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SERIES K: PROTECTION AGAINST INTERFERENCE

Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges

Recommendation ITU-T K.46

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Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges

Summary

Recommendation ITU-T K.46 specifies a procedure to protect telecommunication lines using metallic symmetric conductors against overvoltages and overcurrents imposed on the lines due to nearby lightning discharges. The protection procedure is related to the exposure of the line to the effects of nearby lightning discharges, and includes the earthing and bonding of the cable shield and the installation of surge protective devices (SPDs).

This Recommendation follows the risk management procedure which requires that the expected risk of damage due to both direct flashes and flashes near a telecommunication line shall be not greater than the tolerable risk. The user shall refer to Recommendation ITU-T K.72 for the risk management procedure.

The risk assessment is limited to the failure of insulation of telecommunication lines (buried or aerial cables, shielded or unshielded cables) which can cause the loss of service.

The user shall refer to Recommendation ITU-T K.47 for evaluating the expected risk of damage due to direct lightning discharges, either to the line itself or to the structures where the line enters, and, if necessary, in order to select the protection measures to reduce the risk of damage due to direct flashes.

Examples of application of this Recommendation are reported in Appendix IV.

Source

Recommendation ITU-T K.46 was approved on 13 April 2008 by ITU-T Study Group 5 (2005-2008) under Recommendation ITU-T A.8 procedure.

Keywords

Conventional length, exposure factor, induced overvoltages, installation factor, lightning near a line, node, protection, risk, risk assessment, shielding factor, SPD.

FOREWORD

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges

1 Scope

This Recommendation gives a procedure in order to protect telecommunication lines using metallic symmetric conductors against overvoltages and overcurrents imposed on the lines due to nearby lightning discharges.

The procedure is based on the evaluation of the conventional length. Once an upper limit for the conventional length has been selected, this procedure allows the selection of appropriate protection measures to be adopted to reduce the conventional length at or below the tolerable limit.

This Recommendation follows the risk management procedures as described in [ITU-T K.72]; the risk assessment is limited to the failure of insulation of telecommunication lines (buried or aerial cables, shielded or unshielded cables) which can cause the loss of service.

In accordance with the risk management procedure [ITU-T K.72], the difference between the tolerable risk (R_T) and the expected risk of damage due to direct flashes (R_d) is the tolerable risk (R_T-R_d) for the expected risk of damage due to flashes near a telecommunication line.

The user shall refer to [ITU-T K.47] for evaluating the expected risk of damage due to direct lightning discharges, either to the line itself or to the structures where the line enters, and, if necessary, in order to select the protection measures to reduce the risk of damage due to direct flashes.

The protection needs of line equipment (such as multiplexer, power amplifier, optical network units) and line termination equipment is not considered by this Recommendation and it should be evaluated using the risk assessment applied to the structure where the equipment is located (i.e., exchange, or customer's building, or remote electronic site).

NOTE – Information on line and environment characteristics should be given to the owner of the structure connected to the telecommunication line, who has to perform the risk assessment of his structure (see also Appendix III).

The protection of persons using telecommunication equipment inside the exchange or the customer's structure, from dangerous situations caused by touch voltages, is outside the scope of this Recommendation and it should be evaluated using the risk assessment applied to the exchange or the customer's structure.

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 (2000), *Characteristics of gas discharge tubes for the protection of telecommunications installations*.

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

[ITU-T K.28] Recommendation ITU-T K.28 (1993), *Characteristics of semi-conductor arrester assemblies for the protection of telecommunications installations*.

[ITU-T K.47] Recommendation ITU-T K.47 (2008), *Protection of telecommunication lines using metallic conductors against direct lightning discharges*.

[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.72] Recommendation ITU-T K.72 (2008), *Protection of telecommunication lines using metallic conductors against lightning: Risk management*.

[IEC 60664-1] IEC 60664-1 (2007), *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/037956>

[IEC 62305-2] IEC 62305-2 (2006), *Protection against lightning – Part 2: Risk management*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/035440>

3 Definitions

Definitions given in [ITU-T K.72] and [ITU-T K.47] apply.

This Recommendation defines the following terms:

3.1 number of dangerous events due to flashes near a service N_I: Expected average annual number of dangerous events due to lightning flashes near a service.

3.2 protection factor of SPD (P_{SPD}): Factor taking into account the effect on a given node of the surge protective devices (SPDs) installation in that node.

3.3 rated impulse withstand voltage level U_w: Impulse withstand voltage assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against overvoltages.

NOTE – For the purpose of this Recommendation, only withstand voltage between conductors and earth is considered [IEC 60664-1].

3.4 resistibility level U_r: Resistibility is the ability of telecommunication equipment or installations to withstand, in general, without damage, the effects of overvoltages or overcurrents, up to a certain specified extent and in accordance with a specified criterion.

3.5 shielded node: Reference point of the telecommunication line where the cable(s) is (are) shielded.

NOTE – A shielded node is a point of the telecommunication line where the surge protective devices (SPDs), when required, are installed between conductors and shield.

3.6 surge protection level (SPL): Peak values and waveshape of the expected dangerous surge voltages or currents which could appear in different points of the telecommunication networks due to the lightning current as a source of damage.

NOTE – Three surge protection levels (I to III) are introduced in [ITU-T K.67]. For each SPL, the peak values and the waveshape of the expected dangerous surge voltages and currents are estimated.

3.7 unshielded node: Reference point of the telecommunication line where the cable(s) is (are) unshielded.

4 Reference configurations

Figure 1 shows the reference configurations for the telecommunication lines with metallic symmetric conductors where the reference nodes and the cable sections between them can be seen. Usually, the telecommunication line starts at node E (exchange) and ends at node S (subscriber premises), but the following situations have also to be considered:

a) If equipment installed in the telecommunication line has intrinsic protection against common mode overvoltages given by SPDs installed between conductors of the telecommunication line (at both input and output ports) and equipment reference earth, then this equipment can be treated as an ending point for the line that comes from node E and a starting point for the line that goes to the subscriber premises. This is usually the case for access network equipment located in a remote electronic site (node R).

b) If equipment installed in the telecommunication line has no earthed metallic parts and its intrinsic protection against common mode overvoltages is given by the insulation to ground of the telecommunication line and by SPDs installed inside the equipment between input and output ports, then the presence of this equipment can be neglected for the purpose of this Recommendation.

c) If telecommunication or signal lines are connecting equipment located in different buildings within the subscriber's premises (e.g., ISDN lines or signal lines between computers), then this telecommunication line starts and ends within the subscriber premises (section S/S).

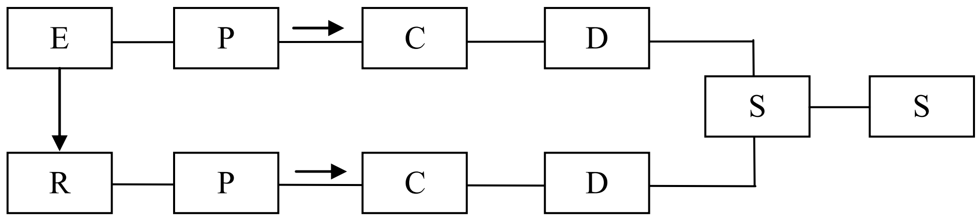


Figure 1 – Reference configurations (arrows show downstream direction)

The nodes of Figure 1 have the following descriptions:

Node E: Exchange building, where the main switching equipment is located.

Node R: Access network equipment, usually installed in shelters at the outside plant (remote electronic site).

Node P: Transition between paper-insulated and plastic-insulated cables.

Node C: Transition between buried and aerial cables.

Node D: Transition between shielded and unshielded cables.

Node S: Subscriber's premises.

