भारतीय मानक

Indian Standard

IS/IEC 60034-18-42 : 2024

Superseding IS 15999 (Part 18 /Sec 42) : 2018

विद्युत घूर्णिय मशीनें

भाग 18 आंशिक डिस्चार्ज प्रतिरोधी विद्युत इन्सुलेशन सिस्टम (टाइप II) वोल्टेज कन्वर्टर्स से संचालित रोटेटिंग इलेक्ट्रिकल मशीनों में उपयोग किया जाता है

अनुभाग 42 योग्यता परीक्षण

Rotating Electrical Machines

Part 18 Partial Discharge Resistant Electrical Insulation Systems (Type II) used in Rotating Electrical Machines Fed from Voltage Converters

Section 42 Qualification Tests

ICS 29.160.01

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Rotating Machinery Sectional Committee, ETD 15

NATIONAL FOREWORD

This Indian Standard (Part 18/Sec 42) which is identical to IEC 60034-18-42 : 2017+AMD1 : 2020 CSV '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' 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.

IS 15999 (Part 18/Sec 42) was first published in 2018. This publication has been brought out to align it with the latest version of IEC 60034-18-42: 2017+AMD1 : 2020 CSV. This standard supersedes IS 15999 (Part 18/Sec 42): 2018.

This standard is published in various parts. Other parts in this series are:

Part 5	Degrees of protection provided by the integral design of rotating electrical machines (IP Code) — Classification (*second revision*)
Part 8	Terminal markings and direction of rotation (*third revision*)
Part 27 Section 4	Winding insulation of rotating electrical machines, Section 4 Measurement of insulation resistance and polarization index

The text of the IEC standard has been proposed as suitable for publication as an Indian Standard without deviations. Certain terminologies 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' appears 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.

In this adopted standard, reference appears to International Standards for which Indian Standards also exists. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60034-1 : 2010 Rotating electrical machines — Part 1: Rating and performance	IS 15999 (Part 1) : 2021/IEC 60034-1 : 2017 Rotating electrical machines: Part 1 Rating and performance	Identical
IEC 60034-18-41 : 2014 Rotating electrical machines — Part 18-41: Partial discharge free (Type I) electrical insulation systems used in rotating electrical machines fed from voltage converters — Qualification and quality control tests	IS 15999 (Part 18/Sec 41) : 2018/IEC 60034-18-41 : 2014 Rotating electrical machines: Part 18 Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters, Sec 41 Qualification and quality control tests	Identical

The Committee has reviewed the provisions of the following international standards referred in this adopted standard and decided that they are acceptable for use in conjunction with this standard.

(*Continued on third cover*)

CONTENTS

INTRODUCTION

The approval of electrical insulation systems for use in rotating electrical machines fed from voltage converters is set out in two International Standards. These standards 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). For both Type I and Type II insulation systems, the power drive system integrator (the person responsible for co-ordinating the electrical performance of the entire power drive system) shall inform the machine manufacturer what voltage will appear at the machine terminals in service. The machine manufacturer will then decide upon the severity of the tests appropriate for qualifying the insulation system. For insulation systems which have been qualified through IEC 60034-18-41 or IEC 60034-18-42 for use in converter-fed applications, an impulse voltage insulation class may be derived. This indicates the ability of the insulation to withstand the electric stresses resulting from converter operation. For Type I systems, the severity is based on the impulse rise time and the peak to peak voltage. For Type II systems, the severity is additionally affected by the impulse voltage repetition rate and the fundamental voltage characteristics. After installation of the converter/machine system, it is recommended that the system integrator measures the phase to phase and phase to ground voltages between the terminals and ground to check for compliance.

IEC 60034-18-41

Type I insulation systems are dealt with in IEC 60034-18-41. These systems are generally used in rotating machines with rated voltage less than 700 V r.m.s. and tend to have random-wound coils. In IEC 60034-18-41, the necessary normative references and definitions are given together with a review of the effects arising from converter operation. Having established the technical basis for the evaluation procedure, the conceptual approach and test programmes are then described.

IEC 60034-18-42

In IEC 60034-18-42, tests are described for qualification of Type II insulation systems. These insulation systems are generally used in rotating machines which have form-wound windings, mostly rated above 700 V r.m.s. The qualification procedure is completely different from that used for Type I insulation systems and involves destructive ageing of test objects under accelerated conditions. The manufacturer requires a life curve (as described in IEC 60034-18-32) for the insulation system that can be interpreted by use of appropriate calculations and/or experimental procedures to provide an estimate of life under the service conditions with converter drive. Great importance is attached to the qualification of any stress control system that is used and testing here should be performed under sinusoidal and repetitive impulse conditions applied separately. If the insulation system can be shown to provide an acceptable life under the specified ageing conditions, it is qualified for use.

Indian Standard

ROATING ELETRICAL MACHINES

PART 18 PARTIAL DISCHARGE RESISTANT ELECTRICAL INSULATION SYSTEMS (TYPE II) USED IN ROTATING ELETRICAL MACHINES FED FROM VOLTAGE CONVERTERS

SECTION 42 QUALIFICATION TESTS

1 Scope

This part of IEC 60034 defines criteria for assessing the insulation system of stator/rotor windings of single or polyphase AC machines which are subjected to repetitive impulse voltages, such as those generated by pulse width modulation (PWM) converters, and are expected to experience and withstand partial discharge activity during service. It specifies electrical qualification tests on representative specimens to verify fitness for operation with voltage-source converters. It also describes an additional classification system which defines the limits of reliable performance under converter-fed conditions.

Although this document deals with voltage converters, it is recognised that there are other types of converters that can create repetitive impulse voltages. For these converters, a similar approach to testing can be used.

Qualification of insulation systems may not be required for rotating machines which are only fed from voltage converters for starting and so they are excluded from this document.

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 60034-1:2010, *Rotating electrical machines – Part 1: Rating and performance*

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

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*

IEC 60034-18-32, *Rotating electrical machines – Part 18-32: Functional evaluation of insulation systems – Test procedures for form-wound windings – Evaluation by electrical endurance*

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

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

IEC TS 61934, *Electrical insulating materials and systems – Electrical measurement of partial discharges (PD) under short rise time and repetitive voltage impulses*

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
partial discharge
PD
electric discharge that only partially bridges the insulation between electrical conductors

Note 1 to entry: It may occur inside or outside the insulation or adjacent to an electrical conductor.

3.2
partial discharge inception voltage
PDIV
lowest voltage at which partial discharges are initiated in the test arrangement when the voltage applied to the test object is gradually increased from a lower value at which no such discharges are observed

Note 1 to entry: With sinusoidal applied voltage, the PDIV is defined as the r.m.s. value of the voltage. With impulse voltages, the PDIV is defined as the peak to peak voltage.

3.3
repetitive partial discharge inception voltage
RPDIV
minimum peak to peak impulse voltage at which more than five PD pulses occur on ten voltage impulses of the same polarity

Note 1 to entry: This is a mean value for the specified test time and a test arrangement where the voltage applied to the test object is gradually increased from a value at which no partial discharges can be detected.

3.4
peak (impulse) voltage
U_p
maximum numerical value of voltage reached during a unipolar voltage impulse (e.g. U_p in Figure 1)

Note 1 to entry: For bipolar voltage impulses, it is half the peak to peak voltage.

3.5
steady state impulse voltage magnitude
U_a
final magnitude of the voltage impulse

SEE: Figure 1.

3.6
voltage overshoot
U_b
magnitude of the peak voltage in excess of the steady state impulse voltage

SEE: Figure 1.

3.7
peak to peak impulse voltage
$U'_{\mathrm{pk/pk}}$
peak to peak voltage at the impulse voltage repetition rate

SEE: Figure 2.

3.8
peak to peak voltage
$U_{\mathrm{pk/pk}}$
peak to peak phase to phase voltage at the fundamental frequency

SEE: Figure 2.

Note 1 to entry: The definition of peak to peak voltage is clarified in Clause 4.

3.9
unipolar voltage impulse
voltage impulse, the polarity of which is either positive or negative

Note 1 to entry: The term impulse is used to describe the transient stressing voltage applied to the test object and the term pulse is used to describe the partial discharge signal.

3.10
bipolar voltage impulse
voltage impulse, the polarity of which changes alternately from positive to negative or vice versa

3.11
impulse voltage repetition rate
f
average of the inverse of time between two successive impulses of the same polarity, whether unipolar or bipolar, in a considered set of pulses, for example for one period

3.12
impulse rise time
t_{r}
time for the voltage to rise from 10 % to 90 % of its final value

SEE: Figure 1.

3.13
electrical insulation system
insulating structure containing one or more electrical insulating materials together with associated conducting parts employed in an electrotechnical device

3.14
motorette
special test model used for the evaluation of the electrical insulation system for random-wound windings

3.15
formette
special test model used for the evaluation of the electrical insulation system for form-wound windings

3.16
electric stress
electric field in V/mm

3.17

rated voltage

U_N

voltage assigned by the manufacturer for a specified power frequency operating condition of a machine and indicated on its rating plate

3.18

impulse voltage insulation class for Type II insulation systems

IVIC

peak to peak voltage classes 1, 2, 3, 4, 5, 6, 7, S including certain time parameters for reliable operation, assigned by the manufacturer in relation to the rated voltage for a specified converter-driven machine and indicated in its documentation and, if applicable, on its rating plate

Note 1 to entry: The limits are shown as severity levels for which the machine has been qualified.

Note 2 to entry: The severity levels are to be shown in the documentation for the machine.

3.19

fundamental frequency

first frequency, in the spectrum obtained from a Fourier transform of a periodic time function, to which all the frequencies of the spectrum are referred

Note 1 to entry: For the purposes of this document, the fundamental frequency of the machine terminal voltage is the one defining the speed of the converter-fed machine.

Note 2 to entry: It is calculated as the reciprocal of the time taken for one complete cycle of the applied voltage (Figure 2).

3.20

impulse duration

interval of time between the first and last instants at which the instantaneous value of an impulse reaches a specified fraction of its impulse magnitude or a specified threshold

3.21

jump voltage

U_j

change in voltage at the terminals of the machine occurring at the start of each impulse when fed from a converter

SEE: Figure 3.

3.22

dc bus voltage

U_{dc}

voltage of the intermediate circuit of the voltage converter (dc-link-circuit)

Note 1 to entry: For a 2-level converter U_{dc} is equal to U_a in Figure 1.

Note 2 to entry: For a multilevel converter, U_{dc} is equal to ½ $U_{pk/pk}$ minus the overshoot in Figure 2.

3.23

power drive system

PDS

complete drive module and rotating machine together with the connecting cable if necessary

3.24

voltage endurance coefficient

n

exponent of the inverse power model or exponential model on which the relationship between life and stressing voltage amplitude for a specific insulation system depends

3.25
life
time to failure

3.26
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 of the coating is to prevent slot discharges from occurring.

3.27
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 grade the surface electric stress.

3.28
stress control system
generic name for the combination of the conductive slot coating and stress control coating in high-voltage stator bars and coils

3.29
maximum allowable peak to peak phase to ground voltage
U_{IVIC}
maximum allowable peak to peak phase to ground voltage in service, according to the IVIC-specification

3.30
test voltage factor
TVF
maximum allowable peak to peak operating phase-ground-voltages in units of U_{N}, divided by $2\sqrt{2}$

4 Machine terminal voltages arising from converter operation

The voltage appearing at the terminals of a converter-fed machine may be estimated using IEC TS 61800-8 [1][1] and depends upon several characteristics of the PDS. In order to apply this standard to the qualification and testing of the insulation system of a winding, it is necessary to specify the required parameters of the voltage appearing at the machine terminals (Clause 7).

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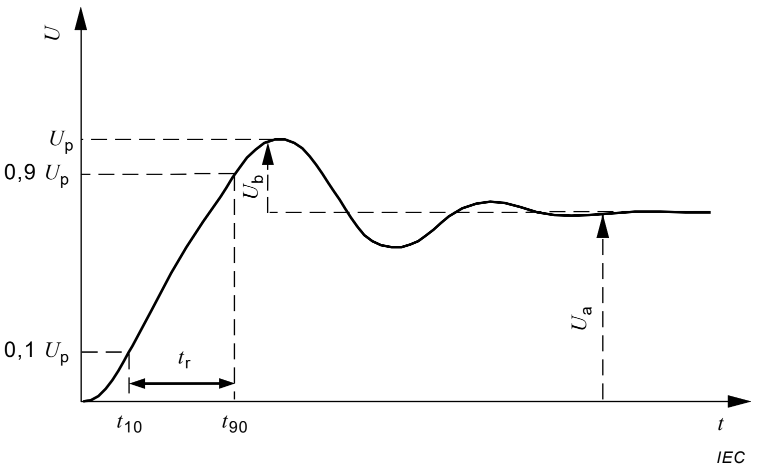
[1] Numbers in square brackets refer to the Bibliography.



