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SERIES K: PROTECTION AGAINST INTERFERENCE

ITU-T K.21 – Rationale for setting resistibility requirements of telecommunication equipment installed in customer premises against lightning

ITU-T K-series Recommendations – Supplement 21

Supplement 21 to ITU-T K-series Recommendations

ITU-T K.21 – Rationale for setting resistibility requirements of telecommunication equipment installed in customer premises against lightning

Summary

Supplement 21 to ITU-T K-series Recommendations includes the technical information (rationale) on resistibility against lightning contained in Recommendation ITU-T K.21, "*Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*".

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T K Suppl. 21	2020-10-23	5	11.1002/1000/14579
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Keywords

ITU-T K.21, ITU-T K.44, customer premises, lightning, resistibility, telecommunication equipment.

* 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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ITU-T K.21 – Rationale for setting resistibility requirements of telecommunication equipment installed in customer premises against lightning

1 Scope

This Supplement provides technical information (rationale) for setting the resistibility requirements against lightning contained in [ITU-T K.21]. This information should be referred to in the case of revision of [ITU-T K.21]. The rationale described in this Supplement is mainly quoted from past contributions and other documents discussed in ITU-T SG5 at the stage of establishment and revision of [ITU-T K.21].

This is a living document in that the rational justifying any future changes in [ITU-T K.21] testing should be added to this Supplement.

This Supplement references the tables, test numbers and test conditions found in [ITU-T K.21]. Rational information for the [ITU-T K.21] test values originates from various events, surveys, standards and ITU-T SG5 contributions.

2 References

[ITU-T K.21] Recommendation ITU-T K.21 (2019), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

[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*.

[ITU-T K.98] Recommendation ITU-T K.98 (2014), *Overvoltage protection guide for telecommunication equipment installed in customer premises*.

[ITU-T K.99] Recommendation ITU-T K.99 (2017), *Surge protective component application guide - Gas discharge tubes*.

[ITU-T K.126] Recommendation ITU-T K.126 (2017), *Surge protective component application guide – High frequency signal isolation transformers*.

[ITU-T K.143] Recommendation ITU-T K.143 (2019), *Guidance on safety relating to the use of surge protective devices and surge protective components in telecommunication terminal equipment*.

[IEC 60664-1] IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*.

[IEC 60950-1] IEC 60950-1:2001, *Information technology equipment – Safety – Part 1: General requirements*.

[IEEE 802.3] IEEE 802.3-2012, *IEEE Standard for Ethernet*

[Handbook] ITU-T Handbook (1995), *The Protection of Telecommunication Lines and Equipment Against Lightning Discharges* – Chapters 9 and 10.

[Koga] *Lightning Surge Waves Induced in Transmission Lines* (1981), Hiroaki Koga, Tamio Motomitsu, Morihiko Taguchi, Review of the Electrical Communication Laboratories, Volume 29, Numbers 7-8, July-August.

[Miyazaki] Teru Miyazaki, Shigemitsu Okabe, Kiyoshi Aiba, Takao Hirai, Jun Yoshinaga (2007), *A Lightning Surge Analysis for the Rationalization of the Ground System in Power Distribution Lines*, IEEJ Trans. PE, Vol. 127, No. 2.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses terms defined in [ITU-T K.21].

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

a.c. Alternating Current

CWG Combination Wave Generator

d.c. Direct Current

dpf Dedicated Power Feed

n/a Not Applicable

PoE Power over Ethernet

STP_E Ethernet Shielded Twisted Pair

USB Universal Serial Bus

UTP_E Ethernet Unshielded Twisted Pair

5 Conventions

The numbering of tables and figures in this Supplement corresponds to the test numbers in [ITU-T K.21].

6 Rationale

Table 1a and Table 1b, adapted from [ITU-T K.21], show references to clause numbers containing the rationale with each test number in [ITU-T K.21]. These tables (Table 1a and Table 1b) have the same table structure as Table 1a and Table 1b of [ITU-T K.21], for external ports and internal ports respectively.

Table 1a – Reference to rationale for each test item – ports connected to external cables

Test type	No. of pairs simultaneously tested	Test connections	Primary protection	Port / Reference to rationale - Test No. in [ITU-T K.21]			
				Symmetric port	Co-axial port	Dedicated power feed port	Mains power port
Lightning/ voltage	Single	Transverse/ differential	No	Not clarified (2.1.1a)	Not clarified (3.1.1)	Not clarified (4.1.1a)	Not clarified (5.1.1a)
		Port to earth	No	Clause 6.1.1 (2.1.1b)	n/a	Clause 6.1.3 (4.1.1b)	Clause 6.1.4 (5.1.1b)

Table 1a – Reference to rationale for each test item – ports connected to external cables

Test type	No. of pairs simultaneously tested	Test connections	Primary protection	Port / Reference to rationale - Test No. in [ITU-T K.21]			
				Symmetric port	**Co-axial port**	**Dedicated power feed port**	**Mains power port**
		Port to external port	No	Clause 6.1.1 (2.1.1c)	n/a	Clause 6.1.3 (4.1.1c)	Clause 6.1.4 (5.1.1c)
		Coordination /Transverse/ differential	Yes	Not clarified (2.1.2a)	Not clarified (3.1.2)	Not clarified (4.1.2a)	Not clarified (5.1.2a)
		Coordination /Port to earth	Yes	Clause 6.1.1 (2.1.2b)	n/a	Clause 6.1.3 (4.1.2b)	Clause 6.1.4 (5.1.2b)
		Coordination /Port to external port	Yes	Clause 6.1.1 (2.1.2c)	n/a	Clause 6.1.3 (4.1.2c)	Clause 6.1.4 (5.1.2c)
	Multiple	Port to earth	No	Clause 6.1.1 (2.1.3a)	n/a	n/a	n/a
		Port to external port	No	Clause 6.1.1 (2.1.3b)	n/a	n/a	n/a
		Port to earth	Yes	Clause 6.1.1 (2.1.4a)	n/a	n/a	n/a
		Port to external port	Yes	Clause 6.1.1 (2.1.4b)	n/a	n/a	n/a
	Ethernet unshielded twisted pair (UTP_E)	Port to earth	No	Clause 6.1.1 (2.1.8)	n/a	n/a	n/a
		Transverse	No	Clause 6.1.1 (2.1.7)	n/a	n/a	n/a
		Voltage impulse test	No	Clause 6.1.1 (2.1.10)	n/a	n/a	n/a
		Power over Ethernet (PoE)	No	Not clarified (2.1.11)	n/a	n/a	n/a
	Ethernet shielded twisted pair (STP_E)	Shield to earth	No	Clause 6.1.1 (2.1.9)		n/a	n/a
		Port to earth	No	Clause 6.1.1 (2.1.8)		n/a	n/a
Lightning current	Single	Port to earth	No	Not clarified (2.1.5a)	n/a	Not clarified (4.1.5a)	n/a
		Port to external port	No	Not clarified (2.1.5b)	n/a	Not clarified (4.1.5b)	n/a
	Multiple	Port to earth	No	Not clarified (2.1.6a, 2.1.10)	n/a	n/a	n/a
		Port to external port	No	Not clarified (2.1.6b)	n/a	n/a	n/a
		Differential	n/a	n/a	Not clarified (3.1.3)	n/a	n/a
		Shield to earth	n/a	n/a	Not clarified (3.1.4)	n/a	n/a
		Shield to external port	n/a	n/a	Not clarified (3.1.5)	n/a	n/a
n/a That test is not applicable to that port in [ITU-T K.21].							

