BS EN 60885-3:2015

BSI Standards Publication

Electrical test methods for electric cables

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

National foreword

This British Standard is the UK implementation of EN 60885-3:2015. It is identical to IEC 60885-3:2015. It supersedes BS EN 60885-3:2003, which will be withdrawn on 14 May 2018.

The UK participation in its preparation was entrusted by Technical Committee GEL/20, Electric cables, to Subcommittee GEL/20/16, Electric Cables — Medium/high voltage.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Electrical test methods for electric cables - Part 3: Test methods for partial discharge measurements on lengths of extruded power cables (IEC 60885-3:2015)

Méthodes d'essais électriques pour les câbles électriques - Partie 3: Méthodes d'essais pour la mesure des décharges partielles sur des longueurs de câbles de puissance extrudés (IEC 60885-3:2015)

Elektrische Prüfverfahren für Starkstromkabel - Teil 3: Prüfverfahren zur Teilentladungsmessung an Längen von extrudierten Kabeln (IEC 60885-3:2015)

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

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Foreword

The text of document 20/1560/FDIS, future IEC 60885-3, prepared by IEC/TC 20 "Electric cables" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60885-3:2015.

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)	2016-02-14
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2018-05-14

This document supersedes EN 60885-3:2003.

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Endorsement notice

The text of the International Standard IEC 60885-3:2015 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60060-1	NOTE Harmonized as EN 60060-1.

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 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60270	2000	High-voltage test techniques - Partial discharge measurements	EN 60270	2001

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTRICAL TEST METHODS FOR ELECTRIC CABLES –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60885-3 has been prepared by IEC technical committee 20: Electric cables.

This second edition of IEC 60885-3 cancels and replaces the first edition, published in 1988 and constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- The definition of sensitivity as twice the background noise level has been removed and replaced by a practical assessment of sensitivity based on the minimum level of detectable discharge.
- References to measurements of pulse heights in mm on an oscilloscope have been replaced by measurements of partial discharge magnitude in pC.

- The order of the clauses has been revised in line with the general numbering scheme of IEC standards and to provide clarity in order to facilitate its practical use. Section 3 of the first edition (Application guide) has been removed as it is considered that background information is better obtained from the original references as listed in the bibliography.

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

FDIS	Report on voting
20/1560/FDIS	20/1587/RVD

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

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

A list of all parts in the IEC 60885 series, published under the general title *Electrical test methods for electric cables*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ELECTRICAL TEST METHODS FOR ELECTRIC CABLES –

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

1 Scope

This part of IEC 60885 specifies the test methods for partial discharge (PD) measurements on lengths of extruded power cable, but does not include measurements made on installed cable systems.

Reference is made to IEC 60270 which gives the techniques and considerations applicable to partial discharge measurements in general.

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 60270:2000, *High-voltage test techniques – Partial discharge measurements*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60270 apply.

3.2 Symbols used in Figures 1 to 14

a_1 discharge magnitude measured with the calibrator at the end near to the detector

a_2 discharge magnitude measured with the calibrator at the end remote from the detector

C_{cal} calibrator

C_K coupling capacitor

C_x power cable

D detector

I double pulse generator

l length of the power cable

M coaxial signal cable

Q discharge magnitude

$R_1 R_2$ matching resistors

RS reflection suppressor

v propagation velocity of partial discharge

V voltage indicator

W power supply

Z impedance/filter

Z_A input unit

Z_W terminal impedance

4 Overview

4.1 General

Partial discharge measurements shall be carried out using the test techniques specified in IEC 60270.

4.2 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 and a declared minimum sensitivity.

4.3 Problem of superposition of travelling waves for long lengths

Short lengths of cable behave in the same way as a single capacitor in that the discharge magnitude can be measured directly by considering the cable as a single capacitor. However longer cables behave like a transmission line and PD pulses travel away from their source in both directions along the cable, in the form of a wave. On reaching the remote end from the measuring equipment, the pulse will be reflected with the same polarity if the end is open circuit. The reflected pulse will then travel back along the length of cable and arrive at the detector at a time after the directly received pulse. If the time between the arrival of the two pulses is short (the time difference depending on the length of the cable) then the detection instrument may give a false response, indicating either a larger or smaller magnitude of discharge than was actually the case. The methods detailed in this standard allow correct measurement of partial discharges under these conditions.

Figures 1 to 4 illustrate the behaviour of travelling waves and possible superposition effects.

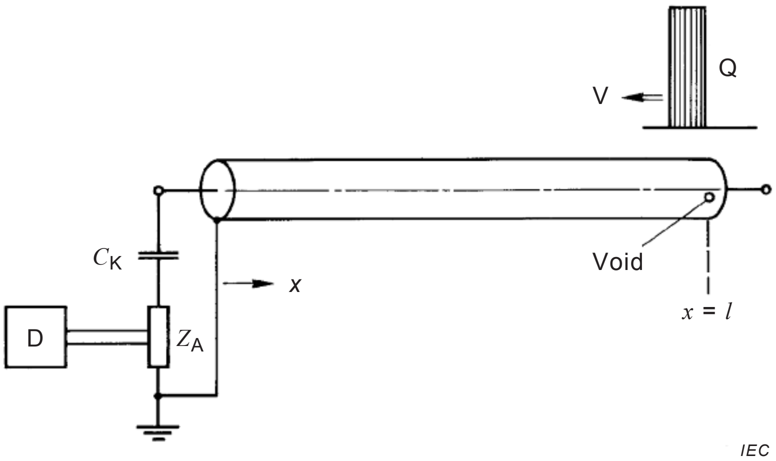


Figure 1 – Discharge site exactly at the cable end remote from the detector ($x = l$)

