and most effective results. In light of IEC TS 60034-25, the drive system integrator should consider using output filters, shortening connection cables (when feasible) and/or adopting multilevel inverters as these solutions can lead to an improved power density of the machine through better heat exchange capabilities, better reliability of the drive, larger maintainability (replacing a filter is easier, faster, and cheaper than replacing a complete machine). An accurate co-ordination of the variable speed drive and electrical rotating machine features leads to an optimal total cost of ownership and a lower environmental footprint. Further, the usage of filters will enhance noise and vibration behaviour for increased environmental performance.

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 (~2000 V peak-to-peak) or less and have either random wound or form wound windings. The procedures described here are directed at:

- Qualification of the insulation system.
- Type and routine (quality control) testing of the complete windings of service machines.

Before undertaking any testing, the machine manufacturer shall decide upon the level of severity that the insulation system will be required to withstand in operation. 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. The overshoot factors and the fraction a of the jump voltage applied to the first coil (random wound machines) or first couple of turns (form wound machines) experienced in operation are classified for the sake of simplicity into four classes. These classes are indicated as impulse voltage insulation class (IVIC).

In qualification testing, a candidate insulation system is used to construct various representative test objects. These are subjected to the sequence of tests described in IEC 60034-18-21 or IEC 60034-18-31 with the addition of a diagnostic partial discharge test. The results of the sequence of tests are compared with those achieved by a system with proven experience (reference) to ascertain if the candidate system performs better than the reference. Provisions for accelerated qualification are also reported in this standard.

Type and routine (quality control) tests are performed on complete windings to demonstrate that they are partial discharge free under impulse voltage conditions (sinewave voltages might be appropriate for the phase-to-ground and phase-to-phase insulation systems, not for the turn-to-turn system) for the band of voltage severity that the manufacturer has chosen. The impulse voltage rise time used for testing should be appropriate for the chosen band of inverter severity. An impulse voltage insulation class (IVIC) and an inverter severity class (ISC) are then assigned to the machine or for each insulation subsystem (turn-to-turn, phase-to-ground, phase-to-phase). A mechanism is described for dealing with special cases.

IEC 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.

Differences between IEC 60034-18-41 Ed. 1 and IEC 60034-18-41 Ed. 2

- Editorial changes were made to help the reader find the contents more easily.
- Introduced the definition of the turn insulation stress factor, a
- The IVIC in Ed. 1 was a unique to all insulation sub-systems. In Ed. 2, each insulation sub-system is characterized by its IVIC.
- For the turn-to-turn insulation system, IVIC is based on the fraction of the jump voltage applied to the first coil or first couple of turns of the winding, for random wound and form wound winding, respectively. This choice allows to deal with wide bandgap converters.
- It is suggested as a good practice to measure, using different rise times, and report the fraction of the jump voltage applied to the first coil or first couple of turns of the winding, for random wound and form wound winding, respectively.
- Following 60034-18-1, if minor changes are made to the insulation system, an accelerated procedure for qualification can be carried out.
- Testing using impulse voltages is considered preferable to testing with AC sinusoidal voltages.
- For the sake of simplicity, test voltages are now reported in per units of the rated voltage U_N . These values are consistent with those reported in Edition 1 assuming that $U_{dc}/U_N = 1.35$.
- Surge testers providing bipolar square voltage waveforms with high repetition rates are to be preferred to surge tester providing unipolar impulses with reduced repetition rates.
- Provisions for testing delta windings are reported.

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ROTATING ELECTRICAL MACHINES –

Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage source 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 peak-to-peak voltage not exceeding twice the minimum of the Paschen curve;
- rotor windings of rotating electrical machines with peak-to-peak voltage not exceeding twice the minimum of the Paschen curve.

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 60034-18-1:2022, *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*¹

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*

¹ This TS is in the process of being transformed into an IS.

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

IEC 60172, *Test procedure for the determination of the temperature index of enamelled winding wires*

IEC 60664-1, *Insulation co-ordination for equipment within low voltage systems – Part 1: Principles, requirements, and tests*

IEC/TS 61800-8, *Adjustable speed electrical power drive systems – Part 8: Specification of voltage on the power interface*

IEC/TS 60034-27-5, *Rotating electrical machines – Part 27-5: Off-line measurement of partial discharge inception voltage on winding insulation under repetitive impulse voltage*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

partial discharge

PD

electric discharge that only partially bridges the insulation between electrical conductors

Note 1 to entry: It may occur inside the insulation or adjacent to an electrical conductor.

3.2

partial discharge inception voltage

PDIV

lowest voltage at which partial discharges are initiated in the test arrangement when the voltage applied to the test object is gradually increased from a lower value at which no such discharges are observed

Note 1 to entry: The PDIV is defined as the peak-to-peak voltage. With sinusoidal applied voltages, the PDIV is normally measured as the r.m.s. value of the voltage. Converting to the peak-to-peak voltage requires the knowledge of the form factor.

3.3

partial discharge extinction voltage

PDEV

voltage at which partial discharges are extinguished in the test arrangement when the voltage applied to the test object is gradually decreased from a higher value at which such discharges are observed

Note 1 to entry: The PDIV is defined as the peak-to-peak voltage. With sinusoidal applied voltages, the PDIV is normally measured as the r.m.s. value of the voltage. Converting to the peak-to-peak voltage requires the knowledge of the form factor.

