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IEEE Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings

IEEE Power and Energy Society

Sponsored by the
Electric Machinery Committee

IEEE
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New York, NY 10016-5997
USA

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Abstract: The procedure for quality control testing of external discharges on stator coils, bars and windings of large air-cooled ac electric machines is described in this recommended practice.
Keywords: ac, corona-imaging instrument, discharge inception voltage, electrical insulation, external discharges, IEEE 1799, stator winding, ultraviolet radiation

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

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Participants

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Remi Tremblay, *Chair*
Claude Hudon, *Secretary*

David Agnew
Kevin Alewine
Raymond Bartnikas
Kevin Backer
Stefano Bomben
Andy Brown
Donald Campbell
William Chen
Doug Conley
Ian Culbert
Jeffrey Fenwick
Shawn Filliben
Nancy Frost
Paul Gaberson
Michel Gagné
Bal Gupta
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Aleksandra Jeremic
Aleksandr Khazanoy
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Gerhard Lemesch
Rimma Malamud
William McDermid
David McKinnon
Charles Millet
Glenn Mottershead
Beant Nindra
Sophie Noel
Ramtin Omranipour
Howard Penrose
Helene Provencher
Emad Sharifi
John Schmidt
Jeffrey Sheaffer
Reza Soltani
Gregory Stone
Chuck Wilson
Hugh Zhu

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

Michael Adams
David Agnew
Martin Baur
Thomas Bishop
Stefano Bomben
Steven Brockschink
Chris Brooks
Donald Campbell
Weijen Chen
Ian Culbert
Matthew Davis
Ray Davis
Gary Donner
Gary Engmann
Jeffrey Fenwick
Jorge Fernandez Daher
Sudath Fernando
Rostyslaw Fostiak
Paul Gaberson
Michel Gagné
Randall Groves
Bal Gupta
Werner Hoelzl
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Innocent Kamwa
Jim Kulchisky
Chung-Yiu Lam
Benjamin Lanz
William Lockley
Greg Luri
Rimma Malamud
William McBride
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William McDermid
David McKinnon
Don McLaren
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Arthur Neubauer
Michael S. Newman
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Lorraine Padden
Christopher Petrola
Alvaro Portillo
Iulian Profir
Bartien Sayogo
John Schmidt
Jeffrey Sheaffer
Gil Shultz
Reza Soltani
Gary Stoedter
Gregory Stone
James Timperley
Remi Tremblay
John Vergis
Kenneth White
Hugh Zhu

When the IEEE-SA Standards Board approved this recommended practice on 19 October 2012, it had the following membership:

Introduction

This introduction is not part of IEEE Std 1799-2012, IEEE Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings.

External discharges in the end-windings are caused by inadequate workmanship for globally vacuum-pressure impregnated (VPI) stators or problems on stators assembled on-site. Poorly finished lashes with an insufficient gap between bars produces coil-to-coil or bar-to-bar discharges. Misalignment between adjacent coils or bars may also reduce the gap distance and generate a high electric stress larger than the air breakdown strength. Sometimes misplaced resistance temperature detector (RTD) or air gap monitor leads have been seen to cause partial discharges (PDs) with high-voltage bars or coils. External discharges for the individual coil/bar could also be a result of improper design, improper material, or improper workmanship. After many years, the deterioration induces surface degradation that may lead, in the long run, to a phase-to-ground fault and reduce the overall reliability of the system. More detail on the theory of external discharges and their effects is given in Annex A. Some utilities have seen deterioration of the junction between the stress control coating and semiconducting slot coating of stator windings after only a few years of operation. Other secondary effects, such as the production of a large quantity of ozone, which may be deleterious to the equipment and dangerous to personnel, is also of concern. In addition, over the years, the ground-wall insulation thickness of stator coils and bars has been reduced to improve heat transfer through the ground-wall insulation. This optimization does, however, increase the dielectric stress on the insulation and on the end-winding stress grading system making them more susceptible to developing electrical discharges.

In the current recommended practice, the term “semiconducting slot coating” is preferred to “semiconductive slot coating” often used in the industry. These coatings, composed of resin, varnish, enamels, or other compounds, are filled with carbon black powder, graphite, or other filler and should have electrical resistivity per unit of surface of $1 \times 10^2 – 5 \times 10^5$ Ohms per square. The semiconducting slot coating applied on the insulation surface of the slot parts of winding must have uniform tight contacts with the grounded walls of the stator slot. This coating provides minimum voltage between the surface of the coil or bar and the grounded stator core.

A stress control coating must be applied on the end turns of high-voltage stator winding and overlap the semiconducting slot coating to provide electrical contact between them. The stress control coating has a non-linear resistance with voltage.

This recommended practice presents two methods for evaluating the quality of materials and design, factory workmanship, and on-site workmanship. The first one, the blackout test, has been used for many years. The second one, the corona-imaging inspection, is more recent and presents several advantages. Each method has its advantages and disadvantages.

IEEE Std 1434 mentions these two inspection methods but with very little detail. The current recommended practice includes a more elaborate description of sample preparation, bench tests, test conditions, and acceptance criteria in the factory and on-site.

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1. Overview

This quality control test is used to confirm that the insulation system of the stator winding of generator and motor operating in air, including the semiconducting slot and stress control coatings, are free of external discharges. Quality control of the semiconducting slot coating, stress control coating, and manufacturing process is best done in the factory. For stators assembled on-site, such as those for large hydro-generators, additional tests can be performed on the fully assembled generator in order to control the quality of the assembly and workmanship. This control includes:

a) evaluation of the spacing between end-arms and with the phase circuit rings or connections to the main phase terminals

b) confirming proper alignment of the ground plane made by the semiconducting slot coating on the straight portion of the bar/coil with regard to the core pressure finger

c) the positioning of all cables (RTD, air gap monitor) with respect to high voltage and

d) inspection of imperfections that may have been introduced during assembly (presence of foreign objects, misplaced slot center filler, chips and scratches to bars or coils coating)

In the case of machines assembled in the factory, such as VPI machines, the complete quality control test can be done in the factory. However, special care should be taken so that no change in the machine's conditions occur during transportation (contamination by water and dust, or damage to end-arms during movement). The use of this recommended practice may eliminate the need for users to specify minimum clearances between bars/coils in the end-winding to avoid surface discharge activity.

1.1 Scope

This recommended practice provides a procedure to detect external discharges in form-wound bars and coils and complete stator windings of rotating machines operating in air with a rated line-to-line voltage greater than 4200 V at power frequency. The recommended practice is applicable to bars, coils, and complete stator windings. The recommended practice covers two inspection methods: the visual blackout test, and the use of corona imaging instruments.

1.2 Purpose

The purpose of this recommended practice is to suggest specimen preparation, test parameters, and procedures for detecting external discharges associated with bars, coils, and complete stator windings using the above mentioned methods. It also recommends acceptance criteria and a procedure for retest in the event of a test failure.

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.

IEC 60204-1, Safety of machinery—Electrical equipment of machines—Part 1: General requirements.

IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems.

IEEE Std 4, IEEE Standard Techniques for High-Voltage Testing.[1, 2]

IEEE Std 4a, Amendment to IEEE Standard Techniques for High-Voltage Testing.

IEEE Std 510-1983 (Withdrawn), Recommended Practice for Safety in High-Voltage and High-Power Testing.[3]

ISO 14121-1, Safety of Machinery—Risk Assessment—Part 1: Principles.

ISO/TR 14121-2, Safety of Machinery—Risk Assessment—Part 2: Practical Guidance and Examples of Methods 2.

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[3] IEEE Std 510-1983 has been withdrawn; however, copies can be obtained from The Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).