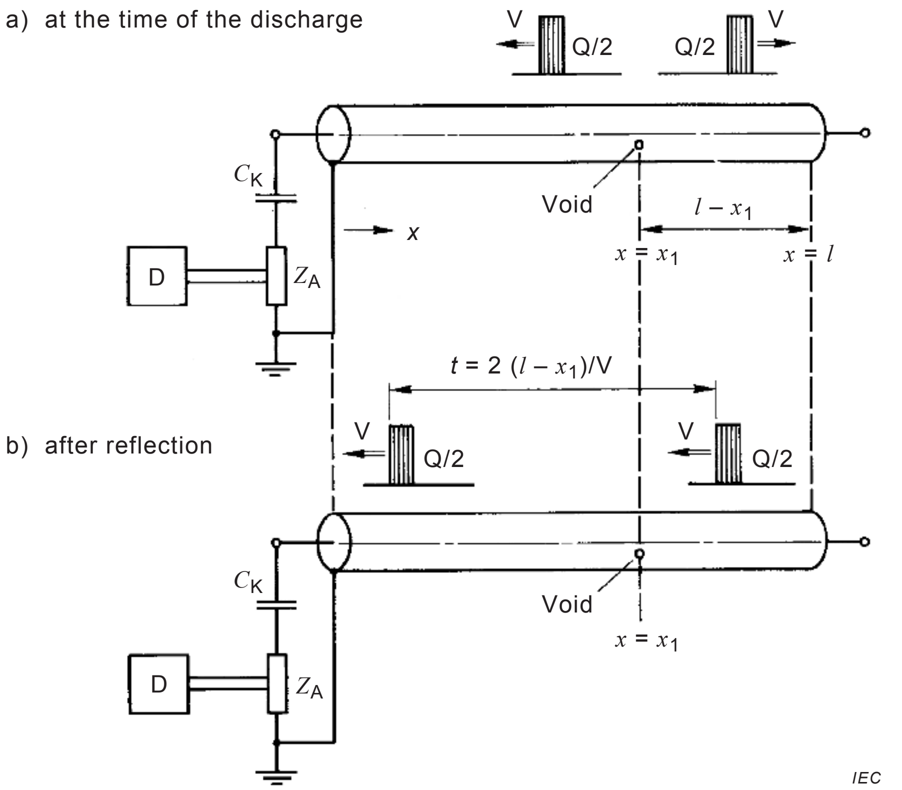


Figure 2 – Discharge site at a distance $x = x_1$ – Travelling waves

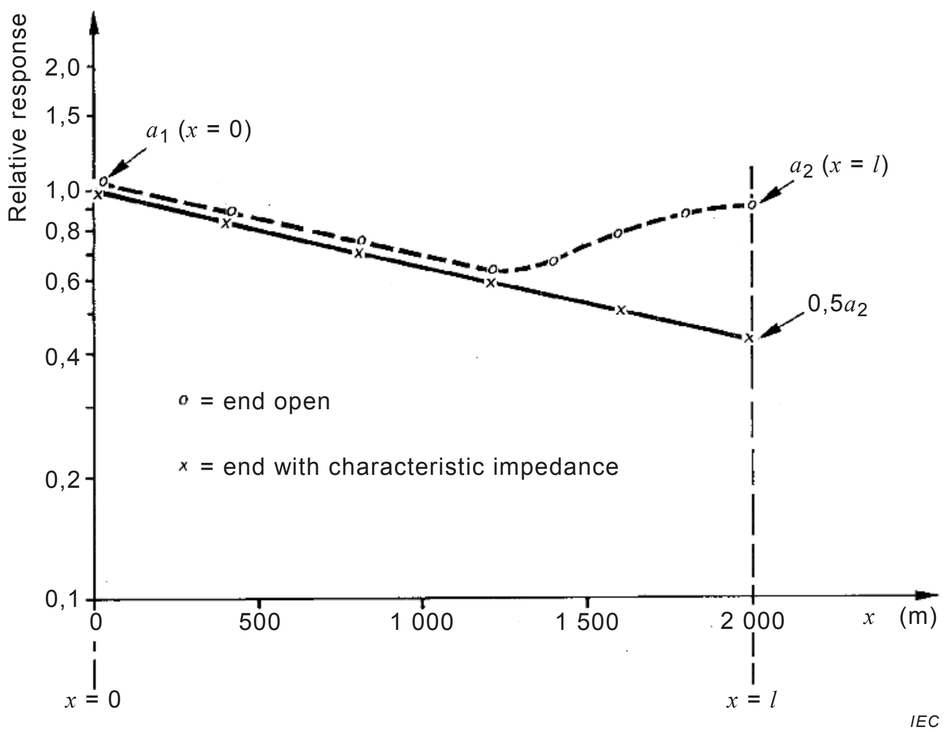


Figure 3 – Attenuation of PD pulses along the cable

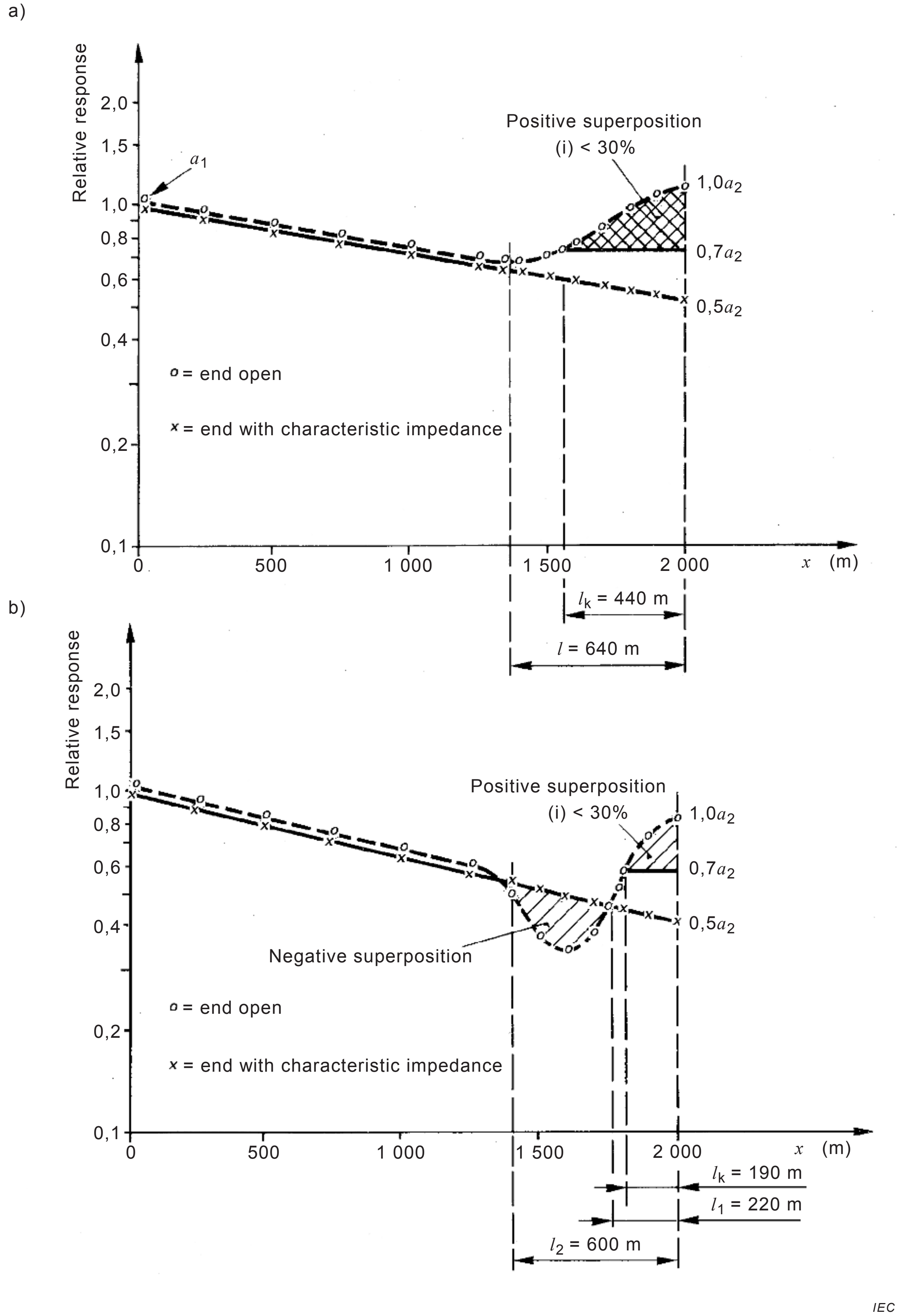


Figure 4 – Superposition and attenuation of PD pulses

5 Partial discharge tests

5.1 Test apparatus

5.1.1 Equipment

The equipment consists of a high-voltage alternating voltage supply having a rating adequate to energise the length of cable under test, a voltmeter for high voltages, a measuring circuit, a discharge calibrator, a double pulse generator and, where applicable, 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 shall be in the range 45 Hz to 65 Hz with a waveshape approximating to a sinusoid with the ratio of peak to r.m.s. values being equal to $\sqrt{2}$ with a maximum tolerance of 5 %.

5.1.2 Test circuit and instruments

The test circuit includes the high voltage power supply, test object, the coupling capacitor and the HV and PD measuring equipment. 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, or other instrument to indicate the existence of partial discharges and to measure the apparent charge. The measuring system shall comply with IEC 60270.

5.1.3 Double pulse generator

A double pulse generator is an instrument producing two equal pulses (with the same apparent charge) following each other within a time interval which can be varied between 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.

5.1.4 Terminal impedance

A terminal impedance is an impedance, equal in value to the characteristic impedance of the test object, which is connected to the open end of the cable remote from the detector. It may be a combination of resistance and capacitance (R & C) or resistance, capacitance and inductance (R, C & L). The components shall be suitable for operation at the test voltage to be applied to the cable under test. Additional requirements are specified in section 5.6.

5.1.5 Reflection suppressor

This is an electronic switch which is designed to block the input of the measuring instrument from pulses reflected from the open end of the cable. This is achieved by blocking the input for a fixed time after the first pulse is received.

