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IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines

IEEE Power Engineering Society

Sponsored by the
Electric Machinery Committee

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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 (270 hp to 135 000 hp). The test levels described do not evaluate the ability of the turn insulation to withstand abnormal voltage surges, only surges associated with normal operation. The suggestions apply to: (1) individual stator coils after manufacture; (2) coils in completely wound stators; (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.
Keywords: ac machines, impulses, surges, testing turn insulation, transients

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Introduction

(This introduction is not part of IEEE Std 522-2004, IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines.)

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:

— One between the various turns (turn insulation), and

— One 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 for the ground insulation of twice-rated voltage plus 1 kV has been in existence for many years. This guide suggests methods and test levels for the turn insulation.

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 surge capacitors at the machine terminals and surge arrestors, or by designing the coils with suitable turn insulation capability. When used for this purpose, capacitor ratings are usually chosen to extend the rise time of voltage surges to 5 μs or longer.

The bibliography (Annex C) contains references that discuss the general surge environment and surge strength of electric machines.

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***We all wish to express our sorrow that Tom Kluk passed away before this standard was published. His input to this document was very valuable and much appreciated by everyone on the working group.**

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Contents

IEEE Guide for Testing Turn Insulation of Form-Wound Stator Coils for Alternating-Current Electric Machines

1. Overview

1.1 Scope

This guide makes suggestions for 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 (270 to 135 000 hp). 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. The repetitive voltage surges (spikes) associated with adjustable frequency drives (AFD) are also not addressed here. This guide applies to

a) Individual stator coils after manufacture.

b) Coils in completely wound stators of original manufacture.

c) Coils and windings for rewinds of used machinery.

d) Windings of machines in service to determine their suitability for further service (preventive-maintenance testing).

1.2 Purpose

The purpose of this guide is to

a) Define surge/impulse testing as applied to the windings of an electric machine.

b) Review the service conditions that affect voltage levels in a coil.

c) Recommend devices suitable for measuring surges, with precautions to avoid erroneous results.

d) Describe various points where surge testing may be performed.

e) Present suggested surge test levels for various types of electric machines.

2. References

ASTM D1711-02, Standard Terminology Relating to Electrical Insulation.[1]

[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/).

ASTM D3426-97 (2004), Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Using Impulse Waves.

IEEE Std 4™-1995, IEEE Standard Techniques for High-Voltage Testing.[2, 3]

IEEE Std 43™-2000, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

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

IEEE P62.2/-D23, Draft Guide for Diagnostic Field Testing of Electric Power Apparatus—Electrical Machinery.[4]

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 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 Practice for Safety in High-Voltage and High-Power Testing.

3. Service conditions

3.1 Operating stress

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

3.2 Transient stress

A second, and less predictable, voltage difference between turns can be caused by voltage 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 in Annex C. Steep-front voltage 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 coil(s) near the line terminals.

3.3 Withstand requirements

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 lower end of this range all that is needed is physical separation, whereas at the other, insulation having considerable dielectric strength is needed.

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[4]This IEEE standards project was not approved by the IEEE-SA Standards Board at the time this publication went to press. For information about obtaining a draft, contact the IEEE.

4. Suggested test devices

4.1 Test requirements

In order to test the turn insulation of a form-wound coil, a voltage must be applied across the individual leads. Form-wound, multiturn coils have a low series impedance at power frequencies, particularly prior to insertion into the stator core. Further, the impedance between turns of a form-wound coil is capacitive or inductive, depending upon frequency. However, the impedance between leads is predominately inductive and is directly proportional to the frequency of the voltage applied across the leads. Following Ohm's law, applying a voltage of sufficient magnitude, at normal power frequencies, across the leads of a form-wound coil yields a high current between the leads. From a testing point of view, this is very undesirable. Therefore, to apply a voltage of reasonable magnitude across the leads, and hence across the turn insulation, without excessive current, a test voltage that has a frequency several orders of magnitude above power frequency is required (examples are given in A.1.2).

4.2 Suitable devices

A suitable testing device should provide voltage control, accurate indication of voltage level, and a means of detecting 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 Figure A.5. 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 coil under test. In each cycle, a capacitor is charged to an appropriate voltage, then discharged by means of a suitable switch (such as a spark gap, thyratron, or a solid-state device) into a circuit that includes the coil. Voltage and current then oscillate at the natural frequency of the circuit.

