INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.44
(02/2000)

SERIES K: PROTECTION AGAINST INTERFERENCE

Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation

ITU-T Recommendation K.44

(Formerly CCITT Recommendation)

ITU-T RECOMMENDATION K.44

RESISTIBILITY TESTS FOR TELECOMMUNICATION EQUIPMENT EXPOSED TO OVERVOLTAGES AND OVERCURRENTS – BASIC RECOMMENDATION

Summary

This Recommendation seeks to establish fundamental testing methods and criteria for the resistibility of telecommunication equipment to overvoltages and overcurrents.

Overvoltages or overcurrents covered by this Recommendation include surges due to lightning on or near the line plant, short-term induction of alternating voltages from adjacent electric power lines or electrified railway systems, earth potential rise due to power faults, and direct contacts between telecommunication lines and power lines.

Source

ITU-T Recommendation K.44 was prepared by ITU-T Study Group 5 (1997-2000) and was approved under the WTSC Resolution 1 procedure on 25 February 2000.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

INTELLECTUAL PROPERTY RIGHTS

The ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. The ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Recommendation K.44

RESISTIBILITY TESTS FOR TELECOMMUNICATION EQUIPMENT EXPOSED TO OVERVOLTAGES AND OVERCURRENTS – BASIC RECOMMENDATION

(Geneva, 2000)

1 Scope

This basic Recommendation describes resistibility tests for all telecommunication equipment against overvoltages and overcurrents for use by network operators and manufacturers.

This Recommendation applies to all telecommunication equipment connected to external or intra-building metallic conductors. It should be read in conjunction with Recommendations K.11 and K.39 which deal with the general economic and technical aspects of protection.

This Recommendation does not specify either test levels or particular acceptance criteria for specific equipment.

The appropriate test levels and test points are contained in the specific product family/product Recommendation.

Therefore, this Recommendation has to be used together with the product family/product Recommendation dealing with the resistibility requirements relevant to the equipment to be tested.

If a product family/product Recommendation or clauses of it differs from this basic Recommendation, the product family/product Recommendation applies. As product Recommendations are updated, they should be coordinated with and refer to Recommendation K.44.

This Recommendation assumes that the earthing and bonding configurations comply with the appropriate Recommendation related to the type of installation.

The tests are type tests and, although they are applicable to a complete system, it is recognized that they may be applied to individual items of equipment during development and design work. In performing the tests, it is necessary to take into account any conditions, either in the unit under test or elsewhere, which may affect the results.

ESD testing is not covered by this Recommendation and IEC 61000-4-2 should be followed.

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; all 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.

– ITU-T Recommendation K.11 (1993), *Principles of protection against overvoltages and overcurrents.*

– ITU-T Recommendation K.12 (2000), *Characteristics of gas discharge tubes for the protection of telecommunications installations.*

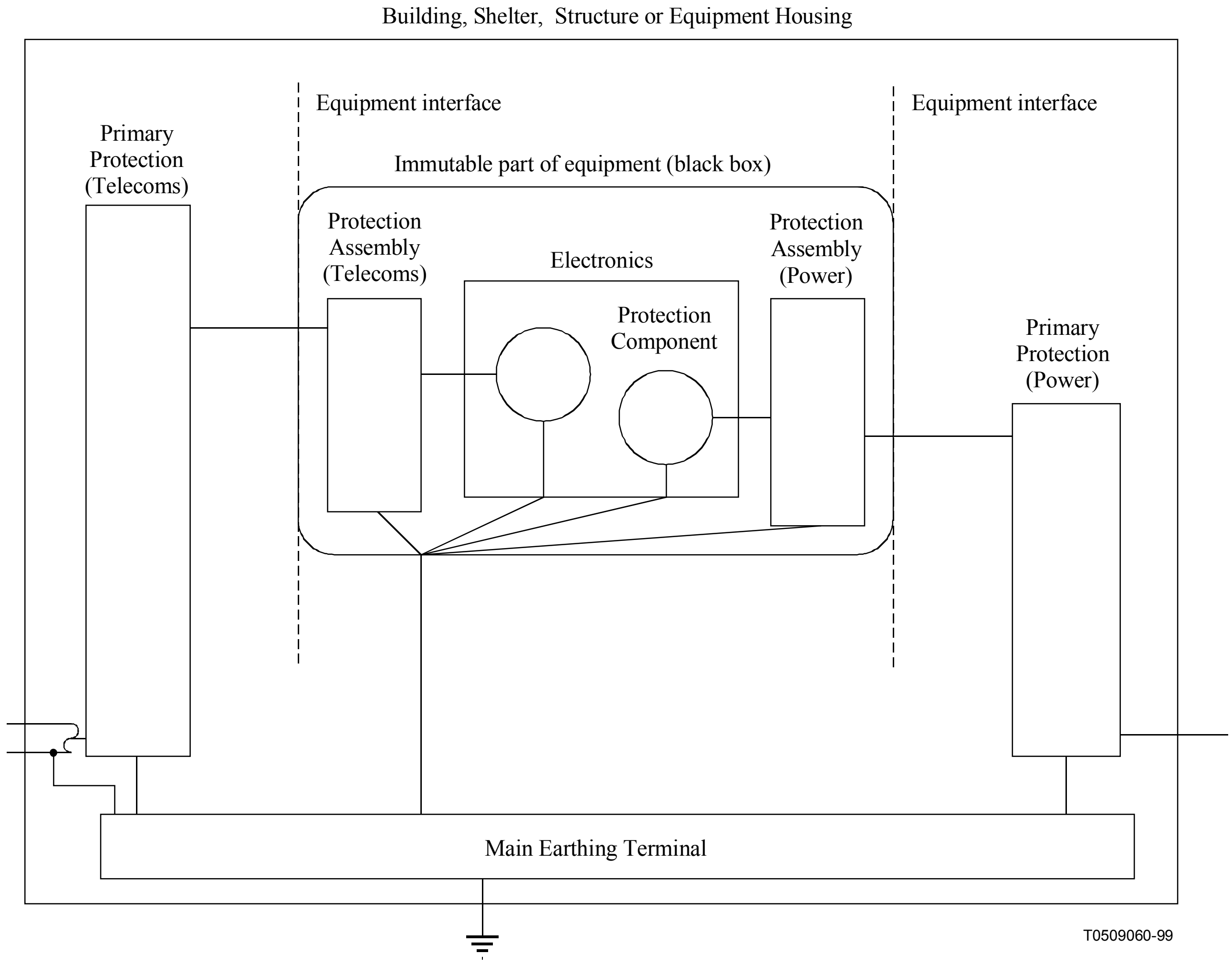
– ITU-T Recommendation K.27 (1996), *Bonding configurations and earthing inside a telecommunication building.*

- ITU-T Recommendation K.28 (1993), *Characteristics of semi-conductor arrester assemblies for the protection of telecommunications installations*.
- ITU-T Recommendation K.39 (1996), *Risk assessment of damages to telecommunication sites due to lightning discharges.*
- ITU-T Recommendations K.40 (1996), *Protection against LEMP in telecommunications centres.*
- IEC 60060-1 (1989), *High-voltage test techniques. Part 1: General definitions and test requirements.*
- IEC 61000-4-2 (1999), *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test.*
- IEC 61000-4-5 (1995), *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test.*
- IEC 61643-1 (1998), *Surge protective devices connected to low-voltage power distribution systems − Part 1: Performance requirements and testing methods.*

3 Definitions and abbreviations

3.1 Definitions

To assist in understanding the various definitions, refer to Figure 1. This figure shows elements associated with protecting the equipment that may be in an installation. Not all of these elements are expected to be used in an installation.



NOTE – The arrangement of the blocks and bonding conductors inside of the building, shelter, structure or equipment housing is to assist in their identification and does infer an optimum physical arrangement from a protection point of view.

Figure 1/K.44 – Illustration of protection elements

This Recommendation defines the following terms.

3.1.1 resistibility: Resistibility to overvoltages and overcurrents is the ability of telecommunication equipment or installations to withstand an overvoltage or overcurrent, to a specified level, with or without damage to the equipment.

NOTE – Criteria for damage are set in clause 9.

3.1.2 Surge Protective Device (SPD): A device that is intended to mitigate surge overvoltages and overcurrents of limited durations. It may consist of a single component or have a more complex design, where several functions are integrated. It contains at least one non-linear component.

3.1.3 primary protection: Primary protection is applied using an SPD to protect an interface of the equipment, at the location where it diverts most of the stressful energy from propagation into the equipment. This SPD must be accessible, removable and connected to equipotential bonding.

3.1.4 agreed primary protection: Agreed primary protection is a type of SPD that is used to protect the equipment based on an agreement between the manufacturer and the network operator. Agreed primary protection may be a specific SPD or a range of SPDs which comply with a particular Recommendation or specification. The agreed primary protection can be nothing if it has been agreed that no external protection elements need to be used for the equipment.

3.1.5 inherent protection: Inherent protection is that protection which is provided at an equipment interface either by virtue of its intrinsic characteristics, by specific design, or by suitable protection components.

3.1.6 high current carrying protection components: A high current carrying protection component is a SPD that is designed to conduct/divert the majority of the surge energy, once it has operated, away from the circuit it is protecting. High current carrying protection components are mainly used as primary protection components, but in some cases may be integrated into the equipment as inherent protection.

3.1.7 specific energy: Specific energy W_{sp} is a measure of the energy available from power induction or power frequency earth potential rise and is equal to the energy that would be dissipated in a resistor of 1 Ω. It is defined as the square of the induced current ($I_{a.c.}$) multiplied by the time t that the current flows:

$$W_{sp} = (I_{a.c.})^2 \times t \tag{3-1}$$

The specific energy from a test generator is determined by applying a short circuit to the output terminal of the generator.

3.1.8 coordination element: A coordination element is an element between the primary protection and the inherent protection to prevent the inherent protection from unduly affecting the primary protection from operating.

3.1.9 special test protector: The special test protector is a component or circuit used to replace the agreed primary protector for the purposes of confirming coordination. The special test protector ensures that the voltage at the input of the equipment will be higher during the test than in service and provides a level of guarantee that the equipment will be protected by the addition of primary protection.

3.1.10 dedicated power feed: A dedicated power feed is a power feed provided by a special cable which leaves the building.

3.1.11 ports: A "Port" is a particular interface of the specified equipment. The equipment may have both external and internal ports. An external port is a port which is connected to metallic conductors extending beyond the building or shelter boundary. An internal port is a port connected to metallic conductors which do not leave the building or shelter.

3.1.12 protection coordination: The act of ensuring that all the protection elements, internal and external to the equipment, react in such a way so as to limit the amount of energy, voltage or current to levels such that damage does not occur to protection elements or equipment.

3.1.13 Customer Premises Equipment (CPE): Equipment intended to be directly connected to the termination of a public telecommunication network in a customers premise.

3.1.14 Access Network (AN): Part of the overall telecommunication network that is located between a telecommunication centre and the customer premise building.

3.1.15 Trunk Network (TN): A part of the telecommunication system that is located between two telecommunication centres.

3.1.16 telecommunication centre: A telecommunication centre is a telecommunication facility where the earthing and bonding is in accordance with Recommendation K.27.

3.2 Abbreviations

This Recommendation uses the following abbreviations:

a.c.	alternating current
AN	Access Network
ANE	Access Network Equipment
CPE	Customer Premises Equipment
d.c.	direct current
dpf	dedicated power feed
ESD	Electrostatic Discharge
EUT	Equipment Under Test
GDT	Gas Discharge Tube
IEC	International Electrotechnical Commission
ISDN	Integrated Services Digital Network
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
LE	Local Exchange
LI	Line Interface
LT	Line Termination
MDF	Main Distribution Frame
MOV	Metal Oxide Varistor
NT	Network Termination
o/c	open circuit
pfv	power feeding voltage
PTC	Positive Temperature Coefficient resistor
RSE	Remote Switching Equipment
SPD	Surge Protection Device
SPD	Surge Protective Device
SSA	Solid State Arrester
TCE	Telecommunication Centre Equipment
TN	Trunk Network
USB	Universal Serial Bus

3.3 Symbols

This Recommendation uses the following symbols:

U_c	d.c. charge voltage of the surge generator
$U_{c(max)}$	Maximum d.c. charge voltage of the surge generator
$U_{a.c.(max)}$	Maximum a.c. (open) voltage for the a.c. voltage tests

4 Overvoltage and overcurrent conditions

Aspects of overvoltage or overcurrent covered by this Recommendation are:

- surges due to lightning strokes on or near to the line plant;
- large currents in common wiring or components when overvoltages or overcurrents occur simultaneously on a number of lines;
- large currents flowing into the equipment when high current carrying protection components, which eliminate the need for primary protection, are integral to the equipment;
- short-term induction of alternating voltages from adjacent electric power lines or electrified railway systems, usually when these lines or systems develop faults;
- earth potential rise due to power faults;
- direct contacts between telecommunication lines and mains power lines;
- transient surges on mains-voltage lines;
- the potential difference which can occur between a TT or IT Power system and the Telecommunication system.

5 Resistibility requirements (basic and enhanced)

Telecommunication lines, remote (dedicated) power feeding lines and mains power lines are more or less influenced in the practical environment by lightning or power lines. The several degrees of influence and protection measures are described in Recommendation K.11. With reference to the resistibility of telecommunication equipment, connected to metallic conductors, there may be different resistibility requirements in different environments. It is for Administrations or network operators to select the appropriate resistibility requirement, from the product family/product Recommendations. In the interest of reducing the number of equipment designs, only the basic and enhanced requirements are recommended.

5.1 Basic resistibility requirement

The equipment needs to be suitable for use in environments with a low exposure and this is achieved by the inherent protection of the equipment. The equipment also needs to be suitable for use in environments with a higher exposure and this is achieved by inherent protection of the equipment and added agreed primary protection.

5.2 Enhanced resistibility requirement

Where the basic resistibility requirements are not sufficient due to environmental conditions, national regulations, economic and technical considerations, installation standards or grade of service requirements, network operators may request the enhanced resistibility requirement.

6 Equipment boundary

The variations of different types of equipment make it necessary for the equipment to be seen as a "black-box" having several ports, a, b, c, d, e and f, etc. and E (Earth). It is possible that some protective devices have already been provided in the equipment, either on the printed circuit board, etc. or connected to its ports. For the purpose of these tests, manufacturers are expected to define the boundaries of the "black-box" and any protective device which is included must be considered as an immutable part of the equipment (small exchange in street cabinet, Multiplexor, CPE, etc.). Where high current carrying protection components are used within the equipment, see 10.1.1. Where any auxiliary telecommunication wire is provided, e.g. to an extension, or as a signalling earth, these wires should be seen to extend the number of terminal to be tested, e.g. a, b, c, d, e and f, etc. and E for Earth.

7 Test conditions

The following conditions apply to all the tests specified in clause 10.

1) All tests are type tests and are tested under standard laboratory conditions unless otherwise specified in the product family/product Recommendation.

2) The ports at which tests on the equipment are to be applied should be identified by the manufacturer:
   - a and b, c and d, e and f, etc. for different single symmetric pair ports;
   - a_1 to a_n and b_1 to b_n, c_1 to c_m and d_1 to d_m, e_1 to e_p and f_1 to f_p, etc. for different multiple symmetric pair ports;
   - inner and outer for coaxial cable ports;
   - dpf1 and dpf2, etc. for dedicated power feed ports;
   - L1, L2, L3 and N for mains power ports; and
   - E for Earth.

3) The equipment shall be tested in any operating state of significant duration.

4) In all cases where a maximum voltage, current or specific energy is specified, tests shall also be made at lower values, if this is necessary, to confirm that the equipment fulfils the specified acceptance criteria for any voltage, current or specific energy up to the maximum value specified.

   NOTE – Particular components which need to be considered during testing include the primary protector, switching or foldback type inherent protectors, PTCs and fuses.

   Where fuse resistors are used, tests shall be applied at a range of test levels to ensure that the worst case is tested.

5) Each test shall be applied the number of times indicated in the product family/product Recommendation. The polarity of lightning surge tests should be reversed between consecutive surges. The time interval between consecutive tests on the same port should be approximately one minute. The tests shall also be applied at longer time intervals, if necessary, to confirm that the equipment fulfils the specified acceptance criteria for surges which occur at intervals exceeding one minute. An example of this is to confirm that the equipment passes when all surges are applied to PTCs at normal operating temperature.

6) Power induction tests should be made at the frequencies of the electric power system or the electrified railway systems used in the country of application.

7) A new primary protection component may be used after the completion of each test sequence.

8) Ports shall be tested with a finite number of untested ports of the same and different types appropriately terminated, as is necessary, to confirm that the equipment fulfils the specified acceptance criteria. Terminations for a tested port include auxiliary equipment e.g. LI, LT, NT, CPE, a power supply, a simulator or a passive termination. If it is not necessary to have the auxiliary equipment connected to verify that the EUT will resist the test voltage, the test may be performed without the auxiliary equipment connected. Untested ports should be terminated, if necessary to prove that the equipment will resist the test voltage, as it would be used in the field. Where different terminations may occur, e.g. with or without primary protection, these terminations need to be considered. To simulate worst-case conditions, the untested ports may need to be left open or connected together with or without earth connection as appropriate. Refer to I.1.5 for more information about effect of terminations.

9) Cards shall be tested in one or more slots as is necessary to confirm that the equipment fulfils the specified acceptance criteria.

10) If a card has two or more identical ports, only one port needs to be tested, for single port tests.

11) When the transverse test is applied between two terminals, one of the terminals shall be connected to the surge generator and the other terminal shall be connected to earth. The test shall then be repeated with the terminals transposed.

8 Protection coordination

8.1 General

For equipment installed in a more exposed environment, it is current practice to protect ports, connected to external metallic conductors, with primary protectors such as GDTs, SSA's or MOVs. The best place for the insertion of the primary protection is the border of the building, shelter or equipment housing. This is not always possible but every attempt should be made to place the primary protection as close as possible to the entry point of the cables into the building, shelter or equipment housing. The characteristics of these primary SPDs shall comply with the requirements of Recommendations K.12, K.28 or IEC 61643-1.

Primary protection coordination is required to ensure compatibility of the equipment with the primary protection.

8.2 Lightning

To have achieved coordination for protection against lightning surges, the following must occur:

- The inherent protection within the equipment must provide protection up to the voltage at which the agreed primary protection operates for generator voltages less than the $U_{c(max)}$ specified in the product family/product Recommendation.
- Between this voltage and a generator voltage of $U_{c(max)}$ the primary protection must operate and protect the equipment.
- The equipment must comply with specified criterion of the product family/product Recommendation.
- To check that coordination has been achieved for protection against lightning surges, a special test protector is used in place of the primary protector during the lightning surge tests, see 8.4. The special test protector must operate for a generator voltage equal to the $U_{c(max)}$ specified in the product family/product Recommendation.

8.3 Power induction, earth potential rise and power contact

Protection against power induction and earth potential rise is achieved by the inherent protection within the equipment or in combination with the agreed primary protection.

Protection against power contacts is achieved by the inherent protection of the equipment.

The input impedance to ground of both the a and b inputs of some equipment may be low when the inherent overvoltage protection is activated. In this case, the voltage across the impedance to ground caused by the current that flows during power induction may be too low to activate the primary protection. If the primary protection is not activated, attention should be paid to the level of energy which may have to be dissipated within the equipment.

8.4 Special test protector

The special test protector shall have similar behaviour to that of the agreed primary protector.

8.4.1 Switching type protector

The d.c. operating voltage of the special test protector shall be equal to 1.15 times the specified maximum d.c. operating voltage, after life test value, of the agreed primary protector. The tolerance of this firing voltage is ±5%. It should also have a similar impulse to d.c. operating ratio as the agreed primary protector. The manufacturer may use a special test protector with a higher operating voltage.

8.4.2 Clamping type protector

The clamping voltage of the special test protector shall be equal to 1.15 times the specified maximum clamping voltage of the agreed primary protector. The tolerance of this clamping voltage is ±5%. The manufacturer may use a special test protector with a higher operating voltage.

8.4.3 Multistage modules

When the primary protection is a multistage module, replace the primary protection with a special test module which uses components according to 8.4.1 and 8.4.2.

9 Acceptance criteria

Two acceptance criteria are recognized:

- Criterion A – Equipment shall withstand the test without damage or other disturbance (such as corruption of software or misoperation of fault-protection facilities) and shall operate properly within the specified limits after the test. It is not required to operate correctly during the test.
- Criterion B – A fire hazard shall not arise in the equipment as a result of the tests. Any damage, if it occurs, shall be confined to a small part of the equipment.

10 Tests

The test generators, test circuits, coupling and decoupling elements, and port terminations are provided in Annex A.

Certain considerations which justify the test proposals are stated in Appendix I. The response of equipment to surges may be modified by the input impedance of the equipment. To explain this effect, Appendix I includes an example circuit and instantaneous levels of voltage at different points in the circuit to show the effect of input impedance. These values are included for illustration only and do not form any part of this Recommendation.

The port types shown in Table 1 are considered.

Table 1/K.44 – Port types

Port type	Test type	Example
Symmetric pair	Lightning	Analogue customer interface ISDN basic-rate interface Remote power feeding circuits xDSL interface
	Power induction and earth potential rise	
	Mains power contact	
Coaxial cable	Lightning	ISDN primary-rate interface
	Power induction and earth potential rise	
Dedicated power feed (a.c., d.c.)	Lightning	Optical network unit/termination power feed interface
	Power induction and earth potential rise	
a.c. mains power	Lightning	a.c. mains power
	Earth potential rise and neutral potential rise	

A summary of the applicable tests is given in Table 2. The numbers given in the "Port Type" columns, e.g. 10.1.2, refer to the appropriate subclause number in Recommendation K.44 which discusses this test. The letters "n.a." mean the test is not applicable. The words "Under study" mean that the ITU-T is still studying this test. The term "Single" or "Multiple" refers to the number of ports tested. For a single port test the test is applied to one port only. For a multiple port test the surge is applied to the number of ports specified simultaneously. The heading and term "Longitudinal" OR "Transverse" refers to whether the surge is applied longitudinally, i.e. line to ground or in common mode OR transversely i.e. line to line, line to shield or in differential mode. There is a heading for Basic test level and Enhanced test level, refer to clause 5 for information.

Table 2/K.44 – Applicable tests

Test type	**No. of ports simultaneously tested**	**Longitudinal/ transverse test**	**Primary protection**	**Port type**			
				Symmetric port	**Coaxial port**	**Dedicated power feed port**	**Mains power port**
Lightning voltage	Single	Longitudinal	No	10.1.1.1	n.a.	10.3.1	10.4.1
		Transverse	No	10.1.1.1	10.2.1 Under study	10.3.1	10.4.1
		Longitudinal	Yes	10.1.1.1	n.a.	10.3.1	10.4.1
		Transverse	Yes	10.1.1.1	10.2.1 Under study	10.3.1	10.4.1
	Multiple	Longitudinal	No	10.1.1.2	n.a.	n.a.	n.a.
		Longitudinal	Yes	10.1.1.2	n.a	n.a.	n.a.
Lightning current	Single	Longitudinal	No	10.1.2	n.a.	10.3.2	n.a.
		Transverse	No	n.a.	10.2.2 Under study	n.a	n.a.
			Yes	n.a.	n.a.	n.a.	10.4.2 Under study
	Multiple	Longitudinal	Yes	10.1.2	n.a.	n.a.	n.a.
Lightning shield	Single	Longitudinal	Yes	n.a.	10.2.3 Under study	n.a.	n.a.
Earth wire voltage drop	Single	Longitudinal	No	10.1.3 Under study	n.a.	n.a.	n.a.
Power induction and earth potential rise	Single	Longitudinal	No	10.1.4	n.a.	10.3.3	10.4.3 Under study
		Transverse	No	10.1.4	10.2.4 Under study	10.3.3	
		Longitudinal	Yes	10.1.4	n.a.	10.3.3	
		Transverse	Yes	10.1.4	10.2.4 Under study	10.3.3	
Neutral potential rise	Single	Longitudinal	No	n.a.	n.a.	n.a.	10.4.4
Mains power contact	Single	Longitudinal	No	10.1.5	n.a	10.3.4	n.a.
		Transverse	No	10.1.5	n.a.	10.3.4	n.a.

10.1 Symmetric pair port

10.1.1 Lightning voltage

For equipment with high current carrying protection components, which eliminates the need for primary protection, the following applies:

- If this component is removable, an exception to clause 6 applies and, it shall be removed and replaced by the special test protector for both the inherent and coordination tests, see 8.4.
- If this component is not removable, all tests are performed with the protection provided and the manufacturer must provide a test report to show that the inherent and coordination tests were performed with the special test protector during the design tests.

10.1.1.1 Single port

The single port lightning test is to check that each port of the equipment has the required level of overvoltage resistibility. Both longitudinal and transverse tests shall be performed.

10.1.1.2 Multiple ports

The multiple ports lightning surge test is to check that the equipment has the required level of resistibility when an overvoltage surge occurs on n ports simultaneously, which can result in a high current flowing into a common component or part of the equipment.

The number or percentage of ports to be tested simultaneously is to be specified in the product family/product Recommendation.

10.1.2 Lightning current

The overcurrent test checks that the equipment has the required level of inherent resistibility when high current carrying protection components are installed within the equipment to eliminate the need for primary protection. This test checks the coordination of high current protectors, integral to the equipment, with connectors and printed circuits tracks, etc. The overcurrent test is to be specified in the product family/product Recommendation.

10.1.3 Earth wire voltage drop

The ITU-T is considering the introduction of an Earth wire voltage drop test to simulate the effect of high current surges flowing in MDFs and associated earth wiring, see Appendix II, subclause II.3.3.

10.1.4 Power induction and earth potential rise

Both longitudinal and transverse tests shall be performed.

