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IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors

IEEE Power Engineering Society

Sponsored by the
Insulated Conductors Committee

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Approved 11 December 2002

IEEE-SA Standards Board

Abstract: A test procedure for impulse testing of insulated conductors (cables) and cables with accessories installed (cable systems) is provided in this standard. This procedure can be used as a design or qualification test for cables or for cable systems. This test procedure is not intended to replace any existing or future standards covering cable or cable accessories, impulse generators, impulse testing, or voltage measurements. It is intended to supplement such standards by providing specific procedures for impulse testing on specific type of cables, accessories, or cable systems.
Keywords: BIL testing, cable, cable systems, impulse testing, insulated conductors

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Introduction

(This introduction is not part of IEEE Std 82-2002, IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors.)

The revision to IEEE Std 82-1994, IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors, contains many changes which are designed to make the standard clearer and easier to follow. The revised standard is now completely metric and contains more details particularly on test reports.

Participants

At the time this standard was approved, Working Group C14 of the Cable Systems Subcommittee C of the Insulated Conductors Committee of the IEEE Power Engineering Society had the following membership:

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When the IEEE-SA Standards Board approved this standard on 11 December 2002, it had the following membership:

Also included is the following nonvoting IEEE-SA Standards Board liaison:

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Savoula Amanatidis
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IEEE Standard Test Procedure for Impulse Voltage Tests on Insulated Conductors

1. Overview

Insulated conductors in service are subjected to voltage surges from lightning, switching, and other sources. These surges vary widely in wave shape, magnitude, and frequency of occurrence. Laboratory tests cannot duplicate the wide variety of surges met in service. Standard test procedures, however, make it possible to compare the impulse strength of different insulations measured by different laboratories, at different times.

1.1 Scope

This test procedure applies to both switching impulse and lightning impulse tests on cables or cable systems incorporating laminated or extruded insulations. The term *laminated cable*, as used in this procedure, includes high-pressure pipe cable, low-pressure gas-filled cable, self-contained liquid-filled cable, solid-paper cable, and other taped cable designs. A cable system is a cable with one or more accessories attached.

This test procedure is not intended to replace any existing or future standards covering cable or cable accessories, impulse generators, impulse testing, or voltage measurements. It is intended to supplement such standards by indicating specific procedures for a specific type of cable system or cable system component.

This test procedure does not apply to cables or cable systems that utilize gas or gas spacers as the sole insulating medium. This test procedure applies to individual cable accessories only when referenced by the specific accessory standard.

1.2 Purpose

This test procedure is intended as a guide for impulse testing of insulated conductors (cables) and cables with accessories installed (cable systems). It can be used as a design or qualification test for cables or cable systems.

2. References

This standard shall be used in conjunction with the following standard. When the following standard is superseded by an approved revision, the revision shall apply.

IEEE Std 4TM-1995, IEEE Standard Techniques for High-Voltage Testing.[1,2]

3. Testing equipment

3.1 Impulse generator

The impulse generator should have sufficient capacity to deliver the required wave shape and magnitude to the test sample within the tolerances set.

3.2 Wave shape

A standard 1.2/50 μs wave shall be used for lightning impulses. When possible, a standard 250/2500 μs wave shall be used for switching impulses. These waves are defined fully in IEEE Std 4-1995.

3.2.1 Wave shape measurement

A calibrated voltage divider and transient recorder or oscilloscope shall be used to observe and record the impulse wave shape. The wave shape and magnitude shall be determined according to IEEE Std 4-1995. The wave shape shall be determined first at reduced voltage with the test sample connected to the test circuit.

3.2.2 Lightning wave shape tolerance

A wave within the following tolerances shall be used for lightning impulses:

a) Wave front time: 1.2 ± 0.36 μs
b) Wave time to half-value: 50± 10 μs
c) Wave peak value: ± 3% of required magnitude

When test circuit constraints or a large capacitance of the test sample make it impractical to meet the lightning impulse wave specifications above, a wave front time of up to 5 μs may be used with mutual agreement of the parties involved.

3.2.3 Switching wave shape tolerance

A wave within the following tolerances shall be used for switching impulses:

a) Wave time to peak: 250 ± 50 μs
b) Wave time to half-value: 2500 ± 1500 μs
c) Wave peak value: ± 3% of required magnitude

When test circuit constraints make it impractical to meet the switching impulse specifications above, a different wave shape may be used with mutual agreement of the parties involved.