4.2.1 Conduction-type devices

In conduction-type devices, the test voltage is applied directly to the coil leads. Failure detection is by visual inspection of the wave shape of either test voltage or current on an oscilloscope. Coils may be tested singly, or two nominally identical 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 higher voltages. A significant difference in the wave shape indicates probable insulation failure.

4.2.2 Induction-type devices

In induction-type devices, the test voltage is induced in the coil under test, which constitutes the secondary of a transformer, the primary of which is excited by a steep-front wave from the capacitor. Failure is indicated by asymmetry of either current in the test coil or voltage at its terminals. See Figure A.3.

NOTE—This test equipment is not generally available—this paragraph is included for informational purposes.[5]

5. Test procedure

5.1 Test sequences

Coils may be tested at one or more of the following steps of manufacture:

a) Prior to insertion into the stator core. This is appropriate when the coils are to be installed at a location remote from the coil manufacturing plant. If the impedance of the coils in air is too low, they may be assembled into a simulated core for testing purposes. Each coil in the winding should be tested.

[5]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

b) After coil installation, wedging and bracing, but before any connections are made. Each coil in the winding should be tested.

c) After series connections are made, but before insulating them and before making the connections between phase groups. Each coil in the winding should be tested.

d) After connecting into phase groups, but before connecting phase groups to one another (before or after insulating the series connections). This test compares phase groups, not individual coils.

e) After all connections are made and insulated. All maintenance tests are normally made under such conditions.

   If the test voltage is applied at the machine terminals, the electrical impulse voltage level should be carefully selected in order to avoid overstressing ground insulation. In this case, the test may disclose only existing short circuits and not incipient weaknesses of the turn insulation.

   Caution is advised in testing a complete phase winding from the machine terminals. A complete phase winding consists of several series coils. Hence, the change in the voltage impulse shape caused by the failure of the insulation between a turn-pair in a single coil in the complete phase winding is often very small. Consequently, the failure of the turn insulation during the impulse test of a complete winding may go undetected.

   Otherwise, the test voltage can be induced into the stator coils by means of a surge-inducing coil (Annex A). The test method given in Annex A will stress incipient weaknesses and may cause these areas to fail.

Extra fully processed or uncured coils (if specified in the agreement between the manufacturer and the user) that are not used in winding the machine may be tested to destruction to determine the turn-to-turn breakdown capability of the electrical insulation system design.

5.2 Test conditions

The ambient conditions should be acceptable for insulation testing. Prior to turn-to-turn testing of fully cured coils, the insulation resistance should be measured in accordance with IEEE Std 43-2000.[6] The insulation surface should be clean and dry. The coil temperature should be at least a few degrees above the dew point, as a minimum, to avoid condensation on the insulation. The turn-to-turn testing should not proceed until the insulation resistance tests have been conducted successfully. Other tests, such as measurement of dissipation factor, may also be used to determine if the insulation is suitable for turn-to-turn testing.

5.3 Voltage levels

For un-impregnated or uncured coils, use voltage levels for the insulation resistance test that will not harm the insulation, but will indicate if it is suitable for testing. It may not be possible to successfully test uncured resin rich coils because of the nature of the uncured insulation. Agreement should be reached between the manufacturer and the user regarding the testing of such uncured coils.

6. Surge test levels for new coils

6.1 General

The minimum turn-to-turn test voltage should be no less than 350 V peak, which is the minimum sparking voltage for a uniform field in air (Paschen's Law—see Dakin and Berg [B8] and Khalifa [B28][7]), though in actual practice tests are usually performed at levels far exceeding this value. Beyond this, no generally accepted approach to the selection of turn-to-turn test voltage has evolved. Manufacturers have used coil and

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

[7]The numbers in brackets correspond to those of the bibliography in Annex C.

machine design parameters such as size and weight of coil, length of turn, arrangement of turns within the coil, operating volts per turn or per coil, system voltage, interturn and turn-to-ground capacitance, and others to determine turn-voltage test levels for their products. These procedures have not been described explicitly in the literature, and it is not feasible to describe them here. Agreement should be reached between the manufacturer and the user as to what testing technique and level should be applied to coils and at what stage(s) of manufacture the tests should be performed.