If the equipment has high current carrying protection components, which eliminates the need for primary protection, the following applies:

- If this component is removable, an exception to clause 6 applies and, it shall be removed and replaced by the special test protector for both the inherent and coordination tests, see 8.4.
- If this component is not removable, all tests are performed with the protection provided and the manufacturer must provide a test report to show that the inherent and coordination tests were performed with the special test protector during the design tests.

10.1.5 Mains power contact tests

Both longitudinal and transverse tests shall be performed.

10.2 Coaxial port

The ITU-T is studying the test requirements for coaxial cable ports.

10.2.1 Lightning voltage

The lightning voltage test is to check that the equipment has the required level of overvoltage resistibility.

10.2.2 Lightning current

The overcurrent test checks that the equipment has the required level of inherent resistibility when high current carrying protection components are installed within the equipment to eliminate the need for primary protection. This test checks the coordination of high current protectors, integral to the equipment, with connectors and printed circuits tracks, etc. The overcurrent test is to be specified in the product family/product Recommendation.

10.2.3 Lightning currents flowing on the shield

This requirement checks the ability of equipment to carry large currents that may flow on the shield of the coaxial cable. This test should be performed on all pair-wise combinations of coaxial ports and earthing terminals.

10.2.4 Power induction and earth potential rise

The power induction and earth potential rise test is to check that the equipment has the required level of overvoltage resistibility.

10.3 d.c. and a.c. dedicated power feeding ports

10.3.1 Lightning voltage

Both longitudinal and transverse tests shall be performed.

10.3.2 Lightning current

The overcurrent test checks that the equipment has the required level of inherent resistibility when high current carrying protection components are installed within the equipment to eliminate the need for primary protection. This test checks the coordination of high current protectors, integral to the equipment, with connectors and printed circuits tracks, etc. The overcurrent test is to be specified in the product family/product Recommendation.

10.3.3 Power induction and earth potential rise

Both longitudinal and transverse tests shall be performed.

10.3.4 Mains power contact

Both longitudinal and transverse tests shall be performed.

10.4 a.c. mains power port

10.4.1 Lightning voltage

Both longitudinal and transverse tests shall be performed.

10.4.2 Lightning current

The ITU-T is studying the need for a test to check coordination of the equipment with a mains primary protector. The purpose of this test is to check coordination under the condition when a direct strike occurs to the building or the mains power line or cable.

10.4.3 Earth potential rise

The ITU-T is studying the need for a test to check resistibility of the equipment from the earth potential rise which can occur when a High Voltage (HV) earth fault occurs on the substation providing mains power to the equipment.

10.4.4 Neutral potential rise

This test applies only on request of the network operator and when the neutral is not connected to the protective earth (i.e. a TT or IT mains system). An example of such a configuration is described in Appendix II, subclause II.5.

ANNEX A

Test schematics

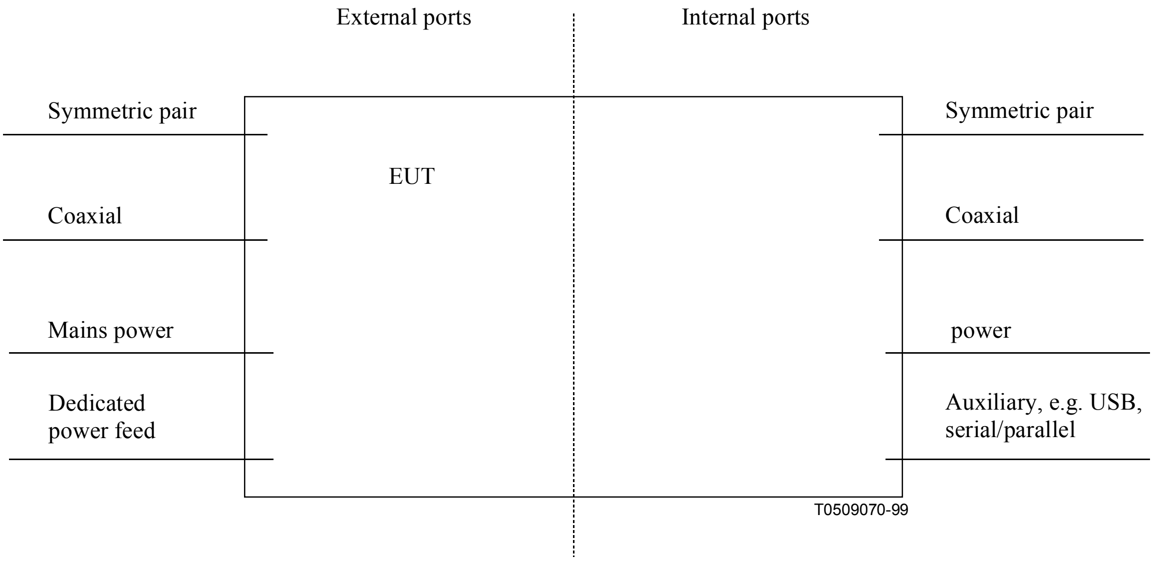
A.1 Introduction

To ensure repeatability of testing by test houses and manufacturers, it is necessary to ensure that the tests are performed in the same way. Following are the generator circuits, coupling, decoupling and powering circuits, the termination of untested ports, and the connection to the equipment under test (EUT).

A.2 Equipment and test schematics

A.2.1 Equipment ports

Figure A.2-1 shows the possible ports of a piece of equipment.



NOTE 1 – Not all ports need to be tested but they may need to be terminated.

NOTE 2 – In this figure, "External ports" means ports connected to cables which exit the building and "Internal ports" means ports connected to cables which remain within the building.

Figure A.2-1/K.44 – Equipment ports

A.2.2 Test schematic

The surge generator, powering, coupling and decoupling elements, and the EUT are connected as shown in Figure A.2-2.

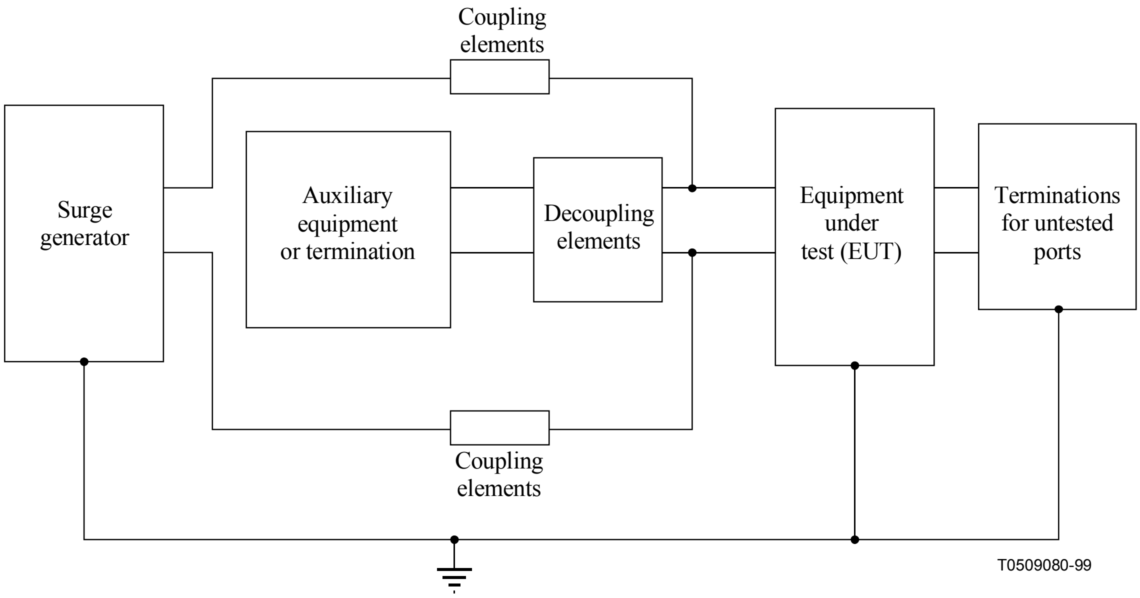


Figure A.2-2/K.44 – Block diagram of a typical test set-up

A.3 Test generators

Examples of circuits of test generators which can be used to generate the waveshapes specified in A.4 are contained in Figures A.3-1 to A.3-6. While the components shown should give the correct waveshape, they may require adjustment.

Alternative test generators may be used providing they give the same result.

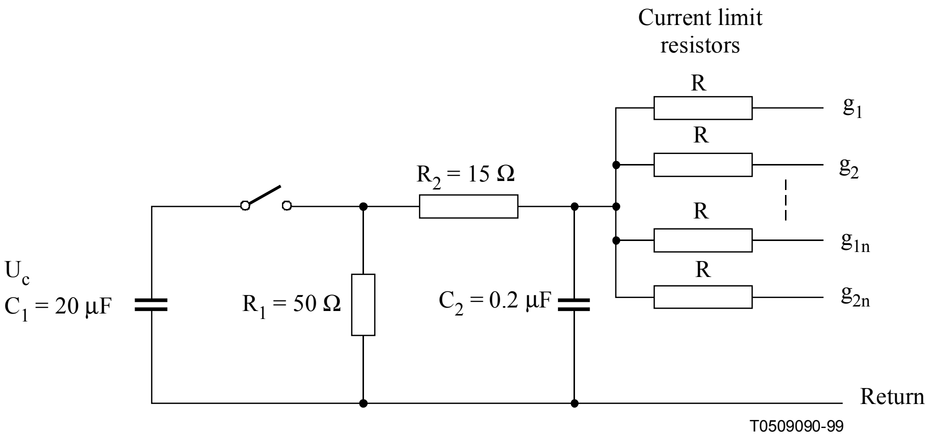


Figure A.3-1/K.44 – 10/700 µs voltage surge generator

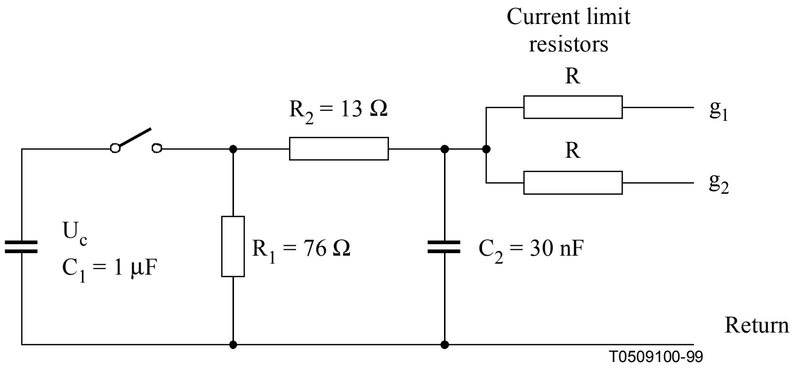
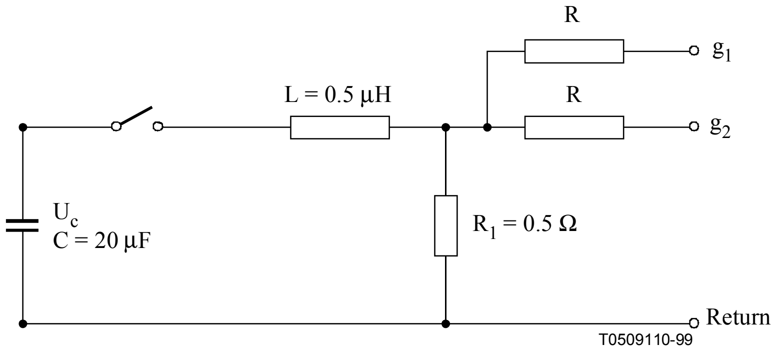


Figure A.3-2/K.44 – 1.2/50 µs voltage surge generator

The test generator may be a combination wave generator according to IEC 61000-4-5 (Figure A.3-5) or an equivalent 1.2/50 µs voltage surge generator.



L is small and mostly parasitic inductance of the wiring, may need to be adjusted to give the required front time of 2 µs. U_c is adjusted to give required o/c output voltage.

Figure A.3-3/K.44 – 2/10 µs voltage surge generator

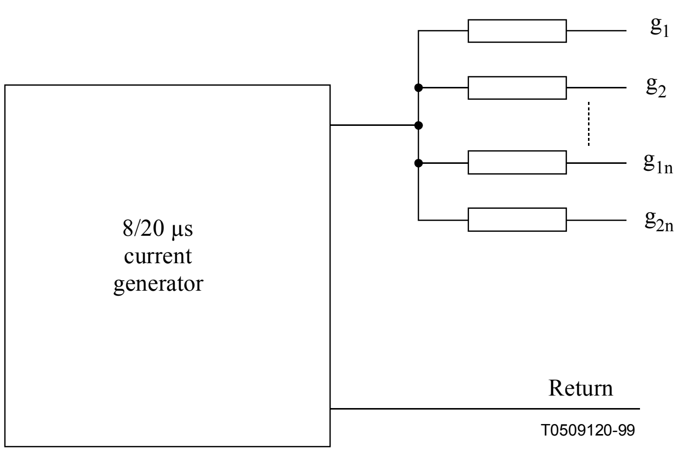


Figure A.3-4/K.44 – 8/20 µs current generator

The test generator may be:

- a combination wave generator according to IEC 61000-4-5 (Figure A.3-5);
- any 8/20 surge current generator of 8/20 µs waveshape.

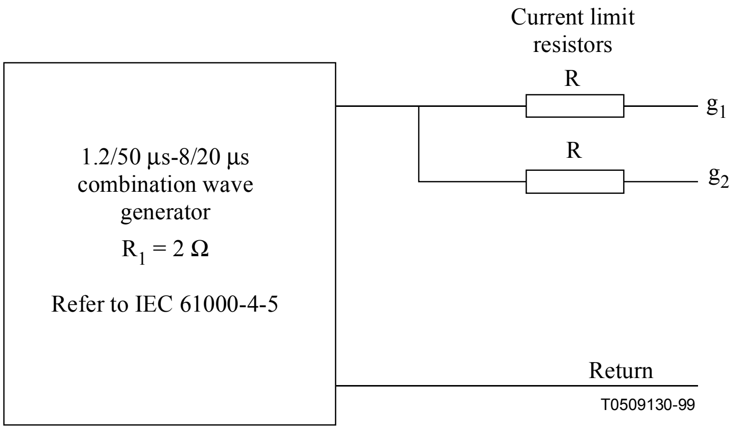
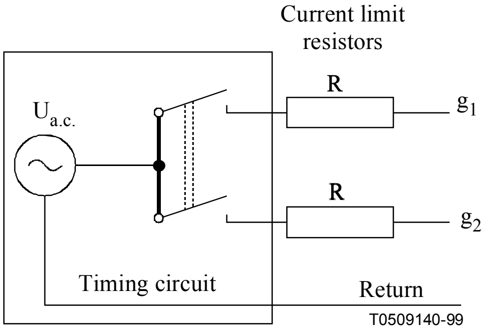


Figure A.3-5/K.44 – Combination wave generator



For the value of R, refer to the appropriate test table in the appropriate product Recommendation.

NOTE – If national regulations require it, the maximum current may be limited.

Figure A.3-6/K.44 – Power induction, power contact and rise of neutral potential generator

A.4 Waveform generation

Where circuit values are provided use this circuit. Where generator circuits are not given, refer to the quoted IEC standard or IEC 60060-1 for guidance on verifying the waveshape.

A.5 Test circuits including coupling, decoupling and powering networks

The coupling element, if required, can be an MOV, a GDT, a capacitor or any other element with an operating voltage in excess of the maximum EUT working voltage. The coupling element should be considered as an integral part of the test generator and should not significantly affect the open circuit voltage nor the short circuit current. It may be necessary to increase the test voltage to compensate for voltage drop in coupling elements.

The decoupling elements, if necessary, can be an impedance that blocks the surge energy from entering the line simulator (e.g. resistance of 200 Ω or greater for symmetric pair circuits, inductance or chokes) but still allowing power and signalling to take place to the EUT.

The equipment is powered via the mains or dpf port, etc. through an appropriate decoupling network, e.g. isolation transformer or chokes, etc.

Figures in A.5.1 to A.5.4 give the principle of connecting the generator to the EUT.

A.5.1 Symmetric pair ports

See Figures A.5.1-1 to A.5.1-3.

A.5.2 Coaxial ports

See Figures A.5.2-1 and A.5.2-2.

A.5.3 a.c. or d.c. dedicated power feed ports

See Figures A.5.3-1 and A.5.3-2.

A.5.4 Mains power ports

See Figures A.5.4-1 and A.5.4-2.

A.6 Terminations

See Figure A.6-1.

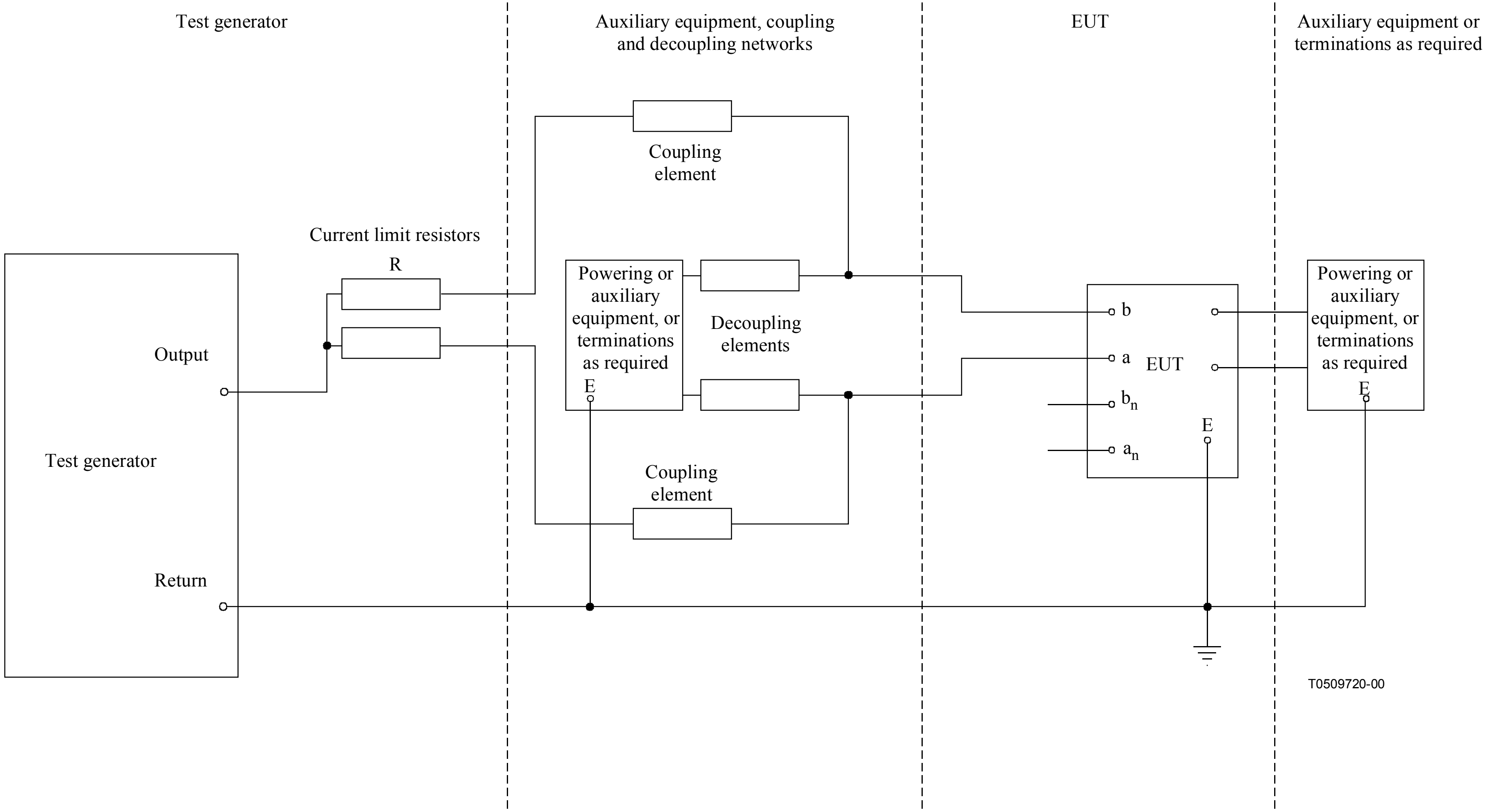


Figure A.5.1-1/K.44 – Example of test circuit for a longitudinal overvoltage or overcurrent on a single port

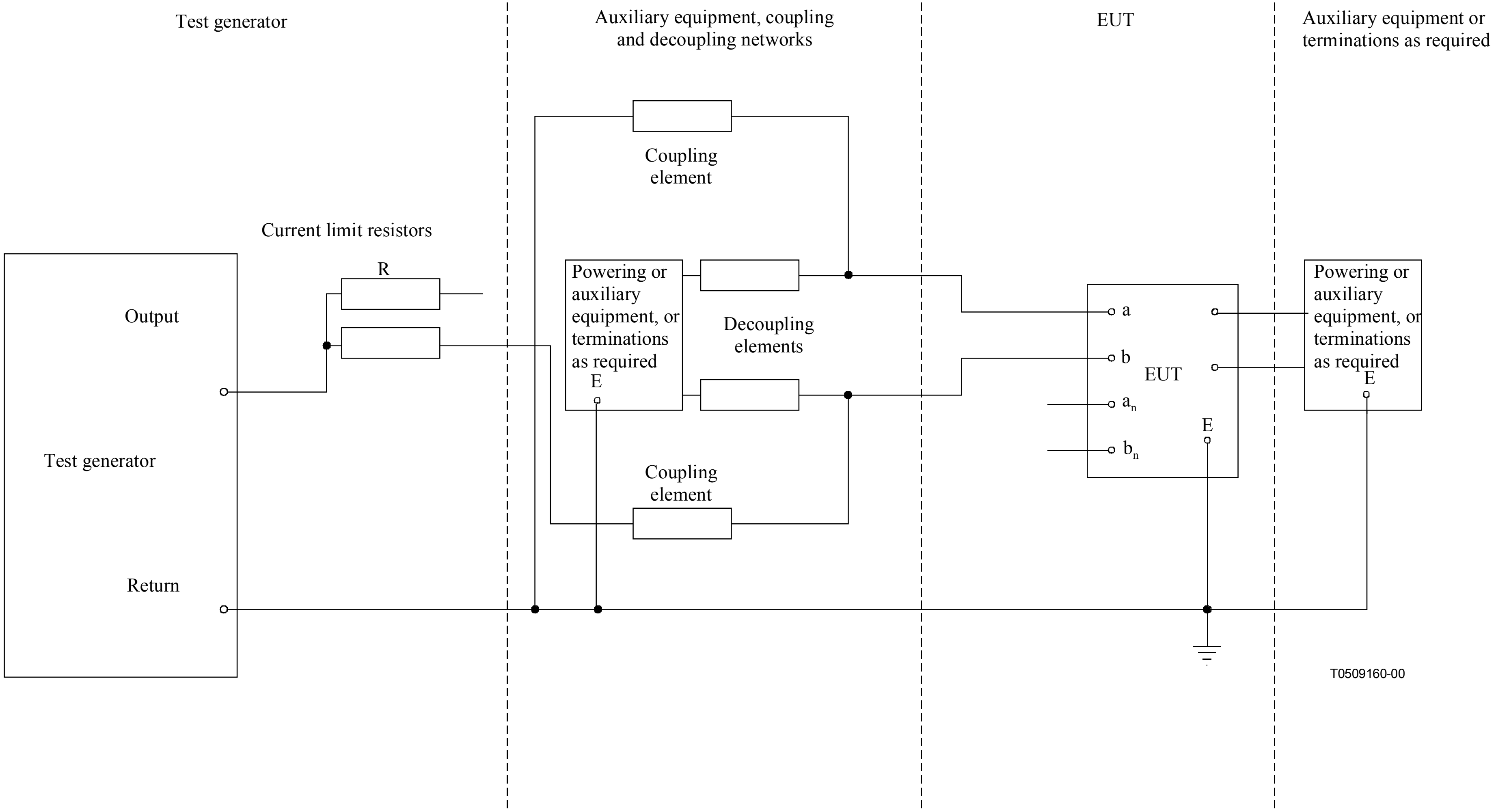


Figure A.5.1-2a/K.44 – Example of test circuit for a transverse overvoltage or overcurrent on a single port (a – terminal to ground)