Table 1b – Reference to rationale for each test item – internal port

No. of pairs simultaneously tested	Test connection	Primary protection	Port / Reference to rationale - Test No. extracted from [ITU-T K.21]				
			Unshielded cable	Shielded cable	PoE power feed	DC powered equipment	DC power source
Single	Shielded cable to earth	No		Not clarified (7.2)			
	USB shielded cable to earth	No		Clause 6.2 (7.3)			
	STP_E simultaneous port to earth	No		Clause 6.2 (7.4)			
	UTP_E/STP_E transverse	No	Clause 6.2 (7.7)	Clause 6.2 (7.7)			
	DC powered equipment port	No				Not clarified (7.8)	
	DC power source port	No					Not clarified (7.9)
Multiple	Unshielded cable with symmetric pairs	No	Not clarified (7.1)				
	PoE Mode A and Mode B transverse testing	No			Not clarified (7.5)		
	UTP_E port rated impulse voltage	No	Clause 6.2 (7.6)				

6.1 Ports connected to external cables

6.1.1 External symmetric pair cables

Table 2a shows the references to the rationale shown in Table 2b for ports connected to external symmetric pair cables.

Table 2a – Reference to rationale for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
2.1.1b	Single pair, lightning, inherent, port to earth	A.3-1 and A.6.1-2 10/700	Basic	$U_{c(max)}$ = 1.5 kV R = 25 Ω	Table 2b No.1, No.2, No.3
			Enhanced	$U_{c(max)}$ = 6 kV R = 25 Ω	Table 2b No.2, No.3
2.1.1c	Single pair, lightning,		Basic	$U_{c(max)}$ = 1.5 kV R = 25 Ω	Table 2b No.4

Table 2a – Reference to rationale for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
	inherent, port to external port	A.3-1 and A.6.1-3 10/700	Enhanced	$U_{c(max)}$ = 6 kV R = 25 Ω	
2.1.2b	Single pair, lightning, co-ordination, port to earth	A.3-1 and A.6.1-2 10/700	Basic	$U_{c(max)}$ = 4.0 kV R = 25 Ω	To be clarified.
			Enhanced	$U_{c(max)}$ = 6.0 kV R = 25 Ω	Table 2b No.5
			Special	$U_{c(max)}$ = 13 kV R = 25 Ω, R1 = 100 Ω	Table 2b No.2, No.3
2.1.2c	Single pair, lightning, coordination, port to external port	A.3-1 and A.6.1-3 10/700	Basic	$U_{c(max)}$ = 4.0 kV R = 25 Ω	To be clarified.
			Enhanced	$U_{c(max)}$ = 6.0 kV R = 25 Ω	Table 2b No.4
			Special	$U_{c(max)}$ = 13 kV R = 25 Ω, R1 = 100 Ω	Table 2b No.4
2.1.3a	Multiple pair, lightning, inherent, port to earth	A.3-1 and A.6.1-4 10/700	Basic	$U_{c(max)}$ = 1.5 kV R = 25 Ω	Table 2b No.6
2.1.3b	Multiple pair, lightning, inherent, port to external port	A.3-1 and A.6.1-5 10/705	Basic	$U_{c(max)}$ = 1.5 kV R = 25 Ω	Table 2b No.4
2.1.4a	Multiple pair, lightning, port to earth	A.3-1 and A.6.1-4 10/700	Enhanced	$U_{c(max)}$ = 6.0 kV R = 25 Ω	Table 2b No.6
2.1.4b	Multiple pair, lightning, port to external port	A.3-1 and A.6.1-5 10/705	Enhanced	$U_{c(max)}$ = 6.0 kV R = 25 Ω	Table 2b No.4
2.1.7	Ethernet transverse/ differential	A.3-5 and A.6.7-5 1.2/50-8/20 CWG R_1 = 10 Ω and R_2 = 10 Ω	Basic	$U_{c(max)}$ = 2.5 kV	Table 2b No.11, No.12, No.13
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 2b No.11, No.12, No.13
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 Ω	Basic	$U_{c(max)}$ = 2.5 kV	Table 2b No.7, No.9, No.10
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 2b No.7, No.8, No.10

Table 2a – Reference to rationale for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
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 Ω	Basic	$U_{c(max)}$ = 2.5 kV	Table 2b No.7, No.9, No.10
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 2b No.7, No.8, No.10
2.1.10	UTP_E port rated impulse voltage test	A.3-5 and A.6.7-3a 1.2/50-8/20 CWG R = 5 Ω	Basic	$U_{c(max)}$ = 2.5 kV	Table 2b No.7, No.9, No.10
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 2b No.7, No.8, No.10

Table 2b – Rationale for ports connected to external symmetric pair cables

No.	Source	Rationale	Added date of rationale
1	[ITU-T K.66] Clause 7 "Objectives for bonding configurations and earthing"	Quoted from source document; To coordinate with the requirements of [IEC 60950-1], it is necessary to prevent the potential difference which can occur between the symmetric pair conductor and other metallic parts, within the premises, from exceeding 1.5 kV for the majority of di/dt expected to occur. Figures III.1 to III.4 show that this voltage is affected by the individual voltage drops occurring across bonding conductors. The requirements for earthing and bonding given in this Recommendation will achieve the objective of preventing the voltage between the telecommunication conductor and the MET from exceeding 1.5 kV for the majority of di/dt expected to occur.	5/2019
2	[Koga] Clause 4.3.1 "Lightning Surge Voltage Distribution"	Quoted from source document; Subscriber end. $Ns = 0.6 * 10^5 * V^{-1.8}$ (See the solid line in Figure 1 of this Supplement.)	9/2019
3	[Handbook] Chapter 10 "Overvoltages and overcurrents measured on telecommunication subscriber lines"	Quoted from source document; Table 10-4 "Voltage end current occurrences in rural area" Table 10-5 "Voltage end current occurrences in urban/suburban area" (See "Subscriber end – voltage" in Figure 2 and Figure 3 of this Supplement.)	3/2020
4	Agreed in SG5	This "port to external port" test level is in line with "port to earth" test level, because this test is specified considering the situation that a port of	3/2020

