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**Resistibility of telecommunication equipment
installed in the access and trunk networks to
overvoltages and overcurrents**

Recommendation ITU-T K.45



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Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents

Summary

Recommendation ITU-T K.45 specifies resistibility requirements and test procedures for telecommunication equipment installed between telecommunication centres and between a telecommunication centre and the customer's premises.

Overvoltages or overcurrents covered by this Recommendation include surges due to lightning on or near the line plant, short-term induction from adjacent AC power lines or railway systems, earth potential rise due to power faults, direct contact between telecommunication lines and power lines and electrostatic discharges.

Changes compared with Recommendation ITU-T K.45 (2018) include:

- A DC insulation resistance test;
- a special requirements annex.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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1.2/50-8/20, 10/700, access equipment, common mode, differential, external port, internal port, longitudinal, overcurrent, overvoltage, power contact, power induction, resistibility, surges, telecommunication equipment, transverse, trunk.

* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

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Recommendation ITU-T K.45

Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents

1 Scope

This Recommendation specifies resistibility requirements and test procedures for telecommunication equipment installed between telecommunication centres and between a telecommunication centre and the customer's premises. Equipment that is attached to or installed within the customer's premises is outside the scope of this Recommendation. [ITU-T K.44], covering basic test methods and test circuits, is an integral part of this Recommendation. It should be read in conjunction with [ITU-T K.11] and [ITU-T K.39] (technical and general economic aspects of protection).

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T K.11] Recommendation ITU-T K.11 (2009), *Principles of protection against overvoltages and overcurrents*.
- [ITU-T K.39] Recommendation ITU-T K.39 (2019), *Risk assessment of damages to telecommunication sites due to lightning discharges*.
- [ITU-T K.44] Recommendation ITU-T K.44 (2019), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.
- [ITU-T K.66] Recommendation ITU-T K.66 (2019), *Protection of customer premises from overvoltages*.
- [IEC 61000-4-2] IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*.

3 Definitions

3.1 Terms defined elsewhere

Definitions used in this Recommendation are defined in [ITU-T K.44].

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the abbreviations and acronyms defined in [ITU-T K.44] as well as the following:

CWG Combination Wave Generator

ESD	Electrostatic Discharge
MSDP	Multiservice Surge Protective Device
PoE	Power over Ethernet
SPD	Surge Protective Device
STP	Special Test Protector
STP _E	Shielded Twisted Pair Ethernet
UTP _E	Unshielded Twisted Pair Ethernet

5 Conventions

This Recommendation uses the conventions defined in [ITU-T K.44] as well as the following:

- | | |
|----|--|
| IT | Designation specified in [b-IEC 60364] for a power distribution system in which there is no point connected with earth (isolation), except perhaps via a high impedance, on the power-supply equipment (generator or transformer) and a direct connection of a point on the electrical device being supplied with earth. |
| TT | Designation specified in [b-IEC 60364] for a power distribution system in which there is a direct connection of a point on the power-supply equipment (generator or transformer) with earth and a direct connection of a point on the electrical device being supplied with earth. |

6 Tests

A summary of the applicable tests is given in Table 1. The numbers given in the "port type" columns, e.g., 2.2.1.a, refer to the "Test No." of Tables 2 to 5. The words "under study" mean that ITU-T is still studying this test. The test conditions applicable to the four ports (symmetric, coaxial, dedicated power feed and mains power) are given in Tables 2 to 5. The test conditions for electrostatic discharge (ESD) are given in Table 6. For information on the headings and terms used in the tables, refer to clause 10 of [ITU-T K.44].

Refer to clause 5.2 of [ITU-T K.44] on selecting the enhanced resistibility requirement.

NOTE 1 – The port to external port test for the basic test level does not apply when the equipment is designed to be always used with a connection to earth.

NOTE 2 – The external port test applies to ports used to connect externally attached equipment to equipment installed within the same building. The mains power contact test does not apply in this situation.

NOTE 3 – The power induction test does not apply to ports used to connect to antennas installed under the scope of [b-ITU-T K.71].

NOTE 4 – Tests of Table 1b and Table 7 do not apply to equipment ports meeting all of the following requirements:

- 1) The distance between two racks/cabinets is not more than 3 m.
- 2) The length of interconnection cable does not exceed 6 m.
- 3) The equipment has a dedicated grounding point and share the same earth/ground. Measures to reduce the potential difference between equipment shall be taken.
- 4) The equipment will have the same power distribution source.
- 5) Interconnected equipment shall use shielded cable bonded at both ends.

If the port meets the intra-system port criteria all of 1-5 listed above, no testing is required on the port. However, other ports types used on the equipment shall be tested as per ITU-T K.45.

Table 7 does not apply to ports connected infrequently such as maintenance ports.