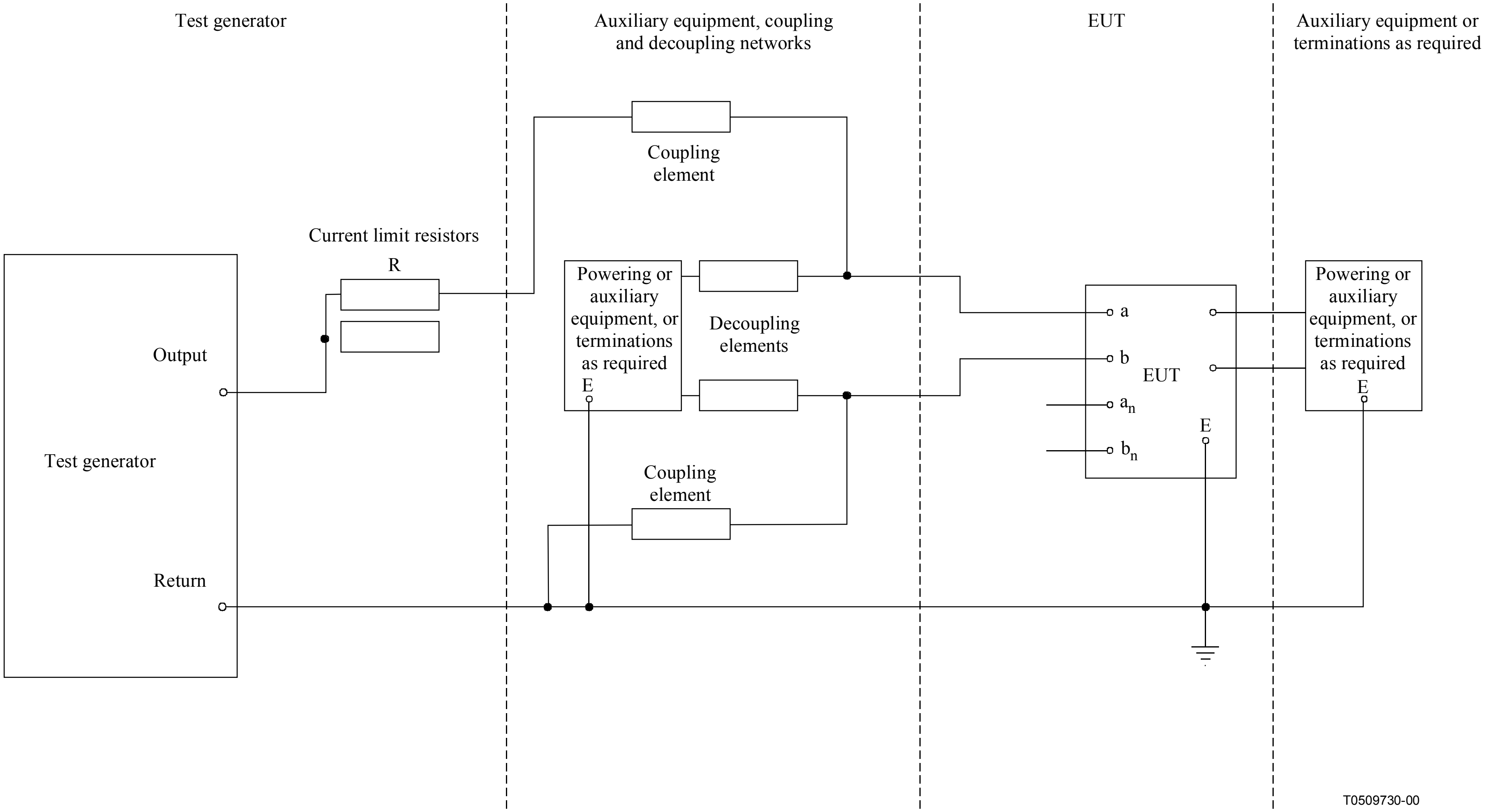


Figure A.5.1-2b/K.44 – Example of test circuit for a transverse overvoltage or overcurrent on a single port (b – terminal to ground)

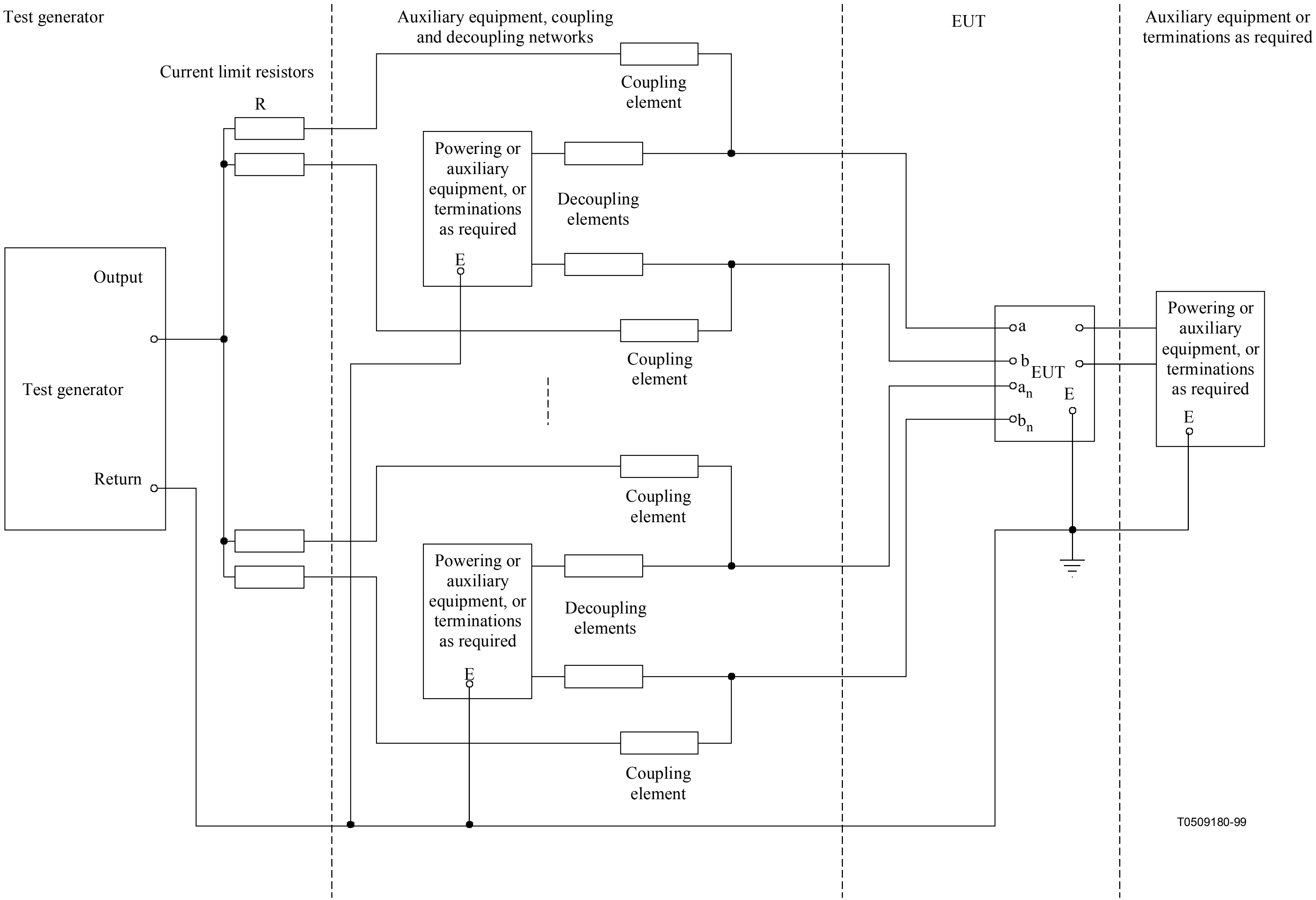


Figure A.5.1-3/K.44 – Example of test circuit for a longitudinal overvoltage or overcurrent on multiple ports

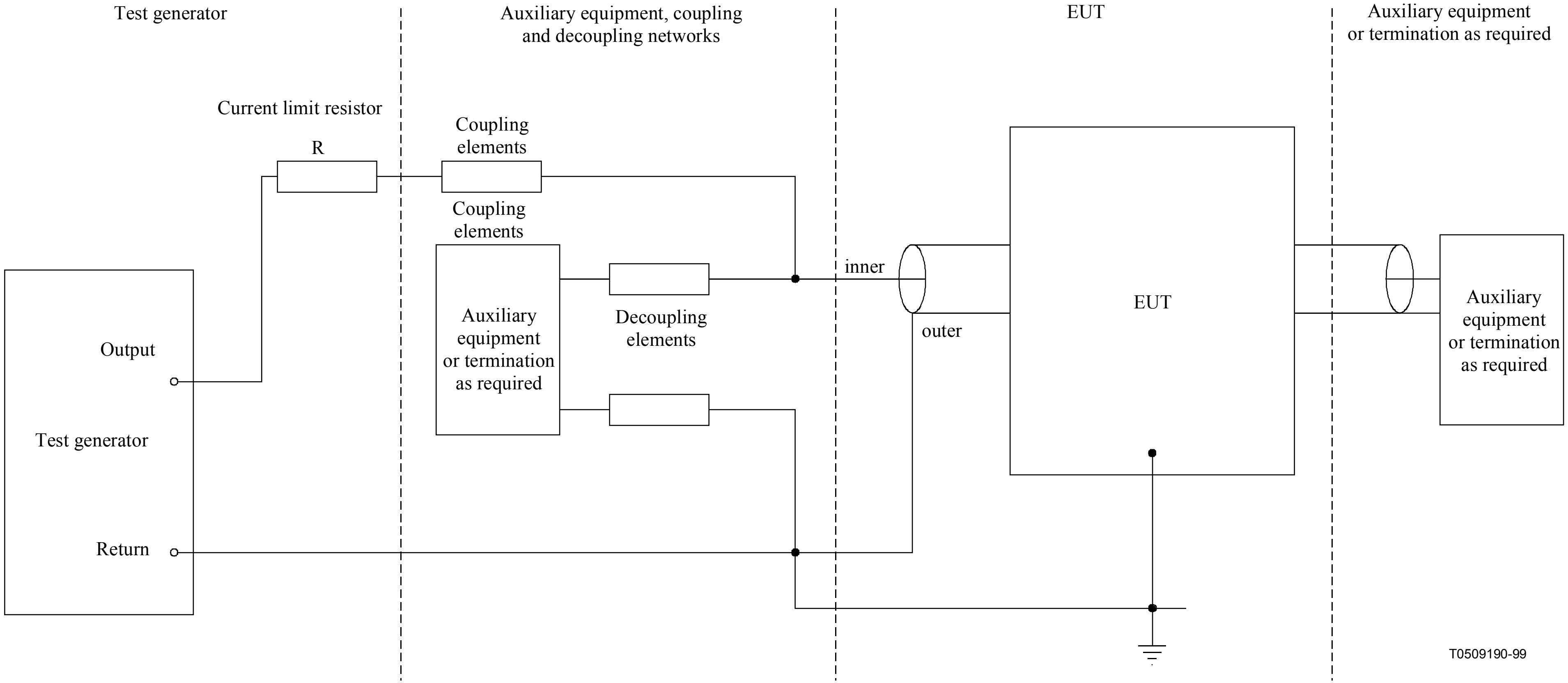


Figure A.5.2-1/K.44 – Example of test circuit for a transverse overvoltage or overcurrent on a single port

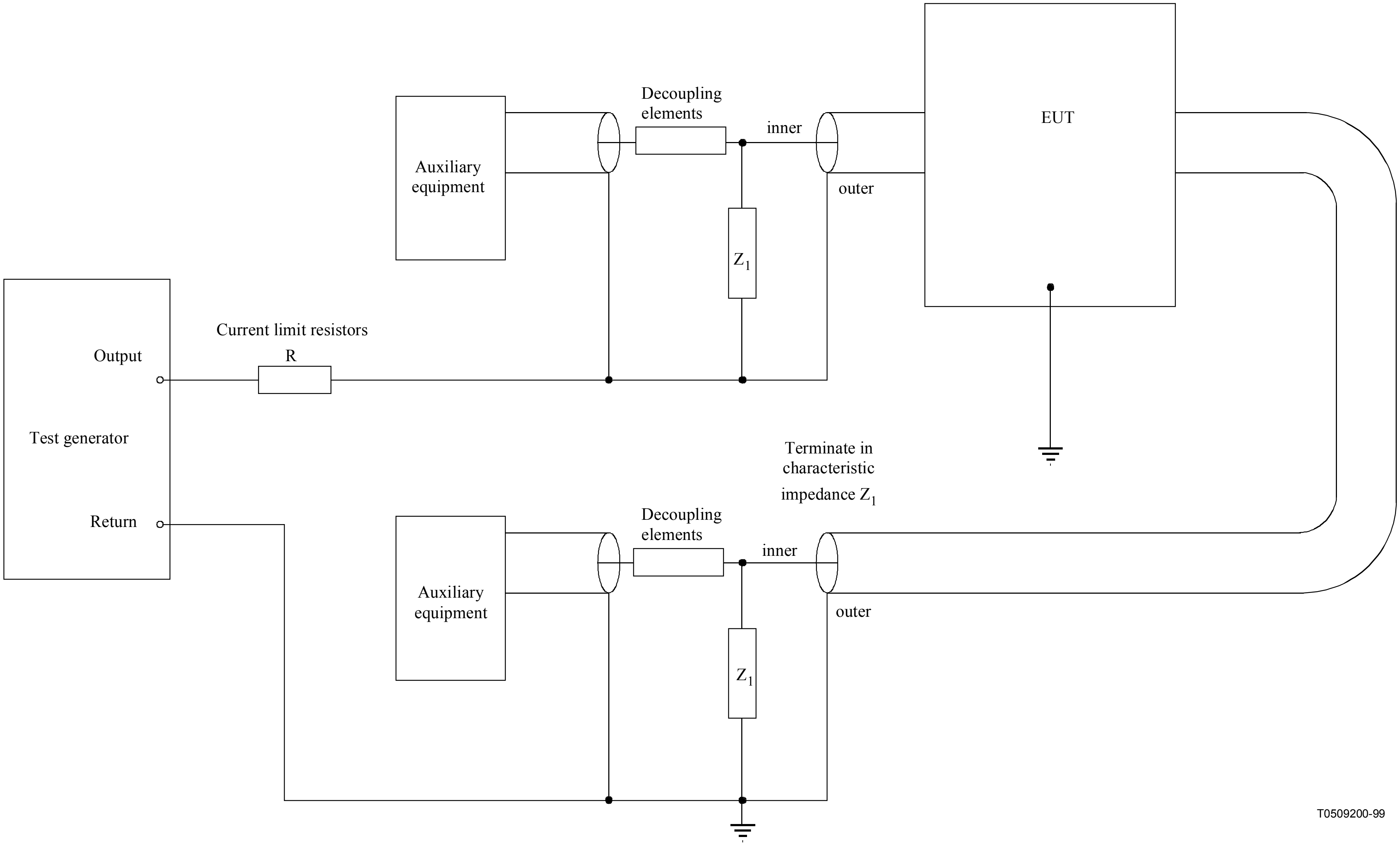


Figure A.5.2-2/K.44 – Example of test circuit for a shield current test

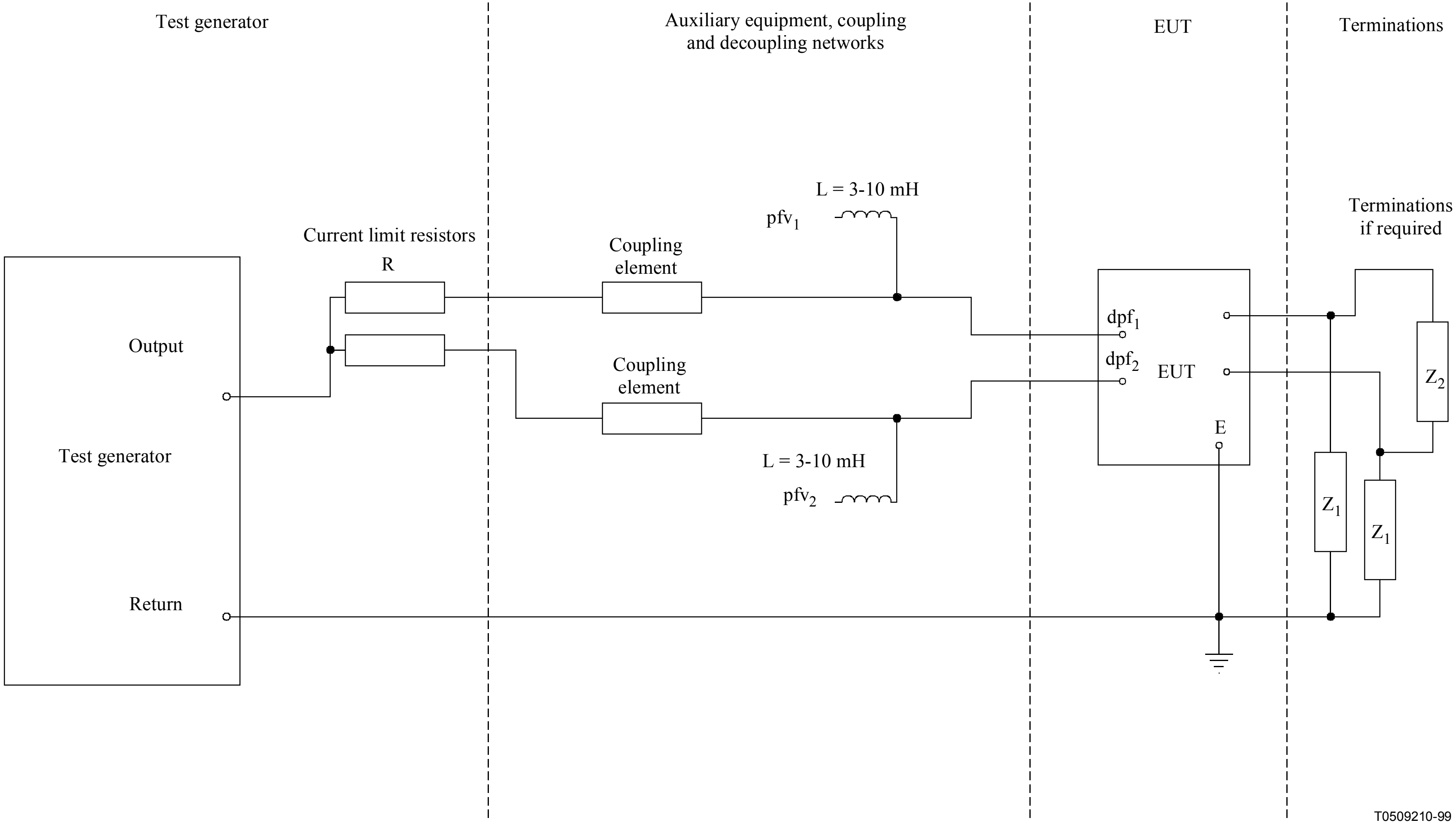


Figure A.5.3-1/K.44 – Example of test circuit for a longitudinal overvoltage or overcurrent on a single port

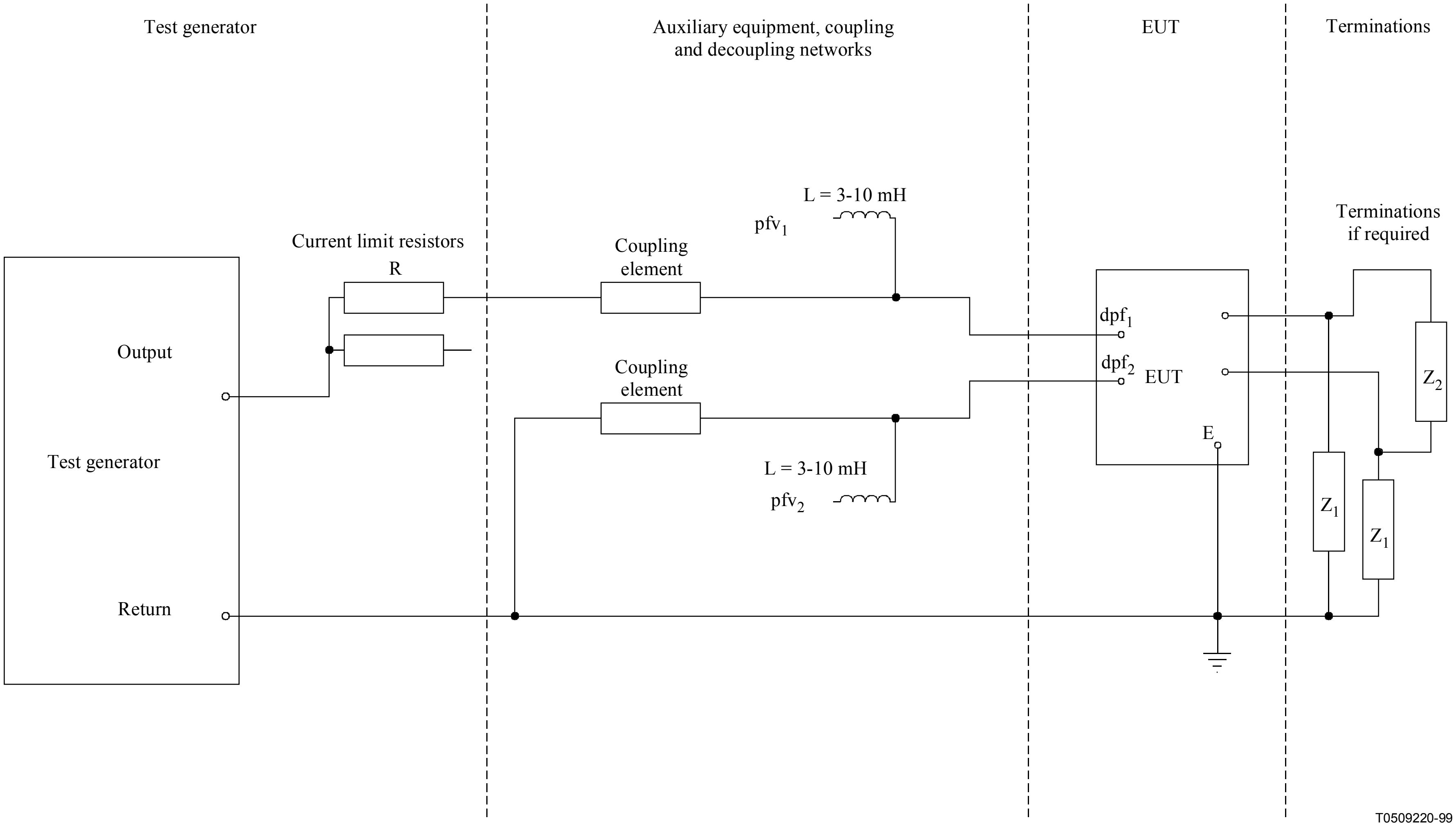


Figure A.5.3-2a/K.44 – Example of test circuit for a transverse overvoltage or overcurrent on a single port (dpf$_2$ grounded)

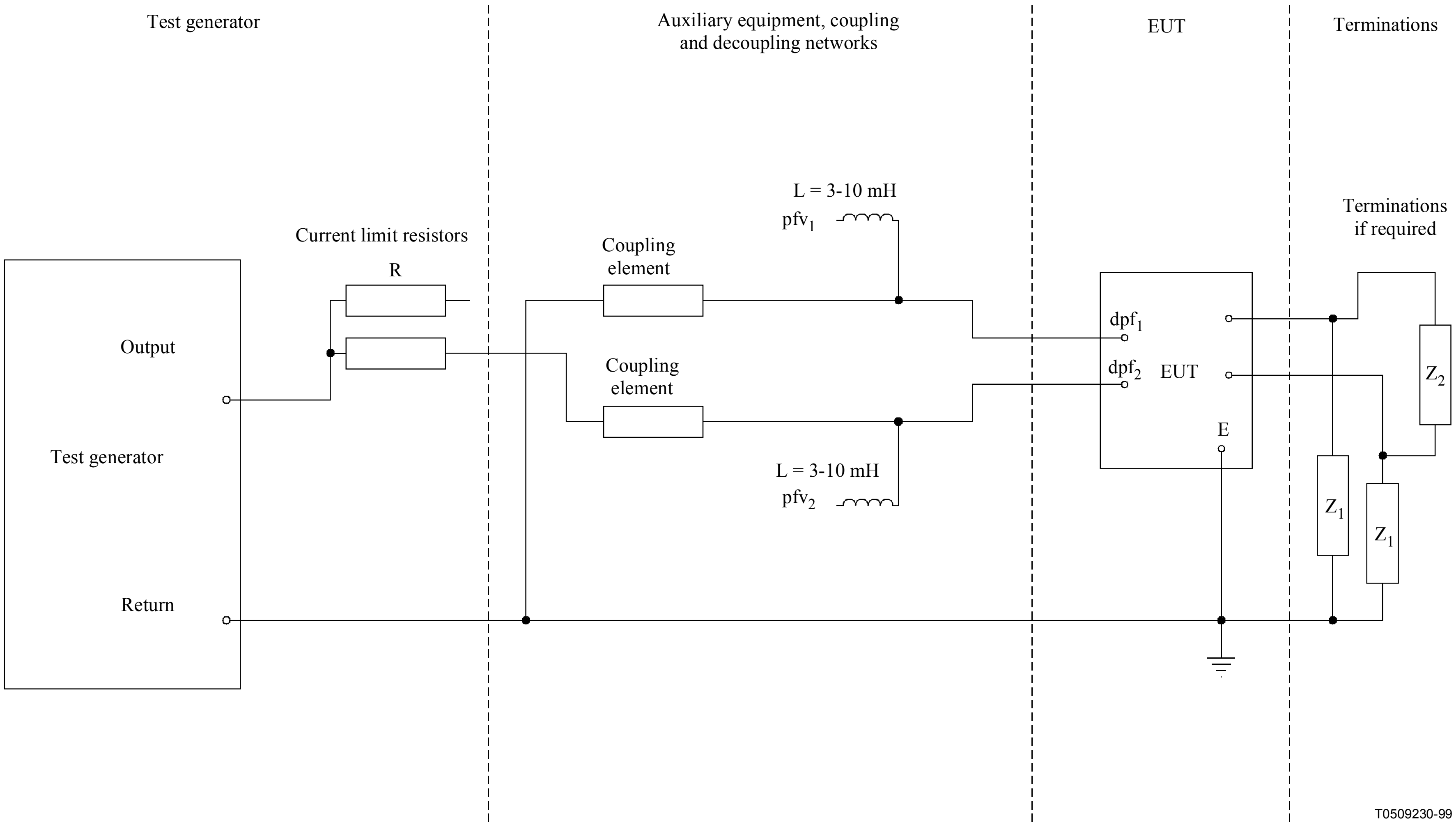


Figure A.5.3-2b/K.44 – Example of test circuit for a transverse overvoltage or overcurrent on a single port (dpf$_1$ grounded)