Table 2b – Rationale for ports connected to external symmetric pair cables

No.	Source	Rationale	Added date of rationale
		equipment is exposed to overvoltage and the potential of the other port is referenced to local line.	
5	Agreed in SG5	This enhanced level of "co-ordination test" (2.1.2b of [ITU-T K.21]) is in line with enhanced test level of "inherent" test (2.1.1b of [ITU-T K.21]), because in the environment where enhanced level is applied, there are the case that primary protector is not normally installed or equipotential bonding at customer premises is difficult to achieve.	3/2020
6	Agreed in SG5	This "Multiple pair port" test level is in line with "Single pair port" test level. And also the value of current limiting resistors R is as the same value as "Single pair port" test regardless of the number of pairs, because this constant resister value retains some extent of surge current even when a switching type SPC on the port operates.	3/2020
7	Agreed in SG5	This test level for Ethernet port is in line with the test level of "Mains power port, lightning, inherent, port to earth (5.1.1b of [ITU-T K.21])"; 2.5 kV (Basic), 6.0 kV (Enhanced).	3/2020
8	Damage to Equipment in the US, ITU-T Study Group 5 Technical Session on Home Networks, Geneva, 29/04/2011	Quoted from source document; For severe environments 5 kV isn't enough. One solution being pursued is to use a 5 kV rms withstand transformer to give a 7 kV impulse withstand barrier.	3/2020
9	[IEEE 802.3] Clause 25.4.6 "UTP isolation requirement"	Quoted from source document; This electrical isolation shall withstand at least one of the following electrical strength tests. c) A sequence of ten 2400 V impulse alternative polarity, applied at intervals of not less than 1 s. The shape of the impulse shall be 1.2/50 µsec (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in [IEC 60950-1] Annex N	3/2020
10	[ITU-T K.98]	Quoted from source document; Annex A "Simulations" A.2.1 TN-S Power System "The surge voltage on the mains conductors will cause a flashover of the mains transformer, telecommunication port isolation and the Ethernet port. The resulting surge current entering the mains port will exit via the telecommunication and Ethernet ports, thus damaging all".	3/2020
11	Agreed in SG5	This transverse/differential test level for Ethernet port is in line with that of "2.1.10 UTP_E port rated impulse voltage test", because this test is specified as the worst case that an entire common mode surge converted to transverse/differential mode. However, the current value is adjusted by the capacitor C1 in the test schematic (see Figure 4) considering the surge current that appears on the secondary side of pulse transformer, etc.	5/2021

Table 2b – Rationale for ports connected to external symmetric pair cables

No.	Source	Rationale	Added date of rationale
12	[ITU-T K.99] Appendix IV "Three-electrode GDT operation in Ethernet circuits" Clause IV.2.2 GDT operation	Quoted from source document; Figure IV.2* substitutes the port magnetics for a low value resistor, R_{AB}, which effectively shunts the 3-electrode GDT outer A and B connected electrodes together. A common mode surge is applied via two current limiting resistors, R_A and R_B to the port and GDT. If the GDT electrode connected to B is the first to spark-over, it draws current, I_B, from the B conductor and current, I_A, from the A conductor via the resistance R_{AB}, see Figure IV.3**. * See Figure 5 in this document. ** See Figure 6 in this document.	5/2021
13	[ITU-T K.126] Clause 9.4 Differential-mode primary winding surge	Quoted from source document; 9.4.2 Saturating core transformer surge conditions Under differential surge conditions, see Figure 9-10*, a saturating core signal transformer has a secondary winding surge let-through current, I_S, that is typically triangular and can be described by three surge waveform parameters of front, peak and decay as follows: – Waveform **front** due to transformer linear surge current transfer from primary winding to secondary winding, the current ratio being set by the transformer's primary to secondary turn's ratio, n. – Waveform **peak** determined by the transformer core saturation event setting the peak secondary current, the event time being set by the transformer's volt–second (V·s) value for core saturation. – Waveform **decay** due to the saturated core secondary winding stored energy dump, the current waveform of which is set by the transformer saturated core winding inductance, the secondary leakage inductance, the peak secondary current, the secondary winding resistance and the secondary load impedance. Figure 9-9** shows an example waveform with the three waveform parameters indicated. 9.4.6 Basic and enhanced test levels Figure 9-13*** shows an example of the different secondary currents at the ITU-T basic (2.5 kV) and enhanced (6 kV) levels. * See Figure 7 in this document. ** See Figure 8 in this document. *** See Figure 9 in this document.	5/2021

