# IEC 60034-18-1

Edition 3.0 2022-12
COMMENTED VERSION

# INTERNATIONAL STANDARD

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## Rotating electrical machines –
## Part 18-1: Functional evaluation of insulation systems – General guidelines

IEC 60034-18-1:2022-12 CMV(en)

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## Rotating electrical machines –
## Part 18-1: Functional evaluation of insulation systems – General guidelines

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

# ROTATING ELECTRICAL MACHINES –

## Part 18-1: Functional evaluation of insulation systems – General guidelines

## FOREWORD

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**This commented version (CMV) of the official standard IEC 60034-18-1:2022 edition 3.0 allows the user to identify the changes made to the previous IEC 60034-18-1:2010 edition 2.0. Furthermore, comments from IEC TC 2 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.**

**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.**

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IEC 60034-18-1 has been prepared by IEC technical committee 2: Rotating machinery. It is an International Standard.

This third edition cancels and replaces the second 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) provides general guidelines for functional evaluation of different types of windings as before but incorporates those changes, which have been introduced for the electrical qualification and evaluation of windings which are electrically stressed by converter-supply;

b) is now focused on general guidelines with all technical details of procedures and qualification principles moved to the subsequent parts;

c) details additional general aspects of functional evaluation and qualification, particularly the procedure for comparison between reference and candidate insulation systems, the introduction of the concept of qualification for different expected life-times in service and the evaluation of minor component or manufacturing changes.

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

| Draft | Report on voting |
|---|---|
| 2/2113/FDIS | 2/2118/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.

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.

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.

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.

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# INTRODUCTION

IEC 60034-18 comprises several parts, dealing with different types of functional evaluation and special kinds of test procedures for insulation systems of rotating electrical machines. IEC 60034-18-1 provides general guidelines for such procedures and qualification principles, whereas the subsequent parts IEC 60034-18-21, ~~IEC 60034-18-22,~~ IEC 60034-18-31, IEC 60034-18-32, IEC TS 60034-18-33, IEC 60034-18-34, IEC 60034-18-41 and IEC 60034-18-42 give detailed procedures for the various types of windings. Beyond that, part IEC 60034-18-41 and IEC 60034-18-42 contain special test procedures for electrical evaluation of windings electrically stressed by converter-supply.

The following standards provide the basis and background for the development of the afore mentioned standards.

IEC 60505 establishes the basis for estimating the ageing of electrical insulation systems under conditions of either electrical, thermal, mechanical, environmental stresses or combinations of these (multifactor stresses). It specifies the general principles and procedures that should be followed defining functional test and evaluation procedures.

The IEC 60216 series deals with the determination of thermal endurance properties of single insulating materials. On the assumption, that the Arrhenius formulas describe the rate of thermal ageing of the materials, test procedures and analyzing instructions for getting characteristic parameters like the “Temperature index” (TI), the “Halving interval” (HIC) and the “Relative thermal endurance index” (RTE) are given. For all these parameters selected properties and accepted end-point-criteria are specified. Consequently, a material may be assigned with more than one temperature index, derived from the measurement of different properties and the use of different end-point criteria.

IEC 60034-18-1 defines general requirements on the qualification of insulation systems, where – for thermal ageing – the Arrhenius equations do not necessarily fit, according to many experiences.

IEC 60085 deals with thermal evaluation of electrical insulation materials and in particular insulation systems used in electrical equipment. In particular, thermal classes of insulation systems are defined and designations are given, such as 130 (B), 155 (F) and 180 (H) for use in rotating machines belonging to IEC 60034-1. In the past, materials for insulation systems were often selected solely on the basis of thermal endurance of individual materials performed according to the IEC 60216 series. However, IEC 60085 recognizes that such selection may be used only for screening materials prior to further functional evaluation of a new insulation system which is not service-proven. Evaluation is performed on the basis of a comparison with a service-proven reference insulation system. Service experience is the preferred basis for assessing the thermal endurance of an insulation system.