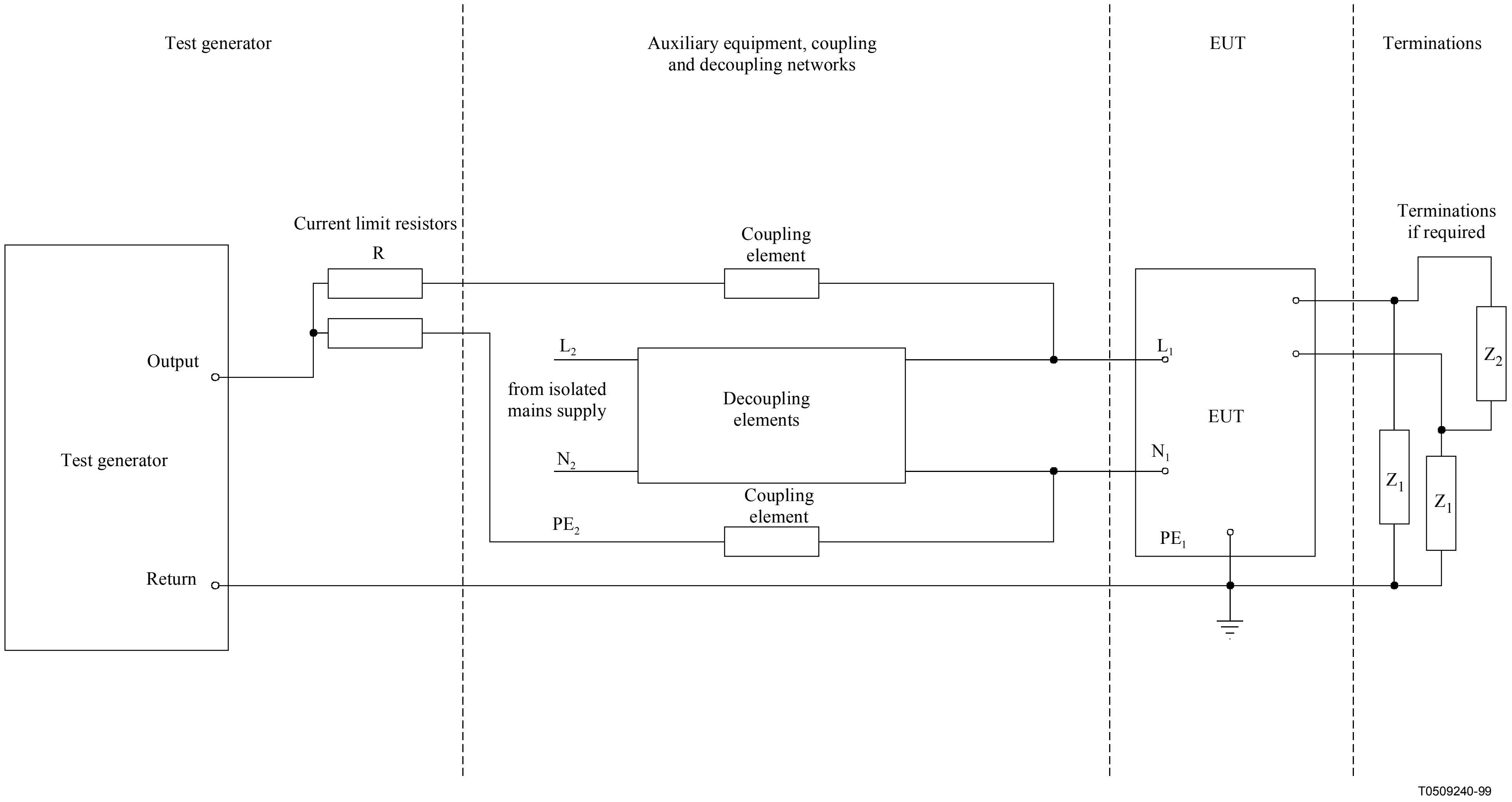


Figure A.5.4-1/K.44 – Example of test circuit for a longitudinal overvoltage, overcurrent and rise of neutral potential

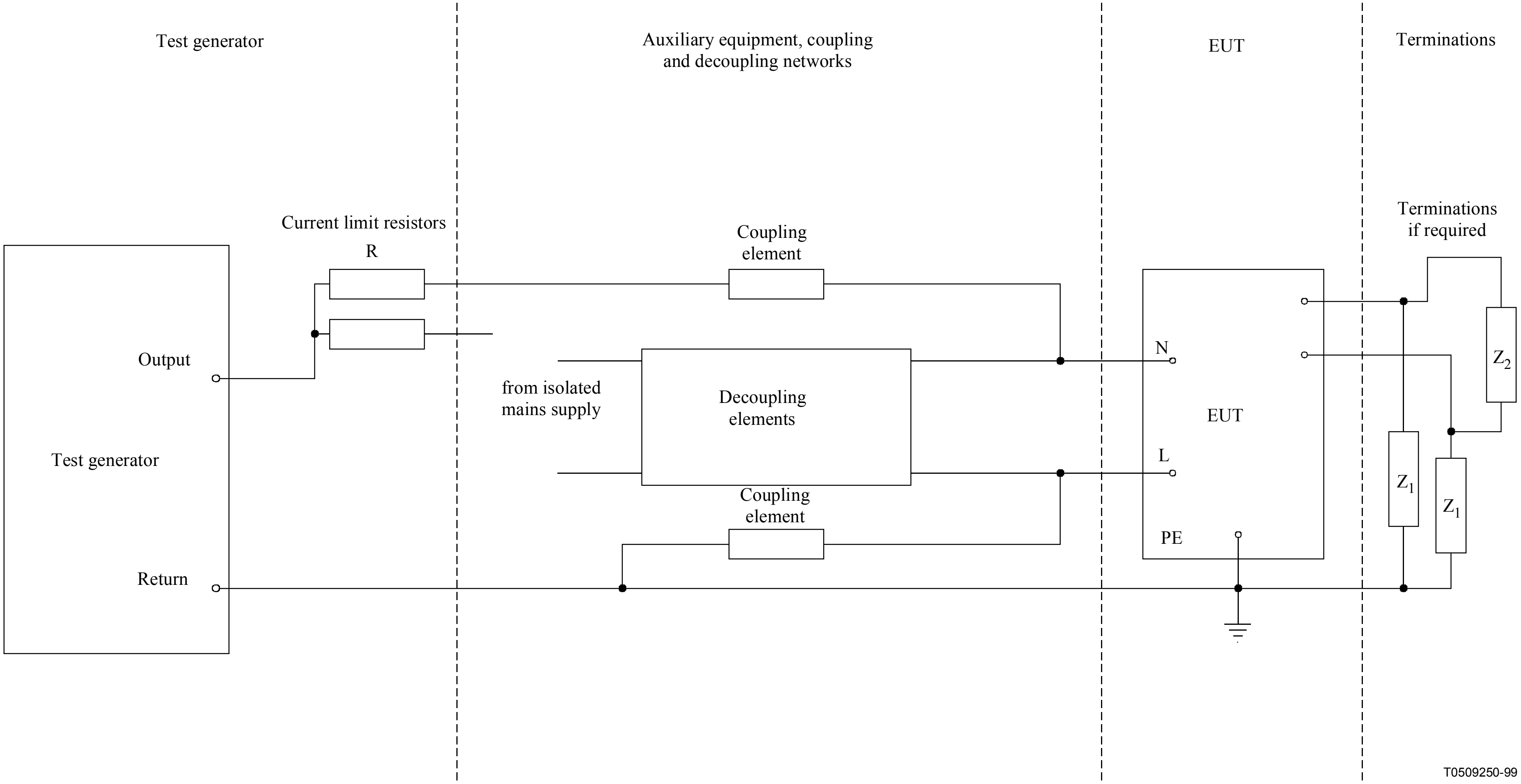
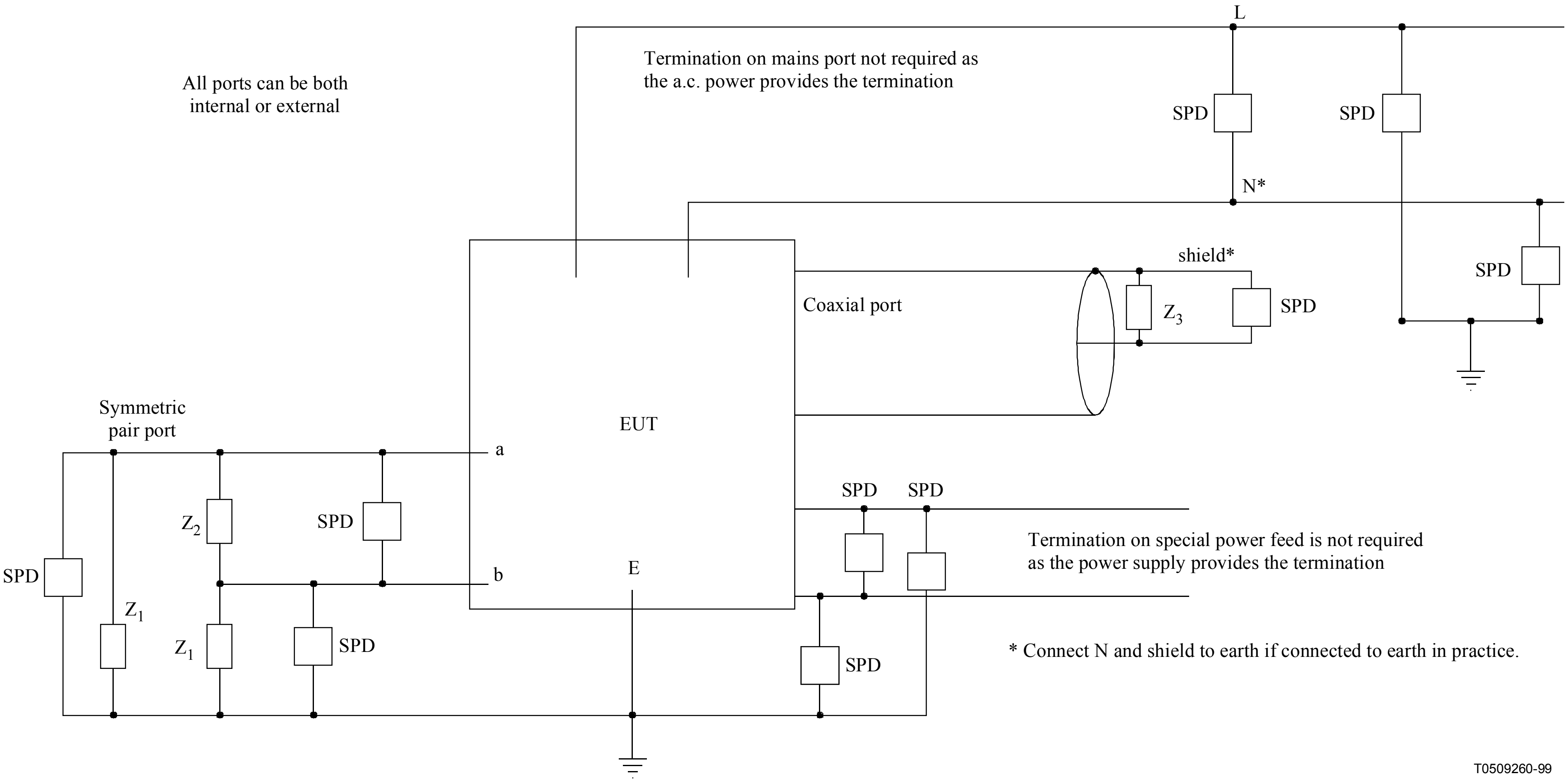
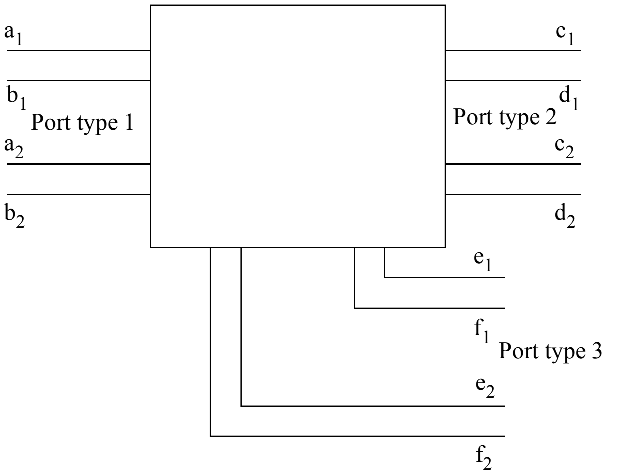


Figure A.5.4-2/K.44 – Example of test circuit for a transverse overvoltage or overcurrent



Z_1, Z_2 and Z_3 are the nominal terminations for a working system or associated equipment.
The SPD is used to simulate a path to ground.

Figure A.6-1a/K.44 – Example of termination of untested ports during testing of a port



Test 1 – Test a_1/b_1 with no termination.
Test 2 – Test a_1/b_1 with a_2/b_2 terminated.
Test 3 – Test a_1/b_1 with c_1/d_1 terminated.
Test 4 – Test a_1/b_1 with e_1/f_1 terminated.
etc.

Figure A.6-1b/K.44 – Example of a termination sequence

APPENDIX I

Explanations which illustrate test conditions

I.1 Testing

I.1.1 General

To check that the equipment fulfils the specified acceptance criteria for all voltage and current levels up to the maximum test level, it is necessary to either test at a large range of test voltages/currents from 0 to the maximum level specified or to perform "intelligent testing". Subsections I.1.2-I.1.4 provide information on intelligent testing which minimizes the number of test levels but ensures that sufficient tests are performed.

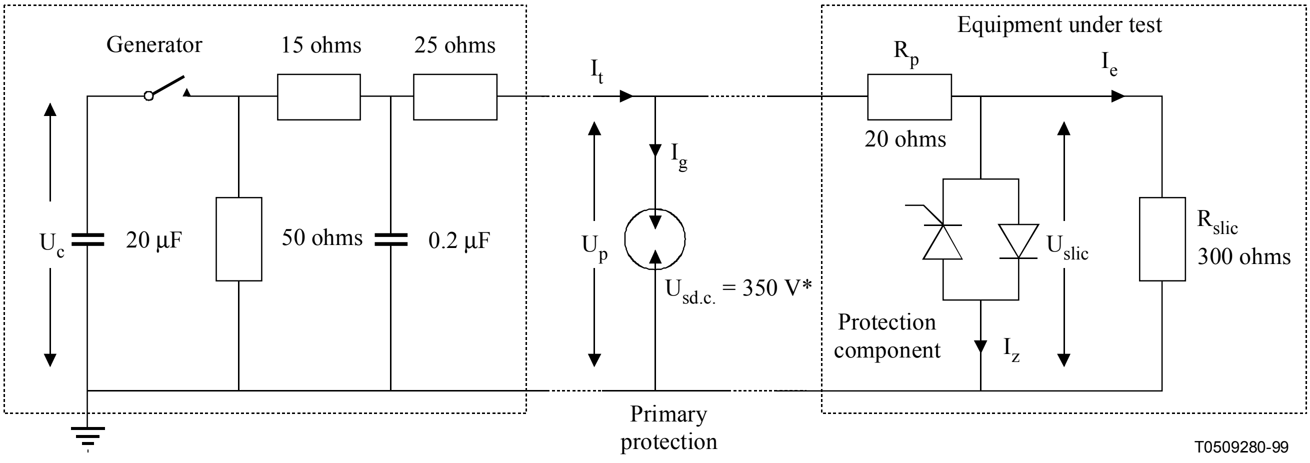
I.1.2 Lightning surge tests

To check that no damage windows exist within the equipment, it is necessary to perform tests at specific test voltages. These specific test voltages are determined by the operating points of such components as the primary protector (GDT or SSA) and switching protective devices within the equipment. Examples of these test voltages are illustrated using an example of a linecard with a 20 Ω fusible resistor and a switching type inherent protector. This example linecard, along with the test generator and the primary protector, is shown in Figure I.1-1. Apart from the test generator, all the circuit layout and component values have been chosen only for explanatory purposes and are not put forward as some recommended practice.

When the charging voltage U_c is progressively raised, the different components are subjected to different voltages, currents and energies. The choice of the components of the circuit is determined by:

- The maximum voltage across the component.
- The maximum current through the component.

– The maximum energy that will be absorbed by the component (the integral voltage current for the duration of the pulse).



* Special test protector for 230 V primary protector.

NOTE – In practice R_p may vary from 10-100 ohms and R_{slic} may also have different values.

Figure I.1-1/K.44 – Example linecard with designated voltages and currents

The above circuit is an example of a linecard with a low input impedance when the inherent protection operates. The equipment is nominally protected in exposed areas with an SSA or a GDT on the MDF. This circuit is to be tested assuming it will be protected with a 230 V GDT. The primary protector has been replaced with a GDT with a 350 V d.c. sparkover voltage as described in 8.4.1 (i.e. 300 V_{dcmx} of 230 V GDT multiplied by 1.15).

R_p is the protection resistor. Its value may vary in practice from 10 to 100 Ω. This resistor performs two functions. Firstly it is designed to fuse in case of power contact to prevent a fire. Secondly it provides a buffer impedance between the primary protection and the inherent protection to achieve coordination. It becomes the input impedance (resistance) of the EUT when inherent protection turns on. R_p can be a resistor, PTC or some kind of hybrid device. In some applications, it is possible that R_p is at the MDF with the primary protection. Note, having R_p at the MDF is not a recommended practice as some operators may have MDFs which do not accept series impedance.

R_e is the resistance of the circuit. Its value may vary with current and frequency. However, it is usual that the maximum current which flows through R_e is less than 0.2 A. This current is negligible compared to the current which is conducted by the inherent protection when it operates.

The inherent protection is a PNPN type device. When positive surges are applied, the diode conducts the current to ground, so the voltage drop is only 1 or 2 V.

When negative surges are applied, the thyristor will turn on if the voltage across it exceeds its firing voltage, usually around 60 V. After the thyristor turns on the voltage drop is only 1 or 2 V.

For a U_c to produce a U_p = 0-69 V, no current flows, see Figure I.1-2, and the voltage U_p and U_{slic} are the same. This is the point of worst stress for the SLIC and 10 surges of alternate polarity should be applied. With a U_c to produce a U_p = 70 V, the inherent protection operates and current is conducted through the 20 Ω resistor, see Figure I.1-3. This will limit the voltage across the SLIC to 70 V. The voltage across the 20 Ω resistor and the current through the resistor will increase until the charging voltage is just below the activation level of the primary protection, see Figure I.1-4.

This is the point of maximum stress for the 20 Ω resistor and 10 surges of alternate polarity should be applied.

When the primary protection is activated, the voltage U_p drops to a low value (typically about 25 V). The current I_z flowing into the equipment falls to a very low value and becomes practically independent of U_c.

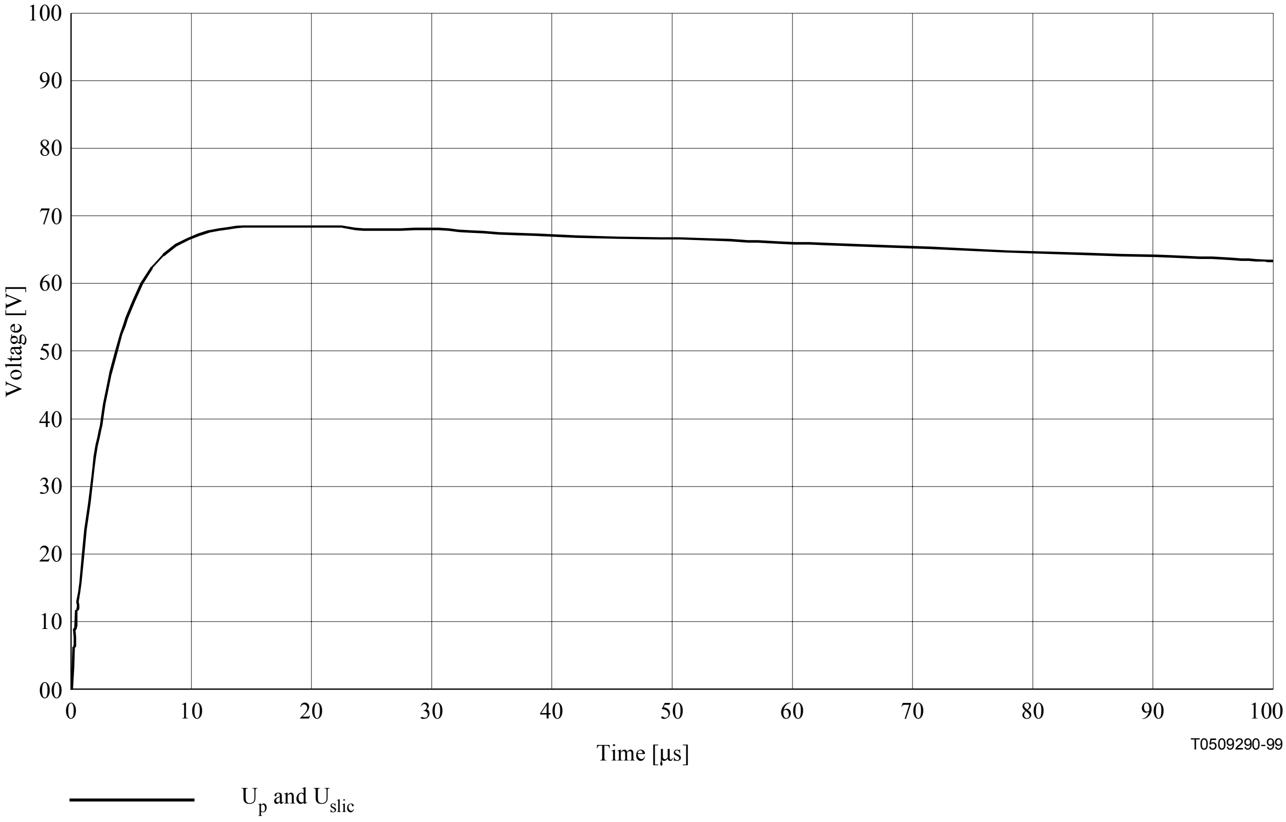


Figure I.1-2/K.44 – Voltages with U_c to give a U_p of 69 V

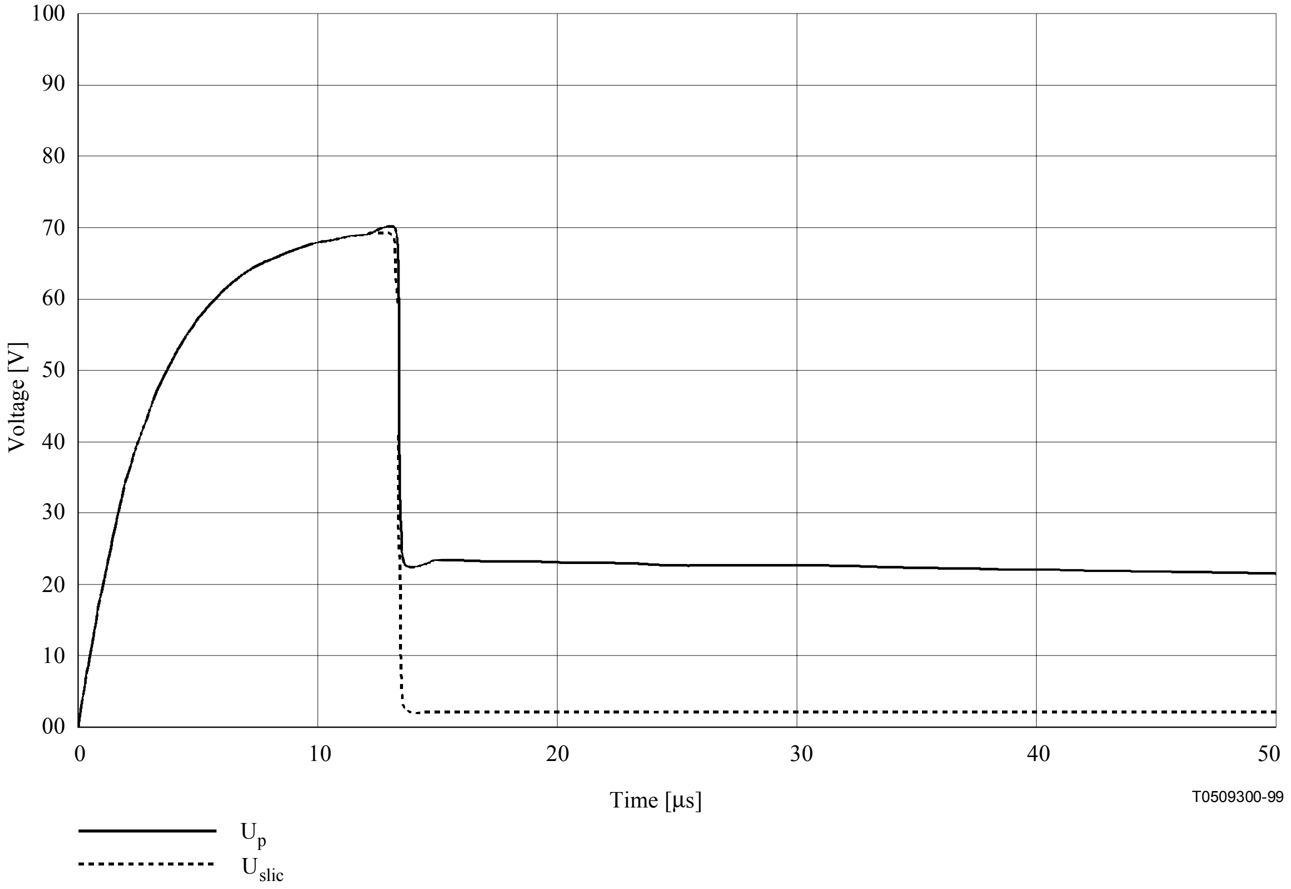


Figure I.1-3/K.44 – Voltages with U_c to give a U_p of 70 V

Figure I.1-4 shows the maximum full wave 10/700 µs voltage which appears at the input of the equipment. Figure I.1-5 shows the protector operating during the tail of the wave. The 10/700 µs firing voltage is the value of U_p which just causes the protector to operate, i.e. the 10/700 µs firing voltage of the protector is 420 V.

