IEEE Std 421.3-1997
(Revision of IEEE Std 421B-1979)

IEEE Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines

Sponsor

Energy Development and Power Generation Committee
of the
IEEE Power Engineering Society

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Abstract: High-potential test voltages for excitation systems used with synchronous machines are established. Test voltages are established based on whether equipment is connected to the exciter power circuit or is electrically isolated from the exciter power circuit.
Keywords: dielectric testing, excitation systems, test voltages

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Introduction

(This introduction is not part of IEEE Std 421.3-1997, IEEE Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines.)

This standard defines high-potential test requirements for excitation systems for synchronous machines. IEEE Std 421B-1979 established test voltages as a function of exciter output circuit and for all other circuits electrically isolated from the exciter output circuit. This standard was written to agree with existing standards as much as possible but expands the test voltages to account for stresses associated with high ceiling exciters.

At the time that this standard was completed, the Hi-Pot Testing Task Force of the Equipment Working Group of the Excitation Systems Subcommittee of the Energy Development and Power Generation Committee had the following membership:

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IEEE Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines

1. Overview

1.1 Scope

This standard applies to high-potential testing of complete excitation systems and their components for synchronous machines. The components of the excitation system are described in IEEE Std 421.1-1986. Also included are auxiliary devices that are exposed to excitation system stresses. On static exciters, auxiliary devices connected to both the input and output side of the rectifier bridge are exposed to similar excitation system stresses. Examples of such auxiliary devices are temperature indicators, transducers, meters, etc. This standard does not cover the synchronous machine field winding or field circuit breaker and discharge resistor since appropriate standards exist for these devices.

1.2 Purpose

The purpose of this standard is to establish requirements for high-potential dielectric testing of complete excitation systems and their components for synchronous machines.

2. References

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

ANSI C50.10-1990, American National Standard General Requirements for Rotating Electrical Machinery—Synchronous Machines.[1]

ANSI C50.12-1982 (R1989), American National Standard Requirements for Salient Pole Synchronous Generators and Generators/Motors for Hydraulic Turbine Applications.

ANSI C50.13-1989, American National Standard Requirements for Rotating Electrical Machinery—Cylindrical Rotor Synchronous Generators.

[1]ANSI publications are available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036, USA.

ANSI C50.14-1977 (R1989), American National Standard Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators.

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

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

IEEE Std 421.1-1986 (Reaff 1996), IEEE Standard Definitions for Excitation Systems for Synchronous Machines.

IEEE Std C37.13-1990 (Reaff 1995), IEEE Standard Low-Voltage AC Power Circuit Breakers Used in Enclosures.

IEEE Std C37.18-1979 (Reaff 1996), IEEE Standard for Enclosed Field Discharge Circuit Breakers for Rotating Electric Machinery.

IEEE Std C57.12.00-1993, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

IEEE Std C57.12.01-1989, IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those With Solid Cast and/or Resin-Encapsulated Windings.[3]

IEEE Std C57.12.91-1995, IEEE Standard Test Code for Dry-Type Distribution and Power Transformers.

NEMA ICS 1-1993, Industrial Control and Systems: General Requirements.[4]

NEMA ICS 2-1993, Industrial Control and Systems: Controllers, Contactors and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC.

NEMA ICS 4-1993, Industrial Control and Systems: Terminal Blocks.

NEMA ICS 5-1993, Industrial Control and Systems: Control Circuits and Pilot Devices.

NEMA ICS 6-1993, Industrial Control and Systems: Enclosures.

3. High-potential tests

3.1 General

High-potential tests, as used herein, are those tests required to establish the adequacy of the various insulations of the excitation-system components to withstand the voltage stresses imposed during normal or transient conditions. Transient conditions include faults, asynchronous operation, or other unusual operation. This standard does not relieve the manufacturer of the responsibility to design and test for appropriate voltage levels.

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[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[3]IEEE Std C57.12.01-1989 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181.

[4]NEMA publications are available from the National Electrical Manufacturers Association, 1300 N. 17th St., Ste. 1847, Rosslyn, VA 22209, USA.

3.2 Type of tests

High-potential tests fall under two categories: acceptance and service tests.

3.2.1 Acceptance

Acceptance tests shall be made at the factory at standard test voltage on all circuits after final assembly. Rotating equipment shall be tested after all functional testing is complete. Controls and other equipment shall be tested before functional testing. Acceptance tests, if repeated in the field during installation, shall be conducted at 75% of the standard test voltage.

