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Electrical insulating materials and systems — General method of evaluation of electrical endurance under repetitive voltage impulses

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National foreword

This British Standard is the UK implementation of EN 62068:2013. It is identical to IEC 62068:2013. It supersedes BS EN 62068-1:2003 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/112, Evaluation and qualification of electrical insulating materials and systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Electrical insulating materials and systems - General method of evaluation of electrical endurance under repetitive voltage impulses (IEC 62068:2013)

Matériaux et systèmes d'isolation électriques -
Méthode générale d'évaluation de l'endurance électrique soumise à des impulsions de tension appliquées périodiquement
(CEI 62068:2013)

Elektrische Isolierstoffe und Isoliersysteme -
Allgemeines Verfahren zur Bewertung der elektrischen Lebensdauer bei Beanspruchung mit sich wiederholenden Spannungsimpulsen
(IEC 62068:2013)

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Foreword

The text of document 112/234/FDIS, future edition 1 of IEC 62068, prepared by IEC TC 112 "Evaluation and qualification of electrical insulating materials and systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62068:2013.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-03-27
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2016-04-15

This document supersedes EN 62068-1:2003.

EN 62068:2013 includes the following significant technical changes with respect to EN 62068-1:2003:

The main changes with regard to EN 62068-1:2003 concern the terms and definitions which are now aligned, in part, on IEC/TS 61934 and CLC/TS 60034-18-42.

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In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC/TS 60034-18-42:2008	NOTE	Harmonised as CLC/TS 60034-18-42:2011 (not modified).
IEC 60505:2011	NOTE	Harmonised as EN 60505:2011 (not modified).
IEC 60270:2000	NOTE	Harmonised as EN 60270:2001 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 62539	-	Guide for the statistical analysis of electrical insulation breakdown data	-	-

CONTENTS

ELECTRICAL INSULATING MATERIALS AND SYSTEMS – GENERAL METHOD OF EVALUATION OF ELECTRICAL ENDURANCE UNDER REPETITIVE VOLTAGE IMPULSES

1 Scope

This International Standard applies to electrical equipment, regardless of voltage, containing an insulation system, which is

– connected to an electronic power supply, and
– requires an evaluation of insulation endurance under repetitive voltage impulses.

This standard proposes a general test procedure to facilitate screening of electrical insulating materials (EIM) and systems (EIS) and to achieve a relative evaluation of insulation endurance under conditions of repetitive impulses.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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.

3.1
electrical insulating material
EIM
material with negligibly low electric conductivity, used to separate conducting parts at different electrical potentials

[SOURCE: IEC 60505:2011, definition 3.1.2 [3] [2]

3.2
electrical insulation system
EIS
insulating structure containing one or more electrical insulating materials (EIM) together with associated conducting parts employed in an electrotechnical device

[SOURCE: IEC 60505:2011, definition 3.1.1 [2]

3.3
candidate EIS
EIS under evaluation to determine its electrical endurance when exposed to repetitive voltage impulses

2 Figures in square brackets refer to the Bibliography.

3.4
reference EIS
evaluated and established EIS with either a known service experience or a known comparative functional evaluation under repetitive voltage impulses

3.5
partial discharge
PD
electric discharge that only partially bridges the insulation between electrical conductors

[SOURCE: IEC 60270:2000, definition 3.1 modified [4] – the word "localized" (electrical discharge) omitted from source definition, and definition shortened to omit reference to "which can or can not occur adjacent to a conductor". Also the three NOTES after the term have been omitted]

3.6
partial discharge pulse
current pulse in an object under test that results from a partial discharge occurring within the object under test

Note 1 to entry: The pulse is measured using suitable detector circuits, which have been introduced into the test circuit for the purpose of the test.

Note 2 to entry: A detector in accordance with the provisions of this standard produces a current or a voltage signal at its output related to the PD pulse at its input.

[SOURCE: IEC/TS 61934:2011, definition 3.3, modified – In Note 2 to entry, "provisions" of this technical specification" edited to read "of this standard"]

3.7
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 discharge can be detected.