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[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc. 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://www.standards.ieee.org/).

4. Specimen

4.1 Length

A minimum cable length of 9 m between grounded ends of the test terminations, when no other accessories are involved or as required by the specific cable standard, shall be provided. When other accessories are included in the test circuit, a minimum cable test length of 4.5 m between the ends of accessories, and between the accessories and grounded end of the test terminations, shall be provided. When testing accessories only, shorter cable lengths are allowed (see specific accessory standard).

4.2 Electrode arrangement

4.2.1 Inner electrode

The inner electrode consists of the cable conductor, including any conductive shielding.

4.2.2 Outer electrode

The outer grounded electrode depends upon the type of cable and voltage rating.

a) *Shielded cables.* Shielded cables, including those having external metallic coverings, shall be tested in their final construction, or as agreed upon between user and manufacturer.
   1) Pressurized cables and cable systems shall be tested at minimum recommended operating pressure, and with the design filling medium, or as agreed between user and manufacturer.
   2) Other shielded cables shall be tested in air, at atmospheric pressure.
   3) Other specifications may require certain extruded cables to be tested in conduit.
b) *Nonshielded cables.* Nonshielded cables (i.e., those having no external metallic or semiconducting coverings over the insulation) shall be tested with the active length (test sample length) in conductive water that serves as the outer electrode. As an alternative, the cable may be tested in air after it has been prepared with semiconducting tape or paint and metal braid or mesh as an outer electrode.

4.3 Sample terminations

If a cable or joint is being evaluated, end preparations may be test terminals, such as water terminals or resistive terminals. If a cable system is being evaluated, the active length shall include at least one of each type of commercial termination designated for use on the cable system.

Preparation of test terminations should be conservative but adequate to ensure a test failure in the active length of the cable or the cable accessory being tested.

5. Test procedures

5.1 Test temperature

The temperature of the cable conductor shall be maintained at a constant value during the test. The temperature of the cable conductor shall be set at the recommended maximum continuous operating temperature (+5 °C, –0 °C) unless otherwise agreed upon. Other specifications may require individual cable system components to be tested at temperatures other than the maximum continuous operating temperature. Temperature control by conductor heating is preferred. External heating is allowed only by agreement between the parties. DC service application cable systems require conductor heating.

The conductor temperature may be determined either by direct measurement in a dummy cable, by direct measurements in the test sample, or by calculation if the thermal resistance of the cable insulation is agreed upon by the parties. A dummy cable is identical to the test sample and subjected to the same conditions, except that no voltage is applied. The dummy cable may be tested prior to the actual test samples.

5.2 Sample conditioning

Both ends of the test sample conductor shall be connected to the impulse generator. A positive polarity impulse of 50%, then 65%, and then 80% of the intended test shall be applied to the conductor, with the outer electrode grounded. This conditioning procedure shall be repeated each time polarity is reversed, using the polarity of the impulse that will follow the conditioning. If agreed to by the parties involved, sample conditioning may be eliminated, which creates a more severe test condition.

5.3 Basic Impulse Insulation Level (BIL) qualification tests

5.3.1 Test level

BIL levels for a voltage class are shown in Table 1 for reference purposes only. Not all cable types are available in all voltage classes. Other withstand levels may be specified for some cable systems and cable accessories. Accessory BIL ratings may differ from these system BIL levels. A withstand level for a cable system that is different than the BIL value shown in Table 1 may be specified. In this case, the specified withstand level should be used as the BIL for the test in 5.3.

Table 1—System BIL Levels

Voltage class (kV phase-to-phase)	BIL (kV)
2.5	60
5.0	75
8.0	95
15.0	110
25.0	150
35.0	200
46.0	250
69.0	350
92.0	450
115.0	550
138.0	650
161.0	750
230.0	1050
345.0	1300
500.0	1550

a) *Positive polarity impulse applications*. The initial positive polarity test impulse voltage shall be applied to the sample at the BIL value (or specified withstand level) after conditioning according to 5.2. This initial impulse shall be followed with nine more positive polarity impulses of the same value in rapid succession.

b) *Negative polarity impulse applications.* Following the positive polarity impulse tests, the impulse generator's polarity shall be changed. The sample shall be conditioned for negative polarity according to 5.2, and the first negative BIL wave shall be applied. The remaining nine negative polarity BIL impulses shall be applied in rapid succession. Figure 1 illustrates the proper procedure in a flowchart format.

c) *Time limitation.* If the required BIL impulses described in Steps 1–5 of Figure 1 are not completed within 2 h, all of the BIL impulses shall be repeated unless an alternate agreement is reached between the parties involved.

