IEC 60034-18-32

Edition 2.0 2022-01
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

**Rotating electrical machines –
Part 18-32: Functional evaluation of insulation systems (Type II) –
Electrical endurance qualification procedures for form-wound windings**

IEC 60034-18-32:2022-01 CMV(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.160.01

ISBN 978-2-8322-1073-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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This commented version (CMV) of the official standard IEC 60034-18-32:2022 edition 2.0 allows the user to identify the changes made to the previous IEC 60034-18-32:2010 edition 1.0. Futhermore, comments from IEC TC 2 experts are provided to explain the reasons of the most relevant changes.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60034-18-32 has been prepared by IEC technical committee 2: Rotating machinery. It is an International Standard.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Title modified.
b) Simplification of clauses.
c) Reduction in the number of test procedures.
d) Inclusion of full bars and coils as test objects.
e) A new clause dealing with failures and failure criteria.

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

Draft	Report on voting
2/2068/FDIS	2/2075/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

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.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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

IEC 60034-18-1 presents general principles for the evaluation of insulation systems used in rotating electrical machines.

This document deals exclusively with insulation systems for form-wound windings (Type II) and concentrates on electrical functional evaluation.

In IEC 60034-18-42, tests are described for qualification of Type II insulation systems in voltage-source converter operation. These insulation systems are generally used in rotating machines which have form-wound windings, mostly rated above 700 V r.m.s. The two standards IEC 60034-18-41 and IEC 60034-18-42 separate 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 experience and withstand partial discharge activity in any part of the insulation system throughout their service lives (Type II).

ROTATING ELECTRICAL MACHINES –

Part 18-32: Functional evaluation of insulation systems (Type II) – ~~Test~~ Electrical endurance qualification procedures for form-wound windings ~~– Evaluation by electrical endurance~~

1 Scope

This part of IEC 60034-18 describes ~~test~~ qualification procedures for the evaluation of electrical endurance of insulation systems for use in ~~a.c. or d.c.~~ rotating electrical machines using form-wound windings energized with sinusoidal power frequency voltage. The test procedures for the main wall insulation are comparative in nature, such that the performance of a candidate insulation system is compared to that of a reference insulation system with proven service experience. ~~The test procedures are principally directed at the insulation systems in air-cooled machines but may also be used for evaluating parts of the insulation systems in hydrogen cooled machines. Note that the qualification procedures of inverter duty insulation systems for form-wound windings can be found in IEC 60034-18-42.~~ If no reference system is available, the diagram in Annex A is available for use. The qualification procedures of inverter duty insulation system for form-wound windings can be found in IEC 60034-18-42 or IEC 60034-18-41. A new and informative test procedure for the stress control system is introduced and defined in Annex B. 2

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 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-15:2009, *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

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

IEC TS 60034-18-33:2010, *Rotating electrical machines – Part 18-33: Functional evaluation of insulation systems – Test procedures for form-wound windings – Multifactor evaluation by endurance under simultaneous thermal and electrical stresses*

IEC 60034-18-41, *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*

IEC 60034-18-42:2017, *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 60034-18-42:2017/AMD1:2020

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

IEC 60034-27-3, *Rotating electrical machines – Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 62539, *Guide for the statistical analysis of electrical insulation breakdown data*

3 Terms and definitions

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

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
mainwall insulation
main electrical insulation that separates the conductors from the earthed stator/rotor core in motor and generator windings

3.2
~~turn~~ strand insulation
electrical insulation that covers each conductor in coils/bars

3.3
~~interturn~~ turn insulation
electrical insulation that separates the conductor turns from each other in coils/bars

~~**3.4**~~
~~**corona protection material**~~
~~material which is used to coat a stator coil/bar within the slot portion of the stator core to avoid slot discharges~~

~~**3.5**~~
~~**stress grading material**~~
~~material generally having a non-linear resistivity characteristic, applied to the endwindings of stators to reduce the maximum surface electrical stress~~

3.4
conductive slot coating
conductive paint or tape layer in intimate contact with the mainwall insulation in the slot portion of the coil side, often called semi-conductive coating

Note 1 to entry: The purpose is to prevent partial discharge from occurring between the coil/bar and the stator core.

3.5
stress control coating
paint or tape on the surface of the mainwall insulation that extends beyond the conductive slot coating in high-voltage stator bars and coils

Note 1 to entry: The purpose of the coating is to prevent surface discharges near the slot exit or in the end winding area.

3.6
stress control system
generic name for the combination of the conductive slot coating and stress control coating in high-voltage stator bars and coils 3

3.7
confidence interval
range of values so defined that there is a specified probability that the value of a parameter (voltage, stress or time) lies within it

3.8
test temperature
temperature of the outer surface of the bar/coil at the straight part of the bar/coil measured with an appropriate selected and placed sensor

4 General considerations

4.1 Relationship to IEC 60034-18-1

The principles of IEC 60034-18-1 should be followed, unless the recommendations of this document indicate otherwise.

4.2 Selection and designation of test procedures

One or more of the procedures in this document should be suitable for the majority of evaluations. Evaluation is usually performed by the manufacturer of the machine/coils or by a third-party laboratory. It is the manufacturer's responsibility to justify the most suitable procedure ~~in Table 1~~ on the basis of past experience and knowledge of the insulation systems to be compared.

~~The test procedure should be selected from Table 1 and designated by IEC 60034-18-32 procedure N, where N is the designation given in the Table 1. Subclauses 4.3, 4.4 and 4.5 give guidance on how to select the test procedure.~~

~~**Table 1 – Test procedure designations**~~

~~**Designation of test procedure N**~~	~~**Applied ageing voltage**~~		~~**Diagnostic tests**~~		
	~~**Mainwall insulation (6.3)**~~	~~**Interturn insulation (6.4)**~~	~~**Mainwall insulation (7.2.1)**~~	~~**Interturn insulation (7.2.2 or 7.2.3)**~~	~~**Stress grading (7.3)**~~
~~AA~~	~~Constant~~	~~None~~	~~Not required (A)~~	~~No test (A)~~	~~Optional (D)~~
~~CA~~	~~Constant~~	~~None~~	~~Other test (C)~~	~~No test (A)~~	~~Optional (D)~~
~~AB~~	~~Constant~~	~~Yes~~	~~Not required (A)~~	~~Impulse test (B)~~	~~Optional (D)~~

~~NOTE 1 The meaning of the letters of the diagnostic test are as follows: A – No test; B – Impulse test; C – Other test (such as dissipation factor and partial discharge tests); D – Visual observation.~~

~~NOTE 2 Where a diagnostic test is not required on the mainwall insulation, the ageing voltage acts simultaneously as the diagnostic factor.~~

~~All the above tests are carried out at room temperature. However, if they are to be performed at any other temperature (see 6.2.2), the designation of the test procedure shall include the Celsius temperature in brackets, e.g. AA(190). Each of the procedures may be used for the full evaluation according to 4.5.1 or for the reduced evaluation according to 4.5.2.~~

~~Procedure AA is the preferred choice if the manufacturer has no past experience or knowledge of the candidate system and the behaviour of the mainwall insulation is defined.~~ 4

Following test procedures are described:

- Mainwall insulation
- Turn insulation only with the main insulation test
- Conductive slot coating (Annex B)
- Stress control coating (Annex B)
- Mainwall insulation, where voltage level and/or life time differs from the reference system

4.3 Reference insulation system

A reference insulation system should be tested using a test procedure equivalent to that used for the candidate system (see IEC 60034-18-1). The reference insulation system should have service experience at not less than 75 % of the intended maximum rated voltage of the candidate system. When extrapolation of the insulation thickness is used, information such as "different insulation thickness at same electrical field stress levels by obtaining equal or similar breakdown time" should be provided showing the correlation between electrical lifetime and electrical stress for the different insulation thicknesses. If no reference insulation system is available the diagram in Annex A shall be used as criterion.

4.4 Test procedures ~~(IEC 61251)~~

4.4.1 General

Electrical ageing tests are usually performed at fixed voltage levels until failure (mainwall insulation) or in combination with elevated temperature until signs of deterioration occur (conductive slot coating system). Statistical evaluation of the results of testing should be performed according to IEC 62539.

4.4.2 Electrical ageing of the mainwall insulation

From such tests, characteristic times to failure at each voltage level are obtained. The results for both the candidate system and the reference system should be reported on a graph, as shown by the example in Figure 1, and compared. There is no proven physical basis for extrapolation of this characteristic to the service voltage level $U_N/\sqrt{3}$, where U_N is the r.m.s. rated phase to phase voltage. ~~Statistical evaluation of the results of testing should be performed according to IEC 62539.~~

In service, electrical ageing of the mainwall insulation is primarily caused by continuous electrical stress at power frequency. In addition, the insulation is required to withstand transient overvoltage arising from switching surges or inverter supply. The ability of the mainwall insulation to withstand transient overvoltage from converter supplies may be demonstrated by the system's performance using IEC 60034-18-42.

This document describes ~~voltage~~ electrical ageing of the mainwall insulation, carried out at power frequency or ~~at a frequency up to 10 times greater~~ higher. In order to keep acceleration of ageing in a linear progression, a maximum of 10 times of the power frequencies is appropriate. Latest experiences with the application of IEC 60034-18-42 show that a frequency of up to 1 000 Hz can be used as well. Care shall be taken that the dielectric losses do not increase the temperature of the insulation beyond the service temperature to avoid additional thermal ageing effects. (IEC TS 60034-18-33:2010, Table 1).

4.4.3 Electrical ageing of the stress control system

In order to allow a full qualification of the entire insulation system Annex B describes methods to qualify the conductive slot coating and stress control coating. 5

4.4.4 Electrical ageing of the turn insulation

~~Electrical ageing of the turn insulation can arise due to the steady-state stress applied across the mainwall insulation. This could be particularly significant at the edges of the conductors where the electrical stress reaches a maximum.~~

~~Where multiturn coils or bars are used, the power frequency voltage between turns is sufficiently low that ageing due to this electric stress is not of major significance. However, steep-fronted surges on the winding caused by switching and other disturbances can generate sufficient stress between turns for ageing to take place. Since the waveforms and frequency of occurrence are variable and dependent upon circuit parameters, this International Standard recommends that, for comparison purposes, electrical ageing of the turn insulation be performed using IEC 60034-18-42.~~

In normal direct-on-line operation of rotating machines the turn insulation is subjected to a stress significantly below the partial discharge inception voltage. Continuous electrical ageing is then not taking place and turn insulation qualification is therefore excluded from this document. Withstand against transient overvoltage should be tested according to IEC 60034-15.

In converter fed or other types of special operation the turn insulation may continuously be subjected to a stress above the partial discharge inception voltage. Electrical ageing should then be performed according to IEC 60034-18-42. 6

4.5 Extent of tests

4.5.1 Full evaluation of the mainwall insulation

The extent of the electrical functional tests will depend upon the purpose of the evaluation. A full evaluation will be needed where there are substantial differences ~~in the compositions of~~ from the reference ~~and candidate systems~~ system according to IEC 60034-18-1.

4.5.2 Reduced evaluation of the mainwall insulation

There are situations when it will be sufficient to carry out reduced evaluation using the minimum number of test specimens and the middle voltage level ~~from~~ used in the ~~range of~~ reference tests.

Comparison of a candidate insulation system to a reference system, where there are no intended or only minor differences in composition or manufacturing procedures (so-called minor changes, see IEC 60034-18-1), may be carried out using only one voltage level but with the recommended minimum number of test specimens (see 5.2). Reduced evaluation is allowed only if the rated voltages are the same for both systems.

~~An example of a minor change might be the sourcing of the same material from a different supplier or a change of pulping process. An example of a minor processing change might be the installation of a new controller or new pipework in a vacuum pressure impregnation (VPI) process. It should be emphasized that a minor change is one which is not expected to have a significant effect on the insulation system. It is the responsibility of the manufacturer to justify the use of the reduced qualification procedure~~

4.5.3 Evaluation of the stress control system

Annex B defines tests and criteria to evaluate conductive slot coating and stress control coating.

5 Test objects

5.1 Construction of test objects

Test objects should preferably be complete bars or coils made to normal design, material and manufacturing ~~standards~~ procedures. Alternatively, they may be constructed to represent the configuration of the finished winding component to be evaluated and be subjected to the full normal or intended manufacturing processes. When using separate coils or bars as models, creepage distances and any necessary voltage grading are to be appropriate to the stresses applied during testing. A ground electrode should extend the full slot length of the model and ~~encircle~~ cover at least the ~~entire circumference~~ two wide sides of the coil cross-section.

~~The sample preparation and test procedures described in IEC 60034-18-42 may be used for qualifying stress grading systems applied to endwinding insulation.~~

Slot models for GVPI systems shall be made from rigid steel plates, not having any other component inserted than in the actual system present and having a length equal to that of the longest actual stator.

Test bars should be designed not to generate flashover between the end of stress control coating and the end of the conductor of the test bar. For reducing excessive electrical stress on the surface of test bars/coils by applying high voltage and/or high frequency, special treatment, for example extending stress control coating length, can be applied for evaluating the mainwall insulation. See also B.5. 7

~~5.2 Number of turns~~

~~For the turn insulation, it is generally necessary to use complete coils in order to include the effects of shaping and conductor reinforcement. The number of turns and the thickness of the turn insulation should be such that when the test voltage chosen in accordance with 6.1 is applied, the turn dielectric stress is not less than the highest that would be imposed by applying the appropriate test voltage to any design of coil for which the insulation system can be used.~~

~~Where a power frequency voltage is to be applied between the turns, the coil should be wound with two parallel conductors, each insulated with turn insulation, or the coil has to be cut in the end windings. When using VPI coils, the cut-through and separation of the conductors in this area have to be done before impregnation. If the test procedure chosen (see 4.2) does not apply a power frequency voltage between the turns, the test object can be a multiturn coil wound in the normal manner with a single (or stranded) conductor.~~ 8

5.2 Number of test specimens

An adequate number of test specimens shall be aged at each test voltage level in order to obtain statistical confidence. This number should not be less than ~~five~~ six bars or three coils for the qualification of the mainwall insulation per each test voltage level. 9

5.3 Initial quality control tests

~~Before starting the first ageing sub-cycle,~~ The following quality control tests shall be performed:

- visual inspection of the test specimens;
- ~~high-voltage tests~~ voltage withstand test according to IEC 60034-1;
- dissipation factor ~~test or/~~and partial discharge test according to IEC 60034-27-3 and IEC 60034-27-1 respectively.

6 Electrical ageing

6.1 General

It is not practicable to design a single test method that simulates all the interactions between the various insulation components. For example, to obtain a life curve for the mainwall insulation system by applying overvoltage would subject the conductive slot coating to excessive stress. Qualification has therefore been divided into separate test procedures. The primary aim is to establish the lifetime curve of the mainwall insulation from which the expected lives may be estimated. The second aim is to establish that the conductive slot coating and the stress control coating is suitable for service. 10

6.2 Voltage levels and intended test lives of the mainwall insulation

For full evaluation as described in 4.5.1, at least three power frequency voltages should be selected so that the intended mean time to failure at the highest voltage is about 100 h, and at the lowest voltage ~~above~~ around 5 000 h. For reduced evaluation, where only one voltage level is required (see 4.5.2), the voltage level should be chosen so that the intended mean time to failure is about 1 000 h. The alternating voltage applied to the test objects should be maintained within ± 3 %.

6.3 Test temperatures during electrical endurance testing of the mainwall insulation

6.3.1 Electrical ageing at room temperature

Electrical ageing is preferably carried out in air at room temperature at voltages and/or frequencies higher than those in the steady-state operating conditions, in order to accelerate the effects of electrical stress.

6.3.2 Electrical ageing at elevated temperature

~~Any appropriate means of heating may be used when the electrical ageing tests are performed at elevated temperatures.~~ If the endurance testing is to be performed at elevated temperatures, then either external heating plates or oven heating are permitted (see also Clause B.5). Note that these two methods may not produce the same results. The temperature rise due to the applied electrical stress can affect the results, especially when using increased frequency, and shall be recorded. If thermal ageing does occur, the testing should follow the procedures in IEC 60034-18-33 for multifactor testing.

NOTE Electrical ageing of the mainwall insulation under power frequency and elevated temperature up to service temperature may lead generally to longer time to failure values compared to tests at room temperature at same electrical stress levels.