Table 1 – Applicable tests

Test type	No. of pairs simultaneously tested	Test connection	Primary protection	Port type				
				Symmetric port	Coaxial port	Dedicated power feed port	Mains power port	
Lightning voltage	Single	Transverse/differential	No	2.1.1a	3.1.1	4.1.1a	5.1.1a	
		Port to earth	No	2.1.1b	n/a	4.1.1b	5.1.1b	
		Port to external port	No	2.1.1c	n/a	4.1.1c	5.1.1c	
		Coordination/Transverse/differential	Yes	2.1.2a	3.1.2	4.1.2a	5.1.2a	
		Coordination/Port to earth	Yes	2.1.2b	n/a	4.1.2b	5.1.2b	
		Coordination/Port to external port	Yes	2.1.2c	n/a	4.1.2c	5.1.2c	
	Multiple	Port to earth	No	2.1.3a	n/a	n/a	n/a	
		Port to external port	No	2.1.3b	n/a	n/a	n/a	
		Port to earth	Yes	2.1.4a	n/a	n/a	n/a	
		Port to external port	Yes	2.1.4b	n/a	n/a	n/a	
	Unshielded twisted pair Ethernet (UTP _E)	Port to Earth	No	2.1.8	n/a	n/a	n/a	
		Transverse	No	2.1.7	n/a	n/a	n/a	
		Voltage impulse test	No	2.1.10	n/a	n/a	n/a	
		Power over Ethernet (PoE)	No	2.1.11	n/a	n/a	n/a	
	Shielded twisted pair Ethernet (STP _E)	Port to Earth	No	2.1.8		n/a	n/a	
		Shield to earth	No	2.1.9		n/a	n/a	
	Lightning current	Single	Port to earth	No	2.1.5a	n/a	4.1.5a	n/a
			Port to external port	No	2.1.5b	n/a	4.1.5b	n/a
			Differential	n/a	n/a	3.1.3	n/a	n/a
			Shield to earth	n/a	n/a	3.1.4	n/a	n/a
Shield to external port			n/a	n/a	3.1.5	n/a	n/a	
Multiple		Port to earth	No	2.1.6a	n/a	n/a	n/a	
		Port to external port	No	2.1.6b	n/a	n/a	n/a	

Table 1 – Applicable tests

Test type	No. of pairs simultaneously tested	Test connection	Primary protection	Port type			
				Symmetric port	Coaxial port	Dedicated power feed port	Mains power port
Power induction and earth potential rise	Single	Transverse	No	2.2.1a	Under study	4.2.1a	n/a
		Port to earth	No	2.2.1b	n/a	4.2.1b	5.2.1 (under study)
		Port to external port	No	2.2.1c	n/a	4.2.1c	5.2.1 (under study)
		Transverse	Yes	2.2.2a	Under study	4.2.2a	n/a
		Port to earth	Yes	2.2.2b	n/a	4.2.2b	n/a
		Port to external port	Yes	2.2.2c	n/a	4.2.2c	[**]
Neutral potential rise	Single	Port to earth	No	n/a	n/a	n/a	5.2.2a
		Port to external port	No	n/a	n/a	n/a	5.2.2b
Mains power contact	Single	Transverse	No	2.3.1a	n/a	4.3.1a	n/a
		Port to earth	No	2.3.1b	n/a	4.3.1b	n/a
		Port to external port	No	2.3.1c	n/a	4.3.1c	n/a
		Ethernet port	No	2.4			

NOTE – There are no internal ports in access network equipment (due to its small physical size).

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables
(Test exemptions for short external cables are under study)

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
2.1.1a	Single pair, lightning, inherent, transverse	A.3-1 and A.6.1-1 (a and b) 10/700	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	This test does not apply when the equipment is designed to always be used with primary protection. When the equipment contains high current-carrying components that eliminate the need for primary protection, this test does not apply. (lower voltage level testing also required for each test – see clause 7.3 of [ITU-T K.44])
2.1.1b	Single pair, lightning, inherent, port to earth	A.3-1 and A.6.1-2 10/700	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$				
2.1.1c	Single pair, lightning, inherent, port to external port	A.3-1 and A.6.1-3 10/700	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$				
2.1.2a	Single pair, lightning, coordination, transverse	A.3-1 and A.6.1-1 (a and b) 10/700	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	Alternating ± 5 surges (60 s between successive surges)	Special test protector (STP); see clause 8.4 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port	A When the test is performed with $U_c = U_{c(max)}$, the special test protector must operate. Of course, it may also operate with a voltage of $U_c < U_{cmax}$	When the equipment contains high current-carrying components that eliminate the need for primary protection, refer to clause 10.1.1 of [ITU-T K.44]. (lower voltage level testing also required for each test – see clause 7.3 of [ITU-T K.44])
2.1.2b	Single pair, lightning, coordination, port to earth	A.3-1 and A.6.1-2 10/700	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$				
2.1.2c	Single pair, lightning, coordination, port to external port	A.3-1 and A.6.1-3 10/700	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$				

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

(Test exemptions for short external cables are under study)

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
2.1.3a	Multiple pair, lightning, inherent, port to earth	A.3-1 and A.6.1-4 10/700	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	The multiple port test is simultaneously applied to 100% of the pairs in the same cable limited to a maximum of eight pairs. This test does not apply when the equipment is designed to be always used with primary protection. When the equipment contains high current-carrying components that eliminate the need for primary protection, this test does not apply. (lower voltage level testing also required for each test – see clause 7.3 of [ITU-T K.44])
2.1.3b	Multiple pair, lightning, inherent, port to external port	A.3-1 and A.6.1-5 10/700	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 1.5 \text{ kV}$ $R = 25 \Omega$				
2.1.4a	Multiple pair, lightning, port to earth	A.3-1 and A.6.1-4 10/700	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 6 \text{ kV}$ $R = 25 \Omega$	Alternating ± 5 surges (60 s between successive surges)	Agreed primary protector. When performing the external port to external port test, also add an STP/primary protector to the untested port	A	The multiple port test is simultaneously applied to 100% of the pairs in the same cable limited to a maximum of eight pairs. When the equipment contains high current-carrying components that eliminate the need for primary protection, do not remove these components and do not add primary protection. (lower
2.1.4b	Multiple port, lightning, port to external port	A.3-1 and A.6.1-5 10/700	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 6 \text{ kV}$ $R = 25 \Omega$				

