



IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee

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Abstract: This guide covers the diagnostic testing of new or service-aged installed shielded power cable systems, which include cable, joints, and terminations, using partial discharge (PD) detection, measurement, and location. Partial discharge testing, which is a useful indicator of insulation degradation, may be carried out on-line or off-line by means of an external voltage source. This guide does not include the testing of compressed gas insulated systems or continuous on-line monitoring at normal service voltage.

Keywords: cable system testing, cable testing, diagnostic testing, off-line partial discharge testing, on-line partial discharge testing, partial discharge testing

The Institute of Electrical and Electronics Engineers, Inc.
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Introduction

This introduction is not part of IEEE Std 400.3-2006, IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment.

Cable systems need to be tested after installation, periodically during their service life, occasionally after frequent failures in specific types of cables or accessories, and whenever a decision needs to be made about cable repair or replacement. The main purpose of testing is to provide a high degree of service reliability in the most economic fashion. To guarantee optimum performance of the power cable system, standards and guidelines have been developed that address the specific testing requirements for newly installed and service-aged extruded and laminated dielectric insulation.

This guide was prepared by working group C-19W of the IEEE Insulated Conductors Committee.

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The following members of the individual balloting committee voted on this guide. Balloters may have voted for approval, disapproval, or abstention.

Roy W. Alexander
Butch Anton
Ali Al Awazi
Saber Azizi-Ghannad
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IEEE Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment

1. Overview

This guide is one of a series of guides introduced in IEEE Std 400™-2001.¹ It is divided into 10 clauses, as follows:

- Clause 1 provides the scope and the purpose of the guide.
- Clause 2 lists the references to other standards or guides that are useful in applying this guide.
- Clause 3 provides definitions that are of particular importance for the understanding of this guide and lists a glossary of abbreviations and acronyms.
- Clause 4 provides basic interpretation of partial discharge (PD) data.
- Clause 5 describes the different types of PD detection methods.
- Clause 6 briefly describes the voltage sources available commercially.
- Clause 7 offers useful practical testing guidelines.
- Clause 8 discusses the expected test results and recommendations.
- Clause 9 is devoted to the safety precautions to be observed during testing.
- Clause 10 provides conclusions.

This guide also contains four annexes. Annex A expounds, in some detail, on the question of water treeing and partial discharge in cables with extruded dielectrics. Annex B shows how the partial discharge inception voltage changes with the cavity shape, location, and material. Annex C discusses in greater detail the subjects of PD calibration and location accuracy. Annex D is the bibliography.

¹Information on references can be found in Clause 2.

1.1 Scope

This guide covers the diagnostic testing of new or service-aged installed shielded power cable systems, which include cable, joints, and terminations, using PD detection, measurement, and location. Partial discharge testing, which is a useful indicator of insulation degradation, may be carried out on-line or by means of an external voltage source. This guide does not include the testing of compressed gas insulated systems or continuous on-line monitoring at normal service voltage.

1.2 Purpose

This guide describes diagnostic methods capable of detecting and locating partial discharges from defects and damage in installed shielded power cable systems. The results of PD tests are used to assess the condition of cables and accessories.

1.3 Background

PDs are small electric sparks or discharges that occur in defects in the insulation, or at interfaces or surfaces, or between a conductor and a floating metal component (not connected electrically to the high-voltage conductor nor to the ground conductor), or between floating metal components if the electric field is high enough to cause ionization of the gaseous medium in which the components are located. The discharges do not bridge the insulation between conductors, and the defects may be entirely within the insulation, along interfaces between insulating materials (e.g., at accessories) or along surfaces (terminations or potheads).

Partial discharge characteristics depend on the type, size, and location of the defects, insulating material, applied voltage, and cable temperature, and they vary with time. The damage caused by PD depends on several factors and can range from negligible to causing failure within days to years.

Advances in digital (electrical) measurement technology, both in the time and frequency domains, have improved the sensitivity of PD measurements. This has led to an increasing number of PD measurements on cable systems, particularly on medium-voltage systems. The purpose of such measurements is to assess the current condition of a cable circuit. At the current state-of-the-art, very good cables and very bad cables can generally be identified. It is the remaining life of the cables between these two extremes that cannot be predicted with great accuracy. As well, this technology cannot determine with complete confidence that a specific cable is in very good condition with essentially no probability of failure in the near future, as failure can be caused by phenomena that do not generate PD. However, the PD measurement can, at times, predict with a high level of confidence that a given cable is in very poor condition and is likely to fail in the near future.

