

High-voltage test techniques — Partial discharge measurements

ICS 29.020; 17.220.20; 19.080

National foreword

This British Standard is the UK implementation of EN 60270:2001+A1:2016. It is identical to IEC 60270:2000, incorporating amendment 1:2015. It supersedes BS EN 60270:2001 (dual numbered as IEC 60270:2000) which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by A1 A1.

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**High-voltage test techniques -
Partial discharge measurements
(IEC 60270:2000)**

Technique des essais à haute tension -
Mesure des décharges partielles
(CEI 60270:2000)

Hochspannungs-Prüftechnik -
Teilentladungsmessungen
(IEC 60270:2000)

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Foreword

The text of document 42/162/FDIS, future edition 3 of IEC 60270, prepared by IEC TC 42, High-voltage testing techniques, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60270 on 2000-12-01.

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Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annexes A and ZA are normative and annexes B to G are informative.
Annex ZA has been added by CENELEC.

The words in **bold** in the text of the standard are defined in clause 3.

Endorsement notice

The text of the International Standard IEC 60270:2000 was approved by CENELEC as a European Standard without any modification.

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Annex ZA (normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60060-1	¹⁾	High-voltage test techniques Part 1: General definitions and test requirements	HD 588.1 S1	1991 ²⁾
IEC 60060-2	¹⁾	Part 2: Measuring systems	EN 60060-2	1994 ²⁾
CISPR 16-1	1993	Specification for radio disturbance and immunity measuring apparatus and methods Part 1: Radio disturbance and immunity measuring apparatus	-	-

¹⁾ undated reference.

²⁾ valid edition at date of issue.

CONTENTS

	Page
1 Scope	1
2 Normative references	10
3 A1 Terms and definitions A1	10
4 Test circuits and measuring systems	15
4.1 General requirements	15
4.2 Test circuits for alternating voltages	15
4.3 Measuring systems for apparent charge	16
4.3.1 General	16
4.3.2 Coupling device	16
4.3.3 Pulse train response of instruments for the measurement of apparent charge	16
4.3.4 Wide-band PD instruments	17
4.3.5 Wide-band PD instruments with active integrator	18
4.3.6 Narrow-band PD instruments	18
4.4 Requirements for measurements with digital PD-instruments	18
4.4.1 Requirements for measurement of apparent charge q	19
4.4.2 Requirements for measurement of test voltage magnitude and phase	19
4.5 Measuring systems for derived quantities	19
4.5.1 Coupling device	19
4.5.2 Instruments for the measurement of pulse repetition rate n	19
4.5.3 Instruments for the measurement of average discharge current I	20
4.5.4 Instruments for the measurement of discharge power P	20
4.5.5 Instruments for the measurement of quadratic rate D	20
4.5.6 Instruments for the measurement of the radio disturbance voltage	20
4.6 Ultra-wide-band instruments for PD detection	21
5 Calibration of a measuring system in the complete test circuit	21
5.1 General	21
5.2 Calibration procedure	21
6 Calibrators	22
6.1 General	22
6.2 Calibrators for the calibration of a measuring system in the complete test circuit	23
6.3 Calibrators for performance tests on measuring systems	23
7 Maintaining the characteristics of calibrators and measuring systems	24
7.1 Schedule of tests	24
7.2 Maintaining the characteristics of calibrators	24
7.2.1 Type tests on calibrators	24
7.2.2 Routine tests on calibrators	24
7.2.3 Performance tests on calibrators	24
7.2.4 Performance checks on calibrators	25
7.2.5 Record of performance	25
7.3 Maintaining the characteristics of measuring systems	26
7.3.1 Type tests on PD measuring systems	26
7.3.2 Routine tests on measuring systems	26
7.3.3 Performance tests on measuring systems	26
7.3.4 Performance checks for measuring systems	27

