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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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Introduction

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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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.	



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IEC TC 2 : ROTATING MACHINERY	
SECRETARIAT: United Kingdom	SECRETARY: Mr Charles Whitlock
OF INTEREST TO THE FOLLOWING COMMITTEES:	HORIZONTAL FUNCTION(S):
ASPECTS CONCERNED:	

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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.

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

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

191 The committee has decided that the contents of the base publication and its amendment will
192 remain unchanged until the stability date indicated on the IEC web site under
193 "http://webstore.iec.ch" in the data related to the specific publication. At this date, the
194 publication will be

- 195 • reconfirmed,
- 196 • withdrawn,
- 197 • replaced by a revised edition, or
- 198 • amended.

199

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 or parts of them into those which are not expected to experience continuous 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.

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. 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 α 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 IVIC. An impulse voltage insulation class (IVIC) are then assigned to the machine or for each insulation subsystem (turn

249 to-turn, phase-to-ground, phase-to-phase). A mechanism is described for dealing with special
250 cases.

251 **IEC 60034-18-42**

252 The tests for qualification and acceptance of electrical insulation systems chosen for Type II
253 rotating electrical machines are described in this technical specification. The qualification
254 procedure is completely different from that used for Type I insulation systems and involves
255 destructive ageing of insulated test objects under accelerated conditions. The rotating machine
256 manufacturer requires a life curve for the insulation system that can be interpreted to provide
257 an estimate of life under the service conditions with converter drive. Great importance is
258 attached to the qualification of any stress grading system that is used and testing here should
259 be performed under repetitive impulse conditions. If the insulation system can be shown to
260 provide an acceptable life under the appropriate ageing conditions, it is qualified for use.
261 Acceptance testing is performed on coils made using this insulation system when subjected to
262 a voltage endurance test.

263 Note: Type I qualification process may also be necessary for parts that are not able to withstand
264 continuous partial discharge activity in what is otherwise a Type II insulation system. As an
265 example, high voltage machines often have turn insulation which is unable to withstand
266 continuous partial discharge activity (Type I), whereas the micaceous ground insulation is able
267 to (Type II).

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

- 269 • Editorial changes were made to help the reader find the contents more easily.
- 270 • Introduced the definition of the turn insulation stress factor, which is now indicated with
271 ρ (it was "a" in Ed. 1)
- 272 • The IVIC in Ed. 1 was a unique to all insulation sub-systems. In Ed. 2, each insulation
273 sub-system is characterized by its IVIC.
- 274 • For the turn-to-turn insulation system, IVIC is based on the fraction of the jump voltage
275 applied to the first coil or first couple of turns of the winding, for random wound and form
276 wound winding, respectively. This choice allows to deal with wide bandgap converters
277 in a flexible way.
- 278 • As a good practice, it is suggested to measure, using different rise times, and report the
279 fraction of the jump voltage applied to the first coil or first couple of turns of the winding,
280 for random wound and form wound winding, respectively.
- 281 • Following 60034-18-1, if minor changes are made to the insulation system, an
282 accelerated procedure for qualification can be carried out.
- 283 • For the sake of simplicity, test voltages are now reported in per-unit of the rated voltage
284 U_N . These values are consistent with those reported in Edition 1 assuming that
285 $U_{DC}/U_N=1,35$.
- 286 • Testing using impulse voltages is considered preferable to testing with AC sinusoidal
287 voltages.
- 288 • Surge testers providing bipolar square voltage waveforms with high repetition rates are
289 to be preferred to surge tester providing unipolar impulses with reduced repetition rates.
- 290 • Provisions for testing delta windings and individual phases are reported.

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 powered from 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 $U_N \leq 120V$ ($U_{DC} \leq 170V$);
- rotor windings of rotating electrical machines with $U_N \leq 120V$ ($U_{DC} \leq 170V$).

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.

329 IEC/TS 60034-27-1, *Rotating electrical machines – Part 27: Off-line partial discharge*
330 *measurements on the stator winding insulation of rotating electrical machines*

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

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

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

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

339 **3 Terms and definitions**

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

341 **3.1**

342 **partial discharge**

343 **PD**

344 electric discharge that only partially bridges the insulation between electrical conductors

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

346 Note 2 to entry: It may accelerate the aging of the insulation system.

347 Note 3 to entry: It may be often detected as electric or electromagnetic pulses

348 **3.2**

349 **PD free**

350 State of an electrical insulation system where no partial discharges occur during operation or
351 during a voltage test. During tests, it means the state of an electrical insulation system where
352 no PD pulses are detected at the test voltage in a certain test time or the numbers of detected
353 PD pulses are less than a certain value mentioned in Annex E.2.

