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Protection of telecommunication lines against direct lightning flashes

Recommendation ITU-T K.47



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Recommendation ITU-T K.47

Protection of telecommunication lines against direct lightning flashes

Summary

Recommendation ITU-T K.47 gives a procedure in order to protect telecommunication lines using metallic components (symmetric pair, coaxial or optical fibre cables) against direct lightning flashes to the line itself or to structures that the line enters.

The procedure is based on the representation of the line by a sequence of sections and the evaluation of the annual number of damages due to direct flashes for each section and for the structures connected to the line. This number shall be multiplied by the relevant loss in order to obtain the risk of failure due to direct lightning flashes. The sum of the risk of each line section and also the risk associated with the structures connected to the line gives the total risk of the line.

The risk of damage due to direct 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_d) shall be compared with the tolerable risk due to direct flashes (R_{Td}), the latter calculated based on Recommendation 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.

Several parts of this Recommendation make reference to the cable sheath breakdown current (I_s) and test current (I_t), so that the assessment of these parameters are given in Annex A and Annex B, respectively. The appendices are organized as follows: Appendix I provides some guidance for the evaluation of the expected loss per damage (L), and Appendix II presents a rationale for the protective effect of guard-wires.

History

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Direct flashes, direct lightning performance, guard-wire, lightning protection, risk assessment, sand-box test, sheath breakdown current.

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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Recommendation ITU-T K.47

Protection of telecommunication lines against direct lightning flashes

1 Scope

This Recommendation gives a procedure to protect telecommunication lines using metallic components against direct lightning flashes to the line itself or to the structures that the line enters. Lines made by the following types of cables are covered by this Recommendation.

- Symmetric cable: Cable with a core made of one or many metallic symmetric pairs, which may have a metallic sheath, and/or a plastic covering, and/or a supporting wire.
- Coaxial cable: Cable with metallic inner and outer conductors separated by a dielectric, which may have a plastic covering and/or a supporting wire.
- Optical fibre cable: Cable with optical fibres, which may also have metallic components such as an inner strength member and/or an outer metallic sheath.

Its calculation procedure allows the assessment of the expected annual number of damages (N_d) and the risk of damage due to direct lightning flashes (R_d). The risk of damage due to direct 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_d) shall be compared with the tolerable risk due to direct flashes (R_{Td}), 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 protection against direct flashes for equipment connected to the line 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, customer's building or remote site).

The protection of persons using telecommunication equipment inside a structure from dangerous situations caused by direct flashes (e.g., touch voltages) is outside the scope of this Recommendation and should be evaluated using the risk assessment applied to the relevant 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.46] Recommendation ITU-T K.46 (2012), *Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges*.
- [ITU-T K.72] Recommendation ITU-T K.72 (2011), *Protection of telecommunication lines using metallic conductors against lightning – Risk management*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 shielded cable [ITU-T K.46]: Group of one or more pairs of twisted wires balanced with respect to earth, assembled together and covered by a continuous metallic sheath.

3.1.2 unshielded cable [ITU-T K.46]: Group of one or more pairs of twisted wires balanced with respect to earth and assembled together without a metallic sheath.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 breakdown voltage (U_b): Impulse breakdown voltage between metallic components in the core and the metallic sheath of a telecommunication cable.

3.2.2 failure current (I_a): Minimum peak value of the lightning return stroke current that causes damage in a telecommunication line.

3.2.3 ground flash density (N_g): Average number of lightning flashes to earth per square kilometre per year.

3.2.4 guard-wire: Metallic wire buried above a cable in order to reduce physical damage due to direct lightning flashes to the cable.

3.2.5 lightning protective cable: Special cable with increased dielectric strength, whose metallic sheath is in continuous contact with the soil either directly or by the use of conducting plastic covering.

3.2.6 lightning protective cable duct: Cable duct of low resistivity in contact with the soil (for example, concrete with interconnected structural steel reinforcements or a metallic duct).

3.2.7 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.

3.2.8 loss due to direct lightning flashes to the line (L_d): Annual mean amount of loss (service to the public and economic value) consequent of damage in a telecommunication line due to direct lightning flashes to the line, relative to the total value of the service.

