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SERIES K: PROTECTION AGAINST INTERFERENCE

Requirements for the mitigation of lightning effects on home networks installed in customer premises

Recommendation ITU-T K.85

ITU-T

International Telecommunication Union

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Requirements for the mitigation of lightning effects on home networks installed in customer premises

Summary

Recommendation ITU-T K.85 gives the requirements for home network equipment and installations in customer premises. It covers the classification of interfaces, resistibility of equipment, impact of installation practices, installation of surge protective devices (SPDs) and a risk assessment of equipment damage according to IEC 62305-2. The risk assessment of user injury will be covered by a separate Recommendation.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T K.85	2011-11-13	5

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. 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 Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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

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Introduction

This Recommendation provides all requirements to minimize disruption and damage to home networks. To ensure a reliable home network service it is essential that a number of interrelated requirements are met. These include the following.

All equipment complies with the appropriate resistibility level of [ITU-T K.21].

- The equipment ports have been correctly classified in accordance with [ITU-T K.75].
- Overvoltage protection, when required, has been installed according to [ITU-T K.66]. This includes the use of both multiservice surge protective devices (MSPDs) and primary (point of entry) protection. It also includes ensuring correct earthing and bonding.
- A risk assessment of equipment damage is performed in accordance with [IEC 62305-2].

Recommendation ITU-T K.85

Requirements for the mitigation of lightning effects on home networks installed in customer premises

1 Scope

This Recommendation applies to home networks installed in customer premises. Service to the home network can be provided by optical fibre, wireless, hybrid fibre/coaxial (HFC) cable or x digital subscriber line (xDSL). This Recommendation predicts the frequency of damage to the home network (telecommunications) equipment within the structure.

NOTE – Consideration of loss of the telecommunication service is contained in [ITU-T K.72]. Consideration of injury of the service user, within the structure, will be considered in a future ITU-T Recommendation.

2 References

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

[ITU-T K.12] Recommendation ITU-T K.12 (2010), *Characteristics of gas discharge tubes for the protection of telecommunications installations.*

[ITU-T K.21] Recommendation ITU-T K.21 (2008), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

[ITU-T K.44] Recommendation ITU-T K.44 (2008), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation.*

[ITU-T K.65] Recommendation ITU-T K.65 (2004), *Overvoltage and overcurrent requirements for termination modules with contacts for test ports or SPDs.*

[ITU-T K.66] Recommendation ITU-T K.66 (2004), *Protection of customer premises from overvoltages*.

[ITU-T K.67] Recommendation ITU-T K.67 (2006), *Expected surges on telecommunications and signalling networks due to lightning*.

[ITU-T K.71] Recommendation ITU-T K.71 (2011), *Protection of customer antenna installations*.

[ITU-T K.72] Recommendation ITU-T K.72 (2011), *Protection of telecommunication lines using metallic conductors against lightning – Risk management.*

[ITU-T K.75] Recommendation ITU-T K.75 (2008), *Classification of interface for application of standards on resistibility and safety of telecommunication equipment.*

[IEC 60364-4-44] IEC 60364-4-44 ed. 2 (2007), *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances.*
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/038219>

[IEC 60950-1] IEC 60950-1 ed. 2 (2005), *Information technology equipment – Safety – Part 1: General requirements*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/035320>

[IEC 61643-21] IEC 61643-21 ed. 1.1 Consol. with am1 (2009), *Low-voltage surge protective devices – Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods.*
<http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_Popup/42865!opendocument>

[IEC 61643-22] IEC 61643-22 ed. 1 (2004), *Low-voltage surge protective devices – Part 22: Surge protective devices connected to telecommunications and signalling networks – Selection and application principles.*
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/033373>

[IEC 62305-2] IEC 62305-2 ed. 2 (2010), *Protection against lightning – Part 2: Risk management*.
<http://webstore.iec.ch>

[IEC 62368-1] IEC 62368-1 ed. 1 (2010), *Audio/video, information and communication technology equipment – Part 1: Safety requirements.*
<http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_Popup/45465!opendocument>

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 home network [b-ISO/IEC 15044]: Internal network for digital and analogue information transport in home or business premises of similar complexity, providing defined access points and using any medium in any topology.

3.1.2 level [b-ETSI ES 201 468]: Measures on a relative scale how important it is that the equipment operates as specified.

NOTE – Two levels are defined for the purpose of the present document and are designated as level 1 and level 2.

Level 1 should be selected if the equipment has moderate failure consequences. Equipment has moderate failure consequences when:

– a failure causes limited inconvenience;

– repairs may be made without compromising the responsibilities of the network operator.

Level 2 should be selected if the equipment has severe failure consequences. Equipment has severe failure consequences when:

– failure compromises the function of vital, centralized systems, or services of a commercially sensitive or security related nature;

– repair or restoration costs are high, or the time the equipment is out of service is unacceptably long;

– corruption of charging or billing information occurs.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 multiservice surge protective device (MSPD): A surge protective device (SPD) containing both telecommunications and mains protection. It may also include port protection for video or Ethernet.

3.2.2 tracer/locate wire (optical fibre cable): Conductive wire in an optical fibre cable that allows a buried cable to be located with a metal detector.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CLP Cell Loss Priority

CPE Customer Premises Equipment

GDT Gas Discharge Tube

HFC Hybrid Fibre/Coaxial (cable)

LEMP Lightning ElectroMagnetic Pulse

LPS Lightning Protection System

LT/NT Line Termination/Network Termination

MET Main Earth Terminal

MOV Metal-Oxide Varistor

MSB Main electrical Switchboard

MSPD Multiservice Surge Protective Device

NTD Network Termination Device

PE Power Earth

POTS Plain Old Telephone Service

SELV Safety Extra-Low Voltage

SPC Surge Protective Components

SPD Surge Protective Device

USB Universal Serial Bus

xDSL Any of the various types of Digital Subscriber Lines

5 Lightning damage

Damage to equipment can occur as a result of:

- surges entering on metallic services, with respect to the local earth;
- lightning strikes to antennas;
- lightning current entering the ground at or near the building with respect to remote earth;
- induction into indoor cabling due to nearby lightning.

6 Requirements

To limit the risk of misunderstanding by the supplier/manufacturer, it is recommended that the equipment specification for overvoltage protection and safety includes a schematic diagram showing the likely or possible applications of the equipment. This diagram should specifically address connections of the equipment within the building and especially its interconnection to any lines, or other equipment type connected to lines, that are external to the building. This should include any antenna connections.

Some conditions might come with a small increase in item cost but could significantly increase application and reduce life cycle cost.

6.1 Classification of ports

[ITU-T K.75] provides information on classifying plain old telephone service (POTS), Ethernet and video ports. A mains port is always an external port.

Correct classification of ports is important. If an internal port is subject to conducted lightning surges or a.c. surges, there will be equipment damage and human safety issues.

Please note that when specifying the above overvoltage and safety requirements it is also very important to clearly advise the vendors where the equipment is to be used and what is expected to be connected to it (for example, whether it will or will not involve any connections to cabling that exits the building). Manufacturers of customer equipment in particular assume that the equipment ports will only be connected to intra-building cabling. A problem then occurs if the network operator, or the customer, decides to extend the service to an outbuilding. Equipment designed for connection to intra-building cabling may have insufficient isolation from the point of view of safety and insufficient resistibility to overvoltages, when connected to inter-building cables. To ensure the equipment use is not limited, the best way to proceed may be to assume that the port will connect to an inter-building cable, unless it is clear that it will not. The types of ports that could be connected to inter-building cabling include:

- POTS/xDSL;
- Ethernet;
- coaxial cable ports.

For those ports that may connect to inter-building cables, classify the ports as follows:

- For [IEC 60950-1] (safety) testing, use TNV-3 for ports with a working voltage higher than the safety extra-low voltage (SELV); or TNV-1 for ports with a working voltage lower than or equal to SELV (see [IEC 60950-1] for definitions).
- For [IEC 62368-1] (safety) testing the applicable value of the transient voltage on an external circuit shall be determined using Table 15 of [IEC 62368-1]. Where more than one location or condition is applicable, the highest transient voltage applies.
- For resistibility testing, classify it as external.

NOTE – Where approved engineering practices have been implemented, a lower port classification may be used. An example involves the use of a non-removable galvanic isolator with the equivalent of double insulation between the coaxial cable and the coaxial cable port.

6.2 Resistibility

[ITU-T K.21] has two levels of resistibility: "basic" and "enhanced". [ITU-T K.44] gives advice on the selection of "basic" and "enhanced".

The required level of resistibility can be determined in Figure 1. Information on "Special requirements" is contained in [ITU-T K.44]. Non-compliance with [ITU-T K.66] could include:

- non-bonded earths;
- difficulty in installing SPDs at the building entry;
- bonding wires in excess of 10 m.