IEC 62539 defines statistical methods to analyse times to breakdown and breakdown voltage data obtained from electrical testing of solid insulation materials, for the purposes of characterization of the system and comparison with other insulation systems. The methods of analysis are described for the Weibull-distribution, but other distributions are also presented.

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# ROTATING ELECTRICAL MACHINES –

## Part 18-1: Functional evaluation of insulation systems – General guidelines

## 1 Scope

This part of IEC 60034 deals with the general guidelines for functional evaluation of electrical insulation systems, used or proposed to be used in rotating electrical machines within the scope of IEC 60034-1, in order to qualify them.

## 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 60034-18-21, *Rotating electrical machines – Part 18-21: Functional evaluation of insulation systems – Test procedures for wire-wound windings – Thermal evaluation and classification*

~~IEC 60034-18-22, *Rotating electrical machines – Part 18-22: Functional evaluation of insulation systems – Test procedures for wire-wound windings – Classification of changes and insulation component substitutions*~~

IEC 60034-18-31, *Rotating electrical machines – Part 18-31: Functional evaluation of insulation systems – Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in rotating machines* ~~*up to and including 50 MVA and 15 kV*~~

IEC 60034-18-32, *Rotating electrical machines – Part 18-32: Functional evaluation of insulation systems (Type II) –* ~~*Test procedures for form-wound windings – Evaluation of electrical endurance of insulation systems used in machines up to and including 50 MVA and 15 kV*~~ *Electrical endurance qualification procedures for form-wound windings*

IEC TS 60034-18-33, *Rotating electrical machines – Part 18-33: Functional evaluation of insulation systems – Test procedures for form-wound windings –* ~~*Multifactor functional evaluation – endurance under combined thermal and electrical stresses of insulation systems used in machines up to and including 50 MVA and 15 kV*~~ *Multifactor evaluation by endurance under simultaneous thermal and electrical stresses*

IEC 60034-18-34, *Rotating electrical machines – Part 18-34: Functional evaluation of insulation systems – Test procedures for form-wound windings – Evaluation of thermomechanical endurance of insulation systems*

IEC 60034-18-41:2014, *Rotating electrical machines – Part 18-41:* ~~*Qualification and type tests for Type I electrical insulation systems used in rotating electrical machines fed from voltage converters*~~ *Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests*
IEC 60034-18-41:2014/AMD1:2019

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IEC~~/TS~~ 60034-18-42, *Rotating electrical machines – Part 18-42:~~ Qualification and acceptance tests for partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters~~ Partial discharge resistant electrical insulation systems (Type II) used in rotating electrical machines fed from voltage converters – Qualification tests*

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

IEC 60085, *Electrical insulation – Thermal evaluation and designation~~ of electrical insulation~~*

~~IEC 60216 (all parts), *Electrical insulating materials – Properties of thermal endurance*~~

IEC 60493-1, *Guide for the statistical analysis of ageing test data – Part 1: Methods based on mean values of normally distributed test results*

IEC 60505:~~2004~~2011, *Evaluation and qualification of electrical insulation systems*

IEC 61858-1:2014, *Electrical insulation systems – Thermal evaluation of modifications to an established electrical insulation system (EIS) – Part 1: Wire-wound winding EIS*

IEC 61858-2:2014, *Electrical insulation systems – Thermal evaluation of modifications to an established electrical insulation system (EIS) – Part 2: Form-wound EIS*

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 General terms

**3.1.1**
**class temperature**
temperature for which the insulation system is suitable, as defined by the thermal class in IEC 60085 and as used in IEC 60505

**3.1.2**
**electrical insulation system**
**EIS**
insulating structure containing one or more electrical insulating materials (EIM)~~ applied over~~ together with associated conducting parts employed in~~ rotating electrical machines~~ an electrotechnical device

[SOURCE: IEC 60505:~~2004~~2011, 3.1.1~~, modified~~]

~~NOTE 1 There may be several insulation components within the windings, each being designed for different stresses in service, i.e. turn insulation, slot insulation and end-winding insulation. Different criteria may be applied to the various components within the overall system.~~