7.3.5	Checks for additional capabilities of digital measuring systems.....	27
7.3.6	Record of performance.....	28
8	Tests.....	28
8.1	General requirements.....	28
8.2	Conditioning of the test object.....	28
8.3	Choice of test procedure.....	29
8.3.1	Determination of the partial discharge inception and extinction voltages.....	29
8.3.2	Determination of the partial discharge magnitude at a specified test voltage.....	29
9	Measuring uncertainty and sensitivity.....	30
10	Disturbances.....	30
11	Partial discharge measurements during tests with direct voltage.....	31
11.1	General.....	31
11.2	A_1 PD quantities A_1	31
11.3	Voltages related to partial discharges.....	32
11.3.1	Partial discharge inception and extinction voltages.....	32
11.3.2	Partial discharge test voltage.....	32
11.4	Test circuits and measuring systems.....	32
11.5	Tests.....	32
11.5.1	Choice of test procedures.....	32
11.5.2	Disturbances.....	32
Annex A (normative)	Performance test on a calibrator.....	39
	General.....	39
A.2	Reference method.....	39
A.3	A_1 Numerical integration method A_1	39
A_1 A.4	Step voltage response method.....	42 A_1
Annex B (informative)	Test circuits.....	44
Annex C (informative)	Measurements on cables, gas insulated switchgear, power capacitors and on test objects with windings.....	46
	General.....	46
C.2	Attenuation and distortion phenomena.....	46
C.3	Resonance phenomena, reflections.....	46
C.4	Location of discharges.....	46
Annex D (informative)	The use of radio disturbance (interference) meters for the detection of partial discharges.....	47
Annex E (informative)	A_1 PD measuring instruments A_1	49
E.1	General.....	49
E.2	Instructions for processing analogue apparent charge signals.....	49
E.3	Recommendations for recording test voltage, phase angle ϕ_i and time t_i of occurrence of a PD pulse.....	50
Annex F (informative)	Non-electrical methods of PD detection.....	55
	General.....	55
F.2	Acoustic detection.....	55
F.3	Visual or optical detection.....	55
F.4	Chemical detection.....	55
F.5	Reference documents.....	55
Annex G (informative)	Disturbances.....	56
	Sources of disturbances.....	56

Detecting disturbances	56
Reduction of disturbances	57
G.1.1 Screening and filtering	57
G.1.2 Balanced circuits	57
G.1.3 Electronic processing and recovering of signals	57
Disturbance levels	58
[A1] Annex H (informative) Evaluation of PD test results during tests with direct voltage	59
Bibliography	61 [A1]
Figure 1 – Basic partial discharge test circuits	34
Figure 2 – Test circuit for measurement at a tapping of a bushing	35
Figure 3 – Test circuit for measuring self-excited test objects	35
Figure 4 – Connections for the calibration of the complete test arrangement	37
Figure 5 – Correct relationship between amplitude and frequency to minimize integration errors for a wide-band system	37
[A1] Figure 6 – Step voltage parameters of a calibrator	38 [A1]
Figure A.1 – Calibration of pulse calibrators	41
[A1] Figure A.2 – Setup for performance tests of calibrators using the numerical integration	42
Figure A.3 – Setup for performance tests of calibrators using the step voltage method	43
Figure A.4 – Impact of the series resistor R_s on the step voltage response appearing across C_m using the circuit according to Figure A.3, where the oscilloscope was connected to the calibrator via a 50 Ω measuring cable of 1 m long	43 [A1]
Figure D.1 – Variation of CISPR radio disturbance meter reading $f(N)$ with repetition frequency N , for constant pulses	48
Figure E.1 – Output voltage signals U_{out} of two different PD measuring systems for apparent charge (double pulse)	51
[A1] Figure E.2 – Block diagram of an analogue PD instrument equipped with an electronic integrator	52
Figure E.3 – Block diagram of digital PD instruments	53
Figure E.4 – Example for a phase-resolved PD pattern	54
Figure H.1 – Display modes of apparent pulses against measuring time	59
Figure H.2 – Histograms of PD pulse count m against apparent charge intervals	60 [A1]
Table 1 – Pulse train response of PD instruments	17
Table 2 – Tests required for calibrators	25
Table 3 – Tests required for measuring systems	27

HIGH-VOLTAGE TEST TECHNIQUES – PARTIAL DISCHARGE MEASUREMENTS

1 Scope

This International Standard is applicable to the measurement of **partial discharges** which occur in electrical apparatus, components or systems when tested with alternating voltages up to 400 Hz or with direct voltage.

