SLOVENSKI STANDARD
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Visokonapetostne preskusne tehnike - Meritve delnih razelektritev

High-voltage test techniques - Charge-based measurement of partial discharges

Techniques des essais à haute tension - Mesures des décharges partielles

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IEC TC 42 : HIGH-VOLTAGE AND HIGH-CURRENT TEST TECHNIQUES	
SECRETARIAT: Canada	SECRETARY: Mr Howard G. Sedding
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 2,TC 14,TC 20,TC 36,TC 112,TC 122	PROPOSED HORIZONTAL STANDARD: ☒ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT	☐ QUALITY ASSURANCE ☐ SAFETY
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TITLE:

High-voltage test techniques - Charge-based measurement of partial discharges

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NOTE FROM TC/SC OFFICERS:

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE TEST TECHNIQUES – CHARGE-BASED MEASUREMENT OF PARTIAL DISCHARGES

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International Standard IEC 60270 has been prepared by IEC technical committee 42: High-Voltage and High-Current Measurement Techniques.

This fourth edition cancels and replaces the third edition published in 2000, and Amendment 1:2015. This edition constitutes a technical revision.

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

a) Use with alternating voltages up to 500 Hz or with direct voltage
b) Clear focus on charge-based partial discharge measurements
c) Streamlined performance checks for partial discharge measurement system components
d) Improved normative Annex for performance tests on calibrators
e) Revised and new informative Annexes

The text of this International Standard is based on the following documents:

Draft	Report on voting
42/XX/FDIS	42/XX/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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HIGH-VOLTAGE TEST TECHNIQUES –
CHARGE-BASED MEASUREMENT OF PARTIAL DISCHARGES

1 Scope

This International Standard is applicable to the charge-based measurement of partial discharges which occur in electrical apparatus, components or systems when tested with alternating voltages up to 500 Hz or with direct voltage (DC).

This standard

– defines the terms used;
– defines the quantities to be measured;
– describes the measurement frequencies as well as the 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 shall 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). It has the status of a horizontal standard in accordance with IEC Guide 108.

This horizontal standard is primarily intended for use by the relevant equipment committees in the preparation of standards in accordance with the principle laid down in IEC Guide 108. One of the responsibilities of a technical equipment committee is, wherever applicable, to make use of horizontal standards in the preparation of its publications. The contents of this horizontal standard will not apply unless it is specifically referred to or it is included in the relevant publications. 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 measurement of partial discharge in terms of apparent charge for specific power apparatus 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 at other frequencies, but special test procedures and measuring system characteristics which are not considered in this standard may be required. For measurements at higher frequency ranges, see IEC TS 62478.

Annex A provides normative requirements for performance tests on calibrators.

NOTE: IEC 60270 defines and provides guidance for charge-based direct electrical PD measurements at the terminals of the equipment under test, differentiating from other PD measurement and detection methods, e.g. acoustic PD techniques or electromagnetic methods in elevated frequency ranges, e.g. ultra-high frequency (UHF).

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*

IEC TS 62478, *High voltage test techniques – Measurement of partial discharges by electromagnetic and acoustic methods*

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 may or may not occur adjacent to a conductor

Note 1 to entry: 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 µs. 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 to entry: "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 to entry: Partial discharges are accompanied by emission of acoustic transients (sound), electromagnetic waves, optical signals (light), heat, and associated chemical reactions. For further information, see annex F.

3.2
partial discharge pulse (PD pulse)
produced by a partial discharge occurring within the object under test, measured using suitable detector circuits introduced into the test circuit.

Note to entry: A partial discharge which occurs in the test object produces a current pulse at its origin. 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 PD pulse.

3.3
quantities related to partial discharge pulses

3.3.1
apparent charge *q*
of a PD pulse is that charge which, if injected between the terminals of the test object in a specified test circuit, would result in the same reading on the measuring instrument as the PD pulse itself, typically expressed in units of picocoulombs (pC) or nanocoulombs (nC).

