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American National Standard

for Rotating Electrical Machinery – Synchronous Machines

ANSI C50.10-1990

ANSI American National Standards Institute
1430 Broadway
New York , New York
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ANSI®
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Revision of
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American National Standard for Rotating Electrical Machinery – Synchronous Machines

Secretariat

National Electrical Manufacturers Association

Approved July 5, 1990

American National Standards Institute, Inc

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Foreword (This foreword is not part of American National Standard C50.10-1990.)

This standard contains general requirements and definitions applicable to all types of 60-hertz synchronous machines, except fractional horsepower motors. Specific topics include classification by structure and methods of cooling, service conditions, output rating, temperature determiniation, insulation systems, efficiency, tests, terminal markings, and nameplate requirements.

ANSI C50.10-1977 was developed over a period of more than two years within a working group that reflected wide industrial experience in both the manufacture and use of synchronous machines. It received unanimous approval of the C50.1 Subcommittee on Synchronous Machines and full endorsement of the Acrcredited Standards Committee C50 on Rotating Electrical Machinery. ANSI C50.10-1977 was approved as an American National Standard on August 4, 1975 and published in 1977.

In 1982, the C50.1 Subcommittee began revision on ANSI C50.10-1977. Subsequently, the reference temperatures (table 1) for use in determining I^2R losses were revised, and test voltages for armature or field windings rated 35 V or less were deleted. Efforts were also made to correlate ANSI C50.10 with related American National Standards, ANSI C50.12, C50.13, and C50.14. Following lengthy review under ANSI consensus procedures, and resolution of all comments received, the revised ANSI C50.10 was approved on July 5, 1990.

This standard is essential to the family of American National Standards covering synchronous machines. It provides the general requirements applicable to all synchronous machines with excitation windings. Specific requirements for each type of synchronous generator and motor are detailed in the standards that are referenced.

This standard contains one informative annex.

Suggestions for improvement of this standard will be welcome. They should be sent to the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee on Rotating Electrical Machinery, C50. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, Accredited Standards Committee C50 had the following members:

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American National Standard for Rotating Electrical Machinery – Synchronous Machines

1 Scope and classification

1.1 Scope

The requirements for synchronous machines with excitation windings are covered by the following American National Standards.

ANSI C50.10, *Rotating electrical machinery – Synchronous machines*;

ANSI C50.12, *Requirements for salient-pole synchronous generators and generator/motors for hydraulic turbine applications*;

ANSI C50.13, *Rotating electrical machinery – Cylindrical-rotor synchronous generators*;

ANSI C50.14, *Requirements for combustion-gas-turbine-driven-cylindrical-rotor synchronous generators*;

ANSI C50.15, *Rotating electrical machinery – Hydrogen-cooled, combustion-gas-turbine-driven, cylindrical-rotor synchronous generators – Requirements*;

ANSI/IEEE 115, *Test procedures for synchronous machines.*

This standard contains general requirements and definitions applicable to all types of 60-Hz synchronous machines, except fractional horsepower motors. Specific requirements for salient-pole synchronous generators will be found in ANSI C50.12, cylindrical-rotor synchronous generators in ANSI C50.13, combustion-gas-turbine-driven, cylindrical-rotor synchronous generators in ANSI C50.14, and hydrogen-cooled, combustion-gas-turbine-driven, cylindrical-rotor synchronous generators in ANSI C50.15.

1.2 Classification

Synchronous machines are classified structurally as salient-pole machines and cylindrical rotor machines. Synchronous machines are also classified with regard to cooling into indirectly cooled machines and directly cooled machines, as follows:

– Indirectly cooled armature or field windings are those in which the heat generated within the principal portion of the windings must flow through the major ground insulation before reaching the cooling medium;

– Directly cooled armature or field windings are those in which coolant flows in close contact with the conductors so that the heat generated within the principal portion of the windings reaches the cooling medium without flowing through the major ground insulation.