This standard

- defines the terms used;
- defines the quantities to be measured;
- describes test and measuring circuits which may be used;
- defines analogue and digital measuring methods required for common applications;
- specifies methods for calibration and requirements of instruments used for calibration;
- gives guidance on test procedures;
- gives some assistance concerning the discrimination of **partial discharges** from external interference.

The provisions of this standard should be used in the drafting of specifications relating to **partial discharge** measurements for specific power apparatus. It deals with electrical measurements of impulsive (short-duration) **partial discharges**, but reference is also made to non-electrical methods primarily used for **partial discharge** location (see annex F).

Diagnosis of the behaviour of specific power apparatus can be aided by digital processing of **partial discharge** data (see annex E) and also by non-electrical methods that are primarily used for **partial discharge** location (see annex F).

This standard is primarily concerned with electrical measurements of **partial discharges** made during tests with alternating voltage, but specific problems which arise when tests are made with direct voltage are considered in clause 11.

The terminology, definitions, basic test circuits and procedures often also apply to tests with other frequencies, but special test procedures and measuring system characteristics, which are not considered in this standard, may be required.

Annex A provides normative requirements for performance tests on calibrators.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

CISPR 16-1:1993, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1: Radio disturbance and immunity measuring apparatus*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. 

3.1

partial discharge (PD)

localized electrical discharge that only partially bridges the insulation between conductors and which can or can not occur adjacent to a conductor

NOTE 1 **Partial discharges** are in general a consequence of local electrical stress concentrations in the insulation or on the surface of the insulation. Generally, such discharges appear as pulses having a duration of much less than 1 μ s. More continuous forms can, however, occur, such as the so-called pulse-less discharges in gaseous dielectrics. This kind of discharge will normally not be detected by the measurement methods described in this standard.

NOTE 2 "Corona" is a form of **partial discharge** that occurs in gaseous media around conductors which are remote from solid or liquid insulation. "Corona" should not be used as a general term for all forms of PD.

NOTE 3 **Partial discharges** are often accompanied by emission of sound, light, heat, and chemical reactions. For further information, see annex F.

3.2

partial discharge pulse (PD pulse)

current or voltage pulse that results from a **partial discharge** occurring within the object under test. The pulse is measured using suitable detector circuits, which have been introduced into the test circuit for the purpose of the test

NOTE A **partial discharge** which occurs in the test object produces a current pulse. A detector in accordance with the provisions of this standard produces a current or a voltage signal at its output, proportional to the charge of the current pulse at its input.

3.3 quantities related to partial discharge pulses

3.3.1 apparent charge q

of a **PD pulse** is that charge which, if injected within a very short time between the terminals of the test object in a specified test circuit, would give the same reading on the measuring instrument as the **PD current pulse** itself. The **apparent charge** is usually expressed in picocoulombs (pC)

NOTE The **apparent charge** is not equal to the amount of charge locally involved at the site of the discharge, which cannot be measured directly.

3.3.2 pulse repetition rate n

ratio between the total number of **PD pulses** recorded in a selected time interval and the duration of this time interval

NOTE In practice, only pulses above a specified magnitude or within a specified range of magnitudes are considered.

3.3.3 pulse repetition frequency N

number of **partial discharge** pulses per second, in the case of equidistant pulses

NOTE **Pulse repetition frequency N** is associated with the situation in calibration.

