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(Revision of
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IEEE Standards

C37.90.2™

IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

IEEE Power Engineering Society

Sponsored by the
Power Systems Relaying Committee

IEEE

3 Park Avenue, New York, NY 10016-5997, USA

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(Revision of
IEEE Std C37.90.2-1995)

IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

Sponsor

Power Systems Relaying Committee
of the
IEEE Power Engineering Society

Approved 1 February 2005

American National Standard Institute

Approved 24 September 2004

IEEE-SA Standards Board

Abstract: Design tests for relays and relay systems that relate to the immunity of this equipment to Radiated Electromagnetic Interference from Transceivers are specified. Field strength, test frequencies, modulation, sweep rates, equipment setup and connection, test procedures, criteria for acceptance, and documentation for test results are described. This standard has been harmonized with IEC standards where consensus could be reached.
Keywords: field strength, keying test, Radiated Electromagnetic Interference, relay, relay systems, step test, sweep test, transceivers

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Introduction

(This introduction is not part of IEEE Std C37.90.2-2004, IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.)

IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers was developed and published initially as a Trial Use Standard with an field strength requirement of 10 volts/meter over the frequency range of 25 Mhz. to 1000 Mhz. The Trial Use standard expired after 2 years of publication. Following reviews of inputs received from use of the Trial Use Standard, the final C37.90.2 document was subsequently released with a field strength requirement of 35 volts/meter. This field strength magnitude was established based upon test information received from the Working Group members.

This publication is a revision of the IEEE Std C37.90.2-1995. This revision of IEEE Std C37.90.2 contains changes so it will harmonize more closely with currently published IEC standards whenever possible. The test requirement changes are as described below.

a) The minimum test frequency of the sweep range has been changed from 25 Mhz to 80 Mhz, which is the same as IEC 60255-22-3 [B1].

b) The maximum sweep rate was changed from 0.005 octave/sec. to 1.5×10^{-3} decades per second, which is the same as IEC 60255-22-3 [B1].

c) Added a Spot Frequency test, as specified in IEC 60255-22-3 [B1].

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IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

1. Overview

1.1 Scope

This standard defines a required withstand level and establishes a test method to evaluate the susceptibility of protective relays to single-frequency electromagnetic fields in the radio frequency domain, such as those generated by portable or mobile radio transceivers and wireless communication devices. This publication includes test requirements, signal levels, and setups.

1.2 Purpose

The purpose of this standard is to establish a common reference and test procedure for evaluating the performance of equipment used for power system protection when subject to Radiated Electromagnetic Interference from Transceivers.

2. Definitions

Definitions of relay terms are not included in this standard. Refer to IEEE Std C37.100™-1992, Standard Definitions for Power Switchgear [B6][1] for definitions of relay terms. These terms are also included in *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B4].

2.1 far field: Region where the power flux density from an antenna approximately obeys an inverse square law of distance.

2.2 frequency band: Continuous range of frequencies extending between two limits.

2.3 polarization: Orientation of the electric field vector of a radiated field.

2.4 shielded enclosure: Screen or solid metal housing designed expressly for the purpose of isolating the internal from the external electromagnetic environment.

[1]The numbers in brackets correspond to those in the bibliography in Annex D.

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3. Test severity level

The rms field strength prior to modulation shall be 20 V/m. The waveform shall be amplitude modulated with a 1 kHz sine wave. Modulation shall be equal to 80%, with the resulting maximum rms field strength not being less than 35 V/m. The test carrier frequency shall be swept or stepped through the range of 80 MHz to 1000 MHz.