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

(Test exemptions for short external cables are under study)

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
								voltage level testing also required for each test – see clause 7.3 of [ITU-T K.44])
2.1.5a	Single pair, lightning current, port to earth	A.3-4 and A.6.1-2 8/20	$I = 1 \text{ kA/wire}$ $R = 0 \Omega$	$I = 5 \text{ kA/wire}$ $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	This test only applies when the equipment contains high current-carrying components that eliminate the need for primary protection. Do not remove these components. The multiple port test is simultaneously applied to 100% of the pairs in the same cable limited to a maximum of eight pairs.
2.1.5b	Single pair, lightning current, port to external port	A.3-4 and A.6.1-3 8/20	$I = 1 \text{ kA/wire}$ $R = 0 \Omega$	$I = 5 \text{ kA/wire}$ $R = 0 \Omega$				
2.1.6a	Multiple pair, lightning current, port to earth	A.3-4 and A.6.1-4 8/20	$I = 1 \text{ kA/wire}$ Limited to 6 kA total $R = 0 \Omega$	$I = 5 \text{ kA/wire}$ Limited to 30 kA total $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	
2.1.6b	Multiple pair, lightning current, port to external port	A.3-4 and A.6.1-5 8/20	$I = 1 \text{ kA/wire}$ Limited to 6 kA total $R = 0 \Omega$	$I = 5 \text{ kA/wire}$ Limited to 30 kA total $R = 0 \Omega$				
2.1.7	Ethernet transverse	A.3-5 and A.6.7-5 1.2/50-8/20 combination wave generator (CWG) $R1 = R2 = 10 \Omega$ and $C1 = 1 \mu\text{F}$, 6 kV	$U_{c(\text{max})} = 2\,500 \text{ V}$	$U_{c(\text{max})} = 6\,000 \text{ V}$	Alternating ± 5 surges (60 s between successive surges)	None	A	

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

(Test exemptions for short external cables are under study)

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
2.1.8	Ethernet longitudinal/common mode to transverse/differential mode conversion tests	A.3-5 and A.6.7-4 1.2/50-8/20 CWG $R = 10 \Omega$	$U_{c(max)} = 2\,500 \text{ V}$	$U_{c(max)} = 6\,000 \text{ V}$	Alternating ± 5 surges (60 s between successive surges)	None	A	
2.1.9	Screen/shield connection high current test	A.3-5 and A.6.7-6 1.2/50-8/20 CWG $R = 5 \Omega$	$U_{c(max)} = 2\,500 \text{ V}$	$U_{c(max)} = 6\,000 \text{ V}$	Alternating ± 5 surges (60 s between successive surges)	None	A	
2.1.10	Ethernet longitudinal/common mode withstand test	A.3-5 and A.6.7-3a 1.2/50-8/20 CWG $R = 5 \Omega$	$U_{c(max)} = 2\,500 \text{ V}$ surge	$U_{c(max)} = 6\,000 \text{ V}$ surge	Alternating ± 5 surges (60 s between successive surges)	None (Note)	A	There shall be no insulation breakdown during the test and the post-test resistance shall be at least $2 \text{ M}\Omega$ when measured at 500 V d.c. , see Figure A.6.7-3 of [ITU-T K.44]. Monitor the impulse voltage to detect insulation breakdown or voltage protector operation.
2.1.11	PoE Mode A and Mode B transverse testing	A.3-5 and A.6.7-2 1.2/50-8/20 CWG $R_1 = 10 \Omega$ and $R_2 = 10 \Omega$	$U_{c(max)} = 2\,500 \text{ V}$	$U_{c(max)} = 6\,000 \text{ V}$	Alternating ± 5 surges (60 s between surges)	None	A	

Table 2a – Lightning test conditions for ports connected to external symmetric pair cables

(Test exemptions for short external cables are under study)

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
NOTE – When the cabling is fitted with SPDs, the equipment user and manufacturer may use different test conditions upon mutual agreement; this topic is currently under study.								

Table 2b – Power induction and earth potential rise test conditions for ports connected to external symmetric pair cables

Test No.	Test description	Test circuit (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
2.2.1a	Power induction, inherent, transverse	A.3-6 and A.6.1-1 (a and b)	$W_{sp(max)} = 0.2 A^2s$ $f = 16\frac{2}{3} \text{ Hz}, 50 \text{ or } 60 \text{ Hz}$ $U_{a.c.(max)} = 600 \text{ V}$ $R = 600 \Omega$ $t = 0.2 \text{ s}$	$W_{sp(max)} = 0.2 A^2s$ $f = 16\frac{2}{3} \text{ Hz}, 50 \text{ Hz or } 60 \text{ Hz}$ $U_{a.c.(max)} = 600 \text{ V}$ $R = 600 \Omega$ $t = 0.2 \text{ s}$	5	None	A	This test does not apply when the equipment is designed to be always used with primary protection. When the equipment contains high current-carrying components that eliminate the need for primary protection, this test does not apply.
2.2.1b	Power induction and earth potential rise, inherent, port to earth	A.3-6 and A.6.1-2						
2.2.1c	Power induction and earth potential rise, inherent, port to external port	A.3-6 and A.6.1-3						