2 Normative references

The following standards contain provisions that, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI C50.12-1982 (R1989), *Requirements for salient-pole synchronous generators and generator/motors for hydraulic turbine applications*

ANSI C50.13-1989, *Rotating electrical machinery – Cylindrical-rotor synchronous generators*

ANSI C50.14-1977 (R1989), *Requirements for combustion-gas-turbine-driven cylindrical-rotor synchronous generators*

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ANSI C50.15-1989, *Rotating electrical machinery – Hydrogen-cooled, combustion-gas-turbine-driven, cylindrical-rotor synchronous generators – Requirements*

ANSI/IEEE 1-1986, *General principles for temperature limits in the rating of electric equipment and for the evaluation of electrical insulation*

ANSI/IEEE 100-1988, *Standard dictionary of electric and electronics terms*

ANSI/IEEE 115-1983, *Test procedures for synchronous machines*

NEMA MG1-1987, *Motors and generators* [1)]

3 Service conditions

Machines conforming to this standard shall be suitable for carrying load in accordance with their ratings under usual service conditions.

3.1 Usual service conditions

Usual service conditions are

– when and where the temperature of the cooling medium of air-cooled machines, excluding synchronous generators driven by combustion gas turbines, included within the scope of ANSI C50.14, does not exceed 40°C and is not less than 10°C;

– when and where the temperature of the cooling hydrogen of hydrogen-cooled machines does not depart, at the rated pressure, from the values listed in ANSI C50.13 or C50.15;

– where the altitude, for air-cooled machines, does not exceed 3300 ft (1000 m);

– where the pressure of hydrogen-cooled machines, when operating at altitudes above 3300 ft (1000 m), is maintained at the same absolute internal pressure as that required for operation at sea level.

3.2 Unusual service conditions

Unusual service conditions should be brought to the attention of those responsible for the design, manufacture, application, and operation of the machines. Among such unusual conditions are

– Exposure to:

  – abrasive or conducting dust;

  – chemical fumes;

  – combustible dust;

  – dusts of explosives;

  – flammable gases;

  – lint;

  – nuclear radiation;

  – oil vapor;

  – salt air;

  – steam.

– operation in pits, entirely enclosed boxes, poorly ventilated rooms, damp or very dry places;

– operation at speeds other than rated. (This excludes normal overspeed tests.);

– exposure to ambient temperatures above 40°C or below 10°C (air-cooled machines, excluding synchronous generators driven by combustion-gas turbines included within the scope of ANSI C50.14);

– exposure to cooling media where the temperature values depart from those listed in ANSI C50.13, C50.14, or C50.15;

– exposure to abnormal shock or vibration;

– where departure from rated voltage, or frequency, or both, exceed limits given in ANSI C50.13, C50.14 or C50.15;

– where the phase voltages, or currents, or both, are unbalanced, and the amount of current unbalance exceeds the limits given in ANSI C50.13 for cylindrical-rotor synchronous generators; ANSI C50.14 for combustion-gas-turbine-driven, cylindrical-rotor synchronous generators; or ANSI C50.15 for hydrogen-cooled, combustion-gas-turbine-driven, cylindrical-rotor synchronous generators;

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– where low noise levels are required;

– exposure to external mechanical loads involving thrust or overhang;

– subject to operation in an inclined position;

– subject to intermittent, periodic, or varying duty;

– operation above 3300 ft (1000 m).

4 Rating

4.1 Output rating

The output rating of a machine shall consist of the kVA (kilovolt-ampere) or horsepower together with any other characteristics, such as speed, voltage, frequency, current, power factor, and hydrogen pressure assigned to it by the manufacturer. The characteristics applying to output rating of a specific type of synchronous machine are given in ANSI C50.12, C50.13, C50.14, and C50.15.

4.2 Continuous output rating

The continuous output rating defines the load that can be carried for an indefinitely long time in accordance with this standard.

4.3 Continuous output rating implied

In the absence of any specification as to the kind of rating, the continuous output rating shall be implied.

4.4 Capability

Capability of a synchronous machine is the highest acceptable continuous loading (kVA) through the full range of power factor at a specified condition.

4.5 Frequency

The standard frequency shall be 60 Hz.

5 Temperature

5.1 Methods of temperature determination[2) 3)]

5.1.1 Thermometer method of temperature determination defined

This method consists of the determination of the temperature by mercury or alcohol thermometers, by resistance thermometers, or by thermocouples, with any of these instruments being applied to the hottest part of the machine accessible to mercury or alcohol thermometers.

5.1.2 Resistance method of temperature determination defined

This method consists of the determination of the temperature by comparison of the resistance of a winding at the temperature to be determined with the resistance at a known temperature.

5.1.3 Embedded detector method of temperature determination defined

This method consists of the determination of the temperature by thermocouples or resistance temperature detectors built into the machine, located outside the major insulation, as specified in 5.2.