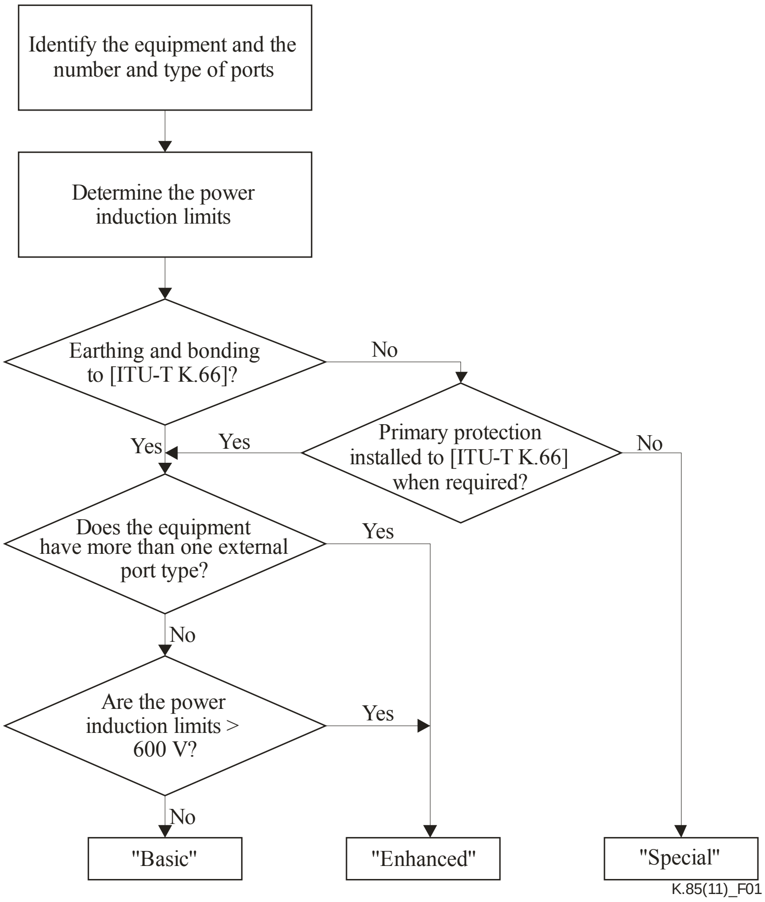


Figure 1 – Flowchart for determining required level of resistibility

The resistibility requirements of [ITU-T K.21] in conjunction with [ITU-T K.44] ensure that the equipment can be protected by the installation of an MSPD or primary protector.

It is expected that protection for ports connected to external cables will only be installed if required and therefore the "inherent" tests in Table 2 of [ITU-T K.21] are required.

It is necessary to determine the special test protector to be used when checking compliance with [ITU-T K.21]. Information on selecting the agreed primary protector, and hence the special test protector, is given in Annex C of Recommendation [ITU-T K.12]. If the product can be used within the customer premises there is a likelihood that the customer may connect it via an MSPD or may request primary protection to be installed. This sets the worst-case scenario for determining the "agreed primary protector" as per [ITU-T K.44].

6.3 Safety

All equipment shall comply with the latest version of [IEC 60950-1] or [IEC 62368-1]. It should be noted that [IEC 62368-1] is the latest safety standard and that it will eventually replace [IEC 60950-1]. National deviations of these standards exist; country specific requirements need to be complied with in these countries.

Safety can be achieved by a combination of insulation and earthing, see [ITU-T K.75].

It is preferable to use reinforced or double insulation, or suitable isolation, between people and an external telecommunications interface instead of basic insulation plus a hard-wired earth. This eliminates the need for a hard-wired earth (see clause 6.4).

6.4 Earthing

Where port insulation/isolation is inadequate, the equipment will need to be earthed. Earthing may also be required for functional (e.g., signalling or testing) purposes.

There are four methods of earthing and these are:

1) no earthing;
2) earthing via the mains plug (i.e., connection to protective earth);
3) hard-wire earthing (i.e., direct bonding to protective earth);
4) connection to a stand-alone earthing system/electrode.

Methods 1 and 2 have both advantages and disadvantages and the choice may depend on national requirements of a.c. wiring rules. Method 2 must only be used where equipment earthing is not required if the equipment is unplugged, i.e., if unplugging the equipment removes the safety hazard.

When purchasing or specifying customer premises equipment, preference should be given to method 1 and, where viable, method 2, due to the high cost of the implementation of method 3. Method 4 is most likely not suitable for customer premises equipment due to the consequences of a lack of bonding to protective earth. The cost of installing a hard-wired earth should be part of any business case and intention to buy equipment.

The method of earthing will impact the overvoltage resistibility requirements and safety requirements of equipment. It is usually cheaper to provide the safety isolation within the equipment than to rely on earthing, unless the earthing/bonding is required for other purposes.

It is worthwhile making it clear to the manufacturer/vendor whether you will accept equipment safety requiring a hard-wired connection to protective earth (requiring installation labour and/or perhaps limiting locations where it can be installed in the building) or whether your preference is for safety provided by isolation/insulation only.

6.5 Risk assessment

A risk assessment of equipment damage should be performed according to [IEC 62305-2]. Input data to perform a risk assessment include:

- strike density
- building dimensions
- external cable types and lengths
- building type
- internal wiring attributes
- equipment resistibility level
- power system type
- existence of SPDs.

Regardless of the risk assessment result, if the building has a lightning protection system (LPS) installed, primary protection, bonded to the protective earth (PE), should be installed at the point of entry for all services; and all metallic pipes should be bonded to the PE at the point of entry.

The information required to perform a risk assessment according to [IEC 62305-2] is given in Annex D.

A risk assessment example is given in Appendix I.

6.5.1 Internal cable interfaces

Perform a risk assessment according to Annex D. There are three scenarios.

1) Ethernet interfaces complying with [ITU-T K.21]: Use the relevant requirement, e.g., "basic" requirement from Table 2 of [ITU-T K.21], as the withstand voltage.
2) Ethernet interfaces not complying with [ITU-T K.21]: The withstand voltage is not known. Check with the manufacturer. In situations where the value cannot be determined, [IEC 62305-2] suggests that P_{MS} be set to 1.
3) The equipment at one end on the cable has a level of insulation, i.e., no earth and no power connection. In this case the risk can be considered quite low.

If the risk of damage to the internal cable interface, for unshielded cable situations, is above acceptable levels install an MSPD as described in clause 6.6.3. If the risk of loss for a shielded cable or coaxial cable situation is considered too high, install an MSPD as described in clause 6.6.3 or use a cable with the necessary shield resistance.

6.5.2 External cable interfaces

Perform a risk assessment according to Annex D. If the risk of damage to the external cable interface, due to flashes near the service line, is above acceptable levels, install an MSPD. If the risk of loss due to flashes to the service line is above acceptable levels, also install SPDs at the point of entry.

6.6 Installation of overvoltage protection

When required by the risk assessment, MSPDs and primary protection should be installed according to [ITU-T K.66]. The MSPD protects the equipment and the primary protection protects the MSPD. The worst-case overvoltages and overcurrents are provided in [ITU-T K.67]. These voltages and currents can be used to dimension SPDs and conductors, etc.

6.6.1 Primary protection

The SPD requirements and installation requirements may be controlled by the network operator or regulator. Country requirements must be observed. To prevent high current surges entering the structure due to lightning strikes to services, it is important to install the primary protection at the point where the services enter the building.

6.6.2 MSPDs

MSPDs with a mains connection may need to comply, depending on national interpretation, with either [IEC 60950-1] or [IEC 62368-1]. Installation should be in accordance with [ITU-T K.66]. Incorrect use of MSPDs may actually increase the probability of damage.

NOTE – The type of MSPD referred to in this Recommendation relies on a protective earth connection for safety. If used without a protective earth users may be exposed to surges exceeding a few hundred volts.

6.6.3 Internal port protection

When protection of internal ports is required there are two possibilities.

1) Ports with a coordination requirement may be protected by the use of an appropriate SPD or MSPD.
2) Ports without a coordination requirement must be protected in accordance with [IEC 61643-21] and [IEC 61643-22].

6.7 Wiring installation

Every attempt should be made to install wiring, earthing and bonding according to [ITU-T K.66] and [IEC 60364-4-44]. Where this cannot be achieved and the risk assessment indicates a need for protection, see clause 6.8.

Equipotentialization for a timber floored building, when required, can be achieved by adding a ring earth around the building (see [ITU-T K.66]).

6.8 Special requirements

Where the earthing and bonding requirements of [ITU-T K.66] and [IEC 60364-4-44] cannot be achieved, an engineering solution may be needed. Possible engineering solutions are:

- special resistibility requirements
- isolation devices, e.g., high voltage a.c. isolation mains transformers.

6.9 Use of wireless and optical fibre

Operators can provide a wireless service to provide communication within the home network. This is a method of protection. An optical fibre solution could also be used.