NOTE – The use of the term "node" is equivalent to that of "transition point" in [IEC 62305-2].

Sometimes two or more transitions may occur at the same node or they may occur in a different sequence from that shown in Figure 1. The notation PC, for example, may be used to identify a node where there is a transition in the line from paper to plastic insulation and from buried to aerial installation.

Additional nodes can be added to the line configuration in order to identify other changes in the line characteristics, such as type of cable (number of pairs), environment (urban/suburban), etc. These nodes are called "virtual nodes", V1, V2, etc. However, the assessment of the protection need shall be performed only for nodes that can be classified according to the reference configuration. Table 1 shows some typical reference configurations.

Table 1 – Typical reference configurations

Nodes E/PC/D/S	Nodes E/P/CD/S	Nodes E/C/D/S
Nodes E/CD/S	Nodes E/C/S	Nodes E/S
Nodes R/C/D/S	Nodes R/CD/S	Nodes R/C/S
Nodes R/S	Nodes E/R	Nodes S/S

The direction from node E to node S is designated as downstream. The opposite direction is designated as upstream. For a given line, it is considered that the shielded sections (if any) start at the first node (for example, node E) and follow the downstream direction until the transition to an unshielded section (node D) or the last node (for example, node S). Therefore, lines with more than one transition between shielded and unshielded sections (node D) are not treated by this Recommendation.

5 General requirements

5.1 Insulation withstand voltage levels

In order to provide adequate protection by use of the procedures of this Recommendation, the following insulation withstand voltage levels shall be observed:

– Shielded cables with paper insulation: The insulation between any two conductors and between any conductor and shield shall withstand an overvoltage of 1.5 kV peak, 10/700 μs wave shape.

– Shielded cables with plastic insulation: The insulation between any two conductors and between any conductor and shield shall withstand an overvoltage of 5.0 kV peak, 10/700 μs wave shape.

– Unshielded cables with plastic insulation: The insulation between any two conductors and between any conductor and earth shall withstand an overvoltage of 15.0 kV peak, 10/700 μs wave shape.

5.2 Selection of SPD

a) The SPD shall comply with [ITU-T K.12] when using gas discharge technology or with [ITU-T K.28] when using semi-conductor technology. The latter are usually used in the exchange building only.

b) The minimum DC breakdown voltage of the SPD shall be greater than the maximum line voltage expected, both to earth and between the line terminals (the latter in the case of three electrode devices). It shall be observed that, in some equipment, the ringing voltage may add to the DC powering voltage. Due to the possibility of variations in the line voltage and/or the presence of power frequency voltage induced on the line, a safety margin shall be provided between the maximum line voltage and the minimum DC breakdown voltage of the SPD.

c) The maximum impulse breakdown voltage of the SPD shall be consistent with the impulse withstand voltage of the insulation to be protected.

6 Characterization of the environment

6.1 Environmental factor (C_e) and exposure factor (K_x)

The number and magnitudes of the lightning-induced surges on a telecommunication line are related to some aspects of the environment, mainly the lightning activity, the soil resistivity and the shielding provided by the structures around the line. In order to take these parameters into account, the exposure factor of the line (K_x) is defined, as given by equation 1:

$$K_x = C_e \times T_d \times \rho^{1/2} \times 10^{-3} \quad (1)$$

where:

- ρ average soil resistivity, in Ω.m;
- T_d keraunic level (number of thunderstorm days per year);
- C_e environment factor:
- $C_e = 0.01$ for urban area with tall buildings (height of buildings greater than 20 m);
- $C_e = 0.1$ for urban area (height of buildings ranging between 10 m and 20 m);
- $C_e = 0.5$ for suburban area (height of buildings less than 10 m);
- $C_e = 1$ for rural area.

If the area is not fully occupied, the value of C_e can be corrected to take this into account. Therefore, the construction factor (φ) is defined, which is 1 for an area fully occupied with constructions and 0 for an area with no construction. The expression for C_e becomes:

$$C_e = 1 + \varphi\left(C_e{}' - 1\right) \quad (2)$$

where:

- C_e' is the environmental factor evaluated by the typical construction parameters;
- C_e is the corrected environmental factor, considering the actual occupation of the area.

For example, consider a typical old suburban area, where most of the land is occupied by houses. In this case, the environmental factor $C_e = 0.5$. However, if it is a new suburban area, where half of the land ($\varphi = 0.5$) is still to be constructed, then $C_e = 0.75$.

6.2 Installation factor (K_i)

The installation factor is intended to take into account the reduction in the coupling between the lightning discharge and the telecommunication line due to the installation of the line underground, as compared with an aerial installation. For an aerial installation $K_i = 1$, while for a buried installation $K_i = 0.5$ (based on chapter 10 of [b-ITU-T Lightning]).

6.3 Shielding factor (η)

The use of properly earthed/bonded shielded cables attenuates the lightning-induced surges on the telecommunication line. This attenuation can be expressed as a shielding factor (η), which is a number between 0 (for perfect shielding) and 1 (for no shielding). In order to evaluate the shielding factor, the shielding must be continuous throughout the shielded section(s) and connected to the bonding bar at both ends.

For a line composed of several sections, the shielding factor shall be calculated for each section of the telecommunication line.

6.3.1 Shielding factor related to the shield (η_s)

If the protection need is considered for a shielded node, then the shielding factors of the shielded section(s) of the telecommunication line are related to the shield (η_s). In this case, the intrinsic shielding factor of each section can be calculated with the following approximated equation.

$$\eta_{sj} = \frac{R_j}{Z_j} \tag{3}$$

where:

- R_j is the shield resistance in Ω of each section; in Appendix II, values of shield resistance of typical telecommunication cables with metallic symmetric conductors are given, as a function of the conductor diameter and number of pairs;
- Z_j is the surge or the characteristic impedance of the shield-earth circuit of each section: Z_j is assumed to be equal to 100 Ω or 400 Ω for buried or aerial cable, respectively.

The shielding factor (η_s) of any shielded sections is the sum of the intrinsic shielding factors of all line sections:

$$\eta_s = \sum_{k=1}^{m} \eta_{si}(k) \tag{4}$$

where:

- η_s is the shielding factor of any shielded sections;
- $\eta_{si}(j)$ is the intrinsic shielding factor of section j, as given by equation 3;
- m is the number of shielded sections of the line.

Considering the examples shown in Figure 2 and using equation 3, the intrinsic shielding factor related to the shield of each section has the following value:

– Configuration E/P/C/S (Figure 2a):

$$\eta_s(1) = \frac{R_s(1)}{100} \quad \text{and} \quad \eta_s(2) = \frac{R_s(2)}{100}$$

– Configuration E/PC/D/S (Figure 2b):

$$\eta_s(1) = \frac{R_s(1)}{100} \quad \text{and} \quad \eta_s(2) = \frac{R_s(2)}{400}$$

The shielding factor of any shielded sections is obtained from equation 4:

– Configuration E/P/C/S (Figure 2a):

$$\eta_s = \eta_{si}(1) + \eta_{si}(2) = \frac{R_s(1) + R_s(2)}{100}$$

– Configuration E/PC/D/S (Figure 2b):

$$\eta_s = \eta_{si}(1) + \eta_{si}(2) = \frac{4 \times R_s(1) + R_s(2)}{400}$$

6.3.2 Shielding factor related to earth (η_e)

If the protection need is considered for an unshielded node, then the shielding factors of the shielded section(s) of the telecommunication line are related to earth (η_e). In this case, the shielding factor of each section can be calculated with the following approximated equation when the shield is connected to earth only at its extremities, as shown in Figure 2:

$$\eta_e(j) = \frac{R_t}{R_t + Z(j)} \quad (5)$$

R_t is the resistance in Ω of the earthing system, closest to the Node being considered, to which the shield is connected.