[SOURCE: IEC/TS 61934:2011, definition 3.4]

3.8
repetitive partial discharge extinction voltage
RPDEV
maximum peak-to-peak impulse voltage at which less 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 decreased from a value at which PD have been detected.

[SOURCE: IEC/TS 61934:2011, definition 3.5]

3.9
partial discharge inception voltage
PDIV
lowest voltage at which partial discharges are initiated in the test arrangement, when the voltage applied to the object is gradually increased from a lower value at which no such discharges are observed

3.10
partial discharge extinction voltage
PDEV
highest voltage at which partial discharges are extinguished in the test arrangement, when the voltage applied to the object is gradually decreased from a higher value at which such discharges are observed

3.11
unipolar impulse
voltage impulse, the polarity of which is either positive or negative

3.12
bipolar impulse
voltage impulse, the polarity of which alternates from positive to negative or vice versa

3.13
impulse-voltage polarity
polarity of the applied impulse, with respect to earth

3.14
impulse-voltage repetition rate
inverse of the time between two successive impulses when the time intervals are the same, whether unipolar or bipolar

3.15
impulse rise time
1,25 times the time interval between 10 % and 90 % of the zero-to-peak impulse voltage, on the leading edge of the impulse

3.16
impulse decay time
time interval between the instants at which the instantaneous value of an impulse decreases from a specified upper value to a specified lower value

Note 1 to entry: Unless otherwise specified, the upper and lower values are fixed at 90 % and 10 % of the impulse magnitude.

[SOURCE: IEC/TS 61934:2011, definition 3.11]

3.17
impulse width
interval of time between the first and last instants at which the instantaneous value of an impulse reaches a specified fraction of impulse magnitude or a specified threshold

[SOURCE: IEC/TS 61934:2011, definition 3.12]

3.18
impulse duty cycle
ratio, for a given time interval,of the impulse width to the total time

[SOURCE: IEC/TS 61934-2011, definition 3.13]

3.19
peak partial discharge magnitude
largest magnitude of any quantity related to PD pulses observed in a test object at a specified voltage following a specified conditioning and test

Note 1 to entry: For impulse voltage tests, the peak magnitude of the PD is the largest repeatedly occurring PD magnitude.

[SOURCE: IEC/TS 61934:2011, definition 3.14]

3.20
rate of voltage rise
0,8 times the impulse-voltage magnitude divided by the time interval between the 10 % and 90 % magnitude of the zero-to-peak impulse voltage

3.21
voltage endurance coefficient
VEC
exponent of the inverse power model or exponential model, which together with the coefficient k, describes the relationship between life and voltage

3.22
life
either time or number of impulses to failure

4 General test procedures

4.1 Overview

Clause 4 describes the general procedures for evaluating the ability of an EIS to resist deterioration due to repetitive impulse voltages. There are two methods, depending on the desired outcome:

a) A screening test can be carried out at a single test voltage to assess alternative EIMs or different physical constructions by comparison with the previously evaluated EIS. The purpose is to find the EIM (or construction) which yields better endurance. In addition, a single EIS can be evaluated at a single test voltage under variable test conditions, such as different humidity, different impulse repetition rates, etc. to determine the effect of the variable.

   NOTE IEC/TS 60034-18-42 gives an example of a screening test for stator winding stress grading coating.

b) An endurance test can be conducted to estimate the relationship between impulse voltage and life for each EIS to be evaluated. The EIS is evaluated at several voltage levels, with the other conditions being usually constant. A possible relationship between voltage endurance and voltage magnitude can be represented by an inverse power law:

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

   where

   L is the time to failure or number of impulses to failure of the test object (at a given probability);

   U is the applied impulse voltage;

   n is the voltage endurance coefficient (VEC);

   k is a constant.

Other relationships are also possible. For example, the exponential model is:

$$L = \mathrm{A}e^{-\mathrm{h}U} \tag{2}$$

where A and h are constants.

The results from an impulse electrical endurance or screening test depend on a large number of factors in addition to the inherent capability of an EIS. These factors shall be specified and controlled in any impulse-ageing test. Annex A reviews these factors.