Operators can also provide a wireless backup solution to maintain availability in case of loss of the optical fibre network.

Annex A

Principles of surge protection

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

To be able to provide effective protection, it is necessary to understand how surges are coupled onto a circuit and their possible impact on the equipment.

A.1 Surge coupling into external telecommunication lines

Consider a lightning strike coupling a surge into an external telecommunication line (see Figure A.1, surges S3 and S4). This coupling can be inductive or conductive. Generally speaking, it is expected that inductive coupling will not result in currents greater than 10 to 35 A or voltages greater than a few kV (see Table 5 of [ITU-T K.67]). For conductive coupling, the total cable current/voltage is unlikely to exceed 1000 A or 100 kV, unless the strike point to the cable is within approximately 100 m of the building. If there is no primary protection installed, the equipment will be subjected to the lightning surge entering the building. If primary protection is installed at the line termination/network termination (LT/NT), the equipment may be subjected to one or more of the following surges:

1) the let-through voltage of the primary protection (surge does not operate the primary protector);
2) a chopped waveform caused by the primary protector operating;
3) the voltage caused by the primary protector current conducted in the primary protector bond wire.

A.2 Surge coupling into internal cabling

The magnitude of the voltage induced into internal cabling depends on many factors such as lightning strike current, closeness of the strike, size of the loop, type of cable and building shielding (surges S1 and S2 in Figure A.1). [ITU-T K.67] provides information on likely maximum voltages. Due to the complexity of the required calculation, a risk assessment should be performed in accordance with [IEC 62305-2] . The current rating of SPDs and bonding conductors should be determined using [ITU-T K.67]. Table 2 of [ITU-T K.67] shows that induced short circuit currents of up to 6 kA 10/350 μs are possible within internal cabling due to lightning flashes to the building. This is likely to be more than the capability of MSPDs. If a very high reliability is required a specialized protection design may be necessary.

A.3 Impact of actual installations

It is likely that the primary protector may be some distance from the equipment and that the primary protector installation will not be perfect. The issues are:

- Inductive drop across the SPD connecting leads: It is not expected that this will be a problem with network termination devices (NTDs) complying with [ITU-T K.65]. [ITU-T K.21] makes allowance for a total of 1 metre of connecting lead for mains SPDs during coordination testing.
- The current conducted in the bonding conductor between the SPD and the main earth terminal (MET): The maximum recommended length of bonding conductor is specified in [ITU-T K.66]. The length of this bonding conductor affects the current sharing between the primary protector and the equipment SPD, or an SPD or MSPD installed at the equipment. If the equipment has high input impedance, the peak voltage at the equipment is proportional to the length of the bonding conductor.

- The voltage induced in the cabling between the protection frame and the equipment: The magnitude of this voltage will depend on the magnitude of the current, the closeness of the lightning strike and whether the cable is shielded or unshielded.
- Surge reflection at equipment port: Some IEC standards consider voltage doubling at the equipment due to reflections a major consideration. Due to the relatively short distance between the primary protection and the equipment, any voltage doubling for high impedance equipment will only occur for a short time (< 1 µs) and is unlikely to cause insulation breakdown. Any current doubling into low impedance equipment will also only occur for a short time and will be easily handled by the equipment SPD.

A.4 Separate earth electrodes

Figure A.1 shows two separated earth electrodes. Unless these are bonded together, a potential difference may occur between the electrodes and damage the ports of equipment A and equipment B. A ring earth can be a solution for equipotentialization (see [ITU-T K.66]).

A.5 Philosophy of protection

The philosophy for protection of customer premises equipment (CPE) is as follows:

- Install an MSPD to protect the equipment when necessary. An MSPD can protect the equipment against surges magnetically coupled into the building wiring and service cables and lines. It may also provide some level of protection of the equipment against direct strikes to the service plant, provided the strike point is more than a few hundred metres from the building.
- Install primary protection at the building entry point on both the telecommunication and power services, to protect the MSPD when the risk assessment requires it.

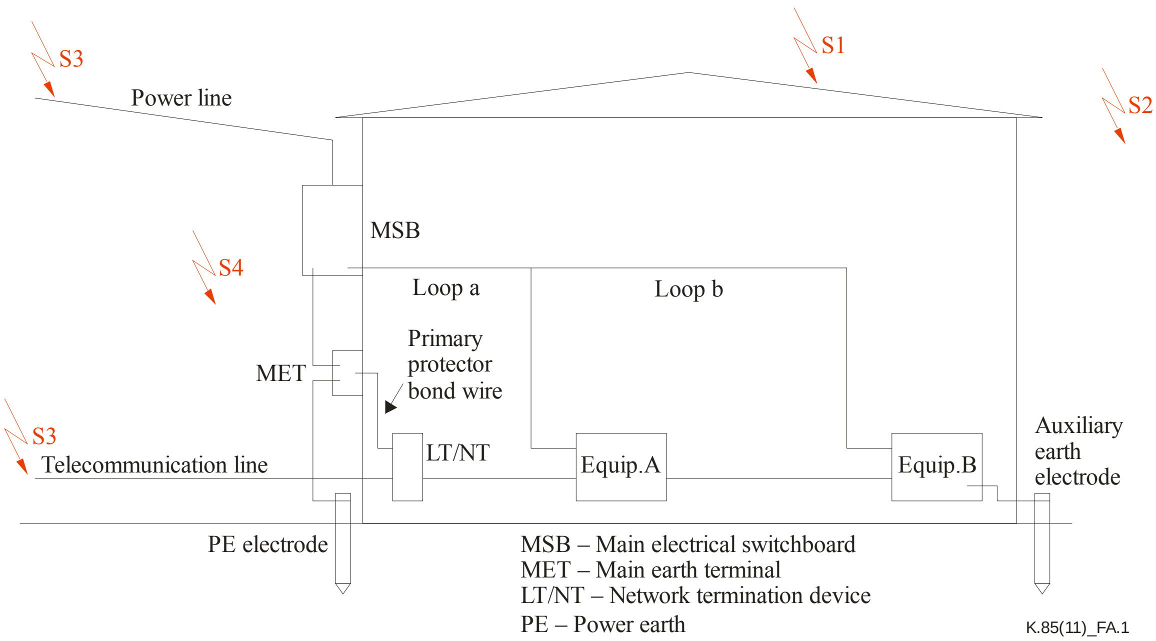


Figure A.1 – Surge coupling

Annex B

Installation practices which may result in damage

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

The following installation practices should not be used as they can damage equipment:

a) Internal port connected to an external cable. The solutions are:

   i. connect the external cable to an external interface;

   ii. install an SPD according to [IEC 61643-21] and [IEC 61643-22];

   iii. use an isolation box to provide the necessary isolation.

b) Internal port connected to an external cable no longer in use. The solutions are:

   - disconnect and earth the external cable. Rather than earthing the copper conductors, they may be insulated to a level higher than the cable insulation.

c) Internal port connects to cable connected to associated equipment within the building but the associated equipment is bonded to a separate earth system. To prevent damage, all earth references must be bonded to the same point, usually the PE. Possible solutions are:

   i. bond all earths to the PE;

   ii. where it is necessary to have two or more separated earth points, the interconnection interfaces must be classified as "external" and primary protection installed, when necessary (or install a primary protector SPD according to [IEC 61643-21] and [IEC 61643-22]).

d) The interconnection of an external interface of equipment A to an internal interface of associated equipment (equipment B), where the external interface of equipment A has inadequate isolation to a second external interface which is exposed to conducted (10/700 µs) surges. In this case the internal interface of the associated equipment (equipment B) is also exposed to 10/700 µs surges. The solutions are:

   i. only connect internal interfaces to internal interfaces and external interfaces to external interfaces;

   ii. use an isolation box to provide the necessary isolation.

e) Internal port is connected to internal cable which has a gas discharge tube (GDT), bonded to a separate earth connected to it. The solution is:

   - remove the GDT.

Annex C

Coordination

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

Coordination may be required between the following SPDs:

- a telecommunications primary protector, normally a GDT, and an MSPD;
- an SPD installed in the MSB and an MSPD;
- an MSPD and an internal port.

C.1 Telecommunication SPD coordination

Figure C.1 shows a primary protector GDT with a 10 m bond wire and an MSPD connected to earth via 10 m of power earth wire. The simulation shows that the operation of the MSPD GDT does not affect the voltage at the customer lightning protection (CLP) GDT. The CLP GDT will always operate. In this simulation the current in the MSPD GDT is less than 1/3 of the total current.

