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

Recommendation ITU-T K.46



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Recommendation ITU-T K.46

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

Summary

Recommendation ITU-T K.46 gives a procedure to protect telecommunication lines using metallic symmetric conductors (i.e., twisted pair cables) against overvoltages and overcurrents imposed on the lines due to nearby lightning flashes.

The procedure is based on the representation of the line by a sequence of sections and nodes, and the evaluation of each node exposure to the lightning-induced surges. Based on the node exposure, the ground flash density and the earth resistivity, the annual number of surges above a given voltage level is calculated. If the voltage level considered is the impulse withstand voltage of the node, then the number of surges above this level corresponds to the annual number of damages to the node. This number shall be multiplied by the loss due to induced surges in order to obtain the risk of failure due to indirect lightning flashes. The highest risk of all nodes is the risk of the line.

The risk of failure due to indirect lightning flashes (R'_Z) can be used in the risk assessment of a larger system to which the telecommunication line is a part, according to IEC 62305-2. The calculated risk can also be used by the line owner (e.g., telecommunication operator) in order to evaluate the need of implementing additional protection measures on the line. In this case, the calculated risk (R'_Z) shall be compared with the tolerable risk due to indirect flashes (R_{Ti}), the latter calculated based on ITU-T K.72. If the calculated risk is lower than the tolerable limit, the line is adequately protected. Otherwise, it is necessary to implement additional protection measures until the risk of damage is lower than or equal to the tolerable limit.

The appendices are organized as follows: Appendix I provides data on the electrical characteristics of cable shields, Appendix II presents an algorithm to guide the elaboration of software based on this Recommendation, Appendix III presents the calculation of the collection area for flashes near the line and Appendix IV shows some examples of calculation.

History

Edition	Recommendation	Approval	Study Group
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2.0	ITU-T K.46	2003-07-29	5
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Earthing resistance, lightning-induced surges, lightning protection, refraction factor, risk assessment, shielding factor, surge protective device, telecommunication lines.

FOREWORD

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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.

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

NOTE

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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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Recommendation ITU-T K.46

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 (i.e., twisted pair cables) against overvoltages and overcurrents imposed on the lines due to nearby lightning flashes.

Its calculation procedure allows the assessment of the expected annual number of damages (N_Z) and the risk of damage due to indirect lightning flashes (R'_Z). The risk of damage due to indirect lightning flashes can be used in the risk assessment of a larger system to which the telecommunication line is a part, according to [IEC 62305-2]. The calculated risk can also be used by the line owner (e.g., telecommunication operator) in order to evaluate the need of implementing additional protection measures on the line. In this case, the calculated risk (R'_Z) shall be compared with the tolerable risk due to indirect flashes (R_{Ti}), the latter calculated based on [ITU-T K.72]. If the calculated risk is lower than the tolerable limit, the line is adequately protected. Otherwise, it is necessary to implement additional protection measures until the risk of damage is lower than or equal to the tolerable limit.

Depending on the user's desire, the resistibility of the external port of network terminal equipment (e.g., exchange line card, modem, POTS telephone set, etc.) may or may not be included in the calculation. This decision implies the selection of the appropriate impulse withstand voltage (U_W) of the relevant line node and the result shall be limited to the damage caused to the external port of the equipment. However, the protection of other equipment ports (e.g., power port) and of equipment that does not have a direct interface with the line is outside the scope of this Recommendation and should be evaluated using the risk assessment applied to the exchange or to the customer's structure.

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 should be evaluated using the risk assessment applied to the exchange or to 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 (2010), *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 (2012), *Parameters of thyristor-based surge protective devices for the protection of telecommunication installations*.
- [ITU-T K.47] Recommendation ITU-T K.47 (2012), *Protection of telecommunication lines against direct lightning flashes*.

- [ITU-T K.66] Recommendation ITU-T K.66 (2011), *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 (2011), *Protection of telecommunication lines using metallic conductors against lightning – Risk management*.
- [IEC 62305-2] IEC 62305-2 (2010), *Protection against lightning – Part 2: Risk management*.
http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/45856?OpenDocument

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

- 3.2.1 conversion factor:** Ratio between the line-to-shield voltage and the line-to-earth voltage arriving at the transition from an unshielded section to a shielded section.
- 3.2.2 downstream direction:** Direction from the first node to the last node of the line.
- 3.2.3 impulse withstand voltage (U_w):** Peak value of the maximum common-mode impulsive voltage (10/700 μ s waveform) that can be applied to an external equipment port or cable insulation without causing damage.
- 3.2.4 lightning flash near a line:** Lightning flash striking close enough to a line so that it may induce dangerous overvoltages on the line.
- 3.2.5 loss (L):** Annual mean amount of loss (humans and goods) consequent to a specified type of damage due to a dangerous event, relative to the total value (humans and goods) of the object to be protected.
- 3.2.6 loss due to lightning-induced surges (L_i):** Annual mean amount of loss (to the public and economic value) consequent to damage in a telecommunication line due to lightning-induced surges, relative to the total value of the service (according to [IEC62305-2], $L_i = L_o$).
- 3.2.7 metallic symmetric conductors:** Transmission media consisting of a pair of twisted wires balanced with respect to earth, usually assembled in groups in order to form a telecommunication cable.
- 3.2.8 node:** Point between two sections of a telecommunication line.
- 3.2.9 node exposure:** Value assigned to a line node (in km) that represents the exposure of this node to the effects of the lightning-induced voltages.
- 3.2.10 number of damages (N_Z):** Expected annual number of damages in the telecommunication line due to lightning-induced surges.
- 3.2.11 protection factor of SPD (P_{SPD}):** Factor taking into account the effect of surge protective device (SPD) installation at a given node.
- 3.2.12 protection measures:** Measures to be adopted in a telecommunication line to reduce its risk of damage.
- 3.2.13 refraction factor:** Ratio between the common-mode surge voltage travelling in the line after passing through a discontinuity in its surge impedance and the surge that would travel in the line if there were no discontinuity in its surge impedance.

