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ANSI C136.2-2015

Roadway and Area Lighting Equipment — Dielectric Withstand and Electrical Transient Immunity Requirements

National Electrical Manufacturers Association

ANSI C136.2-2015

American National Standard for Roadway and Area Lighting Equipment— Dielectric Withstand and Electrical Transient Immunity Requirements

Secretariat:

National Electrical Manufacturers Association

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Foreword

At the time this standard was approved the ANSI C136 committee was composed of the following members:

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American Electric Lighting
Caltrans
Ceravision
City of Kansas City, Missouri
Cree, Inc.
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Vamas Engineering and Consultants
Xcel Energy

1 GENERAL

1.1 SCOPE

This standard covers luminaires and control devices classified for up to 600-volt operation[1] and intended for use in roadway and area lighting applications.

This standard contains the minimum performance requirements and test procedures for evaluating luminaire and control devices under test (DUTs) for the following:

a) Dielectric withstand
b) Electrical transient immunity

1.2 LIMITATIONS

The test procedures contained in this standard are designed to evaluate the performance of luminaires, control devices, and (as applicable) combinations of luminaires and control devices, for the purpose of facilitating consistent performance reporting of such equipment. The results of a given test procedure, including whether or not the DUT achieved the minimum performance requirements specified in this standard, are only valid for the DUT configuration evaluated.

Users are warned that different combinations of luminaires and control devices may perform differently, and specification or knowledge of the independent performance of both a specific luminaire and a specific control device does not necessarily predict or guarantee any level of performance for the specific combination of luminaire and control device. While DUT manufacturers may attempt to identify and report test results for combinations of luminaires and control devices that represent typical or perhaps worst-case conditions according to some logic, these results should be viewed as informative only, as specific combinations of a luminaire and control device may perform better or worse.

The test procedures contained in this standard are not designed to evaluate the performance of components, such as Surge Protection Devices (SPDs) or other varistor-based modules. Test procedures for components are contained in other standards (e.g., UL 1449) that evaluate parameters related to electrical transient immunity performance and, importantly, require over-voltage testing.

1.3 COMPLIANCE REPORTING

DUT manufacturers that choose to claim compliance with this standard in their literature shall note the DUT configuration and environmental conditions, including the following:

- Three-wire (hot, neutral, protective earth) or two-wire (hot, neutral) electrical configuration[2]
- Permanently installed (not intended to be removed) in-line fuses
- Lamp, light engine, or other modular light source part number, if applicable
- Modular ballast or driver part number, if applicable
- Optional modular device part number(s), as applicable
- Ambient temperature and relative humidity

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1. Previous versions of ANSI C136.2 included separate requirements for luminaires classified for 250-volt and 5kV operation. Luminaires classified for 250 volt operation are considered to be under the purview of this standard. For recommendations and/or requirements for 5kV (i.e., series wired) luminaires, see other ANSI C136 standards, as appropriate, or continue to refer to ANSI C136.2-2004 (R2009).
2. A DUT designed or otherwise intended for two-wire operation typically either does not have a protective earth connection or electrically shorts the protective earth and neutral connections within the DUT.

Many factors can impact the dielectric withstand and electrical transient immunity performance of luminaires and control devices. DUT manufacturers that intend to characterize the performance a family of products with the DUT should take care in determining the worst-case family member.

DUT manufacturers that choose to claim compliance with this standard in their literature shall do so only in a manner consistent with one of the following:

- ANSI C136.2-2014, typical electrical transient immunity requirements
- ANSI C136.2-2014, enhanced electrical transient immunity requirements
- ANSI C136.2-2014, extreme electrical transient immunity requirements

DUTs that meet typical electrical transient immunity requirements will be well protected in most lighting applications. Table 1 below contains general guidance on what outdoor lighting applications may warrant enhanced or extreme protection. More comprehensive guidance on the necessity of higher levels of electrical transient immunity protection can be found in ANSI C62.41.1-2002 in the form of education on the origins of transient voltages and currents, their propagation and dispersion, and potential impact on different types and locations of electrical infrastructure. More comprehensive guidance for a particular outdoor lighting source or luminaire type can be found in the appropriate ANSI C136 standard (e.g. ANSI C136.37 for Solid State Light Sources).