Key

U voltage

t time

Figure 1 – Voltage impulse waveshape parameters

The amplitude and rise time of the voltage at the machine terminals depend upon the grounding system, various design aspects of the cable, the machine surge impedance and the presence of any filters that increase the impulse rise time. Examples of characteristics of converter impulses at the machine terminals of two motors are given in Table 1.

Table 1 – Examples of the measured values of characteristics of the terminal voltages for two converter-fed machines

Machine rating	3,3 kV	6,6 kV
Measured peak to peak voltage on the phase to ground insulation	7,9 kV	13,9 kV
Fundamental frequency	50/60 Hz	50/60 Hz
Impulse rise time at the motor terminals	1 µs	3 µs
Impulse repetition rate	1 kHz	900 Hz
IVIC required to qualify the insulation for this service (see Table D.2, column 2)	3	2

In the case of 2-level or other voltage converters, the impulses generate voltage overshoots at the machine terminals, depending on the rise time of the voltage impulse at the converter output and on the cable length and machine impedance. This voltage overshoot is created by reflected waves at the interface between cable and machine or converter terminals due to impedance mismatch. The voltage appearing at the machine terminals when fed from a 3-level converter is shown in Figure 2. The figure shows one cycle at the fundamental frequency.

The maximum change in voltage or jump voltage (U_j) at the impulse repetition rate is shown in Figure 3. This parameter is important in defining the voltage enhancement that can occur across the first or last coil in the winding. A fundamental frequent double jump transition (Figure 3, $U_{j\ max}$)) is possible and needs to be considered accordingly.

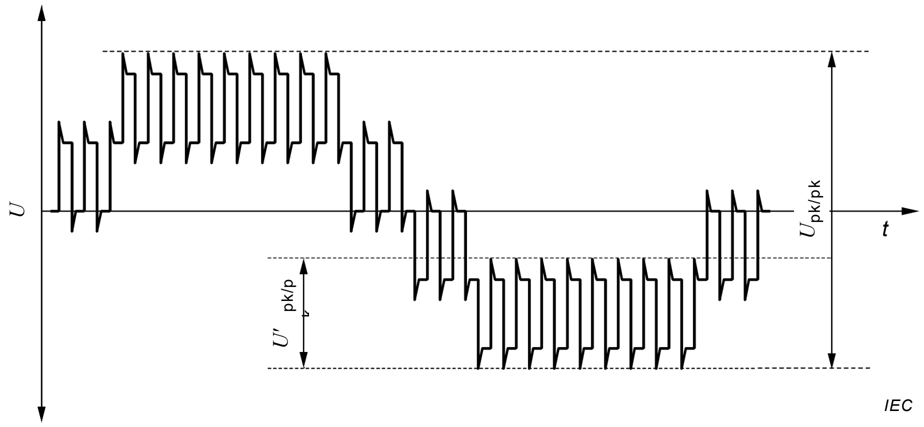


Figure 2 – Waveform representing one complete cycle of the phase to phase voltage at the terminals of a machine fed from a 3-level converter

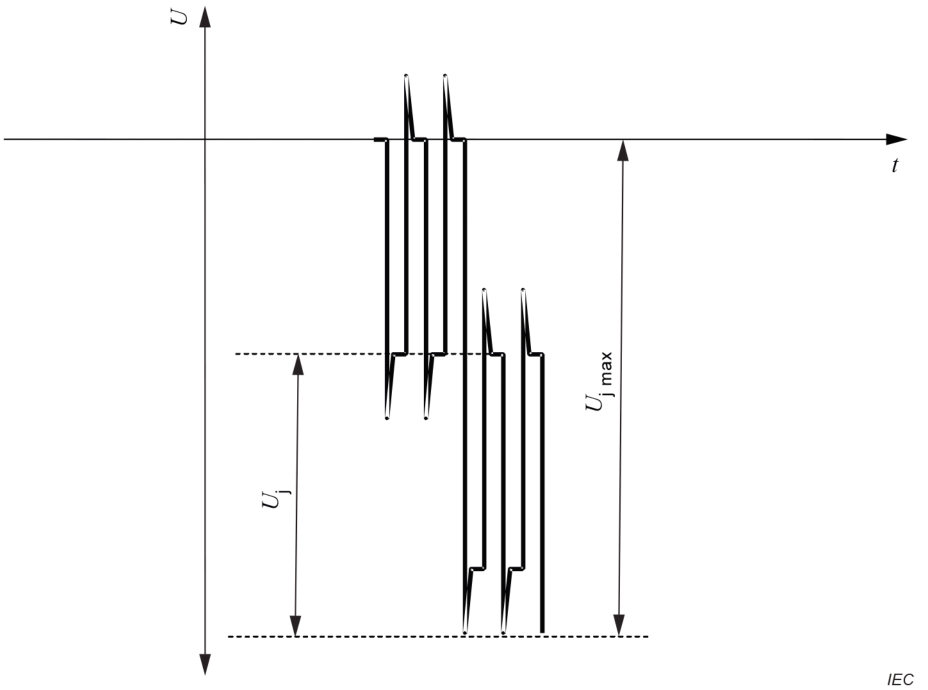
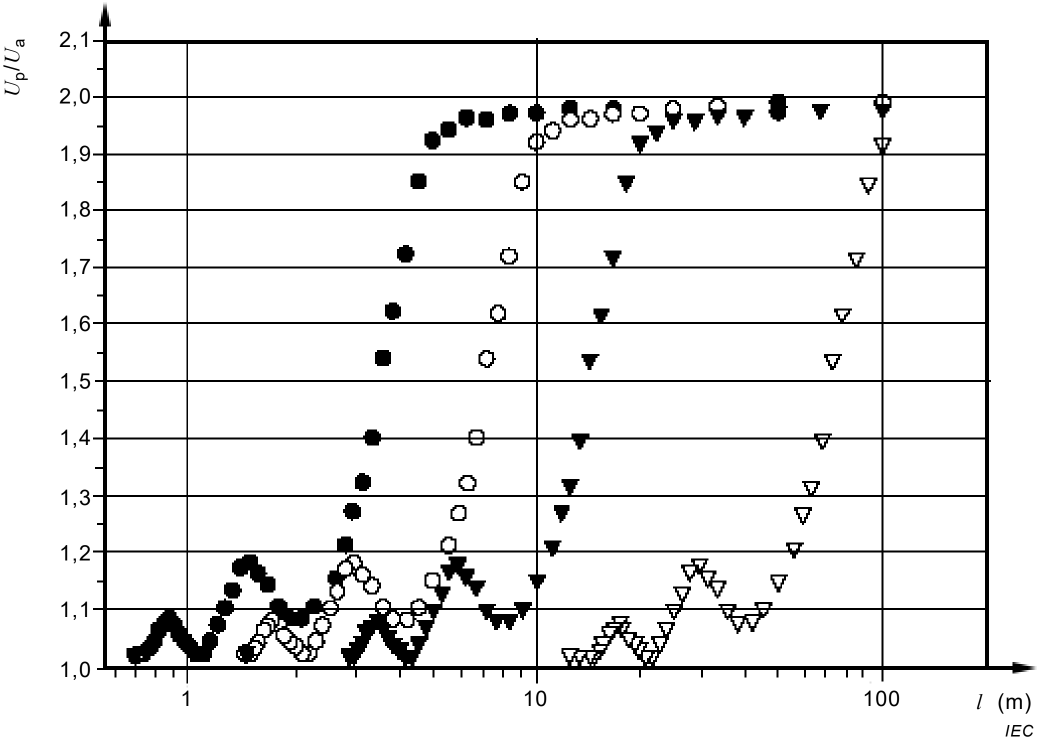


Figure 3 – Jump voltage (U_j or $U_{j\ max}$) at the terminals of a machine fed from a converter drive

Examples of the enhancements that are produced for various rise times and cable lengths are given in Figure 4, where the worst case is shown, arising from an infinite impedance load. In this case, the enhancement to the voltage for an impulse rise time of 1,0 µs is insignificant below about 15 m and only exceeds a factor of 1,2 when the cable length is greater than about 50 m.

Voltages above $2U_{dc}$ can be produced at the terminals of the machine by converter drive double transitions and by a converter-fed drive algorithm that does not allow a minimum time between successive pulses. Double transition occurs, for example, when one phase switches from minus to plus dc bus voltage at the same instant that another phase switches from plus to minus. This generates a $2U_{dc}$ voltage wave which travels to the machine and can then increase in magnitude when reflected at the machine terminals. If there is no minimum impulse time control in the converter drive and if the time between two impulses is matched with the time constant of the cable between the converter and the machine, an over voltage $>2U_{dc}$ can be generated at the machine terminals. The reflection can be reduced or prevented by using a filter in the converter, at the machine terminals or both.

In the event of an earth fault on one of the phases, further damage is avoided by protective systems in the converter that switch it off.



Key

● t_r 0,05 µs

○ t_r 0,1 µs

▼ t_r 0,2 µs

∇ t_r 1,0 µs

l cable length

Figure 4 – Maximum voltage enhancement at the machine terminals at infinite impedance as a function of cable length for various impulse rise times

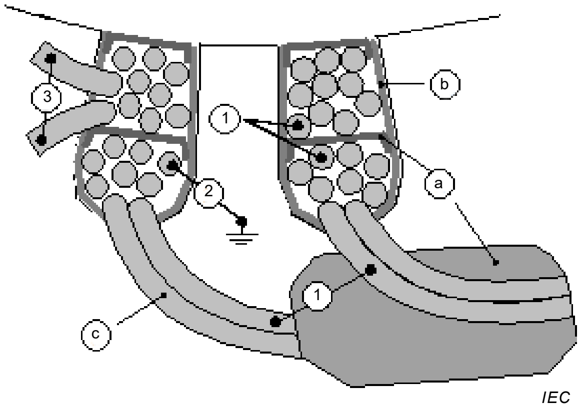
5 Electrical stresses in the insulation system of machine windings

5.1 General

If a winding experiences short rise time voltage impulses with significant magnitude, high voltage stresses will be created in the following locations (Figures 5 and 6):

- between conductors in different phases
- between a conductor and ground
- between adjacent turns, generally in the line-end coil
- in the area of the stress control coating

Due to space and surface charge creation within the insulation components, the electric stress is not only defined by the instantaneous voltage itself but also by the voltages that have been stressing the insulation previously. Generally, it has been shown by experience that, within certain limits valid for converter drive systems, the most significant stressing parameter is the peak to peak voltage. This is also the reason why a unipolar voltage produces the same stress as a bipolar voltage having a peak to peak voltage of the same value.



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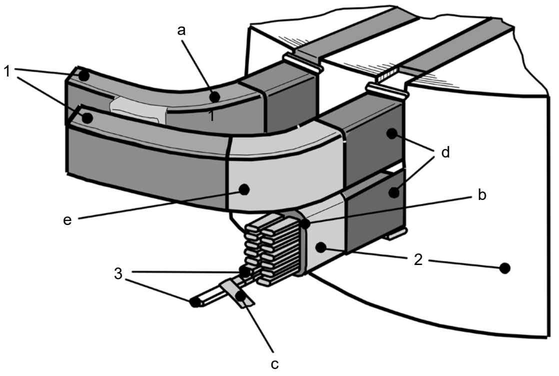

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Key

a	phase insulation/endwinding insulation	1	phase to phase
b	mainwall insulation	2	phase to ground
c	turn insulation	3	turn to turn
d	conductive slot coating		
e	stress control coating		

Figure 5 – Example of a random-wound design

Figure 6 – Example of a form-wound design

5.2 Voltages stressing the phase to phase insulation

The maximum voltage stress on the phase to phase insulation is determined by the design of the winding and by the characteristics of the phase to phase voltage.

5.3 Voltages stressing the phase to ground insulation

The maximum voltage stress on the phase to ground insulation is determined by the design of the winding and by the characteristics of the phase to ground voltage.

