SLOVENSKI STANDARD
SIST EN 60885-3:2004

01-marec-2004

Electrical test methods for electric cables -- Part 3: Test methods for partial discharge measurements on lengths of extruded power cables

Electrical test methods for electric cables -- Part 3: Test methods for partial discharge measurements on lengths of extruded power cables

Elektrische Prüfverfahren für Starkstromkabel -- Teil 3: Prüfverfahren zur Teilentladungsmessung an Längen von extrudierten Kabeln

Méthodes d'essais électriques pour les câbles électriques -- Partie 3: Méthodes d'essais pour mesures de décharges partielles sur longueurs de câbles de puissance extrudés

Ta slovenski standard je istoveten z: EN 60885-3:2003

ICS:

29.060.20	Kabli	Cables

SIST EN 60885-3:2004 en

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 60885-3

September 2003

ICS 29.060.20

English version

Electrical test methods for electric cables — Part 3: Test methods for partial discharge measurements on lengths of extruded power cables
(IEC 60885-3:1988)

Méthodes d'essais électriques
pour les câbles électriques —
Partie 3: Méthodes d'essais pour mesures
de décharges partielles sur longueurs
de câbles de puissance extrudés
(CEI 60885-3:1988)

Elektrische Prüfverfahren
für Starkstromkabel —
Teil 3: Prüfverfahren zur
Teilentladungsmessung an Längen
von extrudierten Kabeln
(IEC 60885-3:1988)

This European Standard was approved by CENELEC on 2003-09-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Lithuania, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom.

CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 60885-3:2003 E

Foreword

The text of the International Standard IEC 60885-3:1988, prepared by IEC TC 20, Electric cables, is submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 60885-3 on 2003-09-01.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2004-09-01
- latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2006-09-01

Annexes designated "normative" are part of the body of the standard.
In this standard, Annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60885-3:1988 was approved by CENELEC as a European Standard without any modification.

CONTENTS

SECTION ONE — GENERAL

Clause
1.1 Scope 4
1.2 Object 4

SECTION TWO — PARTIAL DISCHARGE TESTS

2.1 Definitions 4
2.2 Test apparatus 4
  2.2.1 Equipment 4
  2.2.2 Test circuit and instruments 4
  2.2.3 Double pulse generator 5
  2.2.4 Terminal impedance (characteristic impedance) 5
  2.2.5 Reflection suppressor 5
2.3 Determination of characteristic properties of the test circuit 5
  2.3.1 Superposition 5
  2.3.2 Terminal impedance 5
  2.3.3 Reflection suppressor 5
  2.3.4 Calibration charge 6
  2.3.5 Sensitivity 6
2.4 Measurement procedures 7
  2.4.1 Short cable lengths including type test lengths 7
  2.4.2 Long cable lengths tested without a terminal impedance 7
  2.4.3 Long cable lengths tested with a terminal impedance 8
  2.4.4 Long cable lengths tested with a reflection suppressor 9
2.5 Voltage levels/partial discharge limits 9
2.6 Plotting double pulse diagrams 9
2.7 Requirements for the terminal impedance 10

SECTION THREE — APPLICATION GUIDE

3.1 Background information 12
  3.1.1 Introduction 12
  3.1.2 Superposition and attenuation 14
3.2 Procedures and parameters 15
  3.2.1 Determination of characteristic properties of the test circuit 15
  3.2.2 Measurement procedures 17
3.3 Bibliography 20
List of symbols 21
FIGURES 22
Annex ZA (normative) Normative references to international publications with their corresponding European publications 34

ELECTRICAL TEST METHODS FOR ELECTRICAL CABLES

Part 3: Test methods for partial discharge measurements on lengths of extruded power cables

SECTION ONE - GENERAL

1.1 Scope

This standard specifies the essential requirements for partial discharge measurements on lengths of extruded power cable.

Reference is made to IEC Publication 270 which gives the techniques and considerations applicable to partial discharge measurements in general. The first edition of IEC Publication 270 appeared in 1968. All references in this standard apply to the second edition (1981).

1.2 Object

The object of the test is to determine the discharge magnitude, or to check that the discharge magnitude does not exceed a specified value, at a specified voltage with a given sensitivity.

SECTION TWO – PARTIAL DISCHARGE TESTS

2.1 Definitions

The definitions given in IEC Publication 270 apply.