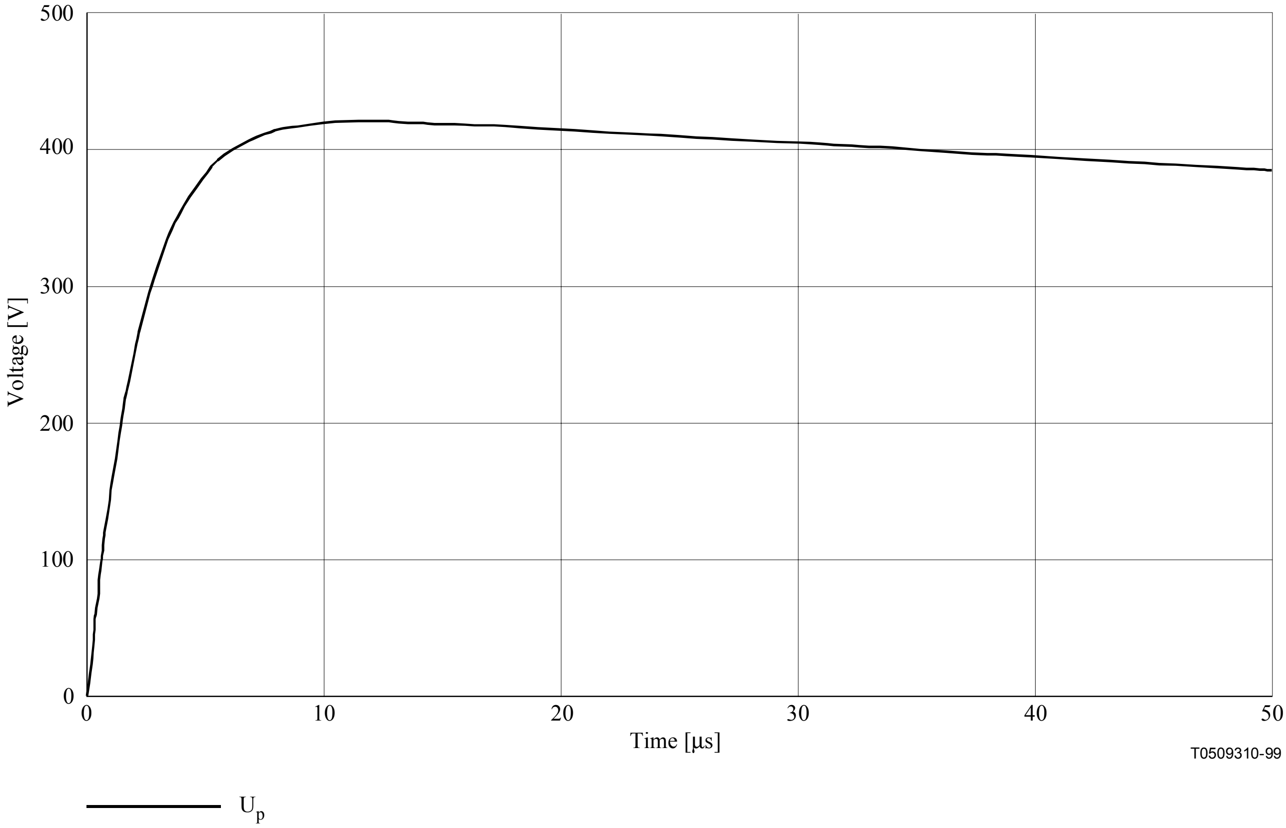


Figure I.1-4/K.44 – Voltages with U_c at the sparkover point of the GDT

Figure I.1-5 shows the measured voltage U_p across the primary protection and the voltage across the 20 Ω resistor for a charging voltage U_c of 1.3 kV and a GDT with a d.c. breakdown voltage of 350 V, the firing voltage of the special test protector used when the agreed primary protector is a 230 V GDT. The different currents can be calculated from the voltages. The primary protector used was activated after 15 µs and the maximum voltage across the GDT was 420 V.

It should be noted that if the primary protection is not activated during the rising edge, it can still be activated during the decay period as the voltage remains initially almost constant during the decay period. When the GDT is activated during the decay period, the breakdown voltage is lower and approaches the d.c. breakdown voltage.

Figure I.1-6 shows the measured voltage U_p across the primary protection and the voltage across the 20 Ω resistor for a charging voltage U_c of 4 kV. The primary protection was activated after 1.0 µs and the maximum voltage across the GDT is 635 V. Although the voltage is higher, the amount of energy that is passed to the equipment is lower.

Figure I.1-7 shows the measured voltage U_p across the primary protection and the voltage across the 20 Ω resistor for a charging voltage U_c of 10 kV. The primary protection was activated after 0.38 µs and the maximum voltage across the GDT is 692 V. Although the voltage is higher, the amount of energy that is passed to the equipment is lower.

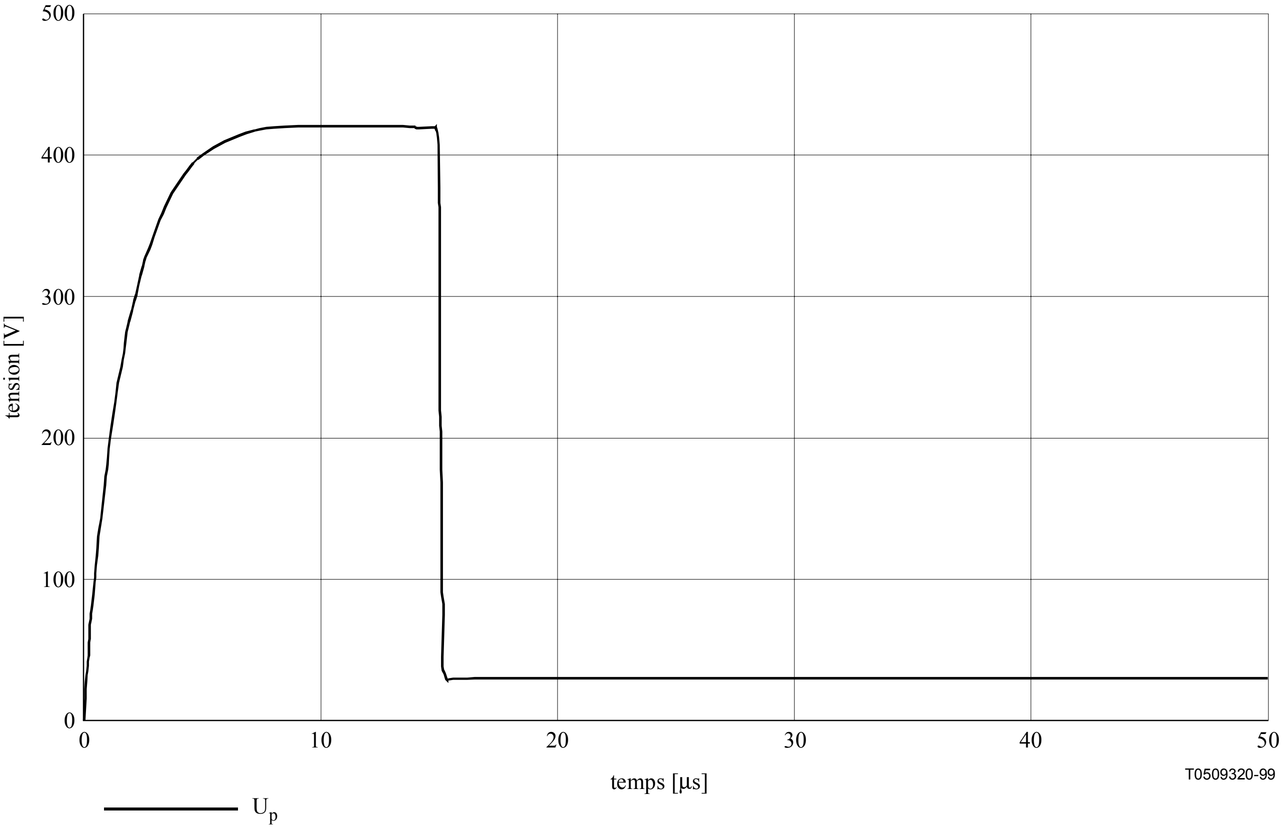


Figure I.1-5/K.44 – Voltage U_p across the special test protector for a charging voltage U_c of 1 kV

This example with six different charging voltages shows the importance of the knowledge of the characteristics of the primary protection and the inherent protection in order to assure a proper coordination between primary and inherent protection, and the equipment.

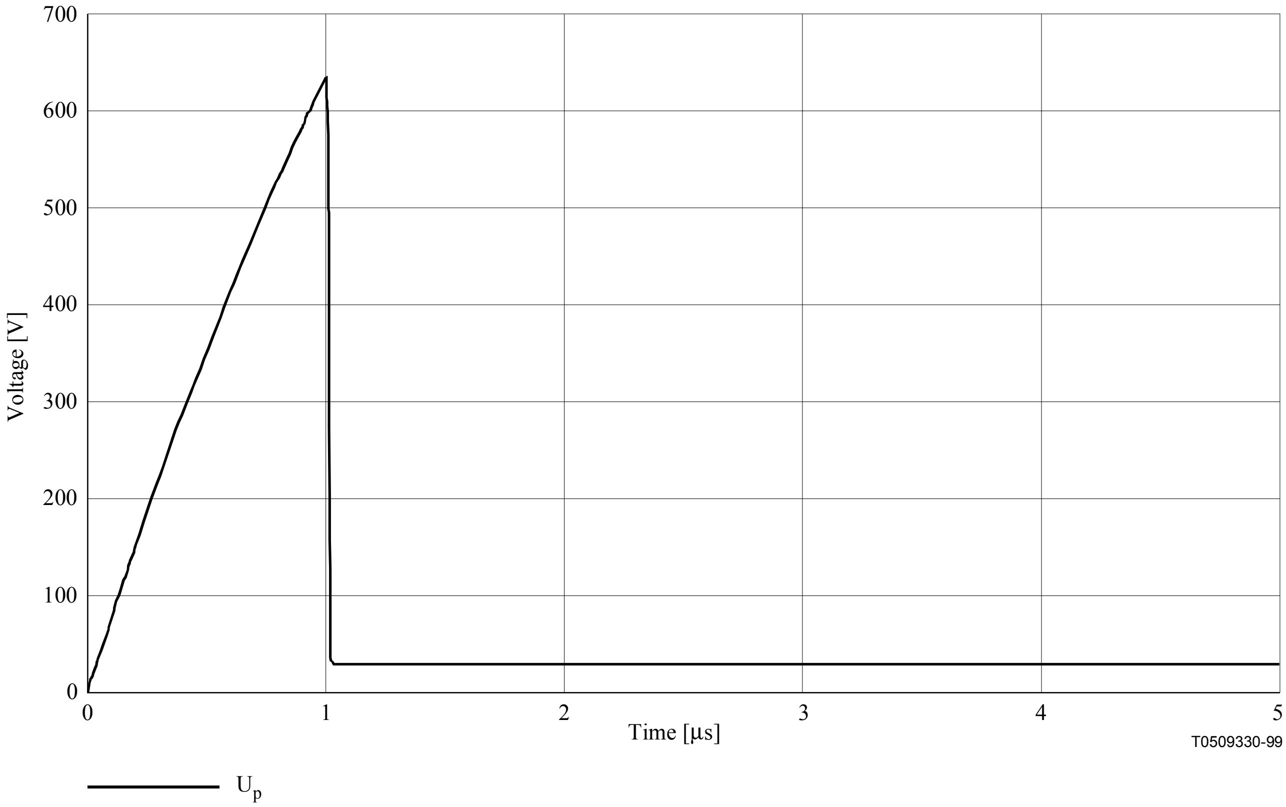


Figure I.1-6/K.44 – Voltage U_p across the special test protector for a charging voltage U_c of 4 kV

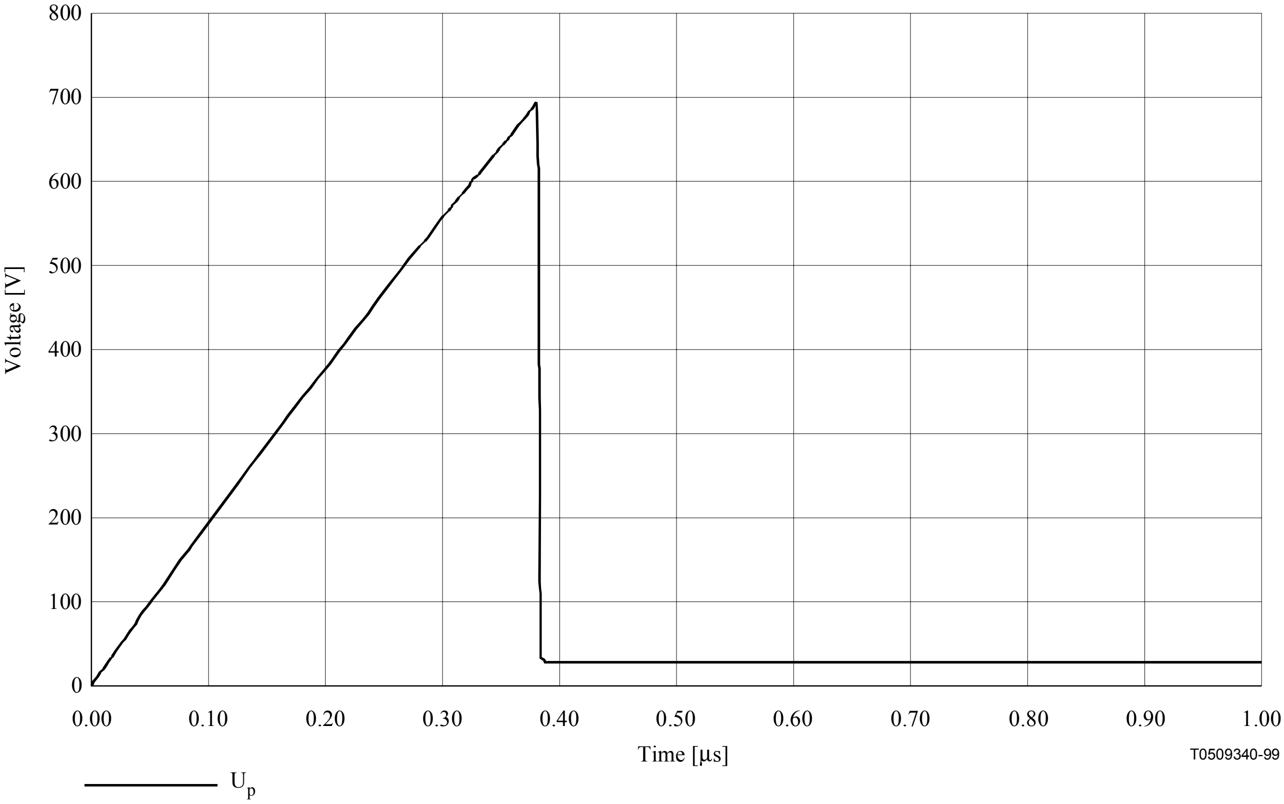


Figure I.1-7/K.44 – Voltage U_p across the special test protector for a charging voltage U_c of 10 kV

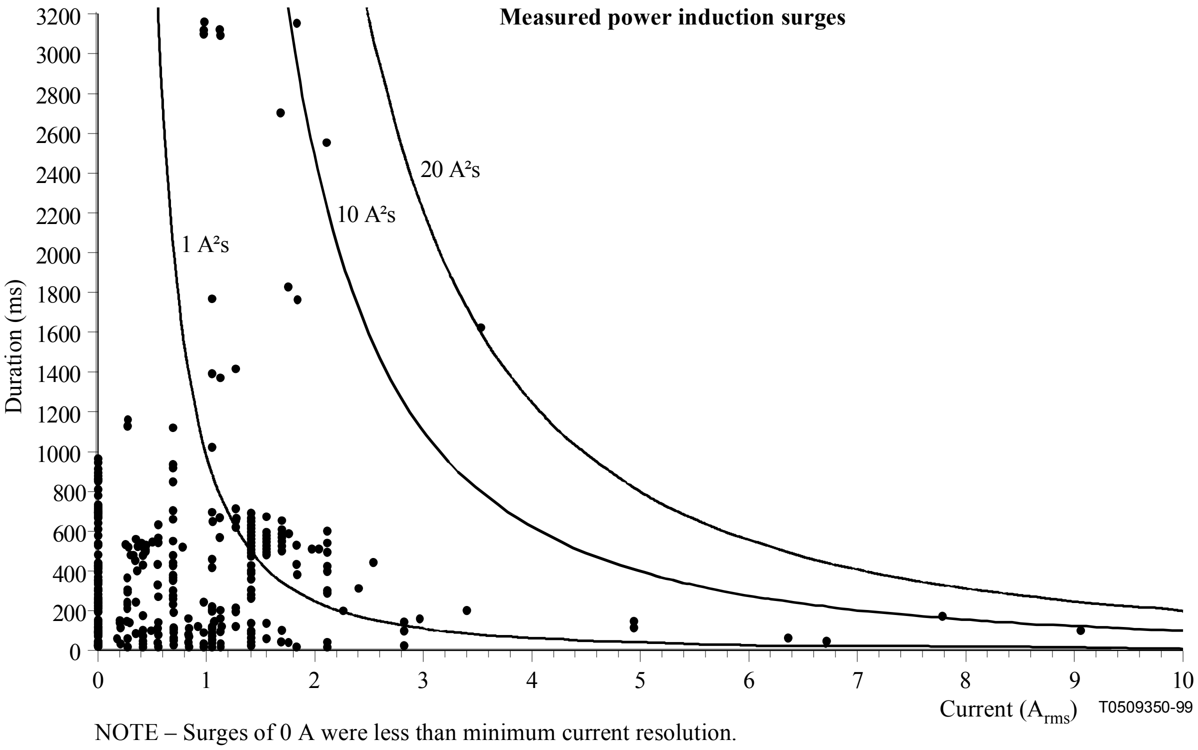
I.1.3 Power induction

Induced voltages are more likely to occur on long lines, and in the common case where customers' lines do not provide a low resistance to earth, induced voltages E may be considered to have a high source impedance consisting of a 600 Ω wire resistance in series with a 0.33 µF line to earth capacitance as shown in Figure I.1-9. The telephone is represented by a 100 Ω resistance and the hook-switch. The GDTs shown in Figure I.1-9 are needed only on lines in exposed areas. However, because of the liberalization of CPE, such protectors may also be present on less-exposed lines. These GDT fire at the customer line end in the short-term power induction case and short-circuit the telephone and the line capacitances. Therefore, the test circuit given in Figure A.3-6 consists only of the induced voltage $E = U_{a.c.}$ and the wire resistances R.

Field experience showed that a large number of linecards in some exchanges were damaged by power induction during thunderstorm days. The damages appeared only in exposed rural areas. The currents induced on such lines and causing the linecard damages were measured in a few cases and showed values between 4 and 6 A and duration between 200 and 500 ms, i.e. specific energy values up to 10-20 A^2s. Figure I.1-8 shows measurements of power induction in Australia.

These overcurrents with high specific energy values were estimated as rare events; therefore it was agreed that the induction test, with agreed primary protection, should simulate an overcurrent with a specific energy of 1 A^2s for the basic requirement and 10 A^2s for the enhanced requirement.

Considering that most test laboratories only had available a test circuit with a maximum test voltage of 600 V, it was decided to define, for the basic requirement induction test, this maximum voltage value $U_{a.c.(max)} = 600$ V and to increase the test duration up to 1 s.



NOTE – Surges of 0 A were less than minimum current resolution.

Figure I.1-8/K.44 – Power induction overcurrents measured in Australia

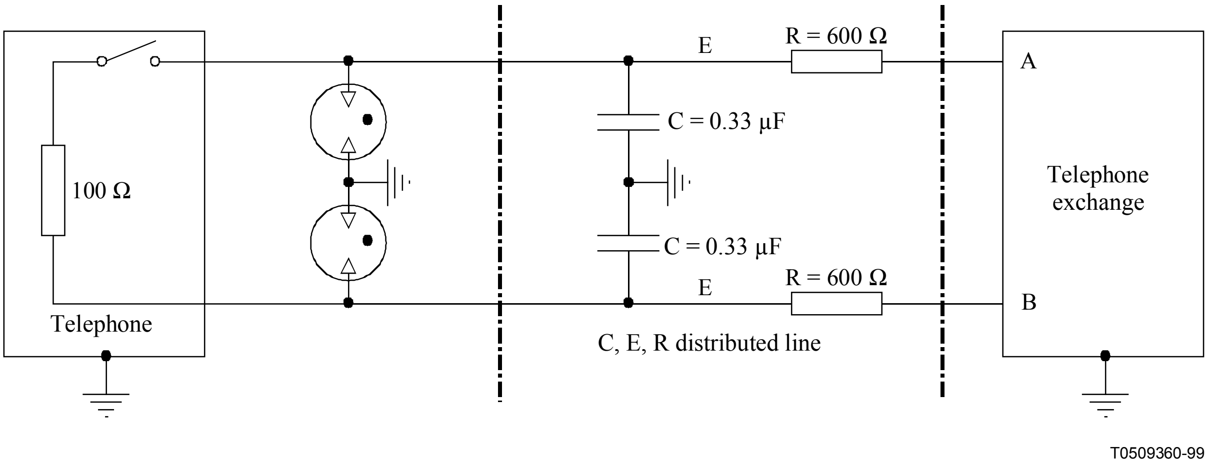


Figure I.1-9/K.44 – Equivalent circuit of a telecommunication line during power induction

As with the lightning surge testing, it is also necessary to be aware of the need to test at specific voltage levels when performing power induction tests. An example of a linecard circuit utilizing a PTC and switching protector is shown in Figure I.1-10. During testing the following points were monitored, V_p, I_g and I_z, to illustrate the operation of various components. The monitoring internal to the equipment was done to help designers and testers to understand the issues to consider when testing the equipment. It is not necessary to monitor internal to the equipment during type approval testing.

As the test voltage is increased it is noticed that the switching devices start to operate, see Figure I.1-11. A generator voltage just below that which operates the inherent protection, for switching and foldback type inherent protection, is the point of maximum voltage stress for the

SLIC. Five surges should be applied with the generator voltage set just below that which operates the inherent protection. Note, for clamping type inherent protection, the maximum voltage stress generally occurs for generator voltages just below that which operates the primary protector, i.e. maximum current through the inherent protector. In this case five surges should be applied with the generator voltage set just below that which operates the primary protector.

As the voltage is increased further it is noticed that the PTC operates and the primary protection fires, see Figure I.1-12. It is necessary to apply five surges at a voltage level which causes the PTC to just operate, and cause operation of the special test protector, at the end of the test duration. It is necessary to wait approximately 15 minutes between surges to allow the PTC to cool.

It is also necessary to apply five surges with the generator set to $U_{a.c.(max)}$ as this is the point of maximum current stress for the PTC.

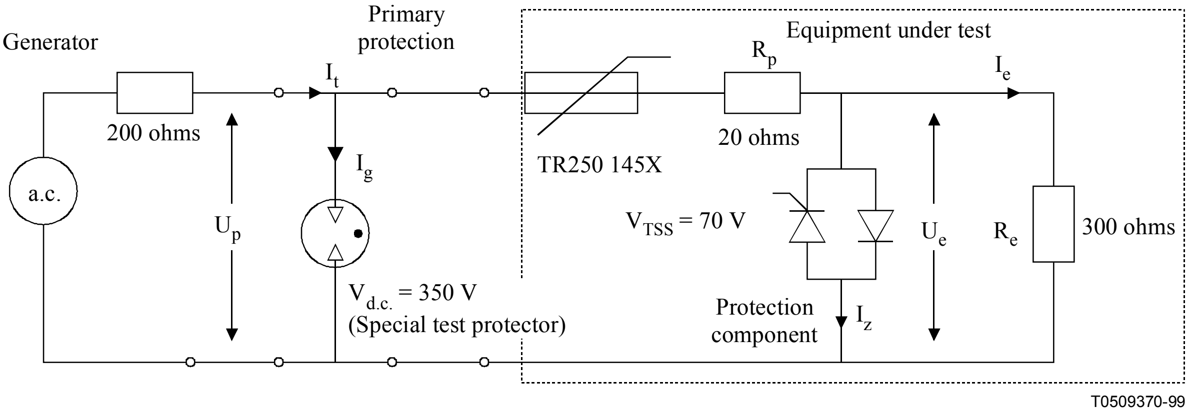


Figure I.1-10/K.44 – Example circuit

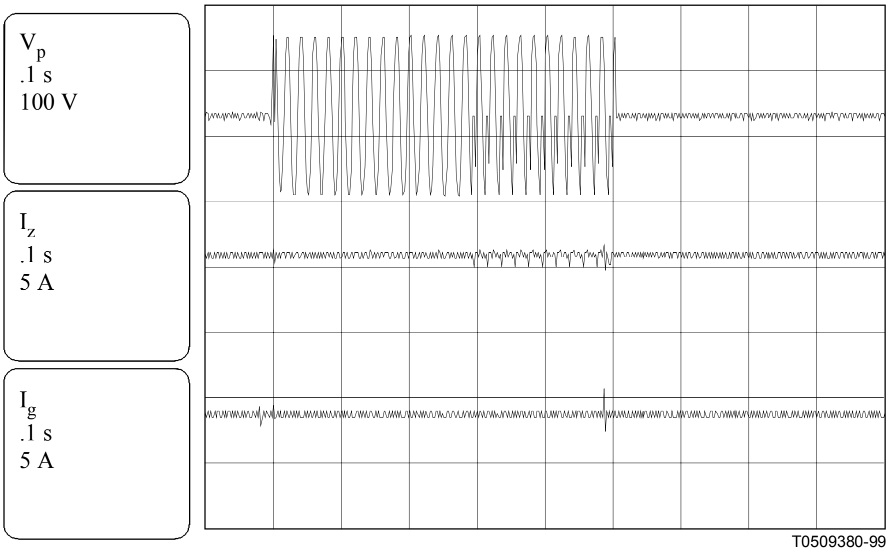


Figure I.1-11/K.44 – $U_{a.c.}$ = 102 V_{rms}, Switching inherent protector starts to operate

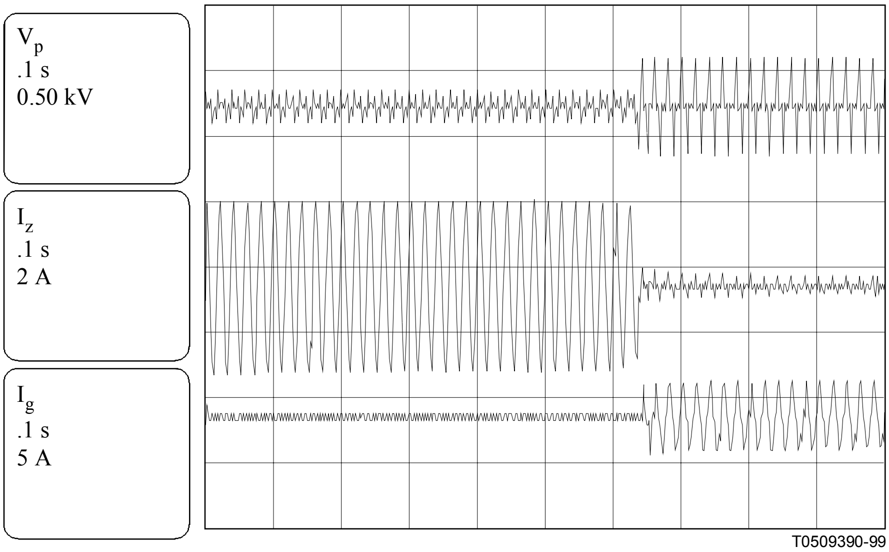


Figure I.1-12/K.44 – $U_{a.c.} = 366\ V_{rms}$, PTC operating

I.1.4 Mains power contact

Mains power contact surges can occur up the amplitude of the mains voltage. The maximum voltage is nominally 240 V_{rms}. The resistance from the source from the equipment is thought to be anywhere from 10 Ω to 1000 Ω.