5.2 Setting up the test circuit

5.2.1 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 5, 6, 7, 8 and 9. Similar test circuits are also applicable when both ends of the cable conductor are connected together; in this case the two ends of the metal cable screen shall also be connected together.

5.2.2 Terminal impedance

If a terminal impedance is connected to the remote end of the cable under test, with an impedance value equal to the characteristic impedance of the cable then the cable will behave as if it is of infinite length and there will be no reflected wave. The circuit for connection of a terminal impedance is shown in Figure 8. The values (RC and L where applicable) of the components of the terminal impedance and its suitability for the type of cable under test should be demonstrated using the procedure described in 5.6. This check should be carried out when the test circuit is set up and also when any changes are made to the circuit.

5.2.3 Determination of superposition of travelling waves

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 10 and a double pulse diagram is plotted (see 5.5 and Figures 11, 12 and 13). This check should be carried out when the test circuit is set up and also when any changes are made to the circuit.

5.2.4 Reflection suppressor

The purpose of using a reflection suppressor is to obtain a double pulse diagram of Type 1 corresponding to Figure 11. Using the arrangement shown in Figure 14, the efficiency of the reflection suppressor should be checked by plotting a double pulse diagram (see 5.5 and Figures 11, 12 and 13), when the test circuit is set up and also when any changes are made to the circuit.

5.2.5 Calibration of the measuring system in the complete test circuit

Calibration of the measuring system in the complete test circuit shall be carried out in accordance with Clause 5 of IEC 60270:2000. The calibrator used shall comply with IEC 60270. For long lengths of cable (> 100 m) there is an additional requirement that the calibrating capacitance shall be not greater than 150 pF.

5.2.6 Sensitivity

The sensitivity of the measuring system is defined as the minimum detectable discharge pulse, q_{min} (in picocoulombs – pC) that can be observed in the presence of background noise.

Value of q_{min} shall be determined by evaluation of the background noise level and shall be no more than twice the apparent noise level, h_{n} (h_{n} is the noise reading on the measuring instrument).

Therefore:

$$q_{\text{min}} = x \times k \times h_{\text{n}}$$

where k is the scale factor and x is the ratio of the minimum detectable discharge to the background noise. The maximum allowed value of x is 2. Typically values of x of between 1,25 and 1,5 should be achievable.

The maximum values of sensitivity shall be determined according to 5.4.

5.3 Measurement procedures

5.3.1 General

The selection of the test circuit depends on whether the cable sample may be considered as a short length (see 5.3.2) or a long length (see 5.3.3, 5.3.4 and 5.3.5). The test circuit shall be discharge free in order to achieve the required sensitivity (see 5.2.6). Calibration does not necessarily have to be done with the HV supply on (see 5.2.5). During the partial discharge measurement, individual pulses clearly identifiable as interference may be disregarded.

5.3.2 Short cable lengths including type test lengths

5.3.2.1 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, however it may be assumed that cable lengths of up to 50 m (or 100 m, if both ends of the cable are connected together) behave as a lumped capacitance and therefore superposition of reflected waves need not be taken into account. For longer lengths whether they can be treated as a lumped capacitance shall be determined using the double pulse diagram as described in 5.5. The maximum length which can be considered as a lumped capacitance is defined as $l_{k;}$ This may be as low as 100 m or even greater than 1 000 m, depending on the particular measuring system in use.

The test circuits normally used are those in Figures 5, 6 and 7.

5.3.2.2 Verification of sensitivity

The determination of the scale factor k for the measurement of the apparent charge shall be carried out in accordance with Clause 5 of IEC 60270:2000. Therefore the partial discharge calibrator shall be connected in parallel with the cable at the end remote from the detector.

5.3.2.3 Test procedure

The measurement shall be made only at one end of the cable.

The test parameters shall be selected according to 5.4.

5.3.3 Long cable lengths tested without a terminal impedance

5.3.3.1 General

For long cable lengths (>50 m or >100 m with ends connected), tested without a terminal impedance, it is necessary to plot a double pulse diagram.

5.3.3.2 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 double pulse generator is connected according to Figure 10 and a double pulse diagram is plotted (see 5.5 and Figures 11, 12 and 13). This shall be carried out when the test circuit is set up and also when any changes are made to the circuit.

A test without terminal impedance is permitted where the double pulse diagram is either

– type 1 (Figure 11), or
– type 2 and type 3 (Figures 12 and 13) but where the cable length, l, lies outside the limits $2l_1 \le l \le 2l_2$.

(See 5.5 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 5.3.4 or 5.3.5 should be adopted.

The test circuits normally used are those shown in Figures 5, 6, 7 and 9.

5.3.3.3 Verification of sensitivity

The determination of the scale factor k for the measurement of the apparent charge shall be carried out in accordance with Clause 5 of IEC 60270:2000. Therefore the partial discharge calibrator shall be connected in parallel with the cable at the end near to the detector.

For the determination of the attenuation correction factor, the partial discharge calibrator shall be connected to each end in turn in parallel with the cable with the same setting of the amplifier and calibration charge. The following values shall be recorded:

- a_1 discharge magnitude measured with the calibrator at the end near to the detector;
- a_2 discharge magnitude measured with the calibrator at the end remote from the detector.