3.3.4 phase angle ϕ_i and time t_i of occurrence of a PD pulse is

$$\phi_i = 360 (t_i/T)$$

where t_i is the time measured between the preceding positive going transition of the test voltage through zero and the **partial discharge pulse** and T is the period of the test voltage

The phase angle is expressed in degrees (°).

3.3.5 average discharge current I

derived quantity and the sum of the absolute values of individual **apparent charge** magnitudes q_i during a chosen reference time interval T_{ref} divided by this time interval:

$$I = \frac{1}{T_{\text{ref}}} (|q_1| + |q_2| + \dots + |q_i|)$$

The **average discharge current** is generally expressed in coulombs per second (C/s) or in amperes (A).

3.3.6

discharge power P

derived quantity that is the average pulse power fed into the terminals of the test object due to **apparent charge** magnitudes q_i during a chosen reference time interval T_{ref} :

$$P = \frac{1}{T_{\text{ref}}} (q_1 u_1 + q_2 u_2 + \dots + q_i u_i)$$

where $u_1, u_2 \dots u_i$ are instantaneous values of the test voltage at the instants of occurrence t_i of the individual **apparent charge** magnitudes q_i . The sign of the individual values must be observed

The **discharge power** is generally expressed in watts (W).

3.3.7

quadratic rate D

derived quantity that is the sum of the squares of the individual **apparent charge** magnitudes q_i during a chosen reference time interval T_{ref} divided by this time interval:

$$D = \frac{1}{T_{\text{ref}}} (q_1^2 + q_2^2 + \dots + q_m^2)$$

The **quadratic rate** is generally expressed in (coulombs)² per second (C²/s).

3.3.8

radio disturbance meter

quasi-peak measuring receiver for frequency band B in accordance with the provisions of CISPR 16-1:1993

NOTE This type of instrument was earlier called a radio interference (or influence) meter.

3.3.9

radio disturbance voltage U_{RDV}

derived quantity that is the reading of a **radio disturbance meter** when used for indicating the **apparent charge** q of partial discharges. For further information, see 4.5.6 and annex D

The **radio disturbance voltage** U_{RDV} is generally expressed in μV .

3.4

largest repeatedly occurring PD magnitude

largest magnitude recorded by a measuring system which has the pulse train response as specified in 4.3.3

The concept of the **largest repeatedly occurring PD magnitude** is not applicable to tests with direct voltage.

3.5

specified partial discharge magnitude

largest magnitude of any quantity related to **PD pulses** permitted in a test object at a specified voltage following a specified conditioning and test procedure. For alternating voltage tests, the specified magnitude of the **apparent charge** q is the **largest repeatedly occurring PD magnitude**

NOTE The magnitude of any **PD pulse** quantity can vary stochastically in successive cycles and also show a general increase or decrease with time of voltage application. The **specified PD magnitude**, the test procedure and also the test circuit and instrumentation should therefore be appropriately defined by the relevant technical committees.

3.6

background noise

signals detected during PD tests, which do not originate in the test object

NOTE **Background noise** can be composed of either white noise in the measurement system, broadcast radio or other continuous or impulsive signals. For further information, see annex G.

3.7

applied test voltages related to partial discharge pulse quantities

as defined in IEC 60060-1. The following voltage levels are of particular interest

3.7.1

partial discharge inception voltage U_i

applied voltage at which repetitive **partial discharges** are first observed in the test object, when the voltage applied to the object is gradually increased from a lower value at which no **partial discharges** are observed

In practice, the inception voltage U_i is the lowest applied voltage at which the magnitude of a **PD pulse** quantity becomes equal to or exceeds a specified low value.

NOTE For tests with direct voltage, the determination of U_i needs special considerations. See clause 11.

3.7.2

partial discharge extinction voltage U_e

applied voltage at which repetitive **partial discharges** cease to occur in the test object, when the voltage applied to the object is gradually decreased from a higher value at which **PD pulse** quantities are observed

In practice, the extinction voltage U_e is the lowest applied voltage at which the magnitude of a chosen **PD pulse** quantity becomes equal to, or less than, a specified low value.