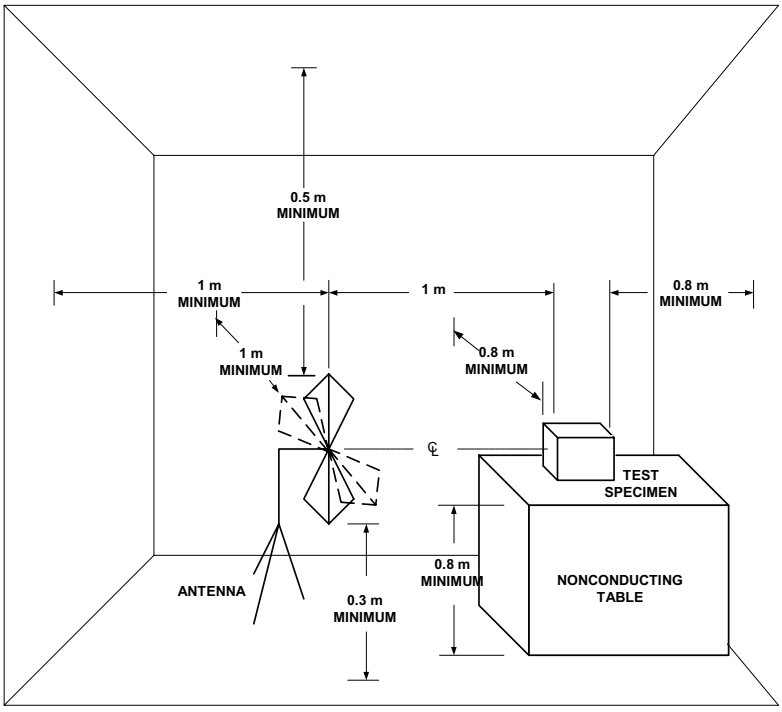

Figure 1—Test set-up

4. Test equipment

The following types of test equipment are recommended. The use of other means of establishing and controlling the field is acceptable providing the required conditions can be verified:

a) Anechoic Chamber: of a size adequate to maintain a uniform field of sufficient dimensions with respect to the equipment under test (EUT). Additional absorbers may be used to damp reflections in chambers, which are not fully lined.

NOTE—Alternative methods of generating electromagnetic fields include TEM cells and stripline circuits, unlined screened rooms, partially lined shielded rooms, and open area test sites. Care should be taken to ensure that the conditions of tests are equivalent to those in the anechoic chamber.[2]

b) Radio Frequency (RF) Signal generator(s) capable of covering the frequency range with capability of an 80% amplitude modulation by a 1 kHz sinewave. If the test carrier is to be swept, the RF signal generator should be capable of achieving a sweep rate of 1.5×10^{-3} decades per second.

c) A power amplifier to amplify signal and provide antenna drive to the necessary field level, if signal generator is inadequate.

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

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d) Field generating antennas capable of covering the frequency range such as biconical, conical logarithmic spiral, or any other linearly polarized antenna system capable of satisfying frequency requirements.

e) Associated equipment to record the power levels necessary for the required field strength and to control the generation of that level for testing.

f) Associated equipment to monitor output of the relay under test to establish operating performance and signals during test.

5. Test set-up

Where possible, it is recommended that all auxiliary equipment should be located outside the boundary of the test enclosure or site.

The equipment under test shall be individually tested, with the EUT placed on a non-conducting table, 0.8 m above the ground plane. All parts of the EUT shall be at least 0.8 m from any metal surfaces.

When the EUT is exclusively mounted in a cubicle, the test may be conducted with the EUT in the cubicle. The cubicle should be placed on a non-conducting support, and for the practical reasons, a distance of approximately 0.1 m is recommended between the cubicle and the ground plane.

Where earth connections are required for safety purposes, they shall be connected to the ground plane. Where they are not otherwise provided or specified by the manufacturer, earth connections shall be, where practical, 0.1 m from the auxiliary power supply connection.

Other earth connections (e.g. for electromagnetic compatibility purposes) either specified or supplied by the manufacturer for connection to the same terminal as the safety earth connection, shall also be connected to the ground plane. The length of these connections shall be as short as possible.

Interconnecting cables shall be as follows:

— The manufacturer’s specified wiring types and connectors shall be used.