6.3.3 Ageing procedure for the mainwall insulation

The electrical stress is applied between the stator core or the ~~outer conductive layer~~ mock up / slot electrode on the surface of the test specimen and the conductors. If the test object is a multiturn coil, both the mainwall insulation and partly the turn insulation are aged by the electrical stress during this period. However this procedure does not qualify the turn- to turn insulation. For test procedures with sub-cycles (Clause 7), the duration of these sub-cycles should be such that approximately ten sub-cycles are performed on a test specimen having a median life. Higher than power frequency is allowed to shorten the test times ~~but experience has shown that the maximum acceptable acceleration factor is 10 times the power frequency~~. Latest experiences with the application of IEC 60034-18-42 show that a frequency of up to 1 000 Hz can be used as shown in 4.4.2. Care should be taken that the dielectric losses do not increase the temperature of the insulation ~~so much that the results are affected~~ beyond the service temperature to avoid additional thermal ageing effects. (IEC TS 60034-18-33:2010, Table 1). This is especially important at elevated temperatures. The same frequency should be used for the candidate and reference insulation system. Increased frequency test results may only be used for direct comparison if the lives of the systems are affected similarly by the increase of frequency.

~~6.4 Ageing procedure for the turn insulation~~

~~Ageing of the turn insulation due to repetitive transient over-voltages is evaluated according to procedure AB in Table 1. The mainwall insulation ageing sub-cycle is followed by a turn insulation ageing sub-cycle consisting of the application of a power frequency voltage between turns for 10 min. This voltage shall be~~

$$\cancel{\frac{1{,}5 \times U_N}{n}}$$

~~where where U_N is the rated voltage of the insulation in kV and n is the number of turns, but not less than 0,3 × U_N.~~

~~The temperature rise due to the applied electrical stress can affect the results, especially when using increased frequency and should be recorded. Increased frequency test results may only be used for direct comparison if the lives of the systems are affected similarly by the increase in frequency.~~ **11**

6.4 Maintenance of stress ~~grading~~ control coatings

A stress ~~grading~~ control coating is usually applied to the outer surface of the coil or bar beyond the earthed ~~semi-~~conductive slot coating. ~~The stress grading coating may take the form of paints or tapes or a combination of the two.~~ During the electrical endurance test of the main insulation, deterioration may occur which does not result in insulation failure. Remedial action to the stress grading material and forced air cooling are permitted during the progress of the voltage endurance test on the basis that it is the mainwall insulation that is being tested rather than the stress grading system.

7 Diagnostic sub-cycle

7.1 General

No diagnostic tests are required for the qualification of the mainwall insulation but may be performed optionally.

Following each ageing sub-cycle, a diagnostic sub-cycle can be performed. Failure of any part of the test specimen during a diagnostic test constitutes failure of the whole system and shall be reported as such. The appropriate voltage tests are selected according to the chosen test procedure as per 4.2.

7.2 Voltage test~~s~~ of the mainwall insulation

If a diagnostic test on the mainwall insulation is performed it shall be done with a power frequency AC withstand test according to IEC 60034-15. Alternatively, a lighting impulse voltage withstand test according to IEC 60034-15 may be used.

~~7.2.1 Mainwall insulation test~~

~~The diagnostic test on the mainwall insulation consists of three successive applications of a 1,2/50 µs impulse voltage with a peak value of U_P = (4 U_N + 5 kV). Alternatively, a mainwall power frequency test according to 4.4 of IEC 60034-15 may be used. In this case, an r.m.s. voltage of (2 U_N + 1 kV) is applied for 1 min between coil terminals and earth. The applied r.m.s. voltage is then increased at the rate of 1 kV/s up to 2 (2 U_N + 1 kV), and then immediately reduced at a rate of at least 1 kV/s to zero.~~

~~**7.2.2 Turn insulation impulse test**~~

~~For test objects comprising multiturn coils wound with a single or stranded conductor the diagnostic test of the turn insulation is carried out by an impulse voltage test. The amplitude (peak) shall be given by the formula U'_p = 0,65 (4 U_N + 5 kV), where U_N is the rated voltage in kV (see IEC 60034-15). The number of impulses to be applied is at least 5.~~

~~**7.2.3 Turn insulation power frequency test**~~

~~For test objects comprising parallel isolated conductors a power frequency voltage of an appropriate magnitude shall be applied between the turns for 1 min. Voltage of an appropriate magnitude should be higher or equal to the highest ageing voltage.~~ **11**

7.3 Other diagnostic tests

Optional diagnostic measurements may be performed for information or to determine end of test life. These may replace the voltage tests. Factors such as insulation resistance, ~~loss tangent, and~~ dielectric dissipation factor, partial discharges and impulse test on the turn-to-turn insulation are examples. An end-point criterion may be established for each diagnostic test, with suitable justification reported.

~~For the stress grading system, there are no electrical tests defined for diagnostic purposes but it may be useful to record the condition of the material, viewed with the unaided eye, in regard to colour and surface imperfections, such as blistering and cracking.~~

8 Failures of the mainwall insulation

8.1 Failure location and verification

Failure of a specimen occurs when any electrical breakdown of the mainwall insulation occurs. This will result in the over-current detection system interrupting current to the high voltage transformer. Failure of the insulation should be verified by re-applying voltage gradually from zero. A specimen insulation failure will prevent the reapplication of the full test voltage. Locating the failure site is desirable and may be undertaken by seeing arcing or heating at the failure site as the voltage is raised. Care shall be taken as locating the failure in applying voltage the local failure area may be additionally damaged and the analysis of the breakdown channel might be more difficult or even impossible. When specimen failure has been verified, the failed sample should be isolated to allow testing to continue on the remaining samples.

Breakdown under stress control coating is acceptable, if only one breakdown of all tested bars/coils at this location occurs. If there is more than one bar or coil affected with a breakdown under the stress control coating, the number of bars or coils needs to be increased to get statistically enough values for the lifetime of the mainwall insulation away from the stress control coating. It is recommended in such a case to review design and manufacturing process for this particular area. **12**

8.2 Failed specimen observations

Each failed specimen should be examined to ensure that the failure is valid for statistical interpretation. This may require some specimen dissection in the area around the insulation puncture to identify the failure location and its probable cause.

~~**8.3 Dimensional measurements**~~

~~The thickness of the insulation wall (mainwall plus turn plus strand) shall be determined at or near the voltage endurance failure site.~~

9 Functional evaluation of the mainwall data

9.1 General

The evaluation of the test data should follow the guidelines set out below. Under the assumption of a Weibull distribution, the appropriate statistical analysis should be applied to calculate the significance of the candidate sample life with regard to that of the reference sample (see IEC 62539). In order to avoid introducing new ageing phenomena the maximum test voltage shall not exceed 4 times U_N.

The general rule is that the candidate insulation system is considered to be qualified if the 90 % confidence interval of the used probability distribution of the breakdown time falls above or within that obtained from the reference system (see IEC 60034-18-1).

If the reference line, given in Annex A, is used, an interpretation of results is mandatory. An example of evalution and interpretation is given in IEC 60034-18-42.

9.2 Full evaluation (same voltage level and same expected service life)

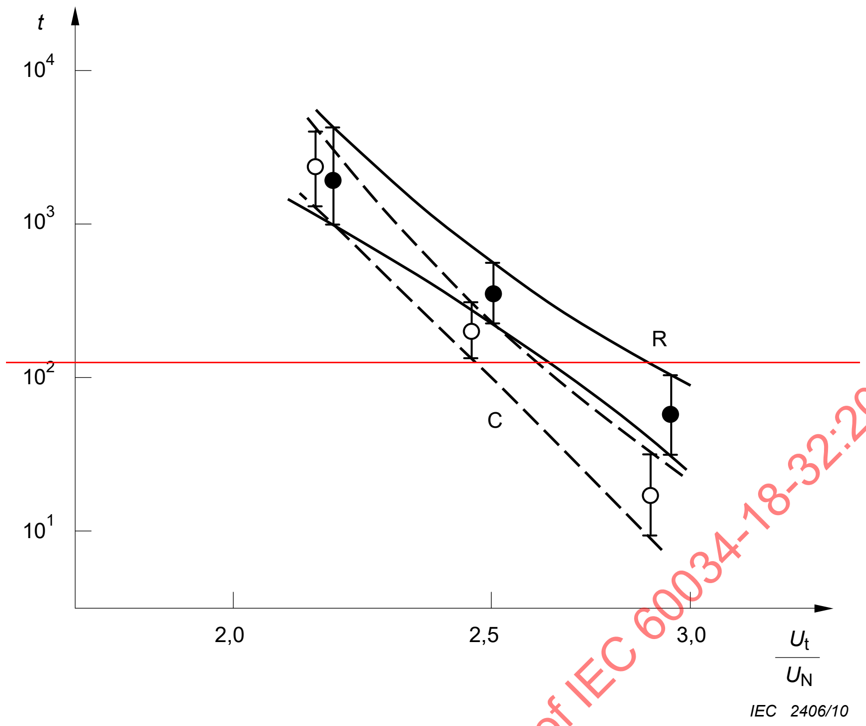
Electrical endurance graphs of the candidate and the reference system are plotted as a log-log representation of the time to failure (t), as a function of the ratio of test voltage (U_t) and rated voltage (U_N), where U_N is the rated voltage of the reference system and the candidate system. The candidate system is qualified if:

a) the upper 90 % confidence limit of the candidate system exceeds the upper 90 % confidence limit of the reference system over the range of reference system test voltages, or

b) the lower 90 % confidence limit of the candidate system exceeds or is equal to the lower 90 % confidence limit of the reference system at the lowest test voltage and the ~~slope of the~~ regression line of the mean values of the candidate system ~~is steeper~~ has a more gentle slope than that of the reference system.

Ageing results for a candidate system which satisfies condition b) are shown in Figure 1. An example of a candidate system which fails to qualify in respect of either condition a) or b) is shown in Figure 2.

The slope of a modern insulation system for instance containing nano particles may change and case B (Table 1) shall be used for qualification.



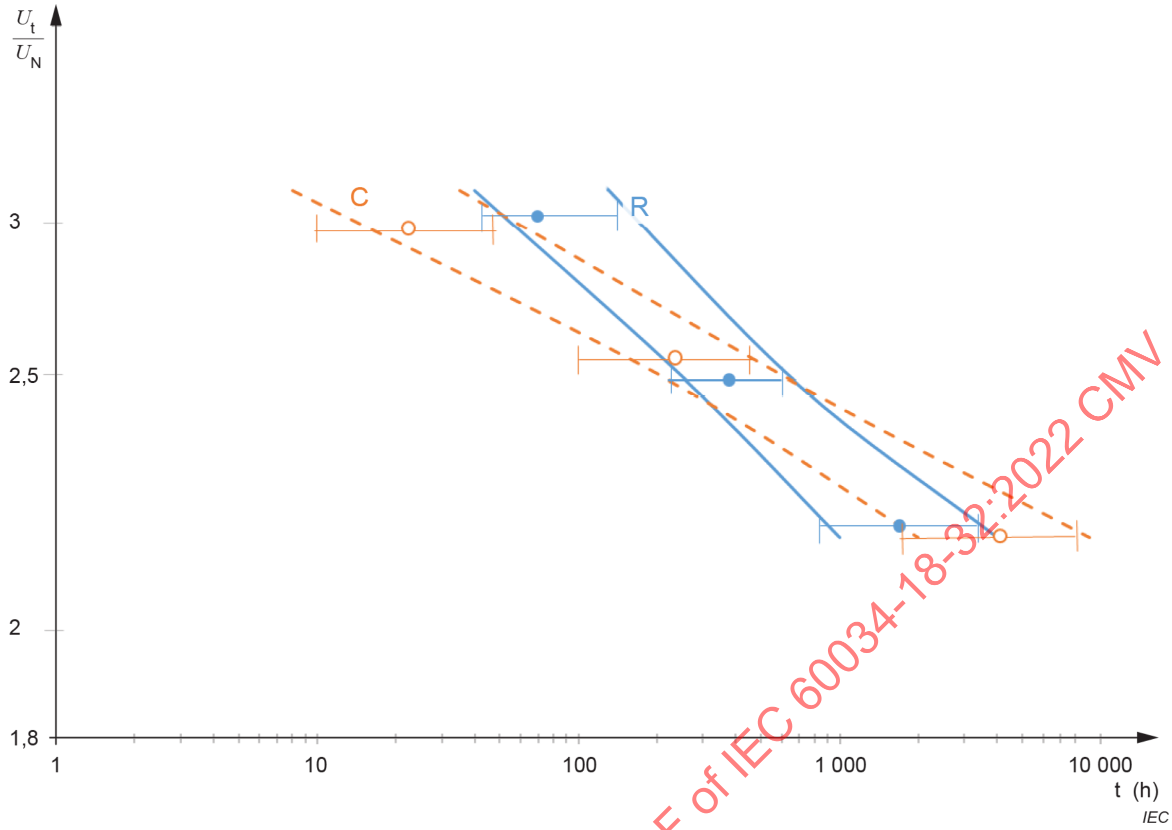
~~**Key**~~

~~R ageing data from the reference insulation system (R) showing the 90 % confidence limits~~

~~C ageing data from the candidate insulation system (C) showing the 90 % confidence limits~~

~~t time in hours~~

~~U_t/U_N ratio of test voltage to rated voltage~~



Key

R ageing data from the reference insulation system (R) showing the 90 % confidence limits

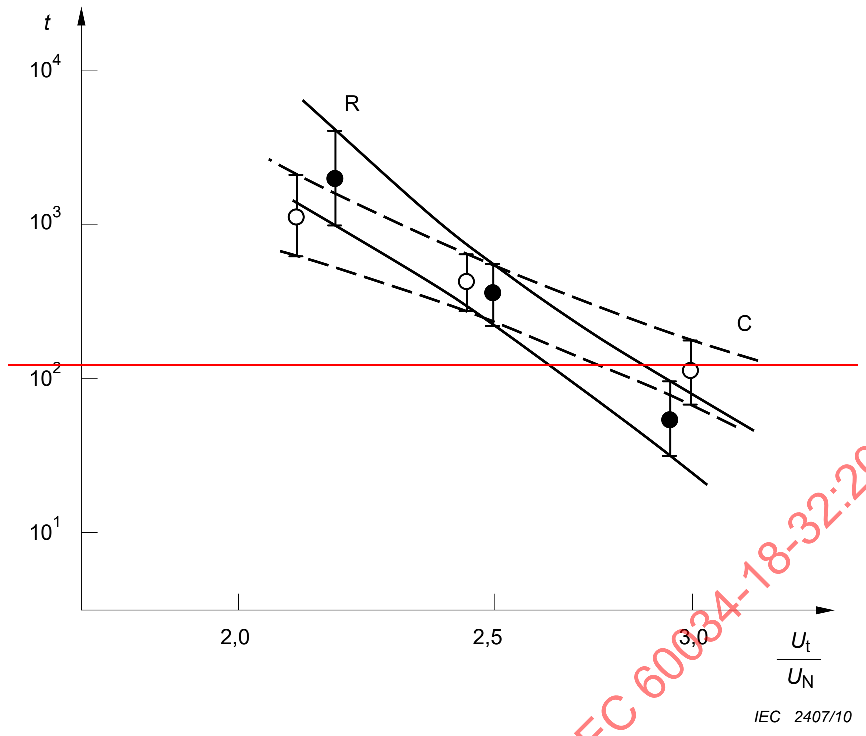
C ageing data from the candidate insulation system (C) showing the 90 % confidence limits

t time in hours

U_t/U_N ratio of test voltage to rated voltage

NOTE Abscissa and ordinate are logarithmic based scales. 13

Figure 1 – Comparison of ageing data from candidate (C) and reference (R) insulation systems showing qualification