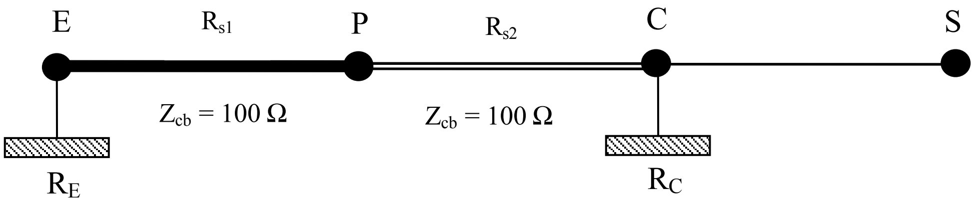
Considering the examples shown in Figure 2 and using equation 5, the shielding factor related to earth of each section has the following value:

– Configuration E/P/C/S (Figure 2a):

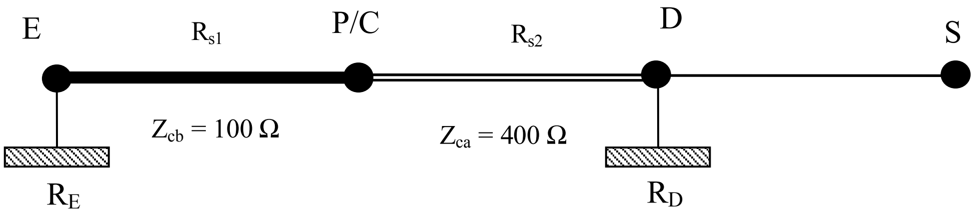
$$\eta_e(1) = \eta_e(2) = \frac{R_C}{R_C + 100}$$

– Configuration E/PC/D/S (Figure 2b):

$$\eta_e(1) = \frac{R_D}{R_D + 100} \quad \text{and} \quad \eta_e(2) = \frac{R_D}{R_D + 400}$$



a) Line configuration E/P/C/S: shield connected to earth in E and C Nodes



b) Line configuration E/PC/D/S: shield connected to earth at E and D Nodes

Figure 2 – Examples of line configurations

Figure 3 shows an example of line configuration where the shield is connected to earth at an intermediate node.

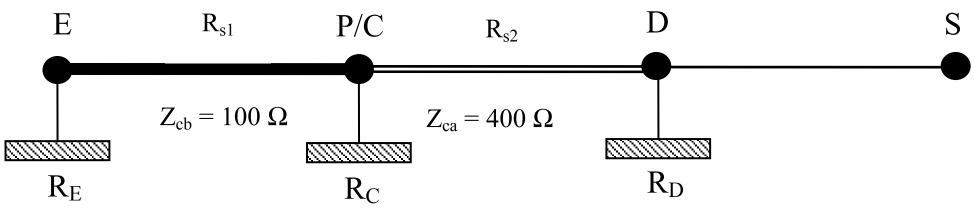


Figure 3 – Example of line configuration with the shield connected to earth at an intermediate node

The surge induced in the buried section (E-P/C) is attenuated at node P/C by the earthing R_C and is further attenuated at node D by the earthing R_D, resulting in:

$$\eta_{se1} = \frac{R_C}{R_C + Z_{cb}} \times \frac{R_D}{R_D + Z_{cb}} \tag{6}$$

The surge induced in the aerial section is attenuated only at R_D, so that using equation 5:

$$\eta_{se2} = \frac{R_D}{R_D + Z_{ca}}$$

NOTE 1 – If R_C is disconnected ($R_C = \infty$), the first term of equation 6 goes to unity and the resulting shielding factors become identical to the ones calculated for Figure 2b. Therefore, if an arbitrarily earthing system $R_t = \infty$ is introduced anywhere in the cable, the shielding factor will not change, as expected.

NOTE 2 – Equation 6 considers that the cable has a minimum length between the earthing systems, so that the concept of surge impedance applies. If the two earthing systems are too close (e.g., less than 200 m apart), they will behave as a single earth with a resistance given by the parallel association.

6.4 Conventional length

In order to take into account the exposure of a cable section to the lightning-induced surges, the conventional length of the section is defined. Let us consider, as a reference cable section, one made of an unshielded cable ($\eta = 1$), in aerial installation ($K_i = 1$) and with a length of 1 km. The average earth resistivity is 400 Ω.m, the keraunic level is 50 thunderstorm days per year, and the cable is installed in a rural area ($K_x = 1$). Defining the convention length as in equation 7 leads to the conclusion that this reference cable section will have a conventional length equal to its real length (1 km).

$$L_c(j) = K_x(j) \cdot \eta(j) \cdot K_i(j) \cdot L(j) \tag{7}$$

where:

$L_c(j)$ is the conventional length of the section j;

$L(j)$ is the real length of the section j.

As can be seen from equation 7 that, for the same real length, the conventional length will increase as the section exposure to lightning-induced surges increases, and vice versa. For example, if an aerial cable section is buried, its conventional length will be reduced by half. In other words, leaving the other conditions the same, a buried section would have twice the real length of an aerial section in order to experience the same level of lightning induced surges.

If a line is composed of n cable sections with different parameters, the conventional length of a given node is the sum of the conventional lengths of all the sections of the line, as shown in equation 8.

$$L_c = \sum_{j=1}^{n} L_c(j) \quad (8)$$

This Recommendation requires that the conventional length be calculated for every node of the reference configuration (see Figure 1) considering the following rules:

a) For a shielded node, the shielding factor of the shielded sections shall be related to the shield (η_s). See clause 6.3.1 for the calculation of η_s.

b) For an unshielded node, the shielding factor of the shielded sections shall be related to earth (η_e). See clause 6.3.2 for the calculation of η_e.

7 Bonding procedures

7.1 Exchange (node E)

All shielded cables entering the exchange building shall have continuous metallic sheaths, which means that the sheath shall be bonded across all splices. At the entrance of the building (cable chamber), all metallic sheaths shall be bonded to the building's main earthing terminal located near this point, according to [ITU-T K.27]. This bonding shall be made using low-impedance conductors (short and wide).

NOTE – In some particular cases, where there is evidence of galvanic corrosion in the cable plant, it is acceptable to perform this bonding by means of SPD, provided that they are adequately dimensioned.

If the cable arriving at the main distribution frame (MDF) has a metallic sheath, it shall be bonded to the MDF bonding bar. The MDF bonding bar shall be connected to the main earthing terminal by means of a low impedance conductor.

7.2 Outside plant (nodes R, P, C and D)

At the transition between two shielded cables, the shield shall be bonded across the transition by means of an adequate bonding conductor. In the case of aluminium sheath, care shall be taken in order to assure good and permanent contact between the sheath and the bonding conductor, which can be accomplished by the use of an adequate clamp. If the transition takes place at a cross-connect cabinet, it is recommended that a bonding bar is provided close to the cable entrance point and that all the metallic sheaths are bonded to this bar.

If the transition between a shielded and an unshielded cable is made by means of a distribution box, its bonding terminal shall be bonded to the cable shield directly or through the metallic sheath of a stub cable. If the cable connected to the access network equipment is shielded, its shield shall be bonded to the equipment bonding bar located at the entrance of the shelter.

7.3 Subscriber premises (nodes S)

If the cable that arrives at the subscriber premises is shielded, its shield shall be bonded to the subscriber's equipotential bonding bar, according to [ITU-T K.66]. The other metallic parts of the subscriber premises (such as metallic water and/or gas pipes, and metal framework of the building) shall be connected to the equipotential bonding bar, in order to reduce the overvoltages between accessible parts.