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

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

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

5.3.3.4 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 discharge magnitudes A_1 and A_2 shall be determined and the higher value A_{max} (pC) selected. With the correction factor F, the discharge magnitude q(pC) is:

$$q = A_{max} \times F$$

The voltage levels used when measuring the highest discharge magnitude A_{max} shall be selected according to 5.4.

NOTE Only if the double pulse diagram is of type 1 (see Figure 11) and $a_2 \geq a_1$, a measurement of A(pC) is sufficient when both cable ends are connected together (see 5.3.2). The discharge magnitude is then: $q = A$.

5.3.4 Long cable lengths tested with a terminal impedance

5.3.4.1 General

For long cable lengths (>50 m or >100 m with ends connected), tested with a terminal impedance, it is not necessary to plot a double pulse diagram.

5.3.4.2 Requirements

To eliminate superposition errors, cables of length greater than l_k may be tested with a terminal impedance as shown in Figure 8. This method may be used with all detectors and all cable lengths provided that the impedance Z_w meets the requirements specified in 5.6. The suitability of the impedance for the cable under test shall be demonstrated using the procedure described in 5.6.

5.3.4.3 Verification of sensitivity

The partial discharge calibrator shall be connected to each end in turn in parallel with the cable with the same setting of the amplifier and calibration charge. The following values shall be recorded:

- a_1 (pC) the discharge magnitude measured with the calibrator at the end near to the detector. This need not be measured if the procedure in 5.3.4.4 b) is sufficient;

– a_2 (pC) the discharge magnitude measured with the calibrator at the end remote from the detector.

For the determination of the scale factor k for the measurement of the apparent charge in accordance with Clause 5 of IEC 60270:2000, the value a_2 (pC) with the partial discharge calibrator connected in parallel with the cable at the end remote from the detector shall be used.

5.3.4.4 Test procedure

The test procedure is as follows.

a) 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 discharge magnitudes A_1(pC) and A_2 (pC) determined. The discharge magnitude q (pC) is given by:

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

where q_{cal} is the calibration discharge magnitude (pC).

b) 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 discharge magnitude A1 (pC) and the scale factor k_2 the discharge magnitude q (pC) is given by:

$$q = k_2 \times A_1$$

The voltage levels used when measuring the discharge magnitudes A_1 and if necessary A_2 shall be selected according to 5.4.

5.3.5 Long cable lengths tested with a reflection suppressor

5.3.5.1 General

For long cable lengths (>50 m or >100 m with ends connected), tested with a reflection suppressor, it is necessary to plot a double pulse diagram.

The connection of the reflection suppressor is shown in Figure 9.

A double pulse generator is connected according to Figure 10 and a double pulse diagram is plotted (see 5.5 and Figures 11, 12 and 13). This shall be carried out when the test circuit is set up and also when any changes are made to the circuit.

5.3.5.2 Requirements

When using a reflection suppressor the double pulse diagram shall be type 1 (see Figure 11).

5.3.5.3 Verification of sensitivity

See 5.3.2.2.

5.3.5.4 Test procedure

See 5.3.2.3.

5.4 Voltage levels/partial discharge limits

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

5.5 Double pulse behaviour and plotting the double pulse diagram

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.

NOTE The test cable is not connected whilst the double pulse plot is being plotted, the double pulse plot depends solely on the measuring system and test circuit, excluding the cable.

The power cable is replaced by a resistive load having the maximum characteristic impedance for extruded cables (generally R_{max} = 40 Ω). The double pulses are injected in the same position as the calibration pulses for the various test circuits shown in Figures 5, 6 and 7. Figure 10 shows, as an example, the double pulse generator connected to the test circuit of Figure 5.

The following conditions should apply:

a) The double pulse generator should satisfy the requirements of 5.1.3. In some cases the dials of the double pulse generator may have numeric (e.g. 0 to 9) markings for pulse separation, in which case it will be necessary to use a suitable oscilloscope to calibrate these scales in terms of µs; the required accuracy is ±3 % or 50 ns whichever is the greater. The overall output impedance should approximately match the characteristic impedance of the cable, which is typically in the range of 20 Ω to 40 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 10). In this case two adapter resistors R_1 and R_2 are necessary to ensure that the system approximately matches the characteristic impedance of the cable, which is typically in the range of 20 Ω to 40 Ω.

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 5.5 a)).

   The time interval of the double pulse generator should be set to 100 µs and the discharge magnitude of the partial discharge detector to the two pulses A_{100} should 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 discharge magnitude 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 11 to 13.

   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 $A_t/A_{100} \leq$ 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 % may 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 × t × 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 1 000 m.

Lengths between $2l_1$ and $2l_2$ have to be tested with a terminal impedance (see 5.3.4.2) 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.

5.6 Requirements for the terminal impedance

5.6.1 General

The terminal impedance Z_w, shown in Figure 8 comprises either RC or RLC elements which are selected on the basis of experimental evaluation.

5.6.2 RC element

The following measurement shall be used to prove the suitability of the terminal capacitor C_w.

The RC element shall be connected in parallel with the cable across the end remote from the detector. The capacitive component shall be short-circuited and the ohmic component shall be adjusted to correspond to the characteristic impedance of the cable. Subsequently the calibrator shall also be connected to the end remote from the detector and the measured discharge magnitude a_2 shall be determined.

With the same amplifier setting, the short circuit of the capacitive component of the terminal impedance shall be removed.