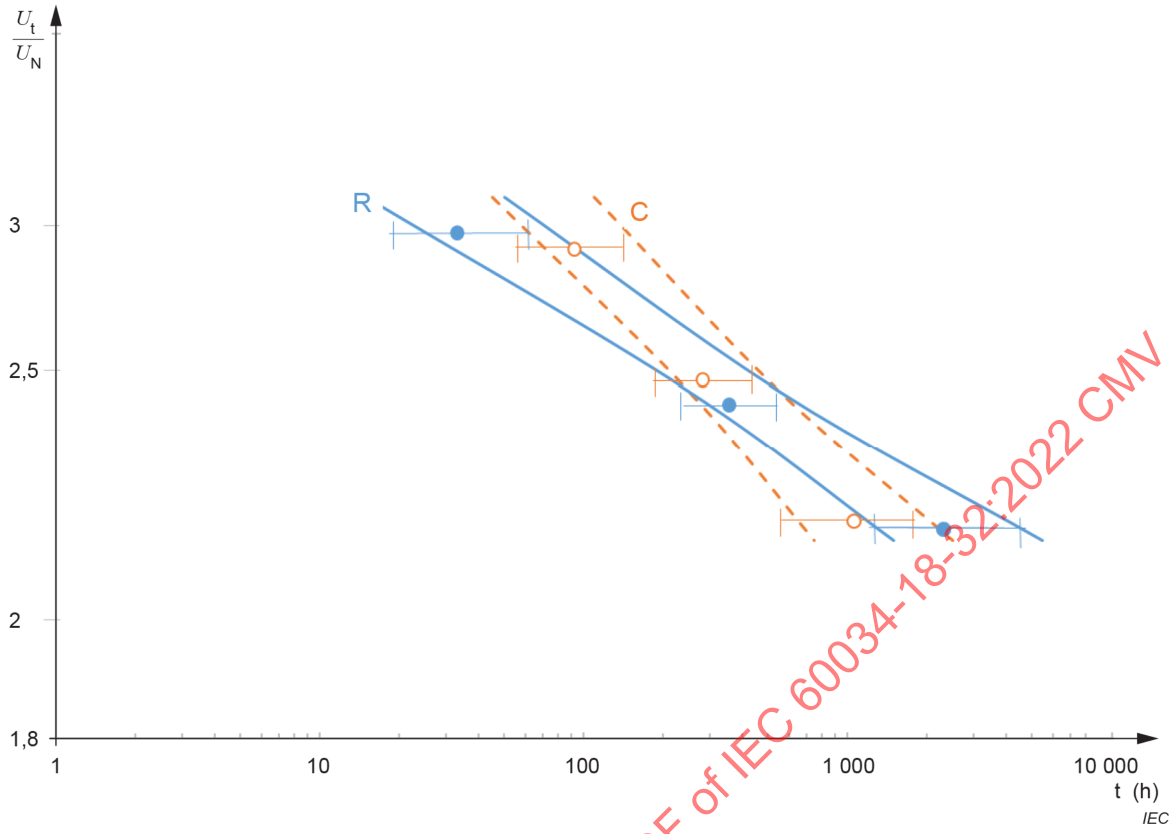
~~**Key**~~

~~R ageing data from the reference insulation system (R) showing the 90 % confidence limits~~

~~C ageing data from the candidate insulation system (C) showing the 90 % confidence limits~~

~~*t* time in hours~~

~~U_t/U_N ratio of test voltage to rated voltage~~



Key

R ageing data from the reference insulation system (R) showing the 90 % confidence limits

C ageing data from the candidate insulation system (C) showing the 90 % confidence limits

t time in hours

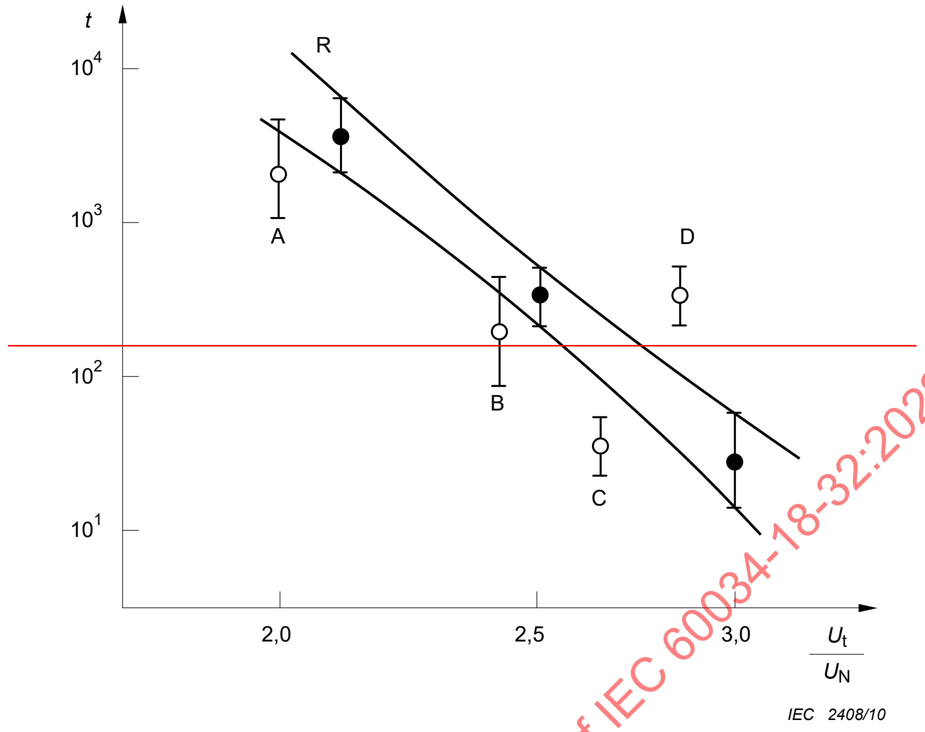
U_t/U_N ratio of test voltage to rated voltage

NOTE Abscissa and ordinate are logarithmic based scales.

Figure 2 – Comparison of ageing data from candidate and reference insulation systems showing failure to qualify

9.3 Reduced evaluation (same voltage level and same expected service life)

For reduced evaluation using a single voltage (see 4.5.2), the basis of analysis shall be as shown in Figure 3, where the 90 % tolerance of the 63 % quantile of the ageing results for the candidate system is compared with the 90 % confidence limits of the reference ageing line at the same quantile. If a partial overlap occurs within the voltage range of the ageing tests on the reference system, as shown by candidate system B, it is qualified. Qualification is not achieved in the case of candidate system A because the measurement is outside the voltage range used to produce the reference system ageing line. Nor is qualification achieved in the case of candidate system C since no overlap occurs. Candidate system D is qualified because the results exceed those of the reference system.



~~**Key**~~

~~R ageing data from the reference insulation system showing the 90 % confidence limits~~

~~A ageing results for candidate system A (not qualified)~~

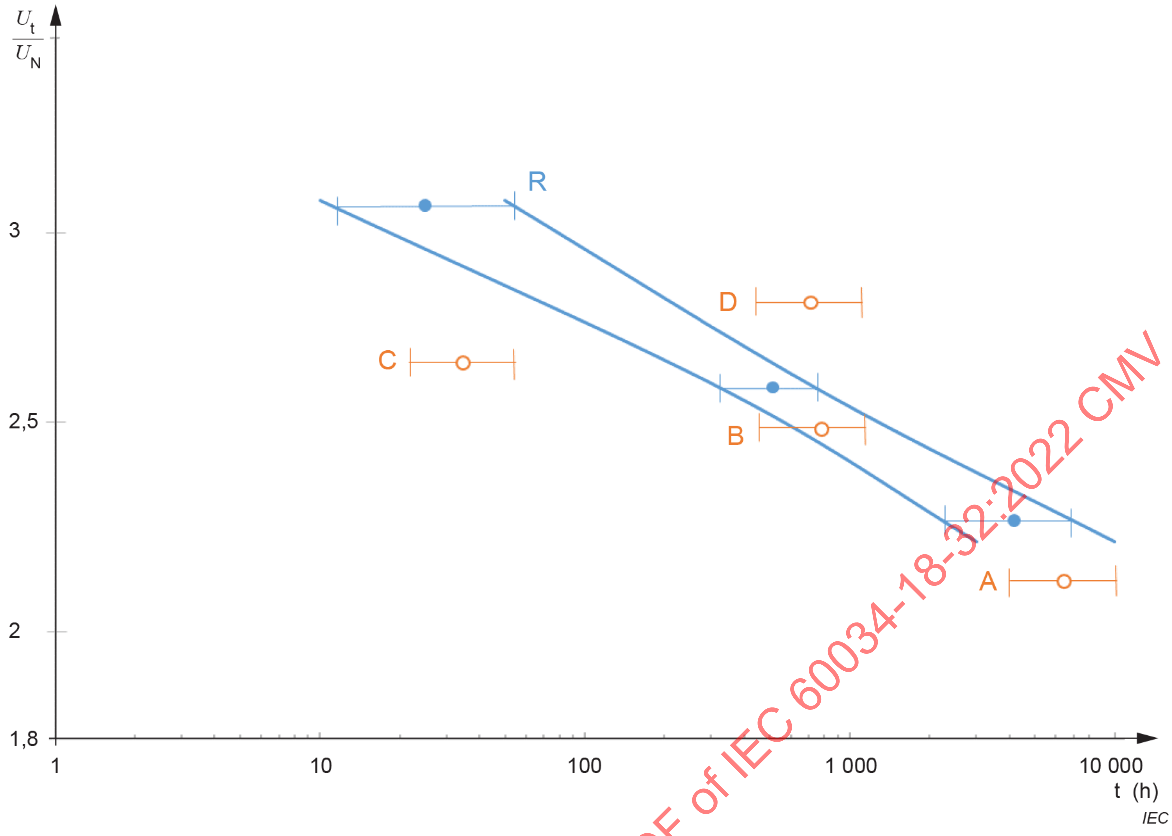
~~B ageing results for candidate system B (qualified)~~

~~C ageing results for candidate system C (not qualified)~~

~~D ageing results for candidate system D (qualified)~~

~~*t* time in hours~~

~~U_t/U_N ratio of test voltage to rated voltage~~



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

A ageing results for candidate system A (not qualified)

B ageing results for candidate system B (qualified)

C ageing results for candidate system C (not qualified)

D ageing results for candidate system D (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

NOTE Abscissa and ordinate are logarithmic based scales. 13

Figure 3 – Comparison of reduced evaluation test data from four separate candidate systems with that from the reference system

9.4 Recommended data to be recorded

The following items are suggested for inclusion in test records.

- Ambient temperature and humidity in the test area, if the specimens are tested at room temperature
- Applied voltage, expressed in equivalent r.m.s.
- Frequency of applied voltage in Hertz
- Total endurance time of each sample
- Results of any preliminary or intermediate diagnostic tests or measurements
- Observations of failure locations
- Observations on the nature of failure or of stress-grading damage
- Voltage endurance test temperature, i.e., the temperature of the thermocouples embedded in the heater plates

- Minimum and maximum test voltage and test temperature during the test

It will also be desirable to include other information, such as the nature of the samples, the nature of the electrodes and the nature of the stress-grading material.

9.5 Determining qualification for performances different to the reference system

9.5.1 Overview

The first step is to define the expected service life and rated voltage of the candidate system, then to compare the performance of reference and candidate systems with respect to the qualification criteria given in Table 1. Caution is recommended when qualifying a candidate system for a different voltage and/or service life, because of the assumptions implicit in the approach.

Before proceeding with the evaluation by comparison, it shall be established that the regression lines of the candidate and reference systems fit the data well (it is recommended that the correlation coefficient ≥ 0,98 according IEC 62539) and there is no indication of any change of ageing mechanism within the range of test voltage. If either of the regression lines is non-linear, refer to 9.5.5, where a simple test of linearity is described.

Table 1 – Conditions for qualification of candidate system

Case	Performance relative to reference system		Test voltage	Qualification criteria
	Voltage level	Expected service life		
A	Same	Same	Same	See 9.2
B	Same	Different	Same	Following the appropriate adjustments to the candidate system confidence limits (see description in the text for each case): 1. Confidence interval of candidate system shall overlap or exceed the confidence interval of the reference system. 2. The candidate system shows continually improving performance, i.e., the slope of its regression line is smaller than or equal to the slope of reference system regression line.
C	Different	Same	Different	
D	Different	Different	Different	

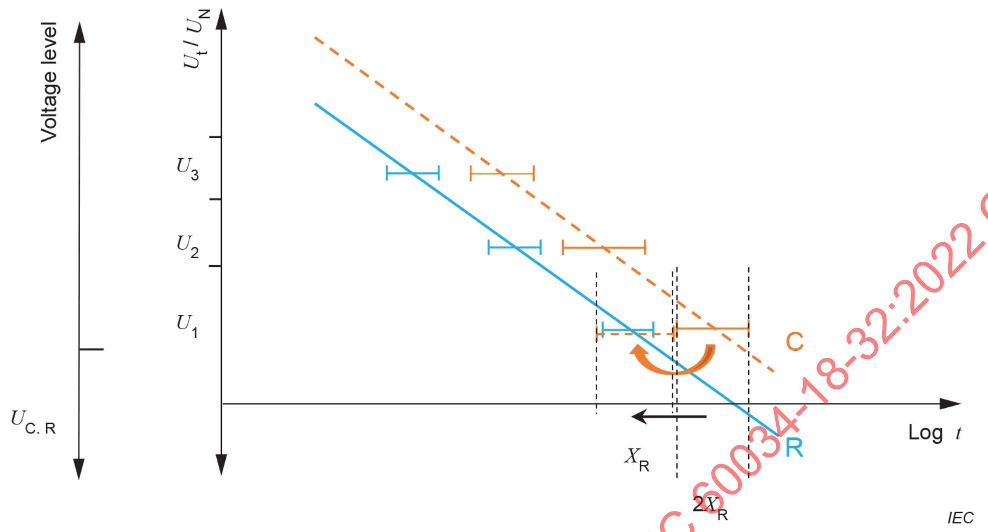
In comparing voltage level in relation to life time it is also possible to increase the field strength by either using thinner main insulation at same voltage or increase the voltage level by maintaining the same thickness. Care shall be taken with increased electrical field strength as also the corona system is subject to higher stresses. 14

9.5.2 Case B: Qualification for the same phase to phase voltage and a different expected service life

To qualify the candidate system for the same phase to phase voltage and a different expected service life (Table 1, Case B), the candidate system and reference system are tested using the same test voltage levels.

The candidate confidence limits at each voltage level are shifted on the horizontal axis by an amount equal to the agreed-upon change in service life, within the range X_R/20 to 20X_R, where X_R is the life of the reference system at each voltage level. The candidate system is qualified if its shifted confidence intervals is above the reference interval or if the confidence interval is overlapping than the slope of the candidate system shall be lower or equal to the reference system.

Figure 4 shows an example of a candidate system assessed for qualification for the same voltage level, and an expected service life double that of the reference system. When the full candidate system line is decreased by a factor of 2, the 90 % confidence limits overlap those of the reference. For simplicity, the shift on the horizontal axis is shown for only the confidence limits at a single voltage level, U_1.



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

C ageing results for candidate system (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

Figure 4 – Candidate system qualified for the same voltage level and different expected service life

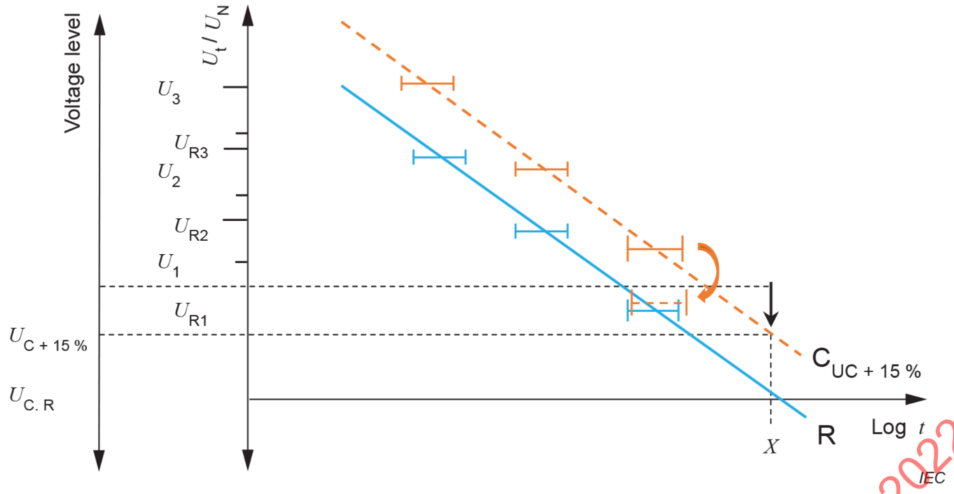
If the candidate system regression line crosses that of the reference system within the range of measurement, it is qualified for a higher service life at $U_{C,\ R}$ only if it demonstrates improved performance compared to the reference system at $U_{C,\ R}$ by the required life interval. **15**

9.5.3 Case C: Qualification for different voltage level and same expected service life

To qualify a candidate system for a different voltage level and the same expected service life (Table 1, Case C), the candidate system is tested using the voltage levels, which are appropriate to its intended voltage in operation.

The candidate confidence limits at each voltage level are shifted on the vertical axis by an amount equal to the agreed upon change in voltage level. The candidate system is qualified if its shifted confidence interval overlaps or exceeds that of the reference system or the candidate system shows continually improving performance, i.e., the slope of its regression line is lower or equal to the slope of reference system regression line.

Figure 5 shows an example of a candidate system assessed for qualification for the same expected service life at a 15 % higher voltage level, where the confidence interval for the candidate tested is shifted back to the voltage level of the reference. When the vertical axis shift is completed, the confidence intervals overlap or exceed those of the reference system, whereas $U_{C,\ R}$ is the voltage level of the reference system and $U_{C+15\ \%}$ is the intended voltage level of the candidate.