8 Surge protective devices (SPDs)

8.1 Installation of surge protective devices (SPDs)

For the installation of SPDs at a node, their line terminals shall be connected to the conductors of the telecommunication line and their earth terminals shall be connected to the bonding bar of an unshielded node or to the cable shield of a shielded node. Figure 4 shows the connections of SPDs at a shielded node (Figure 4a) and at an unshielded node (Figure 4b). If a local earthing system is available, the bonding bar or the cable shield shall be connected to it. However, if there is no earthing system available at an unshielded node, one has to be constructed in order to allow the proper installation of the SPD.

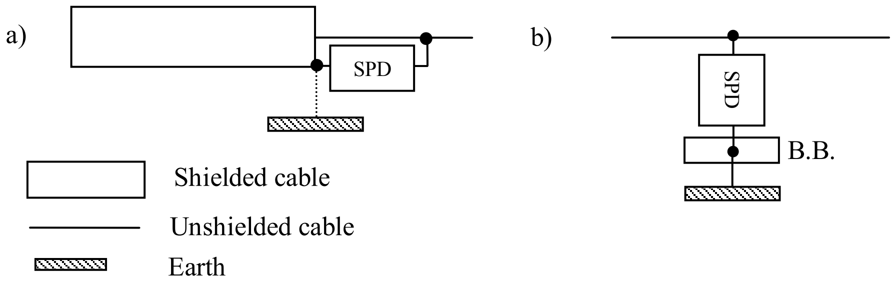


Figure 4 – Installation of surge protective devices (SPDs)

If the cable shield is not connected to earth at a node where the SPDs are installed, the voltage drop due to the current taken by the SPDs in the cable shield shall be less than the breakdown voltage between conductors and shield (see Annex A).

8.2 Assessment of the node's protection need

The conventional length concept is used to assess the need to protect the nodes of the telecommunication line. The limit values given in this clause are based on the selected tolerable risk value [ITU-T K.72], the expected risk of risk of damage R_d due to direct flashes [ITU-T K.47], and the consequential loss due to damage which can be derived considering technical and economical aspects. Depending on the desired reliability for the lines, the repair cost and the field experience, the operator can select R_T and losses values in order to match local requirements taking into account the value of tolerable risk identified by the authority. The conventional length limit (L_{lim}), in kilometres, is calculated with the following equation:

$$L_{\text{lim}} \frac{R_T - R_d}{C \times 10^3 \times L_o} \tag{9}$$

The value of the constant C for each node is evaluated as follows (see Appendix I):

$$C = 2.4 \times U_w^{-1.8} \times 10^3 \tag{10}$$

where U_w, in volts, is the lower peak value of the impulse withstand voltage of the section insulation related to the considered node. Table 2 shows the constant *C* value for each node of a telecommunication line.

The value of the loss L_o shall be evaluated by the network operator or by the owner of the installation. If this evaluation is difficult, this Recommendation suggests the value L_o = 0.001, as shown in Appendix II.

Table 2 – Values of the constant *C* for the nodes of a telecommunication line

Node	Constant *C* value
E and R with P in the line	4.6×10^{-3}
E and R without P in the line	5.3×10^{-4}
P	4.6×10^{-3}
C and D	5.3×10^{-4}
S without D in the line	5.3×10^{-4}
S with D in the line	7.3×10^{-5}
S without P, C and D in the line	4.6×10^{-3}

In the application of Table 2, the following rules shall be considered:

a) If more than one transition occurs at the same node, its value is given by the lower value among those of the transitions. For example, for a node PC the value is 4.6×10^{-3}.

b) If the line is composed of only one section with buried shielded paper insulated cable, the value for the nodes at both ends of the line shall be considered equal to 4.6×10^{-3}.

The conventional length limit value of each node of the line, calculated with equation 9, shall be compared with the conventional length of the node calculated with equation 8. If the conventional length of the node is greater than the limit value, then the node needs protection against the lightning induced surges.

8.3 Determination of the protection schemes

Once the nodes needing protection are known, it is necessary to determine where the SPD shall be installed. It is often possible to obtain more than one scheme for the installation of an SPD that protects the line. Therefore, the decision about which scheme to use shall be based on economic considerations. The following rules shall be considered in determining the protection scheme:

a) The installation of an SPD at a node reduces its conventional length almost to zero (see Figure 5a) and, therefore, protects the node.

NOTE – The installation of an SPD at a node can reduce its conventional length to a value equal to the product between the conventional length of the node and the protection factor P_{SPD} of the SPD. Considering the expected induced overcurrent values shown in [ITU-T K.67], [IEC 62305-2] gives a value of $P_{SPD} = 0.001$. Therefore, this Recommendation considers $P_{SPD} = 0$ as a simplified approach with respect to [IEC 62305-2], which will lead to the same results in most practical cases.

b) The unshielded nodes needing protection shall be protected with an SPD. The installation of an SPD at an unshielded node does not affect the conventional length of the other nodes (see Figure 5a).

c) The node D needing protection shall be protected with an SPD. The installation of an SPD at node D reduces the conventional lengths of the upstream shielded nodes. The new conventional lengths shall be calculated neglecting the unshielded sections downstream from the SPD (see Figure 5b).

d) The installation of an SPD at a shielded node affects the conventional length of the other shielded nodes. The conventional length of the shielded nodes downstream and upstream from an SPD shall be calculated as if the SPD had divided the line into two independent lines (see Figure 5c).

e) The installation of an SPD at a shielded node does not affect the conventional length of the unshielded nodes (see Figure 5c).

In Appendix III, there are some examples of applications of this procedure.

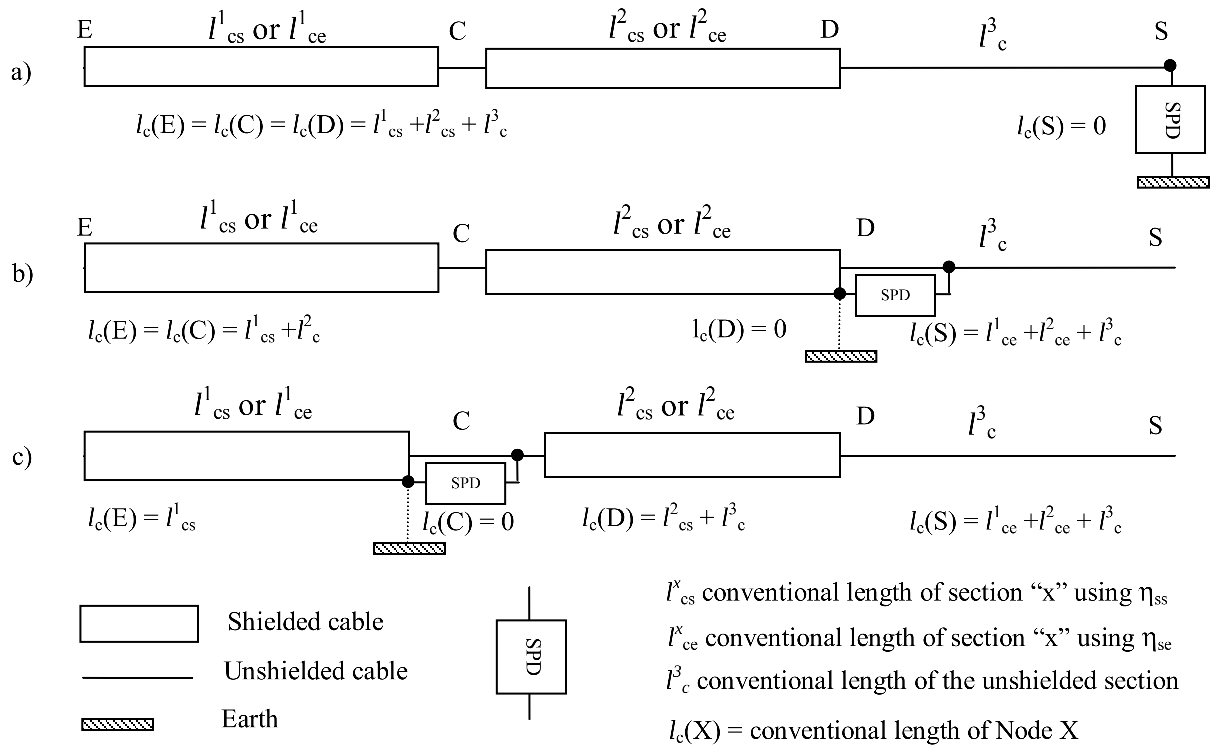


Figure 5 – Effect of SPD on the evaluation of the conventional length

Annex A

Requirements for SPDs installed between conductors and cable shield

(This annex forms an integral part of this Recommendation)