The following subclauses describe the general test procedures for impulse screening and endurance testing. The design and the number of the test object and the impulse-voltage characteristics depend on the EIS that is being modelled.

4.2 Test object

The test object includes a conductor separated from the earth conductor by electrical insulation. A greater number of test objects are needed when greater statistical significance is required to detect small differences. Where practical, a sample consisting of a minimum 5 test objects per voltage level should be used for each test procedure, as mentioned in 12.3 of IEC/TS 60034-18-42:2008.

Overheating at stress grading of test objects may be taken into account during endurance test when repetition frequency of test voltage impulse increases.

4.3 Screening test method

4.3.1 General

Materials and EIS need to be evaluated prior to being designed into a specific product. In most cases the final form of the impulse is not known at this stage. The screening test defines a unique set of test conditions and impulse-voltage characteristics to apply to all materials being evaluated. It is necessary to have a common set of parameters so that different materials can be judged on the same basis.

It is also necessary to establish a fixed set of parameters so that evaluation of the effect of change in parameters can be compared realistically.

4.3.2 Test procedure

A sample of test objects shall be subjected to the specified impulse voltage according to the voltage endurance procedures of IEC 60727-1 [5]. The use of a trip-current device may be a suitable means of monitoring specimen failures. In certain types of test objects, other means of detecting specimen failure may be required. The test conditions selected should take into account the applicable factors described in Annex A. The impulse-voltage characteristics should be consistent with those in Clause 5.

The test voltage selected shall be relevant for the failure process being modelled.

4.3.3 RPDIV and RPDEV measurements

The RPDIV and RPDEV shall be measured under impulse voltage, rather than PDIV and PDEV under power-frequency voltage.

NOTE RPDIV and PPDEV are measured as described in IEC/TS 61934.

As the values of RPDIV and RPDEV may vary significantly depending on the instrument used to make measurements, the measuring system and the criterion used to establish RPDIV and RPDEV should be specified.

4.3.4 Data processing

Time-to-failures shall be processed using the two-parameter Weibull probability distribution. Either complete or singly censored tests can be carried out (providing that at least $(n + 1)/2$ [if n is odd] or $(n/2) + 1$ [if n is even] of the specimens fail). On the basis of the estimates of the scale and shape parameters (the former corresponding to time-to-failure at probability 63,2 %), the mean and median time-to-failure and number of impulses to failure, as well as failure percentiles, can be estimated. The maximum likelihood method can be used to estimate scale and shape parameters. Confidence intervals for the parameters and percentiles can be also calculated; a probability of 90 % is recommended.

Statistical analysis procedures are described in IEC 62539.

4.3.5 Evaluation

Repeat this screening test for each system to be evaluated or for evaluation of changing a single parameter. Relative evaluations are then possible by comparing time-to-failure or the number of impulses to failure at a given probability: the longer time-to-failure or the more impulses to failure, the better the EIM or EIS performance. This procedure will assist in the selection of suitable candidates for the design of the equipment EIM or EIS.

4.4 Endurance test method

4.4.1 Reference EIS

Select at least 3 different impulse-voltage levels for performing the test, which are higher than the expected service stress (for the purpose of test acceleration). The difference between consecutive voltage levels should be at least 10 %. Referring to Formula (1), if n is known to be higher than 15, then consecutive voltage levels can be different by less than 10 %. The voltage levels are selected in order that the failure processes remain the same in the test voltage range. Failure processes shall not differ from those encountered in operating conditions by the EIS under test. Different failure processes can be distinguished, for example, by microscopic examination of the failure sites as well as by a change in the slope of the plot of log voltage versus log number of impulses to failure (or log time-to-failure) due, for example, to test voltage levels in part above or below RPDIV.

Perform the endurance test on each test object, at the selected voltages, and determine the number of impulses to failure or the time-to-failure. Process the number of impulses to failure or time-to-failure (for complete or censored tests) using the two-parameter Weibull function (see 4.3.4). Estimate the scale parameter values (either median, mean, or another prescribed percentile) obtained at each test-voltage level and plot them in a log-log or log-linear (semi-log) coordinate system[3].