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

C ageing results for candidate system (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

Figure 5 – Candidate system qualified for a higher voltage level and the same expected service life 16

9.5.4 Case D: Qualification for different voltage level and different expected service life

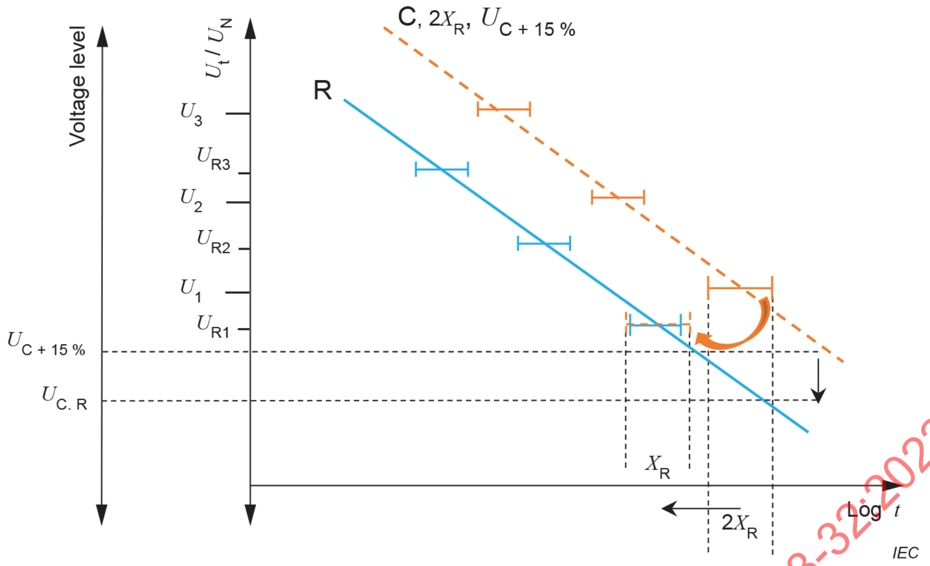
To qualify a candidate system for a different voltage level and a different expected service life (Table 1, Case D), the candidate system is tested using the voltage levels that are appropriate to its intended voltage in operation.

Qualification of the candidate system is determined by a shift of both the vertical and horizontal axes.

The candidate confidence limits at each voltage level are shifted on the horizontal axis by an amount equal to the agreed-upon change in service life, within the range $X_R/20$ to $20X_R$, where X_R is the life of the reference system at each voltage level.

The candidate confidence limits at each voltage level are then shifted on the vertical axis by an amount equal to the agreed upon change in voltage operation level. The candidate system is qualified if its shifted confidence interval overlaps or exceeds that of the reference system or the candidate system shows continually improving performance, i.e., the slope of its regression line is lower than or equal to the slope of reference system regression line.

Figure 6 shows an example of a candidate system assessed for qualification for double the expected service life of the reference, at a voltage level 15 % higher the reference. For simplicity, the shift on the horizontal axis is shown for only the confidence limits at a single voltage level U_1. The same candidate system is also assessed for qualification at a 15 % higher voltage level, where the confidence interval for the candidate tested using the voltage levels is shifted back to the voltage level of the reference, where $U_{C,\ R}$ is the voltage level of the reference system and $U_{C+15\ \%}$ is the intended voltage level of the candidate.



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

C ageing results for candidate system (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

Figure 6 – Candidate system qualified for a different service life and different voltage level from the reference 17

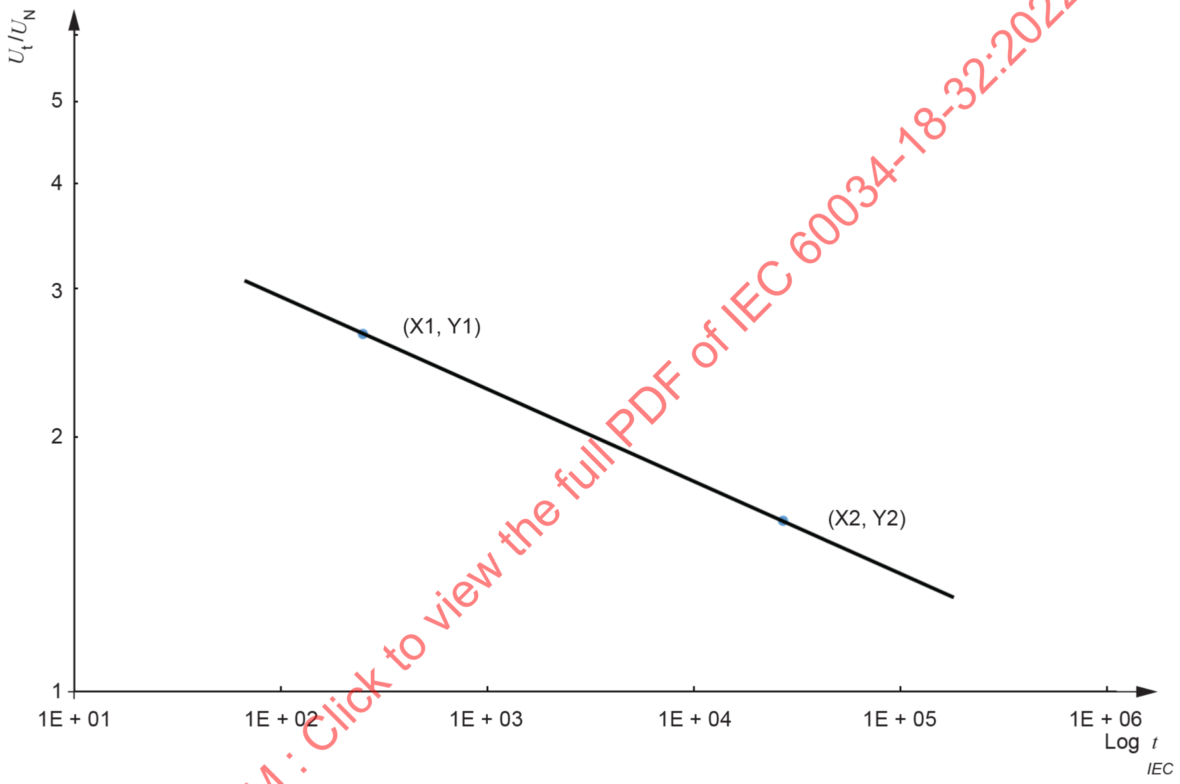
9.5.5 Non-linearity of regression lines

The candidate and reference systems may respond differently to the combination of ageing factors, resulting in curved regression lines. A slight bend in the graph indicates that more than one process or failure mechanism influences electrical ageing. If a straight line cannot be drawn within the tolerance bars of all the points, the data suggest that there is a significant change in the principal ageing mechanism within the range of test voltage levels. Confirmation of the curve by obtaining an additional test point at a lower or intermediate test voltage is recommended.

Annex A
(normative)

Reference life line for mainwall insulation in the absence of a manufacturer's reference life line

Where a reference life line for mainwall insulation is not available for comparison purposes, the qualification procedure shall be for the manufacturer to generate a candidate endurance life line for the intended mainwall insulation system using sinewave voltages. At least six specimens shall be tested at each of 3 voltages. After correction to 50 Hz or 60 Hz using formula (3) of IEC 60034-18-42:2017, the points shall be plotted to show log (mean life in hours) as a function of log (normalized voltage).



Key

Y1 2,65	t	time to electrical failure
X1 250	U_t	test voltage
Y2 1,6	U_N	Rated voltage phase to phase
X2 27000		

Figure A.1 – Reference lifeline for mainwall insulation

Comparison of the measured lifetimes shall be against the reference lifeline shown in Figure A.1. This lifeline, which is based on electrical ageing being the main ageing factor, is consistent with those measured at 50 Hz or 60 Hz from mica/epoxy resin systems that have been shown to give reliable lives in service. Due to older data from various manufactures, only two life time values for Figure A.1 are available.

NOTE Applying case B or D in using the reference line in Annex A may not be valid, because the line is based on long life times (normally 30 to 40 years) and electrical ageing is the main ageing factor. 18

Annex B 19
(informative)

B.1 Electrical ageing of the conductive slot coating

Ageing of conductive slot coating can be described as a successive degradation of the conductive material caused by partial discharges. The conductive slot coating system shows a notable dependency not only of the electrical field strength, but also of the applied temperature in operation and absolute voltage level. It is therefore associated as multifactor ageing. Additionally, larger voltage variations at the terminals as well as ambient stresses like ozone may additionally affect the conductive slot coating, but these additional ageing factors are not part of the qualification.

This document describes electrical ageing under elevated temperature of the conductive slot coating carried out at power frequency.

B.2 Electrical ageing of the stress control coating

Ageing of the stress control coating can be described as deterioration by either too excessive surface electrical stress, too high temperatures or a combination of both. Furthermore, ageing of the stress control coating is also deteriorated by inadequate contact between stress control coating and conductive slot coating.

B.3 Test objects

For qualification of the stress control system also a minimum of six bars or three coils should be used.

Test objects should preferably be complete bars or coils made to normal design, material and manufacturing procedures. Alternatively, they may be constructed to represent the configuration of the finished winding component to be evaluated and be subjected to the full normal or intended manufacturing processes. When using separate coils or bars as models, creepage distances and any necessary voltage grading are to be appropriate to the stresses applied during testing.

A ground electrode should cover at least the two wide sides of the coil cross-section. The electrode should be sectioned or shorter than full slot length for conductive slot coating samples to monitor possible deterioration.

B.4 Evaluation of the stress control system

The evaluation of the conductive slot coating and stress control coating is not a comparison between candidate and reference system. The intention of this evaluation is to stress the conductive slot coating and the stress control coating at a certain electrical field and voltage in combination with design operating temperature until a defined time has elapsed along with certain pass criteria. 20

B.5 Ageing procedure for the conductive slot and stress control coating

B.5.1 General

This ageing of the conductive slot coating and the stress control coating includes the simultaneous application of electrical and thermal stresses.

The electrical stress is applied between the stator core or the mock up / slot electrode on the surface of the test specimen and the conductors. The thermal stress is applied either by using an oven or by heater plates. The test temperature in both cases are controlled to within ±2 °C. No repair methods for the stress control material is allowed if the stress control system is being tested.

B.5.2 Arrangement of temperature control by heater plates

The heater plates are clamped to the slot-section sides of the specimens. It is recommended that the plates be at least 10 mm thick and preferable made of aluminium to achieve good thermal contact along the length of the plates and to enable temperature measurements. These plates also provide the ground connection to the specimen. Heating is provided by attaching heating coils controlled by a thermostat to the outside surface of each pair of plates.

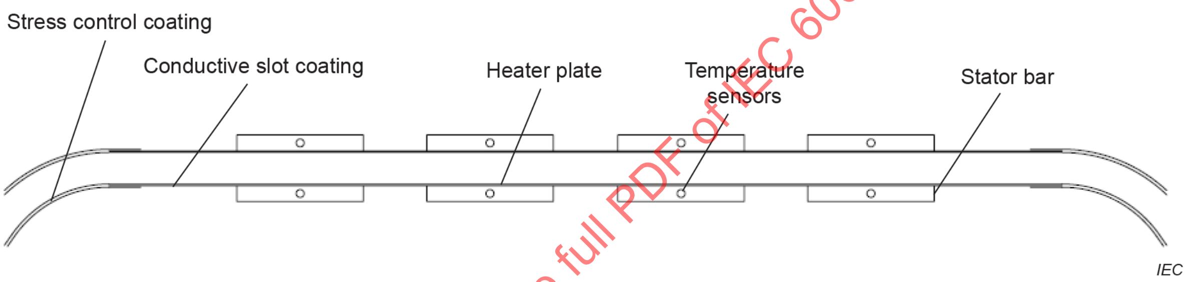


Figure B.1 – Application of heater elements to a stator bar

The metal heater plates should be uniformly distributed over the surface of the slot part of the bar or coil with no more than 10 cm between adjacent plates until the end of the straight part of the bar or coil.

The heater plate sections may be attached to the test specimen by suitable threaded rods across each pair of heater plates, on which the nuts are tightened. Care should be taken to ensure good contact between the heater plates and the bar or coil. Temperature sensors for controlling and monitoring the specimen temperature shall be placed in holes centrally located at the edges of the heater plates as shown in Figure B.1. Temperature sensors may be for instance thermocouples or RTDs. **21**

B.5.3 Heating by means of an oven

Thermal ageing may also be carried out by placing the test objects in an accurately controlled and monitored oven with forced circulation as described in IEC 60216-4-1. Care has to be taken for the simultaneously application of high voltage for the combined test procedure that enough distance between the electrodes and conductor parts at high voltage and the inner oven surface ensures a safe qualification.

B.5.4 Test parameter

In order to prevent too excessive ageing by applying too high simultaneous stresses to the test objects Table B.1 provides recommended voltage and temperature parameters.

Table B.1 – Phase to ground test voltages and test temperatures 22

Thermal class °C	Test temperature	Enhancement ratio for the phase to ground test voltage $U_N/\sqrt{3}$
130	115	2,5
155	140	2,2
180	165	1,9
NOTE If the limit of temperature stated on the rating plate is lower than the thermal class then this limited temperature is the base for defining the test temperature.		

Test temperature represents the average temperature at the surface of the stress control system in service. For electrical machines operating in thermal class 130 °C to 180 °C the surface temperature in service is usually at least between 10 K to 20 K less. This is dependent on the type of cooling, end winding and stator core design as well as insulation design.

The acceleration of the stress control system ageing at higher temperatures depends on the absolute test temperature – higher temperatures lead to faster electrical ageing by overvoltage. Therefore, for the same acceleration of the slot and stress control coating, for higher temperatures lower overvoltage / enhancement factors can be used.

If the thermal class or limit of temperature stated at the rating plate is lower than 130 °C, the enhancement ratio as well as the test temperature shall be taken from the numbers given for 130 °C. From experience, it is known that operation and test temperatures below 130 °C have a low contribution in ageing compared to the ageing factor voltage at service condition.

B.6 Qualification of the stress control system

B.6.1 General

The aim of qualification testing of the stress control system is to provide assurance that it will operate satisfactorily for the required service life. A satisfactory performance in service is one in which partial discharges between stator core and coil/bar and at the surface of the stress control coating is avoided.

B.6.2 Test procedure

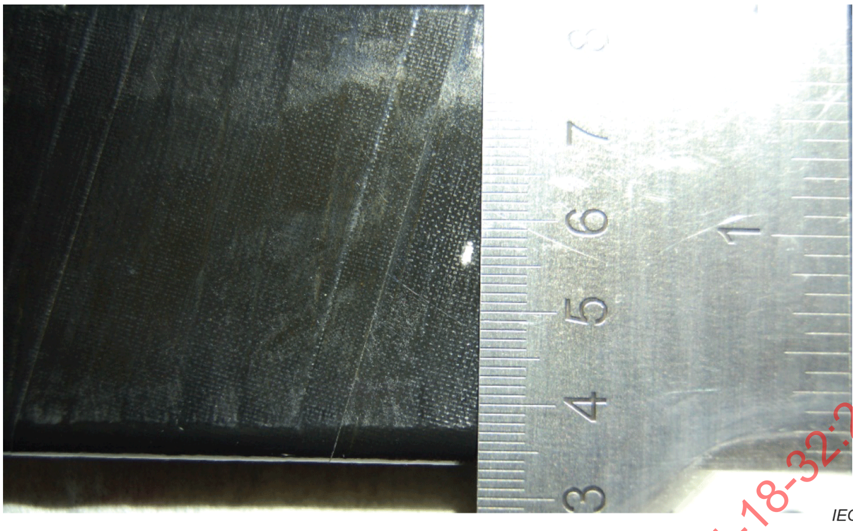
The specimen is subject to a simultaneous test procedure using electrical stress at elevated temperature according to B.5.4 for 1 000 h with sinusoidal voltage, power frequency in operation at the related test temperature (Table B.1).

B.6.3 Test pass criteria

No more than two deterioration marks considered as defect per bar or coil leg are allowed on the outer surface after testing. Deterioration marks are seen as defect, if the diameter is larger than 1 mm but smaller than 5 mm (Figure B.2). Marks below 1 mm are not interpreted as a defect, marks above 5 mm diameter do show a major design defect and are hence not allowed.

However, if one deterioration mark with a diameter of less than 5 mm is present on every bar or coil leg at the same position, the reason for this phenomenon shall be determined and qualification shall be repeated. 23

B.7 Examples of deterioration marks at the stress control system



IEC

Figure B.2 – Typical deterioration mark at the conductive slot coating

~~Bibliography~~

~~IEC 60034-18-33, *Rotating electrical machines – Part 18-33: Functional evaluation of insulation systems – Test procedures for form-wound windings – Multifactor evaluation by endurance under simultaneous thermal and electrical stresses*~~

~~IEC 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*~~

~~IEC 61251, *Electrical insulating materials – A.C. voltage endurance evaluation – Introduction*~~

~~IEC 62539, *Guide for the statistical analysis of electrical insulation breakdown data*~~

List of comments

1 This IS deals explicitly with windings, where partial discharge (PD) occur and the winding can withstand PD. They are referred as type II insulation systems.

