IEC Technical Committee 109: Standards on insulation co-ordination for low-voltage equipment

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Warning

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Introduction

If it involves electricity the IEC usually has a Technical Committee (TC) producing standards covering it. A TC may cover a product or a particular item used in many products. Standards covering particular items can be classified as horizontal standards, meaning the product TC should consider the horizontal standard content.

Scope of TC109 *Insulation co-ordination for low-voltage equipment*

To prepare International Standards on the principles of insulation coordination applicable to all low-voltage equipment (up to and including 1 000 V a.c. and 1 500V d.c.).

To provide IEC Technical Committees with:

- rules for the determination of voltage ratings for insulation coordination,

- physical data for dimensioning of insulations to given voltage rating and

- guidance for determination of clearances, and creepage distances and requirements for solid insulation with respect to insulation coordination and safety aspects up to 2 000 V a.c and 3 000 V d.c operating voltage.

Horizontal Safety Function:

Insulation coordination for voltages up to and including 1 000 V a.c. and 1 500 V d.c., including dimensioning of clearances, and creepage distances and requirements for solid insulation with respect to insulation coordination. This includes all methods of dielectric testing with respect to insulation coordination.

TC109 Standards

IEC 60664-1:2007, Edition 2.0 (2007-04-26): Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests

IEC Technical Report (TR) 60664-2-1:2011, Edition 2.0 (2011-01-31): Insulation coordination for equipment within low-voltage systems - Part 2-1: Application guide - Explanation of the application of the IEC 60664 series, dimensioning examples and dielectric testing

IEC Technical Report (TR) 60664-2-2:2002, Edition 1.0 (2002-01-22), Insulation coordination for equipment within low-voltage systems - Part 2-2: Interface considerations - Application guide

IEC 60664-3:2016, Edition 3.0: Insulation coordination for equipment within low-voltage systems - Part 3: Use of coating, potting or moulding for protection against pollution

IEC 60664-4:2005, Edition 2.0 (2005-09-15): Insulation coordination for equipment within low-voltage systems - Part 4: Consideration of high-frequency voltage stress

IEC Technical Specification (TS) 62993:2017, Edition 1.0 (2017-07-12): Guidance for determination of clearances, creepage distances and requirements for solid insulation for equipment with a rated voltage above 1000 V AC and 1500 V DC, and up to 2000 V AC and 3000 V DC

IEC Technical Report (TR) 63040:2016, Edition 1.0 (2016-09-26): Guidance on clearances and creepage distances in particular for distances equal to or less than 2 mm - Test results of research on influencing parameters

Insulation

insulation: that part of an electrotechnical product which separates the conducting parts at different electrical potentials
IEC 60664-2-1, ed. 2.0 (2011-01)

Insulation may be made up of three components

clearance: shortest distance in air between two conductive parts
IEC 60664-2-1, ed. 2.0 (2011-01)

creepage distance: shortest distance along the surface of a solid insulating material between two conductive parts
IEC 60664-2-1, ed. 2.0 (2011-01)

solid insulation: solid insulating material interposed between two conductive parts

NOTE TO ENTRY In the case of a printed board with a coating, solid insulation consists of the board itself as well as the coating. In other cases, solid insulation consists of the encapsulating material.
IEC 60664-2-1, ed. 2.0 (2011-01)

The performance of these items may be affected by such things as altitude, temperature, pollution, humidity and the electrical environment.

Insulation and isolation

TC109 does not define isolation. You have to go to TC108 (*Safety of electronic equipment within the field of audio/video, information technology and communication technology*) for a component definition

isolating transformer: transformer with protective separation between the input and output windings
IEC 60065, ed. 8.0 (2014-06)

insulation: that part of an electrotechnical product which separates the conducting parts at different electrical potentials
IEC 60664-2-1, ed. 2.0 (2011-01)

The protective separation of isolation is the insulation

Most American standards don't strongly differentiate between the use of isolation and insulation. Isolation is a function fulfilled by the insulation (barrier). It is the insulation barrier that is voltage withstand tested, not the isolation.