6.2 Standard (3.5 p.u.) withstand envelope

Whatever test technique is used, it is suggested that for testing the turn insulation, impulses with a rise time of 0.1 to 0.2 µs should be used. Tests performed at longer rise times (> 1.2 µs) tend to stress the ground insulation. In general, the coils should have sufficient ground and turn insulation to withstand an electrical surge with amplitude defined in Figure 1. For purposes of the calculation of rise time of the surge, the rise time of the front is assumed to be the time interval from 0.1 to 0.9 of the measured surge amplitude. The time to peak is 1.25 times the rise time. The number of pulses should be no fewer than five. The following equations define these various voltages and associated rise times.

$$V_1 = [\sqrt{(2/3)}]V_L = 1\text{p.u.} \qquad T_r = 0.0\ \mu\text{s} \tag{1}$$

$$V_2 = 3.5V_1 = 3.5\ \text{p.u.} \qquad T_r = 0.1\ \mu\text{s} \tag{2}$$

$$V_3 = 5V_1 = 5\ \text{p.u.} \qquad T_r \geq 1.2\ \mu\text{s} \tag{3}$$

where

V_n (n = 1, 2, 3) is the momentary surge withstand capability across the coil,

V_L is the rated rms line-to-line voltage in kV,

T_r is the rise time in µs,

p.u. is “per unit,” where the initial test voltage is multiplied by the given coefficient.

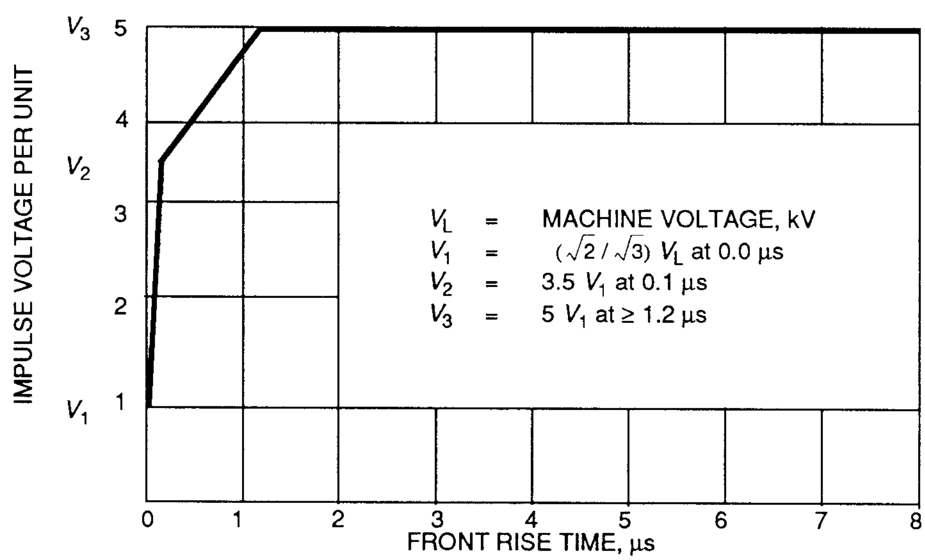

Figure 1—Coil electrical impulse withstand envelope

6.3 Alternate withstand envelope

If agreed between the manufacturer and the user, the impulse withstand envelope given in Figure 2 (from "Impulse voltage strength of ac rotating machines," [B24]) may be used for testing coils in machines that are not likely to see high-magnitude fast-fronted surges.