~~NOTE 2 There may be more than one insulation system in a particular type of machine. These insulation systems may have different thermal classes (e.g. stator and rotor windings).~~

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**3.1.3**
**candidate insulation system**
insulation system being tested to determine its capability with respect to ageing factors

[SOURCE: IEC 60050-411:1996~~, Amendment 1:2007~~, 411-39-26~~, modified~~]

**3.1.4**
**reference insulation system**
insulation system whose performance has been established by satisfactory service experience

[SOURCE: IEC 60050-411:1996~~, Amendment 1:2007~~, 411-39-27]

**3.1.5**
**coil**
one or more turns of insulated conductors connected in series and surrounded by common insulation, arranged to link or produce magnetic flux

[SOURCE: IEC 60050-411:1996, 411-38-03~~, modified~~]

**3.1.6**
**bar**
either of two parts which, after placed in their slots and when connected together, will form the complete form-wound coil (see 3.1.8) and which comprise a coil side and an appropriate end winding

Note 1 to entry: Large AC machines commonly use bars, and usually, though not always, they form single-turn coils in a two-layer winding.

[SOURCE: IEC 60050-411:1996, 411-38-05~~, modified~~]

**3.1.7**
**wire-wound winding**
winding which is wound with one or several insulated conductors and in which the individual conductors occupy random positions in the coil side

Note 1 to entry: It is usually random-wound with round conductors.

[SOURCE: IEC 60050-411:1996, 411-38-13~~, modified~~]

**3.1.8**
**form-wound winding**
winding consisting of coils or bars which are preformed to shape, insulated and substantially completed before they are inserted into their final places

Note 1 to entry: Coils or bars are usually wound with rectangular conductors.

[SOURCE: IEC 60050-411:1996, 411-38-11~~, modified~~]

## 3.2 Terms relating to the objects being tested

**3.2.1**
**test object**
unit being tested

Note 1 to entry: It may be an actual machine or part thereof or a special test model (see 3.2.3 and 3.2.4) which can be subjected to functional tests.

Note 2 to entry: A test object may contain more than one test specimen (see 3.2.2).

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**3.2.2**
**test specimen**
individual component within a test object which can be used to generate one piece of test data (e.g. time to failure)

Note 1 to entry: A test specimen may contain more than one insulation component (e.g. turn insulation and conductor to earth insulation), any one of which can provide that piece of data.

**3.2.3**
**formette**
special test model used for the evaluation of the insulation systems for form-wound windings

[SOURCE: IEC 60050-411:1996~~, Amendment 1:2007~~, 411-53-64]

**3.2.4**
**motorette**
special test model used for the evaluation of the insulation systems for wire-wound (random-wound) windings

[SOURCE: IEC 60050-411:1996~~, Amendment 1:2007~~, 411-53-65]

### 3.3 Terms relating to factors of influence and ageing factors

**3.3.1**
**factor of influence**
stress imposed by conditions of operation, environment or test that may affect ageing or life of an insulation system

**3.3.2**
**ageing factor**
factor of influence that causes ageing

Note 1 to entry: In the winding of an electrical machine, different factors of influence or ageing factors can be dominant in different parts (e.g. turn insulation and end-winding insulation). Therefore, different criteria may be used to assess those parts of the insulation. It can also be appropriate to apply different procedures of functional evaluation to these parts.