2 This IS deals only with windings which are energized by sinusoidal power frequency voltage. For inverter fed insulation systems IEC 60034-18-41 or IEC 60034-18-42 may be used. If for any reason no reference curve for the main wall insulation is available, Annex A provides a diagram, which has been established from publications between the 70s to the 90s of major OEMs.

3 Change of terms to harmonized terms for the stress control system analogue to the entire IEC 60034-18 series.

4 Deletion of the test procedure table because nature and details of various test procedures are not clear and designation is not used anymore to differentiate between different type of diagnostic tests.

5 Old IS version deals only with procedures to qualify the insulation system by means of testing the main wall insulation. A new test method has been introduced in Annex B (informative) to test and evaluate conductive slot coating and stress control coating. The intention is that various user collect experience, which shall be incorporated in the next revision of this IS.

6 This IS deals only with sinusoidal energized insulation systems. The stress for the turn insulation in this respect is low due to missing PD. Consequently the electrical ageing of the turn insulation has been removed.

7 Introduction of a GVPI slot model as test object. It is essential that for the test object same components and design features are used as the actual system to be tested. The length of the test samples shall be close or equal to the length of the longest actual stator.

8 Deleted as test procedure to evaluate turn insulation has been entirely removed.

9 The minimum test sample number has been increased from five to six bars and defined for coils with a minimum of three coils.

10 Testing and qualification of the main wall insulation in order to get a live time curve must be different compared to test methods for the stress control system.

11 Simplification of various diagnostic tests for the main wall insulation by deleting sub chapters. All optional diagnostic tests are referred in IEC 60034-15.

12 Explicit definition if an electrical failure under the stress control coating is allowed or not.

13 Parameter of the abscissa and ordinate have been swapped. Lifetime chart illustrates time on the abscissa and ratio of test voltage to rated voltage on the ordinate.

14 Introduction of a new qualification procedure for the candidate system with either different voltage level and/or expected service life to the reference system. It allows to use the reference line of the reference system for qualification of the candidate system for three different cases and gives examples for qualification.

15 Detailed procedure to qualify a candidate system with same voltage level as the reference system but with different expected service life.

16 Detailed procedure to qualify a candidate system with different voltage level compared to the reference system but with same expected service life.

17 Detailed procedure to qualify a candidate system with different voltage level and different service life compared to the reference system.

18 A reference lifetime curve has been introduced. This diagram may be used in case no reference line is available. The line has been obtained by numerous data of publications over the past 30-40 years of various known OEMs of large high voltage generators and motors.

19 In the previous IS version only qualification of the main wall insulation has been described to test and qualify the entire insulation system. A new method has been introduced (informative) to test and qualify with one test procedure the ageing of the conductive slot and stress control coating. The test has to be done at elevated temperature as temperature, absolute voltage level and electrical stress are the three dominant ageing mechanism.

20 Different to the qualification of the main wall insulation no comparison method is applied. Instead qualification criteria for maximum deterioration marks in size and number are listed for a 1000h ageing under enhanced voltage and elevated temperature conditions.

21 The arrangement to test and qualify the stress control system of bars or coils with means of heater plates are introduced.

22 Based on the thermal class of the insulation system in °C parameter for the test temperature and for the enhancement of the test voltage are given in Table 1. The parameter are based on experience of some known OEMs, who manufacture large high voltage generators and motors. With given parameters it is possible to differentiate between stress control systems, which fail and those which have no indication of deterioration marks after 1000h testing.

23 Deterioration for the stress control system is defined by local termination of the black conductive matrix of the conductive slot coating or the normally "grey" SiC matrix of the stress control coating. Usually developed deterioration marks are white spots which grow by applying further temperature and voltage ageing given in table of Clause B.5.4.

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IEC 60034-18-32

Edition 2.0 2022-01

INTERNATIONAL STANDARD

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Rotating electrical machines –
Part 18-32: Functional evaluation of insulation systems (Type II) – Electrical endurance qualification procedures for form-wound windings

Machines électriques tournantes –
Partie 18-32: Evaluation fonctionnelle des systèmes d'isolation (Type II) – Procédures de qualification de l'endurance électrique pour enroulements préformés

IEC 60034-18-32:2022-01(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ROTATING ELECTRICAL MACHINES –

Part 18-32: Functional evaluation of insulation systems (Type II) – Electrical endurance qualification procedures for form-wound windings

FOREWORD

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IEC 60034-18-32 has been prepared by IEC technical committee 2: Rotating machinery. It is an International Standard.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Title modified.
b) Simplification of clauses.
c) Reduction in the number of test procedures.
d) Inclusion of full bars and coils as test objects.
e) A new clause dealing with failures and failure criteria.

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

Draft	Report on voting
2/2068/FDIS	2/2075/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

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.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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

IEC 60034-18-1 presents general principles for the evaluation of insulation systems used in rotating electrical machines.

This document deals exclusively with insulation systems for form-wound windings (Type II) and concentrates on electrical functional evaluation.

In IEC 60034-18-42, tests are described for qualification of Type II insulation systems in voltage-source converter operation. These insulation systems are generally used in rotating machines which have form-wound windings, mostly rated above 700 V r.m.s. The two standards IEC 60034-18-41 and IEC 60034-18-42 separate 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 experience and withstand partial discharge activity in any part of the insulation system throughout their service lives (Type II).

ROTATING ELECTRICAL MACHINES –

Part 18-32: Functional evaluation of insulation systems (Type II) – Electrical endurance qualification procedures for form-wound windings

1 Scope

This part of IEC 60034-18 describes qualification procedures for the evaluation of electrical endurance of insulation systems for use in rotating electrical machines using form-wound windings energized with sinusoidal power frequency voltage. The test procedures for the main wall insulation are comparative in nature, such that the performance of a candidate insulation system is compared to that of a reference insulation system with proven service experience. If no reference system is available, the diagram in Annex A is available for use. The qualification procedures of inverter duty insulation system for form-wound windings can be found in IEC 60034-18-42 or IEC 60034-18-41. A new and informative test procedure for the stress control system is introduced and defined in Annex B.

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 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-15:2009, *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

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

IEC TS 60034-18-33:2010, *Rotating electrical machines – Part 18-33: Functional evaluation of insulation systems – Test procedures for form-wound windings – Multifactor evaluation by endurance under simultaneous thermal and electrical stresses*

IEC 60034-18-41, *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*

IEC 60034-18-42:2017, *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 60034-18-42:2017/AMD1:2020

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

IEC 60034-27-3, *Rotating electrical machines – Part 27-3: Dielectric dissipation factor measurement on stator winding insulation of rotating electrical machines*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 62539, *Guide for the statistical analysis of electrical insulation breakdown data*

3 Terms and definitions

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

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
mainwall insulation
main electrical insulation that separates the conductors from the earthed stator/rotor core in motor and generator windings

3.2
strand insulation
electrical insulation that covers each conductor in coils/bars

3.3
turn insulation
electrical insulation that separates the conductor turns from each other in coils/bars

3.4
conductive slot coating
conductive paint or tape layer in intimate contact with the mainwall insulation in the slot portion of the coil side, often called semi-conductive coating

Note 1 to entry: The purpose is to prevent partial discharge from occurring between the coil/bar and the stator core.

3.5
stress control coating
paint or tape on the surface of the mainwall insulation that extends beyond the conductive slot coating in high-voltage stator bars and coils

Note 1 to entry: The purpose of the coating is to prevent surface discharges near the slot exit or in the end winding area.

3.6
stress control system
generic name for the combination of the conductive slot coating and stress control coating in high-voltage stator bars and coils

3.7
confidence interval
range of values so defined that there is a specified probability that the value of a parameter (voltage, stress or time) lies within it

3.8
test temperature
temperature of the outer surface of the bar/coil at the straight part of the bar/coil measured with an appropriate selected and placed sensor

4 General considerations

4.1 Relationship to IEC 60034-18-1

The principles of IEC 60034-18-1 should be followed, unless the recommendations of this document indicate otherwise.

4.2 Selection and designation of test procedures

One or more of the procedures in this document should be suitable for the majority of evaluations. Evaluation is usually performed by the manufacturer of the machine/coils or by a third-party laboratory. It is the manufacturer's responsibility to justify the most suitable procedure on the basis of past experience and knowledge of the insulation systems to be compared.

Following test procedures are described:

- Mainwall insulation
- Turn insulation only with the main insulation test
- Conductive slot coating (Annex B)
- Stress control coating (Annex B)
- Mainwall insulation, where voltage level and/or life time differs from the reference system

4.3 Reference insulation system

A reference insulation system should be tested using a test procedure equivalent to that used for the candidate system (see IEC 60034-18-1). The reference insulation system should have service experience at not less than 75 % of the intended maximum rated voltage of the candidate system. When extrapolation of the insulation thickness is used, information such as "different insulation thickness at same electrical field stress levels by obtaining equal or similar breakdown time" should be provided showing the correlation between electrical lifetime and electrical stress for the different insulation thicknesses. If no reference insulation system is available the diagram in Annex A shall be used as criterion.

4.4 Test procedures

4.4.1 General

Electrical ageing tests are usually performed at fixed voltage levels until failure (mainwall insulation) or in combination with elevated temperature until signs of deterioration occur (conductive slot coating system). Statistical evaluation of the results of testing should be performed according to IEC 62539.

4.4.2 Electrical ageing of the mainwall insulation

From such tests, characteristic times to failure at each voltage level are obtained. The results for both the candidate system and the reference system should be reported on a graph, as shown by the example in Figure 1, and compared. There is no proven physical basis for extrapolation of this characteristic to the service voltage level $U_N/\sqrt{3}$, where U_N is the r.m.s. rated phase to phase voltage.

In service, electrical ageing of the mainwall insulation is primarily caused by continuous electrical stress at power frequency. In addition, the insulation is required to withstand transient overvoltage arising from switching surges or inverter supply. The ability of the mainwall insulation to withstand transient overvoltage from converter supplies may be demonstrated by the system's performance using IEC 60034-18-42.

This document describes electrical ageing of the mainwall insulation, carried out at power frequency or higher. In order to keep acceleration of ageing in a linear progression, a maximum of 10 times of the power frequencies is appropriate. Latest experiences with the application of IEC 60034-18-42 show that a frequency of up to 1 000 Hz can be used as well. Care shall be taken that the dielectric losses do not increase the temperature of the insulation beyond the service temperature to avoid additional thermal ageing effects. (IEC TS 60034-18-33:2010, Table 1)

4.4.3 Electrical ageing of the stress control system

In order to allow a full qualification of the entire insulation system Annex B describes methods to qualify the conductive slot coating and stress control coating.

4.4.4 Electrical ageing of the turn insulation

In normal direct-on-line operation of rotating machines the turn insulation is subjected to a stress significantly below the partial discharge inception voltage. Continuous electrical ageing is then not taking place and turn insulation qualification is therefore excluded from this document. Withstand against transient overvoltage should be tested according to IEC 60034-15.

In converter fed or other types of special operation the turn insulation may continuously be subjected to a stress above the partial discharge inception voltage. Electrical ageing should then be performed according to IEC 60034-18-42.

4.5 Extent of tests

4.5.1 Full evaluation of the mainwall insulation

The extent of the electrical functional tests will depend upon the purpose of the evaluation. A full evaluation will be needed where there are substantial differences from the reference system according to IEC 60034-18-1.

4.5.2 Reduced evaluation of the mainwall insulation

There are situations when it will be sufficient to carry out reduced evaluation using the minimum number of test specimens and the middle voltage level used in the reference tests.

Comparison of a candidate insulation system to a reference system, where there are no intended or only minor differences in composition or manufacturing procedures (so-called minor changes, see IEC 60034-18-1), may be carried out using only one voltage level but with the recommended minimum number of test specimens (see 5.2). Reduced evaluation is allowed only if the rated voltages are the same for both systems.

4.5.3 Evaluation of the stress control system

Annex B defines tests and criteria to evaluate conductive slot coating and stress control coating.

5 Test objects

5.1 Construction of test objects

Test objects should preferably be complete bars or coils made to normal design, material and manufacturing procedures. Alternatively, they may be constructed to represent the configuration of the finished winding component to be evaluated and be subjected to the full normal or intended manufacturing processes. When using separate coils or bars as models, creepage distances and any necessary voltage grading are to be appropriate to the stresses applied during testing. A ground electrode should extend the full slot length of the model and cover at least the two wide sides of the coil cross-section.

Slot models for GVPI systems shall be made from rigid steel plates, not having any other component inserted than in the actual system present and having a length equal to that of the longest actual stator.

Test bars should be designed not to generate flashover between the end of stress control coating and the end of the conductor of the test bar. For reducing excessive electrical stress on the surface of test bars/coils by applying high voltage and/or high frequency, special treatment, for example extending stress control coating length, can be applied for evaluating the mainwall insulation. See also B.5.

5.2 Number of test specimens

An adequate number of test specimens shall be aged at each test voltage level in order to obtain statistical confidence. This number should not be less than six bars or three coils for the qualification of the mainwall insulation per each test voltage level.

5.3 Initial quality control tests

The following quality control tests shall be performed:

– visual inspection of the test specimens;
– voltage withstand test according to IEC 60034-1;
– dissipation factor and partial discharge test according to IEC 60034-27-3 and IEC 60034-27-1 respectively.

6 Electrical ageing

6.1 General

It is not practicable to design a single test method that simulates all the interactions between the various insulation components. For example, to obtain a life curve for the mainwall insulation system by applying overvoltage would subject the conductive slot coating to excessive stress. Qualification has therefore been divided into separate test procedures. The primary aim is to establish the lifetime curve of the mainwall insulation from which the expected lives may be estimated. The second aim is to establish that the conductive slot coating and the stress control coating is suitable for service.

6.2 Voltage levels and intended test lives of the mainwall insulation

For full evaluation as described in 4.5.1, at least three power frequency voltages should be selected so that the intended mean time to failure at the highest voltage is about 100 h, and at the lowest voltage around 5 000 h. For reduced evaluation, where only one voltage level is required (see 4.5.2), the voltage level should be chosen so that the intended mean time to failure is about 1 000 h. The alternating voltage applied to the test objects should be maintained within ± 3 %.

6.3 Test temperatures during electrical endurance testing of the mainwall insulation

6.3.1 Electrical ageing at room temperature

Electrical ageing is preferably carried out in air at room temperature at voltages and/or frequencies higher than those in the steady-state operating conditions, in order to accelerate the effects of electrical stress.

6.3.2 Electrical ageing at elevated temperature

If the endurance testing is to be performed at elevated temperatures, then either external heating plates or oven heating are permitted (see also Clause B.5). Note that these two methods may not produce the same results. The temperature rise due to the applied electrical stress can affect the results, especially when using increased frequency, and shall be recorded. If thermal ageing does occur, the testing should follow the procedures in IEC 60034-18-33 for multifactor testing.

NOTE Electrical ageing of the mainwall insulation under power frequency and elevated temperature up to service temperature may lead generally to longer time to failure values compared to tests at room temperature at same electrical stress levels.

6.3.3 Ageing procedure for the mainwall insulation

The electrical stress is applied between the stator core or the mock up / slot electrode on the surface of the test specimen and the conductors. If the test object is a multiturn coil, both the mainwall insulation and partly the turn insulation are aged by the electrical stress during this period. However this procedure does not qualify the turn- to turn insulation. For test procedures with sub-cycles (Clause 7), the duration of these sub-cycles should be such that approximately ten sub-cycles are performed on a test specimen having a median life. Higher than power frequency is allowed to shorten the test times. Latest experiences with the application of IEC 60034-18-42 show that a frequency of up to 1 000 Hz can be used as shown in 4.4.2. Care should be taken that the dielectric losses do not increase the temperature of the insulation beyond the service temperature to avoid additional thermal ageing effects. (IEC TS 60034-18-33:2010, Table 1). This is especially important at elevated temperatures. The same frequency should be used for the candidate and reference insulation system. Increased frequency test results may only be used for direct comparison if the lives of the systems are affected similarly by the increase of frequency.

6.4 Maintenance of stress control coatings

A stress control coating is usually applied to the outer surface of the coil or bar beyond the earthed conductive slot coating. During the electrical endurance test of the main insulation, deterioration may occur which does not result in insulation failure. Remedial action to the stress grading material and forced air cooling are permitted during the progress of the voltage endurance test on the basis that it is the mainwall insulation that is being tested rather than the stress grading system.

7 Diagnostic sub-cycle

7.1 General

No diagnostic tests are required for the qualification of the mainwall insulation but may be performed optionally.

