

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

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

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



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## ROTATING ELECTRICAL MACHINES –

**Part 15: Impulse voltage withstand levels  
of form-wound stator coils for rotating a.c. machines**

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International Standard IEC 60034-15 has been prepared by IEC technical committee 2: Rotating machinery.

This third edition cancels and replaces the second edition published in 1995 and constitutes a technical revision. The principal technical changes are as follows.

- Change of title to clarify that it is form-wound coils that are being tested rather than machines.
- Removal of the limitation on voltage in the Scope.
- Additional definitions for consistency with IEC 60060-1.
- Reduction in tolerances for the risetime of the steep-fronted impulse voltage.
- Guidance on test levels for coils to be used in converter driven machines.
- Guidance on voltage levels for routine tests.
- Additional figures to show testing details and oscillograms of normal and faulty coils.

The text of this standard is based on the following documents:

FDIS	Report on voting
2/1534/FDIS	2/1547/RVD

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

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

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## INTRODUCTION

IEC 60071-1 specifies general requirements for the phase to earth insulation of equipment in three phase a.c. systems and states that each apparatus committee is responsible for specifying the insulation levels and test procedures for its equipment, taking into consideration the recommendations of IEC 60071-1. The object of IEC 60034-15 is to specify requirements for rotating electrical machines. Experience has shown that the values given in this standard meet the insulation requirements for the essential stresses in service. An explanation of the principles adopted in preparing these requirements is given in Annex A. This standard is not intended for soft-start machines.

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## ROTATING ELECTRICAL MACHINES –

### Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines

#### 1 Scope

This part of IEC 60034 relates to a.c. machines incorporating form-wound stator coils. It specifies the test procedures and voltages to be applied to the main and interturn insulation of sample coils.

#### 2 Terms and definitions

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

##### 2.1

##### **sample test**

test carried out on coils in new condition which adequately represent the configuration of the finished item to be used in the machine for the purpose of evaluating the manufacturing procedures and processes incorporated in the insulation system

##### 2.2

##### **routine test**

test carried out on all coils of the machine

##### 2.3

##### **form-wound stator coil**

coil which is preformed to shape, insulated and substantially completed before insertion into the stator

##### 2.4

##### **front time**

$T_1$

time for the impulse voltage to rise from 0 % to 100 % of the peak value and defined as 1,67 times the interval between the instants when the impulse is 30 % and 90 % of the peak value

##### 2.5

##### **time-to-half value**

$T_2$

interval between the origin and the instant when the voltage has decreased to half the peak value

#### 3 Impulse voltage withstand levels

Impulse voltage withstand levels for specific rated voltages shall be calculated in accordance with the formula given in Note 2 of Table 1. Table 1 gives the impulse voltage withstand levels for some common rated voltages rounded to the nearest whole number. The test levels for converter-fed machines depend upon how the rated voltage has been assigned by the manufacturer. It may be appropriate to increase the test levels by a factor to allow for the maximum overshoot which is likely to arise on the voltage at the machine terminals, as described in IEC 60034-18-42. This factor may be as high as 1,7 for a 3-level converter but lower if there are more levels.



**Table 1 – Impulse voltage withstand levels for sample form-wound coils used in a.c. rotating machines**

Rated voltage	Rated lightning-impulse voltage withstand (peak) (see Notes 1 and 2)	Rated steep-front-impulse voltage withstand (peak) (see Notes 3 and 4)
$U_N$	$U_p$	$U'_p$
kV	kV	kV
2,3	14	9
3	17	11
3,3	18	12
4	21	14
6	29	19
6,6	31	20
10	45	29
11	49	32
13,2	58	38
13,8	60	39
15	65	42

NOTE 1 The levels in Column 2 are based on a standard lightning impulse having a front time of  $1,2 \mu\text{s} \pm 30 \%$ , a time-to-half-value of  $50 \mu\text{s} \pm 20 \%$  and a peak value of the impulse voltage  $U_p \pm 3 \%$  as specified in IEC 60060-1.

NOTE 2 The levels in Column 2 are obtained by using the formula:  $U_p = 4 U_N + 5 \text{ kV}$ .

NOTE 3 The levels in Column 3 are based on an impulse having a front time of  $0,2 \pm 0,1 \mu\text{s}$  up to 35 kV. Above 35 kV, the front time is  $0,2 \mu\text{s}$  with a tolerance of  $+0,3 \mu\text{s}/-0,1 \mu\text{s}$ .