A.1 General

The installation of SPDs between conductors and cable shield along the telecommunication line causes the flow of lightning overcurrents and, consequently, a voltage drop in the cable shield. This overcurrent is equal to

$$\sqrt{n} \times I_i \quad \text{(A.1)}$$

where

- n is the number of conductors protected with SPDs installed in one node;
- I_i is the overcurrent induced in each conductor of the telecommunication line; its value is given in [ITU-T K.67] as a function of the selected lightning protection level (LPL).

This overcurrent flows toward the switch earthing system through a total DC resistance, R_t (see Figure A.1)

$$R_t = R_e + \sum R(j) \times L(j) \quad \text{(A.2)}$$

where

- R_e is the resistance value of the earthing system seen from the telecommunication switch (node E);
- $R(j)$ is the DC shield resistance value per unit length of the line section j in parallel with the longitudinal DC resistance of the pairs provided with SPDs at both ends of the section;
- $L(j)$ is the length of the line section j;
- j is the number of line sections between the switch (node E) and the installation point of SPDs.

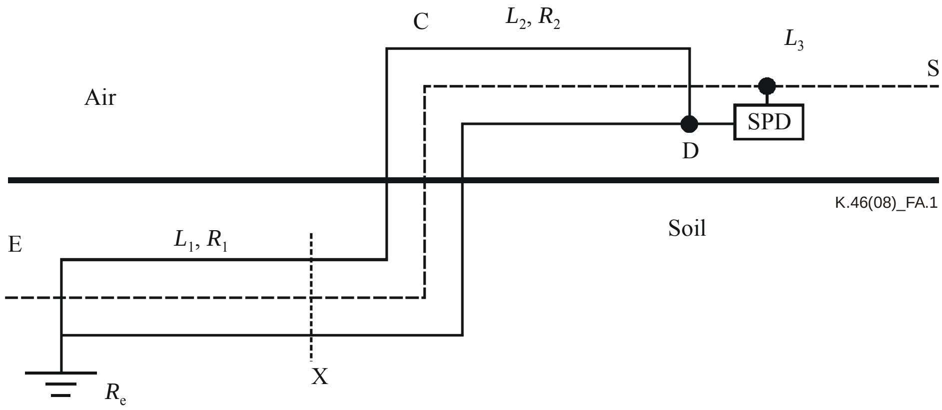


Figure A.1 – Example: SPDs installed in node D

When the voltage drop U_d along the shield is greater than the insulation withstand voltage:

$$U_d = n \times I(j) \times \sum (R(j) \times L(j)) > U_w \quad \text{(A.3)}$$

it is necessary to reduce this voltage drop to value less than or equal to the voltage U_w by one of the following two methods (which can also be combined):

– the installation of SPDs at node E between all cable conductors and the shield. These SPDs are effective if the requirements given in clause A.2 are fulfilled; or

– the connection of the shield to earth in the node along the lines (e.g., node D). The earth resistance value of this earth connection is evaluated in clause A.3.

A.2 Length of cable protected by SPDs

When equation A.3 is fulfilled, there is a point X along the line (see Figure A.1), where the voltage drop is equal to the insulation withstand voltage U_w.

The installation of SPDs at point E between all cable conductors and the shield is effective when the distance between points P and E is lower than or equal to that given by the following equation (Figure A.1):

$$l_{\mathrm{p}} = \frac{(U_w - U_{\mathrm{p/f}})}{k'} \quad \text{(A.4)}$$

where

$$k' = \frac{2 \times S}{v} \quad \text{(A.5)}$$

$$S = \sum (R_{\mathrm{i}} \times l_{\mathrm{i}}) \times n \times \frac{I_{\mathrm{i}}}{T_1} \quad \text{(A.6)}$$

with

U_w is the impulse breakdown voltage between the conductors and the shield of the cable (U_w is 1.5 kV or 5 kV for paper- or plastic-insulated conductors, respectively);

$U_{\mathrm{p/f}}$ is the impulse effective protection level of the SPD (which can be estimated equal to 500 V for switching type SPDs);

S_{T1} is the steepness of front time (which is assumed to be 10 µs for conductor overvoltage and 1 µs for the voltage drop along the shield);

I_{i} is the peak value of the induced current injected in the shield by the SPD firing, evaluated as a function of the selected SPL in accordance with [ITU-T K.67];

T_1 is the front time of the current injected in the shield by the SPD firing, indicated equal to 10 µs in [ITU-T K.67];

v is the propagation speed of the surge voltage which is estimated at 200 m/µs.

A.3 Resistance value of the cable shield connection to earth along the telecommunication line

The resistance value R_{g} of the shield connection to earth can be estimated with the following equation:

$$R_{\mathrm{g}} = \frac{U_w \times R_t}{U_d - U_w} \quad \text{(A.7)}$$

If a line section has a double shield with a DC resistance value per unit length R_{ai} of the additional shield, it is necessary to substitute in equations A.2, A.3 and A.6 the resistance R_i with $R_i \times R_{ai}/(R_i + R_{ai})$.

Appendix I

Frequency of damage (F_Z) due to lightning flashes near a telecommunication line

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

The characteristics of the overvoltages and overcurrents induced by lightning in telecommunication lines are reported in chapter 10 of [b-ITU-T Lightning]. The distributions which give the average number of events per thunderstorm day exceeding voltage thresholds are also presented in [b-ITU-T Lightning]. The measured data are fitted with a straight line in a diagram showing the number of events on a logarithmic scale versus the voltage thresholds on a logarithmic scale. The equations of these voltage occurrences, the average soil resistivity of the rural area, the average length of the lines, and the number of lines of the survey are also shown (see Table I.1). It is interesting to note that the equation of the voltage occurrence at the subscriber's end measured in the three difference surveys have identical slope.

Table I.1 – Equation of the voltage occurrence in three different surveys reported in chapter 10 [b-ITU-T Lightning]

Voltage occurrences at subscriber's end: N_S [Time/year·lines]	Soil resistivity [Ω·m]	Average length l [m]	Number of lines
I: $N_S = 2.3 \cdot 10^5 \cdot T_d \cdot V_p^{-1.8}$	875	3 800	12
J: $N_S = 1.05 \cdot 10^5 \cdot T_d \cdot V_p^{-1.8}$	30-100	4 400	10
USA: $N_S = 5.3 \cdot 10^5 \cdot T_d \cdot V_p^{-1.8}$	~700	11 700	3

The voltage occurrence equations could be useful for evaluating the protection need of the subscriber line. For this purpose, it is assumed that the voltage occurrence equation or frequency of damage has the following normalized equation:

$$F_z = a \times l_c \times V_p^{-1.8} \tag{I.1}$$

where

- l_c is the total conventional length of the telecommunication line (see clause 6.4);
- V_p is the value of the impulse resistibility voltage of the equipment or of the impulse breakdown voltage of the cable insulation. The lower value of V_p is 1 kV, which is the resistibility value of the equipment installed in the exchange (see [b-ITU-T K.20]);
- a = 2.4 is a constant whose average value is based on Table I.1.