Table 2b – Power induction and earth potential rise test conditions for ports connected to external symmetric pair cables

Test No.	Test description	Test circuit (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
2.2.2a	Power induction, inherent/ coordination, transverse	A.3-6 and A.6.1-1 (a and b)	$W_{sp(max)} = 1 \text{ A}^2\text{s}$ $f = 16\frac{2}{3} \text{ Hz}, 50 \text{ Hz or } 60 \text{ Hz}$ $U_{a.c.(max)} = 600 \text{ V}$ $R = 600 \Omega$	$W_{sp(max)} = 10 \text{ A}^2\text{s}$ $f = 16\frac{2}{3} \text{ Hz}, 50 \text{ Hz or } 60 \text{ Hz}$ $U_{a.c.(max)} = 1\,500 \text{ V}$ $R = 200 \Omega$	5	Special test protector (STP); see clause 8.4 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port.	A	If the equipment port has inherent primary protection, which eliminates the need for external primary protection, refer to clause 10.1.3 of [ITU-T K.44].
2.2.2b	Power induction and earth potential rise, inherent/ coordination, port to earth	A.3-6 and A.6.1-2	$t = 1.0 \text{ s}$ (Note 1)	$t_{(max)} = 2 \text{ s}$ $t = \frac{W_{sp} \times R^2}{(U_{a.c.})^2} \quad (6-1)$ (Note 2)				
2.2.2c	Power induction inherent/ coordination, port to external port	A.3-6 and A.6.1-3						
2.3.1a	Mains power contact, inherent, transverse	A.3-6 and A.6.1-1 (a and b)	$U_{a.c.} = 230 \text{ V}$ $f = 50 \text{ Hz}$ $t = 15 \text{ min}$ for each test resistor	$U_{a.c.} = 230 \text{ V}$ $f = 50 \text{ Hz}$ $t = 15 \text{ min}$ for each test resistor	1	None	For basic level: criterion B. For enhanced level: criterion A for test resistors 160, 300, 600, and 1 000 Ω ;	In some situations, the test may be performed with a reduced number of current limit resistors. Refer to item 12 of clause 7.3 of [ITU-T K.44] and clause I.1.4 of [ITU-T K.44] for guidance on selecting the necessary size
2.3.1b	Mains power contact, inherent, port to earth	A.3-6 and A.6.1-2	$R = 10, 20, 40, 80, 160, 300, 600$ and 1 000 Ω See acceptance	$R = 10, 20, 40, 80, 160, 300, 600$ and 1 000 Ω See acceptance criteria				

Table 2b – Power induction and earth potential rise test conditions for ports connected to external symmetric pair cables

Test No.	Test description	Test circuit (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
2.3.1c	Mains power contact, inherent, port to external port	A.3-6 and A.6.1-3	criteria column.	column.			criterion B for the other resistor values.	of resistors. When the equipment is designed to be always used with primary protection, and the operator agrees, perform this test with the special test protector installed. (Note 3) If the equipment port has inherent primary protection, which eliminates the need for external primary protection, refer to clause 10.1.4 of [ITU-T K.44].
2.4	Ethernet port DC insulation resistance	A.6.7-3	$U_{DC} = \pm 500$ V DC	$U_{DC} = \pm 500$ V DC	2	None	Insulation resistance > 2 M Ω	Test in both polarities, Ensures no port to earth conduction up to 350 V AC

Table 2b – Power induction and earth potential rise test conditions for ports connected to external symmetric pair cables

Test No.	Test description	Test circuit (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
<p>NOTE 1 – The test conditions for Test 2.2.2 (basic test level) may be adapted to the local conditions by variation of the test parameters within the following limits, so that $I^2t = 1 \text{ A}^2\text{s}$ is fulfilled:</p> <p>$U_{\text{a.c.}(\text{max})} = 300 \text{ V} \dots 600 \text{ V}$, selected to meet local conditions; $t \leq 1.0 \text{ s}$, selected to meet local conditions; $R \leq 600 \Omega$, is to be calculated according to Equation 6-2.</p> $R = U_{\text{a.c.}(\text{max})} \sqrt{t} \tag{6-2}$ <p>NOTE 2 – For Test 2.2.2 (enhanced test level), the equipment shall comply with the specified criterion for all voltage–time combinations bounded (on and below) by the $10 \text{ A}^2\text{s}$ voltage–time curve in Figure 1. The curve in Figure 1 is defined by Equation 6-1 and boundary conditions in this table.</p> <p>NOTE 3 – The AC mains voltage and frequency for Test 2.3.1 may be changed to the local mains supply voltage and frequency values. For AC test voltage values other than 230 V, the test resistor values should be adjusted to provide the same prospective short-circuit current values that occur in the 230 V test condition.</p>								

Table 3a – Lightning test conditions for ports connected to external coaxial cables

