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IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery

Sponsor

Electric Machinery Committee
of the
IEEE Power Engineering Society

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Abstract: This document describes the recommended procedure for measuring insulation resistance of armature and field windings in rotating machines rated 1 hp, 750 W or greater. It applies to synchronous machines, induction machines, dc machines, and synchronous condensers. Contained within this documentþis the general theory of insulation resistance (IR) and polarization index (P.I.), as well as factors affectingþthe results,þtest procedures, methods of interpretation, test limitations, and recommended minimum values.

Keywords: absorption current, conduction current, discharge current, geometric capacitive current, insulation resistance, polarization index, surface leakage current

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Introduction

(This introduction is not part of IEEE Std 43-2000, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.)

Insulation resistance measurement has been recommended and used for more than half a century to evaluate the condition of electrical insulation. Whereas individual insulation resistance measurements may be of questionable value, the carefully maintained record of periodic measurements, accumulated over months and years of service, is of unquestioned value as a measure of some aspects of the condition of the electrical insulation. Originally, in 1950, this recommended practice was published by the AIEE as a guide to present the various facets associated with the measurement and understanding of electrical insulation resistance. The guide was revised in 1961 and again in 1974. During the 1970s, several changes were made to the types of insulation used in electric rotating machines. The insulation resistance characteristics of these newer insulation systems are different from the older systems, and therefore required this substantial revision to the standard for measuring insulation resistance. Other changes include the addition of further description of the testing theory and the removal of suggestions regarding maintenance dry-out procedures for older windings (previously Annex A). Recommendations for maintenance procedures are beyond the scope of this document. With this publication as a recommended practice, the IEEE is presenting and recommending electrical insulation resistance measurement as an important factor in monitoring the condition of electrical insulation in rotating machinery.

This recommended practice describes the theory, procedure, and interpretation of the insulation resistance test. It is intended for the following:

— Individuals or organizations who manufacture rotating machines
— Individuals or organizations who are responsible for the acceptance of new rotating machines
— Individuals or organizations who test and maintain rotating machines
— Individuals or organizations who operate rotating machines

This recommended practice is designed to help organizations and individuals

— Evaluate the condition of the electrical insulation used in rotating machines
— Determine if the electrical insulation of a rotating machine is suitable for return-to-service
— Determine if the electrical insulation of a rotating machine is suitable for high-potential testing

This recommended practice is intended to satisfy the following objectives:

a) Promote consistency for insulation test procedures and interpretations
b) Provide useful information on proper application of the insulation resistance test
c) Provide useful information on the technical theory of insulation resistance testing

The revision to this recommended practice was prepared by a working group of the Materials Subcommittee of the Electric Machinery Committee of the IEEE Power Engineering Society. Working group personnel were

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IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery

1. Overview

1.1 Scope

This document describes a recommended procedure for measuring insulation resistance of armature and field windings in rotating machines rated 1 hp, 750 W or greater. It applies to synchronous machines, induction machines, dc machines, and synchronous condensers. It does not apply to fractional-horsepower machines.

The document also describes typical insulation resistance characteristics of rotating machine windings and how these characteristics indicate winding condition. It recommends minimum acceptable values of insulation resistance for ac and dc rotating machine windings.

Other IEEE standards that include information on insulation resistance measurement are listed in Clause 2.

1.2 Purpose

The purpose of this recommended practice is to

a) Define insulation resistance and polarization index testing of the winding of a rotating machine.

b) Review the factors that affect or change insulation resistance characteristics.

c) Recommend uniform test conditions.

d) Recommend uniform methods for measuring insulation resistance with precautions to avoid erroneous results.

e) Provide a basis for interpreting insulation resistance test results to estimate winding suitability for service or for an overvoltage test. In particular, this standard describes typical insulation problems detected by the insulation resistance test.

f) Present recommended minimum acceptable insulation resistance values and polarization indices for various types of rotating machines.

2. References

This recommended practice shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ASTM D257-99 Standard Test Methods for DC Resistance or Conductance of Insulating Materials.[1]

ASTM D1711-99 Standard Terminology Relating to Electrical Insulation.

ASTM F855-97e1 Standard Specifications for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment.