3.4

repetitive partial discharge inception voltage

RPDIV

minimum peak-to-peak impulse voltage at which more than five PD pulses occur on ten voltage impulses when the voltage applied to the test object is increased with step-by-step method from a lower value at which no discharges are observed

Note 1 to entry: This is a mean value for the specified test time and a test arrangement where the voltage applied to the test object is gradually increased from a value at which no partial discharges can be detected for the measured PD sensitivity.

3.5**repetitive partial discharge extinction voltage****RPDEV**

maximum peak-to-peak impulse voltage at which less than five PD pulses occur on ten voltage impulses of the same peak-to-peak values when the voltage applied to the test object is decreased with step-by-step method from a higher value at which such discharges are observed.

Note. This is a mean value for the specified test time and a test arrangement where the voltage applied to the test object is decreased with step-by-step method. Details are mentioned in 5.5.

3.6**unipolar impulse**

voltage impulse, the polarity of which is either positive or negative

Note 1 to entry: The term impulse is used to describe the transient stressing voltage applied to the test object and the term pulse is used to describe the partial discharge signal.

3.7**bipolar impulse**

voltage impulse, the polarity of which changes periodically from positive to negative or vice versa

3.8**DC bus voltage** **U_{dc}**

voltage of the intermediate circuit of the voltage converter (dc-link-circuit).

Note 1 to entry: For a two-level converter U_{dc} is equal to U_a in Figure 1.

3.9**initial impulse voltage magnitude** **U_0**

initial magnitude of the voltage impulse (see Figure 1)

3.10**steady state impulse voltage magnitude** **U_a**

final magnitude of the voltage impulse (see Figure 1)

3.11**voltage overshoot** **U_b**

magnitude of the peak voltage in excess of the steady state impulse voltage magnitude.

3.12**peak-to-peak voltage** **U_p**

Difference between the initial voltage value and the maximum voltage reached during a voltage impulse (e.g., $U_p - U_0$ in Figure 1)

3.13**peak to peak impulse frequency voltage** **$U'_{pk/pk}$**

peak to peak voltage at the impulse repetition rate (see Figure F.4)

3.14**peak to peak fundamental frequency voltage** $U_{pk/pk}$

peak to peak voltage at the fundamental frequency (see Figure F.4)

3.15**jump voltage** U_j

change in phase-to-ground voltage at the terminals of the machine occurring at the start of each impulse when fed from a converter (see Figure F.6)

3.16**Turn insulation stress factor** a

fraction of the jump voltage applied to the first coil or first couple of turns for random wound and form wound machines, respectively.

3.17**overshoot factor**

ratio of the voltage appearing at the machine terminals and the voltage at the converter for each converter level

3.18**impulse rise time** t_r

rise time of the voltage is defined as the time between 10 % to 90 % of the voltage transient peak equal to $t_{90}-t_{10}$ (see Figure 1)

3.19**impulse duration****impulse width**

interval of time between the first and last instants at which the instantaneous value of an impulse reaches a specified threshold or a specified fraction of its impulse magnitude

Note 1 to entry: Typically the threshold is the DC bus voltage of the converter.

3.20**impulse voltage repetition rate** f

inverse of the average time between two successive impulses of the same polarity, whether unipolar or bipolar

3.21**electrical insulation system**

insulating structure containing one or more electrical insulating materials together with associated conducting parts employed in an electrotechnical device

3.22**type I insulation system**

insulation systems that are not expected to experience PD over the expected lifetime of the winding. This usually means the insulation system is composed of organic insulating materials only.

3.23**type II insulation system**

insulation system that is likely to have to withstand PD during its life in some part of its electrical insulation and should therefore contain materials that resist PD.

3.24**formette**

special test model used for the evaluation of the electrical insulation systems for form-wound windings

3.25**motorette**

special test model used for the evaluation of the electrical insulation systems of random-wound windings

3.26**statorette**

a stator used as test model for the evaluation of the electrical insulation systems of either random-wound or form-wound windings

3.27**(electric) stress**

electric field in V/m or other multiples as appropriate

3.28**fundamental frequency**

reciprocal of the period of a periodic function

Note 1 entry: first frequency, in the spectrum obtained from a Fourier transform of a periodic time function, to which all the frequencies of the spectrum are referred.

Note 2 to entry: For the purposes of this standard, the fundamental frequency of the machine terminal voltage is the one defining the speed of the converter fed machine.

3.29**power drive system**

complete drive module and rotating machine together with the connecting cable if necessary

3.30**drive system integrator**

the person or organization responsible for co-ordinating the electrical performance of the entire drive system)

3.31**rated voltage**

U_N

voltage assigned by the manufacturer for a specified power frequency operating condition of a machine and indicated on its rating plate

Note 1 to entry: The rated voltage is the r.m.s. value of the 1st harmonic of the voltage between two lines on the machine side

3.32**impulse voltage insulation class****IVIC**

peak to peak voltage classes A, B, C, D, S. The voltage classes are assigned by the manufacturer in relation to the rated voltage. The machine IVIC is indicated in the machine documentation and, if applicable, on its name plate. Using the machine the IVIC voltage limits ensure reliable operation,

3.33**maximum allowable terminal voltage**

U_{IVIC}

maximum allowable peak-to-peak phase to ground voltage in service, according to the IVIC specification