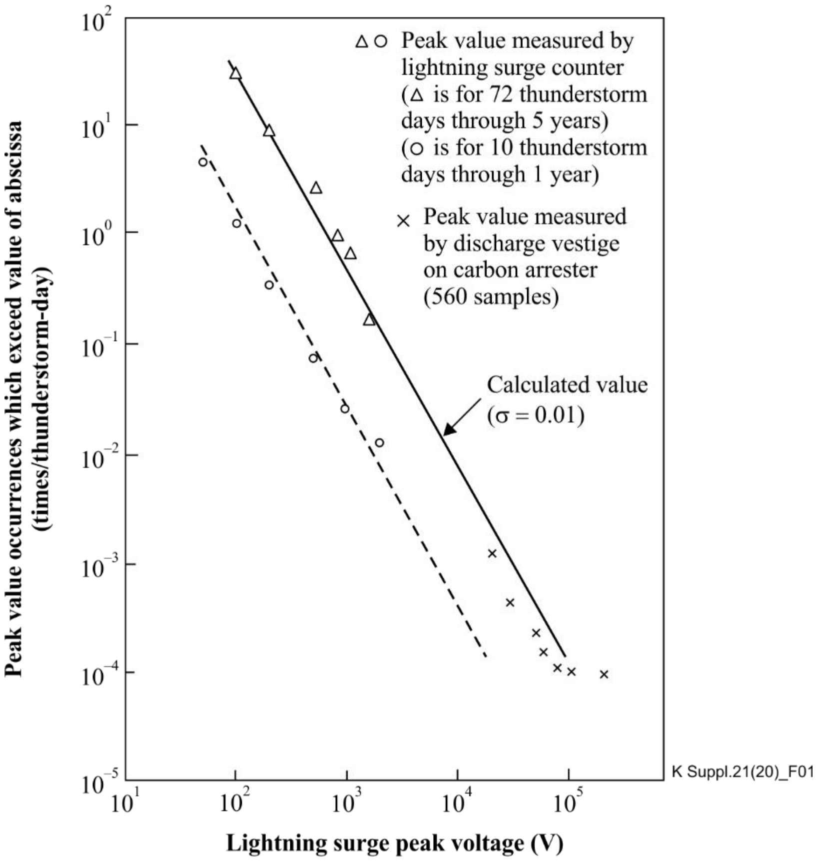


Figure 1 – Peak voltage distribution

Voltage end current occurrences in rural area

Location		**Voltage and current occurrences: N_i (Time/year · lines)**	**Soil resistivity (Ω · m)**	**Average length l (m)**	**Number of lines**
Exchange end	Voltage	F: $N_{1v} = 1.3 \cdot 10^5 \cdot T_d \cdot V_p^{-2.1}$ D: $N_{1v} = 4.4 \cdot 10^5 \cdot T_d \cdot V_p^{-2.1}$ I: $N_{1v} = 1.5 \cdot 10^4 \cdot T_d \cdot V_p^{-1.7}$ J: $N_{1v} = 12.5 \cdot 10^3 \cdot T_d \cdot V_p^{-2}$ USA: $N_{1v} = 5.7 \cdot 10^5 \cdot T_d \cdot V_p^{-2.1}$	~300 30-60 900 30-100 700-8000	6 200 5 000 4 500 4 400 12 750	54 18 9 10 1
	Current	I: $N_{1i} = 7.3 \cdot T_d \cdot I_p^{-1.1}$ J: $N_{1i} = 1.2 \cdot T_d \cdot I_p^{-1.8}$ USA: $N_{1i} = 1.9 \cdot T_d \cdot I_p^{-1.2}$	1500 30-100 700-8000	6 725 3 000 12 750	2 100 1
Subscriber end	Voltage	I: $N_{2v} = 2.3 \cdot 10^5 \cdot T_d \cdot V_p^{-1.8}$ J: $N_{2v} = 1.05 \cdot 10^5 \cdot T_d \cdot V_p^{-1.8}$ USA: $N_{2v} = 5.3 \cdot 10^5 \cdot T_d \cdot V_p^{-1.8}$	875 30-100 ~700	3 800 4 400 11 700	12 10 3
	Current	I: $N_{2i} = 43.3 \cdot T_d \cdot I_p^{-1.55}$ J: $N_{2i} = 11 \cdot T_d \cdot I_p^{-1.8}$ USA: $N_{2i} = 26 \cdot T_d \cdot I_p^{-1.45}$	1000 50-100 ~700	4 000 3 000 11 700	5 100 3

(Labelled: France (F), Germany (D), Italy (I), Japan (J) and the United States of America (USA))

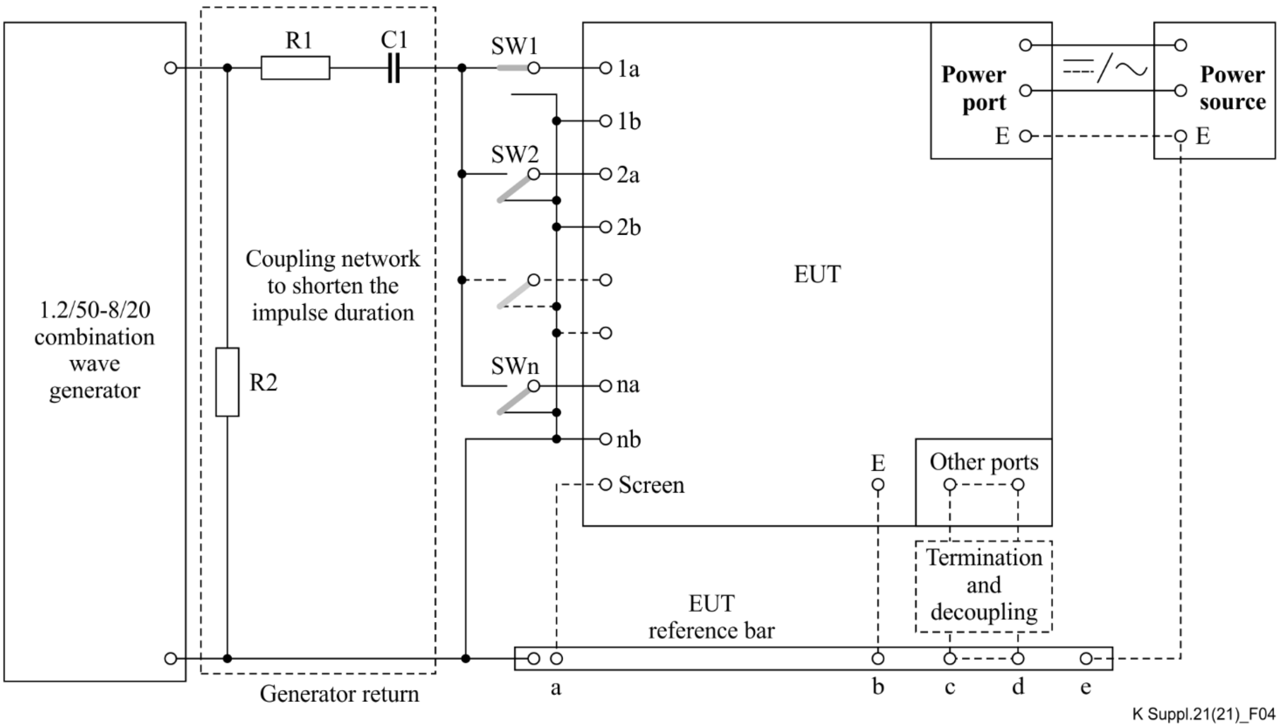
Figure 2 – Voltage end current occurrences in rural area

Voltage end current occurrences in urban/suburban area

Location	Voltage and current occurrences: N_i (Time/year · lines)		Soil resistivity (Ω · m)	Average length l (m)	Number of lines
Exchange end: Voltage	Suburban Urban	D: $N_{1v} = 5.2 \cdot 10^4 \cdot T_d \cdot V_p^{-2.1}$ D: $N_{1v} = 5.8 \cdot 10^3 \cdot T_d \cdot V_p^{-2.1}$	30-60 30-60	3200 1200	34 19
Exchange and Subscriber end: Current	Urban/ Suburban	CAN: $N_{2i} = 1.4 \cdot 10^{-2} \cdot T_d \cdot I_p^{-0.8}$	10-1000		2350

(Labelled: Canada (CAN), Germany (D))

Figure 3 – Voltage end current occurrences in urban/suburban area



Twisted pair terminal pairs are 1a + 1b, 2a + 2b through to na + nb served by switches SW1, SW2 through to SWn, respectively.