NOTE For tests with direct voltage, the determination of U_e needs special considerations. See clause 11.

3.7.3

partial discharge test voltage

specified voltage, applied in a specified **partial discharge** test procedure, during which the test object should not exhibit PD exceeding a **specified partial discharge magnitude**

3.8

partial discharge measuring system

system consisting of a coupling device, a transmission system and a measuring instrument

3.9

measuring system characteristics

The following definitions refer to measuring systems as specified in 4.3

3.9.1

transfer impedance $Z(f)$

ratio of the output voltage amplitude to a constant input current amplitude, as a function of frequency f , when the input is sinusoidal

3.9.2

lower and upper limit frequencies f_1 and f_2

frequencies at which the **transfer impedance $Z(f)$** has fallen by 6 dB from the peak pass-band value

3.9.3

midband frequency f_m and bandwidth Δf

for all kinds of measuring systems, the **midband frequency** is defined by:

$$f_m = \frac{f_1 + f_2}{2}$$

and the **bandwidth** is defined by:

$$\Delta f = f_2 - f_1$$

3.9.4

superposition error

caused by the overlapping of transient output pulse responses when the time interval between input current pulses is less than the duration of a single output response pulse. **Superposition errors** can be additive or subtractive depending on the **pulse repetition rate** of the input pulses. In practical circuits, both types will occur due to the random nature of the **pulse repetition rate**. However, since measurements are based on the **largest repeatedly occurring PD magnitude**, usually only the additive **superposition errors** will be measured

NOTE **Superposition errors** can attain levels of 100 % or more depending on the **pulse repetition rate** and the characteristics of the measuring system.

3.9.5

pulse resolution time T_r

shortest time interval between two consecutive input pulses of very short duration, of same shape, polarity and charge magnitude for which the peak value of the resulting response will change by not more than 10 % of that for a single pulse

The **pulse resolution time** is in general inversely proportional to the **bandwidth Δf** of the measuring system. It is an indication of the measuring system's ability to resolve successive PD events.

NOTE It is recommended that the **pulse resolution time** be measured for the whole test circuit, as well as for the measuring system, as **superposition errors** can be caused by the test object, for example reflections from cable ends. The relevant technical committees should specify the procedure for handling **superposition errors** and particularly, the allowable tolerances including their signs.

3.9.6

integration error

error in **apparent charge** measurement which occurs when the upper frequency limit of the PD current pulse amplitude-spectrum is lower than

- the upper cut-off frequency of a wideband measuring system; or
- the mid-band frequency of a narrow-band measuring system.

See figure 5.

NOTE If required for a special type of apparatus, the relevant technical committees are urged to specify more restrictive values for f_1 and f_2 to minimize the **integration error**.

3.10**digital partial discharge instruments**

instruments which perform a digital acquisition and evaluation of the PD data

Note 1 to entry: The A/D conversion of the PD pulses captured from the terminals of the test object can be done either directly or after the apparent charge pulses have been established employing either an analogue band-pass filter amplifier or an active integrator (see Annex E). 

3.11**scale factor k**

factor by which the value of the instrument reading is to be multiplied to obtain the value of the input quantity (IEC 60060-2:1994, 3.5.1)

3.12**accumulated apparent charge q_a**

sum of the apparent charge q of all individual pulses exceeding a specified threshold level, and occurring during a specified time interval Δt

3.13**PD pulse count m**

total number of PD pulses which exceed a specified threshold level within a specified time interval Δt

3.14**PD pattern**

display of the apparent charge q versus the phase angle ϕ_i of the PD pulses recorded during a specified time interval Δt 

4 Test circuits and measuring systems

4.1 General requirements

In this clause, basic test circuits and measuring systems for **partial discharge** quantities are described, and information on the operating principle of these circuits and systems is provided. The test circuit and measuring system shall be calibrated as specified in clause 5 and shall meet the requirements specified in clause 7. The technical committee may also recommend a particular test circuit to be used for particular test objects. It is recommended that the technical committees use **apparent charge** as the quantity to be measured wherever possible, but other quantities may be used in particular specific situations.