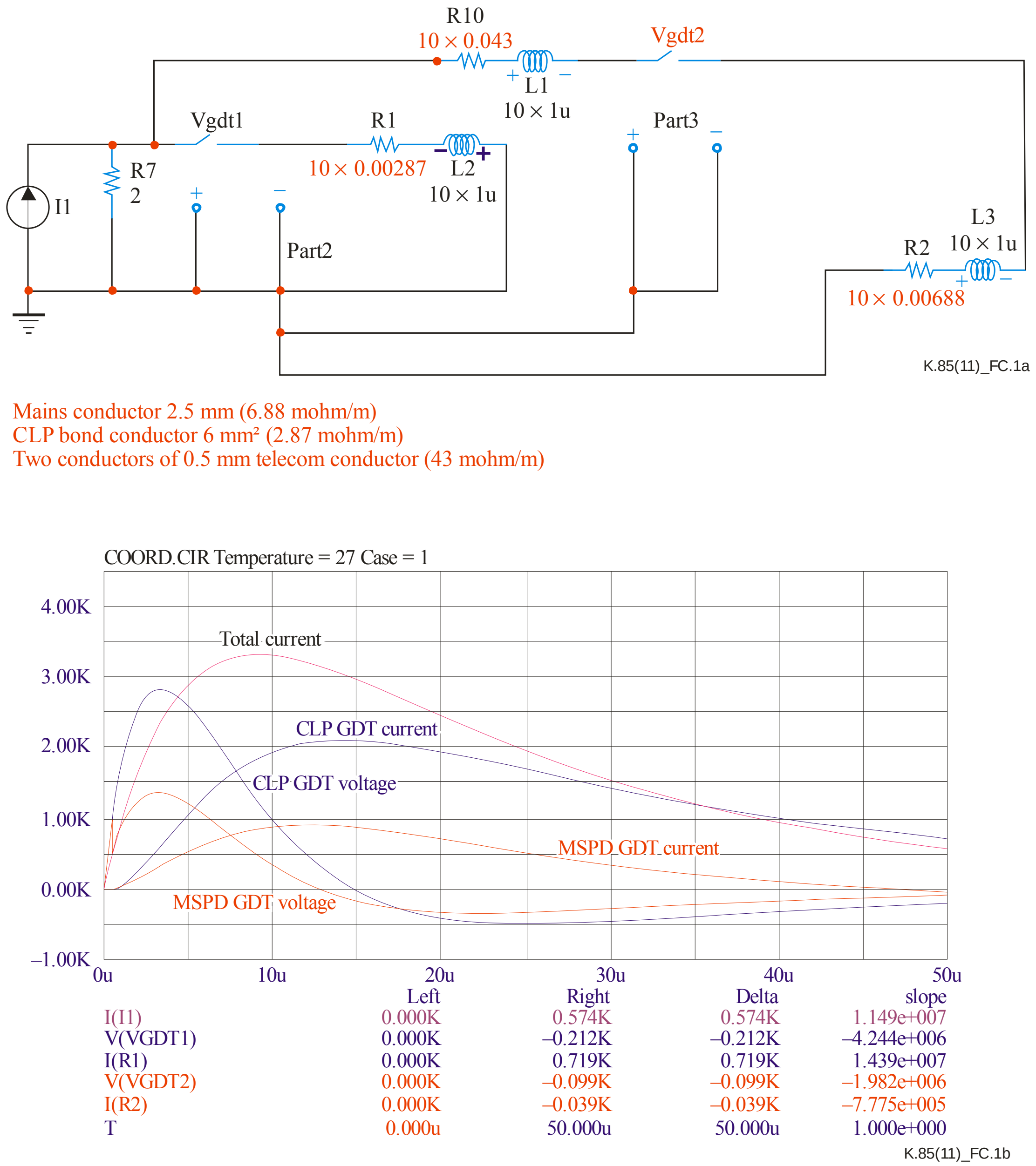


Figure C.1 – Simulation of a 10 m bond wire primary protector GDT with an MSPD connected to earth via 10 m of power earth wire

C.2 Mains SPD coordination

In Figure C.2 an EPCOS B80K275 metal-oxide varistor (MOV) has been used as the primary protector and S20K275 MOVs in the MSPD. The N-E MOV in the MSPD is not shown as it does not conduct current in this type of installation. The current ratio between primary to secondary MOV is 6:1. This current ratio is determined by the lower bulk resistance of the larger B80K MOV and the impedance of the telecoms wiring and earth conductor and the 1 mA voltage of the MOVs.

NOTE – This simulation has been performed with identical MOVs. In practice the 1 mA voltage can vary by +/– 10%. This can affect the current sharing.

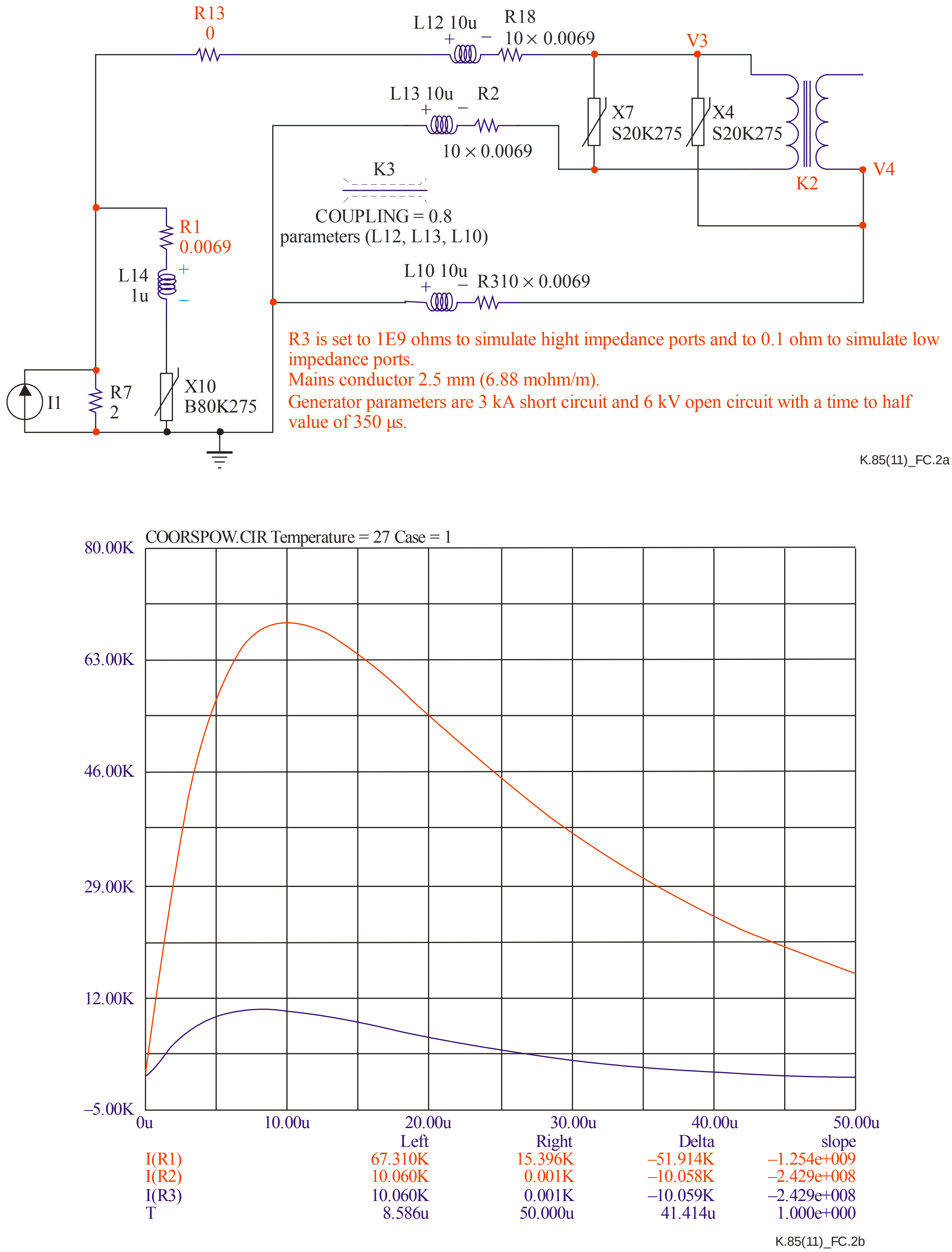


Figure C.2 – Simulation of an EPCOS B80K275 MOV primary protector with S20K275 MOVs in the MSPD

C.3 Internal port coordination

This will need to be determined for each type of port. The IEC 61643 series provides information on designing such an SPD.

Annex D

Risk assessment

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

[IEC 62305-2] provides the tools to determine the frequency of damage of equipment. In this Recommendation the risk of damage to telecommunication equipment within the structure is considered. The loss of the telecommunications network is considered in [ITU-T K.72]. Injury of the service user is currently under study in ITU-T.

D.1 Explanation of terms

D.1.1 Damage

D.1.1.1 Source of damage

The lightning current is the primary source of damage.