It helps to know about insulation and the electrical environment - 1

TC109 standards state:

"The ability of solid insulation to withstand the voltage stresses has to be verified by a voltage test in any case. The stresses caused by transient overvoltages are assessed by the impulse voltage test, which may be substituted by an a.c. voltage test or a d.c. voltage test. The stresses caused by an a.c. steady-state voltage stress can only be assessed by an a.c. voltage test. *The d.c. voltage test with a test voltage equal to the peak value of the a.c. voltage is not fully equivalent to the a.c. voltage test due to the different withstand characteristics of solid insulation for these types of voltages.* However, in case of a pure d.c. voltage stress, the d.c. voltage test is appropriate."

There are two important points here;

1. test with the type of voltage stress expected in the operating environment and
2. the DC test voltage for solid insulation should be higher than the peak value of the AC test voltage.

It helps to know about insulation and the electrical environment - 2

Recently the Telcordia document GR-1089-CORE was revised to Issue 7. The quoted insulation test voltages do not agree with the IEEE 802.3.

GR-1089-CORE Issue 7 has the following test voltage values:

- AC 1500 V rms
- DC 2120 V d.c.
- Impulse 2.4 kV peak, 1.2/50

IEEE 802.3 has the following test voltage values:

- AC 1500 V rms
- DC 2250 V d.c.
- Impulse 2.4 kV peak, 1.2/50

The difference between the DC voltage values is due a simplistic calculation used in GR-1089-CORE. An AC voltage of 1500 V rms has a peak voltage of 2121 V and this was used to set the DC voltage test value of 2120 V d.c. This calculation does not take into account of the properties of solid insulation, which requires a higher DC voltage than the AC voltage peak.

It helps to know about insulation and the electrical environment - 3

Some IEEE 802.3 documents have insulation withstand test values of:

- AC 1500 V rms
- DC 2250 V d.c.
- Impulse 1.5 kV peak, 10/700

Rather than

- AC 1500 V rms
- DC 2250 V d.c.
- Impulse 2.4 kV peak, 1.2/50

This comes about through what I call “standards pick and mix shopping”. You go to a standard and select various quoted values. The impulse of 1.5 kV peak, 10/700 can be traced back to the outcome of a global survey by members of the ITU-T that was published in the ITU-T Directives. The 1.5 kV peak, 10/700 value was the voltage seen at customer premises from long distance telephone lines – the slow rise and decay times being the dispersion effect of the long transmission line.

Hence, the telecommunications line1.5 kV peak, 10/700 is inappropriate for Ethernet, as Ethernet lines are shorter and the impulse voltage is too low to adequately test the insulation compared to the AC and DC values.

It helps to know about insulation and the electrical environment - 4

There is functional insulation and safety insulation

functional insulation: insulation between conductive parts which is necessary only for the proper functioning of the equipment

Safety insulation (types)

basic insulation: insulation to provide a basic safeguard against electric shock
Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

supplementary insulation: independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

double insulation: insulation comprising both basic insulation and supplementary insulation

reinforced insulation: single insulation system that provides a degree of protection against electric shock equivalent to double insulation

The use of the Ethernet transformer was reported to be to break earth/ground loops. This means we are dealing with functional insulation and there is no need to reference safety standards. The test level should reflect the electrical environment. One 1.2/50 impulse definition the source reference is the TC 42 horizontal standard IEC 60060-1:2010, Edition 3.0 (2010-09-29): High-voltage test techniques - Part 1: General definitions and test requirements.

List of TC 42 *High-voltage and high-current test techniques* publications

IEC 60052:2002, Edition 3.0: Voltage measurement by means of standard air gaps
IEC 60060-1:2010, Edition 3.0: High-voltage test techniques - Part 1: General definitions and test requirements (covers 1.2/50)
IEC 60060-2:2010, Edition 3.0: High-voltage test techniques - Part 2: Measuring systems
IEC 60060-3:2006, Edition 1.0: High-voltage test techniques - Part 3: Definitions and requirements for on-site testing
IEC 60270:2000+AMD1:2015, Edition 3.1: High-voltage test techniques - Partial discharge measurements
IEC 61083-1:2001, Edition 2.0: Instruments and software used for measurement in high-voltage impulse tests - Part 1: Requirements for instruments
IEC 61083-2:2013, Edition 2.0: Instruments and software used for measurement in high-voltage and high-current tests - Part 2: Requirements for software for tests with impulse voltages and currents
IEC 61180:2016, Edition 1.0: High-voltage test techniques for low-voltage equipment - Definitions, test and procedure requirements, test equipment (covers 1.2/50, 8/20 and test procedures)
IEC 62475:2010, Edition 1.0: High-current test techniques - Definitions and requirements for test currents and measuring systems (covers 8/20)
IEC Technical Specification 62478:2016, Edition 1.0: High voltage test techniques - Measurement of partial discharges by electromagnetic and acoustic methods