If not otherwise specified by the relevant technical committee, any of the test circuits mentioned in 4.2 and any of the measuring systems as specified in 4.3 are acceptable. In each case, the most significant characteristics of the measuring system (f_1 , f_2 , T_r , see 3.9.2 and 3.9.5) as applied, shall be recorded.

For tests with direct voltage, see clause 11.

4.2 Test circuits for alternating voltages

Most circuits in use for **partial discharge** measurements can be derived from one or other of the basic circuits, which are shown in figures 1a to 1d. Some variations of these circuits are shown in figures 2 and 3. Each of these circuits consists mainly of

- a test object, which can usually be regarded as a capacitor C_a (see, however, annex C);
- a coupling capacitor C_k , which shall be of low inductance design, or a second test object C_{a1} , which shall be similar to the test object C_a . C_k or C_{a1} should exhibit a sufficiently low level of **partial discharges** at the specified test voltage to allow the measurement of the

specified partial discharge magnitude. A higher level of **partial discharges** can be tolerated if the measuring system is capable of distinguishing the discharges from the test object and the coupling capacitor and measuring them separately;

- a measuring system with its input impedance (and sometimes, for balanced circuit arrangements, a second input impedance);
- a high-voltage supply, with sufficiently low level of **background noise** (see also clauses 9 and 10) to allow the **specified partial discharge magnitude** to be measured at the specified test voltage;
- high-voltage connections, with sufficiently low level of **background noise** (see also clauses 9 and 10) to allow the **specified partial discharge magnitude** to be measured at the specified test voltage;
- an impedance or a filter can be introduced at high voltage to reduce **background noise** from the power supply.

NOTE For each of the basic PD test circuits shown in figures 1 and 3, the coupling device of the measuring system can also be placed at the high-voltage terminal side, so that the positions of the coupling device with C_a or C_k are exchanged; then, optical links are used for the interconnection of the coupling device with the instrument, as indicated in figure 1a.

Additional information and particular characteristics of the different test circuits are considered in annexes B and G.

4.3 Measuring systems for apparent charge

4.3.1 General

Partial discharge measuring systems can be divided into the subsystems: coupling device, transmission system (for example, connecting cable or optical link) and measuring instrument. In general, the transmission system does not contribute to the circuit characteristics and will thus not be taken into consideration.

4.3.2 Coupling device

The coupling device is an integral part of the measuring system and test circuit, with components specifically designed to achieve the optimum sensitivity with a specific test circuit. Different coupling devices may thus be used in conjunction with a single measuring instrument.

The coupling device is usually an active or passive four-terminal network (quadripole) and converts the input currents to output voltage signals. These signals are transmitted to the measuring instrument by a transmission system. The frequency response of the coupling device, defined by output voltage to input current, is normally chosen at least so as to effectively prevent the test voltage frequency and its harmonics from reaching the instrument.

NOTE 1 Though the frequency response of an individual coupling device is not of general interest, the magnitude and frequency characteristics of the input impedance are of importance as this impedance interacts with C_k and C_a and is thus an essential part of the test circuit.

NOTE 2 Interconnection leads between the coupling device and the test object should be kept as short as practical so as to minimize effects on the detection bandwidth.

4.3.3 Pulse train response of instruments for the measurement of apparent charge

Provided the amplitude frequency spectrum of the input pulses is constant at least within the **bandwidth** Δf of the measuring system (see figure 5), the response of the instrument is a voltage pulse with a peak value proportional to the (unipolar) charge of the input pulse. The shape, duration and the peak value of this output pulse are determined by the **transfer impedance** $Z(f)$ of the measuring system. Thus, the shape and duration of the output pulse can be completely different from that of the input signal.