5.1.4 Coolant method of temperature determination defined

This method consists of determination of the temperature, by thermocouples, resistance temperature detectors, or other equivalent means, of the coolant at a specific location. This is applicable to those cases in which the coolant path is recognized to be defined and in intimate thermal contact with the part.

5.2 Locations of embedded temperature detectors

5.2.1 Machines having cores 40 in long or longer

For machines having indirectly cooled armature windings and cores that are 40 in long or

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2) It is recognized as good practice for the manufacturer to predict the hottest spot temperature of a component part in lieu of direct measurement of it, by providing a correction to measurements from other methods such as embedded detector or hot coolant. This correction should be based on tests performed on the same or a similar machine.

3) For methods of temperature test, refer to ANSI/IEEE 115.

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longer, the resistance type of detector is recommended. The resistance element shall be copper, approximately 20 in long, 1/4 in wide and shall have a resistance of 10 Ω at 25°C[4] For machines with air or gas core ventilation sections less than 20 in long, copper detectors with a 10-Ω resistance at 25°C[4] and resistance elements approximately 10 in long and 1/4 in wide shall be used. (The term, *core ventilation sections*, refers to an axial length of the core in which the core ventilating air or gas flows in the same direction in the core ventilating passages, either radially inward toward the field or radially outward away from the field.) Although the long resistance detector is given preference as above, the use of thermocouple detectors is recognized as good practice.

At least six detectors shall be built into the machine, suitably distributed around the circumference, located between the coil sides, and in positions along the length of the slots having normally the highest temperature. Each detector shall be assembled with strips of suitable insulating materials, so that the assembled unit shall be as wide as the slots and shall be somewhat longer than the detector. The detector shall be located in the center of the slot (with respect to the slot width) and in intimate contact with the insulation of both the upper and lower coil sides whenever possible; otherwise, it shall be in intimate contact with the insulation of the upper coil side (i.e., the coil side nearest the air gap). Each detector shall be installed and its leads brought out in such a manner that the detector is effectually protected from contact with cooling medium. If the detector strip is not the full length of the core, suitable packing shall be inserted between the coils to the full length of the core, to prevent completely the access of cooling medium to the detector.

5.2.2 Machines having cores shorter than 40 inches

For machines with indirectly cooled armature windings and cores shorter than 40 in, detectors shall be either copper detectors with a 10-Ω resistance at 25°C and resistance elements approximately 10 in long and 1/4 in wide, or at least six thermocouples, located and embedded as described in 5.2.1.

5.3 Location of coolant temperature detectors

For machines with indirectly cooled armature winding, measurement of the temperature of the ingoing coolant (exit coolant from the heat exchanger, if furnished) shall be made by suitable devices whose temperature-sensing elements are located so as to allow determination of the average temperature of the coolant.

For machines with directly cooled armature windings, measurement of the temperature of the coolant shall be made in the coolant exit streams of at least six bars and the temperature-sensing elements shall be located so as to be thermally as near as possible to the hottest spot of the bar conductor.

6 Insulation systems

6.1 Insulation systems defined

An insulation system is an assembly of insulating materials. For definition purposes, the insulation systems of synchronous machine windings (either field or armature) are divided into three components. These components are the coil insulation with its accessories, the connection and winding support insulation, and the associated structural parts.

All of the components described in 6.1.1, 6.1.2, and 6.1.3 that are associated with the armature winding constitute one insulation system and all of the components that are associated with the field winding constitute another insulation system.

6.1.1 Coil insulation with its accessories

The coil insulation comprises all of the insulating materials that envelop the current-carrying conductors and their component turns and strands and forms the insulation between them and the machine structure. This insulation includes the armor tape, the tying cord, slot fillers, slot tube insulation, pole body insulation, and rotor-retaining ring insulation.

[4] Although copper detectors with a 10-Ω resistance at 25°C are usually employed, the use of detectors with other values of ohmic resistance made from other materials is recognized, and these may be employed with agreement between the manufacturer and the user.

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6.1.2 Connection and winding support insulation

The connection and winding support insulation includes all of the insulation materials that envelop the connections, which carry current from coil to coil or from bar to bar, and from field and armature coil terminals to the points of external circuit and attachment; and also the insulation of metallic supports for the winding.

6.1.3 Associated structural parts

The associated structural parts of the insulation system include the field collars, the slot wedges, the filler strips under the support ring insulation, the nonmetallic support for the winding, the space blocks used to separate the coil ends and connections, the lead cleats, and the terminal boards.