— If the manufacturer's specification requires a wiring length of less than or equal to 3 m, then the specified length shall be used. The wiring shall be bundled to 1m lengths.

— If the specified length is greater than 3 m, or is not specified, then the exposed length shall be 1 m. The bundled length of exposed wiring shall be ran in a configuration that essentially simulates normal wiring.

6. Test procedure

It is the intent of this test to duplicate as nearly as possible in-service conditions with the relay in its normal non-transitional state. Where appropriate, the relay shall be energized with rated voltage and with current equal to 75% of the nominal current transformer (CT) rating. The relay settings should be chosen such that the relay is as close as possible to its transitional state, but not closer than the recommended margins for its application. Time delay settings of the EUT shall be set to their minimum practical values as defined by their intended application. Input voltage to the power supply circuits must be within the specified limits. Wiring shall be consistent with the manufacturer's recommended procedures, and the relay shall be tested in its case with the cover(s) and access doors, if any, in the closed position. The effect of radiated electromagnetic interference on the relay in its transitional or operate state is only considered at certain spot frequencies as specified in 6.3.

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The test shall be performed with the antenna facing the front, rear, and each side (excluding top and bottom) of the EUT. If the EUT can be optionally mounted in either the horizontal or vertical configuration, then all 6 sides must be tested. Each facing surface shall be tested twice, once with the antenna positioned vertically and again with the antenna positioned horizontally.

The following tests are to be performed.

a) The EUT shall be subjected to an electromagnetic field from a radiation source operating within the swept or stepped frequency range of 80 MHz to 1000 MHz.

b) The EUT shall be subjected to a keying test over the frequency range of 80 MHz to 1000 MHz.

c) The EUT shall be subjected to an electromagnetic field from a radiation source at given spot frequencies from 80 MHz to 900 MHz.

6.1 Frequency sweep or step test

The frequency range shall be swept or stepped from 80 MHz to 1000 MHz, with the signal 80% amplitude modulated with a 1 kHz sinewave, pausing to adjust the radio frequency signal level or to switch oscillators and antennas as necessary.

If the frequency is swept, the rate of sweep shall not exceed 1.5×10^{-3} decades per second. If the frequency is stepped incrementally through the frequency range, the step size shall not exceed 1% of the fundamental, with linear interpolation between calibrated points. The dwell time at each frequency shall be not less than 0.5 second. If the spot frequency test stated below is to be performed or included in this step test, and in those cases where the EUT operate time is greater than 0.5 second, the dwell time shall be increased until the operation of the EUT is possible.

NOTE—The expression “not exceed 1% of fundamental” means that the frequency of each step is less than, or equal to, the frequency of the previous step after multiplication by a factor of 1.01 (for a 1% step size).

6.2 Keying test

To determine the susceptibility to repeated operation of a transmitter, a keying test shall be performed to evaluate the EUT

If the frequency is swept, the signal source shall be 100% pulse or square-wave modulated, with a rate of sweep not exceeding 1.5×10^{-3} decades per second. The modulating signal shall have on and off durations of not less than 0.5 s each. The pulse or square wave shall have a rise and fall time of no greater than 50 μs.

Alternatively, if frequency steps are used, the test signal may be turned off between steps to produce the keying simulation. The on and off periods should not be less than 0.5 s. This may be done during the frequency step test to eliminate the need for a separate keying test.

6.3 Spot frequency test

Table 1 specifies the spot frequencies that shall be used for testing. In tests 1 through 4, the spot frequency level is amplitude modulated with a 1 kHz sinewave, and may be performed or included in the step test stated above. For test 5, the unmodulated signal is repeatedly switched 2.5 ms on and 2.5 ms off. This is a pulse-modulated signal with 200 Hz to simulate the use of portable digital telephones.

During each spot frequency test, the input energizing quantities shall be adjusted to cause the EUT to change from the normal energized state to the operate state, and held until the EUT operates correctly. The input energizing quantities shall then be re-adjusted to cause the EUT to return to its normal reset condition.