IEC 60085-1: 1984, Thermal evaluation and classification of electrical insulation.[2]

IEEE Std 56-1977 (Reaff 1991), IEEE Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery (10 000 kVA and Larger).[3, 4]

IEEE Std 62-1995, IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus—Part 1: Oil Filled Power Transformers, Regulators, and Reactors.

IEEE Std 67-1990 (Reaff 1995), IEEE Guide for Operation and Maintenance of Turbine Generators.

IEEE Std 95-1977 (Reaff 1991), IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery With High Direct Voltage.[5]

IEEE Std 118-1978 (Reaff 1992), IEEE Standard Test Code for Resistance Measurements.

IEEE Std 432-1992 (Reaff 1998), IEEE Guide for Insulation Maintenance for Rotating Electric Machinery (5 hp to less than 10 000 hp).

IEEE Std 433-1974 (Reaff 1991), IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Voltage at Very Low Frequency.

IEEE Std 434-1973 (Reaff 1991), IEEE Guide for Functional Evaluation of Insulation Systems for Large High-Voltage Machines.

IEEE Std 492-1999 IEEE Guide for Operation and Maintenance of Hydro-Generators.

IEEE Std 510-1983 (Reaff 1992), IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing.

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[1]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

[2]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, 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.

[3]Presently under revision.

[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://www.standards.ieee.org/).

[5]Presently under revision.

3. Definitions

For the purposes of this recommended practice, the following terms and definitions apply. The IEEE Dictionary of Electrical and Electronics Terms should be referenced for terms not defined in this clause.

3.1 absorption (polarization) current (I_A): A current resulting from molecular polarizing and electron drift, which decays with time of voltage application at a decreasing rate from a comparatively high initial value to nearly zero, and depends on the type and condition of the bonding material used in the insulation system.

3.2 conduction current (I_G): A current that is constant in time, that passes through the bulk insulation from the grounded surface to the high-voltage conductor, and that depends on the type of bonding material used in the insulation system.

3.3 electroendosmosis effect: A phenomenon occasionally observed, more often on older windings, when, in the presence of moisture, different insulation resistance values may be obtained when the polarity of the tester leads are reversed. Typically for older wet windings, the insulation resistance for reverse polarity, where the ground lead is connected to the winding and the negative voltage lead to ground, is much higher than for normal polarity.

3.4 insulation resistance (IR_t): The capability of the electrical insulation of a winding to resist direct current. The quotient of applied direct voltage of negative polarity divided by current across machine insulation, corrected to 40 °C, and taken at a specified time (t) from start of voltage application. The voltage application time is usually 1 min (IR_1) or 10 min (IR_{10}), however, other values can be used. Unit conventions: values of 1 through 10 are assumed to be in minutes, values of 15 and greater are assumed to be in seconds.

3.5 geometric capacitive current (I_C): A reversible current of comparatively high magnitude and short duration, which decays exponentially with time of voltage application, and which depends on the internal resistance of the measuring instrument and the geometric capacitance of the winding.

3.6 polarization index ($P.I._{t2/t1}$): Variation in the value of insulation resistance with time. The quotient of the insulation resistance at time (t_2) divided by the insulation resistance at time (t_1). If times t_2 and t_1 are not specified, they are assumed to be 10 min and 1 min, respectively. Unit conventions: values of 1 through 10 are assumed to be in minutes, values of 15 and greater are assumed to be in seconds (e.g., $P.I._{60/15}$ refers to IR_{60s}/IR_{15s}).

3.7 surface leakage current (I_L): A current that is constant with time, and which usually exists over the surface of the end-turns of the stator winding or between exposed conductors and the rotor body in insulated rotor windings. The magnitude of the surface leakage current is dependent upon temperature and the amount of conductive material, i.e., moisture or contamination on the surface of the insulation.

4. Safety considerations

Insulation resistance testing involves the application of high direct voltages to machine windings. These windings have capacitive and inductive properties that can lead to hazards that may not be readily apparent. It is not possible to cover all safety aspects in this recommended practice and test personnel should consult IEEE Std 510-1983;[6] ASTM F855-97e1; manufacturers' instruction manuals; and union, company, and government regulations.

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