6.1.4 Impregnated insulation

Insulation is considered to be impregnated when a suitable substance provides a bond between components of the structure and also a suitable degree of filling and surface coverage sufficient to give adequate performance under the extremes of temperature, surface contamination (moisture, dirt, etc.), and electrical and mechanical stress expected in service. The impregnant shall not flow or deteriorate enough at operating temperature so as to seriously affect performance in service.

6.1.5 Impaired insulation

The word *impaired* is used here in the sense of causing any change that could disqualify the insulating material for continuously performing its intended function whether creepage spacing, mechanical support, or dielectric barrier action. The electrical and mechanical properties of the insulation shall not be impaired by the prolonged application of the hottest spot or limiting observable temperature permitted for the specific insulation class.

6.1.6 Other insulation characteristics

It is important to recognize that other characteristics, in addition to thermal endurance, such as mechanical strength, moisture resistance, and corona endurance are required in varying degrees in different applications for the successful use of insulating materials.

6.2 Classes of insulation systems

The insulation systems usually employed in synchronous machines covered by this standard are defined in 6.2.1 – 6.2.3. These definitions, in general, correspond with the principles set forth in ANSI/IEEE 1, which is also the accepted basis for interpretation.

6.2.1 Definitions of classes

Insulation systems are those which by service experience or accepted comparative tests with service-proven systems can be shown to be capable of continuous operation with the limiting observable temperature rise or hottest spot total temperature as specified in the appropriate American National Standard, ANSI C50.12, C50.13, C50.14, or C50.15. Insulation systems of synchronous machines shall be classified as Class A, Class B, Class F, or Class H.

6.2.2 Experience or accepted test

In accordance with ANSI/IEEE 1: *experience*, as used in this standard, means successful operation for a long time under actual operating conditions of machines designed with temperatures at or near the temperature limits.

Accepted test, as used in this standard, means a test on a system or model system that simulates the electrical, thermal, and mechanical stresses occurring in service.

6.2.3 Test procedures

Where appropriate to the construction, tests should be made in accordance with ANSI/IEEE 275 and ANSI/IEEE 434.

6.3 The use of different classes of insulation systems

6.3.1 Coils, connections, and winding supports

If in any machine the class of the insulation systems used for the connection and winding support insulation is different from that used for the coil insulation, the two distinct classes of insulation that are employed shall be separately listed by the manufacturer. In any such machine having different classes for the coil and for the connection insulation systems, the different temperature limits shall apply in accordance with the limits established for the respective classes.

6.3.2 Associated structural parts

If in any machine the class of the insulation systems used for the associated structural parts is lower than that used for the coil insulation, the insulating materials used for the associ-

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Table 1 — Reference temperatures for use in determining I^2R losses

Class of insulation system	Reference temperature, °C	
	Machines other than large salient-pole synchronous generators and generator motors for hydraulic turbine applications	Large salient-pole synchronous generators and generator motors for hydraulic turbine applications
A	75	—
B	95	90
F	115	100
H	130	—

NOTE – Large salient-pole synchronous generators and generator motors for hydraulic turbine applications are those having a kVA rating of 5000 kVA and above.

ated structural parts shall be equivalent, at the operating temperatures of those parts, to the material used for the coil insulation at its limiting temperature with respect to fire resistance, shrinkage, material deterioration, and corona endurance under conditions of mechanical stress and ionization exposure to which they are subjected under usual service conditions.

7 Efficiency

7.1 Methods

Methods for determining efficiency and losses shall be as described in ANSI/IEEE 115. The losses of machines having no useful power output, such as synchronous condensers, are stated directly in kW (kilowatts). The efficiencies of contained sets, such as steam-turbine generator sets, are specified as set efficiencies and not as efficiencies of the individual machines.

7.2 Reference conditions

7.2.1 The efficiency shall be determined at the rated output, voltage, speed, frequency, and power factor, and balanced load conditions. For hydrogen-cooled machines, the losses affected by pressure shall be included at the hydrogen pressure associated with the rating.

7.2.2 In determining I^2R losses, the resistance of windings shall be corrected to the reference temperature in table 1. This reference temperature shall be used for determining I^2R losses at all loads.

If the rated temperature rise is specified as that of a lower temperature class of insulation system, the temperature for resistance correction shall conform to the lower temperature class, that is, Class B rise with Class F insulation.