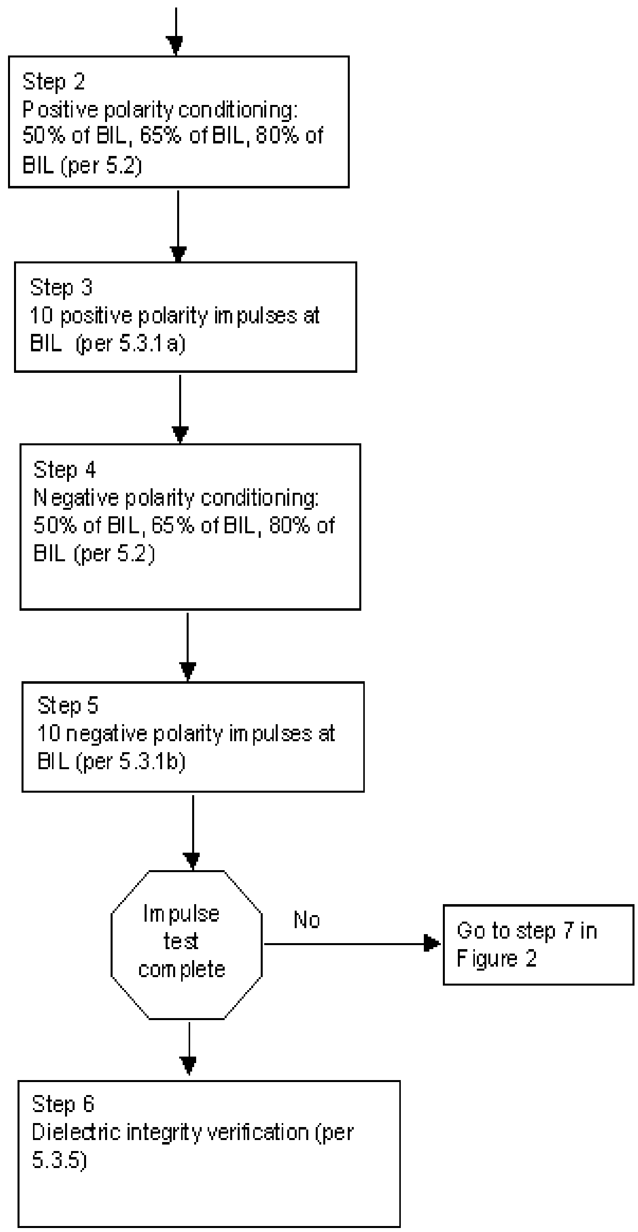

Figure 1—Impulse BIL test

5.3.2 Nonrated cables

Insulated conductors not designed for a specific voltage class shall be tested as described in 5.3.1, with the exception that the BIL value is assumed to be 25% of the anticipated impulse breakdown voltage.

5.3.3 Accessories

Some cable accessory standards require a different impulse BIL test procedure. Refer to the standard for the specific accessory being tested.

5.3.4 Dielectric failure

A dielectric failure at a particular impulse level is indicated by a distinct change in wave shape during the impulse test.

5.3.5 Dielectric integrity verification

A power frequency voltage withstand test shall be used to demonstrate the dielectric integrity of the sample following the BIL impulse tests of 5.3. If impulse testing is to continue above BIL, as in 5.4, a power frequency withstand test shall not be required after the BIL tests. However, if the power frequency test is not performed, the sample shall withstand the first impulse wave above BIL to claim withstand at BIL. The power frequency withstand test shall be performed by subjecting the sample to 2.5 times rated phase-to-ground power frequency voltage for 15 min. If no electrical failure occurs during the test, the sample passes. The sample temperature shall be kept between normal operating temperature and ambient temperature during this test.