Note to entry: 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 to entry: 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

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

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

where t_i is the time measured between the preceding positive going zero crossing of the test voltage and the partial discharge pulse and T is the period of the test voltage, with the phase angle being expressed in degrees (°).

3.3.5
average apparent discharge current *I*
is a derived quantity consisting of 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:

$$I = \frac{1}{T_{ref}}\left(|q_1| + |q_2| + \ldots + |q_i|\right)$$

and is generally expressed in coulombs per second (C/s) or in amperes (A).

3.3.6
apparent discharge power *P*
is a derived quantity, generally expressed in watts (W), consisting of 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}:

$$P = \frac{1}{T_{ref}}\left(q_1 u_1 + q_2 u_2 + \ldots + q_i u_i\right)$$

where u_1, u_2... u_i are the 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.

3.3.7
radio interference or radio disturbance meter
is a specialized measurement receiver utilizing weighted quasi-peak RF measurements on frequency B in accordance with CISPR 16-1.

Note to entry: This type of instrument was commonly known as ‘RIV’ or ‘radio interference voltage’ or ‘radio influence voltage’ meter in earlier times, having been applied to search for HV equipment producing high levels of corona which in turn would interfere with LW and MW broadcast transmission.

3.3.8
radio disturbance voltage U_{RDV}
the output reading of a radio interference meter, generally expressed in μV.
For further information, see 4.6 and Annex D.

3.4
largest repeatedly occurring PD magnitude Q_{IEC}
the value recorded by a measuring system which has the pulse train response as specified in 4.3.3, commonly realized by a quasi-peak detector or a digital emulation of such a circuit, applicable for AC voltages.

3.5.
peak apparent charge Q_{pk}
the largest value recorded by a PD measuring system, commonly realized by a peak detector or a digital emulation of such circuit, applicable for DC voltages.

3.6
specified partial discharge magnitude
is the 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, this is the largest repeatedly occurring apparent charge Q_{IEC}.

Note to entry: 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 equipment committee(s).

3.7
background noise and interference/disturbances
are extraneous signals detected during PD tests, which are not of interest because they are not signals caused by PD originating in the test object.

Note 1 to entry: Background or electrical noise is defined as originating in the PD measurement equipment itself, e.g. thermal, shot, 1/f noise in resistors and amplifiers.

Note 2 to entry: Interference or disturbances may originate from external sources such as motor drives, thyristor control circuits, terrestrial AM broadcast stations, etc. Moreover, external interference can also arise due to partial discharges external to the test object; such PD-like interference can be extremely challenging to differentiate from PD signals within the test object. Refer to Annex G for further information.

3.8
test voltages related to partial discharge pulse quantities

Note to entry: Voltages as defined in e.g. IEC 60060-1.

3.8.1
partial discharge inception voltage U_i
the applied voltage at which repetitive partial discharges are first observed in the test object, after being gradually increased from a lower value at which no partial discharges are observed; in practice, the lowest applied voltage at which the magnitude of a PD pulse quantity becomes equal to or exceeds a specified minimum value.

Note to entry: For tests with direct voltage, the determination of U_i needs special considerations. See clause 11.

3.8.2
partial discharge extinction voltage U_e
the applied voltage at which repetitive partial discharges cease to occur in the test object, after being gradually decreased from a higher value at which PD pulse quantities are observed; in practice, 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 to entry: For tests with direct voltage, the determination of U_e needs special considerations. See clause 11.

3.8.3

partial discharge test voltage

the specified voltage, applied in a specified partial discharge test procedure, during which the test object shall not produce PD exceeding a specified partial discharge magnitude

Note to entry: Partial discharges are usually measured at AC sinusoidal waveform. In real conditions, the test voltage also contains harmonics that modify the shape of the voltage waveform and can thus be considered as a disturbance affecting the PD pulse parameters and PD phase-resolved patterns. Such disturbances should be taken into account and documented during PD measurements. See Annex G for further information.