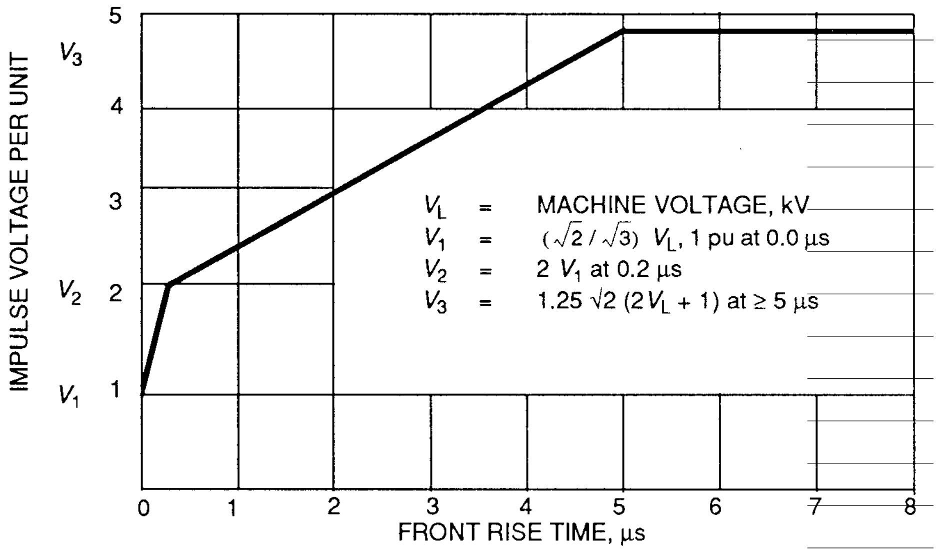

Figure 2—Alternative coil impulse voltage withstand envelope

6.4 Definition of surge envelopes

The envelopes shown in Figure 1 and Figure 2 are NOT the wave shape of the impulse to be applied to test the insulation. These envelopes illustrate the magnitudes of the surge voltages, which might be impressed across the main and turn insulation of the machine during normal operation. Therefore, the coil insulation must withstand these levels. Generally, impulses with rise times 0.1 to 0.2 µs are used for testing the turn insulation (see 6.2). Impulses with rise times 1.2 µs or longer do not generally stress the turn insulation; they are used to test the surge capability of ground insulation.

6.5 Abnormal surges

In the event that the machine is likely to be subjected to abnormal voltage surges during its service life and protective devices are not used (as mentioned in 1.2), turn insulation having a higher-than-normal electric strength should be used in the coils. In this case, the turn-to-turn test voltage may be appropriately adjusted upwards.

6.6 Precautions

It should be noted that unimpregnated or uncured coils—i.e., those tested on the bench or that have been wound in a stator but not VPI'd (vacuum pressure impregnation) or baked—do not have fully cured insulation, and therefore will have a significantly lower surge withstand capability than fully cured coils. Also, when one coil is tested in a stator with the core and frame grounded, the ground insulation of the remaining coils in the winding will experience a reduced-level surge with similar frequency in sympathy with the coil under test (see Stranges, et al. [B54]). The effective voltage of this "sympathetic" surge condition varies with every coil tested.

6.7 Reduction in test levels for uncured coils

To avoid overstressing unimpregnated (dry taped) coils, the test voltage may be reduced to some fraction (generally 60–80%) of the value specified in 6.2 (or 6.3), as agreed between the manufacturer and the user.

To avoid overstressing uncured resin rich coils, the test voltage may be reduced to some fraction (generally 40–60%) of the value specified in 6.2 (or 6.3), as agreed between the manufacturer and the user. The test value in this case should not exceed the DC hi-potential test value.

7. Maintenance tests or tests after installation of machines

7.1 Test voltage level

Applied voltage for tests made in the field may be approximately 75% of V_n as defined in Clause 6. It is good practice to obtain approval from the manufacturer of the coils prior to any test program.

7.2 Conduction-type devices

For maintenance testing, it may be desirable to make the test with no disassembly of the machine. In order to test an installed machine without disassembly, the test must be performed using a conduction-type device as described in 4.2.1. When performing the test from the switchgear, the length of the feeder cables may have a significant effect on voltage impressed at the machine terminals as well as the ability to detect an incipient fault in a fully-configured winding. The most effective method for performing maintenance tests is to connect the test equipment at the machine terminals.

7.3 Induction-type devices

Maintenance tests may also be performed using an induction-type device, as described in 4.2.2, to induce the test voltage in individual coils of a fully-configured winding. See Figure A.2. Performing this type of test on induction and cylindrical-rotor machines will require removing the rotor from the stator. For salient-pole synchronous machines, the degree of disassembly required to perform this test can be minimized by removing a single field coil and rotating the rotor and testing fixtures.