The removal of the short circuit of the capacitor (C_w) shall not change the discharge magnitude a_2 by more than ±15 %.

For PD detectors having a cut-off frequency lower than 2 MHz, a reasonable estimate for the value of the capacitance C_w (high voltage coupling capacitor of Z_w) may be obtained using the following formula:

$$C_w \geq 0{,}5 \frac{1}{R_w \times f_m}$$

where

R_w is the ohmic component of the terminal impedance (corresponding approximately to the characteristic impedance of the cable);

f_m is the mean measuring frequency of the detector (arithmetic mean of the upper and lower limiting frequencies of the detector).

For PD measuring instruments having a wide-band amplifier with an upper cut-off frequency more than 2 MHz in connection with an electronic integrator unit, C_w can be estimated on the basis of the relation:

$$C_w \geq \frac{3\,T_J}{R_w}$$

T_J is the time duration of the original PD pulse (in general smaller than 0,2 μs).

5.6.3 RLC element series resonance circuit

The following measurement shall be used for proving the suitability of the resonant circuit at the respective measuring frequency.

With the terminal impedance removed an ohmic resistor corresponding to the characteristic impedance of the cable shall be connected to the end remote from the detector in parallel with the cable. Furthermore the calibrator shall be connected to the end remote from the detector, and the measured discharge magnitude a_2 shall be determined.

Then the ohmic resistor shall be removed — with the setting of the amplifier kept constant — and replaced by the terminal impedance, consisting of RLC.

At the measuring frequency the ohmic component of the terminal impedance shall correspond to the resistance R_w.

The measured discharge magnitude a_2 shall not change by more than ±15 % when the terminal impedance is connected.

Reasonable estimates of the values of the capacitance C_w and the inductance L_w may be obtained by using the following formulas:

$$C_w \geq \frac{\Delta f}{2\pi \times f_m^2 \times R_w}$$

$$L_w \geq \frac{1}{(2\pi \times f_m)^2 \times C_w}$$

where

R_W is the ohmic component of the terminal impedance (corresponding approximately to the characteristic impedance of the cable);

f_m is the mean measuring frequency of the detector (arithmetic mean of the upper and lower limiting frequencies of the detector);

Δf is the bandwidth of the detector (upper limiting frequency minus the lower limiting frequency of the detector).