2.2 Test apparatus

2.2.1. *Equipment*

The equipment consists of a high-voltage power supply having a kilovolt-ampere capability adequate for the length of cable under test, a voltmeter for high voltages, a measuring circuit, a discharge calibrator, a double pulse generator and, if necessary, a terminal impedance or reflection suppressor. All components of the test equipment shall have a sufficiently low noise level to achieve the required sensitivity.

The frequency of the test supply is assumed to be the power frequency a.c. 49 Hz to 61 Hz of approximately sine-wave form, the ratio peak value/r.m.s. being equal to $\sqrt{2}$ with a tolerance of ± 7%. The main subjects considered in this standard, calibration and attenuation of partial discharge pulses, are not affected by using different frequencies of the power supply. However, the partial discharge characteristics are affected by the test frequency; the measurement procedure should take this fact into consideration.

2.2.2 *Test circuit and instruments*

The test circuit includes the test object, the coupling capacitor and the measuring circuit. The measuring circuit consists of the measuring impedance (input impedance of the measuring instrument and the input unit which is selected to match the cable impedance), the connecting lead and the measuring instrument. The measuring instrument or detector includes a suitable amplifying device, an oscilloscope and, if desired, an additional instrument to indicate the existence of partial discharges and to measure the apparent charge.

2.2.3 *Double pulse generator*

The properties of the partial discharge test circuit shall be checked by means of a double pulse generator, producing two equal pulses (same apparent charge) following each other within a continuously variable time interval of 0.2 µs to 100 µs. The rise time of the pulses shall not exceed 20 ns (10% to 90% of peak value); the time between 10% values of the front and the tail shall not exceed 150 ns. The pulses may be synchronized with the power frequency.

2.2.4 *Terminal impedance (characteristic impedance)*

A terminal impedance equal in value to the characteristic impedance of the test object may be connected to the open end of the cable remote from the detector. This will suppress the reflection of pulses at this end.

2.2.5 *Reflection suppressor*

To avoid superposition effects when testing without a terminal impedance, a reflection suppressor may be used. This is an electronic switch which in most cases can block the input of the detector from pulses reflected from the open end of the cable. However, when the partial discharge source is located at or near the open end some positive superposition is unavoidable.

2.3 Determination of characteristic properties of the test circuit

The characteristic properties of the test circuit should be determined under the conditions to be used. The test circuits normally used for connections to a single cable end are those shown in Figures 1, 2, 3, 4 and 5. Similar test circuits are also applicable when both ends of the cable conductor are connected together. Here the two ends of the screen must also be connected together.

2.3.1 *Superposition*

If a terminal impedance is not used it is necessary to determine the properties of the test circuit with respect to superposition of travelling waves. A double pulse generator is connected according to Figure 6 and a double pulse diagram is plotted (see Clause 2.6 and Figures 7, 8 and 9). This check should be carried out at least once a year and also upon request and when any significant circuit component has been repaired or changed.

2.3.2 *Terminal impedance*

If a terminal impedance is used (see Figure 4) its suitability for the type of cable under test should be demonstrated using the procedure described in Sub-clause 2.7. This check should be carried out at least once a year and also upon request and when any significant circuit component has been repaired or changed.

2.3.3 *Reflection suppressor*

The purpose of using this device is to obtain a double pulse diagram of Type 1 corresponding to Figure 7. Using the arrangement shown in Figure 10, the efficiency of the reflection suppressor should be checked at least once per year and also upon request and when any significant circuit component has been repaired or changed.

2.3.4 *Calibration charge*

The "charge transfer" method of calibration shall be used in accordance with Sub-clause 5.2.1 of IEC Publication 270. Further guidance for the use of discharge calibrators is given in CIGRÉ Report 1968-21-01, Appendix III. In this method, a calibrator is connected directly across one end of the cable being tested to inject short current pulses of predetermined charge magnitude into the test object as detailed in Sub-clause 2.4. The resulting pulse on the oscilloscope should have a height of at least 10 mm.

Unless the calibrating capacitor is rated for use at the test voltages involved, it is necessary to disconnect it before the high-voltage test transformer is energized. The amplifier gain shall not be re-adjusted after this has been done, unless a means is provided for continuous display of a suitable calibrating signal throughout the test.