The frequency of damage of the line is the sum of the frequency of damage of each line section:

$$F_Z = \sum F_{Zi} = \sum a \times l_{ci} \times V_p^{-1.8} \tag{I.2}$$

Substituting equation 7 into equation I.2, the frequency of damage of the line section j can be written as follows:

$$F_p(j) = T_d \times 10^{-6} \times 9.6 \times k_w \times \eta(j) \times K_i(j) \times \sqrt{\rho} \times L(j) \tag{I.3}$$

where k_w is the withstand factor given by the following equation:

$$k_w = (V_p)^{-1.8} \qquad (V_p \text{ in kV}) \tag{I.4}$$

T_d is the number of thunderstorm days per year;

K_i is the installation factor;

ρ is the soil resistivity.

In agreement with [IEC 62305-2], the frequency of damage can also be calculated as the product of the ground flash density (N_g, [ITU-T K.47]), the collection area (A_i) and the probability factor of the protection measures (P_{LI}):

$$F_p(j) = N_g \times 10^{-6} \times A_i(j) \times P_{LI}(j) \quad \text{(I.5)}$$

The comparison between equations I.3 and I.5 gives the following expression of the collection area A_i and the protection factor P_{LI}:

$$A_i(j) = 96 \times k_w \times K_i(j) \times \sqrt{\rho} \times L(j) \quad \text{(I.6)}$$

$$P_{LI}(j) = \eta(j) \quad \text{(I.7)}$$

The values of constant k_w are given in Table I.2.

Table I.2 – Values of constant k_w of equation I.4

	V_p [kV]	**k_w**
Equipment basic resistibility in the exchange	1	1
– Paper-insulated cable (Note 1) – Equipment enhanced resistibility in the exchange and remote site – Equipment basic resistibility in the customer's premises and remote site	1.5	0.48
Plastic insulated cable (Note 1)	5	0.055
Equipment enhanced resistibility in the customer's premises	6	0.040
Unshielded cable (Note 2)	15	0.008
NOTE 1 – This type of cable is always shielded. NOTE 2 – This type of cable is always with plastic-insulated conductors.		

Appendix II

Shield resistance for cables with metallic symmetric conductors

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

Table II.1 – Shield resistance in Ω/km for lead sheath

Conductor diameter (mm) **Number of pairs**	**0.40**	**0.50**	**0.65**	**0.90**
10	6.2	5.4	4.8	3.4
20	5.0	4.2	3.4	2.4
30	4.4	3.4	2.8	2.0
50	3.4	2.7	2.2	1.5
75	2.8	2.3	1.8	1.2
100	2.4	2.0	1.5	1.0
200	1.7	1.4	1.0	0.65
300	1.3	1.1	0.79	0.49
400	1.1	0.91	0.66	0.40
600	0.87	0.70	0.49	–
900	0.66	0.54	0.38	–
1200	0.54	0.43	–	–
1500	0.46	–	–	–
1800	0.40	–	–	–
2400	0.33	–	–	–
NOTE – Values valid for sheath thickness T = 2 mm. For other thickness T'(mm), multiply the value of the table by 2/T'.				

Table II.2 – Shield resistance in Ω/km for aluminium sheath

Conductor diameter (mm) / Number of pairs	0.40	0.51	0.64	0.91
10	5.2	4.9	4.2	3.1
20	4.0	3.6	3.1	2.3
30	3.5	3.1	2.6	1.9
50	2.9	2.6	2.1	1.6
75	2.4	2.2	1.8	1.3
100	2.0	1.9	1.6	1.1
200	1.5	1.4	1.1	0.80
300	1.2	1.1	0.92	0.64
400	1.1	1.0	0.80	0.56
600	0.89	0.80	0.64	–
NOTE – Values valid for sheath thickness T = 0.2 mm. For other thickness T'(mm), multiply the value of the table by 0.2/T'.				

Appendix III

Risk assessment related to a structure: Information related to the telecommunication line

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

The risk assessment applied to a structure shall be carried out applying [IEC 62305-2], which requires the evaluation of the risk as a sum of the risk components.

The risk components related to a telecommunication line are the following:

R_U: Risk of injury to persons inside the structure due to direct flashes to the service;

R_V: Risk of physical damage inside the structure due to direct flashes to the service;

R_W: Risk of damage to equipment inside the structure due to direct flashes to the service;

R_Z: Risk of damage to equipment inside the structure due to flashes near the service.

The objective of this appendix is the calculation of the *equivalent length* of the line section of the telecommunication line entering the structure for which the frequency of damage to equipment inside the structure F_Z is equal to that calculated for the full telecommunication line.

F_Z is calculated with the following equation for node X (i.e., E or S):

$$F_{ZX} = C \times l_{cX} \quad \text{(III.1)}$$

$$C = 2.4 \times (U_r)^{-1.8} \times 10^3 \quad \text{(III.2)}$$

where U_r is the equipment resistibility (V).

The length of the unshielded (l_u) or shielded (l_s) equivalent line is given by the following equations:

$$l_u = \sum (L(j) \times \eta_e(j) \times K_i(j)) \quad \text{(III.3)}$$

$$l_s = \frac{\sum (L_i \times \eta_s(j) \times K_i(j))}{\eta_s(E/S)} \quad \text{(III.4)}$$

where

L(j)	is the length of the line section j;
K_i(j)	is the installation factor of the line section j;
η_e(j)	is the shielding factor related to earth of the line section j;
η_s(j)	is the shielding factor related to the shield of the line section j;
η_s(E/S)	is the shielding factor related to the shield of the equivalent shielded line at node E or S.

This *l* value could be given to the owner of the structure, together with the resistance per unit length of the shield (if any), the number (m) and the resistance per unit length of the conductors, instead of the information of each section composing the telecommunication line entering the customer's premises.

Application of this appendix is shown in the examples reported in Appendix IV.

Appendix IV

Examples of application

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

IV.1 Telecommunication line with shielded and unshielded sections in suburban environment

Consider a subscriber line located in an old suburb, where the land is occupied by houses. The environmental factor according to clause 6.1 is 0.5 ($C_e = 0.5$). The keraunic level of the region is 60 thunderstorm days per year ($T_d = 60$) and the average earth resistivity is 500 Ωm. Therefore, the exposure factor is $K_x = 0.67$ (see equation 1). It shall be observed that this value of K_x has to be evaluated only once and applies to every line constructed in this region. The line fits into the configuration E/PC/D/S (see Figure 1). The characteristics of the sections are tabulated in Table IV.1.

Table IV.1 – Characteristics of the line

Section	Insulation	Sheath material	Sheath thickness	Number of pairs	Conductor diameter	Length	Installation
E/PC	Paper	Lead	2 mm	1200	0.40	3200 m	Buried
PC/D	Plastic	Aluminium	0.2 mm	100	0.40	500 m	Aerial
D/S	Plastic	No sheath	–	1	0.80	140 m	Aerial

The installation factor (K_i) is 0.5 for the buried section and 1.0 for the aerial sections (see clause 6.2). The sheath resistance per unit length (r) can be obtained from Appendix II based on the sheath material, thickness, conductor diameter and number of pairs. For the sections E/PC and PC/D, Appendix II gives $r = 0.54$ Ω/km and $r = 2.0$ Ω/km, respectively. The buried cable is protected by armouring (2 iron tapes: thickness 0.8 mm) with $r_a = 0.37$ Ω/km ($\rho_{fe} = 130$ Ω mm^2/km). The equivalent resistance of this buried cable is $r_e = 0.22$ Ω/km. These values can be used in equations 3 and 4 to calculate the shielding factors related to the shield (η_s), which are shown in Table IV.2. It shall be observed that for the unshielded section $\eta_s = \eta_e = 1$, by definition.

