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**Visokonapetostne preskusne tehnike - Meritve delnih razelektritev**

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

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Techniques des essais à haute tension - Mesures des décharges partielles

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FUNCTIONS CONCERNED: <input type="checkbox"/> EMC <input type="checkbox"/> ENVIRONMENT <input type="checkbox"/> QUALITY ASSURANCE <input type="checkbox"/> SAFETY	
<input checked="" type="checkbox"/> SUBMITTED FOR CENELEC PARALLEL VOTING <b>Attention IEC-CENELEC parallel voting</b> The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) is submitted for parallel voting. The CENELEC members are invited to vote through the CENELEC online voting system.	<input type="checkbox"/> NOT SUBMITTED FOR CENELEC PARALLEL VOTING

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TITLE:

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

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## HIGH-VOLTAGE TEST TECHNIQUES –

## CHARGE-BASED MEASUREMENT OF PARTIAL DISCHARGES

## FOREWORD

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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

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

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

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

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

196 This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in  
197 accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available  
198 at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are  
199 described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).

200 The committee has decided that the contents of this document will remain unchanged until the  
201 stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the  
202 specific document. At this date, the document will be

- 203 • reconfirmed,
- 204 • withdrawn,
- 205 • replaced by a revised edition, or
- 206 • amended.

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212

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

215 **1 Scope**

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

219 This standard

- 220 – defines the terms used;
- 221 – defines the quantities to be measured;
- 222 – describes the measurement frequencies as well as the test and measuring circuits which  
223 may be used;
- 224 – defines analogue and digital measuring methods required for common applications;
- 225 – specifies methods for calibration and requirements of instruments used for calibration;
- 226 – gives guidance on test procedures;
- 227 – gives some assistance concerning the discrimination of partial discharges from external  
228 interference.

229 The provisions of this standard shall be used in the drafting of specifications relating to partial  
230 discharge measurements for specific power apparatus. It deals with electrical measurements  
231 of impulsive (short-duration) partial discharges, but reference is also made to non-electrical  
232 methods primarily used for partial discharge location (see annex F). It has the status of a  
233 horizontal standard in accordance with IEC Guide 108.

234 This horizontal standard is primarily intended for use by the relevant equipment committees in  
235 the preparation of standards in accordance with the principle laid down in IEC Guide 108. One  
236 of the responsibilities of a technical equipment committee is, wherever applicable, to make use  
237 of horizontal standards in the preparation of its publications. The contents of this horizontal  
238 standard will not apply unless it is specifically referred to or it is included in the relevant  
239 publications. Diagnosis of the behaviour of specific power apparatus can be aided by digital  
240 processing of partial discharge data (see annex E) and also by non-electrical methods that are  
241 primarily used for partial discharge location (see annex F).

242 This standard is primarily concerned with electrical measurement of partial discharge in terms  
243 of apparent charge for specific power apparatus made during tests with alternating voltage, but  
244 specific problems which arise when tests are made with direct voltage are considered in clause  
245 11.

246 The terminology, definitions, basic test circuits and procedures often also apply to tests at other  
247 frequencies, but special test procedures and measuring system characteristics which are not  
248 considered in this standard may be required. For measurements at higher frequency ranges,  
249 see IEC TS 62478.

250 Annex A provides normative requirements for performance tests on calibrators.

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

## 254 2 Normative references

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

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

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

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

266

## 267 3 Terms and definitions

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

### 269 3.1

#### 270 **partial discharge (PD)**

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

273 Note 1 to entry: Partial discharges are in general a consequence of local electrical stress concentrations in the  
274 insulation or on the surface of the insulation. Generally, such discharges appear as pulses having a duration of much  
275 less than 1  $\mu\text{s}$ . More continuous forms can, however, occur, such as the so-called pulse-less discharges in gaseous  
276 dielectrics. This kind of discharge will normally not be detected by the measurement methods described in this  
277 standard.

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

280 Note 3 to entry: Partial discharges are accompanied by emission of acoustic transients (sound), electromagnetic  
281 waves, optical signals (light), heat, and associated chemical reactions. For further information, see annex F.

### 282 3.2

#### 283 **partial discharge pulse (PD pulse)**

284 produced by a partial discharge occurring within the object under test, measured using suitable  
285 detector circuits introduced into the test circuit.

286 Note to entry: A partial discharge which occurs in the test object produces a current pulse at its origin. A detector in  
287 accordance with the provisions of this standard produces a current or a voltage signal at its output proportional to  
288 the charge of the PD pulse.