Such a means may be as follows:

a) the calibrating capacitor may be full voltage rated and may form part of the test circuit. It need not, in this case, be disconnected before the high-voltage test transformer is energized, or

b) a secondary calibrator can be used additionally. This calibrator is connected to the input of the detector. In this case, the amplitude of the secondary pulse response shall be pre-calibrated against the primary calibrator before the latter is disconnected and the high-voltage test transformer is energized in accordance with CIGRÉ Report 1968-21-01, Appendix III, Section I, Sub-clause 1.2.

The calibration discharge, q_{cal} (in picocoulombs), is equal to the product of the calibration pulse amplitude ΔU (in volts) and the calibrating capacitance C_{cal} (in picofarads), of the calibrator as long as this capacitance is small compared with the capacitance of the test object, C_x.

$$q_{cal} = C_{cal} \cdot \Delta U$$

The characteristics of the calibrating pulse shall comply with Sub-clauses 5.2 and 5.3 of IEC Publication 270 and CIGRÉ Report 1968-21-01, Appendix III, Section III. For long lengths of cable there is an additional requirement that the calibrating capacitance shall be not larger than 150 pF.

The scale factor of the measuring instrument, k, is the factor by which the reading of the instrument shall be multiplied in order to obtain the magnitude of the discharge quantity injected into the test object during calibration. Its consistency shall comply with Sub-clause 5.2 of IEC Publication 270.

2.3.5 *Sensitivity*

a) The sensitivity of the test circuit (with the high-voltage supply and the instruments) is defined as the minimum detectable discharge pulse, q_{min}, (in picocoulombs) that can be observed in the presence of background noise. Individual, clearly identifiable interference pulses may be disregarded. An oscilloscope display is required to monitor noise signal levels since a picocoulomb meter does not identify the source of the signal indicated. In order to be detectable, a discharge pulse shall be of at least twice the apparent noise height, h_n (h_n is the noise reading on the oscilloscope or the picocoulomb meter if this is used additionally).
Therefore:

$$q_{min} = 2\,k \cdot h_n$$

where k is the scale factor.

b) The values of sensitivity shall be selected according to Sub-clause 2.5.

2.4 Measurement procedures

The test shall be carried out as a type test on short cable samples and as a routine test on production lengths.

The selection of the test circuit depends on whether the cable sample may be considered as a short length (Sub-clause 2.4.1) or a long length (Sub-clauses 2.4.2, 2.4.3 and 2.4.4) depending on the double pulse diagram (Sub-clause 2.6). The test circuit has to be discharge free for achieving the required sensitivity (see Sub-Clause 2.3.5). Calibration does not necessarily have to be done with the HV supply on (see Sub-clause 2.3.4).

2.4.1 *Short cable lengths including type test lengths*

a) Requirements

For short lengths the cable may be considered similar to a lumped capacitance. The limitation on length where this is not acceptable depends upon the test circuit used. The actual value would be determined using the double pulse diagram described in Sub-clause 2.6 and defined as l_k.

Note. — However, lengths up to $2l_k$ behave as short lengths when both ends of the cable are connected together. (See Sub-clause 2.3.)

The test circuits normally used are those in Figures 1, 2 and 3.

b) Verification of sensitivity

The calibrator shall be connected in parallel with the cable and only at the end remote from the detector. The calibration charge, q_{cal}, is injected, and the respective measured deflection value a_2, is used to calculate the scale factor $k_2 = q_{\text{cal}}/a_2$ (pC/ mm) and sensitivity, $q_{\min}$ (pC).

$$q_{\min} = 2k_2 \cdot h_n$$

where:

h_n is the deflection (mm) from background interference

c) Test procedure

The measurement shall be made only at one end of the cable. For the measured deflection A (mm) the discharge magnitude q (pC) is

$$q = k_2 \cdot A$$

The voltage levels used shall be selected according to Sub-clause 2.5.

2.4.2 *Long cable lengths tested without a terminal impedance*

a) Requirements

For cable lengths in excess of l_k it may still be possible to test without a terminal impedance provided superposition and attenuation phenomena are taken into account. A test without terminal impedance is permitted where the double pulse diagram (Sub-clause 2.6) is either:

- Type 1 (Figure 7) or
- Type 2 and Type 3 (Figures 8 and 9) but where the cable length, l, lies outside the limits $2l_1 \leqslant l \leqslant 2l_2$).