354 **3.3**

355 **partial discharge inception voltage**

356 **PDIV**

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

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

363 **3.4**

364 **partial discharge extinction voltage**

365 **PDEV**

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

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

3.5**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.

3.6**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 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 decreased with step-by-step method.

3.7**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.

3.8**bipolar impulse**

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

3.9**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.

3.10**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 (see Figure 1).

3.12**peak voltage** **U_p**

For positive impulses: difference between the maximum voltage and the ground voltage reached during a voltage impulse (see Figure 1). For negative impulses: difference between minimum voltage and ground voltage reached during a voltage impulse.

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** ρ

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

Note 1 to entry: The fraction ρ reported in the following is the ratio of the voltage across the first coil or first couple of turns when the jump voltage is applied between the line terminal and the star point. If the jump voltage is applied to one phase and the other two phases connected in parallel, this value is reduced by 2/3 due to the ratio of the impedances in the three phases.

3.17**overshoot factor****OF**

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 or parts of that are not expected to experience continuous PD activity over the entire lifetime of the winding..

3.23**type II insulation system**

insulation systems or parts of that are likely to have to withstand continuous PD activity during its life.

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**(electric) stress**

electric field expressed in V/m or other multiples as appropriate

3.27**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.

3.28**power drive system**

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

3.29**drive system integrator**

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

3.30**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 RMS value of the 1st harmonic of the voltage between two lines on the machine side

3.31**impulse voltage insulation class****IVIC**

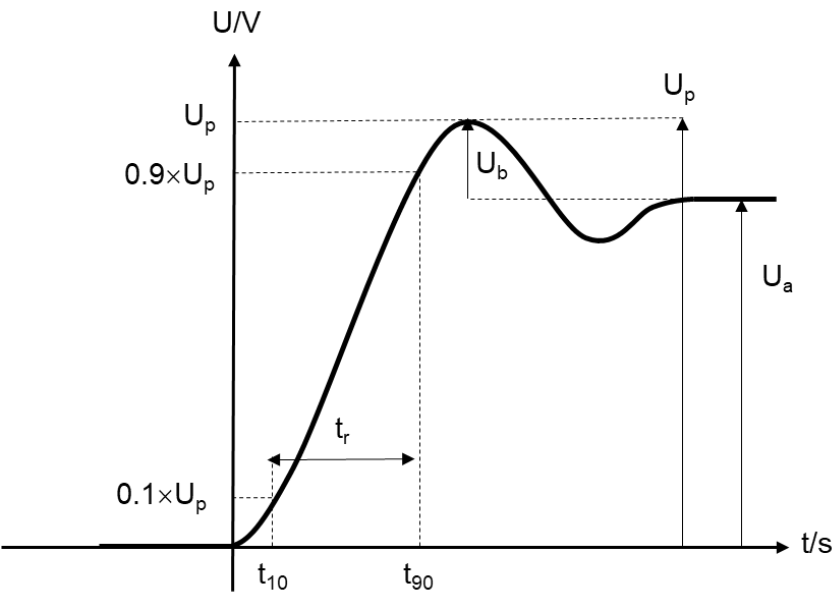
peak to peak voltage classes A, B, C, D, S. The voltage classes are assigned by the manufacturer in relation to the rated voltage. The machine IVIC is indicated in the machine documentation and, if possible, on its name plate. Using the machine the IVIC voltage limits ensure reliable operation,

3.32
maximum allowable terminal voltage
 U_{IVIC}
maximum allowable peak-to-peak phase to ground voltage in service, according to the IVIC specification

3.33
test voltage factor
TVF
maximum allowable peak-to-peak phase to ground voltage in service in units of U_N , divided by $2\sqrt{2}$ ($TVF = \frac{U_{IVIC}}{2\sqrt{2}U_N}$)

3.34
diagnostic factor
variable or fixed stress which is applied to an electrical insulation system to establish the degree of ageing

3.35
diagnostic test
periodic or continuous application of a specified level of a diagnostic factor to a test object to determine whether or when the end-point criterion has been reached



Key

U voltage	U_p peak voltage	U_a steady state voltage
t time	U_b voltage overshoot	

Figure 1 – Voltage impulse waveshape parameters

4 Impulse Voltage Insulation Class (IVIC) for Type I insulation systems used in converter fed machines

4.1 Rationale

Manufacturers typically assign a rated voltage to a machine based on power frequency. This assumes that voltage from the power supply is 50 Hz or 60 Hz sinusoidal. In the case of machines driven by