Display of the individual output voltage pulses on the screen of an oscilloscope can assist in recognizing the origin of **partial discharges** and in distinguishing them from disturbances (see clause 10). The voltage pulses should be displayed either on a linear time-base which is triggered by the test voltage, or on a sinusoidal time base synchronized with the test voltage frequency or an elliptical time-base which rotates synchronously with the test voltage frequency.

In addition, it is particularly recommended that an indicating instrument or recorder should be used to quantify the **largest repeatedly occurring PD magnitude**. The reading of such instruments, when used in testing with alternating voltage, should be based on an analogue peak detection circuit, or digital peak detection by software, with a very short electrical charge time constant and an electrical discharge time constant not larger than 0,44 s. Independent of the type of display used in such instruments, the following requirements apply:

The response of the system to a pulse train consisting of equally large equidistant pulses q_0 with a known **pulse repetition frequency N** , shall be such that the reading R of the instrument indicates magnitudes as given in the following table. The range and gain of the instrument is assumed to be adjusted to read full scale or 100 % for $N = 100$. The calibrator used to produce the pulses shall conform to the requirements of clause 5.

Table 1 – Pulse train response of PD instruments

N (1/s):	1	2	5	10	50	≥ 100
$R_{\min}$ (%):	35	55	76	85	94	95
$R_{\max}$ (%):	45	65	86	95	104	105

NOTE 1 This characteristic is necessary to establish compatibility of readings obtained with different types of instruments. The requirement is to be fulfilled on all ranges. Instruments already in use at the date of issue of this standard are not required to comply with these requirements; however, the actual values for $R(N)$ should be given.

NOTE 2 The measured quantity can be indicated, for example, on pointer instruments, digital displays or oscilloscopes.

NOTE 3 The specified response may be obtained either by analogue or by digital signal processing.

NOTE 4 The pulse train response defined in this subclause is not appropriate for direct voltage tests.

NOTE 5 The relevant technical committee may specify a different response tailored to a particular apparatus.

4.3.4 Wide-band PD instruments

In combination with the coupling device, this type of instrument constitutes a wide-band PD measuring system which is characterized by a **transfer impedance $Z(f)$** having fixed values of the **lower and upper limit frequencies f_1 and f_2** , and adequate attenuation below f_1 and above f_2 . ^[A1] Recommended values for the significant frequency parameters f_1 , f_2 and Δf are:

$$30 \text{ kHz} \leq f_1 \leq 100 \text{ kHz}$$

$$f_2 \leq 1 \text{ MHz}$$

$$100 \text{ kHz} \leq \Delta f \leq 900 \text{ kHz} \quad \text{[A1]}$$

^[A1] NOTE 1 ^[A1] Combinations of different coupling devices with the measuring instrument can alter the **transfer impedance**. The overall response should, however, always fulfil the recommended values.

^[A1] NOTE 2 For test objects with windings like transformers and electrical machines the acquired frequency band may be reduced down to a few 100 kHz and even below. The upper limit frequency f_2 to be accepted for such kinds of test objects should be specified by the relevant Technical Committee. ^[A1]

The response of these instruments to a (non-oscillating) **partial discharge** current pulse is in general a well-damped oscillation. Both the **apparent charge** q and polarity of the PD current pulse can be determined from this response. The **pulse resolution time** T_r is small and is typically 5 μs to 20 μs .

4.3.5 Wide-band PD instruments with active integrator

This type of instrument consists of a very wide-band amplifier followed by an electronic integrator which is characterized by the time constant of its integrating capacitor and resistor network. The response of the integrator to a **PD pulse** is a voltage signal increasing with the instantaneous sum of charge. The final amplitude of the signal is thus proportional to the total charge, assuming that the time constant of the integrator is much larger than the duration of the **PD pulse**. In practice, time constants in the range of 1 μs are typical. The **pulse resolution time** for consecutive **PD** pulses is less than 10 μs .