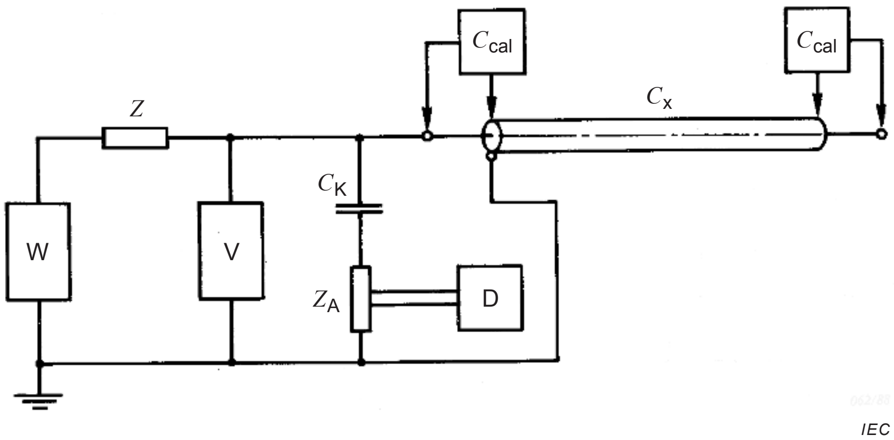


Figure 5 – Input unit Z_A connected in series with the coupling capacitor, C_K

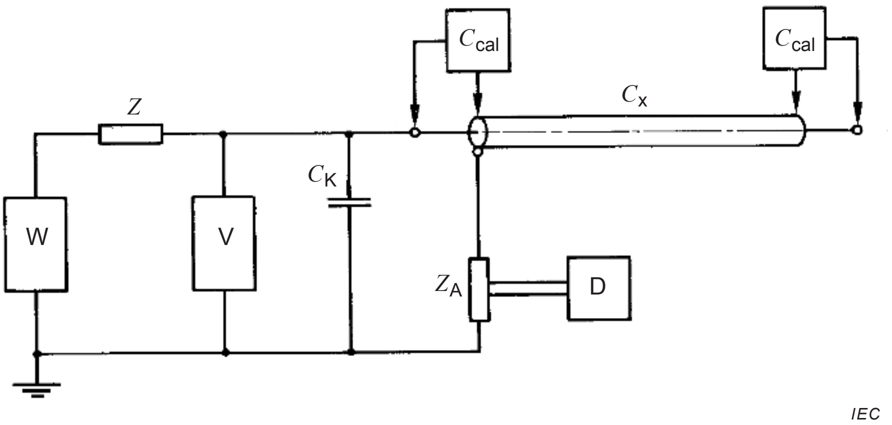


Figure 6 – Input unit Z_A connected in series with the cable, C_x

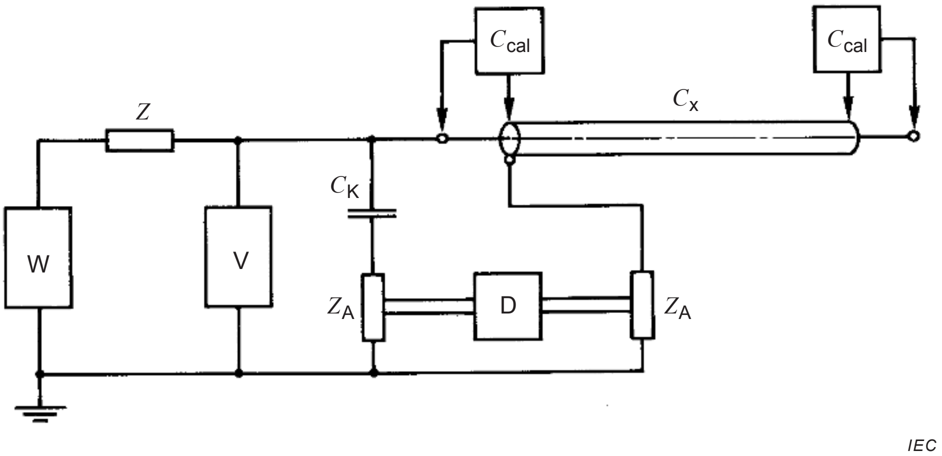


Figure 7 – Bridge circuit

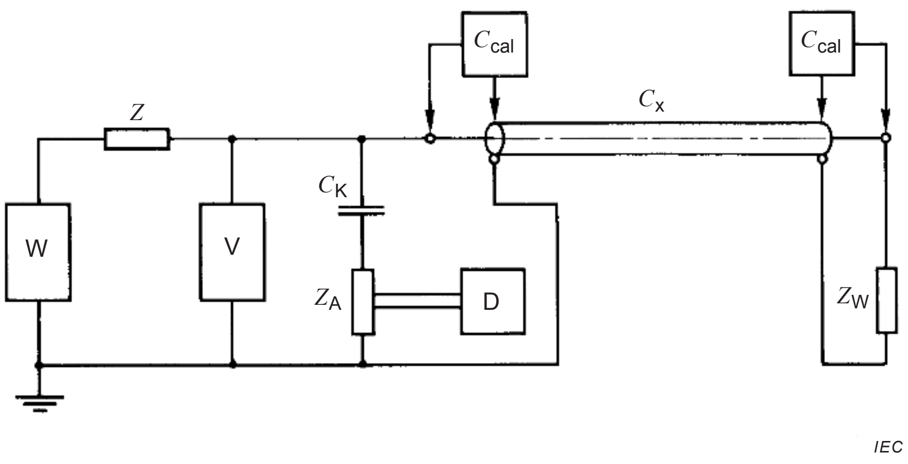


Figure 8 – Connection of the terminal impedance Z_w

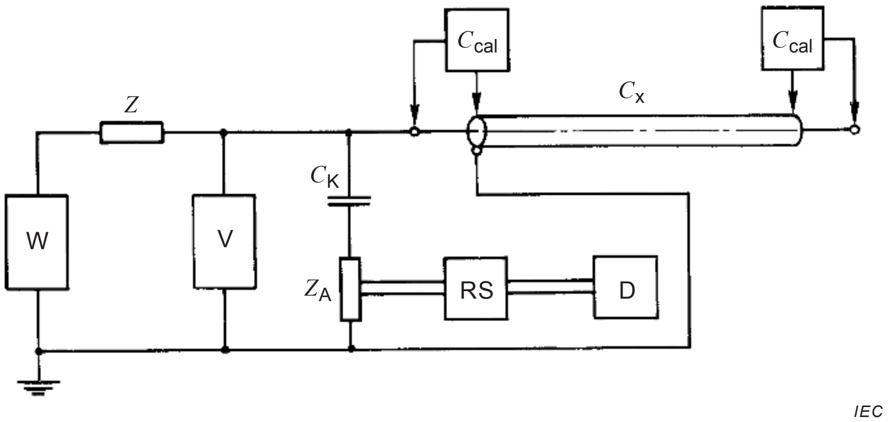
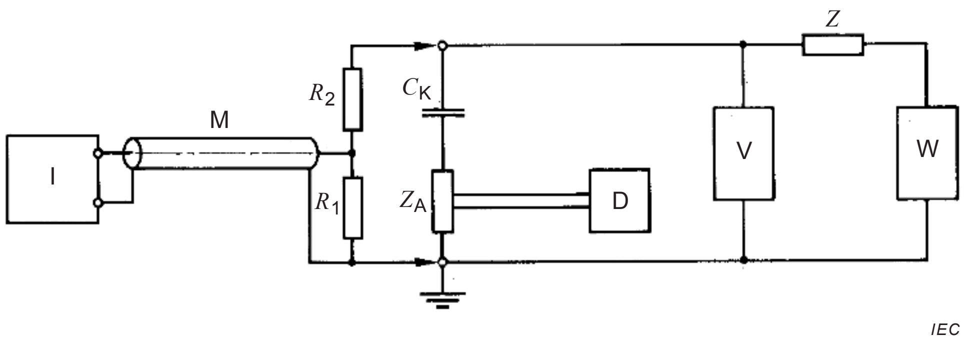


Figure 9 – Connection of the reflection suppressor, RS



Key

R_1 matching resistor with a value corresponding to the characteristic impedance of the coaxial signal cable M

R_2 matching resistor with a value $R_2 = R - \frac{R_1}{2}$ (load resistance R is typically 20 Ω to 40 Ω)