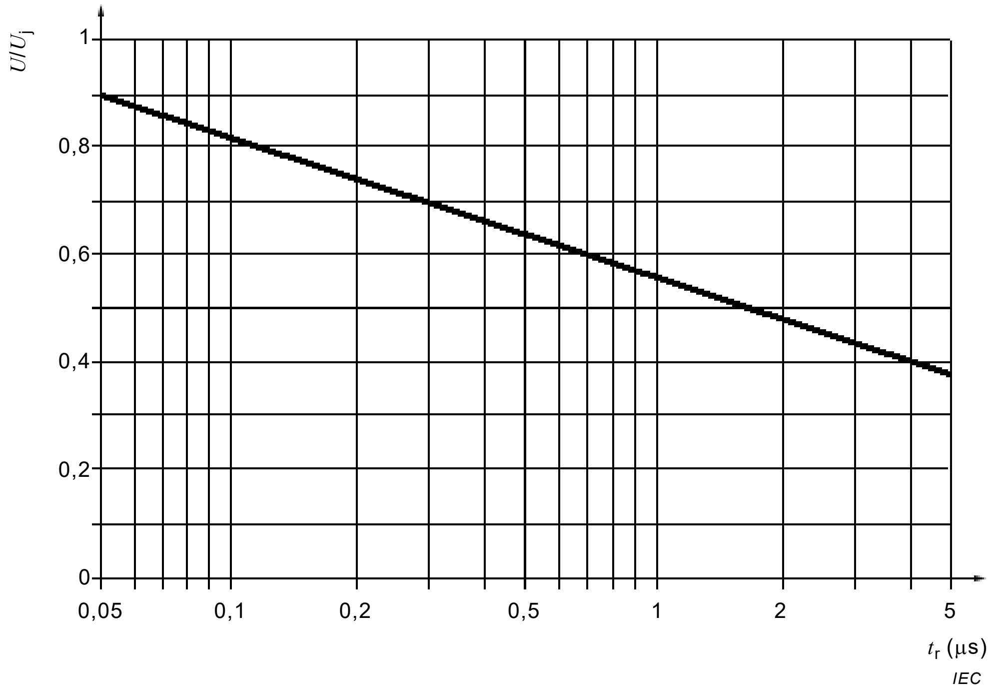
5.4 Voltages stressing the turn to turn insulation

5.4.1 General

The voltage stressing the turn insulation is determined by the jump values of the phase to ground voltage (amplitude and rise time) and by the type of winding, number of coils and the number and length of the turns. The distribution of the transient voltage depends upon the relative position of the individual turns in the slots. Short rise time impulses result in the voltage being unevenly distributed throughout the coils, with high levels of stress present across the first two turns or last two turns, depending upon the winding design. The jump voltage occurs at both the rising and falling edges of the phase to ground voltage. The turn to turn voltage exhibits the same effect at each edge where there is either a positive or a negative peak. If the distribution of voltage stressing the turn to turn insulation in a particular design of rotating machine is known, the manufacturer may use this information to calculate the fraction of jump voltage stressing the turn to turn insulation in the worst case. Otherwise, the fraction may be estimated according to 5.4.2 and 5.4.3.

5.4.2 Random-wound windings

In practice, the first and last turn can be adjacent to each other, in which case the turn to turn voltage can be almost equal to the voltage drop across the coil. Figure 7 shows the worst case voltage stressing the turn to turn insulation in a variety of stators as a function of impulse rise time. The voltage is shown as a proportion of the phase to ground jump voltage. The data has been obtained from a combination of figures provided in [2], [3] and [4] and may be used for guidance when the manufacturer has no other data available.



Key

U/U_j Fraction of jump voltage stressing the turn to turn insulation

t_r Impulse rise time

NOTE 1,0 is the peak phase to ground jump voltage at the machine terminals.

Figure 7 – Worst case voltage stressing the turn to turn insulation in a variety of random-wound stators as a function of the rise time of the impulse

5.4.3 Form-wound windings

There is insufficient data available at present to establish a figure for form-wound windings similar to Figure 7. If the voltage distribution is not known, the manufacturer shall provide assurance to customers by designing the coils so that, in the case of one-layer-coils, the turn to turn insulation can withstand the jump voltage divided by the number of turns in one coil. For multi-layer coils it is possible that the turn to turn insulation is stressed by as much as the complete jump voltage, depending upon the arrangement of the turns.

6 Voltage rating for Type II insulation systems

If any part of an insulation system is likely to have to withstand PD during its life, it is defined to be Type II and shall therefore contain materials that resist PD. Typically, machines with a rated voltage ≥ 700 V use Type II insulation systems although a significant number of machines rated < 700 V also use Type II insulation systems. Manufacturers usually assign a rated voltage to a machine based on power frequency. This assumes that voltage from the power supply is 50 Hz or 60 Hz sinusoidal. In the case of machines fed from converters, the conventional definition of voltage rating is no longer applicable, although the manufacturer may still assign a rated voltage for 50 Hz or 60 Hz operation and put it on the rating plate on the machine. The performance of the insulation system for converter operation should be defined using the stress factors under which its qualification was achieved. To assist the user of the rotating machine, an impulse voltage insulation class (IVIC) is defined in 3.18 for machines driven from converters. Severity codes for the IVIC are assigned in Annex D. For machines with no stress control coating on the endwindings, the IVIC is mainly dependent on the maximum allowable value of $U_{\mathrm{pk/pk}}$. In the case of machines with a stress control coating on the stator endwindings, the performance of the stress control system is also dependent on the impulse voltage repetition rate and the impulse rise time.

7 Stress factors for converter-fed Type II insulation systems

The PDS integrator shall specify to the machine designer the voltage that will appear at the machine terminals. This information shall be included in the purchase specification, in addition to the traditional parameters such as rated voltage, thermal class, humidity, etc. Specifically, the limiting values are to be defined for the following parameters of the voltage that appear at the machine terminals.

a) Fundamental frequency and impulse voltage repetition rate at the machine terminals.

b) Peak to peak voltages at the fundamental frequency and impulse voltage repetition rate as well as the jump voltages that are expected to occur at the machine terminals.

c) The impulse rise time.

Table 2 gives an indication of the significance of the features of the machine terminal voltage on the ageing of components of a Type II insulation system. In machines having Type II insulation systems, the mainwall, phase to phase and turn to turn insulation materials are generally based on combinations of organic and inorganic materials. For stators operating above 700 V, there may be a conductive slot coating present, which is designed to provide a grounded screen to the insulated stator winding in contact with the slot wall. The surface of the insulation on the conductor is subject to a stress concentration as it emerges from the slot. For higher voltage machines, it may be treated with a stress control coating to avoid the occurrence of surface arcing. These five components (turn to turn, mainwall, phase to phase, conductive slot coating and stress control coating) constitute a typical Type II insulation system. Phase to phase voltages are present, for example, where two coils are in contact in the same slot. However, if a conductive slot coating is present, the surface potential will be zero as it is at ground potential through the core. Similarly, where two layers of mainwall insulation exist, usually separated by an insulating spacer, the voltage stress is not considered to be of significant magnitude to merit testing of phase to phase insulation systems. No specific testing is therefore recommended for phase to phase insulation. It is recognised that there can be discharges and breakdown in the endwinding region but this is not covered in the qualification procedures described in this document. The insulation components assessed in qualification tests are shown in Table 2.

Table 2 – Influence of features of the converter drive voltage on acceleration of ageing of components of Type II insulation systems

Insulation component	Fundamental frequency	Impulse voltage repetition rate f	Peak to peak voltage at the fundamental frequency $U_{pk/pk}$	Jump voltage U_j	Peak to peak impulse voltage at the impulse voltage repetition rate $U'_{pk/pk}$	Impulse voltage rise time t_r
Turn to turn insulation	○	●	○	●	○	●
Mainwall insulation	●	○*	●	○	○*	○*
Stress control system	○	●	●	●	●	●

○ Less significant

● More significant

NOTE 1 Testing of the phase to phase insulation is not necessary.

NOTE 2 If there are 2 levels in the converter voltage, these parameters (*) can become significant.

For insulation systems designed to be used with a power frequency supply, the long-term effects of rated line-to-ground voltage across the mainwall insulation and along the length of the stress control coating are of principal concern. The turn insulation is generally specified by the maximum short rise time surge requirement of the design. Such surge events are generally of very short duration and are relatively infrequent compared to the impulse voltage repetition rate. For this reason, the acceptance requirements are generally satisfied by the ability of the mainwall insulation to endure a power frequency withstand test and the turn insulation to withstand a surge test. The ability of the system to meet the design life requirements is usually satisfied by longer-term voltage endurance testing with sinusoidal voltage. This endurance test allows the designer to establish the long-term capability of the mainwall insulation system.

In the case of converter-fed systems, the more complex voltage waveform produced by the converter drive will provide a different stress distribution in the winding. The mainwall insulation is affected by the magnitude of the voltage overshoot at the fundamental frequency. The stress control system is affected by the magnitude of the voltage overshoot (U_b) at the fundamental frequency and by the impulse voltage repetition rate (f). The latter factor may increase dielectric heating in the stress control system. Both parts of the voltage [5] therefore require consideration in the stress control qualification (see 13.4). The turn to turn insulation may be significantly stressed by the jump voltage (U_j) at the impulse repetition rate (f) but not by the fundamental voltage. As the rise time of the impulses decreases, the voltage stress usually increases on the insulation between adjacent turns on the line end coil of multi-turn coils, thereby producing significant overstress. Very short impulse rise times can affect the life of the turn to turn insulation and the mainwall insulation [6]. The latter is particularly affected if the converter has a small number of levels (e.g. two). However, as a first approximation, the rise time contribution to life reduction of the mainwall insulation can be neglected for long term ageing. The combination of these factors and their effect on the insulation system as a whole are difficult to quantify. Table 2 highlights the most important factors which contribute to accelerated ageing and therefore the assumptions which determine the following test procedures for insulation systems qualification.

8 Qualification tests

8.1 General

The electrical insulation system of a rotating machine to be fed from a converter drive is qualified and given an IVIC classification through testing of the mainwall insulation, the turn to turn insulation and the stress control system including its contact to ground. These three components of the overall insulation system are assessed separately. Each component will be defined by the manufacturer's unique design rules governing parameters, such as insulation materials, acceptable stresses, stress control system, application techniques, processing routes and dimensional guides. It is these design rules that are being qualified. For qualification of the mainwall insulation in Type II systems, form-wound coils or bars are subjected to accelerated electrical ageing to determine an electrical life curve. For random-wound machines, motorettes or complete windings are used. For turn to turn insulation, specimen bars or coils with parallel conductors are used to obtain a life curve. Qualification testing is based on the premise that the principal cause of electrical ageing, leading to premature failure, is partial discharge activity and so all tests shall be performed above the PDIV. In general, testing is permitted using sinusoidal voltages. Separate tests involving impulse and sinusoidal voltages are carried out for the stress control system.

8.2 Qualification tests

These tests are based on the general procedures for functional evaluation of insulation systems described in IEC 60034-18-1, according to which the insulation system intended to be used under converter conditions (candidate system) is compared to an insulation system which has given satisfactory service experience (reference system).

For Type II insulation systems, the qualification of the mainwall and turn insulation systems is achieved through voltage endurance testing at room temperature or at elevated temperature according to IEC 60034-18-32. For simplicity, the voltage endurance testing of the turn and mainwall insulation may be performed with sinusoidal voltage. This simplification ignores the fact that the occurrence of PD and thus its effect on the ageing rate is influenced by the rise time of the impulses [6,7,8]. Performing life tests under impulsive voltage waveform, at the appropriate frequency, is recommended when feasible.

By using different sinusoidal over-voltages or frequencies, a life curve may be established. Note that interactive ageing mechanisms between turn and mainwall insulation are ignored in this document. On the basis of the following assumptions, the life of an insulation system under impulse conditions may be estimated from a life curve derived from sinusoidal voltage testing.

a) The ageing rate due to impulse and sinusoidal voltages is the same, provided the peak to peak values and the number of voltage cycles are the same.
b) The voltage endurance coefficient (n) is not frequency dependent below 1 kHz [9].

The lifetime of the mainwall insulation is generally dominated by the peak to peak magnitude and repetition rate of the fundamental voltage. For 2-level converters, the mainwall insulation is stressed principally by $U'_{\text{pk/pk}}$ at the impulse voltage repetition rate. The balance of ageing between these two contributions may be calculated using expressions which are detailed in Annex A.

Qualification of the stress control system is undertaken through an ageing test in which a representative specimen of the insulated winding in a simulated slot is exposed separately to impulse voltage and sinusoidal voltage stresses similar to those expected in service to determine if visible damage occurs, such as significant discolouration or burning.

An IVIC rating may be obtained after satisfactory service experience with a converter-fed supply. The way in which this is derived is explained in Annex E.

9 Qualification of mainwall insulation system

9.1 General

Acceleration of the ageing process that leads to electrical failure will be a desirable feature of the test method used. Care should be taken to avoid introducing a failure mechanism that would not be present in service, for example, by testing above the PDIV. Where acceleration is produced by an increase in voltage excursion (peak to peak), the technique may change the level of partial discharge activity occurring within each impulse. Alternatively, the repetition frequency of the test voltage may be increased to a level above the fundamental frequency of the PDS in service. This is intended to retain the partial discharge activity level and achieve acceleration through an increased repetition rate. In this approach, there may be an increase in heating of the insulation due to frequency dependent losses in the material and the stress control coating. The temperature can be reduced by forced air cooling. Localised hot spot temperature measurements are required in the region where stress control coatings are used to ensure that the insulation material does not exceed the assigned temperature for its thermal class.