7.2.3 No temperature correction shall be applied to losses other than I^2R. When input – output tests are used for determining efficiency, they shall be made, as nearly as possible, at the final temperature attained at operation at rating, and under the conditions of 7.2.1.

7.3 Schedule of losses

The losses to be included in determining the efficiency of specific type machines are specified in ANSI C50.12, C50.13, C50.14, or C50.15. The following losses are or may be present in synchronous machines:

- armature I^2R loss;
- stray load loss;
- core loss;
- field I^2R loss;
- exciter loss;
- rheostat loss;
- brush contact loss;
- brush friction loss;

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- friction and windage loss;
- ventilating and cooling loss.

7.3.1 Armature I^2R loss

The armature I^2R loss is the sum of the I^2R losses in all of the armature current paths. The I^2R loss in each current path shall be the product of its resistance in ohms as measured with direct current and corrected in accordance with 7.2.2 and the square of its current in amperes.

7.3.2 Stray load loss

The stray load loss is determined by subtracting the armature I^2R loss at a specific value of armature current from the short-circuit loss at the same value of armature current. The short-circuit loss shall be taken as the difference in power required to drive the machine at normal speed, when separately excited to circulate current in the armature winding with its terminals shorted, and the power required to drive the unexcited machine at the same speed. The armature I^2R loss shall be calculated for the temperature of the winding during the short-circuit test.

7.3.3 Core loss

The core loss shall be taken as the difference in power required to drive the machine at normal speed when separately excited to produce a voltage at the terminals corresponding to the calculated internal voltage, and the power required to drive the unexcited machine at the same speed. The internal voltage shall be determined by correcting the rated terminal voltage for the resistance drop only.

7.3.4 Field I^2R loss

The field I^2R loss shall be the product of the measured resistance in ohms of the field winding corrected in accordance with 7.2.2 and the square of field current in amperes. The value of field current used shall be such that the conditions of 7.2.1 are fulfilled for the load at which the loss is computed. The field current may be calculated from test data as described in ANSI/IEEE 115.

7.3.5 Exciter losses

These losses are the total of electrical and mechanical losses in the equipment supplying excitation.

7.3.6 Rheostat loss

These losses are the I^2R loss in rheostat controlling field current.

7.3.7 Brush contact loss

These losses are the electrical loss in field collector ring brushes and contacts.

7.3.8 Brush friction loss

These losses are the mechanical loss due to friction of the brushes normally included as part of 7.3.9.

7.3.9 Friction and windage loss

The friction and windage loss, including brush friction, is the power required to drive the unexcited machine at rated speed with the brushes in contact, deducting that portion of the loss which results from:

- forcing the gas through any part of the ventilating system that is external to the machine and cooler (if used);
- the driving of direct-connected flywheels or other direct-connected apparatus. However, when requested by the purchaser, these additional losses will be furnished as a separate item.

7.3.10 Ventilating and cooling loss

This is any power required to circulate the cooling medium through the machine and cooler (if used) by fans or pumps that are driven by external means (such as a separate motor), so that their power requirements are not included in the friction and windage loss. It does not include power required to force ventilating gas through any circuit external to the machine and cooler.[5)]

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5) The power required to produce a given air flow through a ventilating system or any portion thereof can be found approximately by the following formula:

Power in kW = 0.000117 × pressure drop in inches of water × air flow in cubic feet per minute ÷ efficiency of blower

In the absence of specific information as to the efficiency of the blower, it should be taken as 50 percent.

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8 Wave shape

8.1 Maximum allowable deviation factor

The deviation factor[6] of the open-circuit terminal voltage wave of synchronous machines shall not exceed 0.1.

8.2 Telephone influence factor

The limits for telephone influence factors and method of measurement are shown in ANSI C50.12, C50.13, C50.14, and C50.15.

9 Tests

9.1 Test location

Unless otherwise agreed upon, all tests shall be made at the plant of the manufacturer, except as specified in ANSI C50.12, C50.13, C50.14, and C50.15.

9.2 Performance tests

Any tests made to determine the performance characteristics of synchronous machines shall be made in accordance with ANSI/IEEE 115.

When agreed upon by the manufacturer and the user, sound measurements may be made in accordance with ANSI/IEEE 85.

