भारतीय मानक
Indian Standard

IS 15999 (Part 15) : 2017
IEC 60034-15 : 2009
(Superseding IS 14222 : 1995)

घूर्णी विद्युतीय मशीन

भाग 15 घूर्णी एसी मशीनों के लिए फार्म वाउण्ड स्टेटर काइलो के आवेग वोल्टेज सहन स्तर

Rotating Electrical Machines

Part 15 Impulse Voltage Withstand Levels of Form-Wound Stator Coils for Rotating ac Machines

ICS 29.160

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NATIONAL FOREWORD

This Indian Standard (Part 15) which is identical with IEC 60034-15 : 2009 'Rotating electrical machines — Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating ac machines' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Rotating Machinery Sectional Committee and approval of the Electrotechnical Division Council.

This standard supersedes IS 14222 : 1995 'Impulse voltage withstand levels of rotating ac machines with form-wound stator coils'. After publication of this standard, it shall be treated as withdrawn.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminology and conventions are however not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

Only the English language text of the IEC Standard has been retained while adopting it in this Indian Standard and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding of numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ROTATING ELECTRICAL MACHINES

PART 15 IMPULSE VOLTAGE WITHSTAND LEVELS OF FORM-WOUND STATOR COILS FOR ROTATING AC 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 µs ± 30 %, a time-to-half-value of 50 µs ± 20 % and a peak value of the impulse voltage U_p ±3 % as specified in IEC 60060-1.

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

NOTE 3 The levels in Column 3 are based on an impulse having a front time of 0,2 ± 0,1 µs up to 35 kV. Above 35 kV, the front time is 0,2 µs with a tolerance of +0,3 µs/–0,1 µs.

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 ± 0,1 µs up to a test voltage of 35 kV. For test voltages above 35 kV, the front time shall be 0,2 µs with a tolerance of +0,3 µs/ –0,1 µs. 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 ± 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 µs ± 30 % and a time-to-half value of 50 µs ± 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 ± 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 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 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 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 µs.

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

$U_p' = 0,65\ (4\ U_N + 5)$ 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.

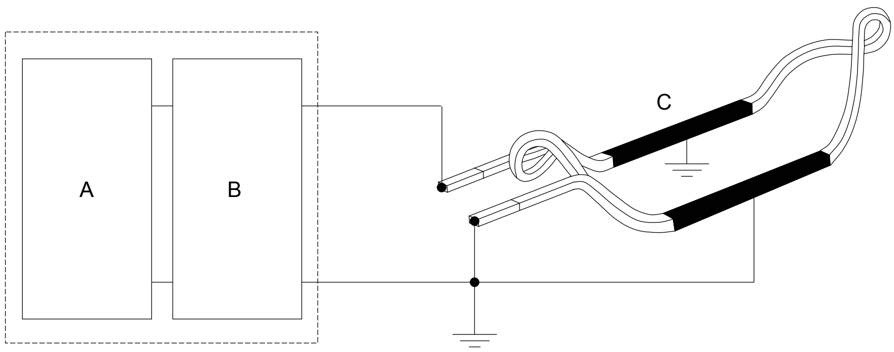
It is considered, therefore, that the three factors mentioned above are too complicated to be used as a basis for practical specifications.

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

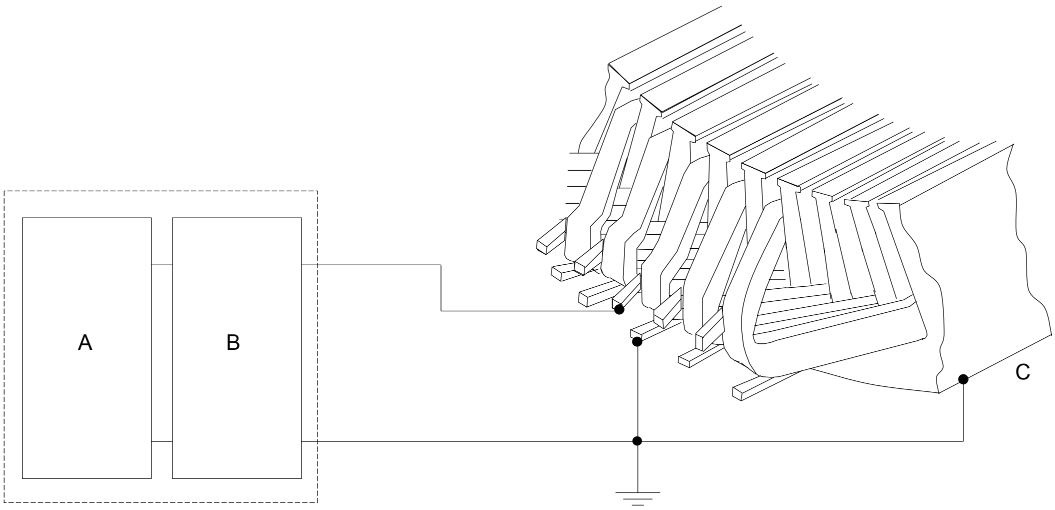
B Voltage measuring unit

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.



Key

A Impulse generator

B Voltage measuring unit

C Stator core

Figure B.2 – Example of the test circuit for routine tests

B.3 Oscillograms of normal and short-circuited coils

Examples of the oscillograms obtained from normal and short-circuited coils during impulse tests on coils assembled in the stator are shown in Figure B.3 on the same scale. Other types of failure or degrees of severity may arise and result in a change to the wave shape which is less significant.

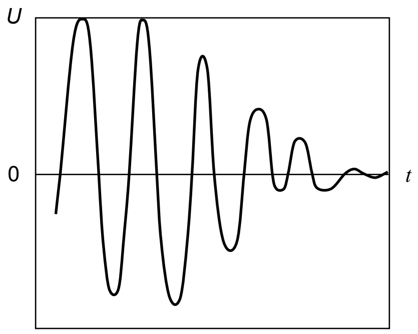


Figure B.3a – Undamaged coil

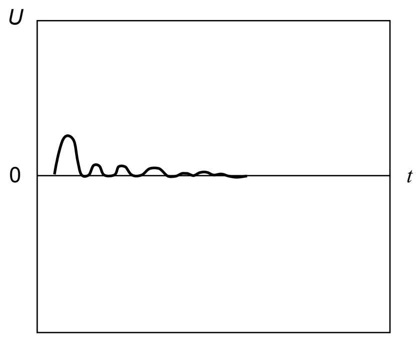


Figure B.3b – Short-circuited coil

Figure B.3 – Examples of the waveforms from undamaged and short-circuited coils tested directly connected in the stator core

Bibliography

The following documents are referred to informatively in the text of this Standard. The latest edition of the referenced document (including any amendment) applies.

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

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*

IEC 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

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