Table 1
Recommended electrical transient immunity levels for common outdoor lighting applications

Lighting application	**Electrical transient immunity level**		
	Typical	Enhanced	Extreme
Building entrance, building exterior	X		
Parking garage, parking lot, tunnel	X	X	
Street, roadway, stadium, airport	X	X	X

2 NORMATIVE REFERENCES

This standard incorporates, by reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed below. For undated references, the latest edition of the respective publication applies (including amendments).

ANSI C62.41.1-2002 *IEEE Guide on the Surge Environment in Low-Voltage (1000V and less) AP Power Circuits*

ANSI C62.41.2-2002 *IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000V and Less) AC Power Circuits*

ANSI C62.45-2002 *IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits*

IEC 61000-4-4 Edition 3.0 (2012-04) *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

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3 INFORMATIVE REFERENCES

This standard is intended to be used in conjunction with the following publications. The latest edition of the publication applies (including amendments).

UL 1449 – 3rd Edition, Surge Protective Devices

UL 1598 – 3rd Edition, Luminaires

4 INSULATION REQUIREMENTS

4.1 GENERAL

Insulation requirements apply to the electrical insulation between ungrounded, current-carrying members and non-current-carrying members that may be grounded by design or accident.

4.2 INSULATION VOLTAGE RATING

The electrical insulation of primary circuit current-carrying members of luminaires or control devices shall be rated for 600 RMS volt 60-Hz AC operation. Luminaires or control devices designed with this class of insulation are intended for use on primary circuits operated under 600 RMS volts.

5 GENERAL TESTING REQUIREMENTS

5.1 TEST SAMPLES

The required tests are design tests, not production tests. They shall be made on at least one sample of each DUT design or design family.

Many factors can impact the dielectric withstand and electrical transient immunity performance of luminaires and control devices. DUT manufacturers that intend to characterize the performance a family of products with the DUT should take care in determining the worst-case family member.

5.1.1 Optional Modular Devices

DUTs designed to allow for the connection of optional modular devices may be tested with or without compatible devices. Examples of optional modular devices include (but are not limited to) internal (to a luminaire) in-line fuses, surge protection devices (SPDs), or control devices, as well as external (to a luminaire) shorting caps and control devices. The connection of any optional modular devices shall be documented in the test report. DUTs shall always include any modular devices required for basic operation. For example, luminaires that require the use of a ballast or driver for basic operation shall not be tested without a ballast or driver.

5.1.2 Control Device Receptacles

Luminaires designed with receptacles that allow for the connection of a control device typically require the insertion of some device in the receptacle in order to achieve normal, powered operation. Examples of compatible control devices for such luminaires include photocontrols and shorting caps,[3] both of which may or may not have integral electrical transient immunity protection. Such luminaires shall be tested, at a minimum, with a shorting cap that does not have integral electrical transient immunity protection. Additional testing with other configurations may be optionally performed. Test results and configurations shall be documented in the test report.

5.2 TEST SETUP

3. A shorting cap is a device that provides an electrical connection between line and load when a locking-type photocontrol is not used.

5.2.1 General

All tests shall be performed on a powered DUT that is completely assembled and wired in the conventional manner, unless otherwise noted. Any switches or other electrical controls that must be configured to achieve nominal operation shall be in the conducting, or "on," position. Non-current-carrying parts or decorative parts not likely to become energized shall not be required to be in place.

Luminaires that use lamps, light engines, or other modular light sources shall be evaluated with a lamp, light engine, or modular light source installed. For luminaires designed to work with a common or widely available class of light sources (e.g., 100W high-pressure sodium (HPS) lamps), a representative sample can be installed, in accordance with manufacturer recommendations. The installed lamp, light engine, or modular light source catalog number shall be documented in the test report.