### 3.4 Terms relating to testing and evaluation

**3.4.1**
**diagnostic factor**
variable or fixed stress~~ applied to an insulation component of a test specimen in order to establish its condition after ageing without significantly adding to the ageing~~ which is applied to an EIS to establish the degree of ageing

[SOURCE: IEC 60505:~~2004~~2011, 3.3.7~~, modified~~]

**3.4.2**
**functional test**
comparative test in which the candidate and the reference insulation systems are exposed to ageing and diagnostic factors in order to qualify the candidate system, or, a functional test may also be related to a diagnostic property 1

**3.4.3**
**endurance test**
test in which the insulation system of a test object is exposed to one or more ageing factors related to service conditions and where changes in specific properties are evaluated by diagnostic tests

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**3.4.4**
**diagnostic test**
test in which the insulation system of a test object is exposed to one or more diagnostic factors in order to discern its condition through measurements or proof tests and to determine when the end-point criterion has been reached

**3.4.5**
**end-point criterion**
selected value of a characteristic of a test object indicating the end of its test life or arbitrarily chosen for the purpose of the comparison of insulation systems

**3.4.6**
**end-point**
end of a test as defined by the end-point criterion

**3.4.7**
**classification**
set of actions leading to the determination of the ~~thermal~~ class of an insulation system, e.g. Thermal Class or Impulse Voltage Insulation Class **2**

**3.4.8**
**type test**
test conducted on first prototype of product to confirm the design specifications, it is usually not repeated on other products of same type

**3.4.9**
**quality control test**
conducted in order to ensure that the quality of a product is maintained against a set of benchmarks and that any errors encountered are either eliminated or reduced

**3.4.10**
**routine test**
test made on each individual device during or after manufacture to check if it complies with the requirements of the standard concerned or the criteria specified

## 4 General aspects of functional evaluation

### 4.1 Introductory remarks

~~All~~ Most functional tests given in the IEC 60034-18 series are comparative. The performance of a candidate system is compared with that of a reference system when both are subjected to equivalent test conditions with respect to test objects, methods of ageing and diagnostic tests.

It is not necessarily required that the reference system is physically to be tested in parallel, if the test results of the reference system used have been documented previously and obtained from same test conditions. **3**

The reference system normally is particular and real – but its quantified minimum performance can also be defined by an agreed reference lifeline, provided by an IEC standard as in IEC 60034-18-42.

At the end of every functional test, the functional evaluation shall be made. This means it is necessary to compare the diagnostic data obtained from the candidate and the reference system, usually to compare the mean times to failure. and its spread, using appropriate statistical methods.

If the data from the candidate system is no worse than from the reference system, the candidate system is considered to be qualified. This is true if the 90 % confidence interval of that

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percentile of the used probability distribution which represents the mean value falls above or within that obtained from the reference system (see IEC 60493-1 and IEC 62539).

The large differences found in rotating electrical machine windings, in terms of size, voltage, operating conditions and expected lifetime-behaviour during service necessitate the use of different procedures for functional evaluation of thermal, electrical and multifactor ageing (IEC 60034-18-21, IEC 60034-18-31, IEC 60034-18-32, IEC TS 60034-18-33, IEC 60034-18-34, IEC 60034-18-41, IEC 60034-18-42) to ~~evaluate~~ qualify various types of windings. These procedures can be of different complexity, the simplest being based on a single ageing factor (e.g. thermal or electrical).

The procedures for functional evaluation will permit comparisons and allow qualification of candidate insulation systems. However, they cannot completely determine the merits of any particular insulation system. Principally, it is not possible to give an operational lifetime forecast of the individual winding insulation based on any kind of functional tests. Such information can be obtained in general only from extended service experience.

The demonstration of IEC 60034-18 series results could contain proprietary information that the manufacturer therefore does not want to share in the documentation. But in order to prove compliance of the candidate system, key points shall be at least shown and explained to the customer without the need to provide documents.

### 4.2 Effects of ageing factors

All ageing factors, i.e. thermal, electrical, environmental and mechanical, affect the life of all types of machines but the significance of each factor varies with the type of machine and the expected duty. In some cases, one of these ageing factors is considered to be dominant.

In other cases, several ageing factors may be acting significantly. These different conditions have to be considered in choosing the appropriate functional test according to this document.

Insulation of small or medium low-voltage line-fed machines is degraded primarily by temperature and environment, with electrical and mechanical stresses being of less importance.

Medium to large machines, using form-wound windings, are also affected by temperature and environment but, in addition, the electrical and mechanical stresses can be important ageing factors.