4.4.2 Comparison test

After a reference EIS endurance curve has been established, another candidate EIS can be evaluated using the same test procedure and test voltages.

A comparison of the VEC for each candidate to the reference EIS indicates the relative degradation caused by the impulse voltage. Furthermore, the time-to-failure or number of impulses to failure, at a given probability, obtained at the lowest test voltage can be compared. The greater the difference between the candidate and the reference system, the better is the expected endurance of the candidate EIM or EIS under operating conditions, assuming the candidate EIM or EIS requires more impulses to failure. The statistical methods given in IEC 62539 can be used to assess significant differences. It is recommended that the

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3 Draw a lifeline (calculated by a regression technique) for each examined EIS using a log-log plot according to Formula (1). If a straight line is not obtained (correlation coefficient <0,85), a semi-log coordinate system can be used where the log of either the number of impulses or number of minutes to failure is plotted versus voltage. If a straight line is obtained, then the life model fits the exponential model, Formula (2). If a non-linear characteristic is still obtained, then it is likely that the failure process has changed at the different voltage levels. The test sequence may have to be repeated with different test voltages, investigating carefully the RPDIV and RPDEV values.

comparison tests should have enough specimens to detect differences at the 10 % significance level if indeed there are differences[4].

5 Test impulse-voltage characteristics

Table 1 shows one example of the range of impulse-voltage characteristics. Any particular test should have test characteristics that are appropriate for the environment for the type of equipment used. The impulse-voltage measurement system should have a bandwidth of at least 10 MHz to record a 40 ns rise-time impulse accurately.

Table 1 – Test impulse-voltage characteristics

Characteristic	Range
Rise time	(0,04 to 1) µs
Repetition rate	(Up to 10 000) Hz
Impulse duration	(0,08 to 25) µs
Shape	Square or triangular
Polarity	Bipolar (preferred) or unipolar

4 Significant differences can be detected by observing if the confidence levels for each EIS overlap.

Annex A
(informative)

Impulse ageing

A.1 General

Equipment circuits may be subject to impulse voltages occurring as the result of lightning or switching impulses. However, the increasing use of electronic technology and electronic equipment is imposing repetitive impulse voltages on many electric insulation systems. Currently, the typical repetition rate of these impulses is in the range of (0,5 – 10) kHz, having an impulse rise time typically in the range (0,1 – 1) µs and a peak voltage exceeding twice the nominal value of the supply voltage.

These short-duration, high-repetition impulses can degrade insulation systems differently from the processes occurring under conventional a.c. power-frequency voltage. The electrical deterioration can result from one or more of several physical processes:

– partial discharges;
– injection and extraction of space charges in the EIMs;
– electromechanical fatigue due to the current impulses resulting from voltage impulses applied to high capacitance EIS;
– dielectric heating due to the high-frequency components in the voltage.

Deterioration due to repetitive voltage impulses from electronic power supplies may, for example, occur in the following types of electrical equipment:

– random-wound motor stator windings;
– medium-voltage, form-wound stator windings;
– power-supply and filter capacitors;
– transformers;
– power cables;
– power-module-drives;
– printed-circuit boards.

A.2 Effect of temperature

Electrical degradation can be greatly altered at elevated temperature. The deterioration rate may be increased if the dielectric loss of EIMs is increased, which causes a further rise of local heating where high electric stress is applied. Higher insulation temperature can also increase the dielectric permittivity of EIMs, which increases electric stress in adjacent air gaps, decreases the partial discharge inception voltage causing the PD activity to increase. In confined EIS, increasing the temperature may reduce the size of voids within the EIS, reducing the PD intensity, and thus the deterioration rate. Thermal cycling can generate or enlarge existing voids, incepting PD and possibly increasing their amplitude and repetition rate. Raising the temperature may increase the gas pressure inside a closed void, which may affect PD activity. Similarly, electric charge trapping and detrapping times may be shorter at higher temperatures. Thus the temperature of the test object must be clearly specified for any endurance test.