3.2.9 loss due to direct lightning flashes to the structure (L_s): Annual mean amount of loss (service to the public and economic value) consequent of damage in a telecommunication line due to direct lightning flashes to a structure connected to the line, relative to the total value of the service.

3.2.10 number of damages due to flashes to the line (N_d): Expected annual number of damages in the telecommunication line due to direct lightning flashes to the line.

3.2.11 number of damages due to flashes to the structure (N_s): Expected annual number of damages in the telecommunication line due to lightning flashes to a structure connected to the line.

3.2.12 protection factor (K_p): Factor that quantifies the capacity of a line to receive a direct flash without suffering damage. It usually takes into account the effect of protective measures.

3.2.13 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.

3.2.14 risk of damage from direct flashes (R_d): Risk component related to failure of lines and connected equipment caused by direct lightning flashes to the line or to the structure connected to the line.

3.2.15 sheath breakdown current (I_s): Minimum current flowing in the metallic sheath which causes breakdown voltages between metallic elements in the cable core and the metallic sheath, thus leading to damage.

3.2.16 striking distance (D): Distance from the line that, when multiplied by 2 – by the line length (L) and the ground flash density (N_g) – gives the number of direct flashes per year that hit the line.

3.2.17 test current (I_t): Minimum current injected by arc in the cable sheath that causes a damage due to thermal or mechanical effects.

3.2.18 tolerable risk of damages (R_T): Maximum value of risk of damages not requiring additional protective measures.

3.2.19 tolerable risk due to direct flashes (RT_d): Maximum value of risk that can be tolerated for the line due to direct lightning flashes to the line or to a structure connected to the line.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

GDT Gas Discharge Tube

OGW Overhead Ground Wire

SPD Surge Protective Device

5 Reference configuration

In order to evaluate the risk of line damage (R_d), the line may have to be segmented in such a way that each section has the same characteristics regarding the type of cable installation (aerial or buried), ground-flash density, average soil resistivity, type of cable, and environment (urban, suburban or rural).

It is also important to identify the structures that the line or its branches enter. The value of R_d has to be evaluated for each section, and the value for the line is the sum of section values, including the values corresponding to discharges to the structures that the line enters. Figure 1 shows an example of a line with different types of cable installation. The risk of damage shall be evaluated for all transmission media of a cable (twisted pair or coaxial), regardless of whether they are being used for a service or kept as spare.

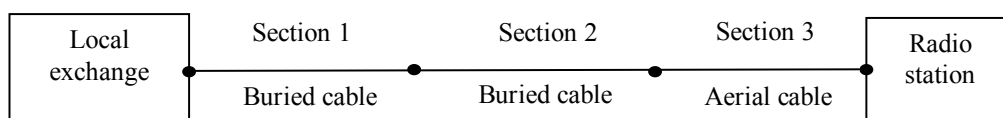


Figure 1 – Reference configuration (example)

6 Line performance for direct flashes

6.1 Annual number of damages

The annual number of line damages due to direct flashes to the line section i is given by:

$$N_d(i) = N_g A_d(i) K_p(i) \quad (1)$$

where:

N_g is the ground flash density;

$A_d(i)$ is the collection area for direct flashes to the line section i ;

$K_p(i)$ is the protection factor related to section i ;

NOTE 1 – If the value of the ground flash density is not available, it can be assessed from the number of days with thunderstorms per year (T_d), as $N_g = 0.1 T_d$.

The annual number of line damages due to direct flashes to the structure j connected to the line is:

$$N_s(j) = N_g A_s(j) K_p(j) \quad (2)$$

where:

$A_s(j)$ is the collection area for direct flashes to the structure j ;

$K_p(j)$ is the protection factor related to the line interface with the structure j ;

The annual number of line damages (N_d) for the entire line is:

$$N_d = \sum_{i=1}^m N_d(i) + \sum_{j=1}^2 N_s(j) \quad (3)$$

where m is the number of line sections.

NOTE 2 – In Equation 3 it is assumed that the line is connected to two structures, as shown in Figure 1. However, the case where line branches are connected to other structures can be considered in this equation by replacing the limit 2 by the number of structures.