Very large machines, which generally utilize form-wound (with bars) windings and which can operate in a special environment such as hydrogen, are normally most affected by mechanical stresses or electrical stresses, or both. Temperature and environment can be less significant ageing factors.

The winding insulation system of small, medium, large and very large converter fed machines may be substantially electrically stressed (see IEC 60034-18-41 and IEC 60034-18-42).

### 4.3 Reference/candidate insulation system

An insulation system qualifies to be used as a reference insulation system if its performance has been established by satisfactory service experience. This means:

– it has shown successful operation over suitably long periods of time at operating conditions characteristic of the rating (or class) and in typical applications of that insulation system;
– its service experience is based on a sufficient number of machines.

A reference insulation system shall be tested together with the candidate system using the same test procedure and the same test equipment, preferably in the same laboratory. Alternatively, if the test results of the reference system used have been documented previously

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and obtained from same test conditions, re-testing the reference system is not necessary (see 4.1).

If it is necessary to verify results in another laboratory, it can be found that the test-life values differ if the conditions in the original test are not duplicated precisely. However, a comparison of results between qualified laboratories should show at least nearly the same relative performance between candidate and reference systems.

### 4.4 Evaluation of minor changes by components, ~~or~~ manufacturing ~~changes~~ or design

Substitution of components, changes in the manufacturing process and design adaptions are usual practice during the lifecycle of qualified insulation systems.

Any substitution of components (insulating materials) or any relevant change in manufacturing process ~~changes~~ or design may turn a reference system into a candidate system with the need for a new functional evaluation~~, unless the new component can be considered to be chemically and physically identical (generically identical) and the intended changes in the manufacturing process are not expected to have any influence on the electrical insulation system properties~~ – unless if the new component and the intended changes in manufacturing process or design are expected to have no practical influence on the functional electrical insulation system properties, e.g. by chemical and physical generic identity of the materials used.

It is to be therefore decided on a first step, if the change may alter the strength of the insulation system against dominant ageing factors like electrical, thermal, mechanical or ambient stresses.

In respect of the dominant ageing factor, or combinations of ageing factors, it may be that the change ~~proposed~~ intended is only minor. Such a minor change is the substitution of a component or a change in the manufacturing process which is expected to have no practical, significant effect on the performance of the insulation system and may be the justification to use, instead of a full functional evaluation, merely a reduced functional evaluation by single point test or other special endurance tests ~~(see IEC 60034-18-22 together with IEC 60034-18-21, IEC 60034-18-31, IEC 60034-18-32 and IEC 60034-18-33)~~.

In other cases, no system testing may be required but only material testing may be adequate, e.g. different suppliers produce according to the same requirement specification of the client on similar chemical basis. For this topic, horizontal standards describe simple material tests, e.g. for round or flat wires, IEC 61858-1 or IEC 61858-2, respectively. **4**

Often, no material nor major process change is intended, however it is desired to change the thickness of the mainwall insulation: If the average and peak electric field stress (kV/mm) of the EIS with the different insulation thickness do not exceed that of the qualified EIS, by more than 5 %, and if the thickness and rated voltage are not exceeding the range of +110 % / -50 % of the qualified insulation system, then a new functional evaluation is not needed. For example, if 6,6 kV system has been functionally evaluated completely and qualified according to this standard, this qualification would also apply for the 13,8 kV and for 3,3 kV system with the same materials and processes but adapted thicknesses. This does not apply to the stress control system which may to be qualified independently. **5**

The voltage range is applicable only up to rated voltages of 15 kV – above that, specific knowledge and alignments between manufacturer and user may be required.

It is the machine manufacturer's responsibility to determine the need for verification and to justify the use and the focus of a reduced functional evaluation ~~or~~ and how special endurance or screening tests should be undertaken. Full or reduced functional evaluation or special endurance tests may be necessary.

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In the documentation on insulation system, the manufacturer should include this verification of a minor change when it is used in the system.

