

IEEE Guide for Testing Turn-to-Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electric Machines

Sponsor

**Electric Machinery Committee
of the
IEEE Power Engineering Society**

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Abstract: Suggestions are made for testing the dielectric strength of the insulation separating the various turns from each other within multiturn form-wound coils to determine their acceptability. Typical ratings of machines employing such coils normally lie within the range of 200 kW to 100 MW. The test voltage levels described do not evaluate the ability of the turn insulation to withstand abnormal voltage surges, as contrasted to surges associated with normal operation. The suggestions apply to: (1) individual stator coils after manufacture; (2) coils in completely wound stators of original manufacture; (3) coils and windings for rewinds of used machinery; and (4) windings of machines in service to determine their suitability for further service (preventive-maintenance testing). Coil service conditions, test devices, and test sequence are discussed. High-frequency test levels for new coils during winding, and for applying surge tests to complete windings, are given.

Keywords: ac machines, power system transients, rotating-machine insulation testing

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Foreword

(This foreword is not a part of IEEE Std 522-1992, IEEE Guide for Testing Turn-to-Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electric Machines.)

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1. Introduction

1.1 Many alternating-current rotating electric machines are designed to have multiturn form-wound stator coils. In these cases, the winding has two separate but interrelated insulating barriers:

- (1) between the various turns (turn insulation)
- (2) between the turns and ground (ground insulation)

Failure of either of these barriers will prematurely terminate the service life of the machine. A test level, twice rated voltage plus 1 kV, for the ground insulation has been in existence for many years. This guide suggests methods and test levels for the turn insulation.

1.2 Experience has shown that turn-insulation failures can be precipitated by abnormal steep-front surges caused by factors such as lightning strokes, faulty breaker closures, or the malfunction of various types of switching devices. However, turn-insulation failures can also be caused by surges during normal breaker operations when the circuit conditions are such that the rise time of the surge at the machine terminals is less than a few microseconds. A measure of protection from such surges may be provided by installation of devices such as wave-sloping capacitors at the machine terminals and surge arrestors, or by increasing turn-to-turn insulation. When used for this purpose, capacitor ratings are usually chosen to extend the rise time of voltage surges to 5 μ s or longer.

1.3 References are given for determining surge environment and strength of electric machines in the Bibliography (Section 8).

2. Scope and Reference

2.1 Scope. The purpose of this guide is to make suggestions on testing the dielectric strength of the insulation separating the various turns from each other within multiturn form-wound coils to determine the acceptability of the coils. Typical ratings of machines employing such coils normally lie within the range of 200 kW to 100 MW. Test voltage levels described herein do not evaluate the ability of the turn insulation to withstand abnormal voltage surges, as contrasted to surges associated with normal operation. These suggestions apply to:

- (1) Individual stator coils after manufacture
- (2) Coils in completely wound stators of original manufacture
- (3) Coils and windings for rewinds of used machinery
- (4) Windings of machines in service to determine their suitability for further service (preventive-maintenance testing)

2.2 Reference. This guide shall be used in conjunction with the following publication:

[1] IEEE Std 43-1974 (1991), IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery (ANSI).¹

3. Service Conditions

3.1. The maximum operating (line frequency) voltage difference between turns in a coil depends upon the voltage between coil terminals and the internal construction of the coil.

3.2. A second and less predictable voltage difference between turns can be caused by transients. Additional information on the nature of such transients and the associated turn voltage distribution may be found in a number of articles cited in the Bibliography. Steep-front waves due to arcing in the associated circuit can be damaging to turn insulation since a substantial portion of the wave can appear across the turn insulation of the coils near the line terminals.

The voltage difference that turn insulation must withstand, therefore, covers a broad range from less than 100 V in normal operation to as much as several thousand volts under transient conditions. At the one end of this range, all that is needed is physical separation; whereas at the other, insulation having considerable dielectric strength is desirable.

4. Suggested Test Devices

4.1. Individual form-wound multiturn coils have a low series impedance at power frequencies, particularly so prior to insertion in the stator core. Because of this, connection across the leads of any power-frequency test source of adequate voltage to test the insulation will result in high current. This, of course, will also be the case with dc and very-low frequency sources. Therefore, to apply a voltage of reasonable magnitude across the coil leads without excessive current, a test voltage having an equivalent frequency several orders of magnitude above power frequency would be desirable (examples are given in Appendix A, A1.2).

4.2. A suitable testing device should provide voltage control, accurate indication of voltage level, and a means of detecting turn-to-turn insulation failure. A single-stage “Marx” generator with a storage oscilloscope is an example of such a device. A schematic diagram of the generator is given in the Appendix. Both conduction- and induction-type testing devices have been developed and applied satisfactorily. In either type, a steep-front voltage wave is applied to the test coil. In each cycle, a capacitor is charged to an appropriate voltage, then discharged by means of a suitable switch (such as a spark gap, thyatron, or a solid-state device) into a circuit that includes the test coil. Voltage and current then oscillate at the natural frequency of the circuit.

4.2.1. In conduction-type devices, the test voltage is applied directly to the coil leads. Failure detection is by visual inspection of either test voltage or current on a cathode-ray oscilloscope. Coils may be tested singly, or two nominally similar coils may be tested simultaneously, thereby facilitating comparison of the wave shape. In testing a single coil, the wave shape at a sufficiently low voltage should be recorded and used to compare with wave shapes at high voltages. A significant difference, approximately 10% or more, in magnitude or frequency of the waves indicates probable insulation failure.

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