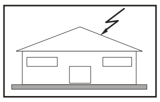
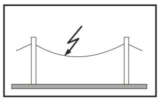
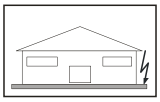
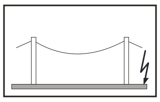
In general, the following sources are distinguished by the strike attachment point (Figure D.1):

S_1: flashes to a structure;

S_2: flashes near a structure;

S_3: flashes to a service (which includes telecommunication lines);

S_4: flashes near a service (which includes telecommunication lines).

Source of damage	Striking point
S1	
S3	
S2	
S4	

K.85(11)_FD-1

Figure D.1 – Lightning as source of damage

D.1.1.2 Types of damage

A lightning flash may cause damage depending on the characteristics of the structure to be protected. Some of the most important characteristics are: type of construction, contents and application, type of service and protection measures provided.

In general, for practical applications of the risk assessment, it is useful to distinguish between three basic types of damage which can appear as the consequence of lightning flashes. They are as follows:

D1: injury to living beings by electric shock;

D2: physical damage;

D3: failure of electrical and electronic systems.

This Recommendation is only concerned with damage D3, and in particular the failure of telecommunication equipment.

A lightning flash may cause equipment damage depending upon the characteristics of the telecommunication network, power network and the structure. Some of the most important characteristics are:

- type of telecommunication network, e.g., buried or aerial cable, screened or unscreened cable, cable shield installed or not installed;
- type of power network, e.g., buried or aerial cable, screened or unscreened cable, cable shield installed or not installed, neutral bonded or not bonded to power earth (PE);
- type of structure construction e.g., timber, brick or reinforced concrete;
- whether or not protection measures have been used at the structure or on the services.

D.1.1.3 Types of loss

Each type of damage, alone or in combination with others, may produce a different consequential loss in the structure to be protected. The type of loss that may appear depends on the characteristics of the structure itself and its contents. The following types of loss shall be considered:

L_1: loss of human life (including permanent injury);

L_2: loss of service to the public;

L_3: loss of cultural heritage;

L_4: loss of economic value (structure, content, and loss of activity).

This Recommendation is only concerned with loss L2, loss of service to the public, specifically the risk of damage to telecommunication equipment installed within the structure.

D.1.2 Risk and risk components

D.1.2.1 Risk

The risk *R* is the value of a probable average annual loss.

To evaluate risk, *R*, the relevant risk components (partial risks depending on the source and type of damage) shall be defined and calculated.

The risk, *R*, is the sum of the risk components.

The risk components, as defined in [IEC 62305-2], which can cause all types of loss, are listed in clauses D.1.2.2. to D.1.2.5.

D.1.2.2 Risk components for a structure due to flashes to the structure

Direct lightning flashes to the structure to which the telecommunication network is connected can cause the following risk component:

R_A: Component related to injury to living beings caused by electric shock due to touch and step voltages inside the structure and in the zones up to 3 m outside the structure. Loss of type L_1 and, in the case of structures holding livestock, loss of type L_4 with possible loss of animals may also arise.

NOTE – In special structures, people may be endangered by direct strikes (e.g., top level of garage parking or stadiums). These cases may also be considered using the principles of this Recommendation.

This Recommendation does not consider R_A.

R_B: Component related to physical damage caused by dangerous sparking inside the structure triggering fire or explosion, which may also endanger the environment. All types of loss (L_1, L_2, L_3 and L_4) may arise.

R_C: Component related to failure of internal systems caused by lightning electromagnetic pulse (LEMP). Loss of type L_2 and L_4 could occur in all cases along with type L_1 in the case of structures with risk of explosion and hospitals or other structures where failure of internal systems immediately endangers human life.

D.1.2.3 Risk component for a structure due to flashes near the structure

R_M: Component related to failure of internal systems caused by LEMP. Loss of type L_2 and L_4 could occur in all cases, along with type L_1 in the case of structures with risk of explosion and hospitals or other structures where failure of internal systems immediately endangers human life.

D.1.2.4 Risk components for a structure due to flashes to a line connected to the structure

R_U: Component related to injury to living beings caused by electric shock due touch voltage inside the structure. Loss of type L_1 and, in the case of agricultural properties, losses of type L_4 with possible loss of animals could also occur.

This Recommendation does not consider R_U.

R_V: Component related to physical damage due to lightning current transmitted through or along incoming lines (e.g., fire or explosion triggered by dangerous sparking between external installation and metallic parts generally at the entrance point of the line into the structure). All types of loss (L_1, L_2, L_3, L_4) may occur.

R_W: Component related to failure of internal systems caused by overvoltages induced on incoming lines and transmitted to the structure. Loss of type L_2 and L_4 could occur in all cases, along with type L_1 in the case of structures with risk of explosion and hospitals or other structures where failure of internal systems immediately endangers human life.

NOTE 1 – The lines considered in this assessment are only the lines entering the structure.

NOTE 2 – Lightning flashes to or near pipes are not considered as a source of damage based on the bonding of pipes to an equipotential bonding bar. If an equipotential bonding bar is not provided, such a threat must also be considered.

D.1.2.5 Risk component for a structure due to flashes near a line connected to the structure

R_Z: Component related to failure of internal systems caused by overvoltages induced on incoming lines and transmitted to the structure. Loss of type L_2 and L_4 could occur in all cases; along with type L_1 in the case of structures with risk of explosion and hospitals or other structures where failure of internal systems immediately endanger human life.

NOTE 1 – The lines considered in this assessment are only the lines entering the structure.

NOTE 2 – Lightning flashes to or near pipes are not considered as a source of damage based on the bonding of pipes to an equipotential bonding bar. If an equipotential bonding bar is not provided, such a threat must also be considered.

D.1.3 Composition of risk components related to a structure

Risk components to be considered for each type of loss in a structure are listed below.

R_1: Risk of loss of human life:

$$R_1 = R_{A1} + R_{B1} + R_{C1}{}^{1)} + R_{M1}{}^{1)} + R_{U1} + R_{V1} + R_{W1}{}^{1)} + R_{Z1}{}^{1)} \qquad (1)$$

1) Only for structures with risk of explosion and for hospitals with life-saving electrical equipment or other structures when failure of internal systems immediately endangers human life.

R_2: Risk of loss of service to the public:

$$R_2 = R_{B2} + R_{C2} + R_{M2} + R_{V2} + R_{W2} + R_{Z2} \quad (2)$$

R_3: Risk of loss of cultural heritage:

$$R_3 = R_{B3} + R_{V3} \quad (3)$$

R_4: Risk of loss of economic value:

$$R_4 = R_{A4}{}^{2)} + R_{B4} + R_{C4} + R_{M4} + R_{U4}{}^{2)} + R_{V4} + R_{W4} + R_{Z4} \quad (4)$$

2) Only for properties where animals may be lost.

This Recommendation will only consider risk R_2 and only that due to damage D3 (failure of electrical and electronic systems). This Recommendation also focuses more on the "frequency of damage" rather than on "loss".

D.2 Risk management

D.2.1 Basic procedure

The following procedure shall be applied to risk management:

a) identification of the structure and the relevant services and their characteristics;

b) identification of the risk components to be used (e.g., loss of service);

c) identification of sources of damage:

   i. flashes to structure (S1)

   ii. flashes near the structure (S2)

   iii. flashes to a telecommunication service (S3)

   iv. flashes to non-telecommunication services (S3)

   v. flashes near a telecommunication service (S4)

   vi. flashes near a non-telecommunication service (S4);

d) evaluation of risk R_2;

e) evaluation of need of protection, by the comparison of the risk R_2 with the tolerable risk, R_T. This Recommendation will compare the frequency of damage F_2 with the tolerable frequency of damage F_T.

D.2.2 Tolerable risk R_T

It is the responsibility of the authority having jurisdiction to identify the value of tolerable risk.

A representative value of tolerable risk, R_T, against the loss of telecommunications service within the structure due to lightning is given in Table D.1.

Table D.1 – Typical values of tolerable risk R_T

Types of loss	$R_T(y^{-1})$
Loss of service to the public	10^{-3}

In this Recommendation the frequency of damage will be calculated. A value of $F_T = 0.1$ is suggested.

D.2.3 Specific procedure to evaluate the need for protection

For risk R_2 the following steps shall be taken:

– identification of the structure and the relevant services and their characteristics;

– identification of the tolerable risk R_T;

– identification of the risk components to be used (e.g., loss of service);

– identification of sources of damage:

  i. flashes to the structure (S1)

  ii. flashes near the structure (S2)

  iii. flashes to a telecommunication service (S3)

  iv. flashes to non-telecommunication services (S3)

  v. flashes near a telecommunication service (S4)

  vi. flashes near a non-telecommunication service (S4);

– calculation of risk R_2 using the relevant risk components;

– calculation of need of protection, by the comparison of the risk F_2 with the tolerable risk, F_T.

