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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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.

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- withdrawn,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

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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: