



# IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques—Partial Discharge Measurements

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**IEEE Power & Energy Society**

Sponsored by the  
Switchgear Committee

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# IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques—Partial Discharge Measurements

Sponsor

**Switchgear Committee**  
of the  
**IEEE Power & Energy Society**

Approved 30 January 2009

**IEEE-SA Standards Board**

**Abstract:** This standard adopts IEC 60270:2000 and defines methods of measuring partial discharges that may occur in energized power switchgear apparatus, in flaws, voids, and interfaces of non-self restoring insulation that may lead to dielectric failure of the switchgear.

**Keywords:** adoption, calibration, Corona, dielectric tests, instrumentation, partial discharge, switchgear

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## Introduction

This introduction is not part of IEEE Std C37.301-2009, IEEE Standard for High-Voltage Switchgear (Above 1000 V) Tests—Partial Discharge Measurements.

A partial discharge is a localized dielectric breakdown of a section of dielectrically stressed insulation path that occurs generally in voids, cracks, or interfaces within that insulating system or from the sharp edges of energized apparatus parts. These discharges may or may not exhibit a glow discharge, based on location and the intensity of these discharges.

The classic form of Corona is usually denoted by a visual glow or dielectric breakdown of the insulating air or gas around overstressed conductors or the sharp edges of energized apparatus parts. Radio influence voltage (RIV) measurements are made to determine the extent of radio interference generated by this Corona and the corrective measures that should be made. This Corona, when associated with the self-restoring insulation of the apparatus, may not necessarily contribute to insulation damage.

In contrast, other types of partial discharges are localized dielectric breakdowns of a section in an insulation path where the discharges occur in voids, cracks, or interfaces of solid and/or solid/gas dielectrics. These localized discharges are undesirable because of the possible deterioration of that insulation with the formation of ionized gas due to this breakdown that may accumulate at or in a critical stress region. This generally involves non-self-restoring insulation that may be subject to permanent damage.

Partial discharge measurements may be made on the basis of the resultant momentary change in the voltage at the terminals of the device. Such a change may be expressed as a voltage change (RIV in microvolts) or by calibration as an apparent charge. When injected between the terminals of the device, this apparent charge, measured in picocoulombs (pC), would cause the same voltage change as that resulting from the partial discharge.

The initial efforts at measuring partial discharge levels on apparatus to provide acceptance criteria between user and manufacturer utilized NEMA 107-1987, Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus. However, it has been determined that this narrow frequency band measuring system has limitations and that measuring partial discharges in terms of apparent charge has many advantages over that of the RIV approach. These advantages include the following:

- a) The internal and stray capacitance of differing switchgear and/or components is accounted for by the calibration procedure. Thus, the measured value is related to the partial discharge level.
- b) The partial discharge measurements are, in most cases, not affected by local radio broadcast signals. It should be noted that apparent charge measurements may be made on either a wide-band or narrow-band basis.

Partial discharge measurement is recognized as a helpful mean to ascertain the insulation quality. Most IEEE standards developed by the Recloser and Other Distribution Equipment subcommittee (RODE) of the IEEE Switchgear Committee now specify partial discharge measurement as a design (type) test and production (routine) test on equipment that use a non self-restoring dielectric as the primary insulation.

This standard is intended to supersede the IEEE Std 1291™-1993, IEEE Guide for Partial Discharge Measurement in Power Switchgear. This standard adopts the IEC 60270:2000 as the base document and forms main part of this standard. Specific IEEE requirements for switchgear are contained in normative Annex I. Other useful data on pattern recognition is given in informative Annex J. Informative Annex K contains a bibliography.

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# IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques—Partial Discharge Measurements

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**CEI  
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**Techniques des essais à haute tension –  
Mesures des décharges partielles**

**High-voltage test techniques –  
Partial discharge measurements**



Numéro de référence  
Reference number  
CEI/IEC 60270:2000

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**HIGH-VOLTAGE TEST TECHNIQUES –  
PARTIAL DISCHARGE MEASUREMENTS**

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International Standard IEC 60270 has been prepared by IEC technical committee 42: High-voltage test techniques.

This third edition cancels and replaces the second edition published in 1981 of which it constitutes a technical revision.

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

| FDIS        | Report on voting |
|-------------|------------------|
| 42/162/FDIS | 42/165/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 3.

Annex A forms an integral part of this standard.

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Terms used throughout this standard which have been defined in clause 3: **bold roman type**.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
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## 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 Definitions

For the purpose of this International Standard, the following 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  $\mu$ 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 $\phi_i$ 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 ( $^\circ$ ).

#### 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  $T_{\text{ref}}$  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  $T_{\text{ref}}$ :

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

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  $T_{\text{ref}}$  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)<sup>2</sup> per second (C<sup>2</sup>/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  $U_{\text{RDV}}$** 

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**  $U_{\text{RDV}}$  is generally expressed in  $\mu\text{V}$ .

**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