Figure D.2 shows the flow chart to evaluate the protection needs and for selecting the protection measures of telecommunication lines.

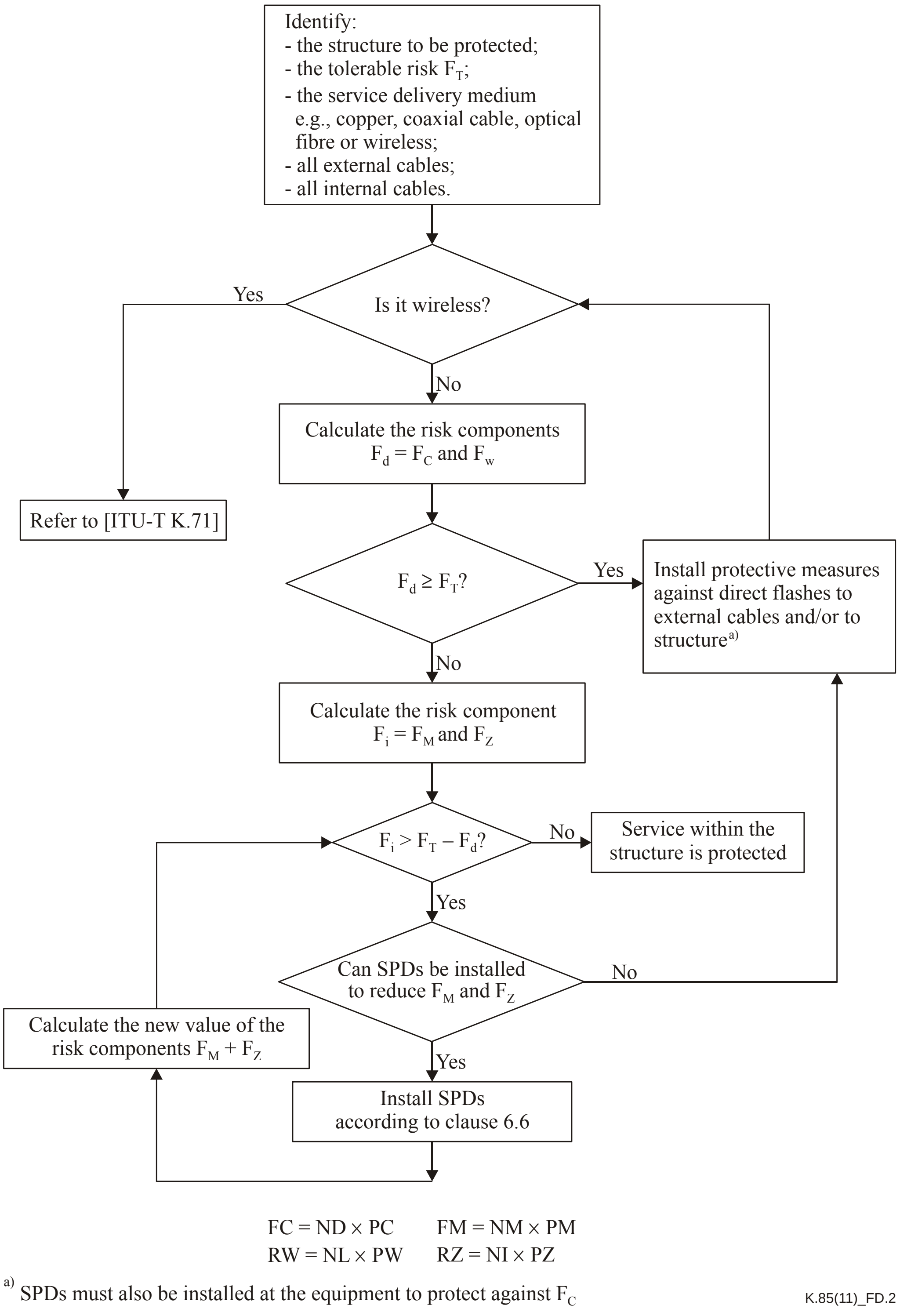


Figure D.2 – Procedure for selecting protection measures in a structure

Appendix I

Risk assessment example

(This appendix does not form an integral part of this Recommendation.)

I.1 General

The structure to be considered is the customer's building with a power line and an optical fibre service. This is shown pictorially in Figure I.1.

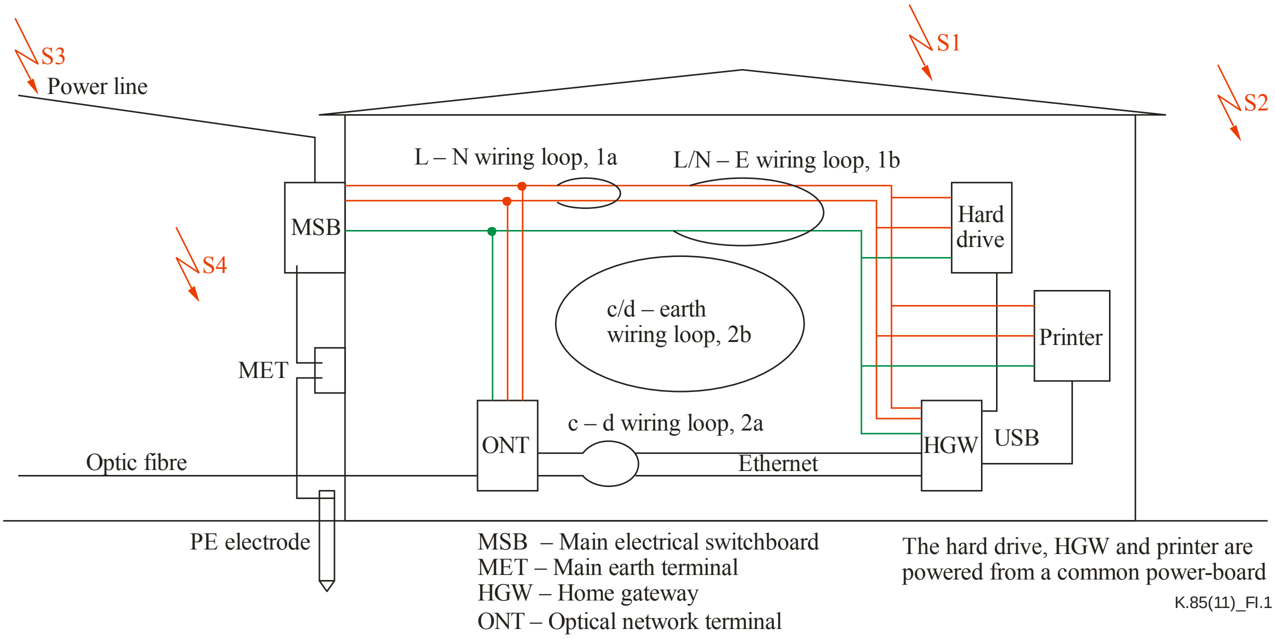


Figure I.1 – Schematic of building wiring showing inductance loops

Damage to telecommunication equipment can occur and F_2 should be evaluated.

Tables I.1 to I.9 follow the risk assessment example in [IEC 62305-2] and may not include all mechanisms of damage. For example, depending on the method of terminating the optical fibre tracer/locate wire, a strike to the wire may cause damage to equipment. Additional items such as this may need to be considered.

The following clauses report the results of the risk assessment to the structure in accordance with [[IEC 62305-2] and the possible protection measures in order to reduce the risks below the tolerable values. An understanding of [IEC 62305-2] is required to understand this appendix.

The frequency of damage will be calculated considering the following port types:

- mains port (external);
- telecommunication ports (external);
- Ethernet ports (unshielded internal);
- USB ports (shielded internal).

I.2 Building characteristics

The main building characteristics are reported in Table I.1.

Table I.1 – Building characteristics

Parameter	Comment	Symbol	Value	Reference (Note)
Dimensions (m)		$(L_b \cdot W_b \cdot H_b)$	20.0×20.0×20.0	
Location factor	Isolated	C_{db}	1.0	Table A.1
Probability P_A		P_A	1.0	Equation B.1
Additional protection measures	None	P_{TA}	1.0	Table B.1
Characteristics of structure	None	P_B	1.0	Equation B.2
Shield at the structure boundary	None	K_{S1}	1.0	Equation B.5
Shield internal to the structure	None	K_{S2}	1.0	Equation B.6
Ground flash density	1/km^2/year	N_g	3	
NOTE – Table and equation references are to [IEC 62305-2].				

I.3 Characteristics of the services

There is one metallic service entering the building: an aerial unshielded low voltage power line (1000 m).

The characteristics of the power line entering the structure are reported in Table I.2 together with the calculated values of the collection areas (A_L and A_I) and the expected dangerous events (N_L and N_I).