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Table 1—Spot frequencies

Test	Spot Frequency MHz	Tolerance	Amplitude Modulation	Duty Cycle	Keying Frequency Hz
1	80	±0.5%	80%	100%	–
2	160	±0.5%	80%	100%	–
3	450	±0.5%	80%	100%	–
4	900	±MHz	80%	100%	–
5	900	±MHz	Pulse	50%	200 ± 2

6.4 Criteria for acceptance

6.4.1 Application of criteria

The criteria below shall apply to the equipment being directly tested, and any devices linked to the equipment via direct or remote connections. Examples of the connections are current loops and voltage circuits (dc, audio, carrier, or microwave). Serial, parallel, optical (fiber or infrared), and radio frequency connections apply as well.

6.4.2 Conditions to be met

The equipment shall be considered to have passed the electromagnetic interference tests if during, or as a result of the tests, all of the conditions below are met for the equipment and the connected devices:

a) The specified performance of the equipment, including the operating time, does not change, beyond stated tolerances.

b) No hardware damage occurs.

c) No change in calibration beyond normal tolerances results.

d) No loss or corruption of stored memory or data, including active or stored settings, occurs.

e) “System resets” do not occur, and manual resetting is not required.

f) Establish communications not affecting protection functions recover within the manufacturer’s time period, if disrupted.

g) Communications errors, if they occur, do not jeopardize the protective functions.

h) No loss of digital pulse synchronization occurs or where the loss of digital pulse synchronization does occur, it shall not produce an out of tolerance condition.

i) No changes in the states of the electrical, mechanical, or status outputs occur. This includes alarms, status outputs, or targets.

j) No erroneous, permanent change of state of the visual, audio, or message outputs results. Momentary changes of these outputs during the tests are permitted.

k) No error outside normal tolerances of the data communication signals (Supervisory Control and Data Acquisitions (SCADA) analogs) occurs.

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6.4.3 Equipment functioning

During and after the tests, the equipment and the connected devices shall be completely and accurately functional as designed, for the equipment to be considered as having passed the electromagnetic interference tests.

7. Test records

The test report shall be adequate to guide another person to duplicate the test program. The record shall include the following:

a) Product model and revision number for the product under test (serial number if applicable).

b) Details of product settings, inputs, and operating conditions for each individual test.

c) Diagrams, Schematics or photographs showing the device under test, any externally connected equipment, and related cabling.

d) Description of the test equipment and its calibration date.

e) Identification of the field strength verification measurement method used.

f) A tabulation for each test performed. The tabulation of each test shall include the following:

   1) Frequency step size and duration, or rate if swept.

   2) Side to which the electromagnetic waveform was directed and waveform polarization.

   3) Identification of all settings of the unit under test, and input levels and type applied.

   4) A description of how the device under test was monitored to ensure that any failure was detected. That is, which output lines, indicators or other features of the device under test were monitored.

   5) The test conclusion (pass/fail).

g) Date(s) and location of the test.

h) Individual responsible for performing the test.

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Annex A

(informative)

Transceiver field strength

A.1 Transceiver field strength

A.1.1 Single-frequency test parameters

The most common source of single-frequency interference to protective and control relays is provided by portable radio transmitters when they are used in close proximity to the relays.

The portable transceivers normally used in power system communications have output power less than 10 W measured at the base of the antenna. There are other factors, besides power level, that may affect the susceptibility of the relay equipment to these devices, such as the frequency and modulation level. In deciding on a meaningful test level, it is important to know what field strengths are produced by commercial portable transceivers, since these are the dominant interfering sources. Data by European researchers on the field strength produced by six portable VHF and UHF transceivers supports the following empirical equation for field strength, *E*. (See IEC 60801:1984 [B2]). All quantities are rms, unless otherwise noted [see Equation (1)].

$$E = (1.6\sqrt{P})/d \text{ (V/m)} \quad (1)$$

where

d is distance, in m
P is manufacturer's advertised rating of the transceiver, in watts