Following each ageing sub-cycle, a diagnostic sub-cycle can be performed. Failure of any part of the test specimen during a diagnostic test constitutes failure of the whole system and shall be reported as such. The appropriate voltage tests are selected according to the chosen test procedure as per 4.2.

7.2 Voltage test of the mainwall insulation

If a diagnostic test on the mainwall insulation is performed it shall be done with a power frequency AC withstand test according to IEC 60034-15. Alternatively, a lighting impulse voltage withstand test according to IEC 60034-15 may be used.

7.3 Other diagnostic tests

Optional diagnostic measurements may be performed for information or to determine end of test life. These may replace the voltage tests. Factors such as insulation resistance, dielectric dissipation factor, partial discharges and impulse test on the turn-to-turn insulation are examples. An end-point criterion may be established for each diagnostic test, with suitable justification reported.

8 Failures of the mainwall insulation

8.1 Failure location and verification

Failure of a specimen occurs when any electrical breakdown of the mainwall insulation occurs. This will result in the over-current detection system interrupting current to the high voltage transformer. Failure of the insulation should be verified by re-applying voltage gradually from zero. A specimen insulation failure will prevent the reapplication of the full test voltage. Locating the failure site is desirable and may be undertaken by seeing arcing or heating at the failure site as the voltage is raised. Care shall be taken as locating the failure in applying voltage the local failure area may be additionally damaged and the analysis of the breakdown channel might be more difficult or even impossible. When specimen failure has been verified, the failed sample should be isolated to allow testing to continue on the remaining samples.

Breakdown under stress control coating is acceptable, if only one breakdown of all tested bars/coils at this location occurs. If there is more than one bar or coil affected with a breakdown under the stress control coating, the number of bars or coils needs to be increased to get statistically enough values for the lifetime of the mainwall insulation away from the stress control coating. It is recommended in such a case to review design and manufacturing process for this particular area.

8.2 Failed specimen observations

Each failed specimen should be examined to ensure that the failure is valid for statistical interpretation. This may require some specimen dissection in the area around the insulation puncture to identify the failure location and its probable cause.

9 Functional evaluation of the mainwall data

9.1 General

The evaluation of the test data should follow the guidelines set out below. Under the assumption of a Weibull distribution, the appropriate statistical analysis should be applied to calculate the significance of the candidate sample life with regard to that of the reference sample (see IEC 62539). In order to avoid introducing new ageing phenomena the maximum test voltage shall not exceed 4 times U_N.

The general rule is that the candidate insulation system is considered to be qualified if the 90 % confidence interval of the used probability distribution of the breakdown time falls above or within that obtained from the reference system (see IEC 60034-18-1).

If the reference line, given in Annex A, is used, an interpretation of results is mandatory. An example of evalution and interpretation is given in IEC 60034-18-42.

9.2 Full evaluation (same voltage level and same expected service life)

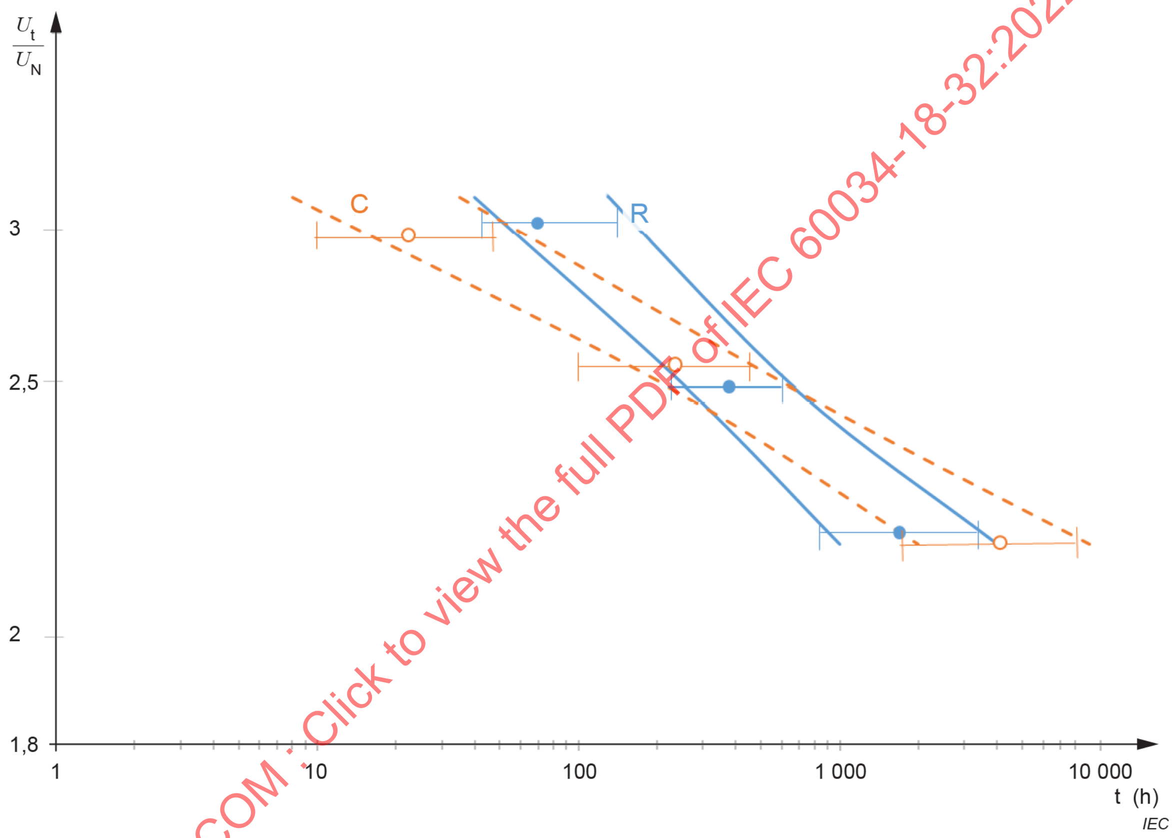
Electrical endurance graphs of the candidate and the reference system are plotted as a log-log representation of the time to failure (t), as a function of the ratio of test voltage (U_t) and rated voltage (U_N), where U_N is the rated voltage of the reference system and the candidate system. The candidate system is qualified if:

a) the upper 90 % confidence limit of the candidate system exceeds the upper 90 % confidence limit of the reference system over the range of reference system test voltages, or

b) the lower 90 % confidence limit of the candidate system exceeds or is equal to the lower 90 % confidence limit of the reference system at the lowest test voltage and the regression line of the mean values of the candidate system has a more gentle slope than that of the reference system.

Ageing results for a candidate system which satisfies condition b) are shown in Figure 1. An example of a candidate system which fails to qualify in respect of either condition a) or b) is shown in Figure 2.

The slope of a modern insulation system for instance containing nano particles may change and case B (Table 1) shall be used for qualification.



Key

R ageing data from the reference insulation system (R) showing the 90 % confidence limits

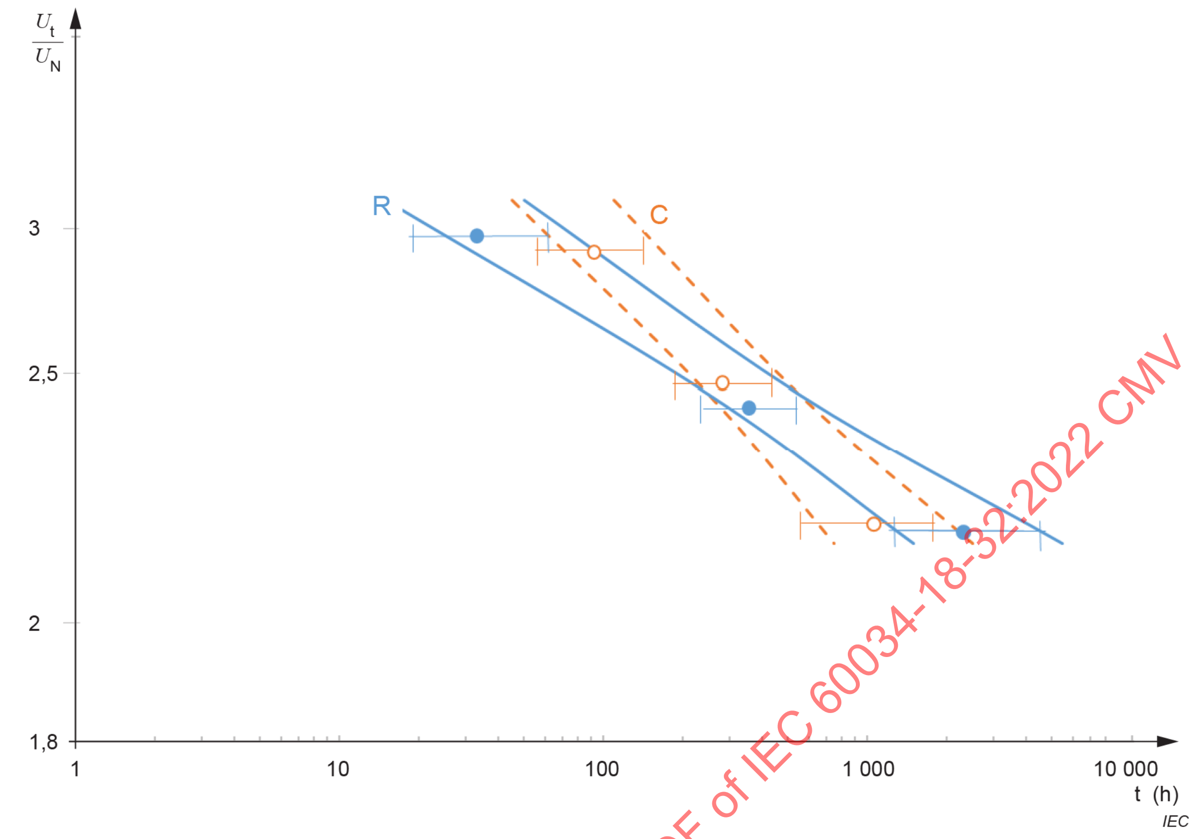
C ageing data from the candidate insulation system (C) showing the 90 % confidence limits

t time in hours

U_t/U_N ratio of test voltage to rated voltage

NOTE Abscissa and ordinate are logarithmic based scales.

Figure 1 – Comparison of ageing data from candidate (C) and reference (R) insulation systems showing qualification



Key

R ageing data from the reference insulation system (R) showing the 90 % confidence limits

C ageing data from the candidate insulation system (C) showing the 90 % confidence limits

t time in hours

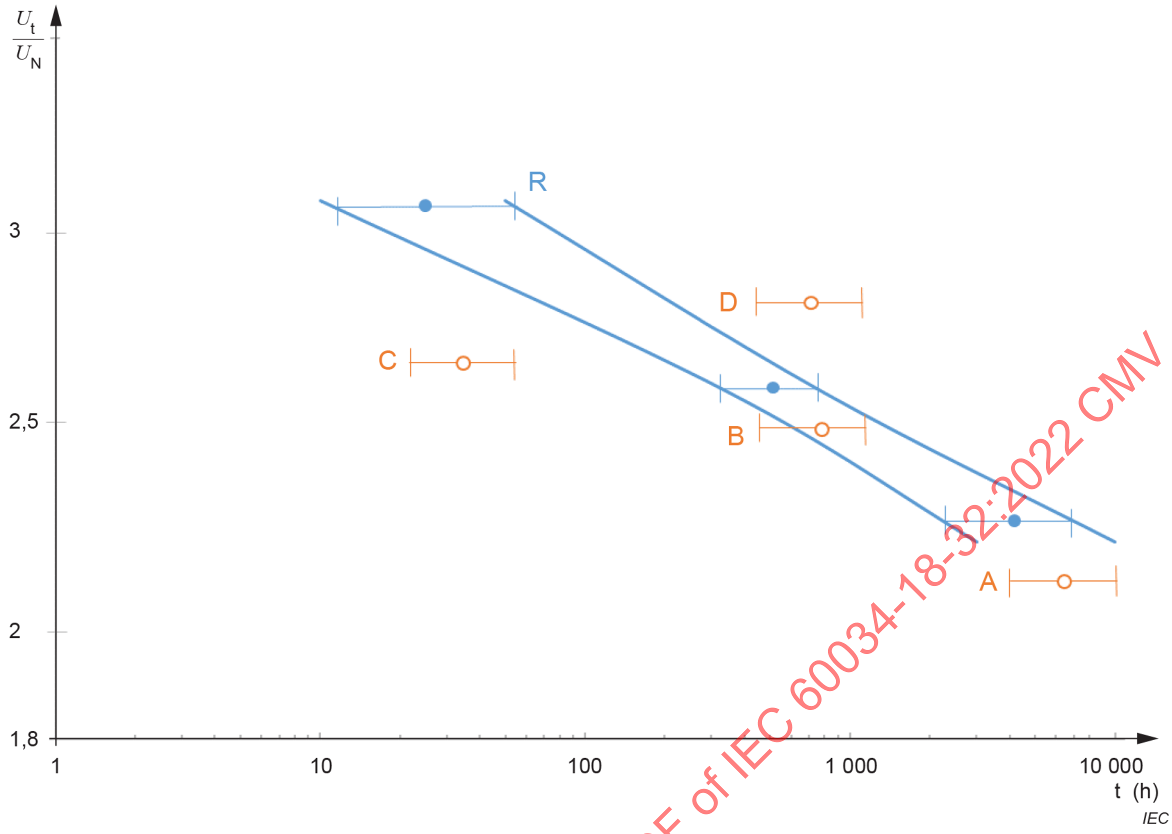
U_t/U_N ratio of test voltage to rated voltage

NOTE Abscissa and ordinate are logarithmic based scales.

Figure 2 – Comparison of ageing data from candidate and reference insulation systems showing failure to qualify

9.3 Reduced evaluation (same voltage level and same expected service life)

For reduced evaluation using a single voltage (see 4.5.2), the basis of analysis shall be as shown in Figure 3, where the 90 % tolerance of the 63 % quantile of the ageing results for the candidate system is compared with the 90 % confidence limits of the reference ageing line at the same quantile. If a partial overlap occurs within the voltage range of the ageing tests on the reference system, as shown by candidate system B, it is qualified. Qualification is not achieved in the case of candidate system A because the measurement is outside the voltage range used to produce the reference system ageing line. Nor is qualification achieved in the case of candidate system C since no overlap occurs. Candidate system D is qualified because the results exceed those of the reference system.



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

A ageing results for candidate system A (not qualified)

B ageing results for candidate system B (qualified)

C ageing results for candidate system C (not qualified)

D ageing results for candidate system D (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

NOTE Abscissa and ordinate are logarithmic based scales.

Figure 3 – Comparison of reduced evaluation test data from four separate candidate systems with that from the reference system

9.4 Recommended data to be recorded

The following items are suggested for inclusion in test records.

- Ambient temperature and humidity in the test area, if the specimens are tested at room temperature
- Applied voltage, expressed in equivalent r.m.s.
- Frequency of applied voltage in Hertz
- Total endurance time of each sample
- Results of any preliminary or intermediate diagnostic tests or measurements
- Observations of failure locations
- Observations on the nature of failure or of stress-grading damage
- Voltage endurance test temperature, i.e., the temperature of the thermocouples embedded in the heater plates

- Minimum and maximum test voltage and test temperature during the test

It will also be desirable to include other information, such as the nature of the samples, the nature of the electrodes and the nature of the stress-grading material.

9.5 Determining qualification for performances different to the reference system

9.5.1 Overview

The first step is to define the expected service life and rated voltage of the candidate system, then to compare the performance of reference and candidate systems with respect to the qualification criteria given in Table 1. Caution is recommended when qualifying a candidate system for a different voltage and/or service life, because of the assumptions implicit in the approach.

Before proceeding with the evaluation by comparison, it shall be established that the regression lines of the candidate and reference systems fit the data well (it is recommended that the correlation coefficient ≥ 0,98 according IEC 62539) and there is no indication of any change of ageing mechanism within the range of test voltage. If either of the regression lines is non-linear, refer to 9.5.5, where a simple test of linearity is described.

Table 1 – Conditions for qualification of candidate system

Case	Performance relative to reference system		Test voltage	Qualification criteria
	Voltage level	Expected service life		
A	Same	Same	Same	See 9.2
B	Same	Different	Same	Following the appropriate adjustments to the candidate system confidence limits (see description in the text for each case):
C	Different	Same	Different	
D	Different	Different	Different	1. Confidence interval of candidate system shall overlap or exceed the confidence interval of the reference system. 2. The candidate system shows continually improving performance, i.e., the slope of its regression line is smaller than or equal to the slope of reference system regression line.