Let us suppose that the earth resistance at the ends of the shield is 5 Ω at node E and 200 Ω at node D. Therefore, the shielding factor related to the shield (η_s) and to earth (η_e) can be calculated as shown in clause 6.3. Using equation 7, it is possible to obtain the conventional lengths of the sections, which are shown in Table IV.2.

Table IV.2 – Conventional lengths

Section	Length (L)	Exposure factor (K_x)	Shielding factor (η)		Installation factor (K_i)	Conventional length (L_c)	
			Related to shield (η_s)	Related to earth (η_e)		Shielded nodes	Unshielded nodes
E/PC	3200 m	0.67	0.01	0.67	0.5	11 m	718 m
PC/D	500 m	0.67	0.01	0.33	1.0	3 m	110 m
D/S	140 m	0.67	1.0	1.0	1.0	94 m	94 m
Total	3840 m	0.67	–	–	–	108 m	922 m

The next step is to assess the node's limits and conventional lengths. The node's limits, obtained from equation 9 and Table 2, with $R_T = 10^{-3}$ and $R_d = 0.558 \times 10^{-3}$ (see Clause III.1 of [ITU-T K.47]), are shown in Table IV.3, as well as the conventional lengths of the nodes.

Table IV.3 – Protection schemes

Node	Conventional length limit	Conventional length	Need for protection	Conventional length with SPD at a node			
				Node E	Node PC	Node D	Node S
E	96 m	**108 m**	Yes	0 m	11 m	14 m	**108 m**
PC	96 m	**108 m**	Yes	**108 m**	0 m	14 m	**108 m**
D	835 m	108 m	No	108 m	94 m	0 m	108 m
S	6061 m	922 m	No	922 m	922 m	922 m	0 m

In Table IV.3, the nodes needing protection can be seen. However, not every node needing protection will require the installation of an SPD. In general, the first step to obtain a protection scheme is to install the SPD at the unshielded nodes requiring protection and at node D. In this case, the unshielded node S does not require protection. Therefore, the installation of an SPD at node S is not useful because it does not affect the conventional length of the other nodes.

If an SPD is installed at node D, it will reduce the conventional length of nodes E and PC by removing the contribution of the unshielded section. Using Table IV.2, it can be seen that the conventional length of nodes E and PC will be reduced to 14 m, which are lower than the limit values for these nodes. The conventional length of node D is reduced to zero and the conventional length of node S is unchanged.

The resulting values after the installation of SPDs are shown in Table IV.3 for the four possibilities (Nodes E, PC, D and S). The bold values are those which are above the limits. Thus, the two effective schemes for the installation of SPDs are at nodes PC or D. The decision about which scheme to use will depend on an economic analysis.

NOTE 1 – The conventional length limit value for basic resistibility level of the equipment inside the exchange's building (i.e., U_r = 1 kV), evaluated with equations 9 and 10, is equal to 46 m. Therefore, this type of equipment is protected against overvoltages coming from the telecommunication network by the installation of SPDs in the transition point PC or D. However, protection by SPDs on the telecommunication conductors at the entrance of the exchange building could be required or suggested by the risk assessment applied to the structure in accordance with [IEC 62305-2].

Assuming that the equipment resistibility inside the customer's building complies with the basic requirement given in [b-ITU-T K.21] (i.e., U_r = 1.5 kV), the frequency of damage $F_Z = C \times L_c(S) = 4.24$ ($C = 4.6 \times 10^{-3}$ and $L_c(S)$ = 922 m). The length of an aerial unshielded line entering the customer's building causing the same frequency of damage of the considered line is calculated with equation III.3: L_e = 1376 m. The information reported in Table IV.4, instead of that given in Table IV.1, could be given to a customer who has to perform the risk assessment related to his structure.

Table IV.4 – Characteristics of the equivalent aerial line entering the customer's building

Number of pairs	$R_{c(Cu)}$ [Ω/km]	Insulation	Shielded cable	Shield resistance [Ω/km]	*L* [m]
1	35.6	Plastic	No	0	1400

NOTE 2 – The conventional length limit value for the basic resistibility level of the equipment inside the customer's building, evaluated with equations 9 and 10, is equal to 96 m. Therefore, SPDs on the telecommunication conductors at the entrance of the customer's premises shall be installed if damage to customer's equipment would be reduced. In this case, GDTs complying with [ITU-T K.12] shall be recommended. If the network operator or the owner of the telecommunication network install these SPDs, the information on the GDT characteristics (i.e., U_p, I_n and I_{imp}) should be given to the customer (e.g., U_p = 0.7 kV, I_n = 2.5 kA 8/20 and I_{imp} = 0.5 kA 10/350).

IV.2 Telecommunication line with only shielded sections in suburban environment

Consider a subscriber line located in a new suburb, where about half of the land is occupied by houses. Based on clause 6.1, the environmental factor is 0.75 ($C_e = 0.75$). The keraunic level of the region is 50 thunderstorm days per year ($T_d = 50$) and the average earth resistivity is 400 Ωm. Therefore, the exposure factor is $K_x = 0.75$ (see equation 1). The line fits into the configuration R/V/S (see clause 4). The characteristics of the sections are tabulated in Table IV.5.

Table IV.5 – Characteristics of the line

Section	Insulation	Sheath material	Sheath thickness	Number of pairs	Conductor diameter	Length	Installation
R/V	Plastic	Aluminium	0.2 mm	100	0.40	2000 m	Aerial
V/S	Plastic	Aluminium	0.2 mm	10	0.40	250 m	Aerial

The installation factor (K_i) is 1.0 for the aerial sections (see clause 6.2). The sheath resistance per unit length (r) can be obtained from Appendix II, based on the sheath material, thickness, conductor diameter and number of pairs. For sections R/V and V/S, Appendix II gives $r = 2.0$ Ω/km and 5.2 Ω/km respectively. The resistance of the earthing systems are not relevant as there is no unshielded node. These values can be used in equations 3 and 4 to calculate the shielding factors related to the shield (η_s). Using equation 7, it is possible to obtain the conventional lengths of the sections, which are shown in Table IV.6.

Table IV.6 – Conventional lengths

Section	Length (L)	Exposure factor (K_x)	Shielding factor related to shield (η_s)	Installation factor (K_i)	Conventional length (L_c)
R/V	2000 m	0.75	0.013	1.0	20 m
V/S	250 m	0.75	0.013	1.0	3 m
Total	2250 m	0.75	–	–	23 m

The next step is to assess the node's limits and conventional lengths. The node's limits, obtained from equation 9 and Table 2 with $R_T = 10^{-3}$ and $R_d = 0.4 \times 10^{-3}$ (see Clause III.2 of [ITU-T K.47]), are shown in Table IV.7, as well as the conventional lengths of the nodes.

Table IV.7 – Protection schemes

Node	Conventional length limit	Conventional length	Need for protection	Installation of SPD
R	1125 m	23 m	No	No
V	–	–	–	–
S	1125 m	23 m	No	No

NOTE 1 – The assessment of the protection need shall not be performed for node V (see clause 4).

In Table IV.7, it can be seen that there is no need for protection. Therefore, no SPD is needed at this line in order to protect it against lightning-induced surges.

