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IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

IEEE Power and Energy Society

Sponsored by the
Insulated Conductors Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

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Abstract: Very low frequency (VLF) withstand and other diagnostic tests and measurements that are performed using VLF energization in the field on shielded power cable systems are described in this guide. Whenever possible, cable systems are treated in a similar manner to individual cables. Tables are included as an aid to identifying the effectiveness of the VLF ac voltage test for various cable system insulation problems.
Keywords: cable fault locating, cable system testing, cable testing, condition assessment, dielectric spectroscopy, grounding, hipot testing, IEEE 400.2™, partial discharge testing, proof testing, safety, tangent delta testing, very low frequency testing, VLF ac voltage testing

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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Dawn Zhao
Tiebin Zhao

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Introduction

This introduction is not part of IEEE Std 400.2-2013, IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz).

A significant investment with respect to electric power systems is underground cables. A high degree of reliability and reasonable life expectancy of cable systems are necessary. In order to get the optimum performance, standards and guidelines have been developed which address the specific testing requirements for new and service-aged extruded and laminated dielectric cable insulations. This Guide is one part of a series of guides that discuss known diagnostic techniques for performing electrical tests in the field on shielded power cable systems. An omnibus guide (IEEE Std 400™) provides a general overview of all technique classes. It is intended that the technique-specific guides provide the definitive information on voltages, times and criteria.

Ideally, field withstand testing of cable systems would be done using the same power frequency as would normally applied to the cable under operating conditions, but at higher test voltage. However, because of the inherent capacitance of long runs of medium-/high-voltage concentric shielded cable, the excessive charging current is beyond the limits of normally available power sources and test equipment found in the field, except costly ac resonant test systems.

High-voltage dc testing would eliminate the charging current issue associated with ac tests, but would not subject the cable system to the voltage stress distribution that it is exposed to under normal operating conditions. Furthermore there are significant negative issues affecting the integrity of aged cross linked polyethylene (XLPE) cable after it is exposed to high-voltage dc tests and then placed back into service. There is also the unknown influence of elevated dc voltage on the extruded cables such as mineral-filled EPR. In addition, dc is not effective in detecting many forms of gross defects that may be present in a cable system that will otherwise be detected by VLF or at operating frequency.

When required to perform field testing on long lengths of medium-/high-voltage cable with an alternating current source, an alternative to applying power frequency is very low frequency (VLF, 0.01 to 1 Hz). The charging current at a very low frequency of 0.1 Hz is only 1/500 or 1/600 of that at 50 Hz or 60 Hz respectively so that significantly smaller and more portable VLF power sources have the capability to test cable systems of relatively long lengths.

This guide provides a definition of VLF, a description of the wave-shapes and their magnitudes and frequencies that can be applied as a source for overvoltage field testing, the issues with different wave shapes, the duration of testing and what diagnostic information can be learned when these VLF voltages are applied.

Contents

IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

1. Overview

This guide provides a description of the methods and practices to be used in the application of very low frequency (VLF) ac high-voltage excitation for field testing of shielded power cable systems (Bach [B1][1] and [B2]; Baur, Mohaupt, and Schlick [B6]; Gnerlich [B11]). VLF ac voltage testing is an alternative method of continuous ac voltage testing and is used for a broad range of accessory and cable types (Kobayashi, et al. [B26], Steennis, Boone, and Montfoort [B32]) as well as testing of rotating machinery, see IEEE Std 433™. It provides a method of evaluation, and helps to fill the need for more complete information on the cable system condition while minimizing or eliminating some potential adverse charging effects of the direct voltage high-potential test method (commonly known as the dc hi-pot test) (Srinivas and Bernstein [B31]; Eager, et al. [B8]; Hampton, et al. [B19]; Groenefeld, von Olshausen, and Selle [B14]; Steennis, Boone, and Montfoort [B32]; Gockenbach and Hauschild [B12]). This guide addresses VLF ac voltage withstand and dielectric loss testing in the frequency range from 0.01 Hz to 1 Hz. The guide does not focus on the effects of insulation materials parameters: the nature of the differences between insulation materials, the subject of the peroxide crosslinking agent by-products, or on the influence of the VLF stress application on the cable system. Therefore, caution is recommended in interpretation of results.

[1] The numbers in brackets correspond to those of the bibliography in Annex A.

The information contained in this guide is intended to provide the methodology, voltages, and factors to be considered when utilizing VLF ac voltage testing, whether as a withstand test or as a diagnostic test. For general information regarding other field testing methods, refer to the omnibus standard, IEEE Std 400™.[2]

1.1 Scope

This guide describes VLF withstand and other diagnostic tests and the measurements that are performed in the field on service-aged shielded medium and high-voltage cables rated 5 kV through 69 kV with extruded and laminated insulation. VLF test methods utilize ac signals at frequencies less than 1 Hz. The most commonly used, commercially available, VLF test frequency is 0.1 Hz. Whenever possible, cable systems are treated in a similar manner to individual cables. Tables are included of the recommended test voltage levels for installation, acceptance, and maintenance tests.

1.2 Purpose

This guide is intended to provide troubleshooting and testing personnel with information to test shielded medium- and high-voltage cable systems rated 5 kV through 69 kV using VLF ac techniques.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). 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 IEEE C2, National Electrical Safety Code® (NESC®).[3]

ANSI/NETA ATS: Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems (Section 7.3.3: Cables ,Medium, and High Voltage).[4]

ANSI/NETA MTS: Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems (Section 7.3.3: Cables ,Medium, and High Voltage).

IEC 60060-3, High Voltage Test Techniques: Definitions and requirements for on-site tests.[5]

IEC 60270-3, High Voltage Test Techniques: Partial Discharge Measurements.

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

[2] Information on references can be found in Clause 2.
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