Direct contact with electrical mains power can occur through network lines or cable faults, faulty or unapproved CPE or other causes. The contact may not cause the operation of a power system circuit breaker. The a.c. currents resulting from direct contact may make effective protection both difficult and expensive. As such events are rare, equipment is not required to withstand overvoltages or overcurrents arising from direct contacts but may fail in an acceptable manner.

The following particular dangers to equipment may arise:

– A contact near to the equipment where the combined resistance of the cable circuit and equipment termination is low and a high current flow occurs. This condition is simulated in the test in Figure I.1-13 by a resistance of 10 Ω. The test current may be limited to lower values according to national regulations.

– A contact at the maximum distance from the equipment where the combined resistance of the cable circuit and equipment termination is high and a small but harmful current flows continuously. This condition is simulated by a resistance of 1000 Ω.

– Experience shows that, in reality with values between 10 and 1000 Ω, equipment is most susceptible to damage and fire hazard from current overheating.

Mains power contact generally has a source voltage equal to the local mains voltage. The resistance between the source and the linecard consists of the line resistance and the fault contact resistance. Experience has shown that the worst-case situation can occur over a narrow resistance range. To ensure that the worst-case condition is checked, the following test resistor values are used: 10 Ω, 20 Ω, 40 Ω, 80 Ω, 160 Ω, 320 Ω, 600 Ω and 1000 Ω.

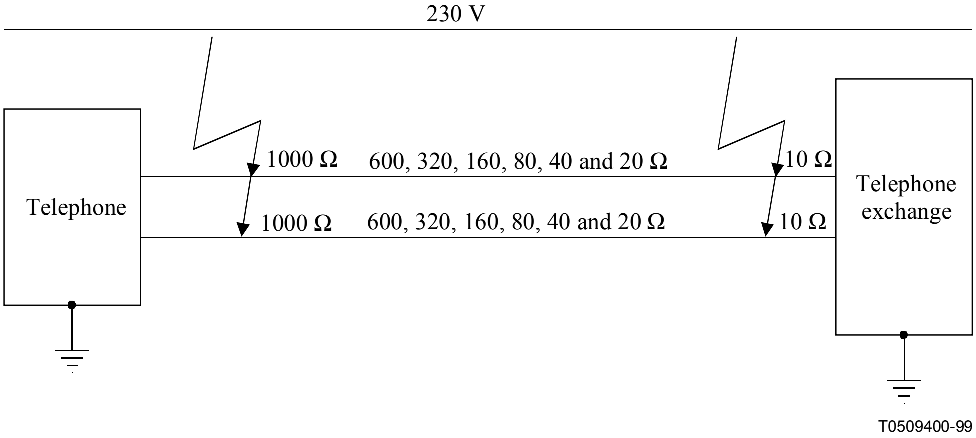


Figure I.1-13/K.44 – Mains power contact mechanism

It was agreed during the study period to perform the power contact with these 8 resistor values as a result of a problem experienced by British Telecom. However, because the power contact test has a duration of 15 minutes it was decided that testing with all eight resistors was too onerous and that the choice of intermediate resistors should be up to the person performing the test. There was also some discussion on reducing the test duration where it does not affect the test result. In this case, some guidance needs to be given on choosing the test resistor and test duration.

There are two known design methods for complying with the power contact test and these are: use a fusible link or use a PTC in series with the line current. For both the fuse link and the PTC the worst case, from a circuit point of view, is the test resistor which results in maximum transfer of energy into the circuit. This can be determined by testing with all test resistor values and determining the maximum energy with an oscilloscope by measuring the voltage at the input of the circuit and current flowing into the circuit and then integrating the product of the voltage and current with time.

a) A fusible link or resistor is designed to overheat and break open interrupting excessive current flow into the equipment. Where minimal testing is to be performed, the test should be performed with the test resistor which causes the maximum energy dissipation in the circuit. Where it is proven that the resistor will not contract and reconnect the circuit when it has cooled, the test may be stopped once the current is interrupted.

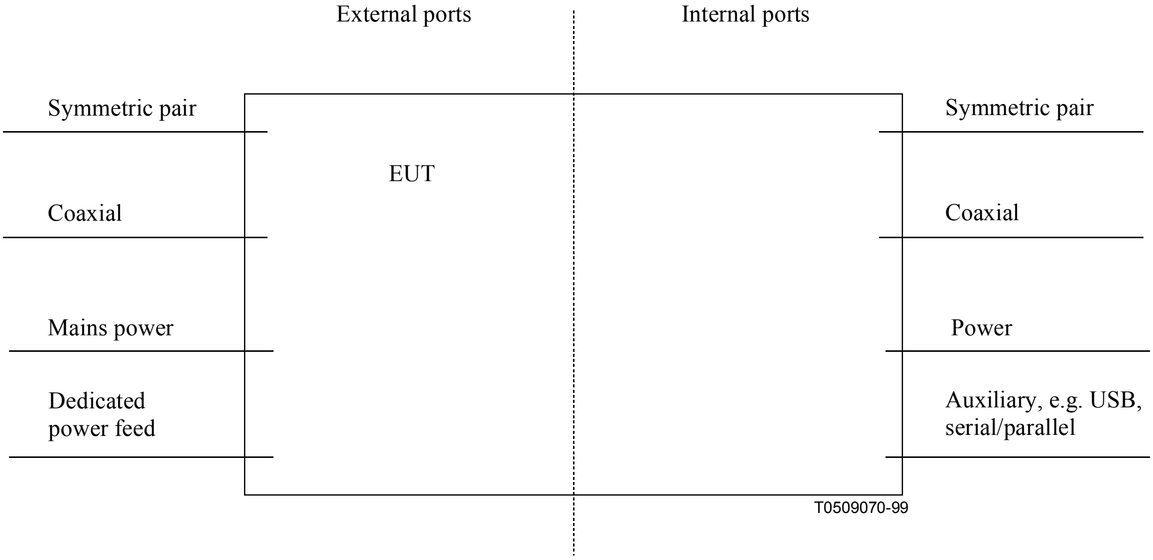
b) A PTC is designed to go high resistance when an excessive current flows through it. The worst-case current for a PTC is the lowest resistor, i.e. the highest peak current. Where minimal testing is to be performed, the test should be performed with the test resistor which causes the maximum energy dissipation in the circuit and with the 10 Ω resistor.

   Generally once a PTC has operated the current will be limited to low values and there will be no change for the remainder of the test. However, there have been cases where the PTC has started to breakdown at the end of the duration which can cause excessive heating and the possibility of a fire. Also there have been cases where the PTC forms a relaxation oscillator with a long time constant. However, where it is proven that the PTC will not fail within the test time or that there is no other which will alter the test result, the test may be stopped once the current has stabilized at a low value which will prevent an overheating situation.

If the worst-case resistor cannot be determined, the test should be performed with all resistor values.

I.1.5 Terminations and SPDs on untested ports

An example of a complex piece of equipment is shown in Figure I.1-14.



NOTE 1 – Not all ports need to be tested but they may need to be terminated.

NOTE 2 – In this figure, "External ports" means ports connected to cables which exit the building and "Internal ports" means ports connected to cables which remain within the building.

Figure I.1-14/K.44 – Equipment ports

This equipment has both external and internal ports and the influence of these on the port being tested has to be considered. In practice ports may be terminated by connection to associated equipment or by a terminating impedance or resistance. These ports may also be connected to one or more SPDs. It is necessary to consider the effect of the termination and SPDs during testing. The termination on untested ports can be simulated by connecting the port to associated or remote equipment or by the addition of the appropriate termination impedance or resistance. The SPD could be within the equipment being tested, external to the equipment being tested, within the associated equipment or external to the associated equipment. The SPDs can be simulated by connecting the port to an appropriate SPD.

Figure I.1-15 is a possible example.

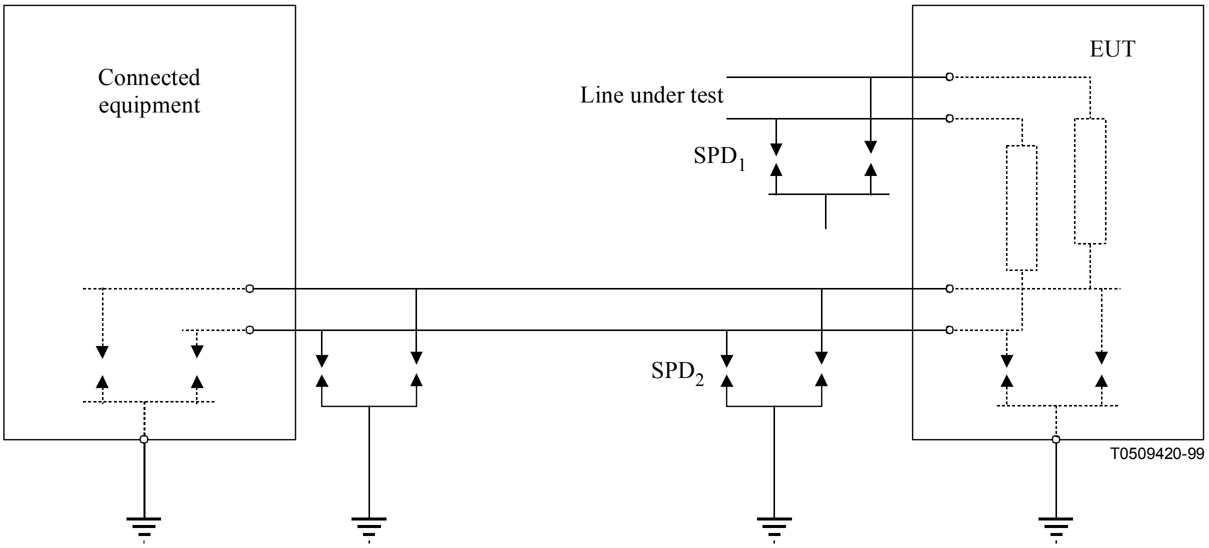


Figure I.1-15/K.44 – Terminations and SPDs on equipment

Issues to consider when terminating the equipment or adding SPDs are:

1) When there is a possible low impedance path from the port being tested to an untested port, the possibility of the protector on the untested port operating first needs to be considered. This is done by using a special test protector on the tested port and a protector with the minimum allowed d.c. sparkover voltage on the untested port.

2) When there is more than one type of untested port, only one type of untested port should be terminated or have SPDs added at a time. The reason for this is that a low impedance path to one type of untested port may prevent current flow to another type of untested port.

3) Where one port may be connected internally to another port, e.g. under some operating conditions or power fail conditions, this port should be tested with the other port terminated and protected.

4) Where the equipment has high current carrying protection components, which eliminates the need for primary protection, it is necessary to remove the GDT, on the port under test, and replace it by the test protector as described in 8.2, 8.3 and 8.4. This is to ensure that coordination has been achieved. During testing of this port, the integral protector is to be left in situ for non-tested ports. If this component is not removable, all tests are performed with the protection provided and the manufacturer must provide a test report to show that the inherent and coordination tests were performed with the special test protector during the design tests.

5) Tests may need to be applied with the following four combinations of termination and SPDs on the untested ports, i.e.:
   a) no termination and no protector;
   b) no termination, add a protector;
   c) no protector, add a termination;
   d) both a protector and a termination.

I.1.6 Test connections for earthed and non-earthed equipment

See Figures I.1-16 and I.1-17.

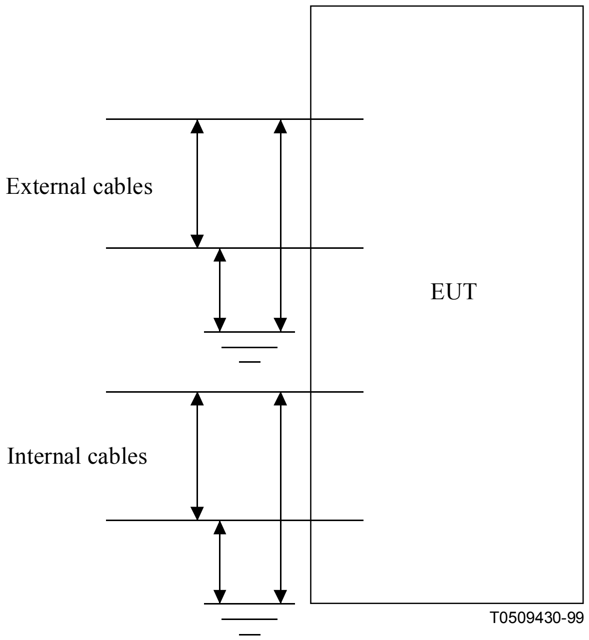


Figure I.1-16/K.44 – Test connections for earthed equipment

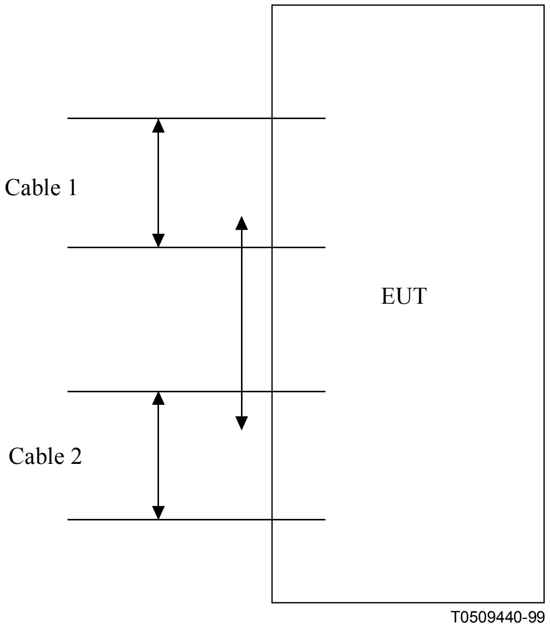


Figure I.1-17/K.44 – Test connections for floating equipment

I.2 Range of lightning and power induction test levels

I.2.1 Lightning

I.2.1.1 Inherent test levels

The range of test voltages used in product Recommendations for the inherent resistibility test levels could be from 1.0 kV to 5.0 kV. Traditionally a test voltage of 1.0 kV has been used in large telecommunication buildings. This is because the majority of surges will be less than 1.0 kV and it is relatively easy to install reliable primary protection on the MDF when required. A figure as high as 5.0 kV could be considered for CPE as they are in a far less controlled environment and it is far more difficult to install GDTs.

I.2.1.2 Coordination test levels

The maximum test level for the coordination requirement has traditionally been 4.0 kV. However recent measurements have shown that surge levels in excess of 7.0 kV do occur. An optional test level of up to 10.0 kV is allowed. The higher test level has a higher dU/dt. This results in a higher firing voltage of the primary protector and higher capacitive charging currents in the equipment.

I.2.2 Power induction test levels

I.2.2.1 Inherent test levels

Traditionally the inherent test has been 0.2 A^2s for equipment in telecommunication centres and CPE. With the liberalization of customer premises, the use of primary protection is less certain and the inherent test level may need to be higher for CPE, e.g. 1.0 A^2s.

I.2.2.2 Inherent/coordination test levels

Traditionally the test level, for the test with primary protection, was 1.0 A^2s. An enhanced test level of 10 A^2s has been introduced to take into account that some countries have higher levels of power induction, maximum level of power induction into short lines (200 Ω) or the need for a high grade of service due to changing regulatory requirements.

The method of specifying the requirements for equipment may need to be different. Recommendation K.20 (1996) specified a $U_{c(max)}$ of 600 V through 600 Ω for 1 second. Measurements have shown that the range of time for which the fault current flows is from 0 to 3.2 seconds and that the current flowing in a telecommunication circuit can vary from 0 to 9 A_{rms}, see Figure I.1-8. Tests on a resistor have shown that its specific energy rating decreases with increasing current for a constant specific energy. This shows that the Inherent/coordination test has to be performed at the maximum current which occurs.

I.3 Relationship between Recommendation K.44 and other product/product family Recommendations

Recommendation K.20 is for the equipment that is installed in telecommunication centre. There is a proper grounding system and metal structure written in Recommendation K.27, so the environment is not so exposed. However due to the large number of telecom cables, total current which flows into the building will be large.

Recommendation K.21 is for the equipment that is installed in a customer's premises where the grounding and bonding system is poor. The earth resistance may be high or no earth system may be provided.

Recommendation K.45 is for the equipment that is installed between the telecommunication centre and the customer's premises building. The grounding system is not as good as a telecommunication centre, but the system is under the control of operator. There is some merit in that the small structure allows ideal equipotential bonding.

Figure I.3-1 shows the example of the location of the equipment and Recommendations to be applied. If the equipment is used in more than one location, it has to be tested according to all relevant Recommendations.

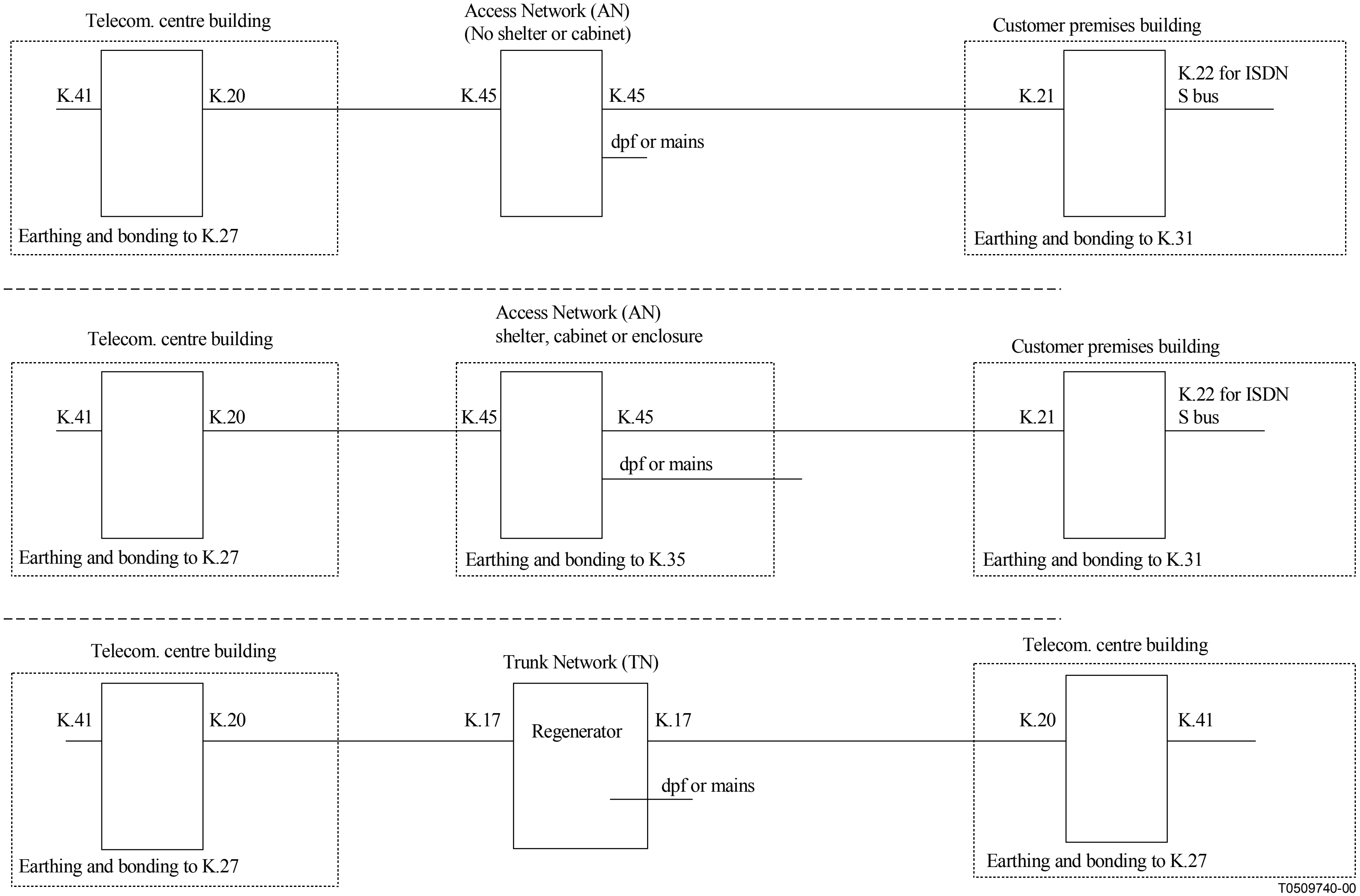


Figure I.3-1/K.44 – Example configuration of a telecommunication network showing the border between a telecommunication centre, the access network and a customer's premises

APPENDIX II

Supplementary information for manufacturers and operators

II.1 Introduction

The following information is under study by ITU-T. It has been provided in this appendix for the information of manufacturers and operators and to promote discussion on these topics.

II.2 Primary protection coordination

The effects of the operation of primary protection are described in Recommendation K.11.

To ensure the coordination of the protection components with the equipment, it is necessary to check that:

1) the equipment will not be damaged by worst-case voltages that may appear between the input terminals and between an input terminal and the equipment ground reference;
2) the equipment will not be damaged or interfered with by the operation of the primary protection over the complete range of surge voltages.

The operation of primary protection with a switching characteristic has two effects:

- It limits the maximum voltage applied to the equipment and hence, depending on the internal impedance of the equipment, the maximum current which the equipment must withstand.
- It produces a very rapid change of voltage and current, which by inductive or capacitive effects can reach sensitive part of the equipment not apparently exposed to line voltages.

II.2.1 Primary protection does not operate

For surge voltages where the primary protection is not activated, attention should be paid to the value of the currents that can flow in the internal cabling network. Large currents in the internal cabling network may disturb other equipment. Recommendation K.27 describes earthing and bonding inside a telecommunication building and Recommendation K.11 treats coordination with electrical protection devices.

II.2.2 Primary protection does operate

Lightning surge simulation requires special attention to be paid to:

- a change in the operating voltage of GDTs with voltage rate of rise;
- potential differences developed across the protection frame and any associated earth wiring due to high current flow;
- the fast dU/dt, caused by the operation of the GDT, which may damage sensitive components or cause misoperation (equipment lockup or corruption of data in memories).

To check coordination with primary protection, attention must be paid to the operating principles of the GDT. Firstly, the 10/700 µs firing voltage of GDT, see Figure I.1-4, is generally higher than the d.c. firing voltage but generally less than the 1 kV/µs firing voltage. Secondly the d.c. firing voltage, and hence the 10/700 µs firing voltage, can vary considerably for the same protector type. For example the d.c. firing voltage of a 230 V GDT is allowed to vary from 180 V to 300 V (K.12).

For these reasons primary protection coordination is checked by replacing the agreed primary protector with a special test protector. The d.c. firing voltage of the special test protector is to be equal to 1.15 times the specified maximum d.c. firing voltage of the agreed primary protector. The tolerance on the firing voltage is ±5%. For a 230 V primary protector the firing voltage of the special test protector is 345 V ± 17 V. This test protector is used for both the lightning, power induction and power contact tests. The special test protector should have a similar characteristic to the agreed primary protector.

II.2.3 Principles of coordination

It is written in K.11 that:

- No device exists which has the characteristics for ideally suppressing all voltages and currents connected with disturbances.
- It is sometimes necessary to use more than one protective device.

Generally, high-current devices operate slowly and there remains a residual voltage. Fast-operating semiconductor device operates fast enough but can only handle smaller energy than high-current devices. Therefore it is necessary to have ladder circuit to reduce the surge energy step by step to the level which is harmless to the equipment. This type of protection is called multistage protection.

Figure II.2-1a shows the principle of protection by a ladder circuit.

A primary protector is applied at the location of the border such as an MDF external to the EUT. The most stressful energy is bypassed to ground at this point. An inherent protector is inside of EUT, and it diverts the residual energy of the primary protector. There may also be a third protector inside the EUT that is part of the black box.

It is important that there should be resistance between the protectors so as not to connect to each other directly and then the circuit looks like a ladder. Considering the coordination between primary and inherent protection, there should be resistance R_{in}. This R_{in} is virtually the same as the input resistance of the EUT when the inherent protector such as a PNPN device or a diode turns on and connects R_{in} to ground. Figure II.2-1b shows the equivalent circuit when the inherent protector turns on. If there is no resistance between the primary and inherent protector, only the protector which has the lower turn-on voltage will operate. In this case, only the inherent protector operates and it prevents the operation of the primary protector, so coordination is not achieved. R_{in} is necessary to increase the voltage across the primary protector high enough to cause the primary protector to operate.