Conclusion

The most logical list of insulation withstand voltage test values is shown below:

a) 1500 V rms at 50 Hz to 60 Hz for 60 s, insert test approach here.

b) 2250 V dc for 60 s, insert test approach here.

c) A sequence of ten 2400 V impulses of alternating polarity, applied at intervals of not less than 1 s. The shape of the impulses shall be 1.2/50 (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in clauses 8.3.1 and 8.3.2 of IEC 60060-1:2010 [alternative 6.0 of IEC 61180:2016]. insert test approach here.

The insulation resistance after the test shall be at least 2 MΩ, measured at 500 V dc.

Options for the definition of 1.2/50 follow.
Possible test approach material is discussed as well.
Green highlights dubious or not wanted items
Turquoise highlights items that could be removed

Definition of 1.2/50 voltage waveform

- The IEC source definition for the 1.2/50 comes from IEC 60060-1.
- TC109 states that the effective source impedance for insulation testing shall not exceed 500 Ω.
- IEC 60950-2 references the Annex N, (normative), Impulse test generators, circuit reference 2 of table N.1 taken from ITU-T Recommendation K.21 (should be K.44) and stated to simulate transients in power distribution systems. This generator has an effective source impedance of 40 Ω.
- Most test houses will likely use the more readily available 1.2/50-8/20 combination wave generator. The ITU-T Recommendation K.44 defines the combination wave generator as having a 1.2/50 open-circuit voltage waveshape according to TC 42 IEC 60060-1, an 8/20 short-circuit current waveshape according to TC 42 IEC 62475 and the ratio of peak open-circuit voltage to short-circuit current shall be 2 Ω ± 10%.
- Rarely one with find a 1.2/50 voltage generator intended for insulation testing with an unspecified source impedance.
- TC 42 IEC 61180:2016 defines the 1.2/50 waveform in clause 6.2.

Test procedures – IEC 60664-1:2007 subclauses 4.1.3.2 and 4.1.3.5

4.1.3.2 Parts to be tested

The test voltage shall be applied between parts of the equipment which are electrically separate from each other.

Examples of such parts are:

– live parts;

– separate circuits;

– earthed circuits;

– accessible surfaces.

Non-conductive parts of accessible surfaces shall be covered with metal foil.

NOTE If a complete covering of large enclosures with metal foil is not practicable, a partial covering is sufficient if applied to those parts which provide protection against electric shock.

4.1.3.5 Test criteria

There shall be no disruptive discharge (sparkover, flashover or puncture) during the test.

Partial discharges in clearances which do not result in breakdown are disregarded, unless otherwise specified by the Technical Committees.

NOTE It is recommended that an oscilloscope be used to observe the impulse voltage in order to detect disruptive discharge.

Test procedures – IEC 60950-1:2001 subclause 5.2.2

5.2.2 Test procedure

The insulation is subjected either to a voltage of substantially sine-wave form having a frequency of 50 Hz or 60 Hz, or to a DC VOLTAGE equal to the peak voltage of the prescribed a.c. test voltage.

Unless otherwise specified elsewhere in this standard, test voltages are as specified in table 5B for the appropriate grade of INSULATION (FUNCTIONAL, BASIC, SUPPLEMENTARY or REINFORCED) and the WORKING VOLTAGE (U), determined in 2.10.2, across the insulation. DC values of WORKING VOLTAGE shall be used for DC VOLTAGES and peak values for other voltages.

The voltage applied to the insulation under test is gradually raised from zero to the prescribed voltage and held at that value for 60 s.

NOTE 1 For ROUTINE TESTS specified elsewhere in this standard, it is permitted to reduce the duration of the electric strength test to 1 s.

There shall be no insulation breakdown during the test. Insulation breakdown is considered to have occurred when the current which flows as a result of the application of the test voltage rapidly increases in an uncontrolled manner, that is the insulation does not restrict the flow of the current. Corona discharge or a single momentary flashover is not regarded as insulation breakdown.