Table I.2 – Characteristics of the power line

Parameter	Comment	Symbol	Value	Reference (Note)
Soil resistivity (Wm)		ρ	1000	
Length (m)		L_c	1000	
Height (m)		H_c	6	
Line installation factor	Isolated	C_I	1.0	Table A.2
Line type factor	No	C_T	1.0	Table A.3
Line environmental factor	Aerial	C_E	1.0	Table A.4
Shield resistance per unit length (Ω/km)	Unshielded			
Probability P_C	None	P_C	1.0	Equation B.3
Probability P_{SPD}	None	P_{SPD}	1.0	Table B.3
Number of conductors entering the structure		m	2	
Collection area for lightning to the line (m^2)		A_L	40 000	Equation A.9
Collection area for lightning near the line (m^2)		A_I	4 000 000	Equation A.11
Number of direct lightning to the line		N_L	0.12	Equation A.8
Number of dangerous lightning near the line		N_I	12.0	Equation A.10
Dimensions of the adjacent structure (m)	None	$(L_a·W_a·H_a)$		
Number of direct lightning to the adjacent structure		N_{Da}	0.0	
NOTE – Table references are to [IEC 62305-2].				

I.4 Characteristics of the internal systems

The main characteristics of the internal systems connected to the power line are reported in Table I.3.

Table I.3 – Main characteristics of the internal installations

Parameter	Comment	Symbol	Value	Reference (Note 1)
Power service port				
Shield resistance per unit length (Ω/km)	Unshielded			
Withstand voltage of the equipment	2.5 kV	K_{S4}	0.4	Equation B.7
Installed coordinated SPD protection	Not installed	P_{SPD}	1	Table B.3
Probability factor due to direct lightning to the structure		C_{LD}	1.0	Table B.4
Probability factor due to direct lightning near structure		C_{LI}	1.0	Table B.4
Probability factor due to direct lightning to the line		P_{LD}	1.0	Table B.8
Probability factor due to lightning near the line		P_{LI}	0.3	Table B.9
Probability factor due to strike to structure		P_C	1.0	Equation B.2
Probability factor due to a strike to the line		P_W	1.0	Equation B.10

Table I.3 – Main characteristics of the internal installations

Parameter	Comment	Symbol	Value	Reference (Note 1)
Probability factor due to a strike near to the line		P_Z	0.3	Equation B.11
L – N				
Characteristics of internal wiring	0.5 m² loop	K_{S3}	0.01	Table B.5
Shielding factors		P_{MS}	1.6×10^{-5}	Equation B.4
Probability of failure		P_M	1.6×10^{-5}	Equation B.3
L/N – E				
Characteristics of internal wiring	0.5 m² loop	K_{S3}	0.01	Table B.5
Shielding factors		P_{MS}	1.6×10^{-5}	Equation B.4
Probability of failure		P_M	1.6×10^{-5}	Equation B.3
Telecommunications service port	n.a.			
USB port				
Shield resistance per unit length (Ω/km)	Unshielded (Note 2)			
Withstand voltage of the equipment	100 V	K_{S4}	10.0	Equation B.7
Installed coordinated SPD protection	Not installed	P_{SPD}	1	Table B.3
Factor C_{LD}		C_{LD}	1.0	Table B.4
c – d				
Characteristics of internal wiring	0.5 m²	K_{S3}	0.01	Table B.5
Shielding factors		P_{MS}	0.01	Equation B.4
Probability of failure		P_M	0.01	Equation B.3
c/d – e				
Characteristics of internal wiring	0.5 m²	K_{S3}	0.01	Table B.5
Shielding factors		P_{MS}	0.01	Equation B.4
Probability of failure		P_M	0.01	Equation B.3
Ethernet data port				
Shield resistance per unit length (Ω/km)	Unshielded			
Withstand voltage of the equipment	1 kV	K_{S4}	1.0	Equation B.7
Installed coordinated SPD protection	Not installed	P_{SPD}	1	Table B.3
Factor C_{LD}		C_{LD}	1.0	Table B.4
e – f				
Characteristics of internal wiring	0.5 m²	K_{S3}	0.01	Table B.5
Shielding factors		P_{MS}	0.0001	Equation B.4
Probability of failure		P_M	0.0001	Equation B.3

Table I.3 – Main characteristics of the internal installations

Parameter	Comment	Symbol	Value	Reference (Note 1)
e/f – e				
Characteristics of internal wiring	20 m²	K_{S3}	0.2	Table B.5
Shielding factors		P_{MS}	0.04	Equation B.4
Probability of failure		P_M	0.04	Equation B.3
NOTE 1 – Table and equation references are to [IEC 62305-2]. NOTE 2 – The rationale for the classification of the USB cable as unshielded is explained in Appendix II.				

I.5 Zones definition in the structure

In the building, there is only one zone (Zone n.1) whose characteristics are reported in Table I.4.

Table I.4 – Characteristics of zone n.1

Parameter	Comment	Symbol	Value	Reference (Note)
Loss due to physical damage	n.a.	L_f	0.01	Table C.8
Loss due to failure of internal system	n.a.	L_o	0.001	Table C.8
Risk of fire	Ordinary	r_f	0.01	Table C.5
Protection against fire	No	r_p	1.0	Table C.4
NOTE – Table and equation references are to [IEC 62305-2].				

I.6 Expected dangerous events to the structure

The number of expected dangerous events for the building is reported in Table I.5.

Table I.5 – Expected number of dangerous events

Parameter	Comment	Symbol	Value	Reference (Note)
Collection area for structure (m^2)		A_D	16,510	Equation A.2
Collection area near structure (m^2)		A_M	825 000	Equation A.11
Number of direct lightning strikes to the structure		N_D	0.05	Equation A.8
Number of dangerous lightning strikes near the structure		N_M	2.5	Equation A.10
NOTE – Clause references are to [IEC 62305-2].				

I.7 Risk assessment for the unprotected structure

I.7.1 Risk assessment of equipment damage (related to R_2)

The frequency of damage can be calculated as follows:

$$\textit{Frequency of damage} = F_C + F_M + F_W + F_Z \quad \text{(I.3)}$$

The values of the probability factors P and of the losses L are reported in Table I.6.

Table I.6 – Risk R_2: values of the probability factors

Probability	Value
P_B	n.a.
P_C	–
External power port	1.0
Internal USB port	1.0
Internal Ethernet port	1.0
P_M	–
External power port	1.6×10^{-5}
Internal USB port	0.01
Internal Ethernet port	0.04
P_V (power)	n.a.
P_W (power)	1.0
P_Z (power)	0.3

The values of the risk components related to the building are reported in Table I.7.

Table I.7 – Risk F_2: values of the frequency of damage

Risk components	Frequency of damage
F_C (Note)	0.05
F_M (Note)	
Power port	4×10^{-5}
USB port	0.025
Ethernet port	0.1
F_W (power) (Note)	0.12
F_Z (power) (Note)	3.60
Total	
Power port	**3.8**
USB port	**0.075**
Ethernet port	**0.15**
NOTE – $F_C = N_D \times P_C$ $F_M = N_M \times P_M$ $F_W = N_L \times P_W$ $F_Z = N_I \times P_Z$	

The risk F_2 is greater than the tolerable value assumed to be equal to 0.1 (1 damage per 10 years). Therefore, protection measures are necessary. Importantly it is estimated that 3.8 damages to the power port will occur per annum mainly due to surges induced into the power line.

The estimated risk of damage to the Ethernet port is 0.15m greater than the suggested tolerable value of 0.1. However, the calculation F_M is based on a vertical loop and a withstand voltage of 1 kV. This is most likely a worst-case situation and it is expected that damage to the Ethernet ports will be lower than indicated in the table. Therefore, it is assumed the Ethernet port will not need protection.

I.8 Selected protection measures

A protected power board or mains SPD can be installed at the equipment in order to reduce the risk components F_M and F_Z of the power port.

I.9 Risk assessment related to the protected structure

I.9.1 Assessment of the risk R2 of loss of service to the public

The values of the relevant probability factors P are reported in Table I.8.

Table I.8 – Risk R_2: values of the probability factors (protected structure)

Probability	Value
P_C	1.0
P_M power port	1.6×10^{-6}
P_W (power)	1.0
P_Z (power)	0.03

The values of the risk components related to a protected building are reported in Table I.9.

Table I.9 – Risk R_2: Values of the risk components related to a protected building

Risk components	Frequency of damage
F_C	0.05
F_M	
Power port	4×10^{-6}
USB port	0.025
Ethernet port	0.1
F_W (power)	0.12
F_Z (power)	0.360
Total	
Power port	**0.53**
USB port	**0.075**
Ethernet port	**0.15**

The selected protection measures reduce the frequency of damage to the mains power port but not below the tolerable value of 0.1. In practice however, it is expected that the additional protection will provide a higher level of protection than the assigned 0.1 reduction factor.