This guide provides background information on PD detection and location techniques for users of PD testing services of cables with laminated or extruded insulations, and it provides background information on the interpretation of PD data. In this guide, cable may also refer to a cable system that includes cables and accessories.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

Accredited Standards Committee C-2, National Electrical Safety Code® (NESC®).²

ICEA T-24-380-1994, Guide for Partial-Discharge Test Procedure.³

IEC 60270, High-voltage test techniques—Partial discharge measurements.⁴

IEC 60885-2, 1987, Electrical test methods for electric cables—Part 2: Partial discharge tests.

IEC 60885-3, 1987, Electrical test methods for electric cables—Part 3: Test methods for partial discharge measurements on lengths of extruded power cables.

IEEE Std 400™-2001, IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems.^{5, 6}

IEEE Std 400.2™-2004, IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF).

IEEE Std 510™, IEEE Recommended Practices for Safety in High-Voltage and High Power Testing.⁷

NFPA-70E, Standard for Electrical Safety Requirements for Employee Workplaces.⁸

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this guide, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B18]⁹ should be referenced for terms not defined in this clause.

² ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ ICEA publications are available from the Insulated Cable Engineers Association, P.O. Box 20048, Minneapolis, MN 55420, USA (<http://www.icea.org/>).

⁴ IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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⁷ IEEE Std 510-1983 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

⁸ NFPA publications are available from Publication Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://nfpa.org/codes/index.html>).

⁹ The numbers in brackets correspond to those of the bibliography in Annex D.

3.1.1 electrical trees: Tree-like growths consisting of non-solid or carbonized microchannels, which can occur at electric field enhancements such as protrusions, contaminants, voids, or water trees subjected to electrical stress for extended time periods. Partial discharges are responsible for electrical tree growth.

3.1.2 extruded insulation: Insulation such as high-molecular-weight polyethylene (HMWPE), crosslinked polyethylene (XLPE), tree-retardant XLPE (TRXLPE), ethylene propylene rubber (EPR), etc. applied using an extrusion process.

3.1.3 laminated insulation: Insulation formed in layers typically from tapes of either cellulose paper or polypropylene or a combination of the two. An example is the PILC (paper insulated lead covered) cable design.

3.1.4 partial discharge (PD) pulse: A current or voltage pulse that results from a partial discharge. In a cable, the pulse propagates away from the PD source in both directions.

3.1.5 pulse sequence: The occurrence of partial discharge (PD) pulses as a function of time that can be used to determine statistical correlations such as the amplitude of one pulse and the time to the next pulse.

3.1.6 water trees: A tree-shaped collection of water-filled micro voids that are connected by oxidized tracks. Water trees can occur at electric field enhancements such as protrusions, contaminants, or voids in polymeric materials subjected to electrical stress and always in the presence of water.

3.2 Acronyms and abbreviations

CAIFI	customer average interruption frequency index
DAC	damped ac voltage
E_d	stress in the insulation adjacent to the cavity
EPR	ethylene propylene rubber
FTRC	frequency tuned resonant circuit
HMWPE	high-molecular-weight polyethylene
ITRC	inductively tuned resonant circuits
MAIFI	momentary average interruption frequency index
n	partial discharge pulse repetition rate
PD	partial discharge
PDEV	partial discharge extinction voltage, V_e
PDIV	partial discharge inception voltage, V_i
PILC	paper insulated lead covered
PPE	personal protective equipment
q	apparent discharge magnitude
SAIDI	system average interruption frequency index
SOV	system operating voltage
T	period of the test voltage
t_i	time measured from the preceding positive going transition of the sinusoidal test voltage through zero to the PD pulse
TDR	time domain reflectometry
TRXLPE	tree-retardant crosslinked polyethylene
V_o	nominal operating voltage to ground
VLF	very low frequency
XLPE	crosslinked polyethylene
Φ	phase angle of PD pulse given by $\Phi_i = 360 (t_i/T)$