### 289 3.3

#### 290 **quantities related to partial discharge pulses**

##### 291 3.3.1

#### 292 **apparent charge $q$**

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

296 Note to entry: The apparent charge is not equal to the amount of charge locally involved at the site of the discharge,  
297 which cannot be measured directly.

298 **3.3.2**299 **pulse repetition rate  $n$** 

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

302 Note to entry: In practice, only pulses above a specified magnitude or within a specified range of magnitudes are  
303 considered.

304 **3.3.3**305 **pulse repetition frequency  $N$** 

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

307 **3.3.4**308 **phase angle  $\phi_i$  and time  $t_i$  of occurrence of a PD pulse**

309 is given by

$$310 \quad \phi_i = 360 (t_i/T)$$

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

314 **3.3.5**315 **average apparent discharge current  $I$** 

316 is a derived quantity consisting of the sum of the absolute values of individual apparent charge  
317 magnitudes  $q_i$  during a chosen reference time interval  $T_{\text{ref}}$  divided by this time interval:

$$318 \quad I = \frac{1}{T_{\text{ref}}} (|q_1| + |q_2| + \dots + |q_i|)$$

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

320 **3.3.6**321 **apparent discharge power  $P$** 

322 is a derived quantity, **generally expressed in watts (W)**, consisting of the average pulse power  
323 fed into the terminals of the test object due to apparent charge magnitudes  $q_i$  during a chosen  
324 reference time interval  $T_{\text{ref}}$ :

$$325 \quad P = \frac{1}{T_{\text{ref}}} (q_1 u_1 + q_2 u_2 + \dots + q_i u_i)$$

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

329 **3.3.7**330 **radio interference or radio disturbance meter**

331 is a specialized measurement receiver utilizing weighted quasi-peak RF measurements on  
332 frequency B in accordance with CISPR 16-1.

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

336 **3.3.8**337 **radio disturbance voltage  $U_{\text{RDV}}$** 

338 the output reading of a radio interference meter, generally expressed in  $\mu\text{V}$ .

339 For further information, see 4.6 and Annex D.

340 **3.4**  
341 **largest repeatedly occurring PD magnitude  $Q_{IEC}$**   
342 the value recorded by a measuring system which has the pulse train response as specified in  
343 4.3.3, commonly realized by a quasi-peak detector or a digital emulation of such a circuit,  
344 applicable for AC voltages.  
345

346 **3.5.**  
347 **peak apparent charge  $Q_{pk}$**   
348 the largest value recorded by a PD measuring system, commonly realized by a peak detector  
349 or a digital emulation of such circuit, applicable for DC voltages.  
350

351 **3.6**  
352 **specified partial discharge magnitude**  
353 is the largest magnitude of any quantity related to PD pulses permitted in a test object at a  
354 specified voltage following a specified conditioning and test procedure; for alternating voltage  
355 tests, this is the largest repeatedly occurring apparent charge  $Q_{IEC}$ .

356 Note to entry: The magnitude of any PD pulse quantity can vary stochastically in successive cycles and also show a  
357 general increase or decrease with time of voltage application. The specified PD magnitude, the test procedure and  
358 also the test circuit and instrumentation should therefore be appropriately defined by the relevant equipment  
359 committee(s).

360 **3.7**  
361 **background noise and interference/disturbances**  
362 are extraneous signals detected during PD tests, which are not of interest because they are not  
363 signals caused by PD originating in the test object.

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

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

370 **3.8**  
371 **test voltages related to partial discharge pulse quantities**

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

373 **3.8.1**  
374 **partial discharge inception voltage  $U_i$**   
375 the applied voltage at which repetitive partial discharges are first observed in the test object,  
376 after being gradually increased from a lower value at which no partial discharges are observed;  
377 in practice, the lowest applied voltage at which the magnitude of a PD pulse quantity becomes  
378 equal to or exceeds a specified minimum value.

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

380 **3.8.2**  
381 **partial discharge extinction voltage  $U_e$**   
382 the applied voltage at which repetitive partial discharges cease to occur in the test object, after  
383 being gradually decreased from a higher value at which PD pulse quantities are observed; in  
384 practice, the lowest applied voltage at which the magnitude of a chosen PD pulse quantity  
385 becomes equal to, or less than, a specified low value.