Temperature monitoring may be performed using any convenient technique. Temperature sensitive paints or films are simple but not very accurate, while thermocouples may have electromagnetic pick-up and HV isolation difficulties. A non-invasive measurement technique, such as infrared thermography, enables surface hot spots to be identified and quantified simply. Hot spots can limit the operating conditions for the machine. Monitoring of the ageing process can be performed at appropriate intervals by measuring electrical parameters, such as partial discharge activity, loss tangent and permittivity. These tests may be performed at 50 Hz or 60 Hz for diagnostic purposes.

9.2 Test methods

Accelerated voltage ageing shall be performed according to IEC 60034-18-32. Further background information may be found elsewhere [10]. The qualification technique is based on a comparison of life tests performed on the candidate system and on a reference system, already assessed for service life. A commonly used electrical life model is

$$L = \mathrm{k}U^{-n} \tag{1}$$

where

n is the voltage endurance coefficient;

L is the life of the test object;

U is the applied periodical peak voltage, and

k is a constant.

The qualification technique requires testing at three or more over-voltages to enable a graph of log (mean time to failure) to be plotted against log (normalised mainwall electric stress). If power frequency voltages (50 Hz or 60 Hz) are used, the intended mean time to failure at the highest voltage should be about 50 h and at the lowest voltage above 5000 h. The candidate and reference systems should be tested under the same conditions, which may involve any prescribed voltage waveform. Statistical analysis should be performed according to the procedures given in IEC 62539 in order to establish the mean life under each test condition. The voltage endurance coefficient is the slope of the regression line. The life line of the candidate insulation system should be at least equivalent to that of a reference system tested at the fundamental frequency or corrected to the fundamental frequency which has been shown to give a service life acceptable to the customer. The acceptance criteria are explained in IEC 60034-18-32 and IEC 60034-18-1. If the data points do not fit a straight line on the log-log coordinate system, this usually indicates that the ageing mechanism has changed within the test stress range. The straightness of the line may be checked by using the R2 (squared) linearity test with a pass criterion of >95 % recommended. If the line fails to achieve this, an extra ageing point is recommended.

For mainwall and turn insulation, publications show that the number of voltage cycles to failure is essentially independent of the applied voltage frequency [6,9,11]. In many cases, therefore, the following formula can be used to calculate the expected life for a given peak voltage.

$$L_2 = L_1 f_1 / f_2 \tag{2}$$

where

L_2 is the life at frequency f_2;

L_1 is the life at frequency f_1.

Combining the frequency and voltage dependent ageing formulae leads to the general expression

$$L_{\mathrm{f2,u2}} = L_{\mathrm{f1,u1}}(U_1/U_2)^{\mathrm{n}}(f_1/f_2) \tag{3}$$

where

$L_{\mathrm{f2,u2}}$ is the life at frequency f_2 and voltage U_2, and

$L_{\mathrm{f1,u1}}$ is the life at frequency f_1 and voltage U_1.

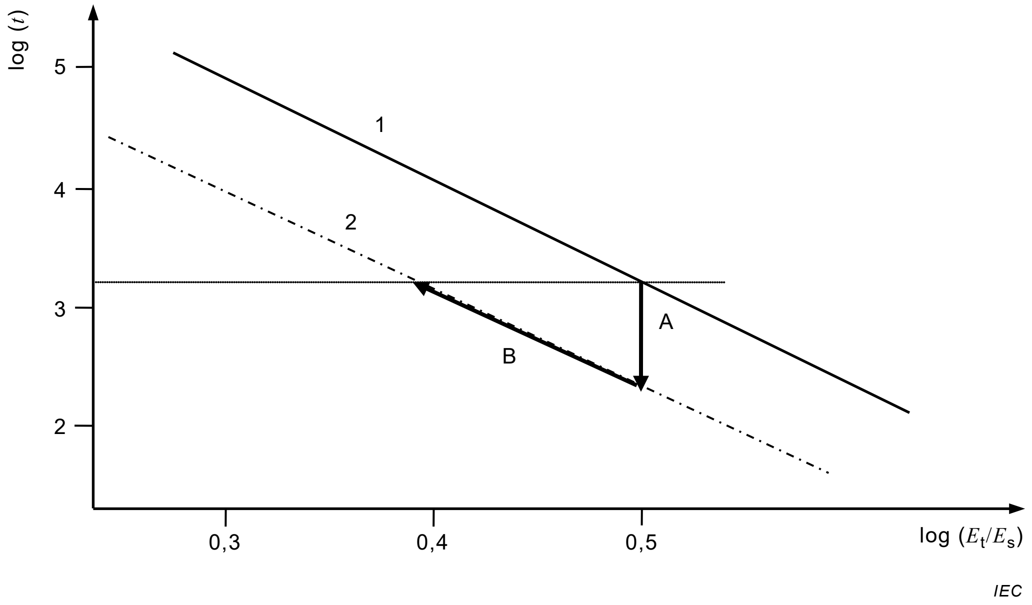
Using formula (3), testing at different frequencies and voltages is generally permitted for mainwall insulation. Experimental evidence exists to support the validity of this approach in calculating life under sinusoidal and impulse voltages at least up to 1 kHz [9]. For the case of a multilevel converter, the dominant factor in ageing under electrical stress is the peak to peak voltage at the fundamental frequency ($U_{\mathrm{pk/pk}}$). The effect of frequency is to increase or decrease life in proportion to the fundamental frequency. For mica-based insulation, which generally has a large voltage endurance coefficient and is used in combination with a multilevel converter drive, the effect of the impulse voltage (U_{j}) on electrical ageing of the mainwall insulation is insignificant compared to $U_{\mathrm{pk/pk}}$ [7].

9.3 Use of 50 Hz or 60 Hz life data to predict the service life with a converter drive

A typical life curve for a Type II insulation system derived from 50/60 Hz voltage endurance testing is shown in Figure 8. The log (mean time to failure) is plotted as a function of log (normalised mainwall electric stress) for the mainwall insulation on a stator bar or coil. The life line is usually straight [8] and the manufacturer is required to know from service experience that it represents a design that will provide a service life under the operating conditions which is acceptable to the customer. For converter-fed machines, the electrical stress is calculated on the basis of the peak to peak voltage occurring in service across the mainwall insulation ($U_{\mathrm{pk/pk}}$). Only one IVIC may be attributed to a machine and it is a requirement that the application for which qualification has been achieved is declared in the documentation of the machine. For example, some applications may only need a reduced life compared with an industrial application.

The effect of voltage frequency on life is to increase or decrease it, as shown in formula (2). If it is expected that the same insulation system may be subjected to a fundamental frequency which is, for example, 10 times greater than that used to derive the curve, the appropriate life curve for this operating condition is obtained by shifting the line downwards by one decade in time, as shown by arrow A in Figure 8. The manufacturer can then compensate by reducing the electric stress on the mainwall insulation to move up this line and thereby restore the life to the original value (arrow B). Alternatively, if the operating frequency is one tenth of that used to derive the life curve, the line will be shifted upwards by a decade in time and the stress may be increased to restore the life to the original value.

The manufacturer shall assess the insulation and may decide that no compensation is required. In this case, a technical justification shall be given in the machine documentation to support the decision. If compensation for a change in lifetime is required, the design of the insulation shall be modified. If a change in the expected lifetime is appropriate, the manufacturer is permitted to move the reference life line in Figure 8. For example, a reduction in the expected life time by a factor of 10 would result in a movement downwards of the line by one decade in a direction parallel to the time axis as shown by arrow A.



Key

E_t Electric stress at the peak to peak test voltage

E_s Electric stress at the peak to peak service voltage

t time to failure in hours

1 Life curve derived from power frequency endurance testing

2 Life curve predicted for the same insulation at x10 frequency

Figure 8 – Example of a life curve for a Type II mainwall insulation system

The qualification test pass criteria are applied after the changes to the reference life line have been made. This procedure shall be recorded in the documentation.

10 Qualification of turn insulation

10.1 General

The turn insulation in the coils of a machine winding operating from a sinusoidal power supply is generally specified according to the requirement to withstand discrete voltages of high magnitude and short duration. The concerns governing turn insulation design are distinct from those for the mainwall insulation. The materials, dimensions and processes used in the construction of turn insulation may be different from those of the mainwall insulation.

The principal features of the applied voltage in regard to ageing of the insulation between turns are the impulse voltage repetition rate, the magnitude of the jump voltage and the impulse rise time (which determines the distribution of jump voltage in the windings). The direct influence of the impulse rise time on ageing of the turn insulation is neglected in this document. When regarded as part of the overall coil design for the winding, the turn insulation also forms part of the mainwall insulation and contributes to the ageing curve described in Clause 9.

In the majority of sinusoidal voltage applications, the insulation between turns will not be stressed significantly during service. Its principal role is to withstand occasional voltage surges or similar events. However, as the rise time of the impulses decreases, the electric stress associated with the jump voltage begins to shift to the regions between turns, particularly at the small radius of curvature on the edge of the turn insulation. This can cause thermal and electrical ageing of the turn insulation in service. The stress between turns intensifies with decreasing rise time, increasing the probability of partial discharges between turns. The effect of the expected phase to ground voltage on the turn insulation will also be dependent on the number of turns in the coil and the number of coils in the phase. In line-fed operation, high voltage impulses are produced as a result of current breaker operations. The turn insulation will not age electrically in line-fed operations but it may in converter operations, due to the high impulse voltage repetition rate. In general, experience indicates that the stress intensification is greatest between the first two or last two turns in the line-end coil but it may be possible for waveform reflection to initiate ageing at sites further into the winding.

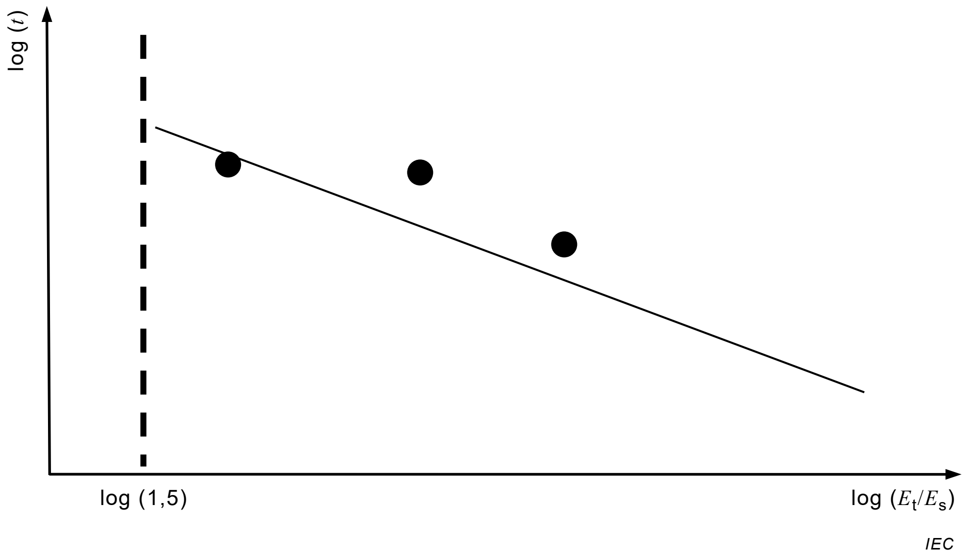
10.2 Test methods

The purpose of testing is to show that the electrical life of the turn insulation provides a life in service which is acceptable to the customer. It is expected that the manufacturer will know the maximum peak to peak voltage to appear between turns in a particular service application. The worst case insulation stress (depending on winding and coil design) shall be chosen. If the maximum peak to peak voltage between turns in service U_{turn} is unknown, it shall be assumed that the complete jump voltage falls across the first coil, and so the amplitude of U_{turn} is the jump voltage divided by the number of turns (for one layer coils) or calculated according to the arrangement of turns (for multilayer coils). The peak-peak turn-turn voltage is normally twice the amplitude –if the rise time and the fall time of the jumps are usually the same.

A partial discharge test is first made according to IEC 60034-27 using sinusoidal voltage or to IEC TS 61934 using the impulse rise time expected in service. The measurement is made across each pair of parallel adjacent conductors. Coil size can influence whether an impulse test voltage gives a higher or lower RPDIV than a PDIV with sinusoidal voltage. If no PD is detected above the noise level in the turn to turn insulation at 1,5 U_{turn} no further testing is required and the turn insulation is deemed to be qualified. The control, acceptance value and reporting of background noise level are detailed in IEC TS 61934, IEC 60034-27 and IEC 60034-18-41.

The safety factor of 1,5 arises from two contributions. Firstly, there is a need to allow for the effect of temperature, thermal ageing and the hysteresis effect between PD inception and extinction voltages which, according to IEC 60034-18-41, accounts for a factor of at least 1,25. Secondly, long term thermo-mechanical ageing is allowed for by an additional factor of 1,2, thereby making a combined safety factor of 1,5. Thermo-mechanical ageing affects the PD inception voltage, even if research indicates that there is no life time reduction. However, this test is not concerned with the effect of ageing on life time but passing the PD test and the effect on PDIV. If the factor of 1,2 is in doubt, it should be confirmed or dismissed by undertaking a test according to IEC 60034-18-31.