### 4.5 Functional tests

As defined in 3.4.2, functional tests are used to qualify the insulation systems. They are performed by endurance test cycles, each cycle consisting of an ageing sub-cycle and a diagnostic sub-cycle. In the ageing sub-cycle, test specimens are exposed to the specified ageing factor, intensified appropriately to accelerate ageing. In the diagnostic sub-cycle, test specimens are subjected to appropriate diagnostic tests to determine the end of test life or to measure relevant properties of the insulation system at that time. In some cases, the ageing factor itself can act as the diagnostic factor and produce the end-point.

Not all diagnostic tests need to be applied in all cases. Special considerations may render certain diagnostic tests inapplicable.

The outcome of these tests is comparative and does not allow an estimate to be made, e.g. by extrapolation or calculation, of a definite lifetime in service because additional factors of influence can intervene.

In specific cases, a qualification for longer or shorter expected lifetimes may be required than that of the service proven reference system used – or for stress parameters not identical to those of the reference system. In these cases, for the purpose of comparative evaluation of the candidate sytem with the reference system, its life lines obtained may be shifted accordingly. This particular comparative evaluation for unequal expected lifetimes or stress parameters is allowed only for certain limited differences and both, the differences as well as the results must transparently be documented (e.g. see IEC 60034-18-31 for thermal qualification) It is possible to exclude a dominant aging factor endurance test by a specific test, e.g. the electrical ageing by an appropriate partial discharge test as defined in IEC 60034-18-41. In this case, this specific test may allow refraining from endurance test cycles for this particular ageing mechanism and replacing it as a functional test. **6**

### 4.6 Acceptance tests

Acceptance tests of the insulation system may be performed to verify that its insulation materials and quantities used as well as the manufacturing procedure employed are of the expected production quality level. In so far, the acceptance tests in themselves do not qualify an insulation system. They are normally non-destructive tests performed with the machine winding to be sold.

~~The decision as to whether acceptance tests are undertaken or not, shall be agreed between the manufacturer and purchaser.~~

Whether and which acceptance tests beyond those defined in IEC 60034-1 are undertaken or not, is usually defined in the manufacturers process standards. Further requirements are to be agreed between the manufacturer and purchaser.

In cases where there is no chance to make the specific acceptance tests with the winding to be sold or with test objects produced together with those windings ~~elements~~ to be sold according to the contract, the acceptance test may be covered by a type test. Here, care has to be taken to ensure and prove that the production quality of the winding to be sold is on the same level as the type test winding tested before.

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# 5 Thermal functional tests

## 5.1 General aspects of thermal functional tests

The purpose of the thermal functional tests in this document is to provide data which may be used to establish the thermal class of a new insulation system before it is service-proven.

These guidelines are used in conjunction with IEC 60034-18-21, ~~IEC 60034-18-22~~ IEC 61858-1 and IEC 60034-18-31 and IEC 61858-2 for the specific type of winding being considered and where the thermal ageing factor shall be considered dominant in comparison to the other ageing factors.

The concepts implemented in this document are based on IEC 60085, IEC 60493-1, IEC 60505 and IEC 62539.

The thermal ageing processes in the insulation system of rotating electrical machines can be complex in nature – refer to IEC 60505 for further information. ~~Since the insulation systems of rotating machines are complicated in varying degrees, simple systems referred to in IEC 60085 do not exist in rotating machines.~~

If the intended thermal class of the candidate system differs from the known thermal class of the reference system, different ageing temperatures, sub-cycle lengths and (when technically justified) different diagnostic values shall be used in an appropriate manner.

Diagnostic tests (such as mechanical, moisture and voltage tests) shall be applied after each thermal ageing sub-cycle to check the condition of the insulation system.

It should be recognized that greater mechanical stress and higher concentration of the products of decomposition can occur during ageing tests above the service temperature. Also, it is recognized that failures from abnormally high mechanical or voltage stresses are generally of a different character to those failures which are produced in long service.