9.3 Dielectric tests

9.3.1 Standard test voltages

9.3.1.1 Armature windings

Armature windings shall be tested with an alternating voltage (ac) whose effective value is 1000 V plus twice the rated voltage of the machine. Alternatively, for windings rated 6000 V and above, and when agreed upon by the manufacturer and the user, the test voltage may be a direct voltage (dc) of 1.7 times the ac rms test voltage. (For further information regarding insulation testing of large ac rotating machinery with high direct voltage, see ANSI/IEEE 95.)

9.3.1.2 Field windings

Field windings shall be tested with an alternating voltage (ac) whose effective value is determined by type and application, as described in 9.3.1.2.1 and 9.3.1.2.2.

9.3.1.2.1 Generator field windings

The test voltage for field windings rated up to and including 500 V shall be an alternating voltage (ac) whose effective value is 10 times the rated excitation voltage but in no case less than 1500 V. The test voltage for field windings rated greater than 500 V shall be an alternating voltage (ac) whose effective value is 4000 V plus twice the rated excitation voltage.

9.3.1.2.2 Machines other than generators

Field windings of synchronous machines, including motors that are to be started with alternating current, shall be tested as follows:

– A machine to be started with its field short-circuited or with its field closed through an exciter armature shall be tested at 10 times the rated excitation voltage, but in no case at less than 2500 V nor more than 5000 V;

– A machine to be started with a resistor in series with its field winding shall be tested at a voltage equal to twice the rms value of the *IR* drop across the resistor, but in no case with less than 2500 V. The *IR* drop shall be taken as the product of the resistance and the current that would circulate in the field winding at standstill, if it short-circuited on itself at the specified starting voltage;

– A machine to be started with its field open-circuited and sectionalized shall be tested at 1-1/2 times the maximum rms voltage that can occur between the terminals of any section under the specified starting conditions, but in no case with less than 2500 V, or 10 times the rated excitation voltage per section, whichever is larger;

– A machine to be started with its field open-circuited and connected in series shall be tested at 1-1/2 times the maximum rms voltage that can occur between the field terminals under the specified starting conditions, but in no case with less than 2500 V, or 10 times the rated excitation voltage, whichever is the larger.

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[6] See the definition of *deviation factor* in ANSI/IEEE 100.

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9.3.2 Exceptions to standard test voltages

Both field and armature windings of single-phase and polyphase synchronous generators of less than 250-W output, having rated voltages not exceeding 250 V, shall be tested at 1000 V ac.

9.3.3 Duration of application of the test voltage

The test voltage shall be applied continuously for a period of 1 minute. Repeated applications of the test voltage are not recommended. Machines for which the test voltage is 2500 V or less may be tested for 1 second with a test voltage 20 percent higher than the 1-minute test voltage, as an alternative to the 1-minute tests.

9.3.4 Test voltage requirements

Frequency, wave shape, and crest value of test alternating voltage shall be as follows:

- The frequency of the test alternating voltage shall be 25 to 60 Hz;
- The wave shape of the test alternating voltage shall be of acceptable commercial standards, that is, it shall come within the deviation specified as allowable in clause 8;
- The crest value of the test alternating voltage shall be equal to 1.414 times the test voltage specified.

NOTE – For a description of the methods of measuring the voltage for dielectric tests, see IEEE 4.[7)]

9.3.5 Measurement of alternating current test voltage

The transformer – voltmeter method shall be used.

9.3.6 Points of application of test voltage

The test voltage shall be successively applied between each electric circuit and the frame, with the windings not under test and the core and other metal parts connected to the frame. Interconnected polyphase windings may be considered as one circuit.

9.3.7 Location of tests

When the windings are completely assembled at the plant of the manufacturer, and unless otherwise agreed upon, dielectric tests shall be made at the plant of the manufacturer after the completion of the manufacturer's other shop tests. They shall be made either with the machine completely assembled, or on the stator with windings and connections completely assembled, and on the rotor completely assembled, unless otherwise agreed upon. When the windings are completely or partly assembled at destination, the tests in accordance with 9.3, shall be made as soon as possible after completing the assembly of the winding. Depending on the agreements covering such cases, the tests may be conducted by either the manufacturer, the purchaser, or a subcontractor.

9.3.8 Condition of machine to be tested

The machine shall be in good condition, and the dielectric tests, unless otherwise agreed upon, shall be applied before the machine is put into commercial service, and shall not be applied when the insulation resistance is low because of dirt or moisture. Dielectric tests to determine whether or not specifications are fulfilled are permissible on new machines only. Where both short-circuit and dielectric tests are made on a machine, the dielectric test shall follow the short-circuit test.