A.3 Effect of mechanical stress

Mechanical stress, both static and dynamic, can enhance electrical degradation significantly through a synergistic effect described in IEC 60505. Mechanical stress can, in fact, produce and/or enlarge defects in insulation, where, for example, the electric field associated with repetitive impulses can more easily give rise to PD, as well as contribute to the damage caused by the energy released by each impulse, reducing the energy barrier for the degradation process.

A.4 Effect of humidity and the environment

Humidity in the environment surrounding an EIS may alter the breakdown strength of the air, and thus the PD activity. Similarly, the humidity in the surrounding air and/or the surface condition of the EIS may affect the electrical stress distribution and/or the conduction of electrical charges on the insulation surface, and thus alter the deterioration rate. Therefore, the humidity and environment during an endurance test must be defined and controlled.

A.5 Effect of voltage magnitude and impulse-voltage characteristics

In some equipment, the voltage distribution can be significantly different under impulse- and power-frequency voltages. The magnitude and duration of the electric stress occurring between elements in electric insulation systems due to these impulse-voltage phenomena are dependent on the physical position of the electric stress relative to the supply voltage connection (phase-to-phase and phase-to-ground), the electric circuit characteristics, series and phase-to-ground capacitances, resistances and inductances. Thus, careful design of the EIS test objects is required to simulate properly the impact of impulse-voltage stresses.

The rise time of the impulse voltage can have several effects on the ageing rate and thus must be defined in a test. In certain EIS, such as those containing multiturn windings, the shorter the rise time, the greater the proportion of the voltage that is across some of the adjacent turns. Thus, shorter rise times could produce a shorter endurance, if partial discharge is a cause of degradation. In addition, the physical processes of deterioration can depend on the rise time. Furthermore, the accumulation of charges may be time dependent, and thus affect the electric field distribution.

The voltage magnitude will have a profound impact on the rate of ageing. In general, the higher the applied test voltage, the greater the ageing rate. Often an inverse power model or exponential model can represent the relationship between voltage endurance and voltage magnitude.

More than one ageing process due to voltage impulses may occur in any particular EIS. For instance, deterioration may occur in some EIS both due to a space charge injection process and a partial discharge process. The test voltage must be selected to simulate the desired deterioration process (generally, the one which is expected to occur in service). For example, if deterioration due to space charge injection is the only process to be simulated, then the test voltage should be below the RPDEV.

A.6 Effect of impulse repetition rate

The impulse-voltage repetition rate may have a positive or negative effect on the number of impulses needed to cause failure. In other words, repetition rate can have nonlinear effect on life, due to dielectric heating and space charge. The local heating may cause secondary effects on PD activities such as change of local voltage distribution through the change of dielectric constant of insulating materials and/or increase of internal gas pressure in voids. Space charge may have complicated effects on PD activity. These effects can change PDIV, which lead to longer or shorter life time. Consequently, the repetition rate must be specified for the testing.

A.7 Effect of impulse polarity

Finally, the oscillatory nature of the impulse can affect the deterioration rate. Unipolar impulses between the conductor and ground generally produce less deterioration per impulse than bipolar impulses of the same magnitude. Similarly, in test objects having non-uniform electric fields, the polarity of the applied voltage can affect the endurance. The specific shape of the impulse (with the exception of rise time) does not seem to have a strong influence on the endurance. For example, a test object subjected either to a square impulse or a triangular impulse (with the same peak magnitude, rise time, and repetition rate) could have approximately the same endurance.

Bibliography

[1] IEC/TS 61934:2011, *Electrical insulating materials and systems – Electrical measurements of partial discharges (PD) under short rise time and repetitive voltage impulses*

[2] IEC/TS 60034-18-42:2008, *Rotating electrical machines – Part 18-42: Qualification and acceptance tests for partial discharge resistant electrical insulation system (Type II) used in rotating electrical machines fed from voltage converters*

[3] IEC 60505:2011, *Evaluation and qualification of electrical insulation systems*

[4] IEC 60270:2000, *High-voltage test techniques – Partial discharge measurements*

[5] IEC 60727-1, *Evaluation of electrical endurance of electrical insulation systems – Part 1: General considerations and evaluation procedures based on normal distributions* (withdrawn)

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