(See Sub-clause 2.6 for the determination of l_1 and l_2.)

For lengths inside these limits an alternative test circuit should be used or the procedures described in Sub-clause 2.4.3 or 2.4.4 should be adopted.

The test circuits normally used are those shown in Figures 1, 2, 3 and 5.

b) Verification of sensitivity

As shown in Figures 1, 2, 3 or 5, the calibrator shall be connected to each end in turn, in parallel with the cable, at first to the end remote from the detector and then—with the same setting of the amplifier and calibration charge—to the end near the detector. The following values shall be recorded:

- a_1 (mm) the deflection measured with the calibrator at the end near to the detector;
- a_2 (mm) the deflection measured with the calibrator at the end remote from the detector.

a_1 and the calibration charge q_{cal} (pC) are used to determine the scale factor k_1 (pC/mm):

$$k_1 = q_{\text{cal}}/a_1$$

a_1 and a_2 are used to determine a correction factor F to allow for attenuation. It is given by:

$$F = 1 \qquad \text{if } a_2 \geqslant a_1$$

$$F = \sqrt{\frac{a_1}{a_2}} \qquad \text{if } a_2 < a_1$$

The sensitivity $q_{\min}$ (pC) is calculated by:

$$q_{\min} = 2k_1 \cdot h_n \cdot F$$

c) Test procedure

The measurement shall be made twice by connecting the high voltage end of the coupling capacitor to each end of the cable in turn. The measured deflections A_1 and A_2 shall be determined and the higher value $A_{\max}$ (mm) selected. With the scale factor k_1 (pC/mm) and the correction factor F the discharge magnitude q (pC) is:

$$q = k_1 \cdot A_{\max} \cdot F$$

The voltage levels used when measuring the highest deflection $A_{\max}$ shall be selected according to Sub-clause 2.5.

Note. — Only if the double pulse diagram is of type 1 (see Figure 7) and $a_2 \geqslant a_1$, a measurement of A (mm) is sufficient when both cable ends are connected together (see Sub-clause 2.3). The discharge magnitude is then:

$$q = k_1 \cdot A$$

2.4.3 *Long cable lengths tested with a terminal impedance*

a) Requirements

To eliminate superposition errors, cables of length greater than l_k may be tested with a terminal impedance as shown in Figure 4. This method may be used with all detectors and all cable lengths provided that the impedance Z_w meets the requirements specified in Sub-clause 2.7. The suitability of the impedance for the cable under test shall be demonstrated using the procedure described in Sub-clause 2.7.

b) Verification of sensitivity

As shown in Figure 4 the calibrator should be connected to each end in parallel with the cable at first to the end remote from the detector and then—with the same amplifier setting and calibration charge—to the end near to the detector.

The following values shall be recorded:

- a_1 (mm) the deflection measured with the calibrator at the end near to the detector. This need not be measured if the following procedure of Item *c* ii) is sufficient;
- a_2 (mm) the deflection measured with the calibrator at the end remote from the detector.

The scale factor k_2 (pC/mm) is determined, and sensitivity $q_{\min}$ (pC) calculated:

$$k_2 = q_{\text{cal}}/a_2$$

$$q_{\min} = 2\,k_2 \cdot h_n$$

c) Test procedure

i) When it is required to determine the value of the partial discharge magnitude as closely as possible, the high voltage end of the coupling capacitor shall be connected to each end of the cable in turn and both measured deflections A_1 and A_2 (mm) determined. The discharge magnitude q (pC) is given by:

$$q = q_{\text{cal}} \cdot \sqrt{\frac{A_1 \cdot A_2}{a_1 \cdot a_2}}$$

ii) When it is sufficient to check that the discharge magnitude does not exceed a specified value, the measurement may be made with the high voltage end of the coupling capacitor connected to one end of the cable only. In this case the calibration pulse is injected only at the end of the cable connected to the terminal impedance remote from the detector (a_2). With the measured deflection A_1 (mm) and the scale factor k_2 (pC/mm) the discharge magnitude q (pC) is given by:

$$q = k_2 \cdot A_1$$

The voltage levels used when measuring the deflections A_1 and if necessary A_2 shall be selected according to Sub-clause 2.5.