## 5.2 Analysis, reporting and classification

Specific requirements on the analysis, reporting and classification for thermal functional tests of rotating machine winding insulations are defined in IEC 60034-18-21 and IEC 60034-18-31.

The end of insulation test life is assumed to have occurred at the mid-point-time of the ageing sub-cycle between the last two consecutive diagnostic sub-cycles.

The total number of hours of thermal ageing to the end of test shall be recorded for each specimen and for each temperature.

A thermal endurance graph is drawn using the results of ageing, according to the guidelines given in IEC 60493-1, IEC 62539, IEC 60034-18-21 and IEC 60034-18-31 for both the candidate system and reference systems. Having chosen a distribution to represent the test results of ageing, it is necessary to check that the distribution is adequate for this purpose.

If, in special cases of application, the requirements for the expected life time of the candidate insulation system essentially differ from that of the reference insulation system within the same thermal class, then the classification can be made, taking account of this fact (see IEC 60034-18-21 and IEC 60034-18-31). This shall be stated in the report together with an appropriate justification.

If the thermal endurance graphs of the reference and candidate systems have clearly dissimilar slopes, it is evident that their ageing processes are significantly different and it is thus doubtful whether a valid classification can be made from the comparison.

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When reporting, it is useful to record all relevant details of the test, including those in the following list:

- references to IEC test standards;
- detailed description of the insulation systems tested (the reference and candidate systems, may partly be internal informations);
- ageing temperatures and ageing sub-cycle lengths for each insulation system;
- diagnostic tests used with applied test or stress levels for each insulation system;
- construction of the test specimens and test objects;
- number of specimens at each temperature for each insulation system;
- method of applying the ageing temperatures and the way in which the temperatures have been measured (including oven type, etc.);
- air change rate of the oven ~~air replacement~~;
- individual times to failure and failure modes;
- mean log times to failure and the log standard deviation, or the lower confidence limits for each ageing temperature and for each insulation system;
- thermal endurance graph with log mean points and regression line;
- temperature index and thermal class of the reference system;
- temperature index and thermal class of the candidate system as determined by the test.

# 6 Electrical functional tests

## 6.1 General aspects of electrical functional tests

Insulation systems are subjected to electrical ageing by applying a voltage between parts operating at different electric potentials and where the electrical ageing factor is to be considered dominant in comparison to the other ageing factors. Qualification procedures for these conditions are given in detail in IEC 60034-18-32, IEC 60034-18-41 and IEC 60034-18-42.

The ageing process can be accelerated by raising the electrical stress and/or increasing the frequency of the test voltage. End of life is manifested either as breakdown during exposure to electrical ageing or as failure in a diagnostic test.

If it is necessary to adapt the design of single components of the insulation systems to make the electrical functional test practicable (e.g. the stress ~~grading~~ control system), then for these components special endurance or acceptance tests are recommended.

By conducting tests at different voltages, a relationship of test life versus electrical stress can be plotted. Note that increased frequency has often been used to accelerate electrical ageing, with the assumption that the test acceleration is proportional to frequency. However, this assumption does not always hold. A discussion on this issue is given in IEC 60034-18-42.

Test life normally exhibits a widespread variation for any particular voltage stress level. Therefore, it is essential that a statistically significant number of specimen and failure times be obtained at each electrical ageing stress.

In certain cases, special endurance or acceptance tests, e.g. non-destructive dissipation factor test at all type of high voltage coils/bars/windings according to IEC 60034-27-3 or PD measurements at converter driven units can be used for electrical qualification, see 4.5 and IEC 60034-18-41.

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Specimens should be at room temperature or at the ~~thermal class~~ specified test temperature. Care should be taken that dielectric losses at high stress or at increased frequency do not raise insulation temperature enough to affect the results.

### 6.2 Analysis and reporting

Specific requirements on the analysis and reporting of electrical functional tests of rotating machine winding insulations are defined in IEC 60034-18-32 and IEC 60034-18-42.