3.2.2 Service

Service tests can be made at any time after installation to verify the integrity of the insulation. The voltage applied during service tests shall not exceed 65% of the standard test voltage.

NOTE—Users are cautioned to follow the manufacturers' recommendations for protecting semiconductor components when performing high-potential tests. If a generator main field circuit breaker or exciter field circuit breaker is used, the exciter may be tested with or without the breaker installed. If tested with the breaker installed, the input side of the breaker (breaker open) will be subjected to the test levels established by this standard. If this test level exceeds the 75% level acceptance test voltage for the breaker, then the test must be performed with the breaker disconnected.

4. Frequency and waveshape of test voltage

The test voltage shall be at the excitation system rated frequency (25–60 Hz), and the shape of the wave shall be a sine wave with a deviation factor not greater than 10% with the equipment under test connected to the test apparatus. As an alternate to the preceding, direct voltage (dc) may be used, in which case the peak test voltage shall be 1.7 times the rms value of the corresponding alternating voltage.

5. High-potential test considerations

High-potential testing is a test of the integrity of the insulation system where little current flows unless there is a failure of the insulation system. Excitation systems may incorporate devices that could carry significant current with no insulation system failures when voltage is applied from circuit to ground. Examples of such devices are line-to-ground capacitors, shaft current suppressors, voltage attenuators, etc. During high-potential testing, the ground connection should be removed and insulated from ground so that the high-potential test applies equal stresses to the device and associated wiring, and the ground current that flows is an indication of dielectric failure.

6. Duration and application of test voltage

The test voltage shall be applied continuously for a period of 60 s. The test voltage shall be successively applied to each electric circuit with all other electric circuits and metal parts grounded. Interconnected polyphase windings may be considered as one circuit.

7. Measurement of test voltage

The test voltage shall be measured by a voltmeter with equipment under test connected to the test equipment. The voltmeter shall derive its voltage directly from the test voltage, through a voltage divider, through an auxiliary ratio transformer, or by means of a voltmeter coil placed in the testing transformer. The voltmeter shall indicate the rms voltage or, if direct voltage is used, the voltmeter shall indicate the peak voltage.

8. Test temperature

High-potential tests shall be conducted at ambient temperature.

9. Standard test voltages

9.1 Exciter power circuit

The exciter power circuit includes all components not electrically isolated from the exciter output. For static exciters, this includes the rectifier and thyristor circuits, transformer windings, line filters, shaft current suppressors, and any auxiliary components connected to either the input or output of the rectifier/thyristor bridge. For rotating exciters, it includes armature windings, commutators, and brushes. For rotating exciter rated outputs 350 V dc or less, the ac rms test voltage shall be 10 times the rated output voltage of the exciter, but with a minimum of 1500 V. For static exciter rated outputs 350 V dc or less, the ac rms test voltage shall be the greater of 10 times the rated output voltage of the exciter, but with a minimum of 1500 V, or twice the rated ac rms input voltage of the exciter plus 1000 V. For rotating exciter rated outputs greater than 350 V dc, the ac rms test voltage shall be 2800 V plus twice the rated output voltage of the exciter. For static exciter rated outputs greater than 350 V dc, the ac rms test voltage shall be the greater of 2800 V plus twice the rated output voltage of the exciter, or twice the rated ac rms input voltage of the exciter plus 1000 V.

The synchronous-machine field winding is not included as it is covered by ANSI C50.10-1990.

The exciter rated output voltage (for determination of the test voltage) shall not be less than the voltage required at the associated generator field terminals when the generator is operated at rated kilovolt-amperes, rated power factor, and rated voltage with the generator field winding at

— 75 °C for field windings designed to operate at rating with a temperature rise of 60 °C or less, or
— 100 °C for field windings designed to operate at rating with a temperature rise greater than 60 °C.

The exciter rated input voltage shall not be less than the voltage at the exciter input terminals when the generator is operated at rated kilovolt-amperes, rated power factor, and rated voltage with the generator field winding at

— 75 °C for field windings designed to operate at rating with a temperature rise of 60 °C or less, or
— 100 °C for field windings designed to operate at rating with a temperature rise greater than 60 °C.

