

IEEE Recommended Practice for Partial Discharge Measurements under AC Voltage with VHF/UHF Sensors during Routine Tests on Factory and Pre-Molded Joints of HVDC Extruded Cable Systems up to 800 kV

IEEE Dielectrics and Electrical Insulation Society

Developed by the
IEEE Standards Committee

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IEEE SA Standards Board

Abstract: The aim of this recommended practice is to establish a protocol for the measurement of partial discharges using ac voltages and VHF/UHF electromagnetic sensors, for quality control during routine tests on factory and pre-molded joints of high-voltage direct-current (HVDC) extruded cable systems having voltage ratings up to 800 kV. The various steps of the protocol for the measurement of partial discharges in such cables are carefully described. Details are given about the procedure for a sensor performance check, test setup preparation, and success criteria. The ultimate goal of this recommended practice is not verifying the compliance with any maximum acceptable limit of partial discharge amplitude, but rather focusing on the whole phenomenon of partial discharges, in order to assess whether critical partial discharges are present in the tested object (either a factory joint or a pre-molded joint of a HVDC extruded cable system). “Critical partial discharge” is used here to mean a discharge within the insulation of the object under test, excluding all external discharges that can be present during the ac voltage test, (e.g., corona discharge due to HV electrodes, conducting leads related to the test setup).

Keywords: HVDC extruded insulation, IEEE 2862™, partial discharge measurements, power cables, power cable joints, power cable testing

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Introduction

This introduction is not part of IEEE Std 2862-2020, IEEE Recommended Practice for Partial Discharge Measurements under AC Voltage with VHF/UHF Sensors during Routine Tests on Factory and Pre-Molded Joints of HVDC Extruded Cable Systems up to 800 kV.

High-voltage direct-current (HVDC) cable systems with extruded insulation are becoming a more appealing option compared with Mass Impregnated Non-Draining (MIND) HVDC cable systems (see [B15],[B12])¹, but still have issues to be addressed. One is the development of long-lasting and reliable accessories, namely joints and terminations. In fact, test and service experience shows that joints, whose number is huge in long HVDC links, are the components that mostly affect the reliability of the whole cable system, but so far only a few tests exist on joints for HVDC extruded cable systems and there is a lack of standardization (see [B13]). Aiming to fill this gap, the IEEE DEIS HVDC Cable Systems Technical Committee followed the suggestions by CIGRÉ Technical Brochure (TB) 496:2012² and [B18], thereby preparing two position papers published in 2019 (see [B13] and [B14]). In [B13] it is shown that today:

- a) Among prospective methods to characterize joints using new qualification and routine tests the electrical techniques identified are:
 - 1) Space charge (SC) measurements, still very challenging when considering full-size accessories.
 - 2) Partial discharge (PD) measurements, fostered in CIGRÉ TB 496:2012 and [B18].
- b) Routine tests are the first practical target for the onset of new PD measurements on joints.
- c) PD measurements under ac voltage are the readily-available measurements from manufacturers' practices for quality control of the insulation of accessories during routine tests. While the logical choice for HVDC extruded cable systems would be PD measurements using dc voltage, the reasons for choosing ac voltage are as follows:
 - 1) PD measurements under dc voltage may lead to insufficient data because of the low PD repetition rate, which can be many orders of magnitude lower than under ac voltage.
 - 2) Under dc voltage there are only very limited means of distinguishing PD from noise because of the lack of voltage phase relations.
 - 3) There is very little knowledge about the interpretation of PD signals obtained under dc voltage. Because the main purpose of PD measurements during routine tests is to detect defects in the insulation, it is, therefore, recommended to use ac voltage. AC voltage is generally more effective for the screening of production process defects, as voids, protrusions, adhesion problems between interfaces, etc. Furthermore, some issues may arise during successive dc energizations for other reasons, for example related to the dc design or to material behavior under dc voltage (space charge accumulation). This recommendation therefore focuses on screening for manufacturing defects for HVDC accessories. It has to be kept in mind that under dc voltage in a cable system under load, the electric field distribution in the insulation can be different from that under ac voltage. Therefore, there is a possibility that some defects that would give rise to PD activity in a loaded dc cable would remain undetected under ac voltage. In particular, this may be the case for defects close to the outer semicon sheath.
- d) VHF/UHF electromagnetic (wireless) sensors are the best tool for performing such measurements on joints effectively in noisy environments like factories. In this respect, page 6 of IEC TS 62478:2016

¹The numbers in brackets correspond to those of the bibliography in Annex C.

²Information on references can be found in Clause 2.

emphasizes the special need to give recommendations for the electromagnetic PD measurement methods³, even though these do not accord with IEC 60270:2000.⁴

For this reason, in [B14] a protocol is proposed for PD measurements using ac voltages and VHF/UHF electromagnetic sensors during routine tests on factory and pre-molded joints of HVDC extruded cable systems. The protocol incorporates experience from manufacturers in similar measurements.

This recommended practice aims at improving this protocol and establishing it as a reference IEEE best practice for the measurement of partial discharges using ac voltages and VHF/UHF electromagnetic sensors on factory and pre-molded joints of HVDC extruded cable systems. At the time of writing, the maximum rated voltage of HVDC extruded cable systems commissioned worldwide is 400 kV [B7], but systems with rated voltage up to 640 kV are being qualified (see [B2] and [B8]) and higher voltages are expected. Aiming to account for these recent and/or ongoing developments, an upper limit of 800 kV has been selected for the rated voltage of HVDC extruded cables to which the present recommended practice is applicable [B14].

Acknowledgments

Grateful acknowledgment is made to CIGRÉ for permission to reprint the following source material:

- Technical Brochure N. 89, Accessories for HV Extruded Cables. CIGRÉ, February 1995.
- Technical Brochure N. 496, Recommendations for Testing DC Extruded Cable Systems for Power Transmission at a Rated Voltage up to 500kV. CIGRÉ, April 2012.

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³“There is a special need to give recommendations for two used non-conventional methods, acoustic and electromagnetic ones, and this document is the first step in this direction.” After IEC TS 62478:2016 ed. 1.0, Introduction, page 6, “Copyright © 2016 IEC Geneva, Switzerland. www.iec.ch.”

⁴“Detection and measurement of effects of PD: activities that can be detected and measured using the following methods: electrical methods: conventional (according to IEC 60270) or electromagnetic (HF, VHF and UHF) methods.” After IEC TS 62478:2016 ed. 1.0, clause 3.1.4, page 8, “Copyright © 2016 IEC Geneva, Switzerland. www.iec.ch.”

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IEEE Recommended Practice for Partial Discharge Measurements under AC Voltage with VHF/UHF Sensors during Routine Tests on Factory and Pre-Molded Joints of HVDC Extruded Cable Systems up to 800 kV

1. Overview

1.1 Scope

This document recommends best practices for the measurement of partial discharges using ac voltages and VHF/UHF electromagnetic sensors for quality control during routine tests on factory and pre-molded joints of HVDC extruded cable systems with rated voltage up to 800 kV. It must be emphasized that this recommended practice aims at focusing on the whole phenomenon of partial discharges, rather than solely on partial discharge pulse amplitude, in order to assess whether critical partial discharges are present in the tested object (either a factory joint or a pre-molded joint of a HVDC extruded cable system). By “critical partial discharge” it is meant here a discharge within the insulation of the object under test, excluding all external discharges that can be present during the ac voltage test, e.g., corona discharges due to HV electrodes, conducting leads related to the test setup.

1.2 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{5,6}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

⁵The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁶The use of *will* is deprecated and cannot be used when stating mandatory requirement; *will* is only used in statements of fact.