

Simplified guide to PD measurements as per IEC 60270: 2025 – basic concepts and changes from earlier versions

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PURPOSE

This document defines DIATECH's internal guidance for Partial Discharge (PD) testing of motors, generators, transformers and instrument transformers, based on IEC 60270:2025 (Edition 4.0). It serves as a bridge between fundamental PD concepts and the technical revisions required to transition from legacy standards.

Intended for both internal training and client communication, this guide ensures that DIATECH's PD measurements are consistent, technically defensible, and validated against systematic errors—such as signal attenuation, resonance, and integration error—found in real-world conditions.

BASICS

What is PD?

A localized electrical discharge within insulation, which can eventually lead to a complete failure.

What do we measure?

Not the discharge itself — but its electrical effect at the terminals

Primary Measurement Parameters (mandatory):

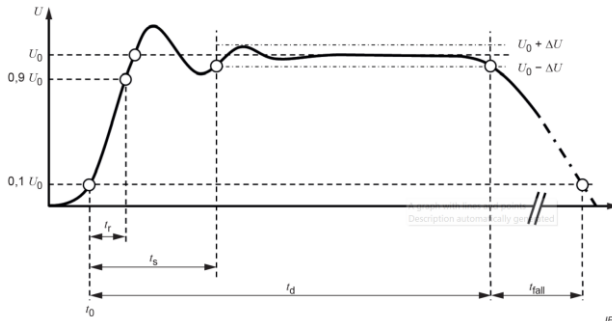
- For AC: Q_{IEC} – The largest repeatedly occurring PD magnitude
- For DC: Accumulated apparent charge q_a , PD pulse count m

Additional Measurement Parameters (optional):

- For AC: Pulse repetition rate n , average discharge current I , discharge power P .
 - For DC: -
 - For AC & DC: Phase-resolved partial discharge patterns (strongly recommended)
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CRITICAL CHANGES IN THE NEW VERSION

1. Strictly specifies this is for charge-based measurements (pC or nC), below 1 MHz (cannot be used for on-line PD measurements).
2. Calibrators must produce pulses that meet the following requirements:



- a. Rise Time (t_r) ≤ 60 ns
 - b. Time to steady state (t_s) ≤ 200 ns
 - c. Step voltage duration and decay time (t_d) ≥ 5 μ s
 - d. Deviation of the step voltage U_0 between t_s and t_d (ΔU) $\leq 0.03 U_0$
 - e. Fall time (t_{fall}) ≥ 100 μ s... this is a new addition
3. In addition, calibrators used for the 5-year "system verification" should have the following features:
 - a. Capability to vary the Pulse Repetition Rate from 0.1 Hz to 100 Hz (or higher)
 - b. Produce pulses at specific phase positions (say 90° and 270°) for verification of phase accuracy
 - c. Apply charge of varying magnitudes
 - d. Generate bipolar pulses
 4. Clarifies that the smallest "accurately measurable PD magnitude" is at least twice the background noise. Thus, a PD report without a background noise measurement is not valid.
 5. Explains the Integration Error (Underestimation" Risk): If a PD pulse is too long relative to the measurement frequency (f_2), the instrument will report a pC value lower than reality. This is common in high-capacitance objects. Use the "Bandwidth Flatness" method - lower the upper frequency until the pC magnitude reaches a stable, maximum value.
 6. While the measurement bandwidth remains the same as earlier (see below), it is recommended to use lower bandwidths for distributed capacitance test objects with a high capacitance (such as motor & generator windings) for the reasons explained in Point No. 4:
$$(30 \text{ kHz} \leq f_1 \leq 100 \text{ kHz})$$

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

$$100 \text{ kHz} \leq \Delta f \leq 900 \text{ kHz}$$
 7. Instruments as well as calibrators must be subject to a full system verification every 5 years. This involves a rigorous, documented test of all characteristics (linearity, scale factor, pulse resolution). If an instrument or calibrator has undergone a major repair, a full performance test is mandatory before field use.
 8. Data validation is strongly recommended – cross-checks required to check for attenuation / resonance in case of very low/ very high PD values.

IMPORTANT PRINCIPLES

1. Measurement depends on system
2. Calibration defines meaning
3. Noise is always present
4. PD value is not absolute

Simple Analogy

PD = sound inside a room

Measurement = microphone outside

What you hear depends on:

- Construction of the room (test specimen)
- Walls (insulation)
- Distance (measurement point)
- Microphone's range and settings (PD detector)

Fundamental Concept – What IEC 60270 measures

IEC 60270 measures apparent charge (q), not the physical discharge inside the insulation. Apparent charge is defined as the equivalent charge injected at the terminals that produces the same measurement response.