NOTE 4 The levels in Column 3 are obtained by application of the formula:  $U'_p = 0,65 U_p$ .

NOTE 5 The levels in Column 3 have been deemed appropriate for stresses related to circuit breaker operation that could occur in service. They may not be adequate for special operating conditions (e.g. interrupted start or direct connection to overhead lines). In such cases the windings should either be designed to withstand other impulse levels or be protected in an appropriate way.

## 4 Sample tests

### 4.1 General

These tests are carried out as an indirect proof of compliance as explained in Clause A.3 of Annex A. The test coils shall have completed their manufacturing process, including corona protection layer and stress grading if used, and shall be either embedded in earthed slots or fitted with the slot portion wrapped in earthed conducting tape or foil. The number of sample coils shall be at least two. Examples of test circuits for individual coils and for coils assembled in stators are shown in Clauses B.1 and B.2.

All sample coils shall withstand the electrical tests described below. In the case of a failure, the manufacturer shall investigate the cause. Failure in an impulse test may be detected from the shape of the signal seen on an oscilloscope. Examples of signals from normal and short-circuited coils are shown in Clause B.3.

### 4.2 Impulse voltage withstand test of the interturn insulation

The impulse test of the interturn insulation shall be carried out by applying a steep-fronted-impulse voltage between the two terminals of the sample coils (Table 1 Column 3).

The interturn test voltage shall be generated by the damped oscillatory discharge of a capacitor. The number of switching operations shall be at least five. The front time of the first voltage peak at the terminals of the sample coil shall be  $0,2 \pm 0,1 \mu\text{s}$  up to a test voltage of 35 kV. For test voltages above 35 kV, the front time shall be  $0,2 \mu\text{s}$  with a tolerance of  $+0,3 \mu\text{s}/-0,1 \mu\text{s}$ . The front time of the last voltage impulse applied during a test should be checked for compliance.

The voltage peak between the terminals of the sample coil shall have the values given in Table 1, Column 3, as appropriate, or the values obtained by application of the formula in Note 4 of Table 1. The tolerance on  $U_p$  is  $\pm 3\%$ .

#### 4.3 Lightning impulse voltage withstand test of the main insulation

The impulse voltage test of the main insulation shall be carried out by applying a lightning-impulse voltage between the coil terminals and earth (Table 1 Column 2).

The main insulation test voltage shall be generated by an impulse generator applying an impulse voltage with a front time of  $1,2\ \mu\text{s} \pm 30\%$  and a time-to-half value of  $50\ \mu\text{s} \pm 20\%$  as specified in IEC 60060-1. The number of impulses shall be at least five and of the same polarity.

The voltage peaks between the coil terminals and earth shall be 100 % of the values given in Table 1, Column 2, or 100 % of the values obtained by application of the formula in Note 2 of Table 1. The tolerance on  $U_p$  is  $\pm 3\%$ .

#### 4.4 Power-frequency voltage withstand test

A power-frequency voltage withstand test may be used instead of the lightning impulse voltage withstand test. In this case, a voltage of  $(2 U_N + 1\ \text{kV})$  shall be applied for 1 min between coil terminals and earth. The applied voltage shall then be increased at the rate of 1 kV/s up to  $2 (2 U_N + 1\ \text{kV})$ , and then immediately be reduced at a rate of at least 1 kV/s to zero. There shall be no voltage breakdown during the sequence. The corresponding impulse voltage withstand level of the main insulation and the overhang corona protection are then considered to fulfill at least the requirements of Table 1, Column 2.

NOTE 1 The rated impulse levels in Table 1, Columns 2 and 3, are lower than the peak value  $2\sqrt{2} (2 U_N + 1\ \text{kV})$  derived from this test, because the impulse level of a machine is determined by the interturn voltage due to longitudinal voltage distribution (see Clause A.1). The purpose of the higher a.c. test level is to produce a voltage gradient in the region just beyond the slot exit as near as possible to that obtained by the impulse test.

NOTE 2 In some countries, it is common practice to apply a d.c. test voltage instead of the power-frequency voltage specified above. This is permitted by this standard when agreed between the manufacturer and the purchaser. It is recommended that the d.c. voltage should be at least as high as 1,7 times the 1 min power-frequency test voltage, in accordance with Table 16 of IEC 60034-1.