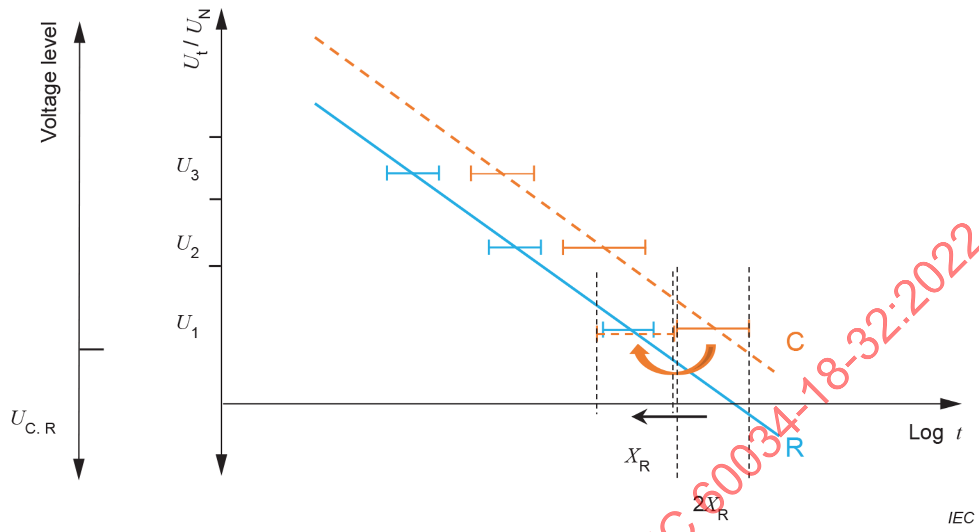
In comparing voltage level in relation to life time it is also possible to increase the field strength by either using thinner main insulation at same voltage or increase the voltage level by maintaining the same thickness. Care shall be taken with increased electrical field strength as also the corona system is subject to higher stresses.

9.5.2 Case B: Qualification for the same phase to phase voltage and a different expected service life

To qualify the candidate system for the same phase to phase voltage and a different expected service life (Table 1, Case B), the candidate system and reference system are tested using the same test voltage levels.

The candidate confidence limits at each voltage level are shifted on the horizontal axis by an amount equal to the agreed-upon change in service life, within the range $X_R/20$ to $20X_R$, where X_R is the life of the reference system at each voltage level. The candidate system is qualified if its shifted confidence intervals is above the reference interval or if the confidence interval is overlapping than the slope of the candidate system shall be lower or equal to the reference system.

Figure 4 shows an example of a candidate system assessed for qualification for the same voltage level, and an expected service life double that of the reference system. When the full candidate system line is decreased by a factor of 2, the 90 % confidence limits overlap those of the reference. For simplicity, the shift on the horizontal axis is shown for only the confidence limits at a single voltage level, U_1.



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

C ageing results for candidate system (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

Figure 4 – Candidate system qualified for the same voltage level and different expected service life

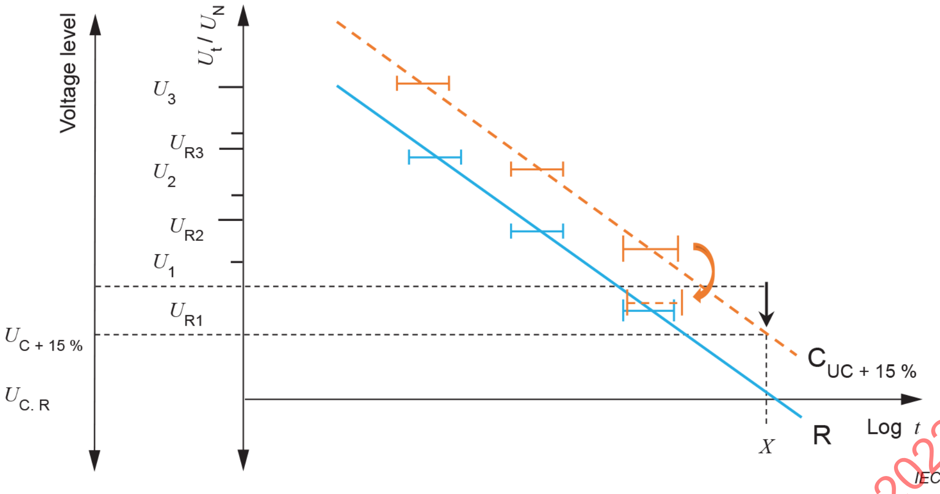
If the candidate system regression line crosses that of the reference system within the range of measurement, it is qualified for a higher service life at $U_{C,\ R}$ only if it demonstrates improved performance compared to the reference system at $U_{C,\ R}$ by the required life interval.

9.5.3 Case C: Qualification for different voltage level and same expected service life

To qualify a candidate system for a different voltage level and the same expected service life (Table 1, Case C), the candidate system is tested using the voltage levels, which are appropriate to its intended voltage in operation.

The candidate confidence limits at each voltage level are shifted on the vertical axis by an amount equal to the agreed upon change in voltage level. The candidate system is qualified if its shifted confidence interval overlaps or exceeds that of the reference system or the candidate system shows continually improving performance, i.e., the slope of its regression line is lower or equal to the slope of reference system regression line.

Figure 5 shows an example of a candidate system assessed for qualification for the same expected service life at a 15 % higher voltage level, where the confidence interval for the candidate tested is shifted back to the voltage level of the reference. When the vertical axis shift is completed, the confidence intervals overlap or exceed those of the reference system, whereas $U_{C,\ R}$ is the voltage level of the reference system and $U_{C+15\ \%}$ is the intended voltage level of the candidate.



Key

R	ageing data from the reference insulation system showing the 90 % confidence limits
C	ageing results for candidate system (qualified)
t	time in hours
U_t/U_N	ratio of test voltage to rated voltage

Figure 5 – Candidate system qualified for a higher voltage level and the same expected service life

9.5.4 Case D: Qualification for different voltage level and different expected service life

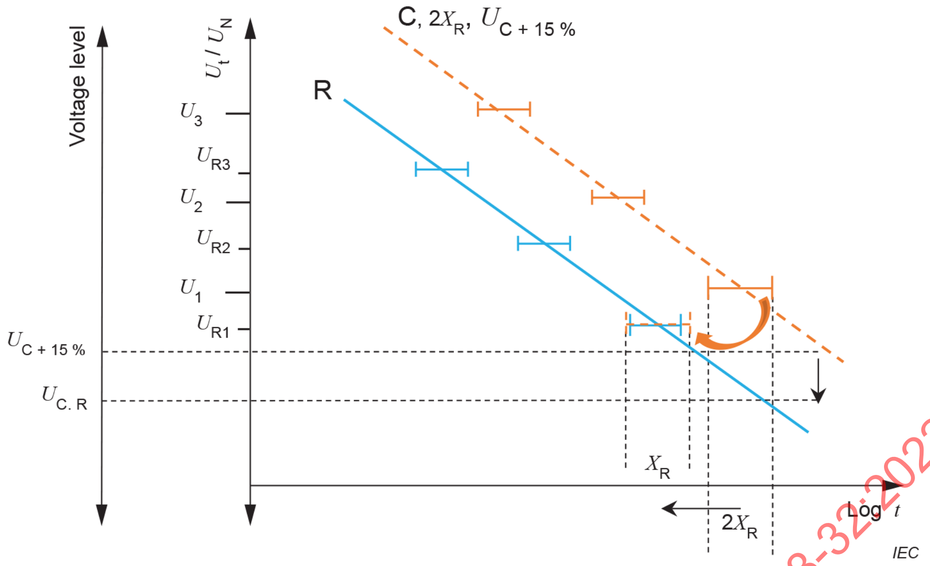
To qualify a candidate system for a different voltage level and a different expected service life (Table 1, Case D), the candidate system is tested using the voltage levels that are appropriate to its intended voltage in operation.

Qualification of the candidate system is determined by a shift of both the vertical and horizontal axes.

The candidate confidence limits at each voltage level are shifted on the horizontal axis by an amount equal to the agreed-upon change in service life, within the range $X_R/20$ to $20X_R$, where X_R is the life of the reference system at each voltage level.

The candidate confidence limits at each voltage level are then shifted on the vertical axis by an amount equal to the agreed upon change in voltage operation level. The candidate system is qualified if its shifted confidence interval overlaps or exceeds that of the reference system or the candidate system shows continually improving performance, i.e., the slope of its regression line is lower than or equal to the slope of reference system regression line.

Figure 6 shows an example of a candidate system assessed for qualification for double the expected service life of the reference, at a voltage level 15 % higher the reference. For simplicity, the shift on the horizontal axis is shown for only the confidence limits at a single voltage level U_1. The same candidate system is also assessed for qualification at a 15 % higher voltage level, where the confidence interval for the candidate tested using the voltage levels is shifted back to the voltage level of the reference, where $U_{C,\ R}$ is the voltage level of the reference system and $U_{C+15\ \%}$ is the intended voltage level of the candidate.



Key

R ageing data from the reference insulation system showing the 90 % confidence limits

C ageing results for candidate system (qualified)

t time in hours

U_t/U_N ratio of test voltage to rated voltage

Figure 6 – Candidate system qualified for a different service life and different voltage level from the reference

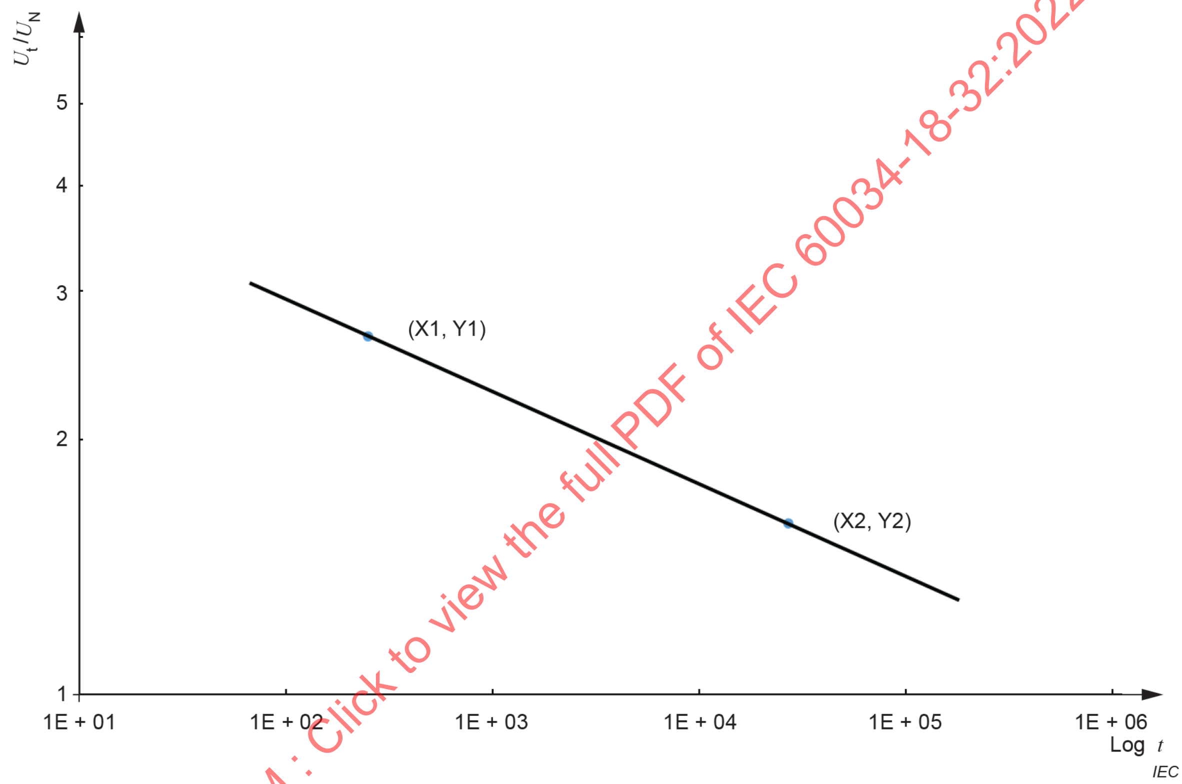
9.5.5 Non-linearity of regression lines

The candidate and reference systems may respond differently to the combination of ageing factors, resulting in curved regression lines. A slight bend in the graph indicates that more than one process or failure mechanism influences electrical ageing. If a straight line cannot be drawn within the tolerance bars of all the points, the data suggest that there is a significant change in the principal ageing mechanism within the range of test voltage levels. Confirmation of the curve by obtaining an additional test point at a lower or intermediate test voltage is recommended.

Annex A
(normative)

Reference life line for mainwall insulation in the absence of a manufacturer's reference life line

Where a reference life line for mainwall insulation is not available for comparison purposes, the qualification procedure shall be for the manufacturer to generate a candidate endurance life line for the intended mainwall insulation system using sinewave voltages. At least six specimens shall be tested at each of 3 voltages. After correction to 50 Hz or 60 Hz using formula (3) of IEC 60034-18-42:2017, the points shall be plotted to show log (mean life in hours) as a function of log (normalized voltage).



Key

Y1	2,65	t	time to electrical failure
X1	250	U_t	test voltage
Y2	1,6	U_N	Rated voltage phase to phase
X2	27000		

Figure A.1 – Reference lifeline for mainwall insulation

Comparison of the measured lifetimes shall be against the reference lifeline shown in Figure A.1. This lifeline, which is based on electrical ageing being the main ageing factor, is consistent with those measured at 50 Hz or 60 Hz from mica/epoxy resin systems that have been shown to give reliable lives in service. Due to older data from various manufactures, only two life time values for Figure A.1 are available.

NOTE Applying case B or D in using the reference line in Annex A may not be valid, because the line is based on long life times (normally 30 to 40 years) and electrical ageing is the main ageing factor.

Annex B
(informative)

B.1 Electrical ageing of the conductive slot coating

Ageing of conductive slot coating can be described as a successive degradation of the conductive material caused by partial discharges. The conductive slot coating system shows a notable dependency not only of the electrical field strength, but also of the applied temperature in operation and absolute voltage level. It is therefore associated as multifactor ageing. Additionally, larger voltage variations at the terminals as well as ambient stresses like ozone may additionally affect the conductive slot coating, but these additional ageing factors are not part of the qualification.

This document describes electrical ageing under elevated temperature of the conductive slot coating carried out at power frequency.

B.2 Electrical ageing of the stress control coating

Ageing of the stress control coating can be described as deterioration by either too excessive surface electrical stress, too high temperatures or a combination of both. Furthermore, ageing of the stress control coating is also deteriorated by inadequate contact between stress control coating and conductive slot coating.

B.3 Test objects

For qualification of the stress control system also a minimum of six bars or three coils should be used.

Test objects should preferably be complete bars or coils made to normal design, material and manufacturing procedures. Alternatively, they may be constructed to represent the configuration of the finished winding component to be evaluated and be subjected to the full normal or intended manufacturing processes. When using separate coils or bars as models, creepage distances and any necessary voltage grading are to be appropriate to the stresses applied during testing.

A ground electrode should cover at least the two wide sides of the coil cross-section. The electrode should be sectioned or shorter than full slot length for conductive slot coating samples to monitor possible deterioration.

B.4 Evaluation of the stress control system

The evaluation of the conductive slot coating and stress control coating is not a comparison between candidate and reference system. The intention of this evaluation is to stress the conductive slot coating and the stress control coating at a certain electrical field and voltage in combination with design operating temperature until a defined time has elapsed along with certain pass criteria.

B.5 Ageing procedure for the conductive slot and stress control coating

B.5.1 General

This ageing of the conductive slot coating and the stress control coating includes the simultaneous application of electrical and thermal stresses.

The electrical stress is applied between the stator core or the mock up / slot electrode on the surface of the test specimen and the conductors. The thermal stress is applied either by using an oven or by heater plates. The test temperature in both cases are controlled to within ±2 °C. No repair methods for the stress control material is allowed if the stress control system is being tested.

B.5.2 Arrangement of temperature control by heater plates

The heater plates are clamped to the slot-section sides of the specimens. It is recommended that the plates be at least 10 mm thick and preferable made of aluminium to achieve good thermal contact along the length of the plates and to enable temperature measurements. These plates also provide the ground connection to the specimen. Heating is provided by attaching heating coils controlled by a thermostat to the outside surface of each pair of plates.