Detection generally requires the PD level to exceed the noise level and so it is important that the background noise is low enough at the test voltage to detect PD. Special care is needed where the parallel turns exit the coil to ensure that corona discharge does not occur here. If PD is detected below 1,5 U_{turn}, a voltage endurance test shall be performed according to 13.3. The criteria for PD inception are described in the documents referred to above. A graph can then be plotted showing log (mean time to failure) of the turn to turn insulation as a function of log (normalised electric stress) as in Figure 9. The normalised value is the test value divided by the estimated service value.



Key

E_t Electric stress at the peak to peak test voltage

E_s Electric stress at the peak to peak service voltage

t time to failure

——— Life curve for turn insulation

▬ ▬ ▪ PD inception

Figure 9 – Example of a life curve for turn insulation

If the life line has not been obtained at the impulse voltage repetition rate, it is corrected by shifting the line as described in 9.3. For example, a life test at 50 Hz shall be corrected for an impulse voltage repetition rate of 1 kHz by shifting the life line downwards, parallel to the time axis, by a factor of 20. The corrected line is then compared with the reference life line for the turn insulation previously obtained by the manufacturer. It is likely that the life line for the turn insulation under converter operation will show shorter lives since the service stress will be significantly larger than the maximum voltage that would be present for power frequency operation of the machine. The manufacturer shall compensate by reducing the turn insulation electrical stress, in order to restore the original intended life, or agree to a reduced life with the customer. In the absence of reference life line, the manufacturer should refer to E.1.2.

11 Qualification of the stress control system

11.1 General

If a stress control coating is to be applied to the endwindings, it will be necessary to qualify it. For this purpose, similar voltages, frequencies and repetition rates to those appearing in service are required. The materials, if based on semi-conductive components such as silicon carbide, have a non-linear resistivity. Their field controlling ability is influenced by frequency, electric stress, temperature and time. In other cases, the stress control may be achieved by capacitive means. For test purposes, the peak to peak voltage, the repetition rate and the impulse rise time are chosen by the manufacturer to ensure that the expected conditions in service are matched or exceeded in severity.

The effect of increasing frequency is to shorten the distance over which the surface electric stress on the endwinding is graded and thereby result in elevated stresses. When these stresses exceed 600 V/mm [12], arcing activity can occur which erodes the surface or produces tracking (conductive carbonaceous paths).

The effect of increased electric stress is to reduce the resistivity of the stress control coating, thereby fulfilling its primary purpose. The effect is also to increase the heat generation. For converter-fed machines, there is a conflict between providing a low enough resistivity to grade the voltage and a high enough resistivity to keep the heat generation within acceptable limits. A surface temperature rise in the endwinding region may be as little as 10 K or as high as 40 K for a converter-fed machine where there is no forced cooling. The dominant influence on the temperature of the insulation is expected to be the heating from the copper losses but the self-heating of the stress control coating can make a significant contribution. When assessing the limiting temperature at which the machine can operate, it is necessary to take account of this factor as it effectively reduces the rated temperature of the machine.

In the case of non-linear stress control coatings, there are two principal effects of temperature [13]. The first is an immediate increase in the conductivity of the material at a particular voltage stress. The second principal effect is of similar significance and is the reduction in slope of the conductivity/electric stress curve on which effective performance of the silicon carbide-based stress control coating depends. In some cases the non-linearity of the conductivity may be lost altogether.

The second effect may be a permanent reduction in conductivity from this temperature excursion. After a single short-term period at 155 °C for as little as a few hours, a return to 20 °C can show a significant reduction in conductivity. After a longer period at 155 °C, such as 500 h, the stress control coating performance may be partially restored. This is attributed to post-curing of the resin in the stress control coating that shrinks and binds the silicon carbide particles closer together.

The conductive slot coating is used to prevent slot discharges and may be based on carbon loaded tapes or paints. At the beginning of the endwinding region, there may be problems with the electrical contact to the stress control coating. Where a good electrical contact is required in the design, a high contact resistance can result in overheating and discharge activity, which can degrade the materials and reduce the performance of the stress control system on the endwindings. Where capacitive coupling is used, no direct connection is required between the conductive slot coating and the stress control coating.

Design of the stress control system is a crucial element in meeting the qualification test pass criteria in 13.4 and 14.3. The governing factors influencing the design are the choice of materials and the application technique.

11.2 Test methods

The aim of qualification testing of the stress control system is to provide assurance that it will operate satisfactorily for the required service life. A satisfactory performance in service is one in which surface arcing is avoided and the temperature rise on the surface of the endwinding does not raise the mainwall insulation above its assigned temperature limit.

The three major influences on the life of the stress control system are the magnitude of the applied voltage, its frequency and the temperature. Ideally, a test is required in which specimen coils or bars, prepared to production standard, are arranged in simulated slots and subjected to a converter voltage which is 1,3 times the magnitude of the voltage to be withstood in service. In practice, it is likely that a suitable converter is unavailable and so an alternative endurance test is provided in which voltage impulses and a power frequency voltage are applied separately. The specimens and slots may be shorter than in the service machine in order to reduce the capacitive load on the impulse generator. However, they should replicate important design features.

The cost of laboratory equipment to provide the required HV impulses may be significant. A proposal is made for two simple test circuits which experience has shown can quickly reveal deficiencies in a stress control system. They avoid the need for a commercial converter drive and are based on an impulse repetition circuit using a semiconducting switch. The two examples of circuits and typical associated waveforms are shown in Annex B.

12 Preparation of test objects

12.1 General

The test objects in this clause are for qualifying the performance of the insulation components described in Table 2 and shall be made according to the full manufacturing specification for a production machine.

12.2 Mainwall specimens

To qualify the mainwall insulation to be used in the stator, testing of coils or bars, built to production standards and fitted into representative slots, is undertaken.

12.3 Turn to turn specimens

The turn to turn specimens shall reproduce the insulation system used in the machine in terms of materials and manufacturing procedure, with each one containing one or more pairs of parallel conductors. Specimens shall consist of coils or bars (for form-wound windings) or motorettes/complete windings (for random-wound windings) made to production standards. PD activity between the parallel turns at the exit from the coil or bar may be reduced or avoided by the insertion of felt between the turns where they separate, to absorb the impregnating material.

12.4 Stress control specimens

To qualify the stress control system to be used, testing of coils or bars, built to production standards and fitted into representative slots, is undertaken. The slots shall be equipped with heaters for the heating of the straight part to service temperature. Heating may be produced by passing current through the conductors. In order to reduce the capacitive load on the test supply, the specimens and slots may be of reduced length but the specimens shall otherwise be manufactured in the same way as the coils or bars used in service. Supplemental heating by thermostatic chamber or other heating devices may be applied for the stable heating. Supplemental heating temperature should be below the operating temperature of stator coils – see Clause 7.

13 Qualification test procedures

13.1 General

It is not practicable to design a single test method that simulates all the interactions between the various insulation components shown in Table 2. For example, to obtain a life curve for the mainwall insulation system by applying over-voltages would subject the stress control coating to excessive stress. Qualification has therefore been divided into separate test procedures. In all cases, the power supplies shall be chosen to provide the required voltage, repetition rate and rise time at the specimen terminals.

The aim is, firstly, to establish the life curves of the mainwall and turn insulation from which the expected lives may be calculated when the machine is driven from a converter supply in service. It is recognised that PD activity may take place between the turn and mainwall insulation. Since the phase to ground insulation includes the turn insulation, the qualification procedure includes this interactive effect. Ageing is performed by the application of electric stress at an elevated voltage or frequency or both. The voltage waveform used for ageing may be sinusoidal or impulsive in the case of turn to turn or mainwall specimens. The end-point is to be electrical breakdown of the insulation. There shall be a sufficient number of specimens to achieve a statistically valid outcome to the test. The second aim is to establish that the stress control system is suitable for service. Testing is undertaken using impulse and sinusoidal voltages separately.

13.2 Mainwall insulation

The purpose of the test is to qualify the mainwall insulation of the candidate insulation system. This is performed by establishing the life curve for the mainwall insulation using elevated voltage. Testing is performed according to IEC 60034-18-32 where the parameter to be used on the horizontal axis is the log of the electric stress at the peak to peak test voltage divided by the electric stress at the peak to peak service voltage, as shown in Figure 8. The value of U_s to be used on the horizontal axis in Figure 8 is derived from the rated voltage for the machine multiplied by the enhancement factor in column 1 of Table D.2 for which qualification is required. The electric stress at the service voltage, E_s, is obtained by dividing U_s by the wall thickness. In the case of mainwall insulation fed from a 2-level converter drive, there may be little or no difference between peak-peak values of U an U'. In this case, U' and the impulse voltage repetition rate are to be used instead of U in Table D.2, column 1.

At least three voltages shall be selected and the end-point is when electrical breakdown of the insulation takes place. At least seven separate bars or coil legs shall be tested at each voltage, using pass criterion a) or b) (see 14.1 below). If pass criterion c) is to be applied, at least four separate bars or coil legs shall be tested at each voltage. The life line for the candidate insulation system is compared with the reference life curve, i.e. one that has been derived from an insulation system that has been shown to provide an acceptable service life at the fundamental frequency (IEC 60034-18-1). The reference life line may have been obtained from satisfactory service life under converter drive.

It is recognised that, where a stress control system is in use on endwinding insulation, it may be subjected to an unacceptable severity during life testing of complete coil systems at elevated voltages. For this reason, the coils may be tested with any stress relieving measure, such as stress cones or additional layers of insulation, in order to ensure that failure occurs only in the mainwall insulation. The stress control system may be repaired during the test period.

13.3 Turn to turn insulation

A partial discharge test is first made on at least five specimens with a sinusoidal voltage, according to IEC 60034-27. Alternatively, the test may be performed according to IEC TS 61934 using an impulse voltage rise time as short as the value expected in service and generally as described in 9.2 of IEC 60034-18-41:2014. The test equipment shall be able to detect PD below the test value. This may be achieved by using test equipment where the background noise is severely attenuated by using signal processing, which is able to separate noise from PD. If the turn to turn insulation is PD free at a peak to peak voltage of 1,5 U_turn on all specimens, no further testing is required and the turn insulation is deemed to be qualified. If PD is detected below this value, a voltage endurance test shall be performed at room temperature. It shall consist of applying a sinusoidal voltage between each pair of parallel conductors in the test specimen until electrical breakdown occurs. The number of test voltages shall be at least three and the preferred peak to peak test voltages are 4,5 U_turn, 4,0 U_turn and 3,5 U_turn. Five specimens shall be tested at each voltage. The time to failure may be calculated using any commonly used statistical methods (see IEC 62539) involving Weibull statistics. A graph shall then be plotted showing the time to failure of the turn to turn insulation as a function of normalised test electric stress, as shown in Figure 9. If power frequency is used for the endurance test, the life will be shorter with a convertor, since the turn insulation is aged by the impulse voltage repetition rate. The candidate life line shall be corrected by the ratio of the impulse voltage repetition rate reported in the documentation for column 4 of Table D.2 to the power frequency used in the ageing test. The correction shall be applied according to Formula 2 before comparison with the reference life line. The normalised value is the test value divided by the estimated service value (i.e. U_turn).

13.4 Stress control system

Where a stress control coating is to be used in the region of the endwinding, specimens shall be made according to the requirements of 12.4 and each one mounted in a representative or simulated grounded slot. The specimen is then subjected to a three part sequential test regime at the expected service temperature. The first part is a 100 h impulse voltage endurance test performed with a peak to peak voltage equal to the maximum jump voltage experienced in service multiplied by a safety factor of 1,3. The rise time of the impulses shall be at least as short and the repetition rate at least as large as the values expected in service. If the impulse voltage parameters in service are unknown, default values of 1 kHz to 1,5 kHz repetition rate and 0,5 µs to 1 µs rise time shall be used. The second part of the test is a 1000 h endurance test with sinusoidal voltage at the fundamental frequency expected in service. The voltage level shall be the maximum peak to peak phase to ground voltage experienced in service multiplied by a safety factor of 1,3. The equivalent r.m.s. voltage is calculated by dividing by $2\sqrt{2}$. In the third part of testing, the first part shall be repeated. At least three specimens shall be tested.