Figure 10 – Connection of the double pulse generator into the measuring circuit in Figure 5

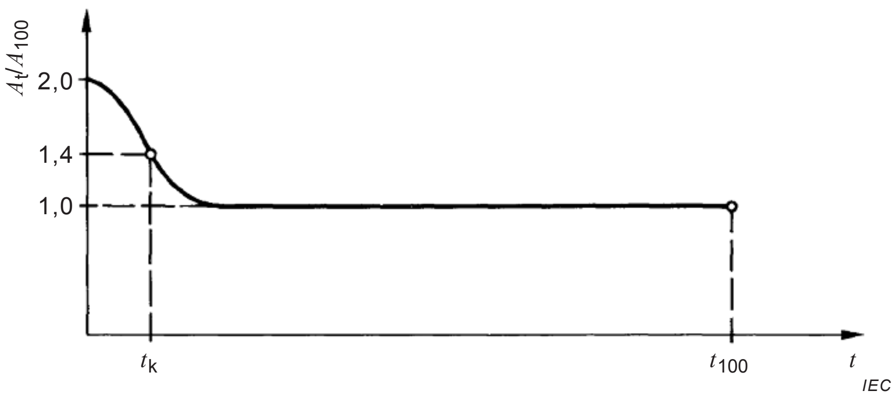
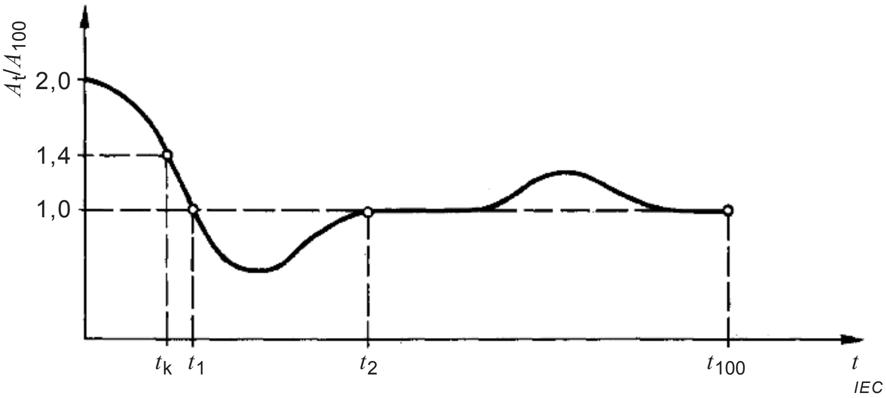


Figure 11 – Double pulse diagram type 1 without negative superposition



NOTE The influence of the positive superposition between t_2 and t_{100} is negligible.

Figure 12 – Double pulse diagram type 2 with negative superposition between t_1 and t_2

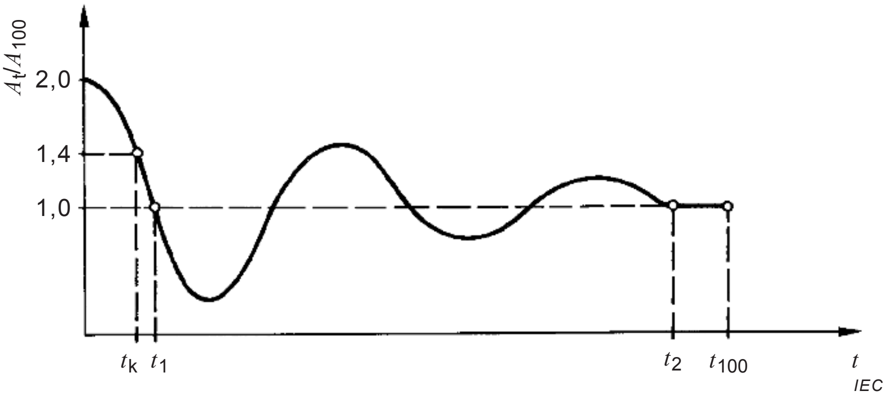


Figure 13 – Double pulse diagram type 3 with negative and positive superpositions between t_1 and t_2

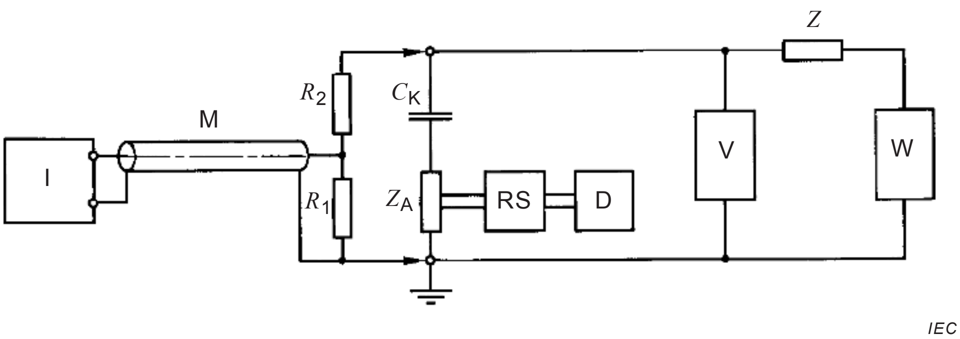


Figure 14 – Connection of the double pulse generator for the test circuit in Figure 9 with the reflection suppressor

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