For each terminal pair, when the switch is up one terminal is connected to the coupling network. When the switch is down that terminal is connected to functional earth.

a = RJ45 screen cable connection for STPE connections

b = EUT protective or functional earth connection

c to d = Terminals of all other signal ports

R1 = R2 = 10 Ω

C1 = 0.5 µF, ±10 %, 5 kV, equivalent series resistance (ESR) < 0.5 Ω, inductance < 1 µH, different parasitic values are acceptable provided Note 3 conditions are met.

NOTE 1 – This test is conducted on each terminal pair selected by having that pair switch up and the remaining switches down. Surging is done with alternating polarities.

NOTE 2 – This circuit shorts out an injector device or power sourcing equipment power supply. IEEE 802.3 compliant power supplies will not be damaged by this condition.

NOTE 3 – The initial rate of rise of the short circuit current, di/dt, at 2.5 kV generator charging voltage shall be 60 A/µs ±10 A/µs in the first 0.5 µs.

Figure 4 – Twisted pair transverse/differential surge test circuit for ports having one or more twisted pair connections such as Ethernet ports, including PoE variants (Figure A.6.7-5 in [ITU-T K.44])

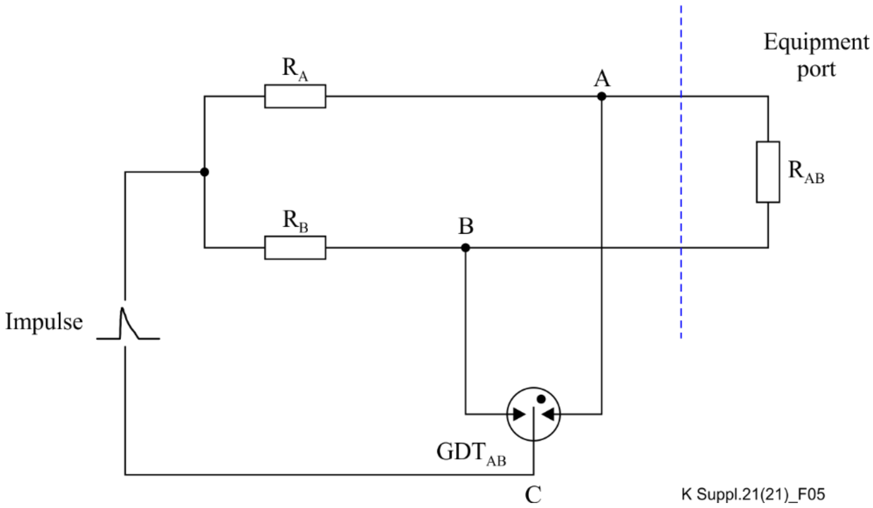


Figure 5 – Equivalent circuit under common-mode surge conditions (Figure IV.2 in [ITU-T K.99])

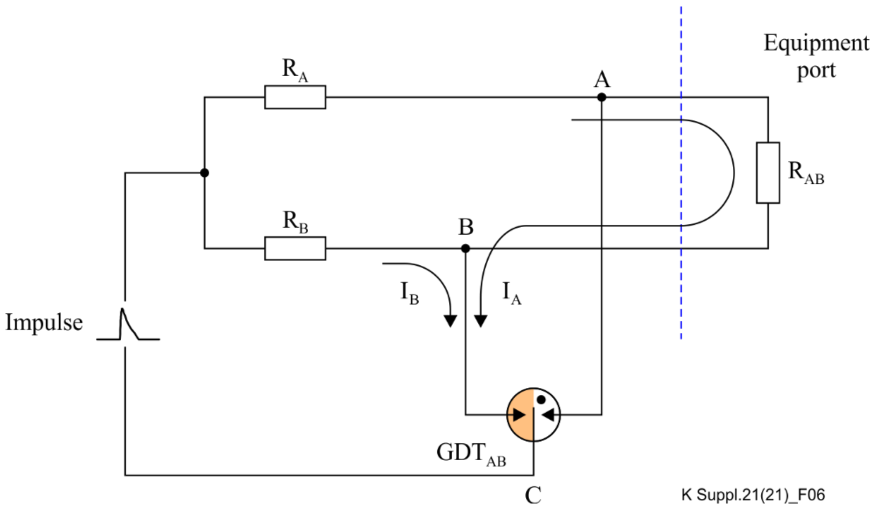
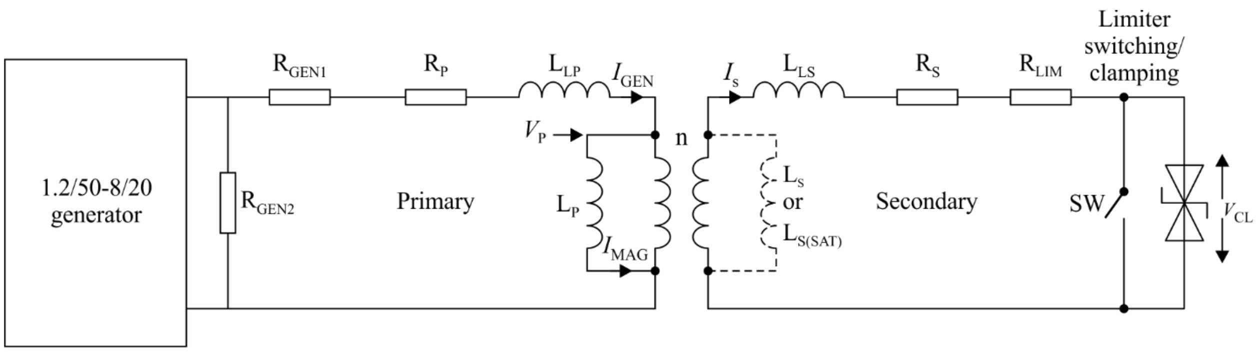


Figure 6 – Circuit currents when electrode connected to B is first to spark-over (Figure IV.3 in [ITU-T K.99])



- R_p Primary winding resistance
- L_{LP} Primary leakage inductance
- R_{GEN} Series resistance from generator
- V_P Primary voltage
- C_{P-S} Inter-winding capacitance
- I_{GEN} Generator current
- I_{MAG} Magnetising current
- L_P Primary magnetising inductance
- R_S Secondary winding resistance
- L_{LS} Secondary leakage inductance
- R_{LIM} Series resistance to limiter
- SW Switching voltage limiter
- V_{CL} Clamping limiter voltage
- L_S Secondary inductance
- n Transformer turns ratio
- $L_{S(SAT)}$ Saturated core secondary inductance