The point is that the inherent protector usually turns on at a lower voltage than the primary protector at the MDF. At first the current flows into the black box and generates voltage across the inherent protector and it turns on. Then the current that flows through R_{in} and the inherent protector generates the voltage across the primary protector.

Therefore the inherent protector is not subsidiary device but essential device because it usually operates earlier than primary protector and protects the following components. The voltage drop across the coordination resistance, due to the current flowing in the inherent protector, operates the primary protector which bypasses the majority of the surge energy to ground.

In a traditional circuit using a bulky transformer or coil inside the EUT, it is possible that there is no inherent protector. The sum of the resistance, R_{in} plus R_e, is high enough so that the primary protector turns on without much current flowing into EUT. Figure II.2-1c shows such equivalent circuit.

If there is an inherent protector, such as semiconductor SPD in EUT, it usually operates faster than the primary protector at the MDF. If there is no resistance between the primary and the inherent protector, the operation of the inherent protector disturbs the operation of the primary protector. Coordination is achieved when there is sufficient resistance between the protectors, and the voltage drop across the resistance allows the primary protection to operate correctly. When coordination is designed correctly, EUT is not damaged up to maximum test level. Above the maximum test level the primary protector must operate for lightning surges.

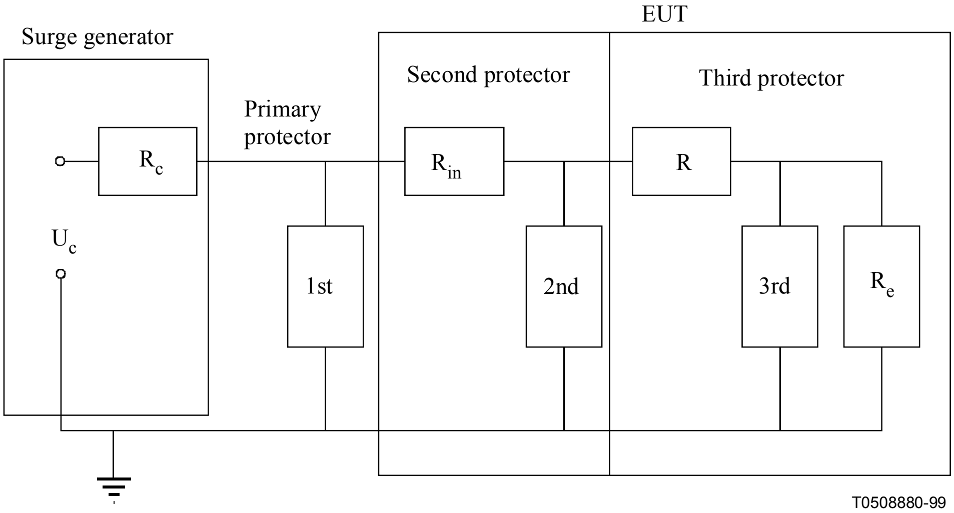


Figure II.2-1a/K.44 – Principle of protection by ladder circuits

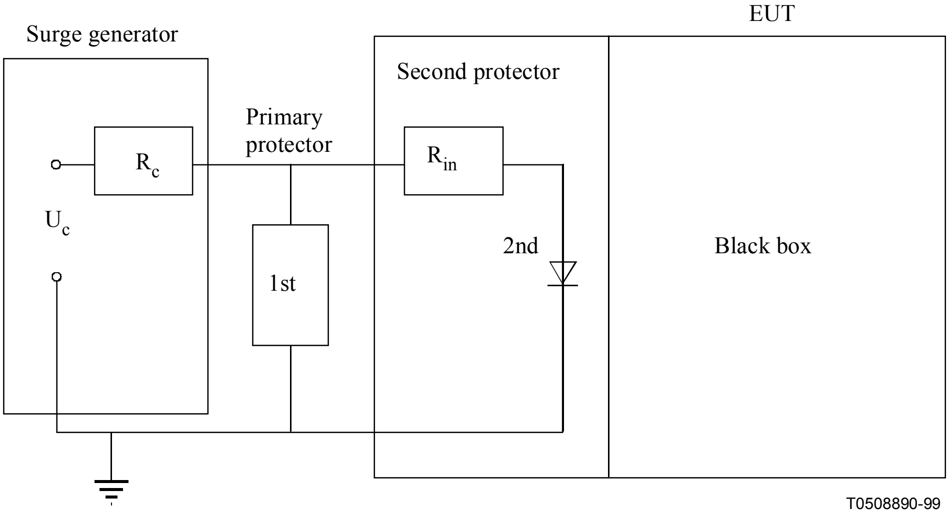


Figure II.2-1b/K.44 – Equivalent circuit when the second protector turns on

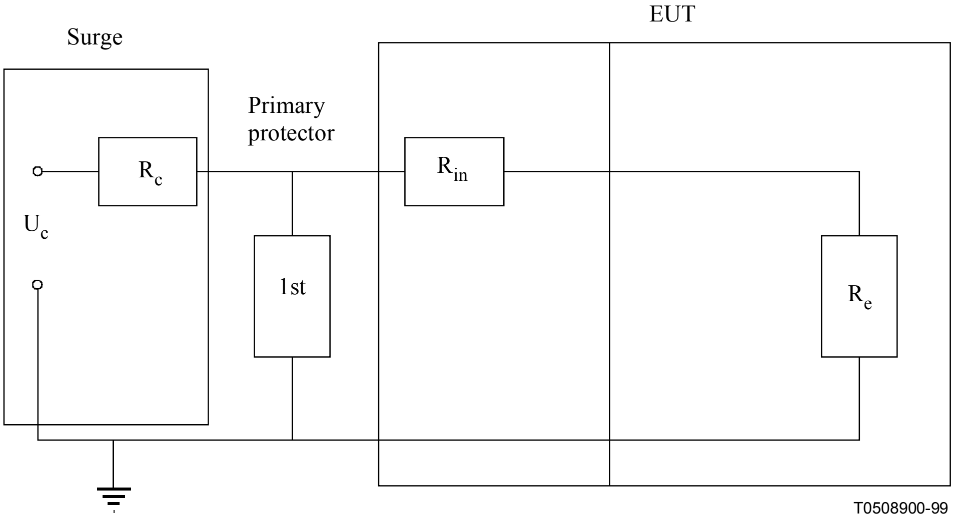


Figure II.2-1c/K.44 – Robust circuits with no second protector

II.3 MDF voltage at the input of equipment

II.3.1 General

The firing voltage of a GDT depends on dU/dt. If R_p is known, the dU/dt of U_{si} can be calculated by SPICE transient simulation. Using the firing voltage versus dU/dt information in the GDT data sheet, the actual firing voltage for each condition can be simulated. Figure II.3-3 shows the simulation results for a 1 m MDF cable between the GDT and the equipment and a 1 m MDF earth cable. It shows that GDT operates at a higher voltage in a shorter period of time when U_c is high. If U_c is small, GDT operates at a lower voltage in a longer period of time.

Figure II.3-4 shows the same simulation but with a 10 m MDF cable between the GDT and the equipment and a 10 m MDF earth cable. The inductance of the 10 m MDF cable and the 10 m earth cable is almost 10 μH respectively. The total inductance of 20 μH can be an effective low pass filter for the high speed residual voltage caused by GDT operation. The MDF cable suppresses the high dU/dt surge caused by operation of the GDT. This simulation shows that the test lead between the surge generator and the EUT has to be short, e.g. less than 2 m.

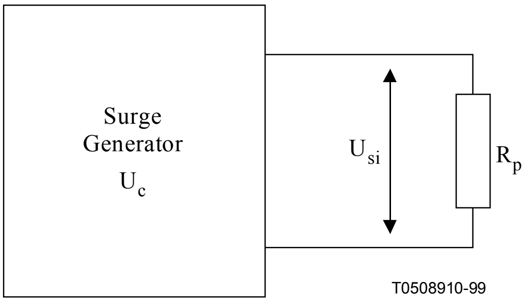


Figure II.3-1/K.44 – A model to calculate the dU/dt of U_{si}

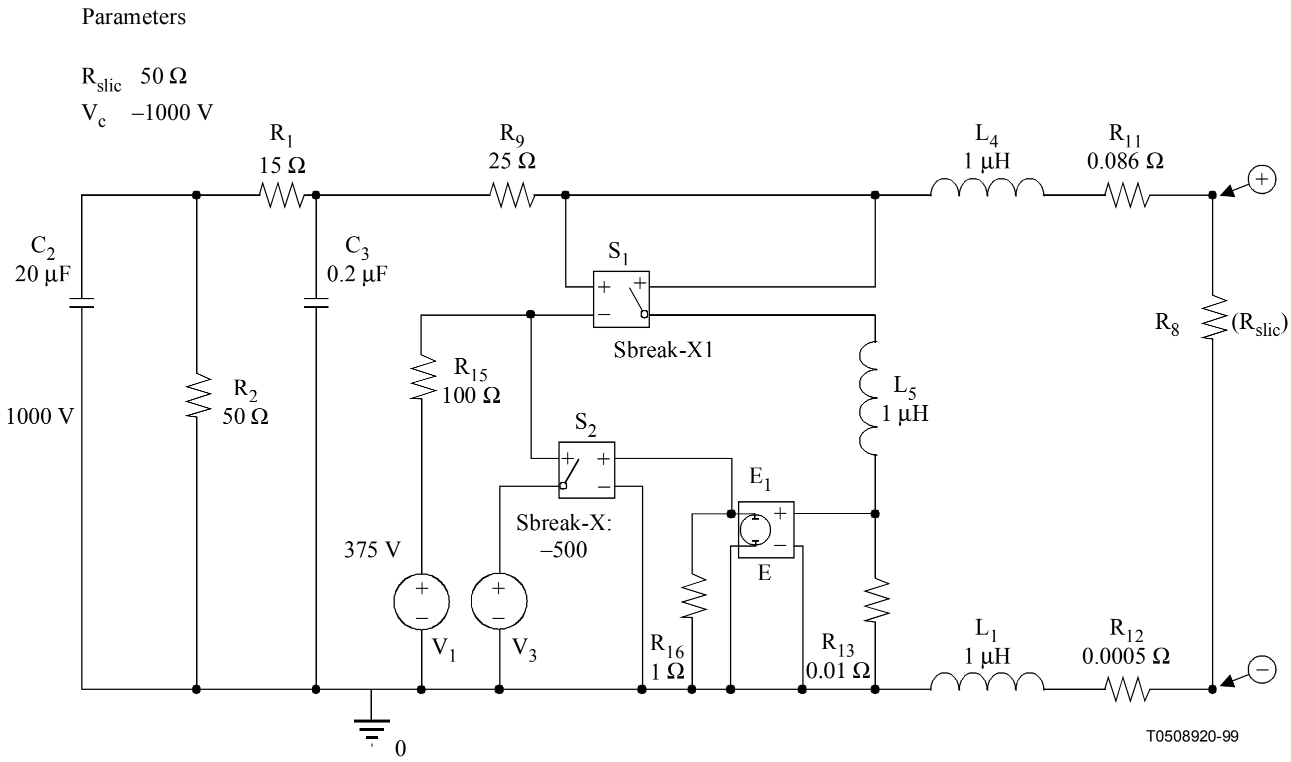


Figure II.3-2/K.44 – The Pspice model used to calculate the reduced voltage at the equipment input due to the impedance of the MDF cable

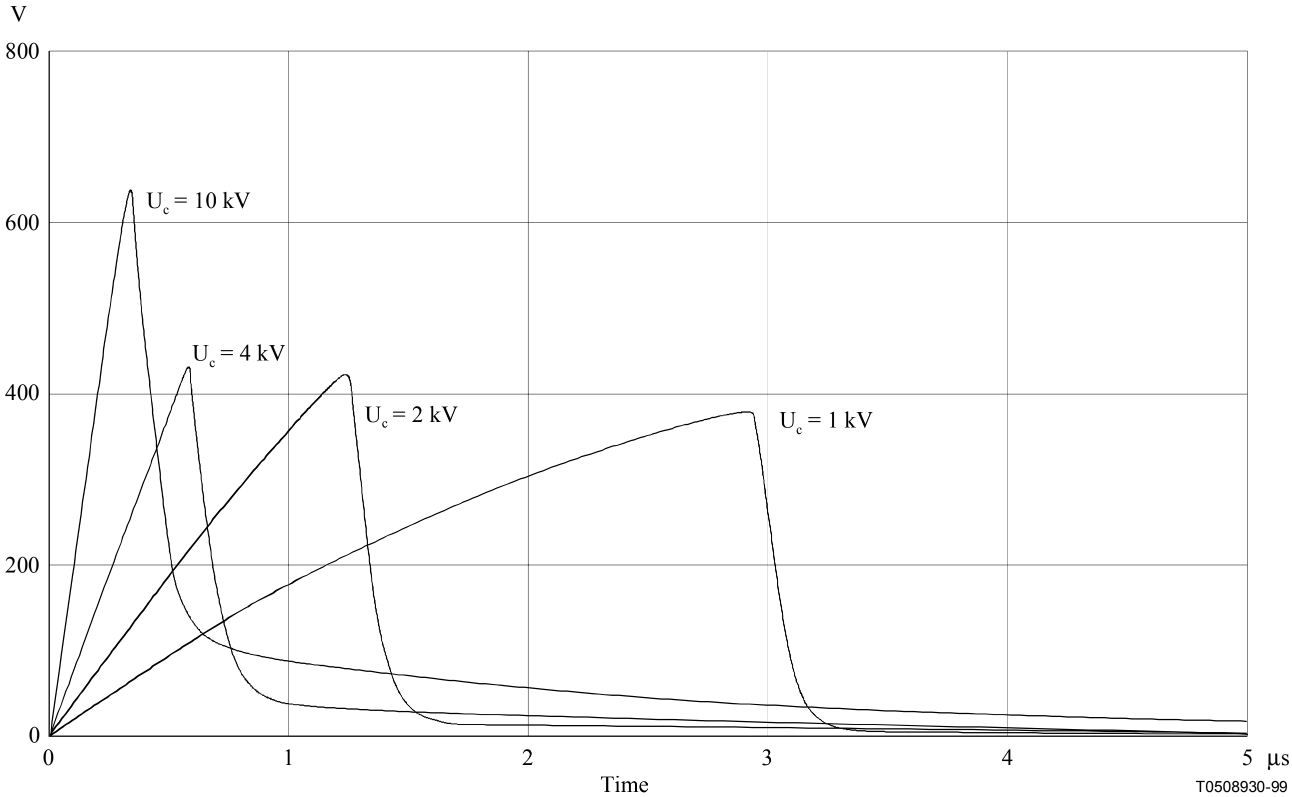


Figure II.3-3/K.44 – MDF cable is 1 m

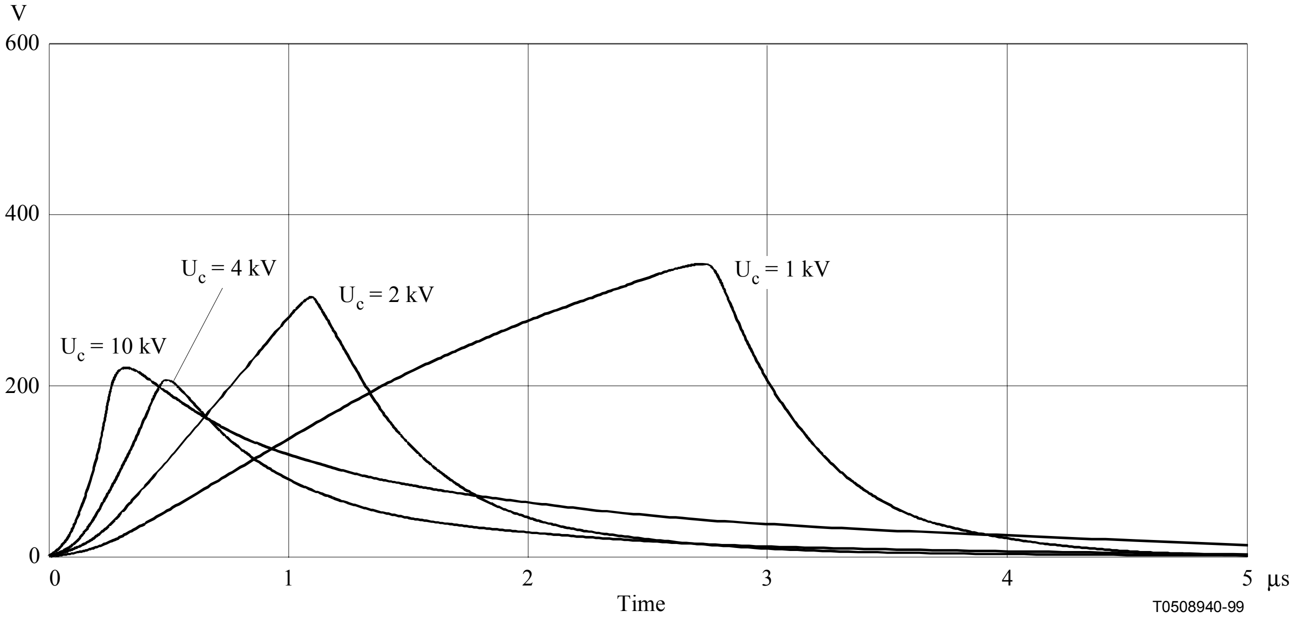


Figure II.3-4/K.44 – MDF cable is 10 m

II.3.2 MDF earth wire voltage drop

The inductance of the MDF cable between the primary protector and the EUT has a good effect for high dU/dt surges, but the inductance of the MDF earth cable has the opposite effect. This is **particularly** so when it is considered that the current from all GDTs, which have operated, flows in the MDF earth cable. Inductance is a function of the length of the cable and does not change much if the diameter of the cable is changed. The length of MDF earth cable cannot be zero, so there is always inductance. The voltage drop caused by the MDF earth cable is due to the surge current which flows after the GDT operates. The voltage drop of MDF earth cable appears at the input of the equipment, so it is necessary to have a bonding configuration which will have the minimum possible inductance and resistance. Figure II.3-5 shows where inductance of the MDF earth cable exists.

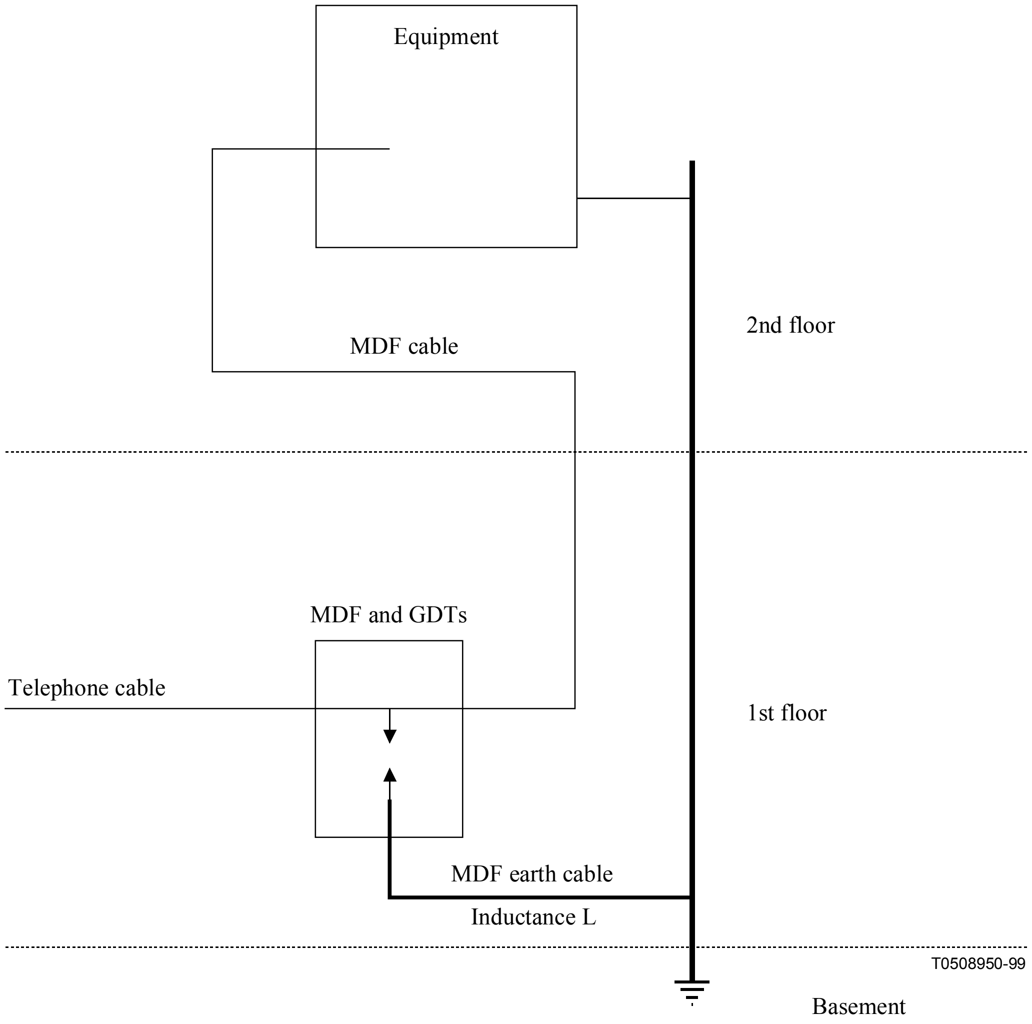


Figure II.3-5/K.44 – Inductance of MDF earth cable

When there is significant length of MDF earth cable, as shown in Figure II.3-5, a multiple cable or mesh configuration is desirable.

Multiple cables which are not tied together but separately connected will reduce the inductance nearly 1/N where N is the number of cables. See Figure II.3-6.

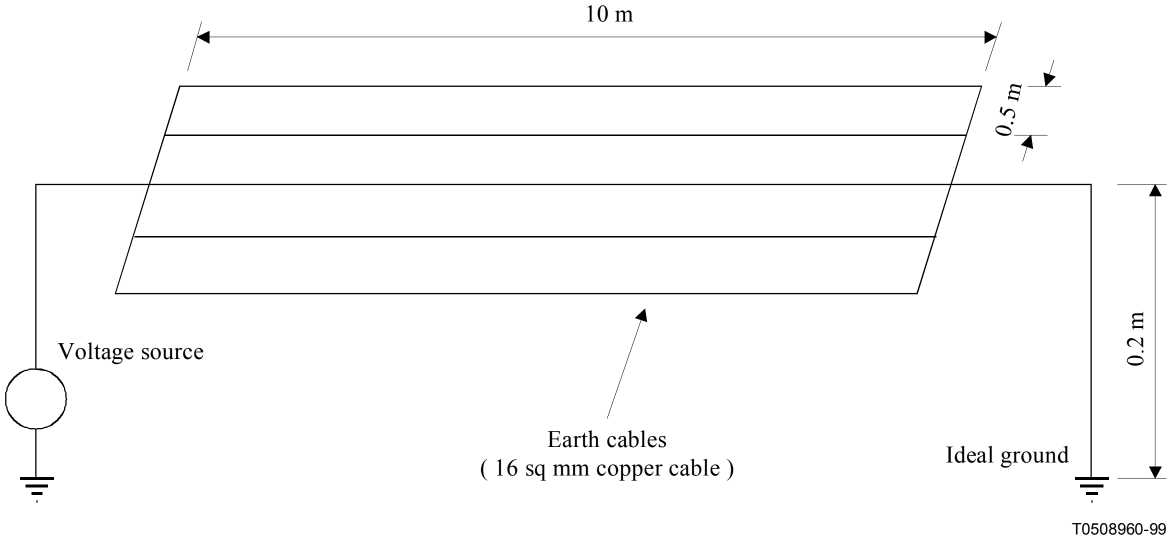


Figure II.3-6/K.44 – Use of multiple earth wires to reduce inductance

The inductance calculated using ACCUFIELD simulation is shown in Table II.3-1.

Table II.3-1/K.44 – Inductance versus number of conductors

N (Number of conductors)	Total inductance
1	10.89 µH
2	6.16 µH
3	4.39 µH
5	3.05 µH

II.3.3 Earth voltage drop test

Where there is an external protection frame and/or an earth wire connecting it to the earth bar, high currents flowing in the protection frame or the earth wire will cause a voltage drop at the input of the equipment, see Figure II.3-7.

Damage due to an earth voltage drop has been observed in the United Kingdom and Australia.

II.3.3.1 United Kingdom's example of earth voltage drop problem

Some small switching systems installed at customers' premises have suffered damage due to the potential difference created by the earth bonding wires of the protection and switching equipment. The bonding for the protection was typically routed over an indirect route to the main earth terminal. The equipment protective earth was connected to the power system wiring earth, and hence the main earth terminal. Due to differences in impedance, a large potential difference was developed between the equipment line terminals and the protective earth of the equipment. This resulted in a small flash-over from the circuitry to the equipment chassis, damaging the equipment. The solution was to bond the protection as close to the equipment as possible using the correct d.c. sparkover voltage protectors such that mains could not get on the line in the event of a power fault on the equipment earth.

II.3.3.2 Australian example of an earth voltage drop problem at customer premises

Australia has suffered a lot of lightning damage to small customer switching systems as a result of potential differences occurring in the telecommunication line and the mains power supply due to the length of the bond wire between the protection frame and the main earth terminal. Where it was not possible to reduce the bond wire length to less than a few metres, a combined telecommunication and mains port protection unit has had to be installed at the equipment. These protection units are very expensive, costing in the order of USD 150.