Thus, PD measurement is inherently system-dependent and influenced by circuit configuration, bandwidth, and signal propagation.

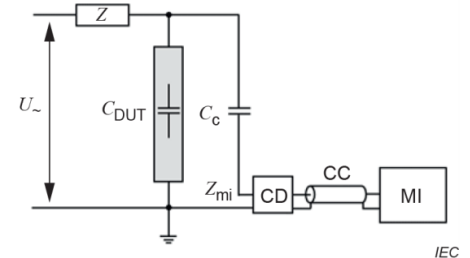
Key implication: Same defect \neq Same PD value across different setups.

PD MEASUREMENTS

Standard Test Circuit (Conceptual)

HV Source → Coupling Capacitor → Test Object → Measuring Impedance → PD Detector

- Coupling Capacitor rating ≥ 1 nF or greater... for large capacitances
- Connection length from test object to coupling capacitor
 - ≤ 0.5 metres (preferred)
 - 0.5 – 2 metres acceptable with uncertainty
 - > 2 metres needs justification (risk of attenuation)
- Single-point grounding mandatory
- No parallel return paths
- Injection at HV terminal preferred
- Calibration must always be performed in the complete test circuit
- Any change in circuit = change in measurement system



PD Detector Capabilities

Minimum requirements

- display the value of the largest repeatedly occurring PD magnitude Q_{IEC}
- the time between successive updates of the digital display shall not exceed 1 s.
- If the instrument is stated to be able to measure the phase angle of the test voltage, the phase displacement of the reading should be within five degrees of the true value.

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

- the instantaneous apparent charge
- the instantaneous value of the test voltage
- the phase angle of occurrence of the PD pulse
- the pulse count rate N

Calibration – Detailed SOP

1. A known charge (for example, 100 pC) is injected into the test circuit
2. This produces a signal at the instrument (for example, 100 mV). The instrument's measurement scale is then adjusted to give a result of 100 pC (*i.e. for this test setup, that signal level is defined as 100 pC*).
3. Later when a real discharge occurs during the actual PD measurement, it produces a signal (in mV) at the terminals.
4. The instrument measures the size of this signal and converts it into a pC value using the calibration established in Step 2.

Calibration Validation Procedure

1. Inject known charge (e.g., 100 pC) – ideally between 50% to 200% of expected PD
2. Record measured value
3. Change lead length or injection point
4. Re-measure
5. Compare results

Calibration Acceptance Criteria

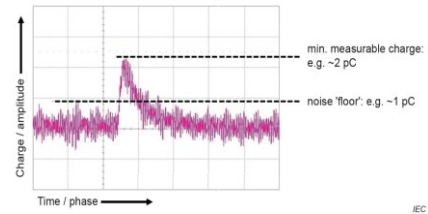
- $\leq 10\%$ variation → Stable measurement system
- 10% to 20% → Acceptable with caution
- $> 20\%$ → Investigate system effects (attenuation/ resonance)

Noise and Measurement Validity Check

Measured PD magnitude must be at least twice the background noise.

Example: Noise = 50 pC → Valid PD ≥ 100 pC

If this condition is not met, the measurement is not reliable.



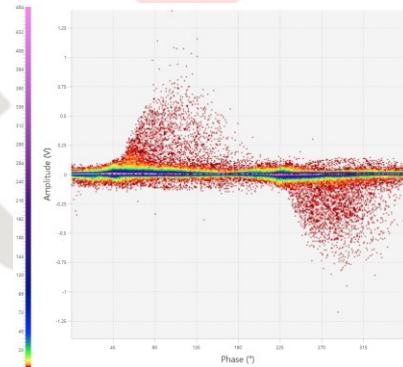
Test Procedure (Clause 8 for AC; Clause 11 for DC)

1. Measure background noise (adjust threshold $\geq 2 \times$ noise).
2. Condition object (gradual voltage rise).
3. Record PD inception (U_i) / extinction (U_e) voltages.
4. Measure magnitude at specified test voltage.
5. Use PRPD patterns for source identification.