2.4.4 *Long cable lengths tested with a reflection suppressor*

The connection of the reflection suppressor is shown in Figure 5.

a) Requirements

When using a reflection suppressor the double pulse diagram must be Type 1 (see Figure 7).

b) and *c) Verification of sensitivity and test procedure*

These are the same as those indicated for testing long lengths without a terminal impedance (see Sub-clause 2.4.2).

2.5 Voltage levels/partial discharge limits

The voltage, sensitivity and partial discharge limits shall be determined in accordance with the requirements in the standard for the type of cable.

2.6 Plotting double pulse diagrams

A double pulse generator should be connected to the components of the measuring circuit as shown in Figure 6.

The double pulse plot is affected by variations in each circuit component. It is important that the double pulse plot be obtained for the precise conditions to be used in the high voltage test. The power cable is replaced by a resistive load having the maximum characteristic impedance for extruded cables ($R = 50\ \Omega$ to $60\ \Omega$). The double pulses are injected in the same position as the calibration pulses for the various test circuits shown in Figures 1, 2 and 3. The following conditions should apply:

a) The double pulse generator I should satisfy the requirements of Sub-clause 2.2.3. Pulse spacing should be determined using an external oscilloscope with calibrated time base. Required accuracy: ± 3% or 50 ns whichever is the greater. The overall output impedance should be in the range of 50 Ω to 60 Ω. To achieve this it may be necessary to add external resistors in parallel to or in series with the output.

Experience has shown that the double pulse plot may be reliably obtained in the following ways:

- The simplest method is to connect the double pulse generator across the high voltage capacitor C_K and the measuring impedance Z_A with wires not longer than 3 m.
- For longer connections a coaxial cable should be used (see Figure 6). In this case two adapter resistors R_1 and R_2 are necessary to ensure that the matched system presents an impedance in the range 50 Ω to 60 Ω as the load resistance.

b) The capacitor C_K and the other high voltage components of the test circuit should be the same and have the same connections as those used in the high voltage test.

c) The matching unit or detector impedance Z_A to be used in the high voltage test should be used to obtain the double pulse plot.

d) The detector amplifier D should be used with the gain setting and amplifier frequency response selected for the high voltage test. For accurate measurement of the changes in pulse magnitude caused by superposition distortions, the output of the detector amplifier D should be displayed on an external oscilloscope (for example the oscilloscope used in Item *a)*).

The time interval of the double pulse generator should be set to 100 µs and the deflections of the partial discharge detector to the two pulses A_{100} be measured. The time interval should then be reduced from 100 µs to 0.2 µs; for different values of an interval t measured between maximum peaks of the two pulses, the maximum deflection A_t should be measured. Particular attention should be given to areas of positive and negative superposition. Values of A_t/A_{100} should then be plotted as a function of t to obtain the double pulse diagram. Examples of diagrams are in Figures 7 to 9.

The value t_k where $A_t/A_{100} = 1.4$ on the initial positive superposition should be determined from the plot. Times t_1 and t_2 where $A_t/A_{100} \leqslant 1.0$ at all areas of *negative superposition* should be determined. Taking into account the errors of measurement, areas of negative superposition with a maximum magnitude up to −10% can be ignored.

The cable lengths l_k, l_1 and l_2 corresponding to t_k, t_1 and t_2 should be calculated using the formula $l = 0.5 \cdot t \cdot v$. The mean propagation velocity is v and typical values for most extruded cable lie between 150 m/µs and 170 m/µs. On request the propagation rate shall be measured by injecting a calibration pulse into a cable not having a terminal impedance and measuring the time delay between incident and reflected pulse.

The cable lengths $l < l_k$ can be considered as short lengths. These may be as low as 100 m and even higher than 1000 m.

Lengths between $2l_1$ and $2l_2$ are considered forbidden lengths. These lengths have to be tested with a terminal impedance (see Sub-clause 2.4.3) or under modified conditions of the test circuit (for example D, Z_A, C_K) to alter l_1 and l_2 to more suitable values. Alternatively it is possible to effectively double the value of l_k by connecting both ends of the cable together.

2.7 Requirements for the terminal impedance

The terminal impedance Z_w shown in Figure 4 comprises either RC or RLC elements which are selected on the basis of experimental evaluation.