II.3.3.3 Australian example of an earth voltage drop problem at a telecom centre

Telstra has experienced damage to equipment installed in a telecommunication centre and protected by primary protection. Investigation of the problem showed that a breakdown was occurring between the wiring from the MDF and the chassis of the equipment. The breakdown voltage between the wire and the chassis was approximately 1.5 kV for a 10/700 µs waveshape. This proves conclusively that earth voltage drops of 1.5 kV and greater can occur in practice. Rather than change the earth wiring in the exchange, different equipment was used to perform the function. These exchanges are earthed in accordance with K.27 and the equipment is in an IBN. There needs to be a balanced approach between installation practices, resistibility of equipment and the addition of external protection.

II.3.3.4 Possible test for resistibility to earth voltage drop

As shown in II.3.2, the most significant voltage occurs when a single earth wire is used to connect the protection frame to the earth bar. Earth voltage drop is less of a problem across the protection frame due to the parallel down conductors in the frame and is also less of a problem when multiple earth wires are used to connect the frame to the earth bar.

This test is not applicable if one or more of the following occurs:

- The equipment earth reference conductor is connected to the base of the protection frame.
- Shielded cables are used between the protection frame and the equipment.
- A mesh BN earthing system is used.
- The protection frame is directly connected to the CBN by short conductors (< 1 m).

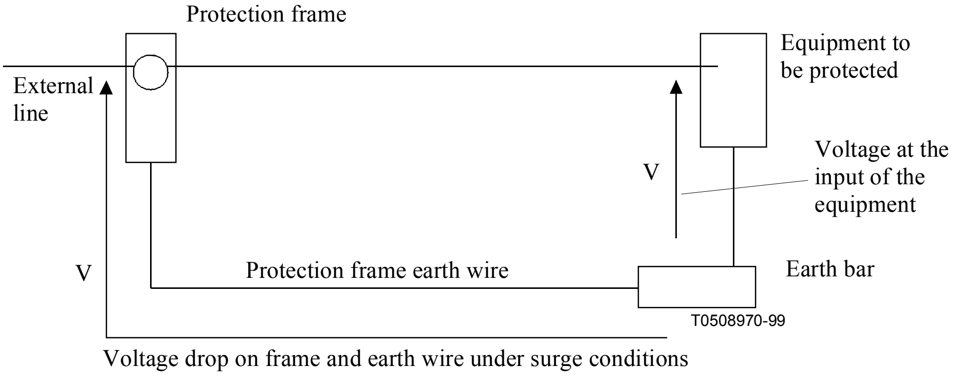


Figure II.3-7/K.44 – Voltage drop in earth wires

Table II.3-2 and the generator in Figure II.3-9 are based on the test Surge 4, specified in 4.5.7 of Bellcore specification GR1089 CORE. The Bellcore test is widely used in North America. The Bellcore test has a maximum peak open circuit amplitude of 2.5 kV.

The approximate surge voltage generated by a surge current being conducted in a bond wire is shown in Figure II.3-8.

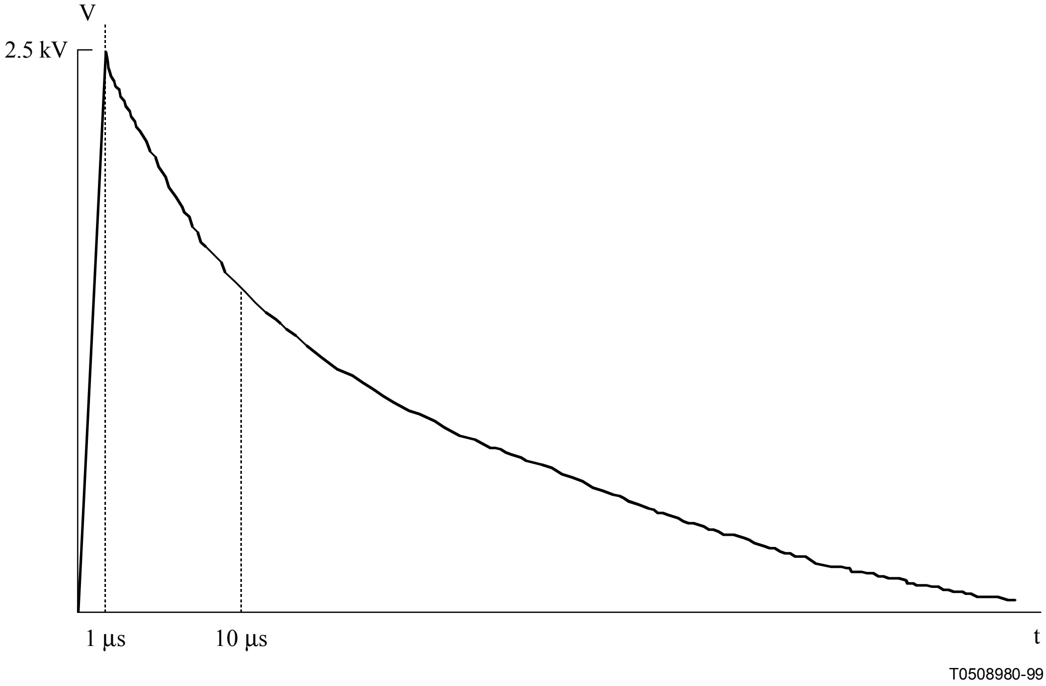


Figure II.3-8/K.44 – Earth voltage drop

The circuit in Figure II.3-9 produces a 2/10 µs waveshape and may be used to reproduce this effect. An approximate magnitude of the voltage which may occur is given in Table II.3-3.

Table II.3-2/K.44 – Test voltage

Description	$U_{c(max)}$
Large external frame, with a small number of down conductors or long earth wire (< 10 m) in a building or large shelter	2.5 kV
External frame in a cabinet with a medium length single earth wire (< 3 m)	1.5 kV
Small external frame with a short earth wire (< 0.5 m)	Test not required. The voltage at the input of the equipment is assumed to be less than that which occurs for tests 1.1 and 1.2 in Table 1a/K.45.

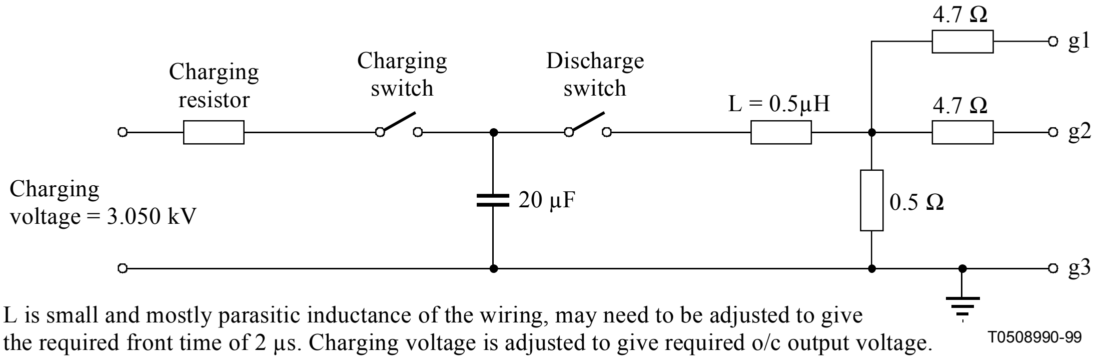


Figure II.3-9/K.44 – 2/10 µs current surge generator

Table II.3-3/K.44 – Earth voltage drop test

Test No.	Test description	Test circuit	Test level	Number of tests	Agreed primary protection	Acceptance criteria	Comments
1.1	Earth wire voltage drop	Figures II.3-9 and A.5.1-1	See Table II.3-2	5	5 of each polarity	A	Applies only to equipment where there is a large protection frame and/or a single earth wire between the primary protection and the common earth point.

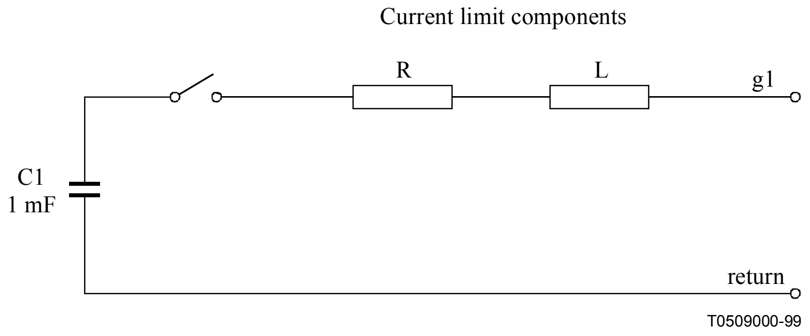
II.4 Current test on mains ports

When lightning strikes a building or shelter housing telecommunication equipment, the current waveshape is considerably longer than the 8/20 µs waveshape traditionally used to test mains ports. Recent studies in Germany have shown that the current waveshape involved in a direct strike can have a 1/2 value of up to 350 µs. Tests on power supplies have shown that a 350 µs tail can cause damage whereas a 20 µs tail does not. It was therefore proposed that a 10/350 µs be used to check coordination of primary protection with the equipment being tested. While this has been discussed in ITU-T agreement for this test could not be obtained. This test remains under study. The coordination test in the product Recommendations requires an 8/20 µs waveshape.

The proposed test is shown in Table II.4-1 below.

Table II.4-1/K.44 – Coordination test for mains ports to simulate a direct strike to the building or shelter

1.x.b	Direct lightning mains port coordination transverse	Figures II.4-1 and II.4-2	$U_{c(max)} = 5$ kA per conductor $R = 0.5\ \Omega$ $L = 2\ \mu H$	$U_{c(max)} = 5$ kA per conductor $R = 0.5\ \Omega$ $L = 2\ \mu H$	5 of each polarity	Agreed primary protector (mains)	A Note, a switching protector must operate at $U_c = U_{c(max)}$



L is small and mostly parasitic inductance of the wiring, may need to be adjusted to give the required front time of 10 µs. U_c is adjusted to give the required o/c output voltage.

Figure II.4-1/K.44 – 10/350 µs current surge generator

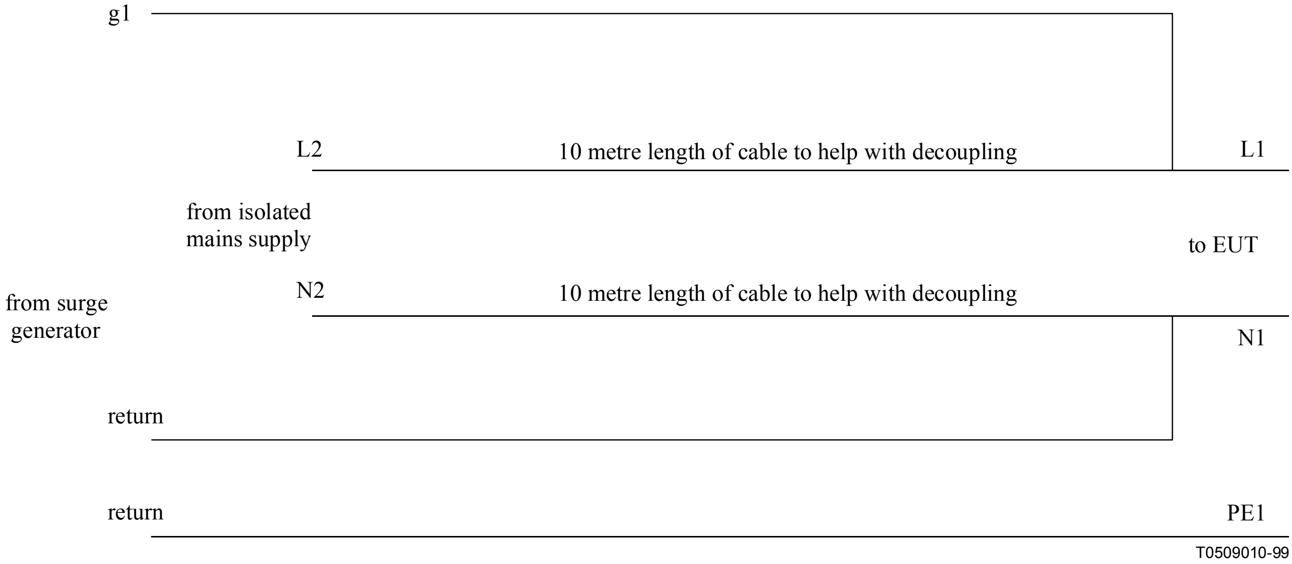


Figure II.4-2/K.44 – Coupling, decoupling and powering network for a high current transverse surge into a mains power port

II.5 Earth and neutral potential rise

II.5.1 Background

Depending on Low Voltage public distribution network design, some risks such as Neutral potential rise and lightning surge transfer may occur on Low Voltage power plant.

II.5.2 Explanation

Rise of Earth and Neutral potential happens mainly when the MV/LV transformer insulation is broken or Spark Gaps operate to prevent transformer destruction by a lightning induction or direct strike to the line. An important 50 Hz current flows and the earth potential rises.

II.5.2.1 Rise of earth potential

The first point is to understand the way to limit rise of earth potential when a fault occurs on the power plant. See Figure II.5-1.

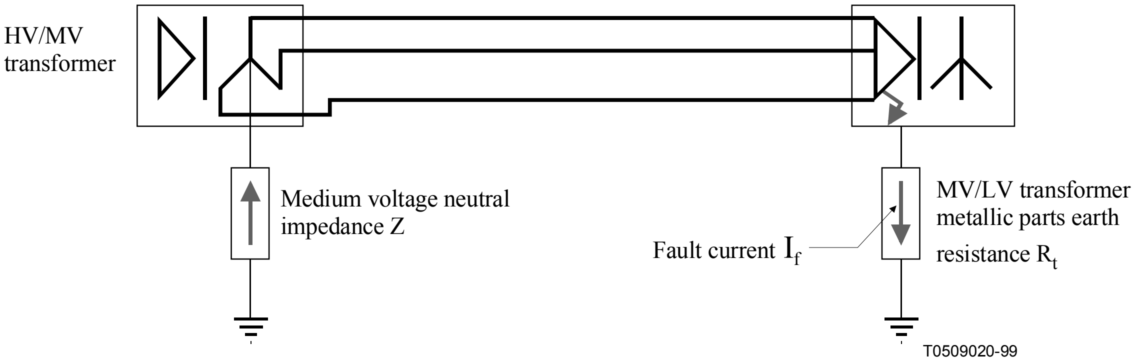


Figure II.5-1/K.44 – Factors affecting the fault current

The worst-case fault current I_f is obtained when neglecting HV line impedance and coupling between transformer's metallic parts earth and other earthing systems as neutral earth.

$$I_f = U / \sqrt{3} \cdot (Z + R_t)$$

where U is the voltage between Medium Voltage active conductors.

The rise of earth potential at the MV/LV transformer is ROEP = $R_t \cdot I_f$. (Note LV = Low Voltage)

In France this ROEP value is limited to 6 kV.

II.5.2.2 Rise of neutral potential

II.5.2.2.1 Coupling between transformer and neutral earth systems

Because of the design of Neutral earthing, Neutral potential rises by conductive coupling when Medium Voltage is connected accidentally to ground.

National regulations may fix limits for this rise of neutral potential (for example 1500 V in France). See Figures II.5-2 and II.5-3.

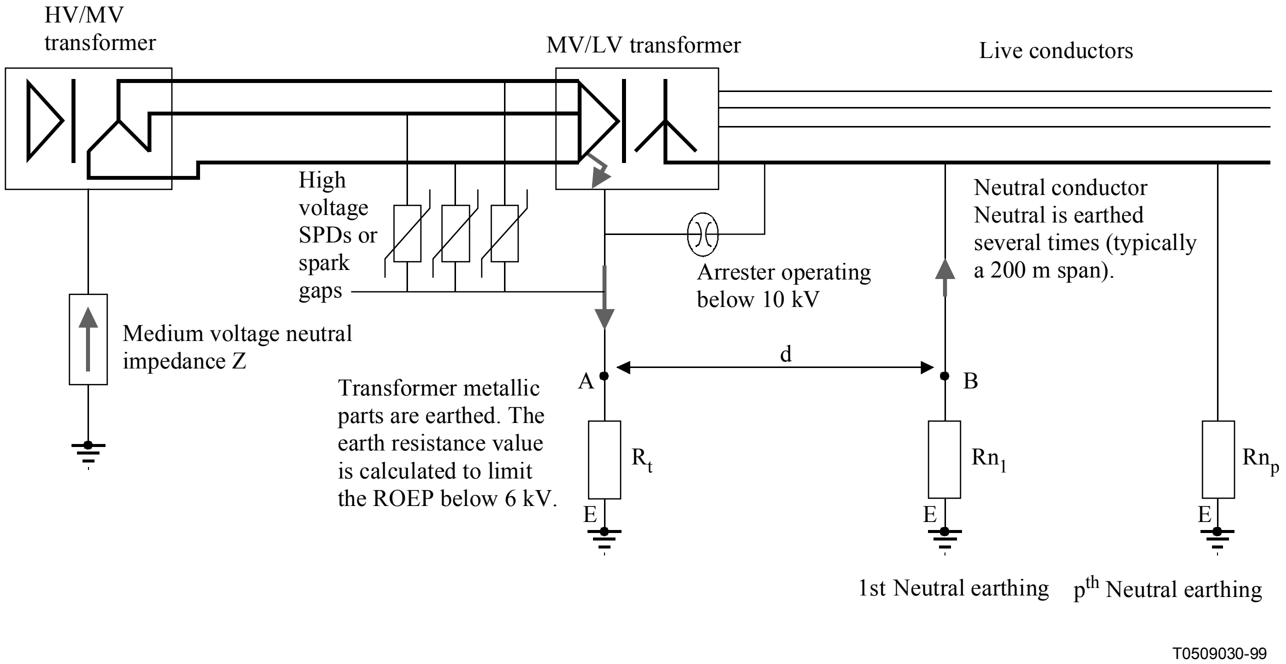


Figure II.5-2/K.44 – Coupling into LV neutral

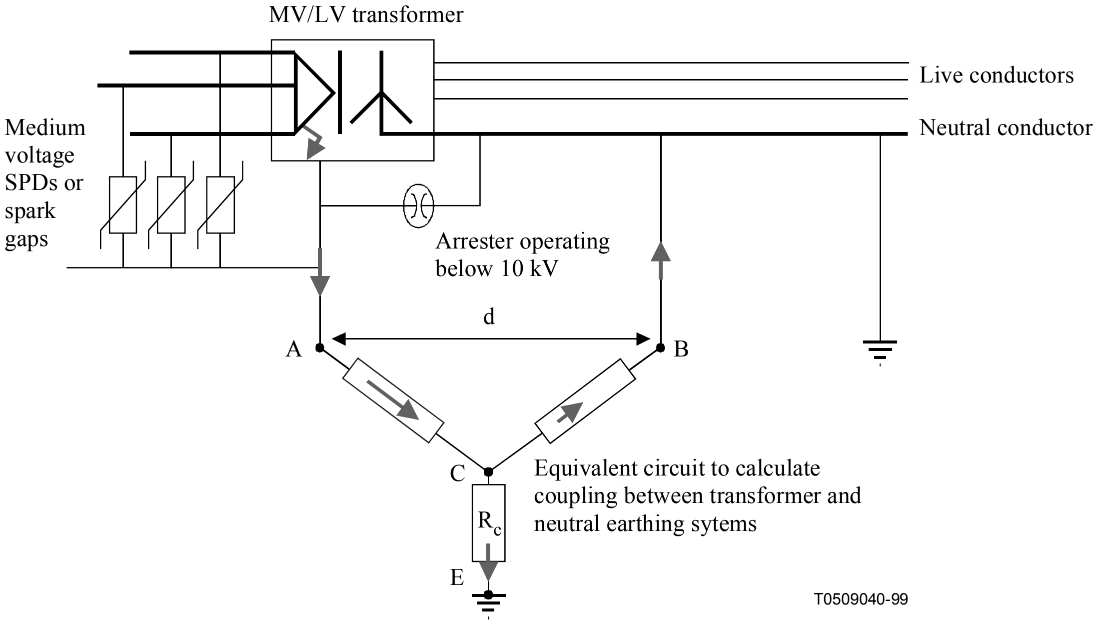


Figure II.5-3/K.44 – Limiting ROEP by earthing design

The Coupling resistance $R_c = \rho \cdot I / 2 \cdot \pi \cdot d$ is adjusted by varying d to obtain a rise of neutral potential below 1500 V or a coupling ratio (V_{AE}/V_{BE}) below 15% when a fault occurs.

When the soil has a high resistivity, the calculated resistance values may sometimes not be achieved and the rise of earth potential may be higher than 1500 V.

II.5.2.3 Currents that may flow through equipment

See Figure II.5.4.

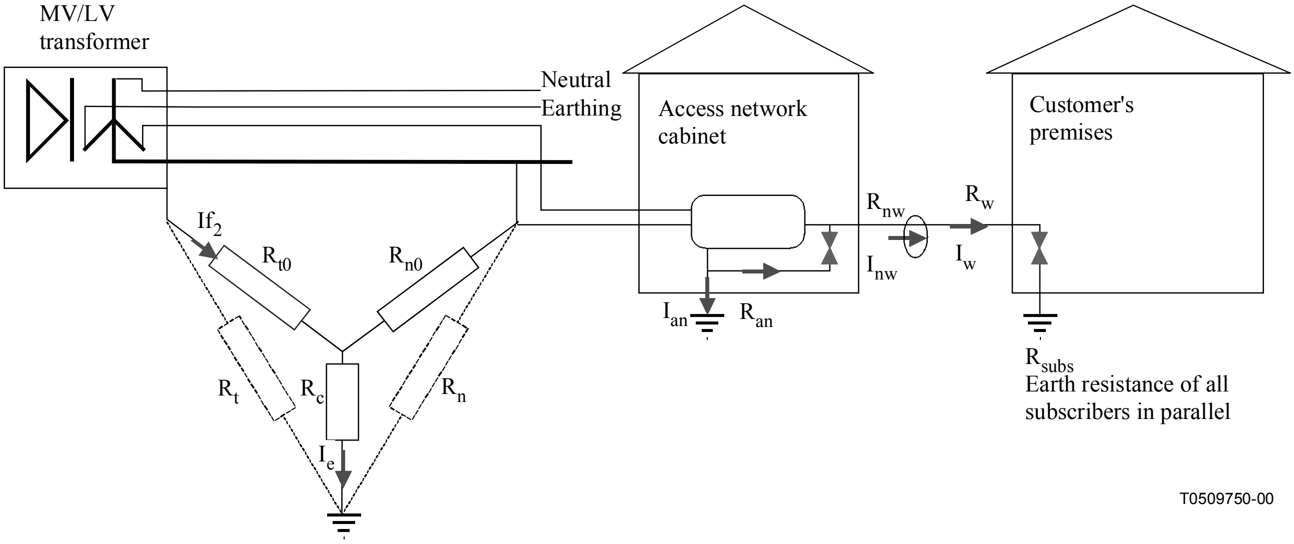


Figure II.5-4/K.44 – Mechanism of current flow through equipment

The results of the calculation when it is assumed that:

- 28 customers are connected with the same symmetric pairs (length 5 km, wires diameter 0.4 mm);
- the equivalent resistance of all their earthing systems in parallel is 2 Ω;
- the access network cabinet earth resistance is 50 Ω;
- the power system characteristics are $Z = j40\ \Omega$, $R_t = 30\ \Omega$, $R_n = 15\ \Omega$, $d = 8$ m;
- the soil resistivity is 300 Ω.m;

show that tens of Amps may flow through the equipment (disruptive discharge between mains port and equipment earth) to the Access network cabinet earthing system.

Current may also flow either directly by telecommunication line SPDs (if they are installed and in case of disruptive discharge between mains port and equipment earth) or through the equipment (disruptive discharge between the mains and telecommunication ports) to the customer's premises, I_w is about 1 A.

Note that the calculation is based on the same principle when replacing in Figure II.5-4 the customer's premises by a telecommunication centre or the Access Network cabinet by the customer's premises.

II.5.2.4 Surge transfer

The lightning induced or direct surges transfer from Medium Voltage to Low Voltage may occur mainly if:

1) the transformer insulation breakdown is prevented by bypassing it with an arrester;
2) the transformer insulation between Medium and low voltage windings is broken.

See Figure II.5-5.

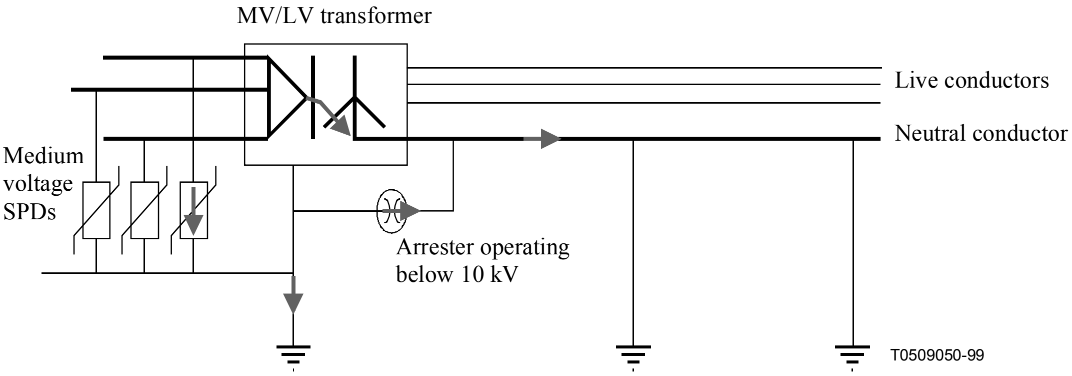


Figure II.5-5/K.44 – Transfer of overvoltage on to neutral

The surge will be followed by a significant 50 Hz current in case 1 when spark gaps are used and always in case 2.

ITU-T RECOMMENDATIONS SERIES

Series A	Organization of the work of the ITU-T
Series B	Means of expression: definitions, symbols, classification
Series C	General telecommunication statistics
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Transmission of television, sound programme and other multimedia signals
Series K	**Protection against interference**
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks and open system communications
Series Y	Global information infrastructure and Internet protocol aspects
Series Z	Languages and general software aspects for telecommunication systems

18834

Printed in Switzerland
Geneva, 2001