Figure 7 – Effective secondary circuit for differential surge (Figure 9-10 in [ITU-T K.126])

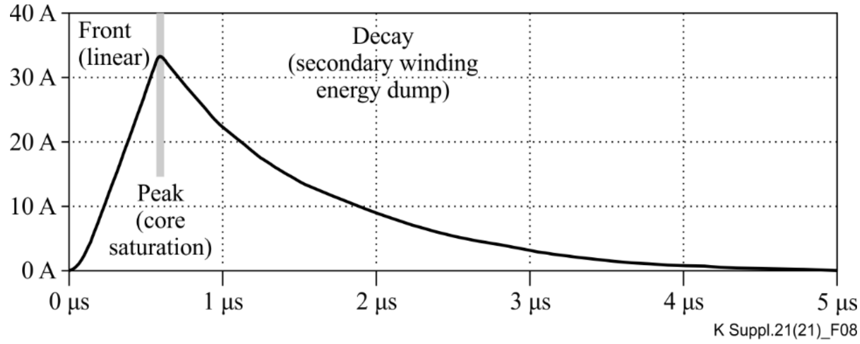


Figure 8 – Example waveform of transformer secondary winding differential surge let-through current (Figure 9-9 in [ITU-T K.126])

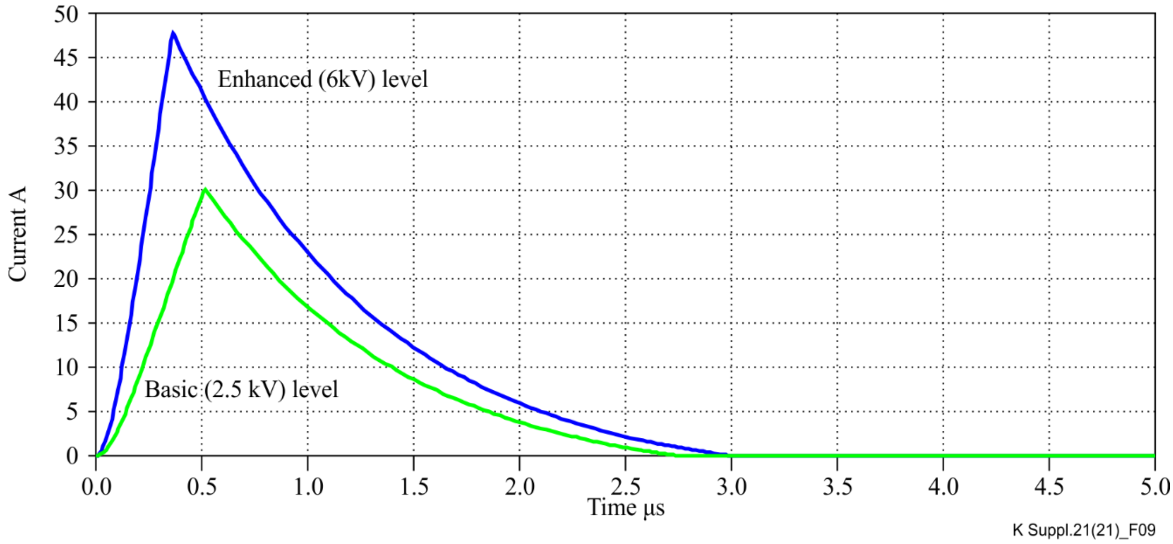


Figure 9 – An example of current levels that appears on secondary side of transformer at Basic and Enhanced test (NOT a test waveform itself) (Figure 9-13 "Basic and enhanced secondary current levels" in [ITU-T K.126])

6.1.2 Lightning test for ports connected to external coaxial cables

Table 3 shows the references to rationale for ports connected to external coaxial cables.

Table 3 – Reference to rationale for ports connected to external symmetric pair cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
3.1.1	Lightning, inherent, differential	A.3-5 and A.6.2-1 1.2/50 – 8/20 CWG	Basic	$U_{c(max)}$ = 1.0 kV R = 0 Ω	To be clarified.
			Enhanced	$U_{c(max)}$ = 1.5 kV R = 0 Ω	To be clarified.
3.1.2	Lightning, co-ordination, differential	A.3-5 and A.6.2-1 1.2/50 – 8/20 CWG	Basic	$U_{c(max)}$ = 4.0 kV R = 0 Ω	To be clarified.
			Enhanced	$U_{c(max)}$ = 6.0 kV R = 0 Ω	To be clarified.
3.1.3	Lightning, current, differential	A.3-4 and A.6.2-1 8/20	Basic	I = 1.0 kA	To be clarified.
			Enhanced	I = 5.0 kA	To be clarified.
3.1.4	Lightning, shield test, port to earth	A.3-4 and A.6.2-2 8/20	Basic	I = 4.0 kA (Note 1) I = 2.0 kA (Note 2)	To be clarified.
			Enhanced	I = 20.0 kA (Note 1) I = 5.0 kA (Note 2)	To be clarified.
3.1.5	Lightning, shield, port to external port	A.3-4 and A.6.2-3 8/20	Basic	I = 4.0 kA (Note 1) I = 2.0 kA (Note 2)	To be clarified.
			Enhanced	I = 20.0 kA (Note 1) I = 5.0 kA (Note 2)	To be clarified.
NOTE 1 – Equipment designed to be connected to antennas or equipment exposed to direct lightning currents, e.g., connected to antennas or equipment mounted on a tower. NOTE 2 – Applicable equipment not covered by NOTE 1.					

6.1.3 Lightning test for ports connected to external d.c. or a.c. dedicated power feeding cables

Table 4a shows the references to the rationale shown in Table 4b for ports connected to external d.c. or a.c. dedicated power feeding cables.