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
3.1.1	Lightning, inherent, differential	A.3-5 and A.6.2-1 1.2/50 – 8/20 CWG	$U_{c(max)} = 1.0 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 1.5 \text{ kV}$ $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	This test does not apply when the equipment is designed to be always used with primary protection. When the equipment contains high current-carrying components that eliminate the need for primary protection, this test does not apply.
3.1.2	Lightning, coordination, differential	A.3.5 and A.6.2-1 1.2/50 – 8/20 CWG	$U_{c(max)} = 4 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 6 \text{ kV}$ $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	Special test protector (STP); see clause 8.4 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port.	A When the test is performed with $U_c = U_{c(max)}$, the special test protector must operate. Of course, it may also operate with a voltage of $U_c < U_{c(max)}$.	When the equipment contains high current-carrying components that eliminate the need for primary protection, refer to clause 10.2 of [ITU-T K.44].
3.1.3	Lightning, current, differential	A.3.4 and A.6.2-1 8/20	$I = 1 \text{ kA}$	$I = 5 \text{ kA}$	Five of each polarity	None	A	This test only applies when the equipment contains high current-carrying components that eliminate the need for primary protection. Do not remove these components.

Table 3a – Lightning test conditions for ports connected to external coaxial cables

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
3.1.4	Lightning shield test, port to earth	A.3.4 and A.6.2-2 8/20	$I = 4$ kA (Note 1) $I = 2$ kA (Note 2)	$I = 20$ kA (Note 1) $I = 5$ kA (Note 2)	Alternating ± 5 surges (60 s between successive surges)	Special test protector (STP); see clause 8.4 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port.	A	Only applies to earthed equipment and equipment without isolation capacitors in the coaxial cable path.
3.1.5	Lightning shield test, port to external port	A.3.4 and A.6.2-3 8/20	$I = 4$ kA (Note 1) $I = 2$ kA (Note 2)	$I = 20$ kA (Note 1) $I = 5$ kA (Note 2)	Alternating ± 5 surges (60 s between successive surges)	Special test protector (STP); see clause 8.4 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port.	A	Only applies to earthed equipment and equipment without isolation capacitors in the coaxial cable path.
<p>NOTE 1 – Equipment designed to be connected to antennas/equipment exposed to direct lightning currents, e.g., connected to antennas/equipment mounted on a tower. NOTE 2 – Applicable equipment not covered by Note 1.</p>								

Table 3b – Power induction and earth potential rise test conditions for ports connected to external coaxial cables

NOTE – The test conditions for earth potential rise are under study.

Table 4a – Lightning test conditions for ports connected to external DC or AC dedicated power feeding cables

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
4.1.1a	Single pair, lightning, inherent, transverse	A.3-1 and A.6.3-1 (a and b) 10/700 μ s	$U_{c(max)} = 1.5$ kV $R = 25$ Ω	$U_{c(max)} = 1.5$ kV $R = 25$ Ω	Alternating ± 5 surges (60 s between successive surges)	None	A	This test does not apply when the equipment is designed to be always used with primary protection. When the equipment contains high current-carrying components that eliminate the need for primary protection, this test does not apply.
4.1.1b	Single pair, lightning, inherent, port to earth	A.3-1 and A.6.3-2 10/700 μ s	$U_{c(max)} = 1.5$ kV $R = 25$ Ω	$U_{c(max)} = 1.5$ kV $R = 25$ Ω	Alternating ± 5 surges (60 s between successive surges)			
4.1.1c	Single pair, lightning, inherent, port to external port	A.3-1 and A.6.3-3 10/700 μ s	$U_{c(max)} = 1.5$ kV $R = 25$ Ω	$U_{c(max)} = 1.5$ kV $R = 25$ Ω	Alternating ± 5 surges (60 s between successive surges)			

Table 4a – Lightning test conditions for ports connected to external DC or AC dedicated power feeding cables

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
4.1.2a	Single pair, lightning, coordination, transverse	A.3-1 and A.6.3-1 (a and b) 10/700 μ s	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	Alternating ± 5 surges (60 s between successive surges)	Special test protector (STP); see clause 8 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port	A When the test is performed with $U_c = U_{c(max)}$, the special test protector must operate. Of course, it may also operate with a voltage of $U_c < U_{c(max)}$.	When the equipment contains high current-carrying components that eliminate the need for primary protection, do not remove these components and do not add primary protection. During the test this protection must operate at $U_c = U_{c(max)}$. If the primary protector is a clamping type device, use the test circuit and test levels specified in test 4.1.5.
4.1.2b	Single pair, lightning, coordination, port to earth	A.3-1 and A.6.3-2 10/700 μ s	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$				
4.1.2c	Single pair, lightning, coordination, port to external port	A.3-1 and A.6.3-3 10/700 μ s	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$				
4.1.3	Multiple pair, lightning, inherent, port to earth and port to external port		n/a	n/a				
4.1.4	Multiple pair, lightning, port to earth and port to external port		n/a	n/a				

Table 4a – Lightning test conditions for ports connected to external DC or AC dedicated power feeding cables

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
4.1.5a	Single pair, lightning current, port to earth	A.3-4 and A.6.3-2 8/20 μ s	$I = 1$ kA/wire $R = 0 \Omega$	$I = 5$ kA/wire $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	This test only applies when the equipment contains high current-carrying components that eliminate the need for primary protection.
4.1.5b	Single pair, lightning current, port to external port	A.3-4 and A.6.3-3 8/20 μ s	$I = 1$ kA/wire $R = 0 \Omega$	$I = 5$ kA/wire $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)			
4.1.6	Multiple pair, lightning current		n/a	n/a				
NOTE – As there is little knowledge of the agreed primary protector, it is not possible to give guidance. In the interim, test conditions for symmetric pair ports have been provided.								