7.4 Insufficient coupling

The degree of coupling that can be achieved by the surge-inducing coil varies rather widely, and in some cases it may not be possible to reach the 75% voltage level in the coils being tested. Therefore, the 75% figure should be considered a general guideline.

7.5 Other methods/further details

Other methods of detecting turn insulation failures and means of minimizing damage due to faults are included in the bibliography ([B5], [B13], [B18], [B31], [B34], [B48], [B50], [B53], and [B54]).

Annex A

(informative)

Test procedures and methods

A.1 Method for applying surge tests to complete windings

A.1.1 General

The arrangement of the surge-inducing coil and laminated-iron sections in the bore of the machine is shown in Figure A.1. The voltage waveform is measured with a one-turn search coil placed in the laminated-iron sections. The search-coil voltage is observed on an oscilloscope through a resistive voltage divider. A consistent pattern for both short-circuited and normal coils is obtained regardless of the electrical position of the coil in the winding since the search coil is affected only to the extent of the reduction of flux resulting from a short-circuited coil. A short-circuited coil generally shows a reduction of the peak amplitude of the wave in the order of 20% when compared to the normal coil. There is also a very slight increase in frequency of the short-circuited-coil waveform, but this is not always sufficiently great to use as a test criterion. It is necessary to utilize wire with multiple, fine, insulated strands in the surge-inducing coil to obtain minimum impedance. One hundred strands of enameled wire, 0.010 in (0.25 mm) diameter, have proven satisfactory for this purpose. It is suggested that the surge-inducing and search coils be insulated to ground for the maximum voltage to appear in each coil. It will be necessary to remove the machine rotor, or for salient-pole machines a pole on the rotor, to provide space for the coils and laminated-iron sections in the bore area. To assure consistent results, it is good practice to fit the laminated iron sections against the bore with uniform tightness.

A.1.2 Formulas

The test circuit (Figure A.2) used consists principally of lumped inductance (*L*) (the surge-inducing coil) and capacitance (*C*), with minimum resistance (*R*). The frequency of oscillation of the surge voltage can, therefore be calculated from the formula:

$$f = \frac{1}{2\pi}\sqrt{\left(\frac{1}{LC} - \frac{R^2}{4L^2}\right)} \qquad \text{(A.1)}$$

Which, when the second term under the radical is small compared to the first, reduces to:

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \qquad \text{(A.2)}$$

For example:

a) A 200 hp motor tested with a two-turn surge-inducing coil of 20 μH inductance and a 16 μF capacitor will have an oscillation frequency of 8900 Hz.

b) A 69 500 kVA hydrogenerator tested with a two-turn surge-inducing coil of 130 μH inductance and a 2 μF capacitor will have an oscillation frequency of 9800 Hz.