For a 10 W rated transceiver, this equation gives a value for *E* of 5 V/m at a distance of 1 m and a value of 34 V/m at 15 cm. These data reveal the practical effects of transmitter and antenna efficiencies when compared to the theoretical equation for the field produced by a half-wave dipole radiator as shown in Equation (2):

$$E = (7.02\sqrt{P})/d \text{ (V/m)} \quad (2)$$

For the same 10 W transceiver, the theoretical equation gives about 22 V/m at 1 m and 148 V/m at 15 cm. The efficiency of antennas used with portable transceivers is not likely to exceed 50%, and may be much less. On this basis, it seems that a field strength of 35 V/m is a realistic value that represents the field that can reasonably be expected due to a portable transceiver operated at a distance of 15 cm.

A.1.2 Single-frequency test data

During the development of the original standard, two members of the Working Group contributed test data on the measured field strength of 5 W, 150 MHz and 450 MHz walkie-talkies at various distances from the measuring point. The maximum values reported are listed below for information in Table A.1.

Table A.1—Single frequency test data

Distance (cm)	Field strength (V/m)
7.5	100
10	60
15	35
22	20
100	5

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Annex B

(informative)

Test waveform specification

B.1 Test waveform field strength

The rms field strength prior to modulation shall be 20 V/m. The waveform shall be amplitude modulated with a 1 kHz sine wave. Modulation shall be equal to 80%, with the resulting maximum field strength not being less than 35 V/m.

B.1.1 Background information:

The use of modulated waveform for testing immunity of protective devices to radiated electromagnetic interference has been a long-standing obstacle for harmonization of IEEE Std C37.90.2-2004 with IEC 60255-22-3 [B1].

IEC 60255-22-3 [B1] specifies the use of an rms field strength of 10 V/m field, 80% modulated with a 1 kHz sine waveform. IEEE Std C37.90.2-1995 [B5] specifies a non-modulated waveform with a 35 V/m field strength. Although undesirable, the difference among the standards reflects an important difference in utility operating practices.

The IEC standard was derived assuming a minimum distance between hand held transceiver and a protective device to be no less than 1m. Operating practices in the United States have not attempted to limit the use of hand held transceivers, resulting with a minimum distance for a 5 W device assumed to be 15 cm.

In order to simplify measurement procedures, and as much as possible harmonize with the existing IEC standards, it was decided to adopt the use of 80% modulated waveform, and adjust the maximum field strength to match the original 35 V/m specification. The rms field strength of a 80% modulated waveform meeting this requirement would be equal to 19.444 V/m, which for the purpose of this standard has been rounded to 20 V/m. Maximum field strength is specified at no less that 35 V/m rms.

To summarize, the revised standard retains the original C37.90.2-1995 [B5] field strength level (35 V/m) present in 1995, while adding a 1 kHz 80% amplitude modulation required by IEC 60255-22-3 [B1]. This makes it possible to design a single test session certifying conformance to both standards.

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Annex C

(informative)

Field strength calibration, IEC 61000-4-3 [B3]

C.1 Field strength calibration

IEC 61000-4-3 [B3] provides a direction on how to assure that the EUT is receiving appropriate radiated field levels. It is well known that in a non-anechoic environment it is possible to have dramatic variations in the field even across the EUT.

The following summarizes items of interest from IEC 61000-4-3 [B3]. These items are being presented as recommendations rather than requirements. IEEE Std C37.90.2-2004 requires that steps be taken to assure that the EUT is being exposed to proper levels. There are no restrictions as to the technique used. IEEE Std C37.90.2-2004 states that the levels are documented as well as the test set up.

C.1.1 Summary

C.1.1.1 Field measurement

The Standard is very specific on the techniques to be used to assure that the field strength at any given point on the radiated surface is within 0 to +6 dB of the desired level. The tolerance has been expressed this way to ensure the field strength does not fall below normal.