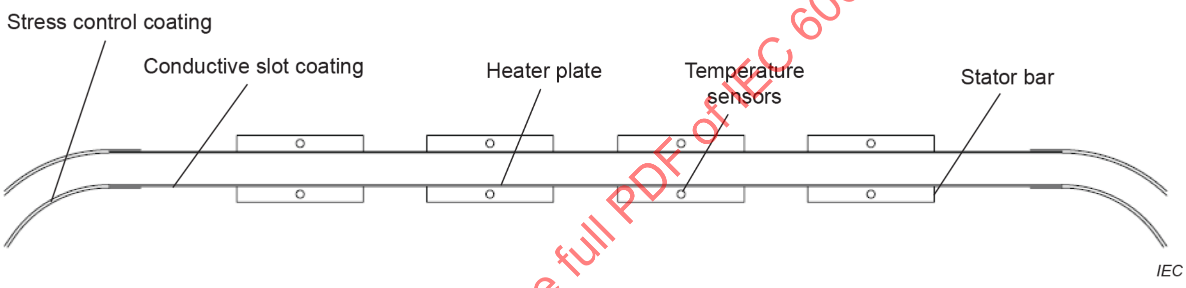


Figure B.1 – Application of heater elements to a stator bar

The metal heater plates should be uniformly distributed over the surface of the slot part of the bar or coil with no more than 10 cm between adjacent plates until the end of the straight part of the bar or coil.

The heater plate sections may be attached to the test specimen by suitable threaded rods across each pair of heater plates, on which the nuts are tightened. Care should be taken to ensure good contact between the heater plates and the bar or coil. Temperature sensors for controlling and monitoring the specimen temperature shall be placed in holes centrally located at the edges of the heater plates as shown in Figure B.1. Temperature sensors may be for instance thermocouples or RTDs.

B.5.3 Heating by means of an oven

Thermal ageing may also be carried out by placing the test objects in an accurately controlled and monitored oven with forced circulation as described in IEC 60216-4-1. Care has to be taken for the simultaneously application of high voltage for the combined test procedure that enough distance between the electrodes and conductor parts at high voltage and the inner oven surface ensures a safe qualification.

B.5.4 Test parameter

In order to prevent too excessive ageing by applying too high simultaneous stresses to the test objects Table B.1 provides recommended voltage and temperature parameters.

Table B.1 – Phase to ground test voltages and test temperatures

Thermal class °C	Test temperature	Enhancement ratio for the phase to ground test voltage $U_N/\sqrt{3}$
130	115	2,5
155	140	2,2
180	165	1,9
NOTE If the limit of temperature stated on the rating plate is lower than the thermal class then this limited temperature is the base for defining the test temperature.		

Test temperature represents the average temperature at the surface of the stress control system in service. For electrical machines operating in thermal class 130 °C to 180 °C the surface temperature in service is usually at least between 10 K to 20 K less. This is dependent on the type of cooling, end winding and stator core design as well as insulation design.

The acceleration of the stress control system ageing at higher temperatures depends on the absolute test temperature – higher temperatures lead to faster electrical ageing by overvoltage. Therefore, for the same acceleration of the slot and stress control coating, for higher temperatures lower overvoltage / enhancement factors can be used.

If the thermal class or limit of temperature stated at the rating plate is lower than 130 °C, the enhancement ratio as well as the test temperature shall be taken from the numbers given for 130 °C. From experience, it is known that operation and test temperatures below 130 °C have a low contribution in ageing compared to the ageing factor voltage at service condition.

B.6 Qualification of the stress control system

B.6.1 General

The aim of qualification testing of the stress control system is to provide assurance that it will operate satisfactorily for the required service life. A satisfactory performance in service is one in which partial discharges between stator core and coil/bar and at the surface of the stress control coating is avoided.

B.6.2 Test procedure

The specimen is subject to a simultaneous test procedure using electrical stress at elevated temperature according to B.5.4 for 1 000 h with sinusoidal voltage, power frequency in operation at the related test temperature (Table B.1).

B.6.3 Test pass criteria

No more than two deterioration marks considered as defect per bar or coil leg are allowed on the outer surface after testing. Deterioration marks are seen as defect, if the diameter is larger than 1 mm but smaller than 5 mm (Figure B.2). Marks below 1 mm are not interpreted as a defect, marks above 5 mm diameter do show a major design defect and are hence not allowed.

However, if one deterioration mark with a diameter of less than 5 mm is present on every bar or coil leg at the same position, the reason for this phenomenon shall be determined and qualification shall be repeated.

B.7 Examples of deterioration marks at the stress control system

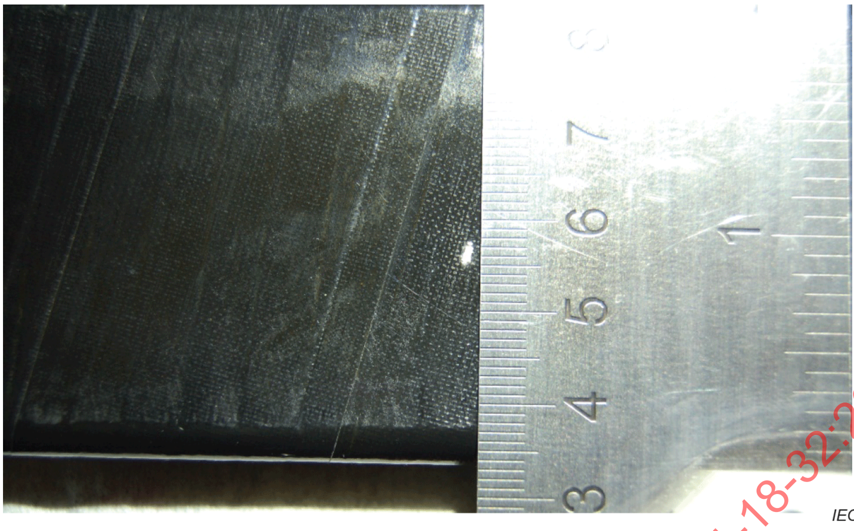


Figure B.2 – Typical deterioration mark at the conductive slot coating

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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MACHINES ÉLECTRIQUES TOURNANTES –

Partie 18-32: Evaluation fonctionnelle des systèmes d'isolation (Type II) – Procédures de qualification de l'endurance électrique pour enroulements préformés

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L'IEC 60034-18-32 a été établie par le comité d'études 2 de l'IEC: Machines tournantes. Il s'agit d'une Norme internationale.

Cette deuxième édition annule et remplace la première édition parue en 2010. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) modification du titre;
b) simplification des articles;

c) diminution du nombre de procédures d'essai;

d) inclusion de barres et bobines complètes comme éprouvettes;

e) ajout d'un article qui traite des défaillances et des critères de défaillance.

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
2/2068/FDIS	2/2075/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Une liste de toutes les parties de la série IEC 60034, publiées sous le titre général *Machines électriques tournantes*, se trouve sur le site web de l'IEC.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2. Il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

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INTRODUCTION

L'IEC 60034-18-1 présente les principes directeurs généraux pour l'évaluation des systèmes d'isolation utilisés dans les machines électriques tournantes.

Le présent document traite uniquement des systèmes d'isolation pour les enroulements préformés (Type II) et porte sur l'évaluation fonctionnelle électrique.

L'IEC 60034-18-42 décrit des essais pour la qualification des systèmes d'isolation de Type II en fonctionnement sur convertisseur de source de tension. Ces systèmes d'isolation sont généralement utilisés dans les machines tournantes avec des enroulements préformés, la plupart avec une tension efficace assignée supérieure à 700 V. Les deux normes IEC 60034-18-41 et IEC 60034-18-42 distinguent les systèmes pour lesquels une activité de décharge partielle n'est pas attendue dans des conditions spécifiées au cours de leur durée de vie en service (Type I) de ceux prévus pour être soumis et résister à une activité de décharge partielle dans toute partie du système d'isolation tout au long de leur durée de vie en service (Type II).

MACHINES ÉLECTRIQUES TOURNANTES –

Partie 18-32: Evaluation fonctionnelle des systèmes d'isolation (Type II) – Procédures de qualification de l'endurance électrique pour enroulements préformés

1 Domaine d'application

La présente partie de l'IEC 60034-18 décrit les procédures de qualification pour l'évaluation de l'endurance électrique des systèmes d'isolation utilisés dans les machines électriques tournantes à enroulements préformés sous tension sinusoïdale à la fréquence d'alimentation. Les procédures d'essai pour l'isolation principale sont comparatives, puisque les performances d'un système d'isolation candidat sont comparées à celles d'un système d'isolation de référence dont l'expérience en service a été démontrée. Si aucun système de référence n'est disponible, l'Annexe A décrit un diagramme utilisable. Les procédures de qualification d'un système d'isolation d'onduleur pour enroulements préformés peuvent être consultées dans l'IEC 60034-18-42 ou l'IEC 60034-18-41. Une nouvelle procédure d'essai informative pour systèmes de contrôle de contrainte est introduite et définie à l'Annexe B.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60034-1, *Machines électriques tournantes – Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement*

IEC 60034-15:2009, *Machines électriques tournantes – Partie 15: Niveaux de tenue au choc électrique des bobines de stator préformées des machines tournantes à courant alternatif*

IEC 60034-18-1:2010, *Machines électriques tournantes – Partie 18-1: Evaluation fonctionnelle des systèmes d'isolation – Principes directeurs généraux*

IEC TS 60034-18-33:2010, *Rotating electrical machines – Part 18-33: Functional evaluation of insulation systems – Test procedures for form-wound windings – Multifactor evaluation by endurance under simultaneous thermal and electrical stresses* (disponible en anglais seulement)

IEC 60034-18-41, *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*

IEC 60034-18-42:2017, *Machines électriques tournantes – Partie 18-42: Systèmes d'isolation électrique résistants aux décharges partielles (Type II) utilisés dans des machines électriques tournantes alimentées par convertisseurs de tension – Essais de qualification*
IEC 60034-18-42:2017/AMD1:2020

IEC 60034-27-1, *Machines électriques tournantes – Partie 27-1: Mesurages à l'arrêt des décharges partielles effectués sur le système d'isolation des enroulements*

IEC 60034-27-3, *Machines électriques tournantes – Partie 27-3: Mesure du facteur de dissipation diélectrique sur le système d'isolation des enroulements statoriques des machines électriques tournantes*

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens* (disponible en anglais seulement)

IEC 62539, *Guide for the statistical analysis of electrical insulation breakdown data* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1
isolation principale
isolation électrique principale qui sépare les conducteurs du noyau de rotor/stator relié à la terre dans des enroulements de moteurs et de générateurs

3.2
isolation des brins
isolation électrique qui recouvre chaque conducteur des bobines/barres

3.3
isolation des spires
isolation électrique qui sépare les unes des autres les spires de conducteur des bobines/barres

3.4
revêtement conducteur de l'encoche
couche conductrice de peinture ou de ruban en contact étroit avec l'isolation principale dans la partie d'encoche du côté des bobines, souvent appelée revêtement semiconducteur

Note 1 à l'article: L'objectif est d'empêcher les décharges partielles entre la bobine/barre et le cœur du stator.

3.5
revêtement de contrôle de contrainte
peinture ou ruban sur la surface de l'isolation principale qui s'étend au-delà du revêtement conducteur de l'encoche dans les barres et bobines de stator à haute tension

Note 1 à l'article: Le revêtement a pour objet d'empêcher les décharges de surface à proximité de la sortie d'encoche dans la zone des développantes.

3.6
système de contrôle de contrainte
nom générique de la combinaison du revêtement conducteur de l'encoche et du revêtement de contrôle de contrainte dans les barres et bobines de stator à haute tension

3.7
intervalle de confiance
plage de valeurs définie de telle sorte qu'il existe une probabilité spécifiée que la valeur d'un paramètre (tension, contrainte ou durée) se situe dans celle-ci

3.8
température d'essai
température de la surface extérieure de la barre/bobine sur la partie droite de la barre/bobine mesurée à l'aide d'un capteur dûment choisi et placé

4 Considérations générales

4.1 Relation avec l'IEC 60034-18-1

Il convient de suivre les principes de l'IEC 60034-18-1, sauf indication contraire dans les recommandations du présent document.

4.2 Sélection et désignation des procédures d'essai

Il convient qu'une ou plusieurs des procédures du présent document soient adaptées à la majorité des évaluations. L'évaluation est habituellement effectuée par le fabricant de la machine/des bobines ou par un laboratoire tiers. La justification de la procédure la plus adaptée est de la responsabilité du fabricant, en s'appuyant sur l'expérience antérieure et sur sa connaissance des systèmes d'isolation à comparer.

Les procédures d'essai suivantes sont décrites:

- isolation principale;
- isolation des spires avec essai de l'isolation principale uniquement;
- revêtement conducteur de l'encoche (Annexe B);
- revêtement de contrôle de contrainte (Annexe B);
- isolation principale, lorsque le niveau de tension et/ou la durée de vie diffèrent par rapport au système de référence.

4.3 Système d'isolation de référence

Il convient de soumettre à l'essai un système d'isolation de référence en utilisant une procédure d'essai équivalente à celle utilisée pour le système candidat (voir l'IEC 60034-18-1). Il convient que le système d'isolation de référence ait une performance en service supérieure ou égale à 75 % de la tension assignée maximale prévue du système candidat. Lorsqu'une extrapolation de l'épaisseur d'isolation est utilisée, il convient de fournir des informations comme "épaisseur d'isolation différente à des niveaux de contrainte de champ électrique identiques en obtenant une durée jusqu'à la rupture égale ou similaire", qui indiquent la corrélation entre la durée de vie électrique et la contrainte électrique pour les différentes épaisseurs d'isolation. Si aucun système d'isolation de référence n'est disponible, le diagramme de l'Annexe A doit être utilisé comme critère.

4.4 Procédures d'essai

4.4.1 Généralités

Les essais de vieillissement électrique sont habituellement réalisés à des niveaux de tension fixes jusqu'à ce qu'une défaillance se produise (isolation principale) ou en combinaison avec une température élevée jusqu'à ce que des signes de détérioration apparaissent (système de revêtement conducteur de l'encoche). Il convient d'effectuer une évaluation statistique des résultats de l'essai conformément à l'IEC 62539.

4.4.2 Vieillissement électrique de l'isolation principale

A partir de ces essais, des durées caractéristiques jusqu'à défaillance à chaque niveau de tension sont obtenues. Il convient de reporter sur une courbe les résultats à la fois du système candidat et du système de référence, comme cela est indiqué par l'exemple de la Figure 1, puis de les comparer. Il n'existe pas de preuve physique de l'extrapolation de cette caractéristique jusqu'au niveau de tension de service $U_{\mathrm{N}}/\sqrt{3}$, où U_{N} est la tension efficace assignée entre phases.

Durant le service, le vieillissement électrique de l'isolation principale est principalement dû à une contrainte électrique continue à la fréquence d'alimentation. De plus, il est exigé que l'isolation supporte la surtension transitoire qui provient des surtensions de commutation ou de l'alimentation par onduleur. L'aptitude de l'isolation principale à supporter une surtension transitoire qui provient des alimentations par convertisseur peut être démontrée par les performances du système en utilisant l'IEC 60034-18-42.

Le présent document décrit le vieillissement électrique de l'isolation principale, effectué à la fréquence d'alimentation ou à une fréquence plus élevée. Afin de maintenir l'accélération du vieillissement en progression linéaire, un maximum de 10 fois la fréquence d'alimentation est approprié. Les dernières expériences avec l'application de l'IEC 60034-18-42 démontrent qu'une fréquence inférieure ou égale à 1 000 Hz peut également être utilisée. Des précautions doivent être prises pour que les pertes diélectriques n'augmentent pas la température de l'isolation au-delà de la température en service afin d'éviter des effets de vieillissement thermique supplémentaires (IEC TS 60034-18-33:2010, Tableau 1)

4.4.3 Vieillissement électrique du système de contrôle de contrainte

Afin de permettre la qualification complète de l'intégralité du système d'isolation, l'Annexe B décrit les méthodes de qualification du revêtement conducteur de l'encoche et du revêtement de contrôle de contrainte.

4.4.4 Vieillissement électrique de l'isolation des spires

En fonctionnement normal avec un démarrage direct sur réseau des machines tournantes, l'isolation des spires est soumise à une contrainte significativement inférieure au seuil d'apparition des décharges partielles. Le vieillissement électrique continu n'a donc pas lieu et la qualification de l'isolation des spires est donc exclue du présent document. Il convient de soumettre à l'essai la résistance aux surtensions transitoires conformément à l'IEC 60034-15.

Dans le cas d'une alimentation par convertisseur ou d'autres types de fonctionnements spéciaux, l'isolation des spires peut être continuellement soumise à une contrainte supérieure au seuil d'apparition des décharges partielles. Il convient alors de procéder au vieillissement électrique conformément à l'IEC 60034-18-42.

4.5 Etendue des essais

4.5.1 Evaluation complète de l'isolation principale

L'étendue des essais fonctionnels électriques dépend de l'objectif de l'évaluation. Une évaluation complète est nécessaire lorsqu'il existe des différences substantielles par rapport au système de référence selon l'IEC 60034-18-1.

4.5.2 Evaluation réduite de l'isolation principale

Dans certains cas, il suffit d'effectuer une évaluation réduite en utilisant le nombre minimal d'échantillons et le niveau de tension médian utilisé dans les essais de référence.