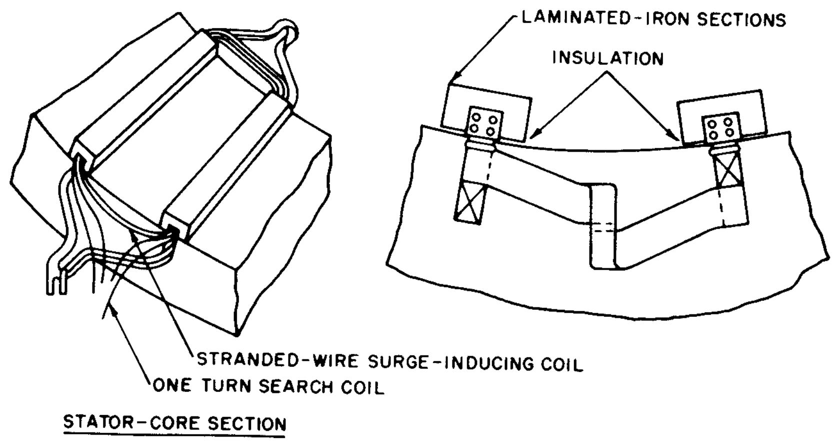

Figure A.1—Surge-inducing coil

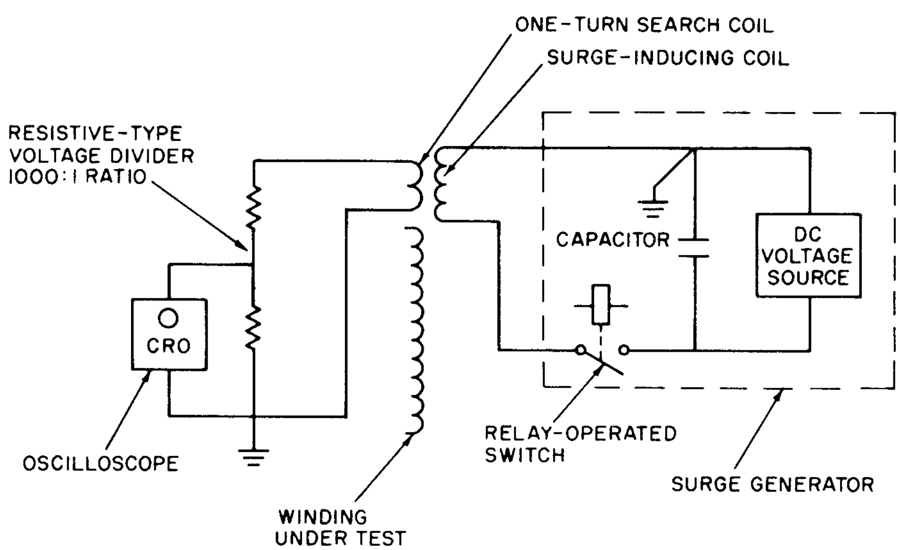

Figure A.2—Suggested arrangement of test equipment

A.2 Suggested test procedure for wound machines

Arrange test equipment as shown in Figure A.2, being certain to connect all grounds including the frame of the machine being tested. Do not ground the windings to be tested; consider them as being energized during all testing since it is not possible to surge test one coil in the core without having some impact on the other coils because of the mutual and cross linking effects.

Expose the leads of one stator coil in the winding by removing the insulation at the connection for calibration of the voltage wave (a line coil may be used and then it will be necessary to expose only the other lead of that coil). Place the laminated-iron sections, including the surge-inducing and search coils, in the bore to line up with the slots of the stator coil selected for calibration. The laminated-iron sections should be insulated from the core of the machine being tested with a thin insulating material, such as 0.010 in (0.25 mm) thick adhesive tape, and should be tightly fitted against the machine core. Connect the voltage-divider leads to the stator coil being used for calibration. Apply a small voltage (1000 V) to the surge-inducing coil and observe the voltage wave induced in a stator coil (this should be approximately 75% of the volts-per-turn applied to the surge-inducing coil). When a suitable waveform is established (refer to Figure A.3 for the expected pattern of the voltage wave), increase the applied voltage to obtain first-peak-amplitude equivalent to the voltage desired for the test. This should be based on a minimum of 350 volts-per-turn peak with maximum voltage of 75% of the coil test voltage specified in Clause 6.

To determine the effect of a short-circuited turn, apply a deliberate short circuit across the exposed leads of the stator coil and apply the same voltage level used to obtain the desired volts-per-turn stress. This will establish the criteria for the test of the remaining coils in the winding and the waveforms of the short-circuited and normal coils should be generally proportional to those shown in Figure A.3. Proceed to test the winding by moving the laminated-iron sections sequentially so they are positioned over each of the coils in the machine. Record the oscilloscope settings, the voltage level applied to the surge-inducing coil, and the amplitude of the first full peak of the voltage wave observed on the oscilloscope, identifying the top-slot number of each coil as it is tested. Since the waveform observed on an oscilloscope screen for any set of conditions can generally be determined more accurately by repetitive sweeps, perform at least three capacitor discharges to establish the form. The accuracy of this test in determining the location of a short-circuited coil can be ascertained by exposing the leads of a stator coil found to be short-circuited, and retesting it with a deliberate short circuit applied across the leads. There should be no significant change from the waveform obtained during the previous test.