5.2.2 Temperature Measurements

The ambient temperature in which measurements are being taken shall be maintained at 77 ± 5.4 degrees Fahrenheit (25 ± 3 degrees Celsius), measured at a point not more than one meter from the luminaire and at the same height as the DUT. The temperature sensor shall be shielded from direct optical radiation from the DUT and optical radiation from any other source.

6 DIELECTRIC WITHSTAND TEST

6.1 GENERAL REQUIREMENTS

6.1.1 Test Potential Generator

The dielectric withstand test potential shall be applied to the DUT using a test potential generator (commonly referred to as a hipot tester) with a two-wire (high voltage, return) output configuration. The dielectric withstand test shall be performed by applying a 60-Hz AC test potential or a DC test potential to the DUT. The selection of which test potential type to apply should be dictated by the DUT construction and documented in the test report. Magnetically ballasted or un-ballasted DUTs should, unless noted otherwise, be tested using the 60-Hz AC configuration, while electronically ballasted or driven DUTs should, unless noted otherwise, be tested using the DC configuration.

The hipot tester shall be capable of providing 60-Hz AC test potentials at varying RMS voltage set points and DC test potentials at varying voltage set points. The hipot tester shall have a minimum capacity of 10 times the volt-amperes draw of the DUT (e.g., 1000 VA for a DUT that draws 100 VA) and shall regulate its output voltage to within ±3% of the established set point. The 60-Hz AC output configuration shall produce a sinusoidal voltage waveshape such that the RMS summation of the harmonic components does not exceed 3% of the fundamental during operation of the luminaire.

6.1.2 Electrical Connections

The dielectric withstand test shall be performed by applying a test potential between all DUT current-carrying terminals (electrically tied together) and accessible non-current-carrying metal parts, including the electrically conductive DUT frame or enclosure. DUTs with non-conductive frames or enclosures (e.g., shorting caps or photocontrols with polymeric enclosures) shall be tested with all exterior surfaces that are accessible when installed wrapped in a metal foil; in such cases the test voltage shall be applied between the current-carrying terminals and the metal foil.

6.1.3 Electrical Disconnections

Solid-state components that are not relied upon to reduce the risk of electric shock and that can be damaged by the applied test potential may be disconnected prior to testing. Circuits containing such components may be re-wired for the purpose of the dielectric withstand test in order to reduce the likelihood of component damage while retaining the representative dielectric stress on the circuit.

Examples of components that may conduct current when the test potential is applied and may therefore be re-wired include the following:

- Ballasts or drivers with internal varistor-based components
- SPDs or modules

6.2 TEST PROCEDURE

The test potential shall be set to zero and increased at a constant rate to the peak potential specified in Table 2 within a period of time equal to the rise time specified in Table 2.

The test potential shall be held at the peak potential specified in Table 2 for a period of time equal to the dwell time specified in Table 2, or until the maximum leakage current specified in Table 2 is exceeded.

The test potential shall be decreased at a constant rate back down to zero within a period of time equal to the fall time specified in Table 2.

Table 2
Dielectric withstand test specification

Parameter	60-Hz AC configuration	DC configuration
Peak potential	[(2 x Vin) + 1000] RMS Volts	[(2 x Vin) + 1000] x √2 Volts
Rise time	10 seconds	2 seconds
Dwell time	1 minute	1 second
Fall time	10 seconds	2 seconds
Maximum leakage current	5 mA	1 mA

Note—Vin refers to the maximum allowed DUT input voltage.

6.3 PASS/FAIL CRITERIA

The DUT must function normally and show no evidence of failure following the completion of the dielectric withstand test.

A DUT failure will be deemed to have occurred if either of the following conditions exists following the completion of dielectric withstand testing:

- The DUT noticeably fails to operate as intended. For example, a luminaire should continue to emit light and should not show a noticeable reduction in full light output (e.g., one or more LEDs fail to produce light or become unstable) or change in light spectrum (e.g., as possibly caused by LED phosphor degradation or HID capacitor failure). Failure of a lamp, light engine, or other modular light source shall be considered a DUT failure. Similarly, a photocontrol should continue to be capable of responding to changes in ambient light level and controlling the delivery of power to a luminaire.
- The current measured between the DUT electrical input terminals and the electrically conductive DUT frame or enclosure exceeds the maximum leakage current specified in Table 2 at any time during testing.