I.10 SPDs

I.10.1 Selection of SPDs

The expected overcurrent values in the installation point must be considered when selecting SPDs, as indicated in [ITU-T K.67] and Annex E of [IEC 62305-2]. According to Table 2 of [ITU-T K.67], the worst-case induced current due to a flash near the structure is 100 A 10/350. According to Table E.2 of [IEC 62305-2], 5 kA 8/20 is the worst-case mains surge on the mains conductors caused by a lightning strike near the power line. This should be handled by a 5 kA 8/20 MOV type protector.

Appendix II

Assessment of protection needs

(This appendix does not form an integral part of this Recommendation.)

Appendix II considers the damage issues with single port equipment and mains powered earthed and non-earthed equipment. Equipment powered from an external power adaptor may be earthed or non-earthed, depending on the equipment and power supply design.

Three types of equipment need to be considered:

- Single port equipment, e.g., POTS;
- mains powered earthed equipment;
- mains powered non-earthed equipment.

Equipment powered by a power adaptor will be considered according to whether the power source supplies an earth to the equipment.

It also looks at the issue of non-earthed power points.

II.1 Single port equipment

Single port equipment has a high level of isolation to earth and only needs an SPD connected a – b. It will normally be protectable by a GDT connected across the symmetric pair.

II.2 Earthed equipment

Earthed equipment is expected to contain inherent earthed surge protective components (SPCs)/SPDs on the mains and any other external ports and will generally have a good level of protection as equipotential bonding is provided in the equipment (see Figure II.1). There is a possibility of damage to the internal port due to current returning to the MET via the earth wire causing the equipment to rise in potential.

When used with an earth, the equipment should be reliable in most installations and there is minimal safety risk. When used without an earth, damage levels are likely to be significant and safety risks exist for both an a.c. earth fault situation and due to lightning.

II.3 Non-earthed equipment

Non-earthed equipment generally relies on insulation barriers between different types of ports for reliability and safety. If this insulation barrier is broken down damage is likely to occur. There is no equipotential bonding between the ports (see Figure II.2).

Adding an MSPD with protection for all ports will provide equipotential bonding. If the MSPD is plugged into an earthed power point, protection of the equipment and its users should be effective. If the power point is not earthed, equipment damage levels may not be reduced and a possible safety risk for users exists for lightning as the mains double insulation transformer will be breached by the main SPDs.

II.4 Level of protection provided by an MSPD

Available MSPDs may have protection only for external ports or protection for both external ports and internal ports. The risk assessment will indicate which ports needs protection. Some MSPDs may also have coordination elements.

Equipment with earthed SPDs includes:

- MSPD with coordination elements. In this case the surge current entering the equipment will be significantly reduced. The reduction factor P_{MSPD} could be assumed to be 0.1.
- MSPD without coordination elements. For external symmetric pair ports the coordination element in the equipment should ensure operation of the MSPD GDT and the reduction factor P_{MSPD} could be assumed to be 0.1. For mains power ports, the current will be shared by the MSPD and the equipment MOVs. In this case the reduction factor P_{MSPD} could be assumed to be 0.5. While it may seem that the mains port of the equipment is at risk of damage, the inherent protection level can be quite high depending on the size of the protection element used.

Equipment without earthed SPDs. In this case current should not enter the equipment and the reduction factor P_{MSPD} could be assumed to be 0.1.

II.5 Consideration of loop areas

It can be seen in the bottom diagram of Figure II.3 that the induced voltage on transformer isolated ports connected by a short cable may be higher than expected. If the risk assessment indicates that protection is needed for ports connected to long internal cables, protection may also be required for ports connected to short cables. It is suggested to always use a loop area of 10 m² for Ethernet ports.

[IEC 62305-2] determines the reduction factor K_{S3} for shielded cables assuming that the withstand voltage conductor to screen is 1000 V. The internal shielded cable test of [ITU-T K.21] applies the test voltage to the screen resulting in a conductor to screen voltage considerably less than the test voltage. In this case the unshielded loop area is used to determine the reduction factor K_{S3}.

For shielded cable USB ports, a loop area of 0.5 m² is recommended. In this case K_{S3} = 0.01, according to [IEC 62305-2]. Now generic USB ports have a resistibility (withstand) level of 100 V. In this case K_{S4} =10, according to [IEC 62305-2].

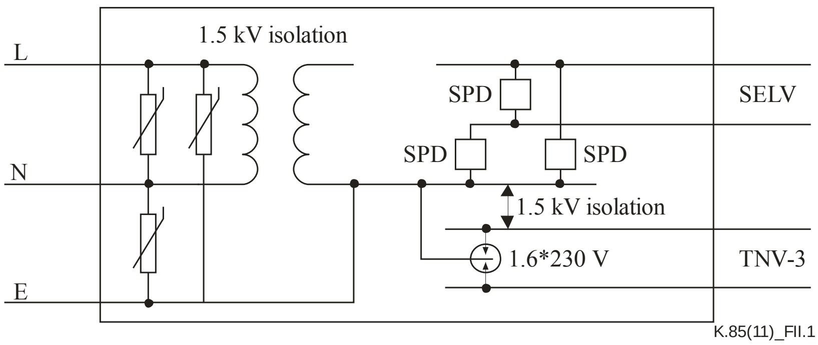


Figure II.1 – Earthed equipment

- Equipment is earthed and safe according to [IEC 60950-1].
- It is understood that surge currents in the earth wire due to surges on the line can cause the equipment to rise in potential with respect to the MET.
- Risk of damage on internal ports due to mains current requires either mains primary protector or all ports (external and internal) to connect via an MSPD.
- If the earth connection is missing from the power point, safety may be compromised. The SELV circuit may be exposed to lightning surges.
- [ITU-T K.21] requirements ensure protection up to the inherent test levels.

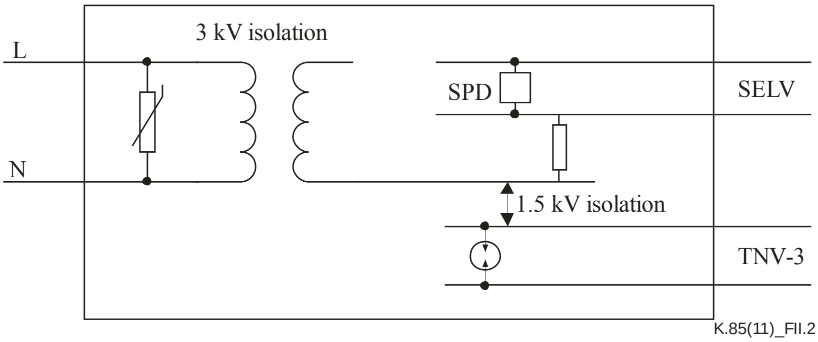


Figure II.2 – Non-earthed equipment

- Equipment is safe according to [IEC 60950-1].
- It is understood that surge currents in the mains conductors can cause the primary winding of the mains port transformer to rise in potential with respect to the MET.
- If the insulation is breached damage and safety issues may occur.
- [ITU-T K.21] requirements ensure protection up to the inherent test levels.
- When protection is required, install an MSPD or primary protection on all external ports.
- If the earth connection is missing from the power point, the MSPD may create a safety issue. The SELV circuit may be exposed to lightning surges.
- An alternative protection method is to use high insulation values on all external ports. This is only effective against induced surges.

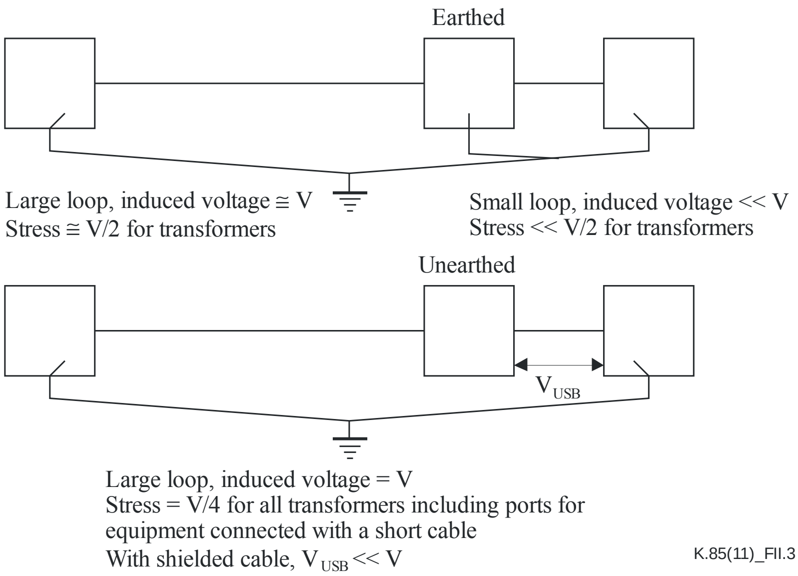


Figure II.3 – Induced voltage depends on the equipment type

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