3.2.14 risk (R): Value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the object to be protected.

3.2.15 risk of damage from indirect flashes (R'_Z): Risk component related to failure of lines and connected equipment caused by surges induced on the line by indirect lightning flashes.

3.2.16 rural environment: Area with a low density of buildings. "Countryside" is an example of rural environment.

3.2.17 section of a telecommunication line: Part of a telecommunication line with homogeneous characteristics where only one set of parameters is involved in the assessment of a risk component.

3.2.18 shielded node: Reference point of the telecommunication line where at least one cable is shielded. A node at the transition between a shielded and an unshielded cable is shielded.

3.2.19 shielded section: Section of the line where the cable is made of one or more pairs of twisted wires balanced with respect to earth, assembled together and covered by a metallic sheath.

3.2.20 shielding factor: Ratio between the voltage at a point of the line when the shield is present and the voltage at the same point when the shield is absent.

3.2.21 suburban environment: Area with a medium density of buildings. "Town outskirts" is an example of suburban environment.

3.2.22 surge: Temporary excessive voltage or current, or both, coupled on a telecommunication line from an external electrical source.

3.2.23 surge impedance (Z): Impedance presented by a line section to the surge propagation. It is generally given by the square root of the ratio between line-to-earth inductance and line-to-earth capacitance.

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

3.2.25 telecommunication line: Transmission medium intended for communication between equipment that may be located in separate structures, such as a phone line and a data line.

3.2.26 tolerable risk (R_T): Maximum value of the risk which can be tolerated for the object to be protected.

3.2.27 tolerable risk due to indirect flashes (R_{Ti}): Maximum value of risk that can be tolerated for the line due to lightning surges.

3.2.28 transition node (q): Node that corresponds to the transition between shielded and unshielded line sections.

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

3.2.30 unshielded section: Section of the line where the cable is made of one or more pairs of twisted wires balanced with respect to earth and assembled together without a metallic sheath.

3.2.31 upstream direction: Direction from the last node to the first node of the line.

3.2.32 urban environment: Area with a high density of buildings or densely populated communities with high buildings. "Town centre" is an example of urban environment.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BB	Bonding Bar
CCP-AP	Colour Coded Polyethylene Aluminium laminated Polyethylene (sheath)
MDF	Main Distribution Frame
SPD	Surge Protective Device

5 Reference configuration

Figure 1 shows the reference configuration for a telecommunication line with metallic symmetric conductors, composed of m sections and $m + 1$ nodes. A generic section or node along the line is designated by the symbol i . The direction from node 1 to node $m + 1$ is designated as "downstream direction", while the direction from node $m + 1$ to node 1 is designated as "upstream direction", as shown in Figure 1.

Usually, the telecommunication line starts at the exchange (node 1) and ends at the subscriber premises (node $m + 1$), but the following situations are possible:

- If equipment installed in the line is protected by SPDs installed between line conductors (at both input and output ports) and the equipment earth connection, then this equipment shall be treated as an ending point for the line that comes from the exchange 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.
- If equipment installed in the line has no earth connection and its protection is given by the insulation to earth and by SPDs installed at both input and output ports against a common reference, then the presence of this equipment can be neglected, but the presence of SPDs shall be considered.
- If telecommunication or signal lines are connecting equipment located in different buildings within the subscriber's premises (e.g., signal lines between computers), then this telecommunication line starts and ends within the subscriber premises.