7 ELECTRICAL TRANSIENT IMMUNITY TESTS

7.1 GENERAL REQUIREMENTS

7.1.1 Input Voltage

All electrical transient immunity tests shall be performed on powered DUTs. DUTs designed for use at a single input voltage shall be tested at that voltage. DUTs designed for use over a range of input voltages shall be tested at both the minimum and maximum input voltages in the manufacturer-specified input voltage range, as described in the test procedures.

7.1.2 DUT Power Source

During electrical transient immunity testing (i.e., the application of electrical transients by test potential generators) the DUT shall be connected to either an AC power supply or an AC mains capable of providing a 60-Hz AC potential suitable for nominal operation of the DUT. If an AC power supply is used to power the DUT, it shall have a minimum capacity of 10 times the volt-amperes draw of the DUT at full rated output (e.g., 1000 VA for a DUT that draws a maximum of 100 VA at its rated full output) and a minimum available short-circuit current of 200 amps. Note that the short-circuit current requirement is not a steady-state requirement; rather, it is effectively an output impedance requirement for a given VA rating and output voltage. If AC mains is used to power the DUT, the input waveform shall be characterized and documented both before and after electrical transient immunity testing, with the DUT operating at rated full output or nominally, as appropriate. The input waveform characterization shall include, at a minimum, voltage, percent voltage regulation, power factor, and current total harmonic distortion relative to the fundamental frequency (THD-I, fundamental).

During electrical transient immunity testing, the DUT shall be connected to the power source through a series coupler/decoupler network (CDN), using a two-wire (hot or hot/neutral) or three-wire (hot or hot/neutral, protective earth) connection (as appropriate or requested) between both the power supply and CDN input and the CDN output and DUT. The test configuration (two or three-wire connection) shall be documented in the test report, along with how the ground wire in a three-wire DUT is connected when testing in a two-wire (no protective earth present) configuration. Note that the nominal function of the CDN is to couple electrical transient waveforms to the DUT and simultaneously prevent those transients from back-feeding to the power supply. However, CDNs are not capable of fully attenuating back-fed waveforms, and, in practice, residual electrical transients with amplitudes of as much as 10% of the generated peak may reach the power source. AC power supplies that contain fast-responding voltage regulation or power factor correction circuitry may respond to back-fed transients by behaving erratically. If an AC power supply is used, care should be taken to ensure that it is not affected by such transients.

During pre- and post-test DUT characterization, the DUT shall be connected to an AC power supply capable of providing a 60-Hz AC potential suitable for nominal operation of the DUT. The AC power supply shall have a minimum capacity of five times the volt-amperes draw of the DUT at full rated output (e.g., 500 VA for a DUT that draws a maximum of 100 VA at its rated full output). The DUT shall be connected to the AC power supply using a two-wire (hot or neutral) or three-wire (hot or neutral, protective earth) connection, as appropriate or requested. The AC power supply shall produce a 60-Hz AC sinusoidal voltage waveshape such that the RMS summation of the harmonic components does not exceed 3% of the fundamental during operation of the luminaire. The AC power supply shall regulate its 60-Hz AC output RMS voltage to within ±1% of the established set point.

7.1.3 Stabilization and Thermal Equilibrium

Once powered, testing of the DUT shall not commence until the DUT operation has stabilized and the DUT has reached thermal equilibrium in a 77-degree Fahrenheit (25-degree Celsius) ambient. The time required for stabilization and thermal equilibrium depends on a number of factors related to the DUT construction. Stabilization shall be considered to exist if the variation (maximum–minimum) of at least three successive measurements of DUT electrical power taken at 15-minute intervals is less than 0.5% of the average of those measurements. Thermal equilibrium shall be evaluated based on measurements of DUT case temperature. DUT case measurements shall be conducted in accordance with UL 1598.[4]

4. See section 19.2.1 in UL 1598, 3rd Edition.

Thermal equilibrium shall be considered to exist if the variation (maximum–minimum) of at least three successive measurements of the DUT case temperature taken at 15-minute intervals is less than 1.8 degrees Fahrenheit (1.0 degree Celsius).