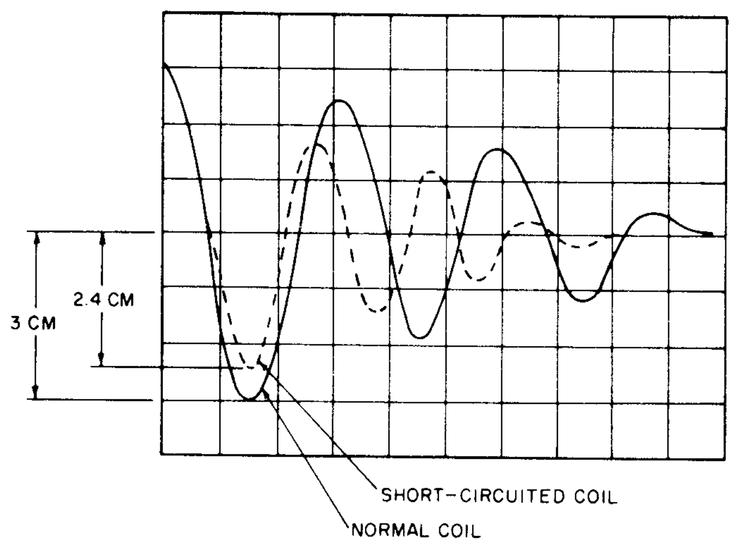

Figure A.3—Voltage waveform for short-circuited and normal coils using induced-voltage test method

A.3 Suggested test procedure for coils during winding (if surge comparison equipment is not available)

The turn-to-turn test can be applied to each coil of a set of new coils, completely assembled in the slots and with slot wedges in place, by applying the surge directly to the stator coil before insulating the connections. In this arrangement, the voltage-divider leads are connected in parallel with the surge-generator leads to the stator coil. The effect of a short-circuited turn under this test condition will be as indicated in Figure A.4. Calibration of the voltage waveform is performed as previously described and the peak voltage is recorded by top-coil-slot number with the voltages applied in steps of 0.2, 0.4, 0.6, 0.8, and 1.0 of the peak test voltage (reduced per the suggestions in paragraph 6.5 for unimpregnated or uncured coils). For a single shot surge generator, five impulses should be applied at each level. (The number 5 is suggested to harmonize 522 with IEC 60034-15 [B21]). With the directly applied test technique, a short-circuited stator coil will provide a flat response (Figure A.4) to the applied voltage and, therefore, the step voltages are of value in approximating the voltage level where a short circuit may develop in the stator coil. Be aware that when applying a turn-to-turn surge test to a single coil in a stator core, all the coils in the core will receive some level of surge voltage to the ground insulation because of the mutual inductance in the slots and the cross linkage on the end windings. The magnitude of this induced surge to the ground insulation will vary as a function of the relative position of the floating coils to the coil under test and has been found to vary from 50% of the applied surge to almost zero. This induced surge in the ground insulation can have detrimental effects as the induced surges may overstress the ground insulation especially at the corners. This stress may initiate a future failure site if the surge voltage level is too high when the coils are tested in the unimpregnated or uncured state Stranges, et al. [B54].