Table 4b – Power induction and earth potential rise test conditions for ports connected to external DC or AC dedicated power feeding cables

Test No.	Test description	Test circuit (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
4.2.1a	Power induction, inherent, transverse	A.3-6 and A.6.3-1 (a and b)	$W_{sp(max)} = 0.2 \text{ A}^2\text{s}$ $f = 16\frac{2}{3} \text{ Hz}$, 50 Hz or 60 Hz $U_{a.c.(max)} = 600 \text{ V}$ $R = 600 \Omega$ $t = 0.2 \text{ s}$	$W_{sp(max)} = 0.2 \text{ A}^2\text{s}$ $f = 16\frac{2}{3} \text{ Hz}$, 50 Hz or 60 Hz $U_{a.c.(max)} = 600 \text{ V}$ $R = 600 \Omega$ $t = 0.2 \text{ s}$	5	None	A	This test does not apply when the equipment is designed to be always used with primary protection. When the equipment contains high current-carrying components that eliminate the need for primary protection, this test does not apply.
4.2.1b	Power induction and earth potential rise, inherent, port to earth	A.3-6 and A.6.3-2						
4.2.1c	Power induction and earth potential rise, inherent, port to external port	A.3-6 and A.6.3-3						
4.2.2a	Power induction, inherent/coordination, transverse	A.3-6 and A.6.3-1 (a and b)	$W_{sp(max)} = 1 \text{ A}^2\text{s}$ $f = 16\frac{2}{3} \text{ Hz}$, 50 Hz or 60 Hz $U_{a.c.(max)} = 600 \text{ V}$ $R = 600 \Omega$ $t = 1.0 \text{ s}$ (Note 1)	$W_{sp(max)} = 10 \text{ A}^2\text{s}$ $f = 16\frac{2}{3} \text{ Hz}$, 50 Hz or 60 Hz $U_{a.c.(max)} = 1\,500 \text{ V}$ $R = 200 \Omega$ $t_{(max)} = 2 \text{ s}$ $t = \frac{W_{sp} \times R^2}{(U_{a.c.})^2}$ (6-1) (Note 2)	5	Special test protector (STP); see clause 8 of [ITU-T K.44]. When performing the external port to external port test, also add an STP/primary protector to the untested port.	A	When the equipment contains high current-carrying components that eliminate the need for primary protection, do not remove these components and do not add primary protection.
4.2.2b	Power induction and earth potential rise, inherent/coordination, port to earth	A.3-6 and A.6.3-2						
4.2.2c	Power induction and earth potential rise, inherent/coordination, port to external port	A.3-6 and A.6.3-3						

Table 4b – Power induction and earth potential rise test conditions for ports connected to external DC or AC dedicated power feeding cables

Test No.	Test description	Test circuit (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
4.3.1a	Mains power contact, inherent, transverse	A.3-6 and A.6.3-1 (a and b)	$U_{a.c.} = 230 \text{ V}$ $f = 50 \text{ Hz}$ $t = 15 \text{ min}$ for each test resistor $R = 10, 20, 40, 80, 160, 300, 600 \text{ and } 1\,000 \text{ }\Omega$ See acceptance criteria column.	$U_{a.c.} = 230 \text{ V}$ $f = 50 \text{ Hz}$ $t = 15 \text{ min}$ for each test resistor $R = 10, 20, 40, 80, 160, 300, 600 \text{ and } 1\,000 \text{ }\Omega$ See acceptance criteria column.	1	None	For basic level: criterion B. For enhanced level: criterion A for test resistors 160, 300 and 600 Ω ; criterion B for the other resistor.	In some situations, the test may be performed with a reduced number of current limit resistors. Refer to item 11 of clause 7.3 of [ITU-T K.44] and to clause I.1.4 of [ITU-T K.44] for guidance on selecting the necessary size of resistors. When the equipment is designed to be always used with primary protection, and the operator agrees, perform this test with the special test protector installed.
4.3.1b	Mains power contact, inherent, port to earth	A.3-6 and A.6.3-2						
4.3.1c	Mains power contact, inherent, port to external port	A.3-6 and A.6.3-3						

NOTE 1 – The test conditions for Test 4.2.2 (basic test level) may be adapted to the local conditions by variation of the test parameters within the following limits, so that $I^2t = 1 \text{ A}^2\text{s}$ is fulfilled:

$U_{a.c.(\text{max})} = 300 \text{ V} \dots 600 \text{ V}$, selected to meet local conditions;

$t \leq 1.0 \text{ s}$, selected to meet local conditions;

$R \leq 600 \text{ }\Omega$, is to be calculated according to Equation 6-2.

$$R = U_{a.c.(\text{max})} \sqrt{t} \quad (6-2)$$

NOTE 2 – For Test 4.2.2 (enhanced test level) the equipment shall comply with the specified criterion for all voltage–time combinations bounded (on and below) by the 10 A²s voltage–time curve in Figure 1. The curve in Figure 1 is defined by Equation 6-1 and the boundary conditions in this table.

NOTE 3 – The AC mains voltage and frequency for Test 4.3.1 may be changed to the local mains supply voltage and frequency values. For AC test voltage values other than 230 V, the test resistor values should be adjusted to provide the same prospective short-circuit current values that occur in the 230 V test condition.