7.1.4 Pre-Test DUT Characterization

A set of diagnostic measurements shall be performed on all DUTs prior to electrical transient immunity testing, and the results shall be documented in the test report to note the pre-test function of the DUT after it has stabilized and reached thermal equilibrium.

The diagnostic measurements shall include the following, at a minimum:

a) For all DUTs: real power, input RMS current, power factor, and current THD-I, fundamental when operating at rated full output or nominally, as appropriate
b) For luminaires specified as step dimmable: real power, input RMS current, power factor and THD-I, fundamental when operating at the rated minimum dimmed power level
c) For luminaires specified as continuously dimmable: real power, input RMS current, power factor and THD-I, fundamental when operating at the rated minimum dimmed power level and two additional dimmed power levels equally spaced between full power and the rated minimum dimmed power

Note that instruments used to make diagnostic measurements (i.e., power quality meters) may be susceptible to damage from electrical transient immunity test potentials, and should therefore be disconnected during electrical transient immunity testing.

7.1.5 Test Potential Generators

Electrical transient immunity test potentials shall be applied to the DUT using appropriate waveform generators (e.g., ring, combination, electrical fast transient) and according to the test procedures described in sections 7.2–7.5, as appropriate. Waveform generators shall be calibrated according to manufacturer recommendations. The most recent waveform generator calibration shall have occurred no more than 12 months prior to the date of testing.

7.1.6 Test Waveform Injection

Electrical transient immunity test waveforms shall be superimposed on the input AC power line at a point within 36 in. (or 1 m) of entry into the DUT using appropriate high-voltage probes and an appropriate, calibrated series CDN for each coupling mode, as defined by ANSI/IEEE C62.45-2002 for ring and combination waves and IEC 61000-4-4 Ed 3.0 for electrical fast transients. The test area for all tests shall be set up according to ANSI/IEEE C62.45-2002 for ring and combination waves and IEC 61000-4-4 Ed 3.0 for electrical fast transients.

7.1.7 Order of Testing

Tests shall be applied in sequential order, starting with the ring wave, as described in section 7.2, followed by combination wave, as described in section 7.3, and then electrical fast transient, as described in section 7.4. If a failure occurs during the electrical fast transient test, then the electrical fast transient test shall be reapplied to a secondary DUT sample of identical construction.

7.1.8 Shorting Cap Failure During Testing

If the shorting cap containing no integral electrical transient immunity protection inserted into a luminaire fails during any test step (e.g., waveform strike or burst), it may be replaced with a new shorting cap and the evaluation continued, starting with the step during which the shorting cap failed. For example, if it is determined that the shorting cap failed during strike five out of the 40 required combination wave strikes, the evaluation may be continued, starting with strike five. If the luminaire under evaluation (with the new shorting cap) does not exhibit any of the failure criteria specified in the test procedure, then it shall be deemed to have passed. If the luminaire under evaluation (with the new shorting cap) does exhibit any of the failure criteria, the test may be repeated with a new luminaire sample.

7.1.9 Post-Test DUT Characterization

Following the completion of each test described in sections 7.2, 7.3, and 7.4, the same set of diagnostic measurements performed pre-test shall be repeated for all DUTs and the results documented in the test report to note the post-test function of the luminaire(s).

7.1.10 Pass/Fail Criteria

The DUT must function normally and show no evidence of failure following the completion of a sequence of three tests, either a) starting with a ring wave (as described in section 7.2), followed by a combination wave at a selected test level (as described in section 7.3), and concluded by an electrical fast transient (as described in section 7.4), all performed on a single DUT; or b) starting with a ring wave and followed by a combination wave at a selected test level, performed on a primary DUT, and concluding with an electrical fast transient, performed on a secondary DUT. Abnormal behavior during testing (e.g., reduction in luminaire light output) is acceptable.