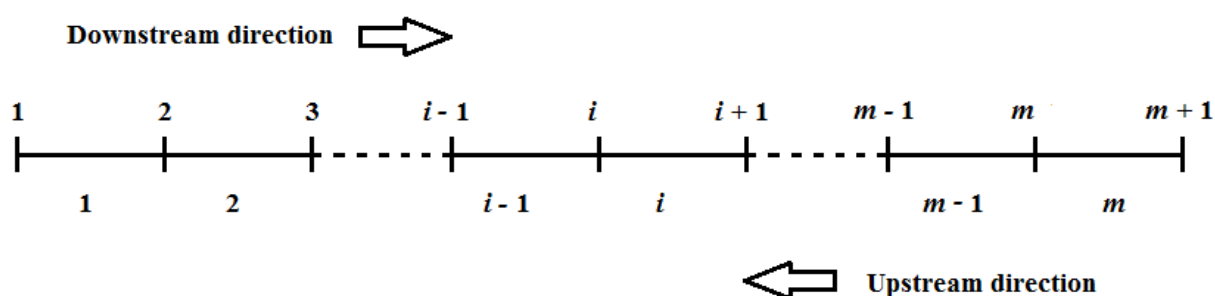


Figure 1 – Reference configuration of a line composed of m sections and $m + 1$ nodes

If there are shielded sections, the first section (section 1) must be shielded and all other shielded sections must be adjacent to each other, so that the shield is kept continuous. An unshielded section between two shielded sections is not allowed by the procedure of this Recommendation. The node containing a transition between shielded and unshielded sections is a shielded node and it is designated by the symbol q (e.g., node q), as shown in Figure 2.

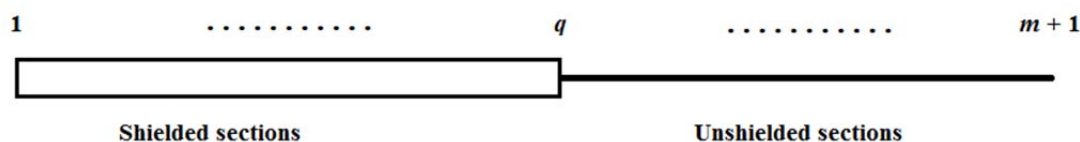


Figure 2 – Sequence of shielded and unshielded sections, with transition node q

The last node (node $m + 1$) usually represents the subscriber premises and the first node (node 1) may represent:

- exchange building, where the main switching equipment is located;
- access network equipment, usually installed in the outside plant (remote electronic site);
- equipment within the subscriber premises.

The intermediate nodes shall be created in the presence of the following conditions:

- transition between paper-insulated and plastic-insulated cables;
- transition between buried and aerial cables;
- transition between shielded and unshielded cables;
- transition between types of cable (e.g., number of pairs);
- earthing system connected to the line;
- surge protective devices connected to the line;
- whenever the user wants it.

NOTE – The term "node" in [IEC 62305-2] has a different meaning.

Sometimes two or more transitions may occur at the same node, such as the transition in the line from paper to plastic insulation and from buried to aerial installation.

This Recommendation uses the concept of surge propagation along the line, which requires that a minimum distance of 200 m shall be observed between consecutive nodes (i.e., the minimum section length is 200 m). If two transitions occur at shorter distances, they have to be considered at the same node. For instance, if two earthing systems are very close (e.g., 50 m apart), they shall be considered as a single earthing with a resistance given by the parallel association.

6 General requirements

6.1 Impulse withstand voltage levels

For the purpose of this Recommendation, the following impulse withstand voltage levels (U_w) shall be considered, when tested with 10/700 μ s waveform.

- Shielded cables with paper insulation: The insulation between any conductor and shield shall withstand an overvoltage of 1.5 kV peak.
- Shielded cables with plastic insulation: The insulation between any conductor and shield shall withstand an overvoltage of 5.0 kV peak.
- Unshielded cables with plastic insulation: The insulation between any conductor and earth shall withstand an overvoltage of 15.0 kV peak.

NOTE – The U_w level of equipment connected to the line (external port) is given by the resistibility level provided by the relevant ITU-T Recommendation.

6.2 Surge protective devices (SPDs)

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.

The minimum DC breakdown voltage of the SPD shall be greater than the maximum line voltage expected. It shall be observed that, in some equipment, ringing voltage may add to 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.

The maximum impulse breakdown voltage of the SPD shall be lower than the impulse withstand voltage (U_W) of the unit to be protected. A significant safety margin is recommended.

The line terminals of an SPD shall be connected to the conductors of the telecommunication line and their earth terminals shall be connected to the earthing bonding bar of an unshielded node or to the cable shield of a shielded node. Figure 3 shows the connections of SPDs at a shielded node (Figure 3a) and at an unshielded node (Figure 3b). 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.

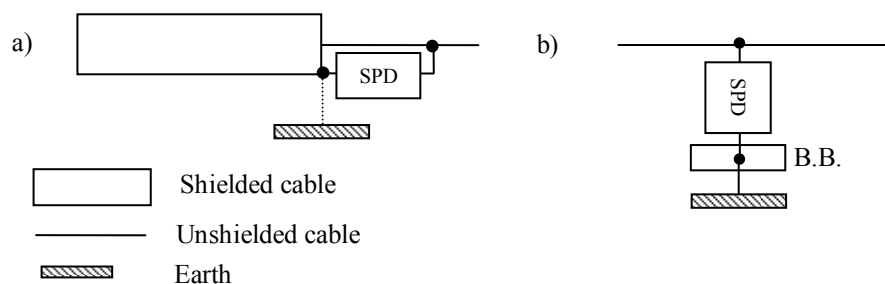


Figure 3 – Installation of surge protective devices (SPDs)

6.3 Earthing and bonding

6.3.1 Exchange

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.