Table 5 – Test conditions for mains power ports

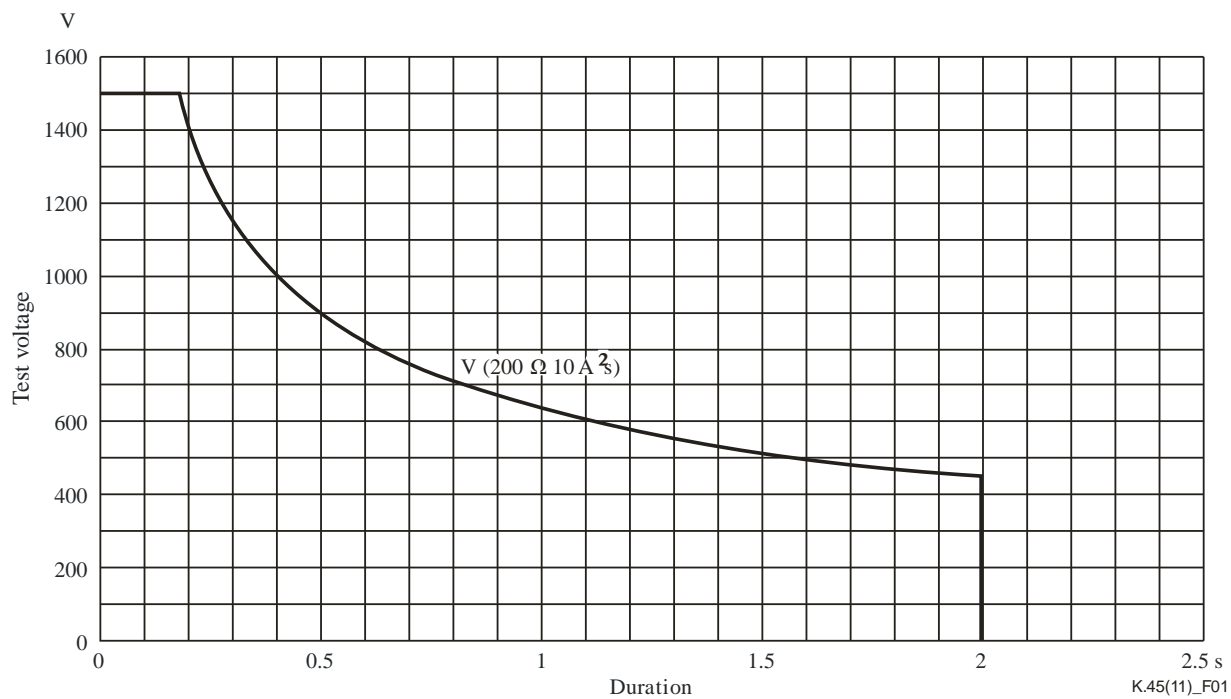
Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
5.1.1a	Lightning, inherent, transverse	A.3-5 and A.6.4-1 1.2/50-8/20 CWG	$U_{c(max)} = 2.5 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 6.0 \text{ kV}$ $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	None	A	This test does not apply when the equipment is designed to be always used with primary protection.
5.1.1b	Lightning, inherent, port to earth	A.3-5 and A.6.4-2 1.2/50-8/20 CWG	$U_{c(max)} = 2.5 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 6.0 \text{ kV}$ $R = 0 \Omega$				
5.1.1c	Lightning, inherent, port to external port	A.3-5 and A.6.4-3 1.2/50-8/20 CWG	$U_{c(max)} = 2.5 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 6.0 \text{ kV}$ $R = 0 \Omega$				
5.1.2a	Lightning, inherent/coordination, transverse	A.3-5 and A.6.4-1 1.2/50-8/20 CWG	$U_{c(max)} = 6.0 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 10.0 \text{ kV}$ $R = 0 \Omega$	Alternating ± 5 surges (60 s between successive surges)	Agreed primary protector (mains). When performing the external port to external port test, also add an STP/primary protector to the untested port.	A	
5.1.2b	Lightning, inherent/coordination, port to earth	A.3-5 and A.6.4-2 1.2/50-8/20 CWG	$U_{c(max)} = 6.0 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 10.0 \text{ kV}$ $R = 0 \Omega$				
5.1.2c	Lightning, inherent/coordination, port to external port	A.3-5 for and A.6.4-3 1.2/50-8/20 CWG	$U_{c(max)} = 6.0 \text{ kV}$ $R = 0 \Omega$	$U_{c(max)} = 10.0 \text{ kV}$ $R = 0 \Omega$				
5.2.1	Earth potential rise		Under study	Under study				
5.2.2a	Neutral potential rise, inherent, port to earth	A.3-6 and A.6.4-2 a.c.	$U_{(AC)} = 600 \text{ V}$ $f = 50 \text{ Hz or } 60 \text{ Hz}$ $t = 1 \text{ s}$ $R = 200 \Omega$	$U_{(AC)} = 1\,500 \text{ V}$ $f = 50 \text{ Hz or } 60 \text{ Hz}$ $t = 1 \text{ s}$ $R = 200 \Omega$	5	None	A	This test applies only when the equipment is to be installed with TT or IT mains system and the operator requests it.