6.2 Risk of damage

The risk of line damage due to direct flashes to the line section i is given by:

$$R_d(i) = N_d(i) L_d(i) \quad (4)$$

where $L_d(i)$ is the loss due to direct lightning flashes to section i .

The risk of line damage due to direct flashes to the structure j connected to the line is:

$$R_d(j) = N_s(j) L_s(j) \quad (5)$$

where $L_s(j)$ is the loss due to line damage from direct flashes to structure j . Therefore, the risk of damages (R_d) for the entire line is:

$$R_d = \sum_{i=1}^m N_d(i) L_d(i) + \sum_{j=1}^2 N_s(j) L_s(j) \quad (6)$$

The values of L_d and L_s shall be determined by the network operator or the owner of the installation. Appendix I provides a procedure for this assessment and also suggests some representative values.

6.3 Tolerable risk

The protective measures contained in this Recommendation are intended to reduce telecommunication line susceptibility to direct lightning flashes and, consequently, to reduce its number of damages N_d and its risk R_d . The need of protection and the evaluation of its effectiveness shall be assessed by the procedure contained in this Recommendation.

According to [ITU-T K.72], the tolerable risk of damage due to direct flashes to a telecommunication line (R_{Td}) is given by the difference between the total tolerable risk (R_T) and the risk of damage due to indirect flashes (R'_Z):

$$R_{Td} = R_T - R'_Z \quad (7)$$

If the risk of damage due to direct flashes is lower than or equal to the tolerable risk for direct flashes ($R_d \leq R_{Td}$), then no additional protective measure is needed. Otherwise, additional protective measures shall be applied until the tolerable condition is achieved ($R_d \leq R_{Td}$). The detailed procedure for this risk assessment is described in [ITU-T K.72] and the procedure for the evaluation of R'_Z is given in [ITU-T K.46].

NOTE – When the determination of R_{Td} is uncertain or difficult, this Recommendation suggests adopting $R_{Td} = 2 \times 10^{-4}$ as a reference value. Combined with the typical consequential loss values suggested in Appendix I ($L_{da} = 2 \times 10^{-3}$ and $L_{db} = 3 \times 10^{-3}$), it leads to an upper limit for N_d equal to 0.1 for aerial lines and 0.067 for buried lines, which corresponds to one line damage due to direct flashes at each ten and fifteen year intervals for aerial and buried lines, respectively. This suggested value shall be revised by the user based on service requirements and field experience.

7 Collection area

7.1 Aerial cable

The collection area for aerial cables (A_{da}) is given by:

$$A_{da} = 6 \times 10^{-6} [L - 3(H_1 + H_2)] h C_e \quad (8)$$

where:

L is the line section length in metres;

H_1 is the height of the structure at one end of the line section (if any), in metres;

H_2 is the height of the structure at the other end of the line section (if any), in metres;

h is the line height, in metres;

C_e is the environmental factor (see Table 1).

7.2 Buried cable

The collection area for buried cables (A_{db}) is given by:

$$A_{db} = 2 \times 10^{-6} [L - 3(H_1 + H_2)] D C_e \quad (9)$$

where:

D is the striking distance, in metres, which depends on the earth resistivity (ρ):

$$D = 0.482(\rho)^{1/2} \quad \text{for } \rho \leq 100 \, \Omega m \quad (10)$$

$$D = 2.91 + 0.191(\rho)^{1/2} \quad \text{for } 100 \, \Omega m < \rho < 1000 \, \Omega m$$

$$D = 0.283(\rho)^{1/2} \quad \text{for } \rho \geq 1000 \, \Omega m$$

7.3 Structure connected to the cable

The current of a direct flash to a structure flows into the earthing system of the structure and into the metallic services connected to the structure. Therefore, part of the lightning current enters into the telecommunication cable and may damage it. The collection area (A_s) for an isolated structure on flat ground is the area defined by the intersection between the ground surface and a straight line with 1/3 slope, which passes from the upper parts of the structure (touching it there) and rotating around it. The determination of the value of A_s may be performed graphically or mathematically.

For an isolated rectangular structure on flat ground, A_s is given by:

$$A_s = (a b + 6 H a + 6 H b + 9 \pi H^2) 10^{-6} [km^2] \quad (11)$$