9.2 All other circuits (electrically isolated from the exciter power circuit)

For circuits rated above 60 V or above 60 VA and not greater than 600 V, the ac rms test voltage shall be 1000 V plus twice the rated voltage. For circuits rated above 600 V, the ac rms test voltage shall be 2000 V plus 2.25 times the rated voltage.

Circuits rated at 60 V or less and 60 VA or less need not be given a high-potential test.

Annex A

(informative)

Background and technical considerations

Standards covering high-potential test requirements for synchronous-machine field windings, transformers, field circuit breakers, and similar components have existed for many years. Modern excitation systems use semiconductor signal and power components for control, instrumentation, and protection that are frequently connected to the synchronous-machine field circuit. This indicates a need for special components built and tested to withstand the voltage and power levels involved. The considerations are both reliability and safety.

The standard test voltages are listed by circuits (see 9.1 and 9.2) because high-potential testing applies voltage stress from circuit to circuit, or from circuit to ground, and is a test of the integrity of the insulation (where little current flows unless there is a test failure). High-potential testing is an overvoltage test. Other dielectric tests may include insulation resistance, power factor, etc. The standard test voltage levels are based on what is considered good design practice for this type of equipment. For the exciter power circuit the worst-case stress can be due to induced voltage from the synchronous-machine field winding caused by asynchronous operation, exciter ceiling operation, or ac supply overvoltage conditions. It is the responsibility of the manufacturer to design and verify that the equipment will withstand the voltage levels that result from the worst-case condition.

An excitation system must contain an effective and dependable means of de-energizing the synchronous-machine field. Devices utilized for this function include but are not limited to generator field discharge circuit breakers, exciter field discharge circuit breakers, ac power breakers, ac or dc shorting breakers, dc contactors, separate rectifier or thyristor discharge devices, nonlinear resistors, or some combination of these devices. All equipment associated with the de-energizing function should be tested to ensure insulation integrity.

If a field discharge circuit breaker is used for this function, then the breaker should be tested by the breaker manufacturer per IEEE Std C37.18-1979. Repeat tests shall be performed at 75% of the standard test voltage. Breakers supplied for this function for which the standard manufacturer test voltage is less than that established by this standard should be tested by the manufacturer at voltages established by this standard. Rectifier or thyristor discharge devices should be tested at voltages established by this standard.

This standard was written to agree with existing standards as much as possible. The determination of the appropriate test voltage for the exciter power circuit has been expanded from the previous standard (IEEE Std 421B-1979) to account for stresses associated with high ceiling exciters. Detailed modeling of solid iron rotors has shown that asynchronous operation is not necessarily the most stressful event, especially with high ceiling exciters. As in the previous standard, the test voltage determined from generator field voltage was chosen as an extension of ANSI C50.5-1955,[5] but is less than the test voltage required by the synchronous-machine field winding per ANSI C50.10-1990. The reasoning for choosing a test voltage lower than ANSI C50.10-1990 (for rated voltages above 350 V dc) is that experience indicates that higher test voltages are not necessary and would impose an unnecessary cost penalty on users. In addition, synchronous-machine field windings are subjected to higher mechanical and thermal stresses and, therefore, should be subjected to a more strenuous high-potential test. The extension to the test voltage determination to account for high ceiling exciters was based on NEMA ICS 1-1993, which bases the test voltage on ac input voltage.

All other circuits, rated at 60 V or less and 60 VA or less (low-voltage and low-power circuits), are exempt from high-potential testing because voltage stresses and transients that may occur during testing can damage

[5]ANSI C50.5-1955 has been withdrawn; however, copies can be obtained from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

semiconductors, integrated circuits, and similar components. At the low operating voltage level of these signal circuits, testing of the insulation is not critical.

The high-potential standard rms test voltages are presented in Table A.1.

Table A.1—High-potential standard rms test voltage

Exciter rated output voltage less than or equal to 350 V dc	
Rotating exciter	Greater of: 1500 V ac or 10 times rated output voltage
Static exciter	Greater of: 1500 V ac or 10 times rated output voltage or 2 times rated input voltage + 1000 V ac

Exciter rated output voltage greater than 350 V dc	
Rotating exciter	2 times rated output voltage + 2800 V ac
Static exciter	Greater of: 2 times rated output voltage + 2800 V ac or 2 times rated input voltage + 1000 V ac