A DUT failure will be deemed to have occurred if any of the following conditions exists following the completion of electrical transient immunity testing:

- The DUT noticeably fails to operate as intended. For example, a luminaire should continue to emit light and should not show a noticeable reduction in full light output (e.g., one or more LEDs fail to produce light or become unstable) or change in light spectrum (e.g., as possibly caused by LED phosphor degradation or HID capacitor failure). Failure of a lamp, light engine, or other modular light source shall be considered a DUT failure. Similarly, a photocontrol should continue to be capable of responding to changes in ambient light level and controlling the delivery of power to a luminaire.
- A hard power reset is required to return to normal operation.
- Any of the post-test diagnostic measurements other than the THD-I, fundamental measurement vary from the corresponding pre-test diagnostic measurement by ±5%.
- The THD-I, fundamental post-test diagnostic measurement varies from the corresponding pre-test diagnostic measurement by ±10%.
- The DUT or any component in the DUT (including but not limited to an electrical connector, ballast or driver, protection component, or module) has ignited or shows evidence of melting. Evidence of cracking, splitting, rupturing, or smoke damage on any component used to provide electrical immunity protection is acceptable. Evidence of cracking, splitting, rupturing, or smoke damage to any other component shall constitute a DUT failure.

7.2 RING WAVE TEST PROCEDURE

The DUT shall be subjected to repetitive strikes of a ring wave, as defined in ANSI/IEEE C62.41.2-2002. The strikes shall be applied as specified by Table 3.

Prior to testing, the ring wave generator and CDN shall be exercised to verify that both the short-circuit current peak and open-circuit voltage peak minimum requirements specified in Table 3 can simultaneously be met. Note that this may require that the generator charging voltage be raised above the specified level to obtain the specified current peak. External differential high-voltage probes connected to the CDN output shall be used to verify test waveform voltages. Calibrated current probes or transformers designed for measuring high-frequency currents and connected to the CDN output shall be used to verify test waveform currents. CDN inputs shall be open during verification. A minimum of three waveform measurements shall be performed to verify correct operation. The average of these short-circuit current peak and open-circuit voltage peak measurements shall meet or exceed test requirements. Individual measurements shall be within 20% of the average value.

Table 3
0.5 µS–100kHz Ring wave test specification

Parameter	Test level/configuration
Short circuit current peak	0.5 kA
Open circuit voltage peak	6 kV
Coupling modes	L1 to PE, L2 to PE, L1 to L2, L1+L2 to PE
Polarity and phase angle	Positive at 90° and negative at 270°
Consecutive test strikes	7 for each coupling mode and polarity/phase angle combination
Time between strikes	1 minute maximum between consecutive strikes
Total number of strikes for DUTs specified for use at a single input voltage	7 strikes x 4 coupling modes x 2 polarity/phase angles (56 total strikes)
Total number of strikes for DUTs specified for use over a range of input voltages	7 strikes x 4 coupling modes x 1 polarity/phase angle (positive at 90°) at minimum specified input voltage, followed by 7 strikes x 4 coupling modes x 1 polarity/phase angle (negative at 270°) at maximum specified input voltage (56 total strikes)

Note—L1 is typically hot, L2 is typically neutral, and PE means protective earth.

7.3 COMBINATION WAVE TEST PROCEDURE

The DUT shall be subjected to repetitive strikes of a combination wave, as defined in ANSI/IEEE C62.41.2-2002. The test strikes shall be applied as specified by Table 4. One of the three specified test levels (typical, enhanced, or extreme) shall be selected for testing.

Prior to testing, the combination wave generator and CDN shall be exercised to verify that both the short-circuit current peak and open-circuit voltage peak minimum requirements specified in Table 4 can simultaneously be met. Note that this may require that the generator charging voltage be raised above the specified level to obtain the specified current peak. External differential high-voltage probes connected to the CDN output shall be used to measure test waveform voltages. Calibrated current probes/transformers designed for measuring high-frequency currents and connected to the CDN output shall be used to verify test waveform currents. CDN inputs shall be open during verification. A minimum of three waveform measurements shall be performed to verify correct operation. The average of these short-circuit current peak and open circuit voltage peak measurements shall meet or exceed test requirements. Individual measurements shall be within 20% of the average value.