Table 4a – Reference to rationale for ports connected to external d.c. or a.c. dedicated power feeding cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
4.1.1b	Single pair, lightning, inherent, port to earth	A.3-1 and A.6.3-2 10/700	Basic	$U_{c(max)}$ = 1.5 kV R = 25 Ω	Table 4b No.1
			Enhanced	$U_{c(max)}$ = 6 kV R = 25 Ω	
4.1.1c	Single pair, lightning, inherent, port to external port	A.3-1 and A.6.3-3 10/700	Basic	$U_{c(max)}$ = 1.5 kV R = 25 Ω	Table 4b No.1
			Enhanced	$U_{c(max)}$ = 6 kV R = 25 Ω	

Table 4a – Reference to rationale for ports connected to external d.c. or a.c. dedicated power feeding cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
4.1.2b	Single pair, lightning, co-ordination, port to earth	A.3-1 and A.6.3-2 10/700	Enhanced	$U_{c(max)}$ = 6.0 kV R = 25 Ω	Table 4b No.1
4.1.2c	Single pair, lightning, co-ordination, port to external port	A.3-1 and A.6.3-3 10/700	Enhanced	$U_{c(max)}$ = 6.0 kV R = 25 Ω	Table 4b No.1

Table 4b – Rationale for ports connected to external d.c. or a.c. dedicated power feeding cables

No.	Source	Rationale	Added date of rationale
1	Agreed in SG5	This test level for ports connected to external d.c. or a.c. dedicated power feeding cables is in line with the test levels of the port connected to external symmetric pair cables.	3/2020

6.1.4 Test for mains power ports

Table 5a shows the references to the rationale shown in Table 5b for mains power ports.

Table 5a – Reference to rationale for mains power ports

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
5.1.1b	Lightning, inherent, port to earth	A.3-5 and A.6.4-2 1.2/50-8/20 CWG	Basic	$U_{c(max)}$ = 2.5 kV R = 0 Ω	Table 5b No.1, No.2 , No.3
			Enhanced	$U_{c(max)}$ = 6.0 kV R = 0 Ω	Table 5b No.1, No.2, No.3
5.1.1c	Lightning, inherent, port to external port	A.3-5 and A.6.4-3 1.2/50-8/20 CWG	Basic	$U_{c(max)}$ = 2.5 kV R = 0 Ω	Table 5b No.1, No.2, No.3, No.5
			Enhanced	$U_{c(max)}$ = 6.0 kV R = 0 Ω	Table 5b No.1, No.2, No.3 No.5
5.1.2b	Lightning, inherent/co-ordination, port to earth	A.3-5 and A.6.4-2 1.2/50-8/20 CWG	Basic	$U_{c(max)}$ = 6.0 kV R = 0 Ω	Table 5b No.1, No.2, No.3
			Enhanced	$U_{c(max)}$ = 10.0 kV R = 0 Ω	Table 5b No.1, No.2, No.4
5.1.2c	Lightning, inherent/co-ordination, port to external port	A.3-5 and A.6.4-3 1.2/50-8/20 CWG	Basic	$U_{c(max)}$ = 6.0 kV R = 0 Ω	Table 5b No.1, No.2, No.3, No.5
			Enhanced	$U_{c(max)}$ = 10.0 kV R = 0 Ω	Table 5b No.1, No.2, No.4, No.5

Table 5b – Rationale for mains power ports

No.	Source	Rationale	Added date of rationale
1	[ITU-T K.143]	Quoted from source document; Fig. 5 "Occurrence rate of lightning voltage on LV power distribution line" (See Figure 10 of this Supplement) "The occurrence rate for lightning surges on low-voltage (LV) power distribution lines in Japan is shown in Figure 5".	10/2020
2	[Miyazaki]	Quoted from source document; Fig.6 "Distribution of voltage at low-voltage line" (See Figure 11 of this Supplement)	10/2020
3	[IEC 60664-1]	Table F.1 "Rated impulse voltage for equipment energized directly from the low-voltage mains" Rated impulse voltage: 2500 V for "Overvoltage category II" and 6000 V for "Overvoltage category IV" on "Voltage line to neutral derived from nominal voltages a.c. or d.c. more than 150 V and up to and including 300 V" Quoted from source document; "Equipment of overvoltage category II is energy-consuming equipment to be supplied from the fixed installation. NOTE – Examples of such equipment are appliances, portable tools and other household and similar loads." "Equipment of overvoltage category IV is for use at the origin of the installation. NOTE – Examples of such equipment are electricity meters and primary overcurrent protection equipment."	10/2020
4	Agreed in SG5	In February 2000, SG5 discussed this resistibility level based on the experience that an European telecommunication operator needed to specify this level as their company standard in order to achieve acceptable failure rate of their equipment. This level applied to the draft of [ITU-T K.21] attached to the report of that SG5 meeting.	10/2020
5	Agreed in SG5	This "port to external port" test level is in line with "port to earth" test level, because this test is specified considering the situation that a port of equipment is exposed to overvoltage and the potential of the other port is referenced to local line.	10/2020

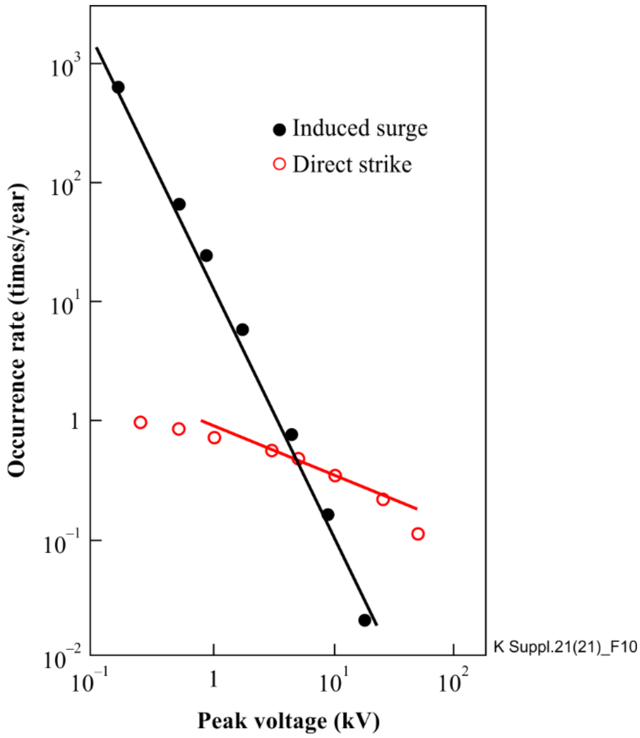


Figure 10 – Occurrence rate of lightning voltage on LV power distribution line

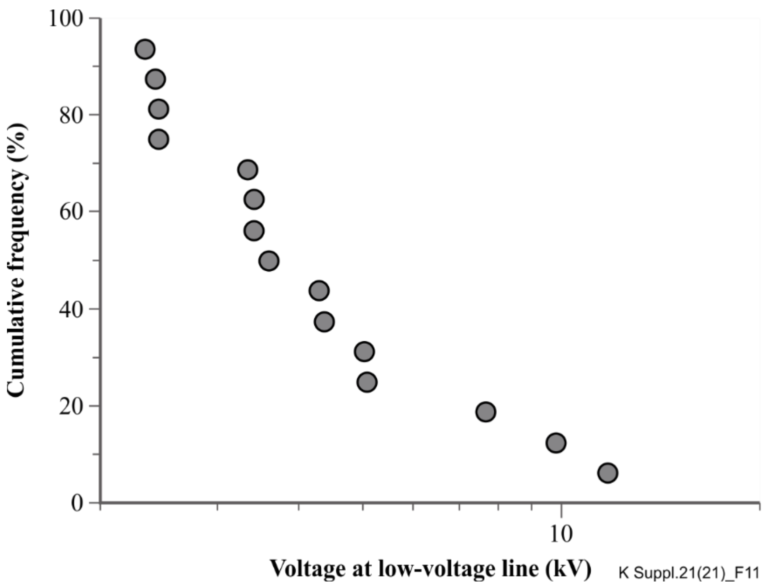


Figure 11 – Distribution of voltage at low-voltage line in Japan

6.2 Ports connected to internal cables

Table 6a shows the references to the rationale shown in Table 6b for ports connected to internal cables.