An electrical endurance graph is drawn using the results of ageing, according to the guidelines given in IEC 62539 and IEC 60034-18-32 and IEC 60034-18-42 for both the candidate system and reference systems. Having chosen a distribution to represent the test results of ageing, it is necessary to check that the distribution is adequate for this purpose. According to present experience it would normally be the Weibull distribution.

When reporting, it is useful to record all relevant details of the test, including those in the following list:

– maximum intended rated voltage of the system;
– test temperature;
– detailed description of the insulation systems tested (the reference and the candidate systems, may partly be internal informations);
– ageing voltages, frequencies and ageing sub-cycle lengths if appropriate;
– diagnostic tests including the values of the diagnostic factors used;
– construction of the test object;
– number of test specimens at each voltage (fixed voltage test);
– individual times to failure and failure modes;
– method of statistical treatment used for the test data (preferably the Weibull-distribution) to determine the mean time to failure (63 % value in the case of Weibull) and the confidence limits, see IEC 62539;
– electrical endurance graph with mean or median points for each electrical ageing stress and regression line.

## 7 Mechanical functional tests

It is recognized that mechanical stress in some applications acts as an ageing factor, either alone or in combination with other ageing factors. Mechanical ageing can be a consequence of vibrational stresses, stresses caused by electrodynamic forces or thermomechanical stresses due to very large number of considerable load changes during normal operation, see IEC 60034-18-34. Depending on type of stator winding different mechanical tests like thermo-mechanical cycling test or dynamic-mechanical bending cycle test are used for insulation system qualification.

Sufficient technical information is not available at the present time to permit standard mechanical ageing test procedures with dominant mechanical ageing factors to be presented.

NOTE An approach of an empirical life model and test procedures are discussed in IEC 60505.

## 8 Environmental functional tests

It is recognized that environmental factors in some applications act as ageing factors.

Environmental ageing factors include chemically/physically active or electrically conductive substances in industrial atmospheres, ~~exceptionally~~ high moisture content of the ambient air,

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fungus or microbe-contaminated environments, or mechanically abrasive materials (e.g. sand) in the cooling air.

Such chemical/physical environmental ageing factors can e.g. also be the effect of refrigerants in hermetic motors or the ionizing radiation in nuclear power plants. For insulation materials and systems of these special applications, extensive endurance test procedures beyond the IEC 60034-18 series exist.

Sufficient technical information is not available at the present time to permit standard environmental ageing test procedures with dominant environmental ageing factors to be presented.

## 9 Multifactor functional tests

It is recognized that more than one factor of influence, e.g. thermal and electrical, can affect the performance of insulation systems, particularly when these factors act simultaneously, see IEC TS 60034-18-33.

Such multifactor ageing can occur in mechanically or thermo-mechanically high-stressed low and high voltage machines.

In general, for multifactor functional tests, the following principles which are derived from IEC 60505 shall be considered:

a) Simultaneously acting factors of influence in service should preferably be simulated in simultaneous ageing tests, while sequentially acting factors of influence should preferably be simulated with sequential ageing cycles, to ensure that possible direct or indirect interactions between the different ageing factors during the funtional test act as in service.

b) When one of the ageing factors is known to be more important than the others, then the multifactor tests may be performed by accelerating the effects of that factor only and keeping other factors at service levels.

c) In other cases, all the important ageing factors should be accelerated. It is recommended that the acceleration factor (relative rate of ageing) be similar for each ageing factor and that the levels of the ageing factors be established on the basis of single-factor ageing tests until experience is obtained.

d) It is recommended that the reference operating conditions be established. This is the set of the service conditions for which the machine and its insulation system have been designed.

   The levels of the factors of influence in the set of reference operating conditions serve as the basis for estimating the acceleration factors during the ageing sub-cycle and for setting the levels of the diagnostic tests.

   Care has to be taken, that the acceleration factor of chosen aging process does not change the dominant physical/chemical aging mechanisms of the insulation system

e) For tests with multifactor acceleration, comparison between the candidate and reference system should be performed only within the range of test levels.

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