Table 4
1.2⁄50 µS–8⁄20 µS Combination wave test specification

Parameter	Test level/configuration		
$^{1.2}/_{50}$ µS open-circuit voltage peak	Typical: 6 kV	Enhanced: 10kV	Extreme: 20kV
$^{8}/_{20}$ µS short-circuit current peak	Typical: 3 kA	Enhanced: 5kA	Extreme: 10kA
Coupling modes	L1 to PE, L2 to PE, L1 to L2, L1+L2 to PE		
Polarity and phase angle	Positive at 90° and negative at 270°		
Consecutive test strikes	5 for each coupling mode and polarity/phase angle combination		
Time between strikes	1 minute maximum between consecutive strikes		
Total number of strikes for DUTs specified for use at a single input voltage	5 strikes x 4 coupling modes x 2 polarity/phase angles (40 total strikes)		
Total number of strikes for DUTs specified for use over a range of input voltages	5 strikes x 4 coupling modes x 1 polarity/phase angle (positive at 90°) @ minimum specified input voltage, followed by 5 strikes x 4 coupling modes x 1 polarity/phase angle (negative at 270°) @ maximum specified input voltage (40 total strikes)		

Note—L1 is typically hot, L2 is typically neutral, and PE means protective earth.

7.4 ELECTRICAL FAST TRANSIENT TEST PROCEDURE

The DUT shall be subjected to electrical fast transient (EFT) bursts, as defined in IEC 61000-4-4 Ed 3.0. The bursts shall be applied to all DUT power, protective earth (PE), signal, and control ports as specified by Table 5.

Direct coupling is required when applying EFT bursts to power and PE ports; the use of a coupling clamp is not allowed. The use of a calibrated capacitive coupling clamp is allowed for signal and control ports. Calibration of the capacitive coupling clamp shall be done according to the procedure described in IEC 61000-4-4 Ed 3.0.

Prior to testing, the EFT generator shall be exercised to verify that the open-circuit voltage peak minimum requirements specified in Table 5 can be met. Verification of the open-circuit voltage peak shall be done according to the calibration procedure described in IEC 61000-4-4 Ed 3.0. Verification and calibration shall be done using a burst repetition rate of 5 kHz for both 50 Ω and 1000 Ω coaxial terminations. A minimum of three pulse measurements shall be performed to verify output voltage peak requirements. The average of these output voltage peak measurements shall meet or exceed the requirements described in IEC 61000-4-4 Ed 3.0. Individual measurements shall be within 10% (50 Ω termination) or 20% (1000 Ω termination) of the average value, as described in IEC 61000-4-4 Ed 3.0.

Prior to testing, the EFT generator and CDN shall be calibrated according to the procedure described in IEC 61000-4-4 Ed 3.0. The EFT waveform shall be individually calibrated for each coupling line at each output terminal of the CDN with a single 50 Ω termination to reference ground. The test generator output and other test conditions shall be established according to the procedure described in IEC 61000-4-4 Ed 3.0. CDN inputs shall be open during calibration. The output voltage peak and burst characteristics shall meet the associated calibration requirements described in IEC 61000-4-4 Ed 3.0.

Table 5
Electrical fast transient (EFT) test specification

Parameter	**Test level/configuration**	
Open-circuit voltage peak	Power and PE ports: 2 kV	Signal and control ports: 1 kV
Burst repetition rate	Power and PE ports: 5 kHz	Signal and control ports: 5 kHz
Burst duration	15±3 milliseconds	
Burst period	300±60 milliseconds	
Coupling modes	L1 to PE, L2 to PE, L1+L2 to PE, L1+L2+PE to PE	Signal and control port(s) to PE
Polarity	Positive and negative	
Test duration	1 minute minimum for each coupling mode and polarity combination	
Total test duration	Power and PE ports: 1 minute x 4 coupling modes x 2 polarities (8 total minutes)	Signal and control port(s): 1 minute x 2 polarities (2 total minutes per port)

Note—L1 is typically hot, L2 is typically neutral, and PE = protective earth.

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