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

387 **3.8.3**388 **partial discharge test voltage**

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

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

395 **3.9**396 **partial discharge measuring system**

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

399 **3.10**400 **measuring system characteristics**401 **3.10.1**402 **transfer impedance  $Z(f)$** 

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

405 **3.10.2**406 **lower and upper limit frequencies  $f_1$  and  $f_2$** 

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

409 **3.10.3**410 **midband frequency  $f_m$  and bandwidth  $\Delta f$** 

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

$$412 \quad f_m = \frac{f_1 + f_2}{2}$$

413 and the bandwidth is defined by:

$$414 \quad \Delta f = f_2 - f_1$$

415 **3.10.4**416 **superposition error**

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

420 Note 1 to entry: Superposition errors can be additive or subtractive depending on the pulse repetition rate of the  
421 incoming pulses in combination with the transient response of the detector circuit elements. In practical circuits, both  
422 types will occur due to the random nature of the pulse repetition rate. However, since measurements are based on  
423 the largest repeatedly occurring PD magnitude, usually only the additive superposition errors will be measured

424 Note 2 to entry: Superposition errors can attain levels of 100% or more depending on the pulse repetition rate and  
425 the characteristics of the measuring system.

426 **3.10.5**427 **pulse resolution time  $t_{res}$** 

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

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

435 Note 2 to entry: It is recommended that the pulse resolution time be measured for the whole test circuit, as well as  
 436 for the measuring system, as superposition errors can be caused by the test object, for example reflections from  
 437 cable ends. The relevant equipment committee(s) should specify the procedure for handling superposition errors and  
 438 particularly, the allowable tolerances including their signs.

### 439 3.10.6

#### 440 **dead time $t_{DT}$**

441 is defined as the time period following successful digital acquisition of a PD pulse during which  
 442 the instrument does not accept or acquire signals or neglect detected pulses

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

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

446

### 447 3.10.7

#### 448 **noise modulation**

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

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

### 453 3.10.8

#### 454 **integration error (of apparent charge measurement)**

455 occurs when the upper frequency limit of the PD current pulse amplitude-spectrum is lower than

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

458 See Figure 5.

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

### 461 3.11

#### 462 **digital partial discharge instruments**

463 perform digital acquisition and evaluation of the PD data as described in Annex E

### 464 3.12

#### 465 **scale factor $k$**

466 is the factor by which the value of the instrument reading is to be multiplied to obtain the value  
 467 of the input quantity

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

### 471 3.13

#### 472 **accumulated apparent charge $q_a$**

473 sum of the apparent charge  $q$  of all individual pulses exceeding a specified threshold level, and  
 474 occurring during a specified time interval  $\Delta t$

### 475 3.14

#### 476 **PD pulse count $m$**

477 total number of PD pulses which exceed a specified threshold level within a specified time  
 478 interval  $\Delta t$

479 **3.15**480 **Phase-resolved PD pattern (PRPD)**

481 display of the apparent charge  $q$  versus the phase angle  $\varphi_i$  of the PD pulses recorded during a  
482 specified time interval  $\Delta t$

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

484 **4 Test circuits and measuring systems**485 **4.1 General requirements**

486 In this clause, basic test circuits and measuring systems for partial discharge quantities are  
487 described, and information on the operating principle of these circuits and systems is provided.  
488 The test circuit and measuring system shall be calibrated as specified in clause 5 and shall  
489 meet the requirements specified in clause 7.

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

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

500 If not otherwise specified by the relevant equipment committee(s), any of the test circuits  
501 mentioned in 4.2 and any of the measuring systems as specified in 4.3 are acceptable. In each  
502 case, the most significant characteristics of the measuring system (section 3.10) as applied  
503 shall be recorded.

504 For tests with direct voltage, see clause 11.

505 **4.2 Test circuits for alternating voltages**

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

- 509 – a test object, which can usually be regarded as a capacitance  $C_{DUT}$  (however, see Annex  
510 C);
- 511 – a coupling capacitor  $C_c$ , which shall be of low inductance design, or a second test object  
512  $C_{DUT1}$ , which shall be similar to the test object  $C_{DUT}$ .  $C_c$  or  $C_{DUT1}$  shall exhibit a sufficiently  
513 low level of partial discharges at the specified test voltage to allow the measurement of the  
514 specified partial discharge magnitude. A higher level of partial discharges can be tolerated  
515 if the measuring system is capable of distinguishing the discharges from the test object and  
516 the coupling capacitor and measuring them separately;
- 517 – a measuring system with its input impedance (and sometimes, for balanced circuit  
518 arrangements, a second input impedance);
- 519 – a high-voltage supply, with sufficiently low level of background noise (see also clauses 9  
520 and 10) to allow the specified partial discharge magnitude to be measured at the specified  
521 test voltage;