NOTE A corresponding **upper limit frequency** of some hundred kilohertz can be attributed to such instruments, calculated from the time constant of the combination of the amplifier and active integrator.

4.3.6 Narrow-band PD instruments

These instruments are characterized by a small **bandwidth** Δf and a **midband frequency** f_m , which can be varied over a wide frequency range, where the amplitude frequency spectrum of the PD current pulse is approximately constant. Recommended values for Δf and f_m are

$$9 \text{ kHz} \leq \Delta f \leq 30 \text{ kHz}$$

$$50 \text{ kHz} \leq f_m \leq 1 \text{ MHz}.$$

It is further recommended that the **transfer impedance** $Z(f)$ at frequencies of $f_m \pm \Delta f$ should be 20 dB below the peak pass-band value.

NOTE 1 During actual **apparent charge** measurements, midband frequencies $f_m > 1 \text{ MHz}$ should only be applied if the readings for such higher values do not differ from those as monitored for the recommended values of f_m .

NOTE 2 In general, such instruments are used together with coupling devices providing high-pass characteristics within the frequency range of the instrument. If resonance coupling devices are used, f_m has to be tuned and fixed to the resonance frequency of the coupling device and the test circuit to provide a constant **scale factor** of the circuit.

NOTE 3 **Radio disturbance meters** with quasi-peak response are not qualified under this standard for the measurement of the **apparent charge** q , but they can be used for detection of PD.

The response of these instruments to a **partial discharge** current pulse is a transient oscillation with the positive and negative peak values of its envelope proportional to the **apparent charge**, independent of the polarity of this charge. The **pulse resolution time** T_r will be large, typically above 80 μs .

4.4 Requirements for measurements with digital PD-instruments

The minimum requirement for a **digital PD-instrument** is to:

- display the value of the **largest repeatedly occurring PD magnitude**. The instrument shall conform to the requirements of 4.3.3.

Additionally, one or more of the following quantities may be evaluated and recorded:

- the **apparent charge** q_i occurring at time instant t_i ;
- the instantaneous value of the test voltage u_i as measured at the time instant t_i of occurrence of the individual **apparent charge** q_i ;
- the **phase angle** ϕ_i of occurrence of the **PD pulse** occurring at time t_i .

4.4.1 Requirements for measurement of apparent charge q

The time between successive updates of the digital display shall not exceed 1 s.

The instrument response will normally include some level of continuous or base line noise. This noise can be caused by **background noise** or by a large number of **partial discharge pulses** whose magnitude is small compared with the highest level to be measured. Thus, a bipolar sensitivity threshold may be introduced to prevent such signals from being recorded. If a threshold level is used, this level shall be recorded.

Guidelines regarding the digital acquisition of the analogue response signals are provided in annex E.

4.4.2 Requirements for measurement of test voltage magnitude and phase

If the digital instrument is stated to be able to record the voltage level of the power frequency test voltage, it shall comply with the requirements of IEC 60060-2, 1994.

If the instrument is stated to be able to measure the phase angle of the test voltage, it shall be suitably demonstrated that the phase displacement of the reading is within 5 degrees of the true value.

4.5 Measuring systems for derived quantities

4.5.1 Coupling device

The provisions of 4.3.2 are also valid for measuring systems for derived quantities.

4.5.2 Instruments for the measurement of pulse repetition rate n

An instrument for the determination of the **pulse repetition rate** shall have a sufficiently short **pulse resolution time** T_r to resolve the highest **pulse repetition rate** of interest. Magnitude discriminators which suppress pulses below an adjustable, predetermined magnitude, may be required to avoid counting of non-significant signals. Several discriminator levels can be suitable to characterize PD, for example, in tests with direct voltage.

It is recommended that the counter input is connected to the output of a PD measuring system as described in 4.3. If a pulse counter is used with a PD measuring system with oscillatory or bi-directional response, suitable pulse shaping must be done to avoid obtaining more than one count per pulse.