3.9

partial discharge measuring system

consists of a coupling device, a transmission system and a partial discharge measuring instrument

3.10

measuring system characteristics

3.10.1

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

3.10.2

lower and upper limit frequencies f_1 and f_2

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

3.10.3

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:

$$\Delta f = f_2 - f_1$$

3.10.4

superposition error

is caused when successive PD pulses overlap one another because the time interval between successive pulses is less than the duration (settling time) of a single pulse response; it is also known as 'pulse pile-up'.

Note 1 to entry: Superposition errors can be additive or subtractive depending on the pulse repetition rate of the incoming pulses in combination with the transient response of the detector circuit elements. 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 2 to entry: Superposition errors can attain levels of 100% or more depending on the pulse repetition rate and the characteristics of the measuring system.

3.10.5

pulse resolution time t_{res}

is the shortest time interval between two consecutive PD pulses within which the PD measurement instrument is still able to resolve two separate pulses and for which the peak value of the resulting response does not change by more than 10% of the value for a single pulse

Note 1 to entry: The pulse resolution time t_{res} is an indication of the PD measuring system's ability to resolve successive PD pulses and is inversely proportional to the lower frequency cut-off frequency f_1.of the PD measurement bandwidth.

Note 2 to entry: 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 equipment committee(s) should specify the procedure for handling superposition errors and particularly, the allowable tolerances including their signs.

3.10.6

dead time t_{DT}
is defined as the time period following successful digital acquisition of a PD pulse during which the instrument does not accept or acquire signals or neglect detected pulses

Note 1 to entry: Dead time is closely related to pulse resolution time

Note 2 to entry: Especially for strongly oscillatory input signals, dead time is introduced in order to avoid false or repeat triggering on successive oscillatory remnants of the same pulse.

3.10.7

noise modulation
results from superimposition of an actual PD pulse with a simultaneously occurring noise signal leading to an incorrect registering of the peak amplitude of the PD signal.

Note to entry: Such noise modulation occurs when calibrating and measuring low amplitude PD pulses close to the noise floor and can cause apparent non-linearities in such cases.

3.10.8

integration error (of apparent charge measurement)
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 to entry: If required for a special type of apparatus, the relevant equipment committee(s) are urged to specify more restrictive values for f_1 and f_2 to minimize the integration error.

3.11

digital partial discharge instruments
perform digital acquisition and evaluation of the PD data as described in Annex E

3.12

scale factor *k*
is the factor by which the value of the instrument reading is to be multiplied to obtain the value of the input quantity

Note to entry: In modern digital PD measurement instruments, the scale factor is usually automatically calculated and set internally. After calibration, the instruments display the result of the multiplication with the internal scale factor k.

3.13

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

3.14

PD pulse count *m*
total number of PD pulses which exceed a specified threshold level within a specified time interval Δt

3.15
Phase-resolved PD pattern (PRPD)

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

Note to entry: See Annex E Figure E.4 Conceptual diagram of phase-resolved PD pattern (PRPD) diagram.

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 relevant equipment committee(s) may also recommend a particular test circuit to be used for particular test objects. It is recommended that the equipment committee(s) use apparent charge as the quantity to be measured wherever possible, but other derived quantities may be used in particular specific situations.

A number of derived quantities such as ‘PD pulse repetition rate n’, ‘average apparent discharge current’, ‘apparent discharge power’, etc. may be derived using appropriate algorithms employed by the charge-based PD measurement instrument, either in real-time or via post-processing. These derived quantities may be desirable for characterizing or quantifying certain aspects of the test object’s PD behaviour, i.e. assessing risk or fulfilling acceptance criteria, and may be specified by the relevant equipment committee(s).

If not otherwise specified by the relevant equipment committee(s), 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 (section 3.10) 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 capacitance C_{DUT} (however, see Annex C);

– a coupling capacitor C_c, which shall be of low inductance design, or a second test object C_{DUT1}, which shall be similar to the test object C_{DUT}. C_c or C_{DUT1} shall 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;