C.1.1.2 Basic concepts

An Anechoic Chamber is not required. However, care should be taken to ensure that the conditions of the test are equivalent to those in the anechoic chamber.

Any linearly polarized antenna system can be used. Circular is not allowed but under consideration.

The device used for measuring the field strength must be capable of measuring horizontal and vertically polarized fields. The antenna must use dipoles that are 1 m total length or less. Immunity of the equipment is essential.

The field in the test area is calibrated without the EUT. Modulation is not present during the calibration process. A partial verification of the calibration is carried out before each batch of testing. It is intended that the full area calibration is performed at least annually or when changes have been made in the test facility.

A 1.5×1.5 m grid is developed to define the plane that will be used to develop a uniform area. This grid is to be no further than .8 m above the earth reference. This is the location where the EUT test surface will be placed.

When performing the calibration test, the field sensor shall be at least 1 m from the field-generating antenna. A distance of 3 m is preferred.

The uniform area grid is divided into 16 points. The field is considered uniform if the magnitude of at least 12 of the 16 points are within 0 dB to +6 dB of the nominal test value. Different grid sizes (and number of points) are allowed for small versus large EUT's.

The field calibration requirements are fulfilled if a maximum of 3% of the frequencies do not meet the 6 dB criterion but are at least within the tolerance of 0 dB to +10 dB.

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The calibration is done with an unmodulated carrier for both horizontal and vertical polarizations. The calibration is done with the field strength at least 1.8 times as high as the field strength to be applied to the EUT to ensure that the amplifiers can handle the modulation without being saturated. Other methods are allowed.

C.1.1.3 Calibration methods

There are two methods of calibration described. The exact location of the antenna's, cables, shall be recorded. The same configuration will be used for testing.

C.1.1.3.1 Constant field strength calibration method

The power is varied such that the desired field is obtained. Power level is recorded.

The frequency is varied over the test ranges in 1% increments.

Test is performed at each point of the grid.

Power level data for each point is evaluated to assure that at least 11 of the 16 values are within the tolerance of –6 dB to 0 dB of the highest value recorded.

C.1.1.3.2 Constant power calibration method

The first grid point is established. The power is set such that the field strength is 1.8 times the strength that will be applied to the EUT.

The power is not varied.

The frequency is varied over the test range by 1% increments.

The field strength and forward power is recorded.

Field strength data for each point is evaluated to assure that at least 11 of the values are within the tolerance of 0 dB to +6 dB of the lowest value recorded.

C.1.2 Test set-up

Configuration shall be as close as possible to the way it will be installed. All covers and access panels are to be in place. Manufacturers recommend wiring procedures are to be followed.

If the equipment is designed to be mounted in a panel rack or cabinet, it shall be tested in this configuration. A metallic ground plane is not required. Wiring, unless specified, shall be unshielded and parallel. Wiring is left exposed to the electromagnetic field for a distance of 1 m from the EUT.

"The test is normally performed with the generating antenna facing each of the four sides of the EUT. When equipment can be used in different orientations (i.e., vertical or horizontal), the test shall be performed on all sides."

Attempts shall be made to fully exercise the EUT during testing.

The test report fully documents all specific conditions, i.e., wire length, shielding, grounding or operating conditions required to achieve compliance.

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Annex D

(informative)

Bibliography

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[B2] IEC 60801-3:1984, Electromagnetic compatibility for industrial-process measurement and control equipment — Part 3: Radiated Electromagnetic field requirements.

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[B4] IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition.[4, 5]

[B5] IEEE Std C37.90.2-1995, IEEE Standard for Withstand Capability of Relaying Systems to Radiated Electromagnetic Interference from Transceivers.

[B6] IEEE Std C37.100-1992, IEEE Standard Definitions for Power Switchgear.

[3]IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iso.ch/). IEC publications are also available in the United States from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (http://global.ihs.com/). Electronic copies are available in the United States from the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

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