Frequency Selection

Typical IEC range:

$$\begin{array}{lll} 30 \text{ kHz} & \leq f_1 & \leq 100 \text{ kHz} \\ f_2 & \leq & 1 \text{ MHz} \\ 100 \text{ kHz} & \leq \Delta f & \leq 900 \text{ kHz} \end{array}$$



Bandwidth (Δf) selection must be based on test object and noise environment:

- Too narrow → loss of signal
- Too wide → increased noise/ resonance
- Wide-band recommended
- Consider narrow-band or reduced-band for motor windings (see below)

**** Bandwidth for PD measurement and bandwidth for calibration must ALWAYS be the same. If bandwidth is to be changed during PD measurement for any reason, be sure to perform a calibration again for that frequency band.**

Large Object Behaviour (Underestimation)

PD signals may attenuate, distort or reflect as they propagate through the test object and measurement circuit. IEC 60270 recognizes that, in distributed systems such as windings and cables, these can influence the measured apparent charge.

As a result, the magnitude measured at the terminals may be lower than the discharge magnitude at its source. The extent of this underestimation cannot be quantified, as it depends on the geometry of the test object, measurement bandwidth, and coupling configuration.

In general, larger and more distributed systems tend to exhibit greater propagation-related effects, and therefore greater potential for underestimation. Large objects are defined electrically by capacitance (nos. below are based on experience only):

Category	Capacitance Range	Examples
Small	< 1 nF	CTs, PTs, CVTs
Medium	1 to 10 nF	Small transformers
Large	10 to 50 nF	Large transformers Small MV/ HV motors Short cables
Very large	> 50 nF	Large MV/ HV motors Generators Medium to long length cables

Resonance (Signal Amplification)

Resonance occurs due to interaction of inductance and capacitance in the system. This can result in artificial amplification of PD signals. Indicators of resonance and validation would be as under:

Observation	Interpretation	Recommended Validation Steps	Interpretation
PD magnitude unusually high for that equipment type and setup	Suspicious	Check background noise level (is PD >> noise?)	Measurement valid, follow next steps.
		Repeat measurement to confirm stability	Measurement valid, follow next steps.
		Compare with previous data / similar assets	If all are high, then probably resonance. If not, then real PD.
Clean PRPD pattern but unexpectedly high magnitude	Possible resonance	Change bandwidth and observe	Amplitude changes a lot, PRPD does not → Probable resonance, use results for trending only
			Amplitude changes a bit, PRPD changes a lot → Multiple PD locations, use a higher bandwidth
			Both change a lot → Complex issues, use max. bandwidth, consider results for trending only
			Neither change much → Almost definitely PD
Large change with small voltage step	Ambiguous – could be PD inception or resonance	Increase voltage gradually and observe trend (smooth vs erratic)	Smooth → Likely PD Erratic → Measurement instability or resonance
		Reduce voltage to check extinction behaviour	Clear extinction → Likely PD Erratic or no extinction → Measurement instability, resonance, or noise
		Change bandwidth and observe if behaviour changes	Small change → Likely PD Large change → Likely resonance or multiple PD sources

RECOMMENDED ACTIONS

1. Keep test leads as short as possible
2. Use single-point grounding
3. Always perform calibration for the complete set-up, including the test object
4. Calibration and PD measurements should be in the same frequency band
5. Always measure the background noise level
6. Always condition the test object prior to PD measurements
7. Use a low-noise power source to energize the test object
8. Always add the frequency band and the Apparent Charge in the Report
9. Preferably, measure the test object's capacitance and add to the Report
10. Do not rely on a single measurement
11. Use comparative analysis
12. Report uncertainty if resonance suspected

KEEP IN MIND

- IEC 60270 (2025) defines how to measure PD, not how to interpret it.
- IEC 60270 states that measurement uncertainty will be 10%, even when all procedures are followed.
- IEC 60034-27-1 (2017) should be referred for specifics about off-line PD measurements and interpretation of motors & generators.
- IEEE C57.113 (2023) should be referred for specifics about off-line PD measurements of oil-filled transformers.
- IEEE C57.160 (2023) should be referred for specifics about off-line PD measurements of HV bushings and instrument transformers.
- IEC 60270 assumes lumped-capacitance behaviour, but motor/ generator/ transformer windings are distributed. Hence, absolute **pC levels are not comparable** across machines or detectors. Compare only for identical machines tested with identical PD detectors, as well as trends over time and the PRPD patterns.
- IEC 60270 is **not applicable for any on-line PD** measurements.