Insulation coatings are tested with metal foil in contact with the insulating surface. This procedure is limited to places where the insulation is likely to be weak, for example, where there are sharp metal edges under the insulation. If practicable, insulating linings are tested separately. Care is taken that the metal foil is so placed that no flashover occurs at the edges of the insulation. Where adhesive metal foil is used, the adhesive shall be conductive.

To avoid damage to components or insulation which are not involved in the test, disconnection of integrated circuits or the like and the use of equipotential bonding are permitted.

For equipment incorporating both REINFORCED INSULATION and lower grades of insulation, care is taken that the voltage applied to the REINFORCED INSULATION does not overstress BASIC INSULATION or SUPPLEMENTARY INSULATION.

NOTE 2 Where there are capacitors across the insulation under test (for example, radio-frequency filter capacitors), it is recommended that d.c. test voltages are used.

NOTE 3 Components providing a d.c. path in parallel with the insulation to be tested, such as discharge resistors for filter capacitors and voltage limiting devices, should be disconnected.

Where insulation of a transformer winding varies along the length of the winding in accordance with 2.10.10, an electric strength test method is used that stresses the insulation accordingly.

NOTE 4 An example of such a test method is an induced voltage test which is applied at a frequency sufficiently high to avoid saturation of the transformer. The input voltage is raised to a value which would induce an output voltage equal to the required test voltage.

No test is applied to FUNCTIONAL INSULATION, unless 5.3.4 b) has been selected

Test procedures – IEC 61180:2016 subclause 6.3

6.3 Test procedures

6.3.1 Calibration of impulse voltage waveshape

Using an approved measuring system, the waveshape of the impulse voltage applied to the test object shall be verified using impulses not less than 50 % of the test voltage level.

6.3.2 Withstand voltage tests

Five impulses of the specified shape and of each polarity are applied at the withstand voltage level. The requirements of the test are satisfied if no indication of disruptive discharge or partial breakdown is obtained.

The relevant technical committee shall specify the criteria for identification and evaluation of partial breakdown, where applicable.

6.3.3 Assured disruptive discharge voltage tests

Five impulses of the specified shape and of each polarity are applied at the assured disruptive discharge voltage level. The requirements of these tests are satisfied if there is a disruptive discharge at every application.

The relevant technical committee may also specify other procedures for specific test objects.

Test procedures – Example embedded procedure in document

Connect all active all the active signal and PoE terminals (screen/shield terminal excluded) of the tested equipment Ethernet port together. Apply the selected insultation withstand test voltage to the connected Ethernet terminals and other electrically separate conductive parts of the equipment. Other PoE ports, which have an internal connection to the tested port, are classed as not being electrically separate conductive parts. Non-conductive parts of accessible surfaces shall be covered with metal foil. For AC and DC voltage testing the applied voltage shall be gradually raised from zero to the prescribed voltage and held at that value for 60 s. It is recommended that an oscilloscope be used for the impulse voltage test in order to detect disruptive discharge.

The requirements of the test are satisfied if no disruptive discharge (sparkover, flashover or puncture) occurs during the test. Partial discharges in clearances which do not result in breakdown are disregarded

FYI definitions

sparkover: electrical breakdown in a gaseous or liquid medium
IEC 60664-1, ed. 2.0 (2007-04)
(clearance breakdown)

flashover: electrical breakdown along a surface of solid insulation located in a gaseous or liquid medium
IEC 60664-2-1, ed. 2.0 (2011-01)
(creepage breakdown)

puncture: electrical breakdown through solid insulation
IEC 60664-1, ed. 2.0 (2007-04)
(solid insulation breakdown)

partial discharge: discharge that does not completely bridge the insulation between electrodes
Note 1 to entry: The term corona is preferably reserved for partial discharge in air around a conductor, but not within the bushing assembly.
IEC/IEEE 65700-19-03, ed. 1.0 (2014-07)

Summary

- The TC 108 and the related TC 42 approaches to insulation coordination have been described.
- The preferred values of test voltage are reasoned to be:

  a) 1500 V rms at 50 Hz to 60 Hz for 60 s

  b) 2250 V dc for 60 s

  c) A sequence of ten 2400 V, 1.2/50 impulses of alternating polarity, applied at intervals of not less than 1 s

- There are several options to specify the 1.2/50 impulse (page 13)
- Examples of test procedure references have been given, which need discussion to arrive at a robust solution (pages 14 through 17)