### 5 Routine tests

#### 5.1 Coils

Routine tests may be performed on coils after insertion in the stator core but before processing and making the connections. In this condition, the insulation does not have the electrical withstand capability of fully processed coils and generally an impulse test (Table 1 Column 3) is performed at a reduced voltage. The steep front impulse test should be used and, as a guide, the test level may be typically 40 % to 80 % of the value shown in Table 1 Column 3. The precise test level is dependent upon the insulation technology used.

#### 5.2 Complete stators

Interturn impulse testing of complete windings is not recommended due to the difficulty of detecting an interturn failure.

## Annex A (informative)

### Principles involved in the specification of impulse voltage withstand levels and test procedures

#### A.1 Impulse voltage stress of a machine winding

When a short rise time voltage surge occurs between one machine terminal and earth, the corresponding phase cannot instantaneously adopt the same potential at all points. As a result, two types of voltages arise in the winding, namely, the voltage between the conductor and earth (transverse voltage) and the voltage along the conductor (longitudinal voltage).

Whilst the transverse voltage stresses the main wall insulation, the longitudinal voltage also stresses the interturn insulation. The highest voltage components of both kinds normally appear on the first or last coil of the winding. In practice, voltage surges can be of various shapes and may have rise times down to 0,1  $\mu$ s.

#### A.2 Impulse voltage withstand level of a machine winding

A machine winding should have a defined impulse voltage withstand level within the system of insulation co-ordination. The impulse voltage withstand levels specified in Column 3 of Table 1 are based on the formula

$$U_p' = 0,65 (4 U_N + 5) \text{ kV}$$

#### A.3 Indirect proof of impulse voltage withstand levels by sample tests on coils

The impulse voltage withstand level of a complete machine winding can be proved indirectly by tests on a sample coil, based on the principle that the sample coil during this sample test should be stressed, as near as practicable, in the same manner as that coil (or those coils) within the complete winding with the maximum stresses between turns and/or to ground, i.e. normally the first coil of the winding.

The maximum value of the transverse voltage (between conductor and earth) appearing on the line coil (and therefore on the coil used in the sample test) is equal to the peak value of the impulse voltage on the complete winding.

The peak value of the longitudinal voltage (along the conductor) appearing on the line coil varies widely due, at least, to the following factors:

- rise time  $t_s$  of the voltage impulse;
- conductor length of the line coil;
- number and arrangement of the turns.

The actual value may be investigated by applying a model impulse voltage with, for example, a few hundred volts peak on the terminal of the complete machine.

Corresponding investigations have been made in several countries and results have been published, but, as expected, no simple law has been found for pre-calculating this peak value from a given machine configuration.

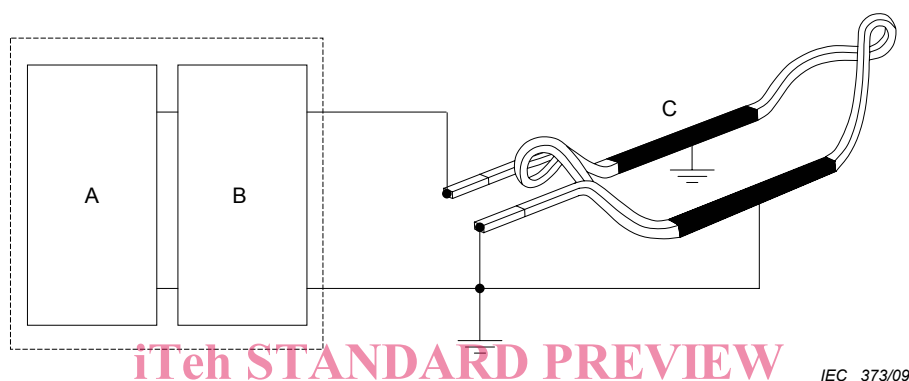
It is considered, therefore, that the three factors mentioned above are too complicated to be used as a basis for practical specifications.

## Annex B (informative)

### Testing details

#### B.1 Circuit details for impulse testing sample coils

A circuit for impulse testing sample coils is shown in Figure B.1. Several coils may be connected in parallel to enable simultaneous testing to be undertaken.



#### Key

A Impulse generator

B Voltage measuring unit

C Sample coil wrapped with an earthed foil in each slot section

**Figure B.1 – Example of the test circuit for sample tests**

#### B.2 Example of the test circuit for routine tests (Figure B.2)

Only line side coils should be tested. Several coils may be tested simultaneously by applying voltages in parallel. Insulation sheets or caps may be inserted between terminals to avoid a flashover when testing coils. The test voltage should be reduced below that used for sample tests. In addition, before resin impregnation and cure, the test voltage should be reduced as described in 5.1.