14 Qualification test pass criteria

14.1 Mainwall insulation

Comparison between the candidate and reference life lines shall be at the same frequency. Any corrections for a different frequency used in testing shall be undertaken according to 9.3 before the comparison is made. The mainwall insulation is qualified according to IEC 60034-18-32 if

a) the upper 90 % confidence limit of the candidate system life line exceeds the upper 90 % confidence limit of the reference mainwall insulation life line over the same test voltages; or

b) the lower 90 % confidence limit of the candidate system life line exceeds or is equal to the lower 90 % confidence limit of the reference mainwall insulation life line at the lowest test voltage and the slope of the regression line of the mean values of the candidate system life line is steeper than that of the reference mainwall insulation life line (i.e. the value of n for the candidate system is greater than for the reference system);

c) if there are no confidence intervals available from the reference system – for example the reference line in Annex E – the pass criterion for the candidate system shall be that not more than one of the specimens at each voltage has a lifetime less than indicated by the reference line (see E.1.1). If one sample of the four falls below the reference line, then at least two more specimens have to be tested and pass. [15]

14.2 Turn to turn insulation

If the application of 1,5 U_{turn} between conductors does not give rise to partial discharge activity in any of the five specimens tested, the insulation is deemed to be qualified. If PD activity is detected at the test voltage in one or more specimens, qualification of the insulation is assessed by comparison of the life line with that obtained for the reference turn insulation system as defined in IEC 60034-18-32. The comparison is performed at normalised service field stress with any corrections for frequency made beforehand so that the comparison is made at the same frequency. The turn insulation is qualified if

a) the upper 90 % confidence limit of the turn to turn life line exceeds the upper 90 % confidence limit of the reference turn insulation life line over the range of turn to turn insulation test voltages, or

b) the lower 90 % confidence limit of the candidate turn to turn life line at the lowest test voltage exceeds or is equal to the lower 90 % confidence limit of the reference life line and the slope of the regression line of the mean values of the candidate turn to turn insulation life line is steeper than that of the reference turn insulation life line (i.e. the value of n for the turn to turn insulation is greater than for the reference insulation system).

14.3 Stress control system

No partial discharge activity shall be visible to the unaided eye (i.e. without the aid of a microscope or magnifying glass) in a dark room or by a UV detector during the final stage of testing with impulse voltages. No significant deterioration of the stress control coating or conductive slot coatings shall be visible by the unaided eye on the outer surface of the endwinding after the final stage of testing.

15 Routine test

A mandatory voltage withstand test is required according to IEC 60034-1. This withstand test may be at an increased voltage level for converter-fed machines, according to the specified IVIC, as described in Clause D.1. The results of any routine test that is undertaken shall be reported in the documentation for the machine.

16 Optional screening tests

Optional screening tests are described in Annex F. The results of any screening test that is undertaken shall be reported in the documentation for the machine.

17 Analysis, reporting and classification

The approach given in 6.2 of IEC 60034-18-1:2010 to analysis, reporting and classification shall be adopted so that all relevant data is analysed correctly and reported in a traceable manner.

Annex A

(informative)

Contributions to ageing of the mainwall insulation

A.1 Life time consumption of the mainwall insulation

Under converter operation, the insulation system is stressed by a complex voltage (Figure 2) consisting of the peak to peak impulse voltage ($U'_{\mathrm{pk/pk}}$) at the impulse repetition rate and the peak to peak voltage ($U_{\mathrm{pk/pk}}$) at the fundamental frequency. For a multilevel converter, the life time consumption of Type II mainwall insulation with a relatively high voltage endurance coefficient, such as 10, is mainly defined by the fundamental frequency with its associated peak to peak voltage. This is due to the fact that, in this example, the influence of the voltage on the lifetime consumption is 10 times greater than the influence of the frequency.

The share of the life time consumption between the fundamental and the impulse repetition rates with their associated peak to peak voltages can be calculated on the assumptions that the general life expression in 9.2 applies and that the value of "n" does not change with voltage or frequency in the range considered. The contribution of these voltages and frequencies to the life time consumption depends strongly on the voltage endurance life time exponent of the insulation [7] according to formula (3). Although it has not been shown scientifically, it is assumed that the superposition effect for ageing is valid. This means that the sequential application of impulse and fundamental voltages is equivalent to their simultaneous application.

A.2 Calculation of the contributions to ageing from a 3-level converter drive

An example is given here of the contributions to accelerated ageing of stator mainwall insulation in 3-level converter-fed machines. It shows only the effects of electrical ageing and ignores thermal ageing. The converter characteristics chosen for this example are a 3-level system with an impulse repetition rate of 1 kHz, which is a commonly found value. The contribution to the ageing from the converter impulses is given as a percentage of the total ageing for different values of overshoot factor, U_b/U_a.

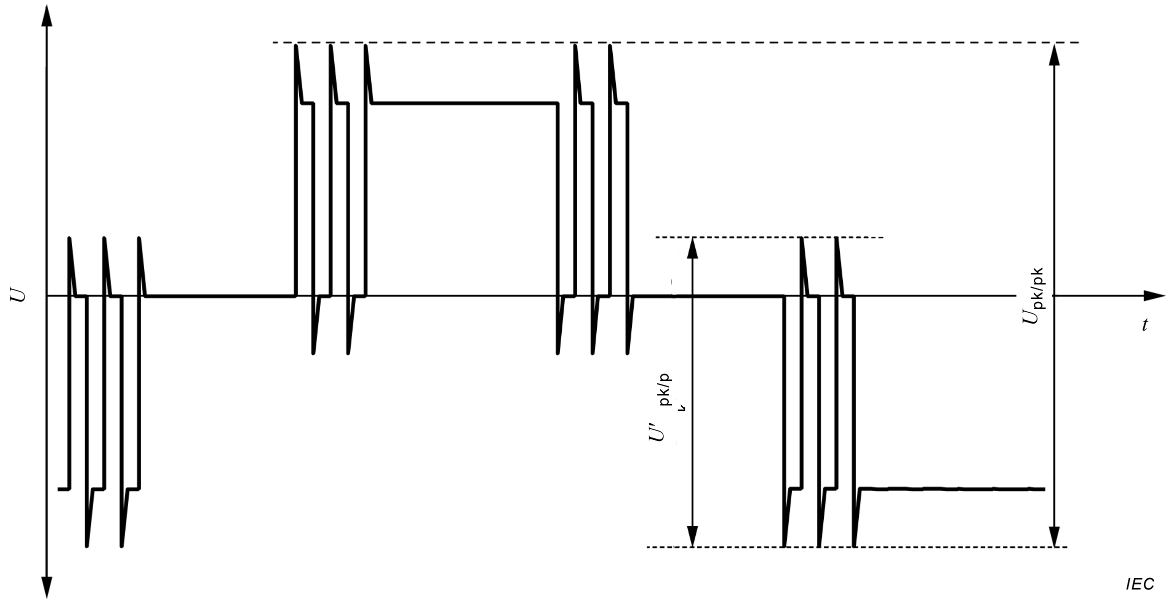


Figure A.1 – Representation of the phase to ground voltage at the terminals of a machine fed from a 3-level converter

The calculation used for each contribution to ageing is based on the formulae given in 9.2. The ageing rate per impulse is proportional to $1/L$ so, as an example, for a fundamental impulse at 50 Hz and a peak to peak fundamental voltage of $U_{\text{pk/pk}}$ the contribution to ageing over a period of 20 ms is given by

Ageing rate (50 Hz) = $(U_{\text{pk/pk}})^{\text{n}}/\text{k}$ where k is a constant.

For a 3-level converter with no voltage overshoot, the contribution to ageing from 1 kHz impulses over 20 ms is given by

Ageing rate (1 kHz) = $\frac{(U'_{\text{pk/pk}})^{\text{n}} \times 20}{k}$ (see Figure A.1)

According to the cumulative ageing rate theory and, in the absence of synergism, the total ageing rate is therefore the sum of these two contributions.

Table A.1 has been generated by substituting appropriate values in the two formulae above. As an example, a 20 % overshoot factor ($U_{\text{b}}/U_{\text{a}}$) as shown in Figure 1 would give

$$U'_{\text{pk/pk}} = 1{,}4\ U_{\text{a}} \text{ and } U_{\text{pk/pk}} = 2{,}4\ U_{\text{a}}$$

and the percentage contribution to ageing from the converter impulses for n = 10 is given by

$$\frac{(1{,}4)^{10} \times 20 \times 100}{(2{,}4)^{10}}$$

Table A.1 – Contribution to electrical ageing by 1 kHz impulses from a 3-level converter as a percentage of the ageing from the 50 Hz fundamental voltage (endurance coefficient of 10)

Overshoot factor ($U_{\text{b}}/U_{\text{a}}$) %	Impulse repetition rate kHz	Ratio of ageing from impulse and fundamental voltages %
0	1	2
10	1	4
20	1	9
50	1	35

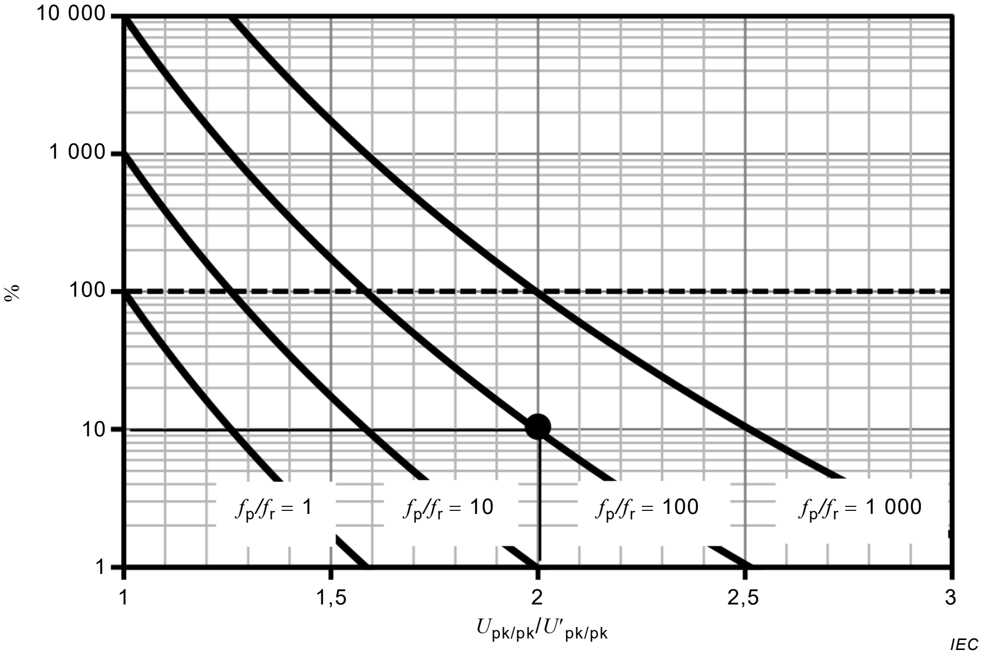
A.3 Calculation to derive an equivalent voltage amplitude and frequency

An alternative approach combines the accelerated electrical ageing from the fundamental and impulse voltages. It renders an equivalent peak to peak voltage U_{eq} and frequency f_{eq}, resulting in the same life time consumption as two peak to peak voltages U_1 and U_2 and their respective frequencies f_1 and f_2:

$$U_{\text{eq}}^{\text{n}} \times f_{\text{eq}} = U_1^{\text{n}} \times f_1 + U_2^{\text{n}} \times f_2 \tag{A.1}$$

where f_1 stands for the fundamental frequency and f_2 for the average impulse repetition rate. The value chosen for f_{eq} is likely to be 50 Hz or 60 Hz but should be appropriate for the application.

For this formula, the calculated result of the life time consumption by the impulse voltage and the fundamental frequency voltage is shown in Figure A.2. It shows that for a voltage endurance coefficient of 10, a fundamental/impulse voltage ratio of 2 and an impulse/fundamental frequency ratio of 100, the fundamental part of the voltage will consume 90 % of the life while the impulse repetition rate contribution to the life time consumption is only 10 %.



Key

f_p/f_r ratio of impulse/fundamental repetition rate

Figure A.2 – Ratio of the life time consumption (y-axis) of impulse voltage ($U_{pk/pk}$) to fundamental voltage ($U'_{pk/pk}$) expressed as a percentage for various impulse/fundamental frequency ratios (n=10)

For this reason, the qualification procedure of Type II mainwall insulation generally uses the fundamental peak to peak voltage ($U_{pk/pk}$) and the fundamental repetition rate expected in service (or as defined by the IVIC) and ignores the life time consumption contribution of the impulse repetition rate with its associated peak to peak voltage ($U'_{pk/pk}$).

If the frequency ratio becomes larger and the voltage ratio or voltage endurance coefficient becomes smaller than in the above example, the impulse voltages may contribute considerably to the life time consumption as well. In this case, an equivalent voltage and frequency can be calculated which will consume the same life time as the more complex voltage with two frequencies. For 2-level converters, where there may be little or no difference between peak-peak values of U and U'. In this case U' is to be used instead of U in Table D.2, column 1, and the qualification procedure for Type II mainwall insulation will in this case use the impulse peak to peak voltage at the impulse repetition rate.