Table 5 – Test conditions for mains power ports

Test No.	Test description	Test circuit and waveform (see figures in Annex A of [ITU-T K.44])	Basic test levels (also see clause 7 of [ITU-T K.44])	Enhanced test levels (also see clauses 5 and 7 of [ITU-T K.44])	No. of tests	Primary protection (clause 8 of [ITU-T K.44])	Acceptance criteria (clause 9 of [ITU-T K.44])	Comments
5.2.2b	Neutral potential rise, inherent, external port to port	A.3-6 and A.6.4-3 a.c.						
NOTE – The total lead length used to connect the agreed primary protector shall be 1 m.								

Table 6 – Test conditions for electrostatic discharge applied to the enclosure

Test No.	Test description	Test circuit	Basic test level	Enhanced test level	Number of tests	Primary protection	Acceptance criteria
6.1.a	Air discharge	IEC 61000-4-2 (2008)	Level 3 (8 kV)	Level 4 (15 kV)	5	n/a	A
6.1.b	Contact discharge	IEC 61000-4-2 (2008)	Level 3 (6 kV)	Level 4 (8 kV)	5	n/a	A
NOTE 1 – Tests 6.1.a and 6.1.b are applied to the equipment enclosure.							
NOTE 2 – The performance criterion A of [ITU-T K.44] is applied.							



Test voltage versus duration for a specific energy and source resistance.

Figure 1 – Test voltage versus duration to give 10 A²s with 200 Ω

Annex A

Special resistibility requirements

(This annex forms an integral part of this Recommendation.)

A.1 Introduction

There are circumstances where even the enhanced resistibility requirements are not sufficient for access equipment due to environmental conditions, national regulations, economic and technical considerations, installation standards or reliability of service requirements. Network operators may then request the special resistibility requirement.

The special resistibility requirement applies when all of the following conditions coexist:

- IT or TT power system,
- Earthing and bonding is not installed in compliance with [ITU-T K.66],
- Primary protection is not installed in compliance with [ITU-T K.66] when required by a risk assessment,
- There is difficulty in installing multiservice surge protective devices (MSPDs).

In this case, the network operator may need to request special resistibility requirements. Some guidance and possible test levels are provided in clause A.2.

Informative clause A.2 contains both test descriptions and requirements for special resistibility requirements. It is proposed that the test requirements, described in clause 7 of [ITU-T K.44] be amended as indicated.

A.2 Special resistibility requirements

Clause A.1 specifies when these special resistibility requirements are necessary.

Table A.2-1 provides special requirements that are used to ensure safety and resistibility when bonding cannot be achieved.

These special requirements are in addition to the enhanced ITU-T K.45 tests and apply to equipment with both earthed surge protective devices (SPDs) and without earthed SPDs.

To ensure the safety of the customer, without appropriate earthing and bonding, the equipment shall contain port-to-port isolation as given in Table A.2-1. To ensure safety with earthed SPDs, appropriate earthing and bonding is required.

Table A.2-1a – Special lightning test conditions for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform (see Figures in Annex A of [ITU-T K.44])	Special test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection	Acceptance criteria	Comments
2.1.2a	Single port, lightning, coordination, transverse	A.3-1 and A.6.1-1 (a and b) 10/700	$U_{c(max)} = 4 \text{ kV}$ $R = 25 \Omega$ $R_1 = 100 \Omega$	5 of each polarity	Special test protector, see clause 8.4 of [ITU-T K.44]	A When the test is performed with $U_c = U_{c(max)}$, the special test protector must operate. Of course, it may also operate with a voltage of $U_c < U_{c(max)}$.	When the equipment contains high current-carrying components which eliminate the need for primary protection, refer to clause 10.1.1 of [ITU-T K.44]. Ethernet port tests are under study.
2.1.2b	Single port, lightning, coordination, port to earth	A.3-1 and A.6.1-2 10/700	$U_{c(max)} = 13 \text{ kV}$ $R = 25 \Omega$ $R_1 = 100 \Omega$				
2.1.2c	Single port, lightning, coordination, port to external port	A.3-1 and A.6.1-3 10/700	$U_{c(max)} = 13 \text{ kV}$ $R = 25 \Omega$ $R_1 = 100 \Omega$				

Table A.2-1b – Special lightning test conditions for mains power ports

Test no.	Test description	Test circuit and waveform (see Figures in Annex A of [ITU-T K.44])	Special test levels (also see clauses 5 and 7 of [ITU-T K.44])	Number of tests	Primary protection	Acceptance criteria	Comments
5.1.1a	Lightning, inherent, transverse	A.3-5 and A.6.4-1 combination wave generator	$U_{c(max)} = 10 \text{ kV}$ $R = 0 \Omega$	5 of each polarity	None When performing the external port to symmetric pair port test, also add an STP/primary protector to the untested port. $R1 = 100 \Omega$ for the untested port.	A	
5.1.1b	Lightning, inherent, port to earth	A.3-5 and A.6.4-2 combination wave generator	$U_{c(max)} = 10 \text{ kV}$ $R = 0 \Omega$				
5.1.1c	Lightning, inherent, port to external port	A.3-5 and A.6.4-3 combination wave generator	$U_{c(max)} = 10 \text{ kV}$ $R = 0 \Omega$				

Bibliography

- [b-ITU-T K.71] Recommendation ITU-T K.71 (2011), *Protection of customer antenna installations*.
- [b-IEC 60364] IEC 60364 (all parts), *Low-voltage electrical installations*.

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