Table 6a – Reference to rationale for ports connected to internal symmetric pair cables

Test no.	Test description	Test circuit and waveform	Test levels		Reference to rationale
7.3	USB shielded cable to earth	A.3-5 and A.6.5-2 1.2/50-8/20 CWG R = 0 Ω	Basic	$U_{c(max)}$ = 100 V	To be clarified.
			Enhanced	$U_{c(max)}$ = 150 V	
7.4	Screen/shield connection high current test	A.3-5 and A.6.7-3a 1.2/50-8/20 CWG R = 5 Ω	Basic	$U_{c(max)}$ = 2.5 kV	Table 6b No.3, No.4, No.5
			Intermediate	$U_{c(max)}$ = 4.0 kV	Table 6b No.6, No.7
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 6b No.1, No.2, No.4, No.5
7.6	Ethernet longitudinal/common mode withstand test	A.3-5 and A.6.7-3a 1.2/50-8/20 CWG R = 5 Ω	Basic	$U_{c(max)}$ = 2.5 kV	Table 6b No.3, No.4, No.5
			Intermediate	$U_{c(max)}$ = 4.0 kV	Table 6b No.6, No.7
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 6b No.1, No.2, No.4, No.5
7.7	Ethernet transverse/ differential	A.3-5 and A.6.7-5 1.2/50-8/20 CWG	Basic	$U_{c(max)}$ = 2.5 kV	Table 6b No.8, No.9, No.10
			Intermediate	$U_{c(max)}$ = 4.0 kV	Table 6b No.8, No.9, No.10
			Enhanced	$U_{c(max)}$ = 6.0 kV	Table 6b No.8, No.9, No.10
7.8	DC powered equipment port	A.3-5 (1.2/50-8/20 CWG) and A.6.6-1a Coupling element: 10 Ω + 9 µF in series	Basic	$U_{c(max)}$ = 1.0 kV	To be clarified.
			Enhanced	$U_{c(max)}$ = 1.5 kV	
7.9	DC power source port	A.3-5 (1.2/50-8/20 CWG) and A.6.6-1b Coupling element: 10 Ω + 9 µF in series	Basic	$U_{c(max)}$ = 1.0 kV	To be clarified.

Table 6b – Rationale for ports connected to internal symmetric pair cables

No.	Source	Rationale	Added date of rationale
1	Damage to Equipment in the US, ITU-T Study Group 5 Technical Session on Home Networks, Geneva, 29/04/2011	Quoted from source document; For severe environments 5 kV is not enough. One solution being pursued is to use a 5 kV rms withstand transformer to give a 7 kV impulse withstand barrier.	5/2019

Table 6b – Rationale for ports connected to internal symmetric pair cables

No.	Source	Rationale	Added date of rationale
2	Damage to equipment in Japan, ITU-T Study Group 5 Technical Session on Home Networks, Geneva, 29/04/2011	Quoted from source document; Failure rates is over 0.1%@2 kV and 0.01%@7 kV. Adequate test levels is needed for Internal Port to Internal Port for ONT/HGW	5/2019
3	[IEEE 802.3] Clause 25.4.6 "UTP isolation requirement"	Quoted from source document; This electrical isolation shall withstand at least one of the following electrical strength tests. c) A sequence of ten 2400 V impulse alternative polarity, applied at intervals of not less than 1 s. The shape of the impulse shall be 1.2/50 µsec (1.2 µs virtual front time, 50 µs virtual time of half value), as defined in [IEC 60950-1] Annex N	9/2019
4	[ITU-T K.98]	Quoted from source document; Annex A "Simulations" A.2.1 TN-S Power System "The surge voltage on the mains conductors will cause a flashover of the mains transformer, telecommunication port isolation and the Ethernet port. The resulting surge current entering the mains port will exit via the telecommunication and Ethernet ports, thus damaging all."	9/2019
5	Agreed in SG5	This test level for Ethernet port is in line with the test level of "Mains power port, lightning, inherent, port to earth (5.1.1b of [ITU-T K.21])"; 2.5kV (Basic), 6.0kV (Enhanced).	3/2020
6	[ITU-T K.44]	Quoted from source document; 5 Resistibility requirements 5.2 Intermediate resistibility level "This resistibility requirement may be applied to the cases that the basic resistibility is not sufficient considering the aspects of environmental condition, and/or customer's requirement on reliability of service, nevertheless, the enhanced resistibility cannot be applied due to the cost. It has better resistibility than the basic requirement, and also it is achieved by relatively small cost addition and has a good price-performance ratio".	9/2019
7	[ITU-T K.21]	Table 7 – Lightning test conditions for ports connected to internal cables 7.6 Ethernet longitudinal/common mode withstand test Basic test levels: Uc(max) = 2.5 kV Enhanced test levels: Uc(max) = 6.0 kV	9/2019
8	Agreed in SG5	This transverse/differential test level for Ethernet port is in line with that of "7.6 Ethernet longitudinal/common mode withstand test", because this test is specified as the worst case that an entire common mode surge converted to transverse/differential mode. However, the current value is adjusted by the capacitor C1 in the test schematic (see Figure 4) considering current that appears on the secondary side of pulse transformer, etc.	5/2021

Table 6b – Rationale for ports connected to internal symmetric pair cables

No.	Source	Rationale	Added date of rationale
9	[ITU-T K.99] Appendix IV "Three-electrode GDT operation in Ethernet circuits" Clause IV.2.2 GDT operation	See No. 12 in Table 2b.	5/2021
10	[ITU-T K.126] Clause 9.4 Differential-mode primary winding surge	See No. 13 in Table 2b.	5/2021

7 Addition of rationale to this Supplement

Rationale for revision of Recommendation [ITU-T K.21] will be added in the case that [ITU-T K.21] is revised.

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