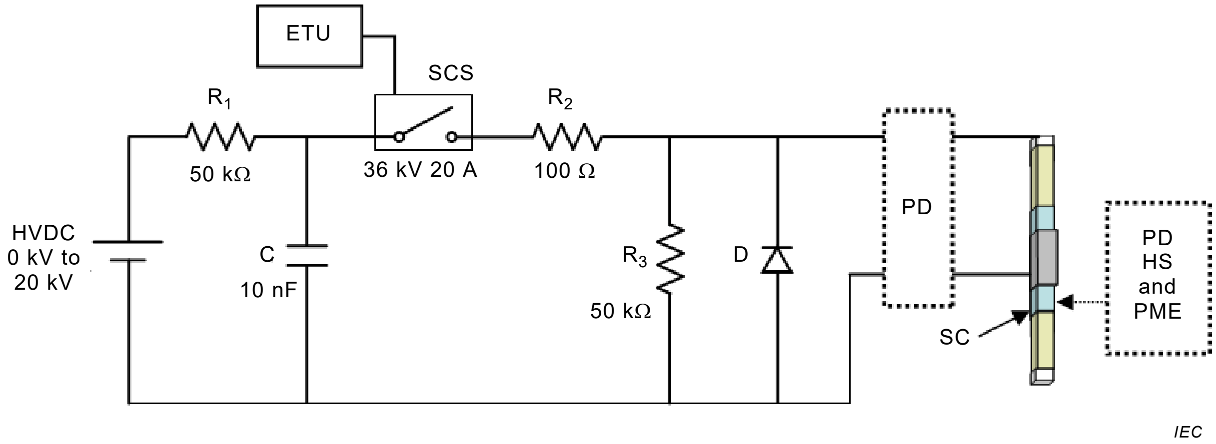
Annex B
(informative)

Examples of circuits for impulse testing

B.1 Impulse test circuit using a semiconducting switch

A circuit diagram is shown in Figure B.1 for a laboratory test kit to produce impulses similar in magnitude, repetition rate and rise time to those used in commercial converter/machine assemblies. It has been found suitable for turn to turn and stress control system testing of the specimens of coils or bars described in 12.4. The peak to peak impulse voltage is controlled by the output voltage of the HVDC power supply. In this example, a maximum output voltage of 20 kV is available. The impulse voltage repetition rate is adjusted by the electronic trigger unit (ETU) which controls the semiconducting switch (SCS), rated at 36 kV 20 A. A power diode may be used if perfect unipolar repetitive impulse voltages are required. The peak to peak voltage, maximum repetition rate and rise time of the impulse voltage can be adjusted through the circuit parameters R_1, R_2 and C. The impulse fall time may be adjusted through R_3.

A PD detecting sensor may be inserted into the circuit to measure RPDIV with the required impulse voltage parameters. Hot spot temperature and surface potential measurement systems [14] may also be installed, depending upon the test requirements.



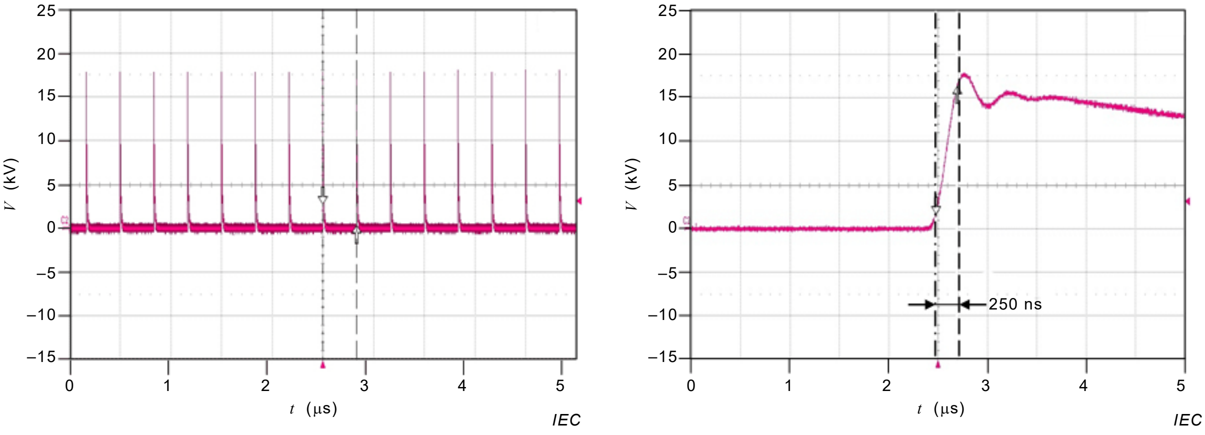
Key

C	Capacitor
D	Power diode
R	Resistor
HS	Hot spot detector
PD	Partial discharge measurement equipment
PME	Surface potential measurement equipment
SC	Stress control region
SCS	Semiconducting switch
ETU	Electronic trigger unit

Figure B.1 – Example of a simple converter voltage simulation circuit

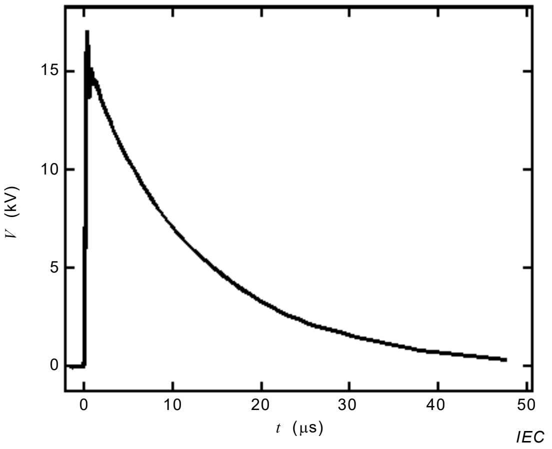
B.2 Typical waveform generated from the impulse generator

Figure B.2a) shows an example of a stream of voltage impulses generated from the simple converter voltage simulation circuit shown in Figure B.1. The peak to peak impulse voltage and the impulse voltage repetition rate are 17 kV and 1,5 kHz respectively. The impulse rise time and fall time are 250 ns and about 50 µs respectively. These are shown in greater detail in Figures B.2b) and c).



a) Voltage and repetition rate

b) Rise time of an impulse



c) Fall time of an impulse

Key

V voltage

t time

Figure B.2 – Typical waveform generated from the impulse generator

B.3 Alternative impulse test circuit using a semiconducting switch

An alternative circuit diagram is shown in Figure B.3 for a laboratory test kit to produce impulses similar in magnitude, repetition rate and rise time to those used in commercial converter/machine assemblies at present. It has been found suitable for turn to turn and stress control system testing.

In this circuit, the sample bar is C_S and typically has a value of 2 nF. If its capacitance is greater, additional parallel capacitance should be added to reach this value. The semiconducting switch (SCS) should be set to give an appropriate breakdown voltage to produce a stream of impulses with an average repetition rate of 1,5 kHz. The impulse waveform is typically a falling voltage until breakdown occurs after which the voltage rises in 1,5 µs with a peak to peak value determined by the semiconducting switch. The maximum dV/dt in the wavefront may be 15 kV/µs. The repetition rate, rise time and peak to peak voltage can be changed through the circuit parameters. Figure B.4 shows the output voltage when a spark gap was used instead of a semiconducting switch. The advantage of using a spark gap is offset by the higher maintenance involved in its use due to wear during operation.

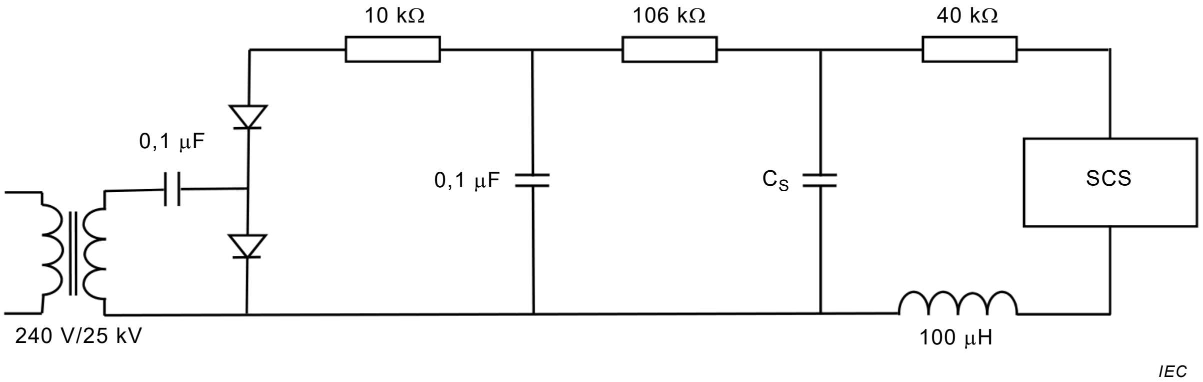
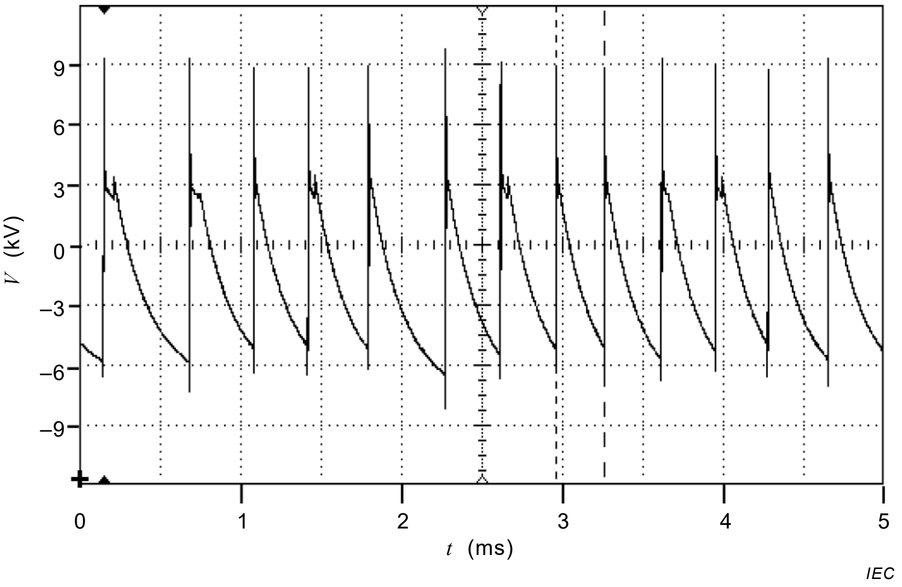


Figure B.3 – Example of a simple converter voltage simulation circuit



Key

V Voltage

t time

Figure B.4 – Typical waveform generated from the impulse generator

Annex C
(informative)

Derivation of the short term endurance test voltage

For many years, it has been accepted that the mainwall insulation in a line-fed (sinusoidal) rotating machine should be able to withstand 2,5 U_N for at least 250 h in an electrical endurance test performed at power frequency [15]. This is equivalent to 4,3 times the phase to ground voltage. In the case of converter-fed machines, the meaning of rated voltage is not clear. Nonetheless, the ageing mechanism of the mainwall insulation fed from a multilevel drive is still considered to be dependent on the peak to peak voltage excursion and the number of cycles in the same way as for line fed machines. For a 3-level drive, the voltage excursion and frequency to be used are described in Annex A. This enables the equivalent test for converter-fed machines to be calculated as follows, assuming that all testing is referenced to the same power frequency.

Test voltage for line fed coils = 2,5 U_N (r.m.s.)

= $2{,}5 \times \sqrt{3} \times U_0$ (where U_0 is the phase to ground r.m.s. voltage)

= $\frac{2{,}5 \times \sqrt{3}}{2\sqrt{2}} \times$ (phase to ground peak to peak voltage)

= 1,53 x (phase to ground peak to peak voltage)

Therefore

Short term endurance test voltage for converter-fed coils = 1,53 x (maximum phase to ground peak to peak voltage)

For example, if the maximum peak to peak phase to ground voltage on a coil in a converter-fed machine is 8 kV,

the r.m.s. value of the sinusoidal test voltage = 1,53 x 8 kV = 12,25 kV.

Note that, for a converter-fed machine, the equivalent rated voltage for estimating the life line of the mainwall insulation is U_N x the enhancement factor in column 1 of Table D.2.

Annex D

(informative)

Derivation of the impulse voltage insulation class for the machine insulation

Where a rotating machine is to be fed from a converter, an additional classification (IVIC X) may be assigned to the machine insulation system which defines the maximum allowable enhancement ratio for the phase to ground fundamental voltage under converter fed conditions. The enhancement ratio is the peak to peak converter output voltage divided by the peak to peak line voltage. Table D.2 shows an arbitrary range of severities for this parameter from which one is selected by the manufacturer to indicate the maximum value permitted in service. This value is determined from the results of qualification tests. If a manufacturer wishes to qualify the mainwall insulation at a different enhancement ratio, a special classification of IVIC S shall be used, with the precise value given in the documentation for the machine. It is recommended that the IVIC classification is put onto the rating plate. There are four other parameters, shown in columns 2 to 5 of Table D.2, which affect the performance of the insulation under converter operation, as follows.