9.3.9 Temperature at which dielectric tests are to be made

Unless otherwise agreed upon, dielectric tests may be made at room temperature, or at any higher temperature attained in the process of commercial testing up to rated-load operating temperature of the machine.

9.3.10 Assembled group of machines and apparatus

When the test is made on an assembled group of several pieces of new apparatus, each one of which has previously passed its dielectric test, the test on such assembled group shall not exceed 85 percent of the lowest test voltage appropriate for any part of the group.

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7) At the time of publication, this standard was under revision by the Institute of Electrical and Electronics Engineers. Contact the secretariat for more recent information.

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9.3.11 Additional tests after installation

When a test is made after installation on a new machine that has previously passed its dielectric test at the factory, and whose windings have not since been disturbed, the test voltage, unless otherwise agreed upon, shall be:

– 85 percent of the value specified in 9.3.1.1, 9.3.1.2.1, 9.3.1.2.2, and 9.3.2 for tests in the manufacturing plant, in the case of hydraulic turbine generators and reversible generator/motor units, synchronous condensers, and steam- or combustion-gas-turbine-driven generators that are rated 10 000 kVA and above and more than 5000 V;

– 75 percent of the value specified in 9.3.1.1, 9.3.1.2.1, 9.3.1.2.2, and 9.3.2 for tests in the manufacturing plant, in the case of all other machines.

9.3.12 Armature winding turn insulation test

When agreed upon by the manufacturer and user, the armature winding turn-to-turn insulation of multiturn coils may be tested for machines rated 50 000 kVA and larger. A method of test is described in IEEE 522. The value of test voltage must be agreed upon, since it is not presently defined by standards.

10 Heat exchangers

Water-cooled heat exchangers used for cooling the ventilating air, gas, or liquid shall be designed for the specified inlet water temperature and working pressure. They shall be designed so as not to become airbound, and to withstand a test pressure of 150 percent of the rated working pressure. Heat exchangers are usually designed for inlet water temperatures of 85°F, 90°F, or 95°F, and working pressures of 50 psig (pounds per square inch gauge) or 125 psig.

11 Terminal markings

11.1 Purpose

Markings shall be placed on or adjacent to the terminals of synchronous machines to identify the phases. The purpose of the markings is to aid in making up connections to other parts of the electric power system and to avoid improper connections that may result in unsatisfactory operation or damage. They are not intended to be used for internal machine connections.

11.2 Terminal letters and subscript numerals

The terminal markings shall consist of a capital letter followed by a subscript numeral. The letter identifies the function of the winding, *T* for armature and *F* for field. The subscript numerals 1, 2, or 3 indicate, for a three-phase machine, the order in which the voltages at the terminals reach their positive maximum value (phase sequence) with clockwise shaft rotation when facing the connection and of the winding, unless otherwise specified. The subscript numeral 0 indicates a neutral connection. For a three-phase synchronous machine with one armature winding per phase with each end of each winding brought out externally, the subscript numerals 4, 5, or 6 denote, in sequence, the opposite ends of the windings (relative to 1, 2, or 3).

For synchronous machines with additional terminals (such as machines with two or more windings per phase, or dual voltage windings), machines to be delta-connected, and machines with a different number of phases, terminal markings shall be as specified in NEMA MG1, Part 2, Terminal markings.

11.3 Precautions

Because of possible serious damage to equipment, it is desirable to test for phase rotation, phase relation, polarity, and equality of voltage before connecting synchronous machines to power supply systems.

12 Nameplate

A nameplate having the minimum information given in ANSI C50.12, C50.13, C50.14, or C50.15 shall be provided.

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Annex A
(informative)

Bibliography

ANSI/IEEE 85-1973 (R1986), *Test procedure for airborne sound measurements on rotating electric machinery*

ANSI/IEEE 95-1977 (R1984), *Recommended practice for insulation testing of large ac rotating machinery with high direct voltage*

ANSI/IEEE 275-1981, *Recommended practice for thermal evaluation of insulation systems for ac electric machinery employing form-wound pre-insulated stator coils, machines rated 6900 V and below*

ANSI/IEEE 434-1973 (R1984), *Guide for functional evaluation of insulation systems for large high-voltage machines*

IEEE 4, *Techniques of high-voltage testing* [7)]

IEEE 522-1977 (R1987), *Guide for testing turn-to-turn insulation on form-wound stator coils for ac rotating electric machines* [8)]

8) Available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

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