5.4 Impulse design test

When testing samples to failure, or to values above BIL, the procedures of this clause shall be followed. This test is conducted strictly for engineering information or at the request of the user. Test terminations often fail before the cable fails. This is due to the difficulty of making test terminations that can withstand high impulse voltage levels. A reasonable effort should be made to build test terminations that will yield a failure in the cable. However, at times this may be very difficult to achieve and the involved parties may want to agree on a minimum acceptable impulse level for the test.

5.4.1 Laminated cables, high-stress extruded cables (rated ≥230 kV), and all cable systems

These samples shall be tested with the applied impulse voltage increasing in steps equal to 5% of the BIL voltage. Following step 5 of Figure 1, 10 negative polarity impulses shall be applied at the previous voltage plus 5% of BIL. Then, polarity of the impulse generator shall be reversed and the sample shall be reconditioned as in 5.2. Ten positive polarity impulses shall be applied at the same level. The impulse voltage shall be increased by 5% of BIL, and 10 positive polarity impulses shall be applied. This changing polarity test shall be repeated as necessary, and the impulse level shall be increased in equal increments to sample failure or until the desired withstand level is reached. The flowchart in Figure 2 illustrates the proper steps for this procedure.

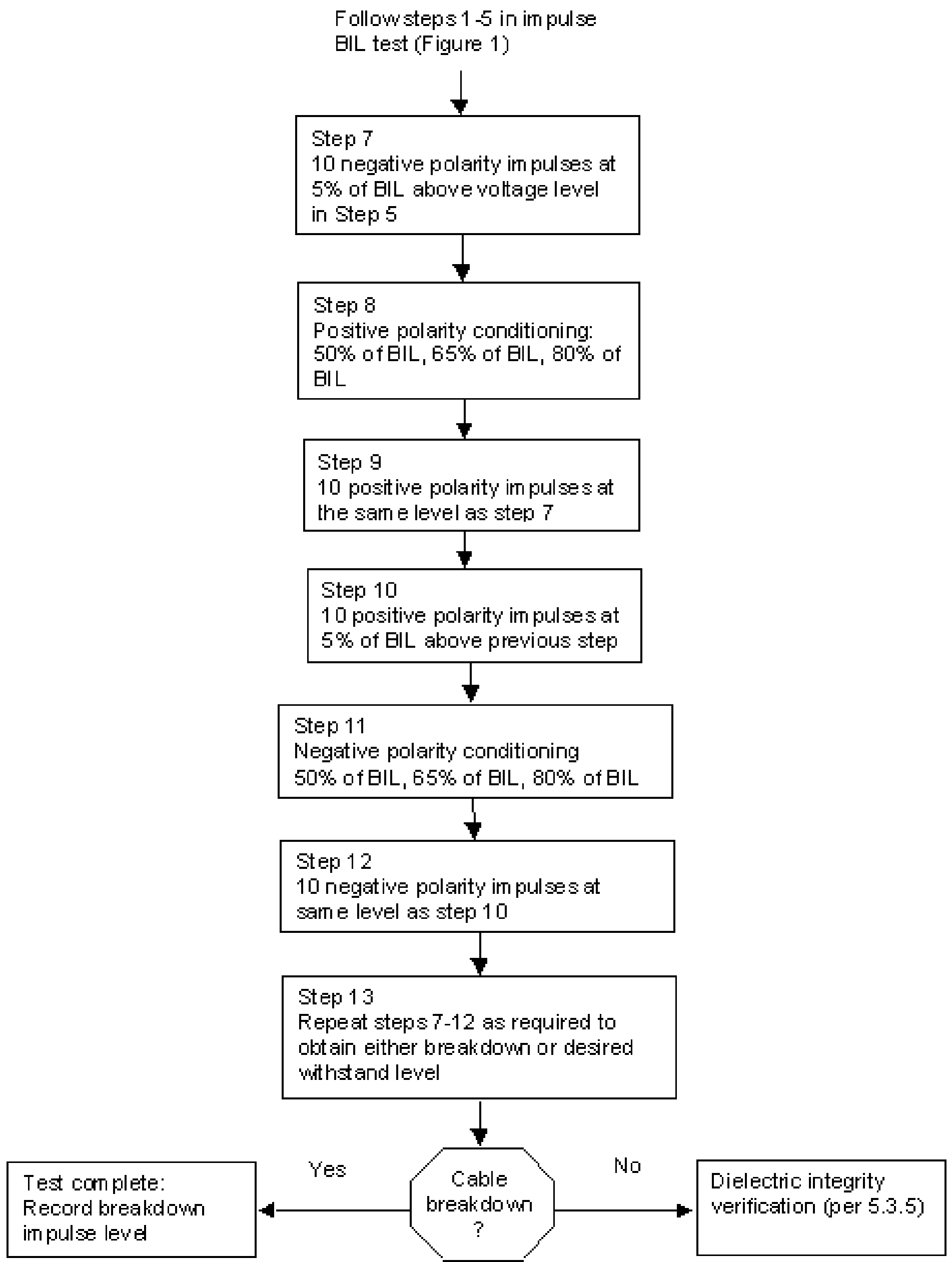

Figure 2—Impulse tests for establishing a withstand level above BIL

5.4.2 Accessories

Normally, there is no requirement to test accessories above their BIL rating. See the appropriate accessory standard for impulse test requirements.

5.4.3 Extruded cables rated less than 230 kV

Extruded cables rated less than 230 kV are the only samples that shall be tested with the applied impulse voltage increasing in steps equal to 25% of the BIL voltage. The final negative impulse of step 5 in Figure 1 shall be followed with three negative polarity impulses at 125% of BIL. The applied impulse voltage shall be increased continuously in 25% of BIL steps, and three impulses shall be applied at each step until either a cable failure occurs or the desired impulse level is reached. This procedure shall not be used to determine a new withstand level (the procedure in 5.4.1 shall be used for that purpose).

5.4.4 Test interruptions

If an interruption occurs during an impulse test, testing may resume in the following manner:

a) If a test terminal failure occurs during a cable or cable system test and it is desired to continue the test, the failed test terminal may be rebuilt. However, a minimum sample length of 4.5 m between grounded ends of the terminations or between terminations and accessories shall be maintained. The test shall be resumed by conditioning with the polarity of the last impulse and restarting at the point at which the failure occurred. The normal procedure shall be followed thereafter.