Maximum allowable phase to ground fundamental frequency

Maximum allowable ratio of the jump voltage (U_j) to the phase to ground peak/peak voltage

Maximum allowable phase to ground impulse voltage repetition rate

Minimum allowable phase to ground impulse voltage rise time

The values of these parameters for which qualification has been achieved shall be given in the documentation for the machine. The maximum allowable peak to peak phase to ground voltage may be converted into units of U_N as in Table D.1. Additionally a test voltage factor (TVF) is shown in Table D.1 for the derivation of IVIC-related routine test voltages. It is defined by the ratio of the maximum allowable operating peak to peak phase to ground voltage in units of U_N divided by $2\sqrt{2}$. Machines with an IVIC having a test voltage factor >1 will need higher test voltages than non-IVIC qualified machines.

Table D.1 – IVIC- and test voltage factor definition for Type II insulation systems

IVIC	Maximum allowable operating peak-peak-phase-ground-voltages (U_{IVIC}) in units of U_{N}	TVF	Maximum allowable enhancement ratio for the phase to ground peak to peak voltage	Examples of r.m.s. routine test voltages at 50/60 Hz (U_{N} = 6,6 kV)	
				Converter fed	Line fed
None (line)	1,6	-	1,0	-	14,2
1	1,8	1,0	1,1	14,2	-
2	2,1	1,0	1,3	14,2	-
3	2,4	1,0	1,5	14,2	-
4	2,8	1,0	1,7	14,2	-
5	3,3	1,2	2,0	16,4	-
6	3,8	1,3	2,3	18,5	-
7	4,2	1,5	2,6	20,8	-
S (manufacture specified)	Y	$\frac{Y}{2\sqrt{2}}$	$\frac{Y\sqrt{3}}{2\sqrt{2}}$	TVF × 2 U_{N} +1 kV	-

NOTE 1 Enhancement ratio is the phase-ground peak to peak machine terminal voltage under converter operation divided by the phase-ground peak to peak machine terminal voltage under normal line operation. The latter one is being calculated by $U_{\text{N}} \times 2 \times \sqrt{2} / \sqrt{3}$

NOTE 2 The value Y = $U_{\text{IVIC}}/U_{\text{N}}$ – as it is used in 60034-18-41, is chosen by the manufacturer, specifying different values of U_{IVIC} than given in the second column, using IVIC S.

NOTE 3 14,2 kV is the test voltage specified by IEC 60034-1 for U_{N} = 6,6 kV.

NOTE 4 The test voltage is defined only by the maximum allowable peak to peak voltage at the motor terminals in operation. Other differences in the voltage waveform in operation are not taken into consideration.

NOTE 5 The formulas in the line of IVIC “S” apply to the other IVICs 1…7 as well.

Table D.2 – Impulse voltage insulation classes (IVIC)

Impulse voltage insulation classes for Type II insulation systems – Severity codes and limiting values						
IVIC		**Independent parameters of the IVIC**				
		Phase to ground machine terminal voltage		**Phase to ground impulse voltage**		
		Maximum allowable enhancement ratio for the voltage (Column 1)	**Maximum allowable fundamental frequency (Column 2)**	**Ratio of the maximum allowable jump voltage to the maximum allowable phase to ground peak to peak voltage (Column 3)**	**Maximum allowable impulse voltage repetition rate (f) (Column 4)**	**Minimum allowable phase to ground impulse voltage rise time (t_r) (Column 5)**
		Maximum $U_{pk/pk}$ converter operation divided by $U_{pk/pk}$ direct on line operation $\sqrt{3}(U_{IVIC}/U_N)/2\sqrt{2}$	**Hz**	$U_j/U_{pk/pk}$	**kHz**	**µs**
Severity code	1	1,1	Value to be reported in the documentation	Value to be reported in the documentation	Value to be reported in the documentation	Value to be reported in the documentation
	2	1,3				
	3	1,5				
	4	1,7				
	5	2,0				
	6	2,3				
	7	2,6				
	S	To be chosen by the manufacturer				

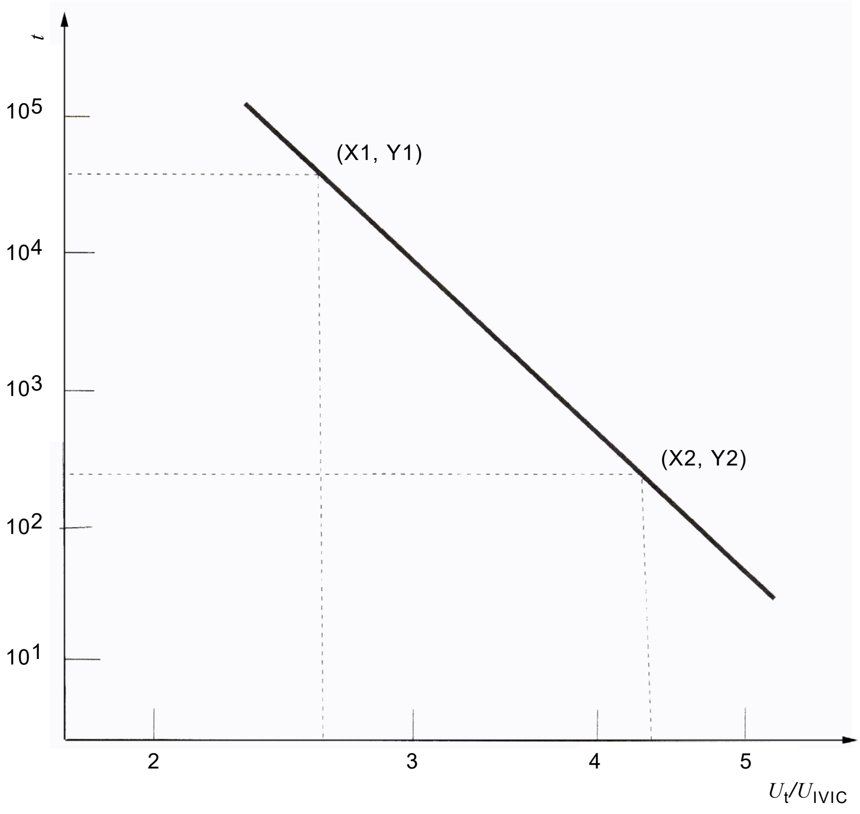
Annex E
(normative)

Derivation of an IVIC in the absence of a manufacturer's reference life line

E.1 Derivation of an IVIC from endurance tests

E.1.1 Mainwall insulation

Where a reference life line for mainwall insulation is not available for comparison purposes, the qualification procedure shall be for the manufacturer to generate a candidate endurance life line for the intended mainwall insulation system using sinewave voltages. At least four specimens shall be tested at each of 3 voltages. After correction to 50 Hz or 60 Hz using formula (3), the points shall be plotted to show log(mean life in hours) as a function of log(normalised voltage). Normalised voltage is the peak to peak test voltage divided by U_{IVIC}. The value of U_{IVIC} is calculated to be the maximum phase to ground peak to peak voltage for which qualification is required.



IEC

Key

X1	2,6	t	time to electrical failure in hours
Y1	41 000	U_t	peak to peak test voltage
X2	4,33	U_{IVIC}	maximum allowable peak to peak phase to ground operating voltage
Y2	250		

Figure E.1 – Reference life line for mainwall insulation

Comparison of the measured lifetimes shall be against the reference life line shown in Figure E.1. This life line reflects the electrical ageing at room temperature. It is consistent with those measured at 50 Hz or 60 Hz from mica/epoxy resin systems that have been shown to give reliable lives in service [16,17,18]. It is valid for an expected design life time of very large machines in steam, gas or hydro power plants, for example of 40 years.

If the pass criterion has been satisfied, IVIC X is assigned to the machine, where X is the severity code selected from column 1 of Table D.2. Details shall be given in the machine documentation describing the severity code for which qualification has been achieved and stating that it has been obtained according to the reference insulation life line shown in this Annex. If the insulation is qualified to a value of U_{IVIC} different to those in Table D.2, an IVIC S may be assigned.

E.1.2 Turn insulation

In the absence of a reference life line for the turn insulation, it will be necessary to demonstrate that the turn to turn insulation is PD free at the selected qualification jump voltage. The meaning of PD free is clarified in 13.3. Specimens are produced according to 12.3 and tested according to 13.3. If PD inception occurs below 1,5 U_{turn}, qualification shall be to the highest value of U_{turn} at which the specimens are PD free. If qualification is required at a higher value of U_{turn}, it may only be achieved by obtaining a life line according to 13.3 and comparing it against a reference line. The life line in Figure E.1 has been obtained from mica-based mainwall insulation, rather than turn insulation, and so may not be appropriate. If a reference life line is used, U_{IVIC} is replaced by the maximum permissible peak to peak voltage stressing the turn insulation in service (U_{turn}). Alternatively, the value used in a machine shown to provide satisfactory service experience with converter-fed PDS is acceptable. The IVIC for the machine will be shown in the documentation as IVIC S and details shall be given for the limiting value of U_{turn}.

E.1.3 Stress control system

Where a stress control system is used in service, the qualification is performed by using the specimens and procedures described in 12.4 and 13.4 respectively. The test conditions are derived from the value of peak to peak phase to ground voltage for which the mainwall insulation system has been qualified in E.1.1 and the value of U_{turn} for which the turn insulation has been qualified in E.1.2.

E.2 Derivation of the IVIC X on the basis of satisfactory service experience

Where satisfactory service experience has been obtained for the insulation system when fed from a converter, an IVIC may be derived from the operating parameters. The value shall conform to one of the severity codes shown in column 1 of Table D.2. An example of how this is performed is shown in Table 1 where the IVIC code is taken as the next least severe level shown in column 1 of Table D.2. If a severity level in service coincides with a level shown on Table D.2, it may be used. For insulation systems which have been shown to perform satisfactorily in service, the values for parameters in columns 2 to 5 of Table D.2 shall be reported in the documentation.

E.3 Derivation of an IVIC S on the basis of satisfactory service experience

It is recognised that the procedure in Clause E.2 may not reflect the required capability of the insulation system and, in this case, the code IVIC S is used. The precise values for the five parameters in Table D.2 for which satisfactory service experience has been achieved shall be reported in the documentation, together with the other relevant information on the service experience, such as, service operating time and application.

Annex F
(informative)

Optional screening tests

F.1 General

Tests are described which offer the opportunity for providing short-term screening of the mainwall insulation system. It is not intended that they be viewed as type tests nor that they are required for every contract.

F.2 Short term endurance test on the mainwall insulation

Coils or bars made to production standards are mounted in simulated slots and subjected to a 50 Hz or 60 Hz sinusoidal voltage with an r.m.s. value of 1,53 or 1,31 times U_{IVIC}, respectively, the maximum peak to peak phase to ground voltage appearing on the coils during converter operation (see Annex C). The slot simulators should be earthed. Any stress control system to be used should be applied to the coils beforehand. This is a quality test of the mainwall insulation. It is similar to the test described in [15] and is primarily a test of the mainwall insulation. As such, the test conditions may be too severe for the stress control coating to last the complete test period and so remedial work on the stress control coating is permitted. The recommended number of test specimens is four and the pass criterion shall be that not more than one of the specimens at the test voltage has a lifetime less than 250 h or 400 h, respectively. If one sample of the four falls below the reference line, then at least two more specimens have to be tested and passed [15].

These optional winding insulation tests have rendered good experiences with quality checks for very large machines for example in steam, gas or hydro power plant applications, where a winding insulation life time of for example 40 years could be expected.

A withstand does not guarantee an acceptable service life with a converter drive. This is a damaging test and the specimens should not be used in a production machine.

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(*Continued from second cover*)

International Standard	*Title*
IEC 60034-18-1 : 2010	Rotating electrical machines — Part 18-1: Functional evaluation of insulation systems. — General guidelines
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
IEC 60034-18-32	Rotating electrical machines — Part 18-32: Functional evaluation of insulation systems —Test procedures for form-wound windings — Evaluation by electrical endurance
IEC TS 60034-27	Rotating electrical machines — Part 27: Off-line partial discharge measurements on the stator winding insulation of rotating electrical machines
IEC TS 61934	Electrical insulating materials and systems — Electrical measurement of partial discharges (PD) under short rise time and repetitive voltage impulses
IEC 62539	Guide for the statistical analysis of electrical insulation breakdown data

Only English language text 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 International 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: 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Amendments Issued Since Publication

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