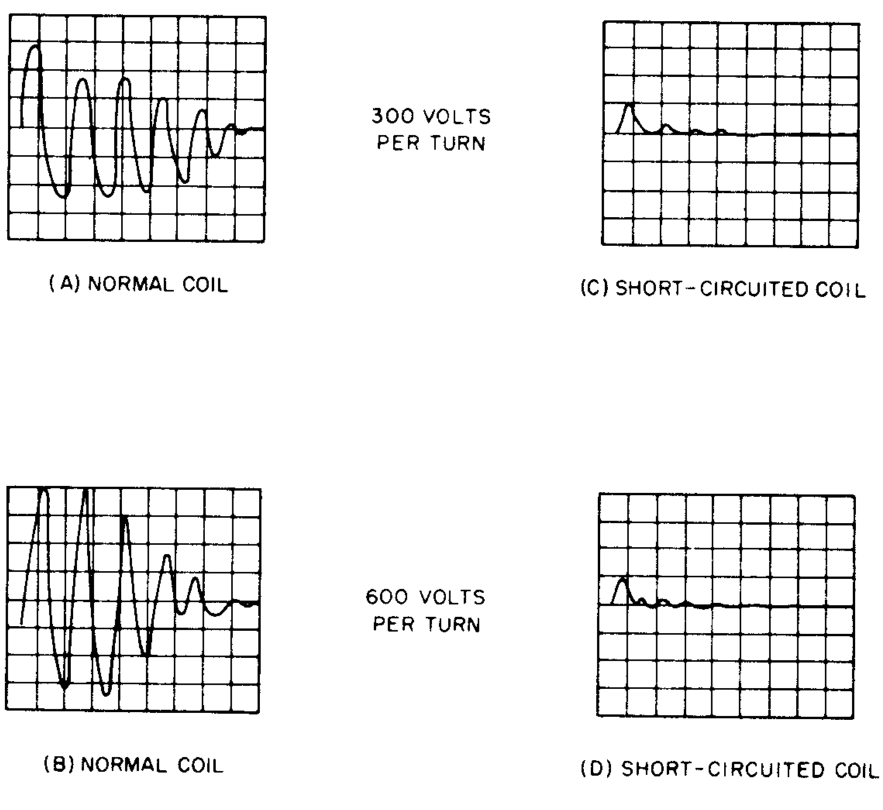

Figure A.4—Waveforms of short-circuited and normal coils tested directly connected, in the iron

A.4 Further details

For further details concerning this method, such as the design of laminated-iron sections, see Oliver, et al. [B42].

A.5 Marx Generator circuit

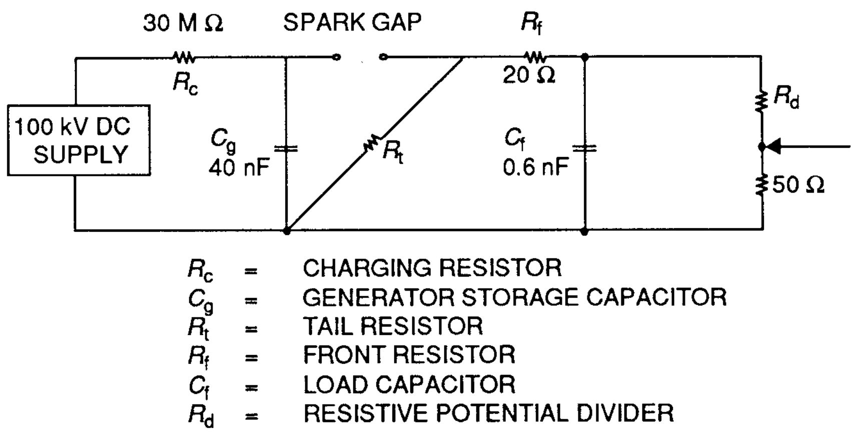

Figure A.5—Schematic circuit for Marx Generator

Circuit parameters are for guidance only. Other appropriate values may be used to produce the required impulse shape.

Annex B

(informative)

Sample test form

Name ____________________________ Machine S/N __________________ Test No. _______________

Date _________________ Manufacturer _______________________________ Time ________________

Insulation Resistance Test

1 min _____________ 10 min ___________ P.I. _______ Passed: Yes ___ No ___

1 min (40 °C) _____________ 10 min (40 °C) ______________ Temp. _____ Rel. Hum. ____________

Test Equipment: ______________________S/N: ________________Cal. Date: _______Cal. Due: ________

Electrical Voltage Impulse Test

Test Equipment: ______________________S/N: ________________Cal. Date: _______Cal. Due: ________

Test Equipment: ______________________S/N: ________________Cal. Date: _______Cal. Due: ________

Total No. of Coils: ____________Coils Passed: ____________Coils Failed: ___________________

Coil	Impedance/ Resistance	Impulse test		Coil	Impedance/ Resistance	Impulse test		Coil	Impedance/ Resistance	Impulse test	
		Passed	Failed			Passed	Failed			Passed	Failed

Extra Coil Destructive Test

1. Test Level (kV): _________Test Level (PU*): ________Failure Location: _________________

2. Test Level (kV): _________Test Level (PU*): ________Failure Location: _________________

3. Test Level (kV): _________Test Level (PU*): ________Failure Location: _________________

Comments: ____

*per unit

Annex C

(informative)

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