b) If a test is interrupted for other reasons, the testing shall be resumed by conditioning with the polarity of the last impulse and continuing from the point at which the test was interrupted.

NOTE—Abnormal voltages resulting from a component failure may damage other system components and thus reduce the impulse strength of a cable system.

5.4.5 Establishing withstand above BIL

To establish withstand above BIL, the impulse tests in 5.3 shall be followed. If the test is terminated prior to cable failure, the dielectric integrity of the sample shall be tested by performing a dielectric integrity test, as in 5.3.5. This dielectric integrity test shall be performed only if establishing a withstand level above BIL is required.

5.5 Switching impulse test

Switching impulse tests are only required for some high-voltage cable terminations (see specific accessory standards). However, switching impulse tests are occasionally performed on cable and/or cable systems for design test.

When switching impulse tests are required on a cable or cable system, the test shall be in accordance with the preceding requirements of Clause 5, with the basic switching level (BSL) substituted for BIL. The BIL values in Table 1 are not appropriate as BSL levels. The BSL level should be specified by the user or agreed on by the parties involved.

5.6 Test reports

a) The voltage wave shape and the polarity of each impulse shall be monitored by a transient recorder or an oscilloscope. The number of impulses, magnitude, and polarity shall be reported.
b) A recording of the wave shape at the maximum positive and negative impulse voltage shall be provided. The wave front time, time to half-value and peak value shall be reported. Any deviation from the tolerances given in 3.2.2 and 3.2.3 shall be reported.
c) The ambient temperature, cable conductor test temperature, and test sample pressure (for pressurized samples), before and after the impulse test, shall be reported.
d) All terminal failures and other test interruptions shall be recorded.

Annex A

(informative)

Bibliography

[B1] AEIC CS1-1990, Specifications for Impregnated-Paper-Insulated Metallic Sheathed Cable, Solid Type (11th Edition).[3]

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[B11] IEEE Std 404™-2000, IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500–500 000 V.

[3]AEIC publications are available from the Association of Edison Illuminating Companies, 600 N. 18th Street, P.O. Box 2641, Birmingham, AL 35291-0992, USA (http://www.aeic.org/). AEIC publications are also available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112-5704, USA (http://global.ihs.com/).

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