NOTE 2 – The conventional length limit value for the basic resistibility level of the equipment inside the remote site, evaluated with equations 9 and 10, is equal to 62 m. Therefore, this type of equipment does not require protection against the overvoltages coming from the telecommunication network. However, protection by SPDs on the telecommunication conductors could be required or suggested by the risk assessment applied to the remote site in accordance with [IEC 62305-2].

Assuming that the equipment resistibility inside the customer's building complies with the basic requirement given in [b-ITU-T K.21] (i.e., U_r = 1.5 kV), the frequency of damage $F_Z = C \times L_c(S) = 0.1$ ($C = 4.6 \times 10^{-3}$ and Lc(S) = 23 m). The length of an aerial shielded line entering the customer's building causing the same frequency of damage of the considered line is calculated with equation III.4: $\eta_s(S) = 0.0195$ and $l_s = 1530$ m. The information reported in Table IV.8, instead of that shown in Table IV.5, could be given to a customer who has to perform the risk assessment related to his structure.

Table IV.8 – Characteristics of the equivalent aerial line entering the customer's building

Number of pairs	$R_{c(Cu)}$ [Ω/km]	Insulation	Shielded cable	Shield resistance [Ω/km]	*L* [m]
10	141	Plastic	Yes	5.2	1550

NOTE 3 – The conventional length limit value for basic the resistibility level of the equipment inside the customer's building, evaluated with equations 9 and 10, is equal to 130 m. Therefore, this type of equipment does not require protection against the overvoltages coming from the telecommunication network. However, protection by SPDs on the telecommunication conductors could be required or suggested by the risk assessment applied to the structure and performed by the customer in accordance with [IEC 62305-2].

IV.3 Telecommunication line with shielded and unshielded sections in rural environment

Consider a subscriber line located in a rural area. The environmental factor is 1.0 ($C_e = 1.0$). The keraunic level of the region is 50 thunderstorm days per year ($T_d = 50$) and the average earth resistivity is 600 Ωm. Therefore, the exposure factor is $K_x = 1.2$ (see equation 1). The line fits into the configuration E/P/CD/S (see Figure 1). The characteristics of the sections are tabulated in Table IV.9.

Table IV.9 – Characteristics of the line

Section	Insulation	Sheath material	Sheath thickness	Number of pairs	Conductor diameter	Length	Installation
E/P	Paper	Lead	2 mm	400	0.40	1500 m	Buried
P/CD	Plastic	Aluminium	0.2 mm	50	0.40	2400 m	Buried
CD/S	Plastic	No sheath	–	2	0.80	400 m	Aerial

The installation factor (K_i) is 0.5 for the buried sections and 1.0 for the aerial section (see clause 6.2). The sheath resistance per unit length (r) can be obtained from Appendix II, based on the sheath material, thickness, conductor diameter and number of pairs. For sections E/P and P/CD, Appendix II gives $r = 1.1$ Ω/km and $r = 2.9$ Ω/km, respectively. The buried cable is protected with armouring (2 iron tapes: thickness 0.5 mm) with $r_a = 1.7$ Ω/km (ρ_{fe} = 130 $\Omega mm^2/km$). The equivalent resistances of these buried cables are $r_e = 0.67$ Ω/km and $r_e = 1.1$ Ω/km, respectively. These values can be used in equations 3 and 4 to calculate the shielding factors related to the shield

(η_s), which are shown in Table IV.10. Using equation 7, it is possible to obtain the conventional lengths of the sections, which are shown in Table IV.10.

Let us suppose that the operator controls the earth resistance of the shield at the outside plant (node CD) to a value below 30 Ω. Neglecting the resistance at node E, the shielding factor related to the shield (η_s) and to earth (η_e) can be obtained as shown in clause 6.3. The resultant conventional length related to earth is shown in Table IV.10.

Table IV.10 – Conventional lengths

Section	Length (L)	Exposure factor (K_x)	Shielding factor (η)		Installation factor (K_i)	Conventional length (L_c)	
			Related to shield (η_s)	Related to earth (η_e)		Shielded nodes	Unshielded nodes
E/P	1500 m	1.2	0.036	0.23	0.5	32 m	207 m
P/CD	2400 m	1.2	0.036	0.23	0.5	52 m	331 m
CD/S	400 m	1.2	1.0	1.0	1.0	480 m	480 m
Total	4300 m	1.2	–	–	–	564 m	1018 m

The next step is to assess the node's limits and conventional lengths. The node's limits, obtained from equation 9 and Table 2 with $R_T = 10^{-3}$ and $R_d = 0.6436 \times 10^{-3}$ (see Clause III.3 of [ITU-T K.47]), are shown in Table IV.11, as well as the conventional lengths of the nodes.

Table IV.11 – Protection schemes

Node	Conventional length limit	Conventional length	Need for protection	Conventional length with SPD at a node			
				Node E	Node P	Node CD	Node S
E	77 m	**564 m**	Yes	0 m	32 m	**84 m**	**564 m**
P	77 m	**564 m**	Yes	**564 m**	0 m	**84 m**	**564 m**
CD	672 m	564 m	No	564 m	532 m	0 m	564 m
S	4883 m	1018 m	No	1018 m	1018 m	1018 m	0 m

In Table IV.11, the nodes that need protection can be seen. The first step to obtain a protection scheme is to install an SPD at node P. The installation of an SPD at node P reduces the conventional length of node E. Using Table IV.10, it can be seen that the conventional length of node E will be reduced to 32 m, which is lower than the limit value (77) for node E. Another possibility is to install an SPD at node CD; in this case, it can be seen that the conventional length of both nodes E and P will be reduced to 84 m, which is still above the limit. The resulting values after the installation of SPDs are shown in Table IV.11 for the four possibilities (nodes E, P, CD and S). The bold values are those which are above the limits. Thus, the only effective scheme for the installation of an SPD is at the node P.

NOTE 1 – The conventional length limit value for the basic resistibility level of the equipment inside the exchange's structure, evaluated with equations 9 and 10, is equal to 37 m. Therefore, this type of equipment is protected against the overvoltages coming from the telecommunication network by the installation of SPDs at node P ($L_c(E)$ = 32 m). In this case, however, protection by SPDs on the telecommunication conductors at the entrance of the exchange building could be required or suggested by the risk assessment applied to structure in accordance with [IEC 62305-2].

Assuming that the equipment resistibility inside the customer's building complies with the basic requirement given in [b-ITU-T K.21] (i.e., U_r = 1.5 kV), the frequency of damage $F_Z = C \times L_c(S)$ = 4.7 ($C = 4.6 \times 10^{-3}$ and $L_c(S)$ = 1018 m). The length of an aerial unshielded line entering the customer's building causing the same frequency of damage to the considered line is calculated with equation III.3: L_u = 850 m. The information reported in Table IV.12, instead of that given in Table IV.9, could be given to a customer who has to perform the risk assessment related to his structure in accordance with [IEC 62305-2].

Table IV.12 – Characteristics of the section line entering the customer's building

Number of pairs	$R_{c(Cu)}$ [Ω/km]	Insulation	Shielded cable	Shield resistance [Ω/km]	*l* [m]
2	35.6	Plastic	No	0	850

NOTE 2 – The conventional length limit value for the basic resistibility level of the equipment inside the customer's building, evaluated with equations 9 and 10, is equal to 77 m. Therefore, SPDs on the telecommunication conductors at the entrance of the customer's premises shall be installed if damage to a customer's equipment would be reduced. In this case, GDTs complying with [ITU-T K.12] shall be recommended. If the network operator or the owner of the telecommunication network install these SPDs, the information on the GDT characteristics (i.e., U_p, I_n and I_{imp}) should be given to the customer (e.g., U_p = 0.7 kV, I_n = 2.5 kA 8/20 and I_{imp} = 0.5 kA 10/350).

Bibliography

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